GREAT LAKES INDIAN FISH AND WILDLIFE COMMISSION

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● MEMBER TRIBES ●

MICHIGAN	WISCONSIN		MINNESOTA
Bay Mills Community	Bad River Band	Red Cliff Band	Fond du Lac Band
Keweenaw Bay Community	Lac Courte Oreilles Band	St. Croix Chippewa	Mille Lacs Band
Lac Vieux Desert Band	Lac du Flambeau Band	Sokaogon Chippewa	

Via Electronic Mail / Original by Mail August 11, 2015

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Re: Comments on PolyMet mine site contaminant northward flowpath and groundwater model calibration.

NorthMet EIS Co-lead Agency Project Managers:

Following up on the web-meeting of July 22, emails of February 26, April 10 , April 20, letter of June 18 and emails of July 21 and July 29, we will clarify our concerns related to a northward flowpath and model calibration These comments are based on: 1) our letter of June 18th; 2) the materials provided in the Co-lead Agency draft memos on a northern flowpath and model calibration; 3) the webinar/meeting conducted July 22, 2015; 4) materials in the PFEIS of June 2015; and 5) further analysis. Since before 2008, GLIFWC staff have consistently raised concerns about the quality and validity of the groundwater characterization at the mine site. Most recently it has come to our attention that the mine site MODFLOW model was incorrectly bounded and calibrated and unlikely to provide the hydrologic characterization of the site that is needed in order to perform adequate project impact evaluations. It has also come to our attention that detailed (MODFLOW) and simplistic (MathCad) models predict that a northward contaminant flowpath is probable under likely closure conditions.

GLIFWC is acting in coordination with our member tribes, including the Fond du Lac Band, to review and contribute to the PolyMet EIS process. As you may know, GLIFWC is an organization exercising delegated authority from 11 federally recognized Ojibwe (or Chippewa) tribes in Wisconsin, Michigan and Minnesota.[1] Those tribes have reserved hunting, fishing and gathering rights in territories ceded in various treaties with the United States. GLIFWC's mission is to assist its member tribes in the conservation and management of natural resources and to protect habitats and ecosystems that support those resources. The proposed PolyMet mine is located within the territory ceded by the Treaty of 1854.

Mine-site MODFLOW model calibrated to conditions that did not exist in the 1980s, do not exist now and will not exist in the future:

The existing Northshore Peter-Mitchell (P-M) taconite mine pits on the north side of the PolyMet project area play a significant role in the groundwater hydrology of the project site. In the applicant's groundwater model of 2014 (and earlier versions), documented in the "Water Modeling Data Package Vol 1-Mine Site v13 DEC2014.pdf" (WMDPv13), those pits supply approximately 90% of the groundwater baseflow to the upper Partridge River (see GLIFWC email of 4/20/2015). It is not surprising that those taconite pits play a significant role in the local groundwater hydrology since they are positioned high in the local terrain, at times contain large volumes of water, and sit in relatively high conductivity bedrock (Biwabik Iron Formation or BIF and Virginia Formation). Because they play a dominant role in the local hydrology, it is critical that they be correctly incorporated into the project hydrologic modeling.

Unfortunately, the existing project MODFLOW model for the PolyMet mine site was calibrated using P-M taconite pit water levels that were 13 or more meters too high. The project model incorporates the P-M pits as constant-head-cell boundary conditions (Large Figure 7 of Attachment B of the WMDPv13, attached as Figure 1**)**. The project model sets the P-M pit lakes as constant-head-cells approximately 5 meters above the level of the upper Partridge River, yet pit lakes during the period when flow data was collected (1979-88) were actually well below the elevation of the upper Partridge. Because of this error, the calibration model has the local direction of groundwater flow from the pits 180 degrees reversed from the actual conditions during the calibration period. The model predicts that during the calibration period water was flowing from the hydrologic high at the P-M pits to the hydrologic low at the upper Partridge River, when in fact, because the pits were partly to completely empty, water would have been flowing from the upper Partridge River to the P-M pits.

Attached is a figure that shows the predicted water tables and groundwater flow between the upper Partridge and the P-M pits when the P-M pits are set at different levels (attached as Figure 2). In red are the project model results used in recent and past project reports. In those models the P-M pits are assumed to be at their 1996 elevation of 493 meters. The 483 meter model (in purple) is the same as the project model except that the water levels in the P-M pits, that are adjacent to the upper Partridge, are set to 483 meters. An average pit water elevation of less than 480 meters appears to be the correct elevation for the calibration period of 1979-1988 (attached as Table 1). Calibration and use of the MODFLOW model with the P-M pits erroneously set to the unusually high conditions in 1996 (493 meters) is a problem for the following reasons:

- The baseflow used in formulating (calibrating) the PolyMet project MODFLOW mine site

1 GLIFWC member tribes are: in Wisconsin -- the Bad River Band of the Lake Superior Tribe of Chippewa Indians, Lac du Flambeau Band of Lake Superior Chippewa Indians, Lac Courte Oreilles Band of Lake Superior Chippewa Indians, St. Croix Chippewa Indians of Wisconsin, Sokaogon Chippewa Community of the Mole Lake Band, and Red Cliff Band of Lake Superior Chippewa Indians; in Minnesota -- Fond du Lac Chippewa Tribe, and Mille Lacs Band of Chippewa Indians; and in Michigan -- Bay Mills Indian Community, Keweenaw Bay Indian Community, and Lac Vieux Desert Band of Lake Superior Chippewa Indians.

model was calculated from flow conditions in the 10 years of 1979 through early 1988. During calibration, the MODFLOW model was adjusted until the baseflow it predicted matched the 0.51 cfs baseflow target at station SW003, where the Dunka Road crosses the Partridge River.

