Technical Memorandum

To: Dave Blaha and Fred Marinelli, ERM; Mike Liljegren, MDNR; Marty Rye, USFS
From: Barr Engineering Co.
Subject: NorthMet FTB East Dam Conceptual Model – Draft-02
Date: June 20, 2014
Project: NorthMet EIS – 23690862.00
c: Jennifer Saran, Poly Met Mining Inc.; Bill Johnson, MDNR

This memorandum presents a conceptual model for seepage in the area of the east side of the existing LTV Steel Mining Company (LTVSMC) tailings basin and the proposed NorthMet Flotation Tailings Basin (FTB) and has been prepared at the request of the Co-lead Agencies in response to comments received on the NorthMet SDEIS. The conceptual model presented in this memorandum is intended to support future discussions regarding how seepage is simulated in the area east of the FTB, but does not provide recommendations for implementation of the conceptual model within the water quality modeling framework (i.e., MODFLOW and GoldSim).

Introduction to the Issue

Poly Met Mining Inc. is planning to construct a flotation tailings basin on top of a portion of the existing LTVSMC tailings basin. Future FTB perimeter dams would be raised in an upstream construction method using compacted LTVSMC bulk tailings. A bentonite amended oxygen barrier layer would be added on exterior sides of the FTB dams as part of construction. The flotation tailings would be deposited in a slurry form, with tailings deposited into Cell 2E for the first seven years of operation, then into both Cell 1E and 2E and eventually forming a single cell (Cell 1/2E). During closure, bentonite would be added to the beach areas and beneath the pond to reduce infiltration, resulting in a permanent pond.

The design of the FTB has changed during the environmental review process. As aspects of the design have changed, groundwater flow modeling using the industry standard code, MODFLOW, has been conducted to estimate seepage losses from the FTB. Two different FTB designs were considered as part of the Draft Environmental Impact Statement (DEIS) for the NorthMet Project (Project): Proposed Project (referred to here as DEIS Proposed Project) and the Tailings Basin Alternative (also referred to as the Tailings Basin – Mitigation Design). Separate MODFLOW models were constructed for each of these FTB designs. MODFLOW modeling of the DEIS Proposed Project was conducted in 2007 and documented in RS-13 Draft-03 Attachment A-6. MODFLOW modeling of the Tailings Basin Alternative was conducted in 2008 and documented in RS-13b Draft-01 Attachment A-6.

In addition to changes in how the FTB was modeled due to differences in the designs, changes were made to the MODFLOW model when it was updated in 2008 to simulate the Tailings Basin Alternative. As stated in Section 4.6.1 of RS-13b Draft-01 Attachment A-6:

> *"The location of the bedrock hills that flank the Tailings Basin to the east and south were updated. The location of the bedrock hills is used in the model to define the extent of the low hydraulic conductivity zone that represents the bedrock. Because the footprint of the Tailings Basin – Mitigation Design is closer to these hills on the southeast side of the footprint than was the footprint for the proposed design, it was important to get the location of these hills as accurate as possible. The location of the bedrock hills was defined using information from the Minnesota Geological Survey's map M-164."*

The MODFLOW model was once again updated when the design of the FTB changed following the publication of the DEIS. The MODFLOW modeling for the FTB design presented in the Supplemental Draft Environmental Impact Statement (SDEIS) was conducted in 2011 and documented in Attachment A to Water Modeling Data Package Volume 2 – Plant Site version 9. The MODFLOW modeling of the SDEIS FTB design used the 2007 DEIS Proposed Project model as the base model. Thus, the changes that were made between 2007 and 2008 to refine the location of the bedrock hills were not incorporated into the 2011 modeling (Figure 1). This was identified by the Cooperating Agencies during the SDEIS public review process.

