Memorandum

To: Jennifer Saran, Poly Met Mining Inc.
From: Barr Engineering Co.
Subject: Groundwater Containment System Modeling in GoldSim - Version 3
Date: January 21, 2015
Project: 23690862.00-042-008

1.0 Introduction

The Co-Lead Agencies have requested a summary of the four containment systems that are planned for the NorthMet Project (Mine Site and Flotation Tailings Basin [FTB]) and the justification for how they are represented in the water quality (GoldSim) modeling. This memorandum represents the rationale for the modeling assumptions for each of the following containment systems:

- FTB Seepage Containment System (north and west)
- FTB Seepage Containment System (east)
- FTB South Seepage Management System
- Category 1 Waste Rock Stockpile Groundwater Containment System

Each of the containment systems discussed in this document, except for the FTB South Seepage Management System, share similar features: a cutoff wall (low permeability hydraulic barrier below and/or above ground) with a drainage collection system on the interior side. These systems are designed to collect groundwater and surface water flowing from project features while maintaining the existing groundwater table on the exterior (unimpacted) side of the cutoff wall. Because of differences in the characteristics and expected performance of these systems, they are modeled with varying assumptions in GoldSim (Table 1). The FTB South Seepage Management System is different in that it is designed to capture surface water only.

The following sections discuss the particulars of each containment system with respect to the analysis and rationale that inform the assumptions in the GoldSim modeling.

Table 1 Containment System Characteristics and Modeling Assumptions

	FTB Seepage Containment System		FTB South Seepage Management System	Category 1 Waste Rock Stockpile Groundwater Containment System
	North and West	East		
Purpose	Capture FTB seepage (surface and subsurface)		Capture FTB seepage (surface only)	Capture stockpile drainage (largely subsurface)
Characteristics	Cutoff wall and seepage collection		Dam	Cutoff wall and seepage collection
Surface Water Capture in GoldSim	100%	100%	100%	100% (minimal flow)
Groundwater Capture in GoldSim	90% (of aquifer capacity)	100%	N/A	90%[1] (of drainage)
Analysis Method	2D MODFLOW (cross-sections)	Site topography and hydrology	Site topography and hydrology, existing system monitoring	3D MODFLOW
Primary Analysis Document	Attachment C of Water Management Plan - Plant v3	Barr Memo dated June 20, 2014	Sections 2.1.3 and 4.1.3 of Water Management Plan - Plant v3	Section 2.1.2.3 and Attachment E of Rock and Overburden Management Plan v6
Additional Documents	Attachment F of Geotechnical Data Package Volume 1 – FTB v5	Section 2.1.4 of Water Management Plan – Plant v3		
Potential Mitigations Identified	Containment system improvements or extraction wells		Dam improvements or secondary dam	Containment system modifications or extraction wells in limited areas

[1] Capture percent changes through time, with a minimum capture of 90% in Mine Year 10 and a maximum capture of 94% in Mine Year 1

2.0 FTB Seepage Containment System (North and West)

2.1 Characteristics

The FTB Containment System that surrounds the FTB on the north and west sides is designed to capture surface water and groundwater flow leaving the FTB. The system includes a low-permeability cutoff wall constructed through the unconsolidated material and extending to bedrock, with a drainage collection system on the interior side. Recent geotechnical exploration along the proposed alignment (Attachment F to Geotechnical Data Package Volume 1 – Flotation Tailings Basin, v5) confirms our understanding of the subsurface conditions, including the low hydraulic conductivity of bedrock relative to the overlying unconsolidated deposits. Current hydraulic gradients are to the north and west, away from the tailings basin.

2.2 Analysis and Results

Cross-sectional groundwater modeling of the FTB Containment System using MODFLOW was completed to evaluate the effectiveness of the containment system during operation and long-term closure conditions (Attachment C of Water Management Plan – Plant, v3). Three assumed thicknesses of the more permeable fractured zone at the top of the bedrock were considered. These models provided estimates of the proportion of seepage from the FTB likely to be captured by the containment system. Model results indicated that all seepage from the Tailings Basin will be captured from the north and northwest flow paths under all assumptions of bedrock fracture zone thickness. From the west flow path all seepage is captured for bedrock fracture zone thicknesses of 25 feet and 50 feet. However, when the bedrock fracture zone thickness is assumed to be 100 feet, the model estimates that up to 8 gpm of seepage bypasses the FTB Containment System during operations and long-term closure. This represents 7% of the aquifer capacity (see Section 5.2.1.3.1 of Water Modeling Data Package Volume 2 – Plant Site v10 for description of "aquifer capacity").