- The water level in the P-M pits used as boundary conditions when calibrating the project model was assumed to be 493 meters elevation, the water elevation in 1996. This level is much higher than any water levels that occurred during the period when flow was measured.

- The average water level in the P-M pits, when the baseflow at SW003 was estimated to be 0.51 cfs (i.e. in the 10 years of 1979 to early 1988), was actually more than 13 meters lower, at less than 480 meters.

As the diagram shows, with the pit water levels that occurred in November of 1986 (i.e. ~483 meters), the upper Partridge would have been losing water to the pits and would have had no baseflow. The water table would have sloped down northward from the Partridge River toward the P-M taconite pits. This is because the riverbed of the upper Partridge River is at 486-489 meters elevation, whereas the water levels in the adjacent P-M pits were at approximately 483 meters elevation in 1986. Average water levels in the P-M pits during the 10 years for which baseflow was calculated (1979-1988) were *even lower* than the 483 meter elevation found in 1986.

Water levels in the P-M Area003-East pit increased from an elevation of less than 478 meters in 1979 to 488 meters in the fall of 1987. During most of that period the Area003-East pit was empty, i.e. less than 478 meters elevation. In contrast the 1996 water level used for the Area003-East pit was 492.6 meters elevation. The P-M pit water levels were not vaguely "variable" as stated in the draft memo on calibration, but rather consistently well below the levels used in the Barr MODFLOW modeling. The 1996 water level used for the P-M pits as a boundary condition in the modeling was abnormally high. Such high levels did not occur in the 1980s, do not occur now and will not occur at closure.

The significance of this is that the MODFLOW model was calibrated (adjusted to fit reality) to average baseflow calculated for 1979-88, yet the P-M pit water levels used as boundary conditions in calibration were the unusually high levels that occurred in 1996, not those that occurred in 1979-88 or those that occur now. A fundamental requirement of model calibration is that the calibration targets (i.e. baseflows) and the model boundary conditions (i.e. the water levels in the taconite pits) must be from the same time period. The hydrologic system in 1996 was significantly different from the system in 1979-88 because the water levels in the taconite pits were so different. The result of this mis-match of boundary conditions and calibration targets is that the model is incorrectly calibrated and can not be expected to produce accurate predictions. The model gives the impression of generating reasonable results but is based on conditions that never existed at the same point in time. The 1996 boundary conditions in the form of P-M pit water levels did not occur in the 1980s, do not occur now and are not expected to occur in the future. Given the importance of the P-M pit water elevations as boundary conditions, this is a critical flaw.

Contrary to statements in the WMDP (v13) section on Model Technical Review Checklist, the MODFLOW model was not evaluated to sensitivity of some of the most significant boundary conditions, the Constant-head boundary conditions representing the P-M pits. If such evaluation had been done, it would have been obvious that the model was very sensitive to the levels specified at those pits. Our analysis suggest that approximately 90% of upper Partridge River baseflow comes from the P-M pits when the P-M are at their 1996 level and the shape of the watertable and bedrock potentiometric surface is highly dependent on the P-M pits boundary condition in the model.

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Sensitivity analysis as a substitute for correct model bounding and calibration:

It has been proposed that sensitivity analysis can substitute for understanding site hydrology. While sensitivity analysis on a properly bounded and calibrated model provides insights on the range of possible predictions, sensitivity analysis conducted on a grossly mis-configured model can not be depended upon. The closure period model, on which the sensitivity analysis was conducted, was configured with boundary condition in the form of P-M pit water levels at their 1996 levels, over 300 feet higher than the water levels actually expected at the time of PolyMet closure. Those P-M pits are close to the center of the model used for sensitivity analysis and, therefore, erroneous boundary conditions of this magnitude invalidate the results of the sensitivity analysis.

Northward Flow of Contaminants from PolyMet Pits and Category 1 Stockpile at Closure:

Northward flow in the bedrock aquifer:

The project mine site MODFLOW model distributed to cooperating agencies on January 5, 2015 was used by the applicant to predict that contaminants would flow from the mine site at closure to the south and south-east (for example: Large Figures 28 & 29 of the WMDPv13, attached as Figures 3 and **4**). In those project model runs of closure conditions, the water levels in the P-M taconite pits were assumed to remain at the level found in 1996. At closure the P-M pits will not be at 1996 levels but over 300 feet lower. In fact those 1996 levels were atypical; they did not occur in the 1980s, do not occur now and will not occur at closure. A plot of water levels in the Area003-East P-M pit, the pit closest to the PolyMet east pit, shows how atypical the mid-1990s water levels were (attached as Figure 5). In the project predictive models of closure conditions, the adjacent taconite pits to the PolyMet project site were set to have a 1996 water elevation of 1616 feet or 493 meters. However, the P-M taconite pit water levels expected at P-M pit closure are 1300 feet or 396 meters. After reflooding of the P-M pits, the water levels in those pits will be maintained by an outfall in the north-east at 1500 feet or 457 meters (see figure from the Northshore Watershed Mitigation Plan of 2011, attached as Figure 6).