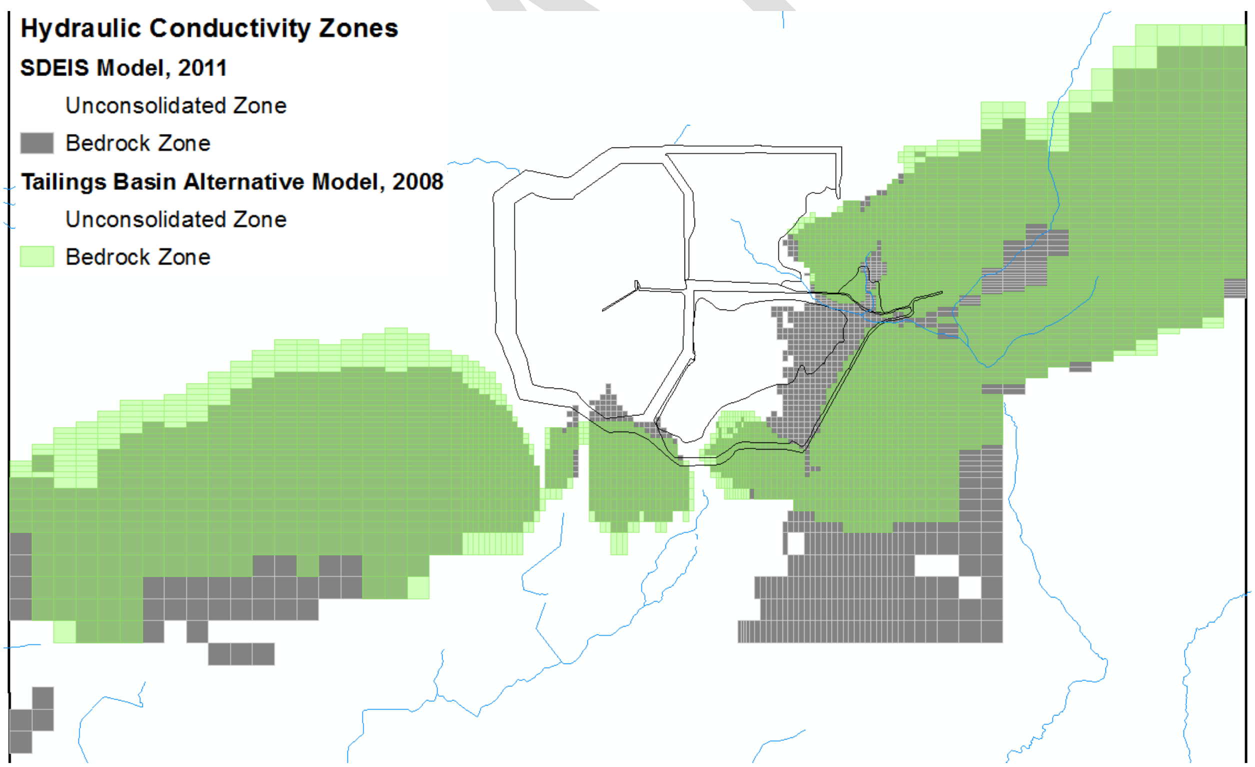


Figure 1 Comparison of Bedrock Hydraulic Conductivity Zone Extents

The question was raised whether the less refined (i.e., the 2007) bedrock zonation in the model was inappropriately limiting potential seepage out the east side of the SDEIS FTB and, by extension, potentially resulting in underestimates of potential impacts to water resources. In addition, the Cooperating Agencies suggested potential modifications to the way that seepage in the area of the East Dam is simulated in the MODFLOW model. This memorandum presents a conceptual model for groundwater flow and tailings basin seepage in the area of the East Dam to help address these questions.

Historic and Existing Conditions

The existing LTVSMC tailings basin is unlined and was constructed in stages beginning in the 1950's. It was configured as a combination of three adjacent cells, identified as Cell 1E, Cell 2E, and Cell 2W, and was developed by first constructing perimeter starter dams and placing tailings from the iron-ore process directly on native material. In some areas, perimeter dams were reportedly initially constructed from rock, and subsequent perimeter dams were constructed of coarse tailings using upstream construction methods. The tailings basin operations were discontinued in January 2001 and the basin has been inactive since then, except for reclamation activities consistent with the MDNR-approved Closure Plan currently managed by Cliffs Erie, and more recently, activities associated with the April 6, 2010 Consent Decree between Cliffs Erie and Minnesota Pollution Control Agency.

Seepage from the existing LTVSMC tailings basin

Surface seepage from the tailings basin toe of slope had been noted during dam inspections during basin operations, and more formally have been monitored annually, typically in October, starting in 2002 as part of the NPDES permit. During operations, wet spots were noted near the toe of slope or at the first or second bench of the dams in various locations. In addition, the presence of trees or wet vegetation (e.g., cattails) was used to identify areas where seepage may have been occurring. Occasionally, measurable flows were observed, particularly along the South Dam of Cell 2W near the emergency basin (near seeps 1-9 from Large Figure 1), where seepage at the toe of the dam had been estimated at approximately 30 gpm.

Following basin closure in 2002, the reported surface seepage flow rates generally decreased over time, with many of the individual seep locations described as having no flow or too little to measure in 2013 (Large Table 1). This is consistent with the observed dissipation of the groundwater mound within the tailings basin following closure. The flow from some seeps was collected in culverts or weirs downstream, but flow measurements at some of these locations also include surface water runoff and flow from outside the tailings basin. Also, some identified seep locations are outlets for pipes extending back into the tailings basin (including Seeps 24 through 29), so may not represent areas of "natural" seepage from the dams.