2.3 Monitoring and Mitigation

Groundwater monitoring wells and piezometers located both within and outside of the FTB Seepage Containment System will be used to monitor the effectiveness of the seepage capture (Water Management Plan – Plant, v3, Section 5.5). Monitoring data proposed for assessing the effectiveness of the containment system ("FTB Containment System Performance Monitoring" memo from Tina Pint to Erik Carlson and Richard Clark, April 3, 2014) includes the hydraulic head differential (FTB side versus Embarrass River side), drainage system pumping records, and water quality of the collected water and groundwater outside of the containment system. Contingency mitigation measures to collect additional seepage could include repairs to the containment system or downgradient extraction wells (Water Management Plan – Plant, v3, Section 6.5).

2.4 Rationale and GoldSim Modeling Assumptions

Groundwater flow modeling demonstrated that under expected conditions, the FTB Seepage Containment System will capture 100% of the seepage. Due to the potential for unforeseen subsurface conditions and the current hydraulic gradients away from the tailings basin, the Co-lead Agencies, along with Poly Met Mining Inc. (PolyMet), decided to not assume 100% capture efficiency for the FTB Containment System along the north and west sides of the FTB. Given the fact that the groundwater model demonstrated 100% capture under a variety of conditions, professional judgment was used in selecting a capture efficiency for the GoldSim model. At the request of the Co-lead Agencies, capture efficiency assumptions of 100% of the surface flow and 90% of the groundwater flow in the aquifer were used. This value was originally selected as a conservative minimum value relative to the potential for groundwater quality impacts; additional data collection and modeling performed to date has confirmed that this value is conservatively low.

3.0 FTB Seepage Containment System (East)

3.1 Characteristics

The east side FTB Seepage Containment System is designed in the same manner as the FTB Containment System on the FTB north and west sides. As was previously documented (technical memo from Barr Engineering Co. to Co-Lead Agencies dated June 20, 2014), groundwater and surface water flows are currently into the tailings basin (flow from east to west) in the area where the East Dam will eventually be constructed.

3.2 Analysis and Results

The construction of the East Dam and the associated tailings deposition behind the dam will result in hydraulic heads that will allow water to flow from the FTB to the east towards the toe of the dam. However, the hydraulic heads further east of the dam (near Spring Mine Lake) are higher than the ground surface near the toe of the dam, which will constrain the hydraulic heads inside of the containment system. Therefore any seepage leaving the FTB at the East Dam will emerge either at the toe of the dam or in the topographic low area just outside of the dam.

The east side FTB Seepage Containment System is designed to efficiently collect the FTB seepage, while minimizing the collection of unimpacted water that will continue to flow from east to west towards the FTB. The unimpacted water flowing towards the FTB will be directed to the swale that is to be constructed north of the East Dam consistent with the Project as described in the SDEIS, while the seepage collection system on the interior of the containment system will be constructed at an elevation lower than the swale in order to maintain an inward gradient across the containment system. See the attached Figure 1 for a map of the area, and Figure 2 for an example cross-section of the east side FTB Seepage Containment System and swale.

3.3 Monitoring and Mitigation

Monitoring and mitigation measures for the east side FTB Seepage Containment System will be the same as for the FTB Containment System on the FTB north and west sides.

3.4 Rationale and GoldSim Modeling Assumptions

Based on the existing topography, inward hydraulic gradients, and the design of the containment system and the swale to control unimpacted water, the east side FTB Seepage Containment System is assumed for the GoldSim modeling to have a capture efficiency of 100% (i.e., all water from the FTB that reports to the east side FTB Containment System, both surface and/or groundwater, is captured).

4.0 FTB South Seepage Management System

4.1 Characteristics

The FTB South Seepage Management System is designed to collect surface seepage in a confined area where the bedrock and surface topography create a narrow valley at the headwaters of Second Creek. Due to this topography, it is expected that all existing seepage from the LTVSMC Tailings Basin to the south emerges as surface seepage within a short distance of the dam toe rather than being transported via subsurface flow. An existing seepage management system currently captures the majority of the seepage leaving the Tailings Basin, and Cliffs Erie and PolyMet have recently implemented improvements to the existing system to increase its capture efficiency (ditching upstream of the existing system to drain a small pond contributing seepage).