Given the large effect that the project groundwater MODFLOW model and ERM's MathCad cross-section model indicate the water in the taconite pits has on the local bedrock hydrology, one would expect that a large change in the elevation of the water in the taconite pits would have a significant impact on local hydrology and predictions of closure conditions. The close proximity of the P-M pits to the Partridge River and PolyMet mine features (attached Figure 7) suggests that the taconite mine pits would impact the hydrology of these features. In fact, runs of the project model indicate that the groundwater flow direction between the PolyMet project and the taconite pits would be reversed if the taconite pits had the correct P-M pit closure water elevation of 396 meters or even the very long-term level of 457 meters (attached as Figure 8). This initial modeling, conducted by GLIFWC, limited the amount of water that could be lost by the Partridge River to the aquifer because the Partridge can not be an infinite source of water. However, supplemental modeling such as that provided during the July 22nd meeting, (see email of July 21 "Materials for July 22nd modeling discussion, part 2", attached as Attachment A) had no such limitation, yet still showed a strong bedrock gradient toward the P-M taconite pits at closure. That supplemental modeling, without limiting leakage from the bottom of the Partridge River, showed a steep bedrock groundwater gradient from the PolyMet east pit to the P-M pits at closure water levels of 1300 ft (396 meters) and 1500 ft (457 meters) (attached as Figure 9). Additional MODFLOW modeling with recharge to the top of the model set at over 8 in/yr also showed northward flow from the PolyMet project at closure. Under this high recharge modeling scenario, a small mound does develop in the bedrock aquifer but not one large enough to prevent northward flow. Development of a groundwater mound is limited, not because of low recharge, but because of the low vertical conductivity of the surficial deposits and the strong pull of the low water levels in the P-M pits.

Northward flow of groundwater is in agreement with ERM's Mathcad model which shows bedrock water levels sloping steeply to the north given the water levels expected at closure of the P-M pits. According to ERM's MathCad analysis, only if a groundwater mound forms in the bedrock would flow to the north not occur (attached as Attachment B). Formation of such a substantial mound by movement of water downward from the 100 Mile Swamp is simply not possible given the hydrogeology defined by project documents (e.g. WMDPv13 Table 3-4, attached as Table 2).

The draft co-lead memo on a northward flowpath correctly states that:

> "for the case where downward leakage is negligible ..., the mound does not develop, there is no drainage divide, and the bedrock system would have continuous northward flow from the proposed NorthMet East Pit to the Northshore pits."

and

> "a key factor in the conceptual model is the amount of downward leakage from the surficial deposits into bedrock."

The memo goes on to state that at least 8 inches/year of leakage into the bedrock would be necessary to prevent northward flow. What has not been demonstrated is that the 8 inches per year of leakage into the bedrock is theoretically possible, given the low vertical conductivity of the overlying wetlands.

The result, from both the project MODFLOW model runs with the correct closure water elevations and ERM's MathCad model runs, indicate that water in bedrock will flow to the north from the PolyMet site at closure, unless a bedrock groundwater mound forms. <u>No feasible natural mechanism for such a mound has been articulated.</u> A bedrock groundwater mound at the level necessary to prevent northward flow, i.e. a mound of elevation of approximately 1600 feet, appears to be hydrologically impossible without long-term active management. Northward flow would be primarily from the PolyMet east pit and, despite attempted containment in the surficial aquifer, from the Category 1 stockpile. These flowpaths have been overlooked in project evaluations of contaminant transport. The current project contaminant transport modeling, which assumes contaminant flow paths only to the south and south-east, is incomplete because it is based on the incorrect assumption of 1996 era water levels in the taconite pits, even during closure, a water level that is more than 300 feet too high.

Northward flow in the surficial aquifer:

In addition to potential for northward flow of contaminants in the bedrock that is documented in our previous correspondences, including our email of July 21 ("Materials for July 22nd modeling discussion, part 2", attached as Attachment A) and ERM's MathCad modeling, there is evidence that flow may be to the north in the surficial aquifer. In the examples from other taconite pits represented by Figures 2 and 3 of the Barr June 4th memo (attached as Figures 10 and 11), accounting for the compressed x-axis scale, the cross-sections appear to show that the cone of depression caused by taconite pits extends 1.4 to 1.5 miles from the pits in the surficial aquifer. The PolyMet east pit is only 1.2 miles and the Category 1 stockpile is only 0.8 miles from the edge of the final Peter-Mitchel pit (attached as Figure 7). Preliminary MODFLOW modeling of the surficial aquifer shows northward flow of contaminants from the PolyMet east pit in the surficial aquifer. This is the case if model recharge is limited to the 0.75 in/yr used in the PolyMets closure model (PFEIS page 5-27) but also if the model is run with more than 8 in/yr of recharge to the surficial aquifer. The drawdown by the over 300 foot deep taconite pits is so great that the surficial aquifer becomes partly dewatered and all baseflow in the upper Partridge ceases.

Importance of understanding groundwater hydrology for prediction of surface water impacts:

Adequate characterization of the groundwater system at a proposed mine site is essential to understanding most of the potential impacts from the project. The amount of water entering the groundwater system, be it precipitation or discharge from the bed of lakes, rivers or mine pits, determines the direction of flow and dilution of contaminants, and dictates points of compliance for both ground and surface waters. The horizontal and vertical conductivity of the soil and bedrock materials determines how the groundwater system responds to stresses and the rate at which the groundwater flows horizontally and vertically. The character of interaction between surface water features and the groundwater system, whether it is loss of water from rivers or wetlands to the groundwater system, or discharge from the groundwater system to the surface water features, determines predicted impacts to surface water features by stresses such as mine dewatering. Estimating water budgets and quantities of water that must be treated requires an adequate understanding of the groundwater system. None of the above effects of a mine project can be predicted accurately if there is not an adequate characterization of the groundwater system. Without an integrated model of the groundwater system, one would be left with only professional judgment to determine the value of the many interrelated parameters that are used for impact prediction. Professional judgment is useful in checking the reasonableness of the predictions from a groundwater model but, by itself, can not adequately integrate the complex site specific information, all pieces of which must fit together like a complex puzzle.