Of the regularly monitored toe of slope seep locations, six seeps have consistently had measurable flows: Seeps 20 and 22 (NPDES Permit monitoring station SD004), Seep 24 (North Side Seep), Seep 30, Seep 32, and Seep 33 (Large Figure 1). Seeps 20 and 22 (SD004), on the northwest corner of Cell 2W, have consistently had flow rates below 10 gpm. A pump-back system was installed at Seep 22 (SD004) and

SD006 in 2011 and water that reports to those locations is pumped to Cell 1E. Seep 24 (North Side Seep), located on the north side of Cell 2W, has a maximum estimated flow rate of 25.6 gpm. Seep 30, on the north side of Cell 2E, has had an increase in seepage through time, although estimated flows in 2012 and 2013 declined relative to 2011. The maximum estimated flow rate at Seep 30 was 232 gpm, observed in October 2011. This seep is located in the vicinity of the former Trimble Creek channel, which may represent a preferential flow pathway from the tailings basin. Seeps 32 and 33, where combined flow was usually measured, had a maximum estimated flow of 1379 gpm in 2010. In the following year, a pump-back system was installed to transfer water from these locations to Cell 1E. Seeps 32 and 33 form the headwaters of Second Creek and were modeled with drain cells in the MODFLOW model submitted with the SDEIS. The combined flow of all tailings basin seeps, excluding Seeps 32 and 33, is less than the flow rate at these two seeps for all monitoring events except August 2008.

Seep monitoring conducted during operations and closure supports the conceptual model that seepage exits near the toe of slope and further downstream of the toe of slope along the North and West dams. This is by design; the hydraulic conductivity and geometry of the dams is designed to minimize seepage from the face of the dams. Instead, the dams are configured to maintain the phreatic surface within the structure of the dam, thereby limiting seepage from the dam face. This can be attributed to using free-draining rock starter dams and coarse tailings material. This results in achievement of the desired slope stability factors of safety for the dams.

Conceptual cross-sections illustrate the existing topography and geology with inferred groundwater flow directions (Large Figure 2 through Large Figure 4) for existing and future conditions. The surfaces shown on the cross-sections were developed based on publically-available topographic and geologic data sources and should be considered approximate and conceptual. The specific data sources used to develop the cross-sections are indicated on Large Figures 3 and 4. With the exception of Wells A and B, which are projected on to Cross-Section Z-Z' (Large Figure 4), no drilling has been completed in the area to the east of the LTVSMC tailings basin.

Under existing conditions, seepage from the tailings basin to the east does not occur, because the Cell 1E pond within the LTVSMC tailings basin is topographically lower than the surface water features to the east (see top panels of Large Figure 3 and Large Figure 4). Groundwater in the native unconsolidated material currently flows to the northwest toward the tailings basin. The presence of wetlands east of the tailings basin indicates that the water table is near the ground surface in this area. As shown on the top panel of Large Figure 4, there is an inferred groundwater divide beneath Stockpile 5021, due to a likely groundwater mound associated with the elevated topography of the stockpile relative to the surrounding area. To the east of this divide, groundwater flows east toward the Area 5NW Pit. To the west of the divide, groundwater generally flows west toward the LVTSMC tailings basin. The static water levels measured at wells A and B, which are projected onto cross-section Z-Z' (Large Figure 4), are approximately 1670 and 1675 feet, respectively. The elevation of the Area 5NW Pit lake is approximately

1667 feet, confirming that groundwater flows east-northeast from the Well A/B area toward the Area 5NW Pit.

As shown on Large Figure 5, Spring Mine Lake is located topographically higher than the existing LTVSMC tailings basin and the Area 5NW Pit and appears to represent a local groundwater high and likely groundwater divide within the surficial deposits. Therefore, the lake may receive very little (if any) inflow of shallow groundwater from these areas. However, the lake has a unique geologic setting, which may allow for more significant groundwater inflow from bedrock than is typical for surface water features in the area. Spring Mine Lake occupies the location of the Siphon Mine, a former mine pit that targeted a natural ore zone within the Biwabik Iron Formation. Although the Biwabik Iron Formation is "almost impermeable where unaltered and unfractured," higher zones of permeability are associated with natural ore zones where weathering and/or hydrothermal fluid processes have enhanced permeability[1]. In addition, the former mine pit and current lake are located in an area of regionally significant faulting known as the Siphon structure, which trends generally north-south through the area. Faults within the bedrock may allow deeper bedrock groundwater from areas outside the surface watershed to discharge to the lake. Note that the tailings basin is not underlain by the Biwabik Iron Formation, nor does the Siphon structure extend toward the tailings basin area.