4.2 Analysis and Results

Because the location of the FTB South Seepage Management System represents the headwaters of Second Creek, there is virtually no watershed contributing to the stream other than seepage from the Tailings Basin. Therefore, there is no water available for diluting any impacted seepage water, and nearly complete capture of the seepage is needed to prevent impacts to Second Creek. These conditions are expected to continue essentially unchanged with the construction of the FTB above the existing LTVSMC Tailings Basin.

4.3 Monitoring and Mitigation

The effectiveness of the recent improvements to the existing seepage management system are currently being assessed by Cliffs Erie and PolyMet through water quality monitoring downstream of the existing system. PolyMet has committed to collecting essentially all of the seepage from the FTB in this area (Water Management Plan - Plant, v3, Section 4.1.3), and will implement additional improvements to the seepage management system if necessary. Potential measures that could bring the capture efficiency of the system to 100% include improvements to the existing dam such as lining the upstream dam face with bentonite and injecting grout into the dam. If seepage is observed to bypass the existing dam, a second dam could be constructed approximately 500 feet downstream of the existing system, in an area where the Second Creek headwaters valley is more constricted and any remaining subsurface seepage will have come to the surface. This potential second dam could be constructed as an earthen dam with a clay or concrete cutoff wall (extending to bedrock if necessary) in order to achieve 100% capture of the surface seepage.

4.4 Rationale and GoldSim Modeling Assumptions

Based on PolyMet's commitment to collect essentially all seepage to the south, the FTB South Seepage Management System is assumed for the GoldSim modeling to have a capture efficiency of 100% for surface water and there is assumed to be no subsurface transport of seepage.

5.0 Category 1 Waste Rock Stockpile Groundwater Containment System

5.1 Characteristics

Like the FTB Seepage Containment System, the Category 1 Waste Rock Stockpile Groundwater Containment System is designed to capture all surface water and groundwater flow leaving the stockpile. Due to the coarse nature of the stockpiled material, it is anticipated that there will be very little true surface runoff leaving the stockpile during operations, and the majority of the stockpile drainage will flow as toe seepage or shallow subsurface flow.

5.2 Analysis and Results

There is a potential that some seepage may be drawn into the bedrock beneath the stockpile due to the horizontal and vertical hydraulic gradients that will be created by the dewatered West Pit. Because the mine pits extend to significant depths within the bedrock and dewatering of the pits will result in significant changes to groundwater flow directions relative to existing conditions, it was determined that a three-dimensional MODFLOW model was needed to assess capture efficiency of the Category 1 Waste Rock Stockpile Groundwater Containment System. This was not the case at the FTB, where project features do not extend into bedrock and groundwater flow directions during and following the project will remain similar to existing conditions. Given the simpler hydraulics, it was determined that cross-sectional models were appropriate for evaluating capture efficiency of the FTB Seepage Containment System. Three-dimensional groundwater modeling of the Category 1 Waste Rock Stockpile Groundwater Containment System (Attachment E to the Rock and Overburden Management Plan, v6) has estimated that the maximum amount of stockpile drainage that may bypass the containment system and enter the mine pits directly is 8% of the total stockpile infiltration, occurring for a limited time when the West Pit and East Pit are fully dewatered. Up to 2% of the stockpile infiltration may flow offsite via bedrock for a limited period during operations; under long-term closure conditions, the amount of stockpile infiltration that is predicted to flow offsite is less than 0.01 gpm (<1%).

5.3 Monitoring and Mitigation

PolyMet has committed to monitoring and modifying the design (e.g. adding extraction wells) if necessary to achieve sufficient capture (see Section 2.1.2.3 and Attachment E of the Rock and Overburden Management Plan, v5). The performance monitoring planned for the Category 1 Stockpile Groundwater Containment System will be similar to that proposed for the FTB Containment System, and includes a number of paired piezometer sets along the northern containment system boundary to evaluate the hydraulic head differential and groundwater quality.

5.4 Rationale and GoldSim Modeling Assumptions

Based on the 3D MODFLOW modeling of the containment system, the maximum amount of drainage flowing to the West Pit (6% of stockpile drainage) is assumed for the GoldSim modeling to continue during the entire simulation period, without consideration of the West Pit water level. This value is the maximum flow to the West Pit from the MODFLOW model; lower flows in early and late years of mining are not considered as a modeling simplification. In long-term closure the drainage to the West Pit is the only loss of water from the containment system.