The essential role of groundwater system characterization, characterization that integrates information from the available sources into a coherent model, is demonstrated by the myriad of uses that the project groundwater model has been put to by the applicant during impact evaluation. We have compiled, from the text in the WMDPv13 and the PFEIS, references to the use of the groundwater modeling to predict impacts from the proposed project . Those uses range from contaminant flow direction and gradients (PFEIS page 5-26) to delineation of the Area of Potential Effect for cultural impacts (PFEIS page 4-309 and Figure 4.2.9-5). Project documents include very clear statements about the importance of MODFLOW in formulating impacts, for example the Water Modeling Data Package v13 Section 5.1.2.6 states:

> "Groundwater contours for the unconsolidated deposits and bedrock are the primary source of information used to delineate the flow path areas. The groundwater contours are from the Mine Site MODFLOW model"

The GoldSim contaminant transport modeling in particular uses many outputs from the MODFLOW groundwater modeling (attached as Table 3). These extend far beyond the original purpose of the groundwater model; which was to predict pit inflow, thus making it very clear that a valid model that characterizes site groundwater hydrology is foundational for impact prediction.

The project MODFLOW model was used to characterize the general nature of the groundwater system such as mine site head distribution (e.g. watertable, Large Figure 14 of the WMDPv13, attached as Figure 12), groundwater levels at closure (e.g. Large Figure 30 of Attachment B of WMDPv13, attached as Figure 13) and contaminant flow paths (Large Figures 28 & 29 of the WMDPv13, attached as Figures 3 & 4). In addition, the MODFLOW model was used to supply the numeric input parameters to the GoldSim model that is used for prediction of contaminant flow and contaminant concentrations (WMDPv13, Table 1-1). That table, attached as Table 4, identifies approximately 12 critical GoldSim input parameters that are outputs from the mine site MODFLOW groundwater model. Of those twelve, approximately 6 parameters are related to mine pit inflow; the rest of the 12 parameters relate to the groundwater system across the entire mine site. Those parameters include contaminant flowpath conductivity (K_flowpath), flowpath gradients (I_ops), bedrock porosity (Bedrock_Porosity), recharge (Recharge_min and Recharge_max) and flowpath gradients at closure (I_close). While some of these parameters, such as flowpath conductivity, are secondarily derived from MODFLOW outputs, MODFLOW is an input to calculation of the GoldSim parameter, as documented in WMDP(v13) Section 5.2.3.3.

It is clear that without the conceptual (flow directions etc.) and numeric (gradient, conductivity etc.) outputs from the MODFLOW model, the GoldSim model could not be run. Because of the dependence of the GoldSim modeling of contaminant transport on MODFLOW model outputs, it is essential that the MODFLOW outputs be valid. Because the MODFLOW model was incorrectly calibrated to baseflow from 1979-88 and bounded with taconite pit water levels from 1996 it is very unlikely that the MODFLOW outputs are correct. Not only was the calibration model incorrectly bounded but the predictive runs use the same abnormally high P-M pit water levels. In particular the predictive runs for long-term closure (MODFLOW run "SS_west_fill_Sept2014_1585ec1595" resulting in Large Figures 29 and 30, WMDPv13 and PFEIS Figure 5.2.2-7) use the 1996 taconite pit water levels that are over 300 feet higher than the expected closure water levels.

Need for a consistent conceptual model of site hydrology:

There are two conflicting conceptual models presented in the draft northward flowpath memo: 1) that surface water features are not well connected to the bedrock, e.g. the Argo & Iron Lakes examples, and a multitude of previous EIS documents arguing for separated surficial and bedrock aquifers and against wetland impacts (see email of July 29, 2015, attached as Attachment C); and 2) that surface water features are well connected to the bedrock aquifer and that the 100 Mile Swamp (a wetland) can supply at least 8 inches/year of leakage. These two arguments would seem to be mutually exclusive. Both arguments can not be used simultaneously to support the concept of a groundwater mound between the PolyMet and Peter-Mitchel projects. A third argument has been hinted at during meetings; that the bedrock between PolyMet and the P-M pits is of such low conductivity that the cone of depression from the mine pits does not extend any significant distance from the pits. This argument is not supported by the site-specific conductivity data collected on the Virginia Formation or the documented conductivity of the Biwabik Iron Formation (see PFEIS tables 4.2.2-5 and 5.2.2-7).

A coherent conceptual model needs to be articulated, either one in which surface water features are poorly connected to the bedrock aquifer and are therefore, unaffected by pit dewatering, or one in which surface water features are well connected to the bedrock aquifer and can provide leakage to support a groundwater mound between the PolyMet and Peter-Mitchel pits. If the first model is accepted then wetlands and the upper Partridge River may be little affected by pit dewatering but dewatering of the Peter-Mitchel pits causes a bedrock northward flowpath to develop at closure. If the second conceptual model is accepted then a bedrock groundwater mound develops, but wetlands and the upper Partridge River are severely impacted by PolyMet and Peter-Mitchel pit dewatering.

"Adaptive management" as a substitute for understanding the site and predicting impacts:

Given the uncertainty that the co-leads feel there is in characterization of contaminant flowpath direction, the draft co-lead memo of June 22 proposes several mitigations that attempt to prevent northward flow of contaminants. The feasibility of any of those measures has not been evaluated. Even with the minimal information presented in the memo, several obstacles to successful mitigation of a northward flowpath are evident: 1) The thickness of the low conductivity surficial deposits between the PolyMet site and the P-M pits, approximately 50 feet thick according to Minnesota Geological Survey 2005 publication M158, makes the practicality of an infiltration trench questionable; 2) Lowering of water levels in the the PolyMet pits would expose reactive Virginia Formation rock to air and water, creating acid generation and dewatering surrounding wetlands; 3) Groundwater injection or extraction wells may be a feasible, but costly, mechanism to block northward flow but, as noted in the memo, would require perpetual operation, care and replacement.