Future Conditions

Seepage from the face of the new dams that will be constructed for the Project is undesirable from the standpoint of geotechnical slope stability. As noted previously, the FTB dam construction materials and dam geometry selected for the construction of the FTB dams will yield minimal seepage, because the phreatic surface will be set well back from the face of the dams. This is not a unique aspect of the proposed FTB dam design; this a typical dam design approach.

Following the completion of the east dam of the NorthMet FTB, groundwater within the unconsolidated deposits is generally expected to continue to flow from the east toward the tailings basin (lower panels on Large Figure 3 and Large Figure 4). The water in the FTB Pond and infiltration entering the tailings basin outside the pond area will seep downward through the Flotation Tailings and into LTVSMC tailings, prior to moving laterally within the higher hydraulic conductivity unconsolidated material below the LTVSMC tailings. The presence of the FTB Pond will not alter the existing regional groundwater flow direction, but may result in radial flow away from the tailings basin area on a local scale. Some water may seep through the unconsolidated material below the eastern dam (lower panels on Large Figure 3 and Large Figure 4). However, based on topography and the inferred groundwater divides to the area east of the tailings basin, this seepage would likely discharge near the toe of the eastern dam and it is not anticipated to flow

[1] Maclay, R.W., 1966. Reconnaissance of the Geology and Ground-Water Resources in the Aurora Area, St. Louis County, Minnesota. U.S. Geological Survey Water-Supply Paper 1809-U.

east toward the Area 5NW pit or Spring Mine Lake. The historic seepage observations described above support the expectation that any potential seepage through the future tailings basin east dam would likely exit near the toe of the dam, because the phreatic surface will be set well back from the dam face by design. As with seepage that may pass beneath the dams, any water that does pass through the east dam is expected to collect in the topographically low areas directly adjacent to the dam and would not flow to the east toward the Area 5 NW pit or Spring Mine Lake.

Large Tables

Large Table 1 Historic Seepage Data from Annual Seep Surveys

	Estimated Flow (gpm)														
Seep ID	**May 2002**	**Dec 2002**	**Oct 2003**	**Oct 2004**	**Oct 2005**	**Oct 2006**	**Oct 2007**	**Aug 2008**	**Oct 2008**	**Oct 2009**	**Oct 2010**	**Oct 2011**	**Oct 2012**	**Oct 2013**	**Notes**
Seep 1	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Seep 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Seep 3	6.0	12.0	0	0	0	0	0	0	0	0	0	0	0	0	
Seep 4	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Culvert (WS-011)	27.0	42.0	11.0	21.8	7.2	0	0	0	0	0	0	0	0	5.0	Combined flow in area of and including Seeps 1-4
Seep 5	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	
Seep 6	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	
Seep 7	1.6	0.9	0	0	0	0	0	0	0	0	0	0	0	0	
Seep 8	3.5	35.0	33.0	0	0	0	0	0	0	0	0	0	0	0	
Seep 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Weir (WS-012)	94.0	25.0	25.3	35.3	0.2	0	0	0	0	0	0	0	0	15.5	Combined flow in area of and including Seeps 4-9
EB Inflow						80.0	4.2	2.3	12.0	21.0	18.0	20.0	23.0	45.0	Combined flow in area between Seep 9 and WS-012
EB Outflow	1051.0	568.0	797.4	927.5	896.0	554.0	789.6	453.6	1100.0	740.0	409.0	485.0	475.0	904.0	Includes watershed runoff
Seep 10	0	50.0 [1]	0	0	0	0	0	0	0	0	0	0	0	0	
Seep 11	0	0.5		0	0	0	0	0	0	0	0	0	0	0	
Seep 12	0	0.5		0	0	0	0	0	0	0	0	0	0	0	
Seep 13	1.5	0.5		0	0	0	0	0	0	0	0	0	0	0	
Seep 14	0.8	0		0	0	0	0	0	0	0	0	0	0	0	
Seep 15	0	0		0	0	0	0	0	0	0	0	0	0	0	
Seep 16	0	0		0	0	0	0	0	0	0	0	0	0	0	
Seep 17	0	0		0	0	0	0	0	0	0	0	0	0	0	
Seeps 14-17					0.2	0.5	0.9				0	0	0	0	
Weir (West Side Seep)	24.0	25.0 [2]	9.0	3.2	0	0	0	0	0	0	0	0	0	0	Combined flow of area including Seeps 11-17