The GoldSim model also includes temporary drainage flows to the East Pit and to bedrock. Flows to the East Pit increase from 0 in Mine Year 1 to 2% of drainage (or 6 gpm) in Mine Year 10 and decrease to 0 by Mine Year 20. During reclamation and long-term closure, flows to the East Pit are negligible and are assumed to be zero in the model. The flow from the Category 1 Waste Rock Stockpile to bedrock is represented in the GoldSim model as contributing to the upstream end of the bedrock flow paths leaving the West Pit, which begin to transport flow and load when the water in the West Pit reaches the bedrock rim elevation (in approximately Mine Year 50). This flow increases from 0 at Mine Year 1, to 2% of drainage (or 6 gpm), at Mine Year 10 and decrease to 0 by Mine Year 20. During reclamation and long-term closure, flows to bedrock are negligible and are assumed to be zero in the model.

In operations, reclamation, and long-term closure the GoldSim model assumes no loss of water from the containment system to the west, north, or northeast based on PolyMet's commitment to collect seepage in these directions.

Figures

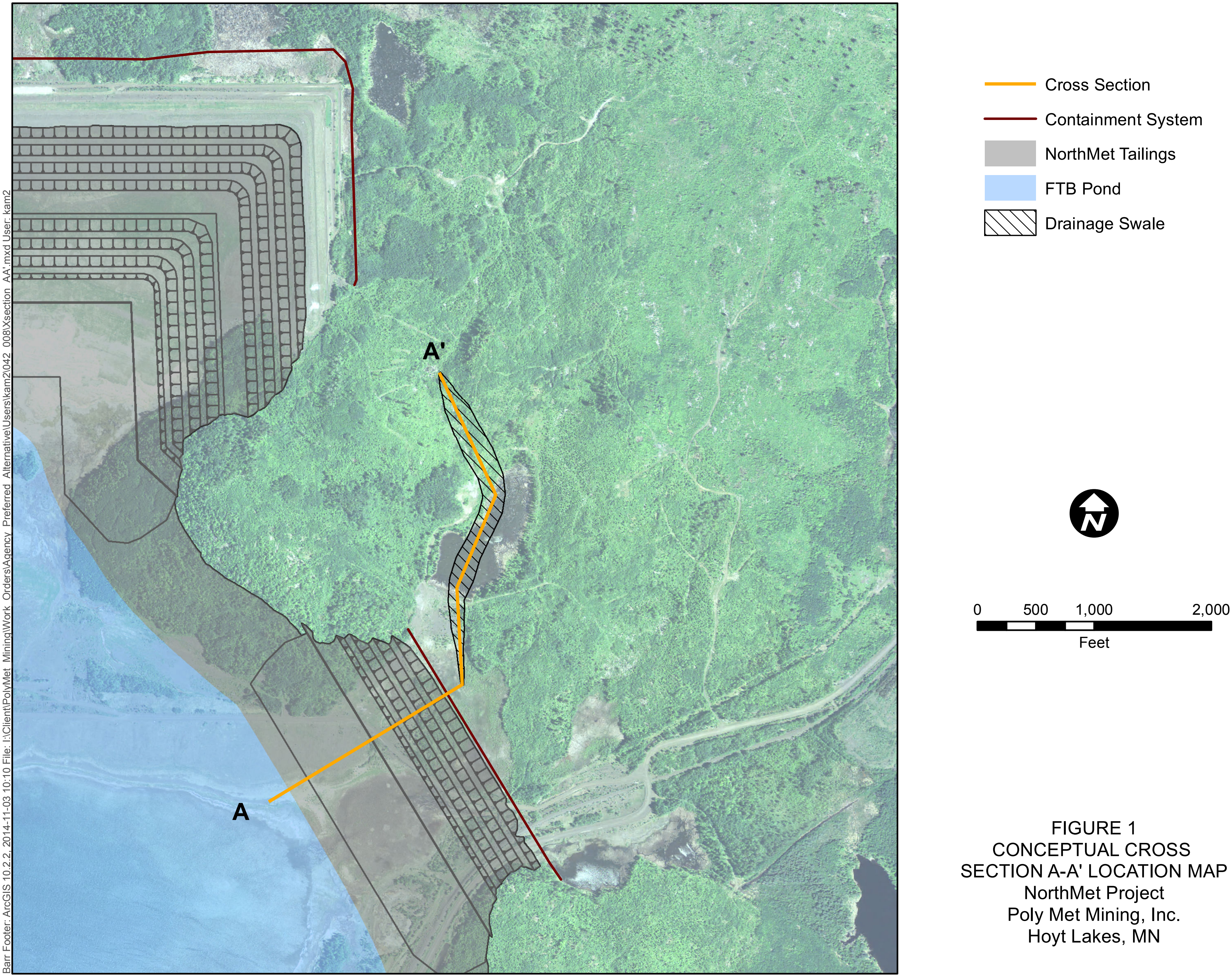

FIGURE 1
CONCEPTUAL CROSS SECTION A-A' LOCATION MAP
NorthMet Project
Poly Met Mining, Inc.
Hoyt Lakes, MN