In addition to the proposed adaptive management appearing to be impractical, substituting 'adaptive management" for understanding of the hydrologic system is contrary to the NEPA concept of site characterization and impact prediction. NEPA is a forward looking process with the goal of anticipating and describing impacts so that measures can be taken to avoid or minimize those impacts. A northward flowpath for contaminants is indicated by both MODFLOW and MathCad. The character of the hydrology between the PolyMet and P-M projects needs to be described correctly so that impacts of that northward flowpath can be evaluated and the feasibility of mitigation measures can be determined.

In summary:

- The project mine site groundwater flow model (MODFLOW) was calibrated with multiple conditions that did not exist simultaneously, i.e. boundary conditions in the form of taconite pit water levels from 1996 and river baseflows from 1979-88. This means that the mine site model is not correctly configured and, therefore, unlikely to generate accurate predictions.

- The project model was configured and used by the applicant as a basis for contaminant transport predictions at closure. As configured, it predicts that contaminants would flow from the PolyMet site south to the Partridge River at project closure. However, if the model is configured with correct closure boundary conditions in the form of taconite pit water levels at their closure level of 396 meters (1300 feet) or the very long-term level of 457 meters (1500 feet), contaminants are predicted to flow to the north toward the P-M pits. This contaminant flow direction (to the P-M pits) is opposite the direction assumed for the current project contaminant transport modeling. The project contaminant modeling is incomplete because it does not evaluate northward flow of contaminants from either the PolyMet pits or the Category 1 stockpile.

- The conceptual model used for the basis of many of the conclusions in project reports and in the PFEIS text is that the taconite pits have little influence on the surrounding aquifer, regardless of whether they are full of water or pumped dry and that the surface water features are not hydraulically connected to the bedrock aquifer. However, the mine site MODFLOW model, which incorporates historical and site-specific conductivity data on the bedrock formations and is used by the applicant to predict closure conditions, indicates that the taconite pits have a profound impact on the surrounding aquifer. This is because the cone of depression caused by taconite pit dewatering extends well into the surrounding bedrock. Impact on the aquifer makes sense because of the relatively high horizontal conductivity of the bedrock in which the taconite pits sit.

-The current concept, articulated in the draft co-lead memo on a northward flowpath and the supporting MathCad modeling, appears to recognize the documented horizontal conductivities of the bedrock formations, yet seems to propose both the isolation of surface water features and the transmission of large quantities of water from surface water features to the bedrock. Both isolation and transmission are not simultaneously possible. A consistent conceptual model must be presented.

-Pit dewatering may induce significant quantities of water from the surficial aquifer into the bedrock. Although this would likely cause substantial wetland & stream impacts, natural formation of a groundwater mound in the bedrock, adequate to prevent northward flow, is impossible given the conductivities documented in the project materials.

The mine site groundwater model needs to be reconfigured to contain realistic water levels in the P-M taconite pits, both for a "current conditions" model and a "closure conditions" model, not the 1996 water levels that were unusually high. The predictive modeling for the post closure period must use the correct closure water elevations for the P-M pits which are 300 feet lower than the unusually high 1996 levels. Groundwater modeling with MODFLOW, with correct P-M pit closure water levels of 396 meters, and MathCad modeling, both indicate that at closure contaminants are likely to flow north in addition to the southward direction currently assumed by project reports. Evaluation of contaminate flow to the north must be conducted and impacts predicted. Sensitivity analysis and adaptive management can not be substitutes for consistent and rational characterization of site hydrology.

Sincerely,

John Coleman

John Coleman, GLIFWC Environmental Section Leader

cc: Randall Doneen, Environmental Review Unit Supervisor, MN-DNR
Brenda Halter, Forest Supervisor, Superior National Forest
Tamera Cameron, Chief, Regulatory Branch, St Paul District of the Army Corps of Engineers
Kenneth Westlake, NEPA Coordinator, USEPA Region 5
Nancy Schuldt, Water Projects Coordinator, Fond du Lac Environmental Program
Neil Kmiecik, GLIFWC Biological Services Director
Ann McCammon Soltis, Director, GLIFWC Division of Intergovernmental Affairs

Subject:	Materials for July 22nd modeling discussion, part 2
From:	"john.coleman" <jcoleman@glifwc.org>
Date:	7/21/2015 3:41 PM
Attachments:	Fig.30_Attach.B_of_Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf (417 KB), Fig.30_with_Peter-Mitchel_pits_at_closure_level_of_1500ft.pdf (553 KB)
To:	"Johnson, Bill H (DNR)" <bill.johnson@state.mn.us>, Sedlacek.Michael@epa.gov, mwatkins@grandportage.com, NancySchuldt@FDLREZ.COM, blatady@boisforte-nsn.gov, est [...]