Seep ID	Estimated Flow (gpm)														Notes
	May 2002	Dec 2002	Oct 2003	Oct 2004	Oct 2005	Oct 2006	Oct 2007	Aug 2008	Oct 2008	Oct 2009	Oct 2010	Oct 2011	Oct 2012	Oct 2013	
Culvert/ Pipe						2.0	1.0	1.0	0.5	0.5	0.5	0.5	0.25	0.3	Culvert beneath road
SD-006	1387.0	247.0	359.0	406.0	509.0	356.0	303.2	383.3	710.0	618.0	722.0	0 [3]	0 [3]	0 [3]	
Seep 18	0	2.0	0	0	0	0	0	0	0	0	0	24	15	16	
Seep 19	0	22.0	0	0	0	0	0	0	0	0	0	0	0	0	
Seep 20	2.0	5.0	9.0	0	2.1	1.6	1.5	1.5	2.5	3.0	3.0	3.5	2.0	1.5	Flow from pipe
Seep 21	0.5	1.5	0	0	0	0	0	0	0	0	0	0	0	0	
Seep 22 (SD-004)	1.5	7.0	5.0	5.0	5.0	1.4	2.0	3.0	3.0	3.5	3.0	0 [3]	0 [3]	0 [3]	
Seep 23	0	6.0	0	0	0	0	0	0	0	0	0	0	0	0	
SD-005			0											0	
Seep 24 (North Side Seep)	1.5	20.0	20.6	3.0	2.7	1.1	25.6	7.2	10.0	12.0	11.0	9.0	9.0	10.0	Flow from pipe
Seep 25	3.0	15.0	29.4	5.0	15.5	21.5	10.8	26.9	0	0	0	0	0	0	Flow from pipe
Seep 26	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	Flow from pipe
Seep 27	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	Flow from pipe
Seep 28	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	Flow from pipe
Seep 29	30.0	12.0	5.5	0.7	0	0	0	0	0	0	0	0	0	0	Flow from pipe
Seep 30	2.0	12.0	98.7	62.0	81.0	127.0	53.9	206.0	100.0	189.0	161.0	232.0	182.0	64.0	
Seep 31	0.0	60.0	0	0	0	0	0	0	0	0	0	0	0	0	
Seeps 32,33	554.0	332.0	379.7	449.0	409.0	199.0	490.1	195.2	600.0	781.0	1379.0	0 [3]	0 [3]	0 [3]	
Inflow (culvert)				42.0	67.0	151.0	745.1	0	80.0	116.0	0	0	39.0	69.0	Northeast end of TB process water pond
SD-026									660.0						

Blank cells indicate that data were not recorded for that location during that monitoring period

Gray cells indicate that the measurement may include both tailings basin seepage and watershed runoff

[1] Visual estimate of total flow for area including Seeps 10-17

[2] Combined flow for area including Seeps 11-17; either flow at Seep 10 approximately 25 gpm or visual estimate poor

[3] No discharge at SD station - tailings basin pump-back system installed and operating in accordance with the 2010 Consent Decree

Large Figures

Barr Footer: ArcGIS 10.2.1, 2014-06-06 10:02 File: I:\Client\PolyMet Mining\Work Orders\Agency Preferred Alternative\Maps\Support Document\Water\Groundwater\Memo 2014 06 05\Large Figure 2 Seep Locations.mxd User: arm2

- Existing Surface Discharges
- Seeps
- Emergency Basin Outflow
- Culvert
- Weirs

0 1,000 2,000 4,000
Feet

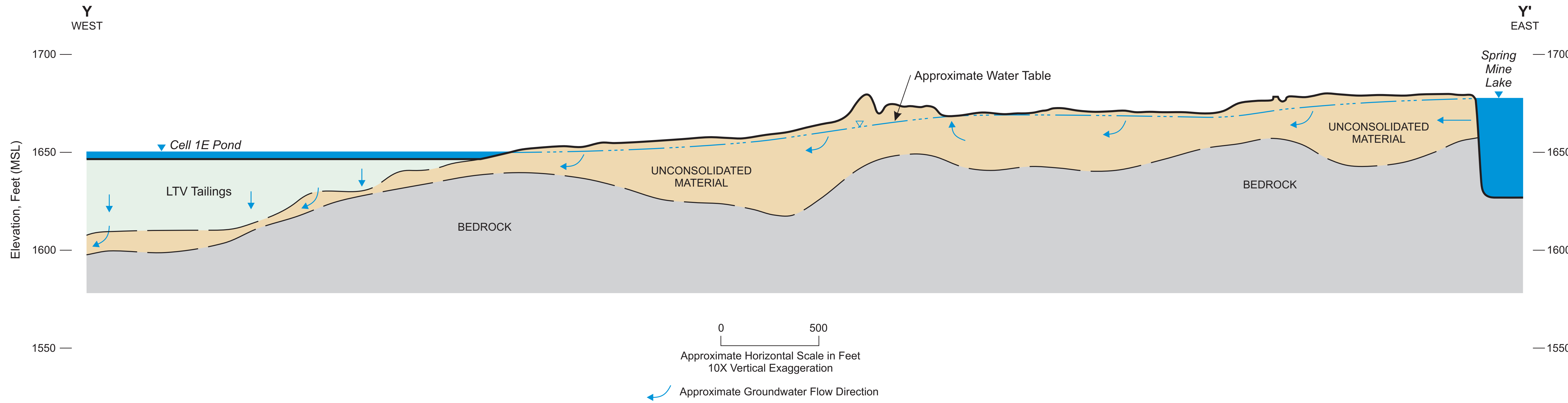
Large Figure 1
SEEP LOCATIONS
NorthMet Project
Poly Met Mining Inc.
Hoyt Lakes, MN