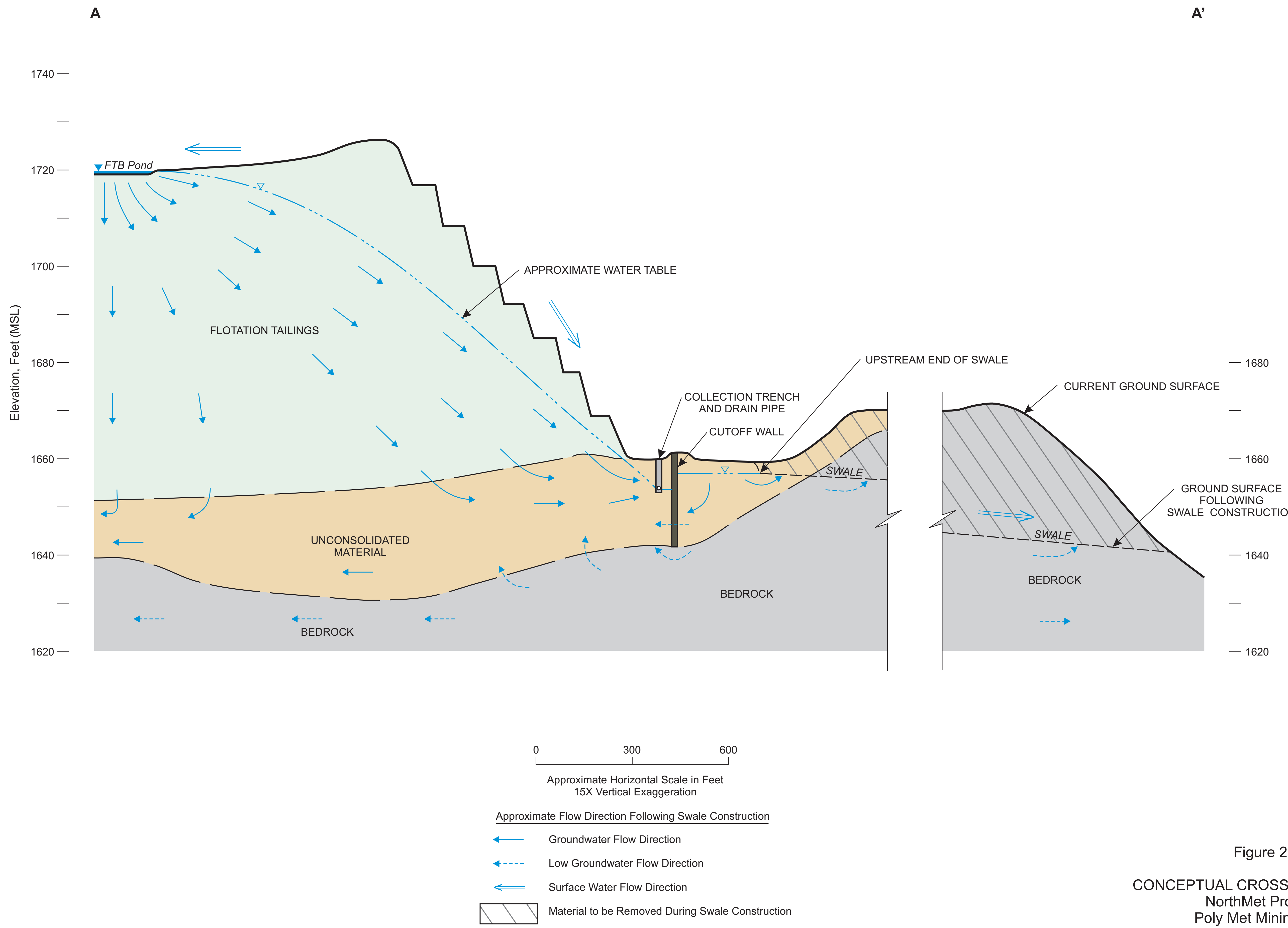

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Figure 2

CONCEPTUAL CROSS SECTION A-A'
NorthMet Project
Poly Met Mining Inc.
Hoyt Lakes, MN