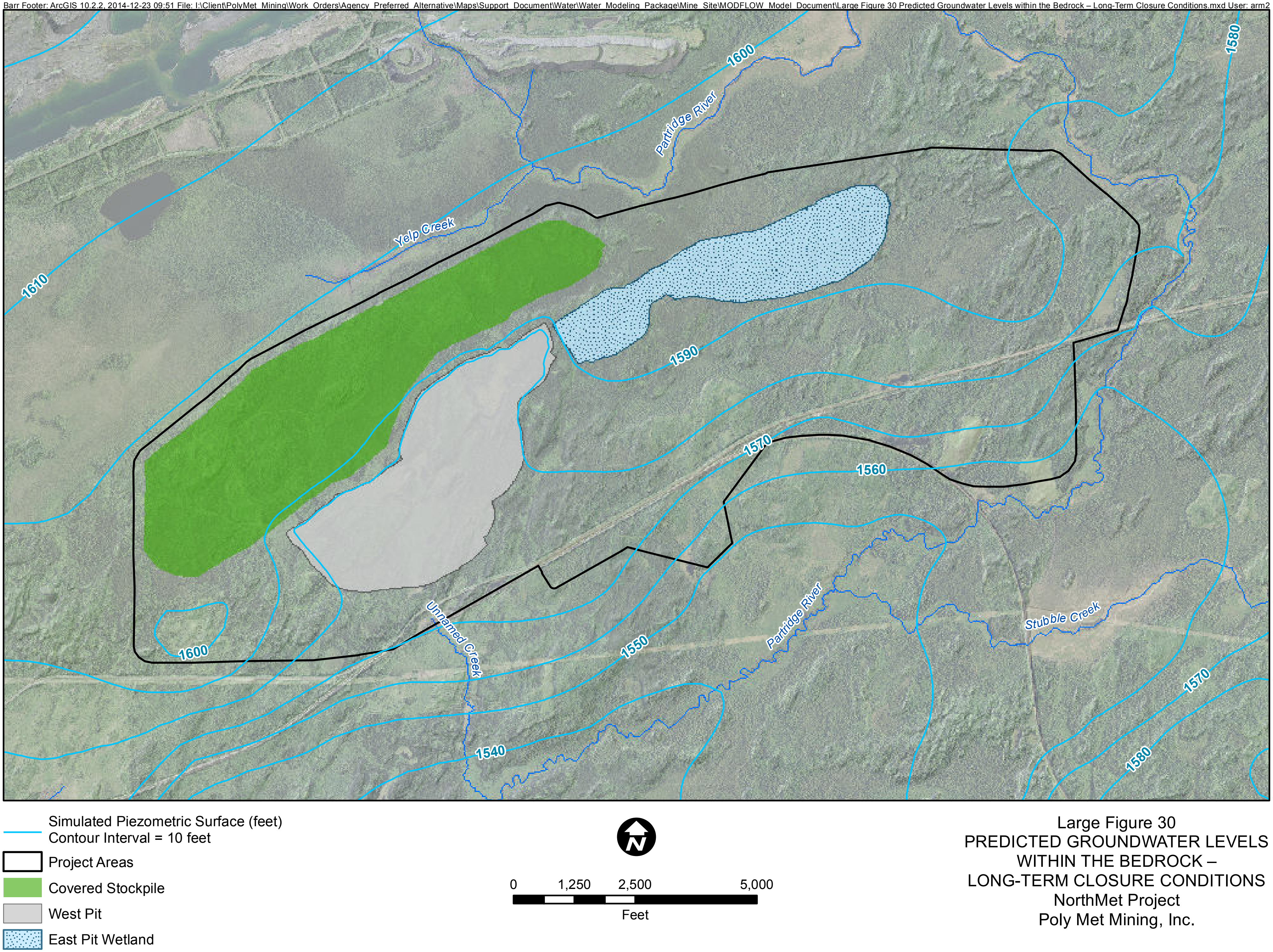
Closure period modeling files:
The Barr modeling file for the closure period is named "Steady_State_west_pit_filling_Sept2014_1585ft_ec1595ft.gwv" and "SS_west_fill_Sept2014_1585ec1595.nam ."   It is the model run used to generate:
Large Figures 28 and 29 of the Water Modeling Data Package Vol_1-Mine_Site_v13_DEC2014, .pdf pages 510 & 511 (contaminant flowpaths)
and
Large Figures 29 and 30 of Attachment B of Water Modeling Data Package Vol_1-Mine_Site_v13_DEC2014, .pdf pages 713 & 714 (bedrock and surficial water levels)

The model files were distributed to cooperating agencies by Bill Johnson in February of this year.
Is is described by Barr in an accompanying txt file as:
"Steady-state simulations of closure under baseline conditions:"
"West pit at 1585 feet MSL, East and Central pit at 1595 feet MSL:
Steady_State_west_pit_filling_Sept2014_1585ft_ec1595ft.gwv"