Barr Footer: ArcGIS 10.2.1, 2014-06-06 10:02 File: I:\Client\PolyMet_Mining\Work_Orders\Agency_Preferred_Alternative\Maps\Support_Document\Water\Groundwater\Memo_2014_06_05\Large Figure 3 Conceptual Cross Section Locations.mxd User: arm2

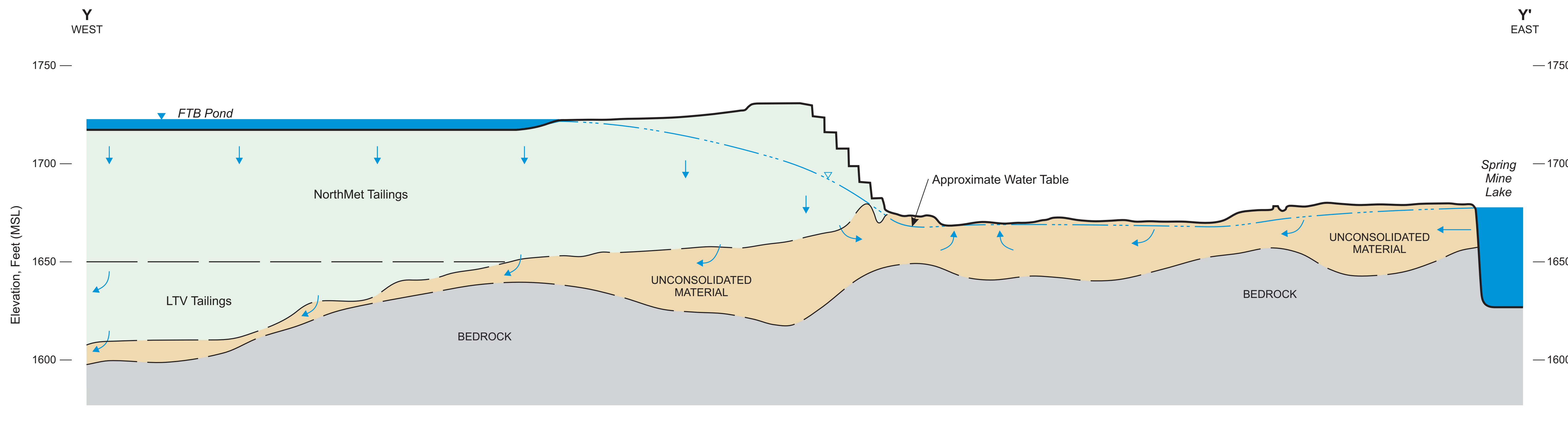
Well
Cross Section Y
Cross Section Z
Tailings Basin Design - Year 20

0 1,000 2,000 4,000
Feet

Large Figure 2
CONCEPTUAL CROSS-SECTION LOCATIONS
NorthMet Project
Poly Met Mining Inc.
Hoyt Lakes, MN



CROSS SECTION Y-Y' CURRENT CONDITIONS



0 500
Approximate Horizontal Scale in Feet
10X Vertical Exaggeration

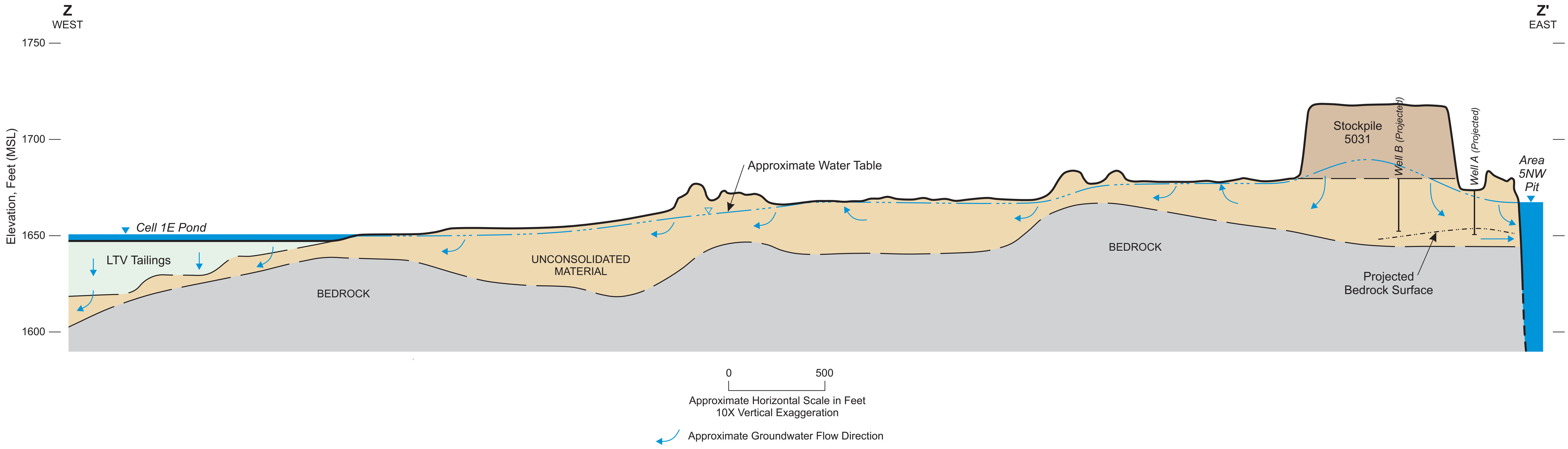
Approximate Groundwater Flow Direction

Contacts are approximate and are based on the following data sources:
- NorthMet Flotation Tailings Basin Design - Year 20.
- MN DNR, 2011, LiDAR Elevation, Arrowhead Region, NE Minnesota.
- MN DNR Division of lands and Minerals, 2006, DEM for Depth of Bedrock.
- USGS, 1949, Allen 7.5 Minute Quadrangle.