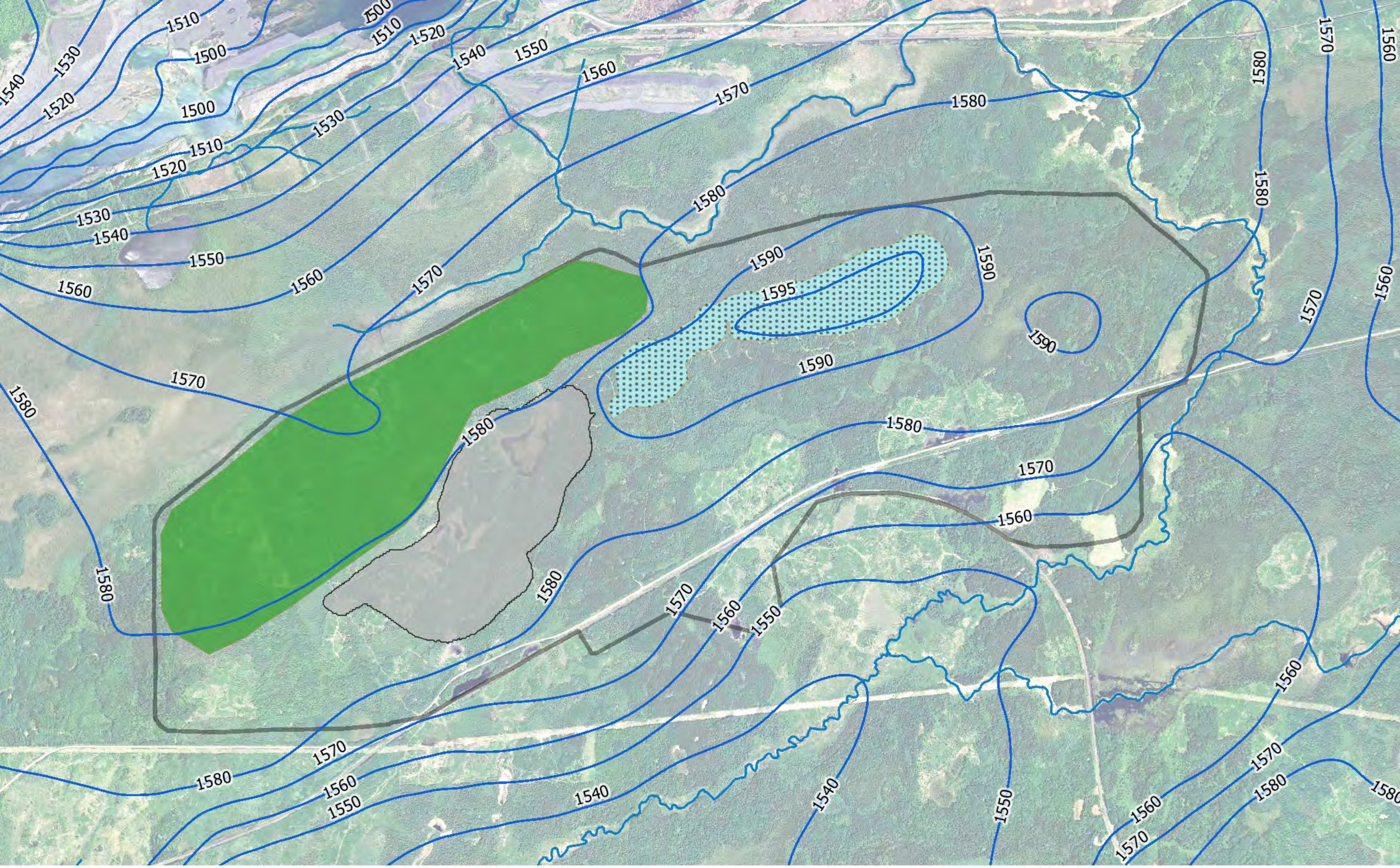
Polymet use of closure period modeling files:
Polymet predicted groundwater levels in the bedrock under long-term closure conditions using the MODFLOW model run referenced above. For example, the attached Large Figure 30 of Attachment B of the Water Modeling Data Package Vol_1-Mine_Site_v13_DEC2014 shows the bedrock water level contours predicted by that model run.
Those predicted contours were used in the Water Modeling Data Package to define flow paths (Large Figure 29 of the Water Modeling Data Package Vol_1-Mine_Site_v13_DEC2014). As stated on page 75 of the Water Modeling Data Package v13 (.pdf page 82):

> "Groundwater contours for the unconsolidated deposits and bedrock are the primary source of information used to delineate the flow path areas. The groundwater contours are from the Mine Site MODFLOW model"

Closure period model with correct closure levels:
Using the same model "Steady_State_west_pit_filling_Sept2014_1585ft_ec1595ft.gwv" except that water levels in the Peter-Mitchel taconite pits were set at their correct long term level of 1500 feet, we find that the model predicts different groundwater contours in the bedrock (figure attached). Neither "downward leakage" nor any other parameters in the model were modified. The contours predicted by the model when the P-M pits are at their long-term closure level of 1500 ft, indicate that there are bedrock flow paths to the north from the Polymet pits. At the time of Polymet closure, the P-M pits are expected to be at an elevation of approximately 1300 ft, amplifying the effect on the aquifer.



Large Figure 30
PREDICTED GROUNDWATER LEVELS WITHIN THE BEDROCK – LONG-TERM CLOSURE CONDITIONS
NorthMet Project
Poly Met Mining, Inc.