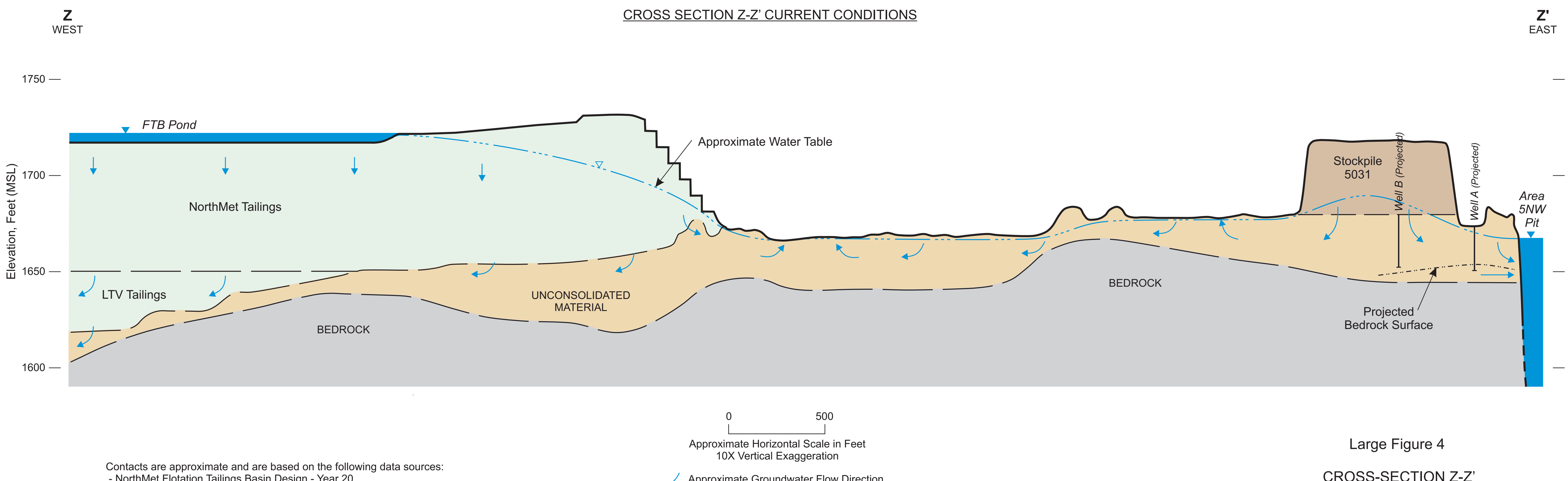
CROSS SECTION Y-Y' YEAR 20

Large Figure 3

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



CROSS SECTION Z-Z' CURRENT CONDITIONS

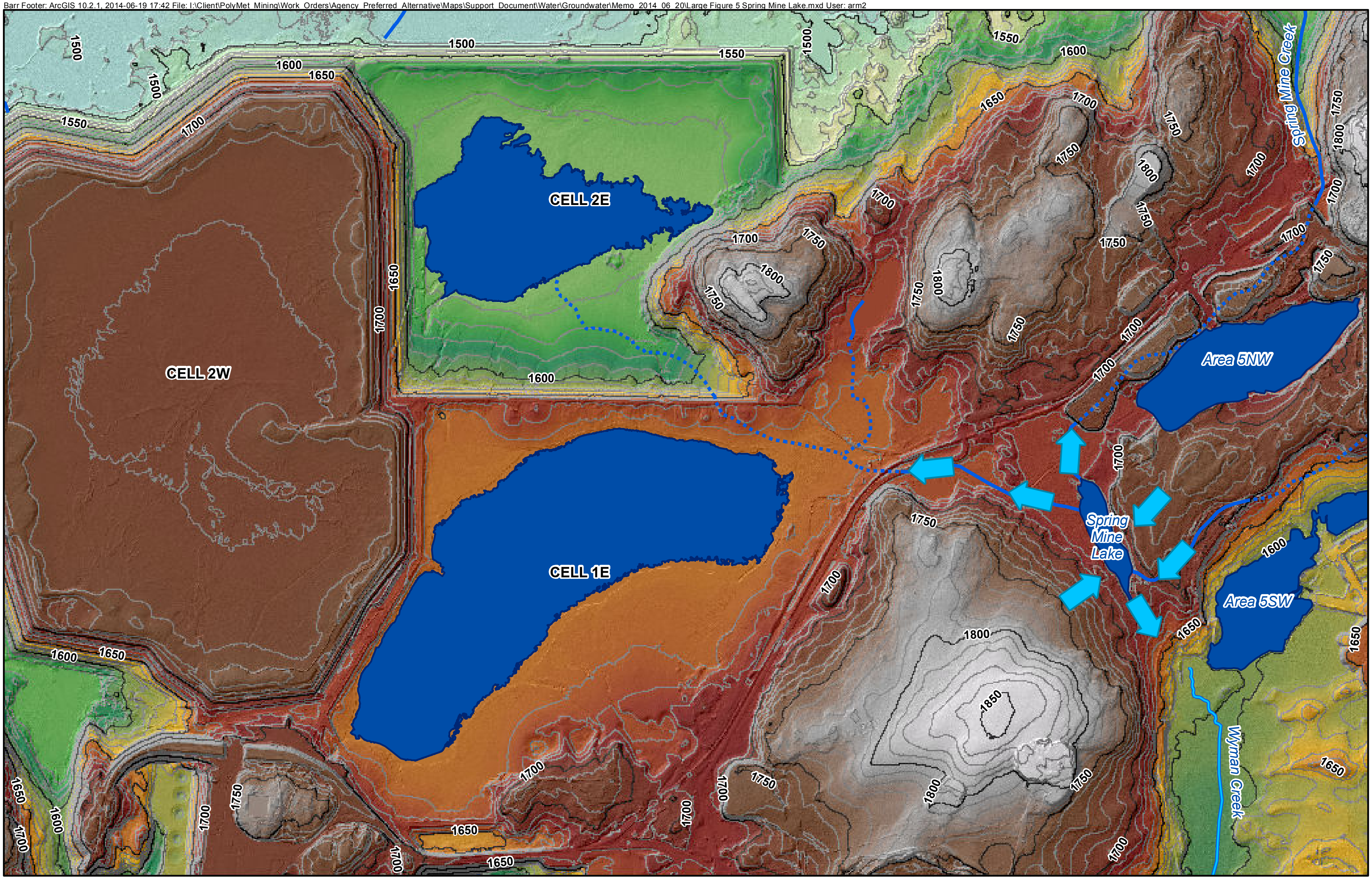


CROSS SECTION Z-Z' YEAR 20

Contacts are approximate and are based on the following data sources:
- NorthMet Flotation Tailings Basin Design - Year 20.
- MN DNR, 2011, LiDAR Elevation, Arrowhead Region, NE Minnesota.
- MN DNR Division of lands and Minerals, 2006, DEM for Depth of Bedrock.
- USGS, 1949, Allen 7.5 Minute Quadrangle.
- Barr, 2008, Arera 5 Hydrology Data Gaps Memorandum.

Large Figure 4

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



Public Waters Inventory (PWI)
NHD Flowline
NHD Flowline Former Channel
Mine Pit or Tailings Pond
Flow Direction

Surface Elevation Contours
50-Foot
10-Foot

Surface Elevation
High : 1854.23
Low : 1477.21

0 1,000 2,000 4,000
Feet

Large Figure 5
GENERAL SURFICIAL FLOW PATTERNS
NEAR SPRING MINE LAKE
NorthMet Project
Poly Met Mining Inc.
Hoyt Lakes, MN