Simulated Piezometric Surface (feet)
Contour Interval 10 feet

Project Areas

Covered Stockpile

West Pit

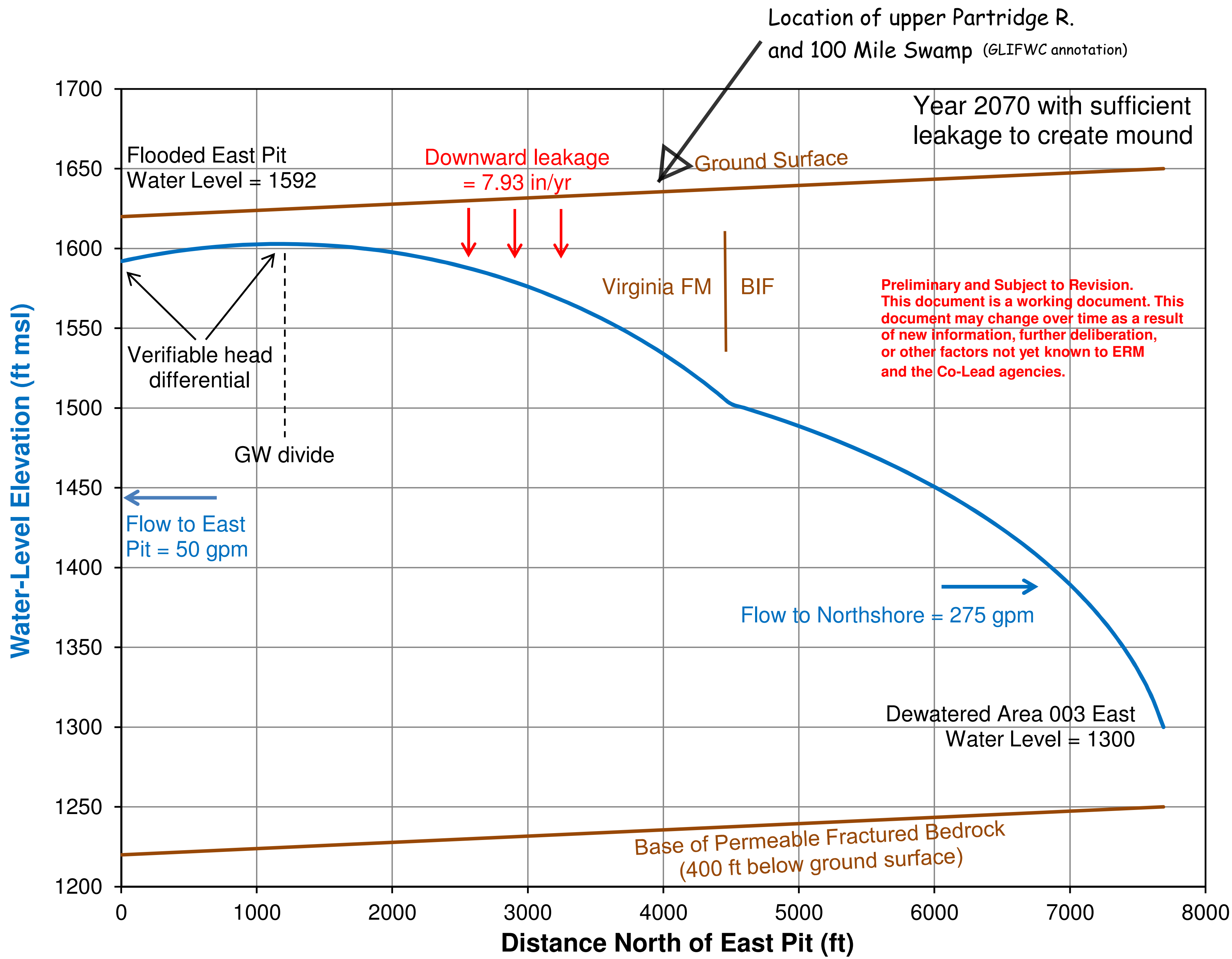
East Pit

N

2500 0 2500 5000 ft

PREDICTED GROUNDWATER LEVELS
WITHIN THE BEDROCK -
LONG-TERM CLOSURE CONDITIONS
FOR NORTHMET
AND NORTHSHORE PROJECTS

GLIFWC, 2015-06-28



Location of upper Partridge R.
and 100 Mile Swamp (GLIFWC annotation)
Year 2070 with sufficient
leakage to create mound
Flooded East Pit
Water Level = 1592
Downward leakage
= 7.93 in/yr
Ground Surface
Virginia FM
BIF
Preliminary and Subject to Revision.
This document is a working document. This
document may change over time as a result
of new information, further deliberation,
or other factors not yet known to ERM
and the Co-Lead agencies.
Verifiable head
differential
GW divide
Flow to East
Pit = 50 gpm
Flow to Northshore = 275 gpm
Dewatered Area 003 East
Water Level = 1300
Base of Permeable Fractured Bedrock
(400 ft below ground surface)
Water-Level Elevation (ft msl)
Distance North of East Pit (ft)
1700
1650
1600
1550
1500
1450
1400
1350
1300
1250
1200
0
1000
2000
3000
4000
5000
6000
7000
8000

Polymet - Leakage conditions for mound at year 2070

Units below are ft-day

$KK_1 := 0.31 \cdot \frac{ft}{day}$	Hydraulic Conductivity Upper Virginia Fm.	$K_1 := KK_1 \cdot ft^{-1} \cdot day$	$K_1 = 0.310$
$KK_2 := 0.9 \cdot \frac{ft}{day}$	Hydraulic Conductivity Biwabik Fm.	$K_2 := KK_2 \cdot ft^{-1} \cdot day$	$K_2 = 0.900$
$WW := 7.93 \cdot \frac{in}{yr}$	Downward leakage flux into bedrock	$W := WW \cdot ft^{-1} \cdot day$	$W = 1.81 \times 10^{-3}$
$LL := 7690 \cdot ft$	Length of flow system (East Pit to PMP)	$L := LL \cdot ft^{-1}$	$L = 7690.0$
$DD := 4490 \cdot ft$	Distance to Virginia/Biwabik contact	$D := DD \cdot ft^{-1}$	$D = 4490.0$
$ww := 4500 \cdot ft$	Flow tube width	$w := ww \cdot ft^{-1}$	$w = 4500.0$
$GG_o := 1620 \cdot ft$	Ground elevation at x=0	$G_o := GG_o \cdot ft^{-1}$	$G_o = 1620.0$
$HH_o := 1592 \cdot ft$	Head at x=0	$H_o := HH_o \cdot ft^{-1}$	$H_o = 1592.0$
$BB_o := 1220 \cdot ft$	Base elevation at x=0	$B_o := BB_o \cdot ft^{-1}$	$B_o = 1220.0$
$S_G := 0.0039$	Ground slope		$S_G = 0.00390$
$S_B := S_G$	Aquifer base slope		$S_B = 0.00390$
$QQ_o := -50 gpm$	Inflow at x=0	$Q_o := QQ_o \cdot ft^{-3} \cdot day$	$Q_o = -9.625 \times 10^3$
$G(x) := G_o + S_G \cdot x$	Ground elevation	$G(0) = 1620.0$	$G(L) = 1650.0$
$B(x) := B_o + S_B \cdot x$	Base elevation	$B(0) = 1220.0$	$B(L) = 1250.0$

$$K(x) := \begin{cases} K_1 & \text{if } x \le D \\ K_2 & \text{otherwise} \end{cases}$$

Hydraulic conductivity distribution along flowpath

Given
$$H'(x) = -\frac{\frac{Q_o}{w} + W \cdot x}{K(x) \cdot (H(x) - B(x))} \qquad H(0) = H_o \qquad H := \text{Odesolve}(x, L)$$

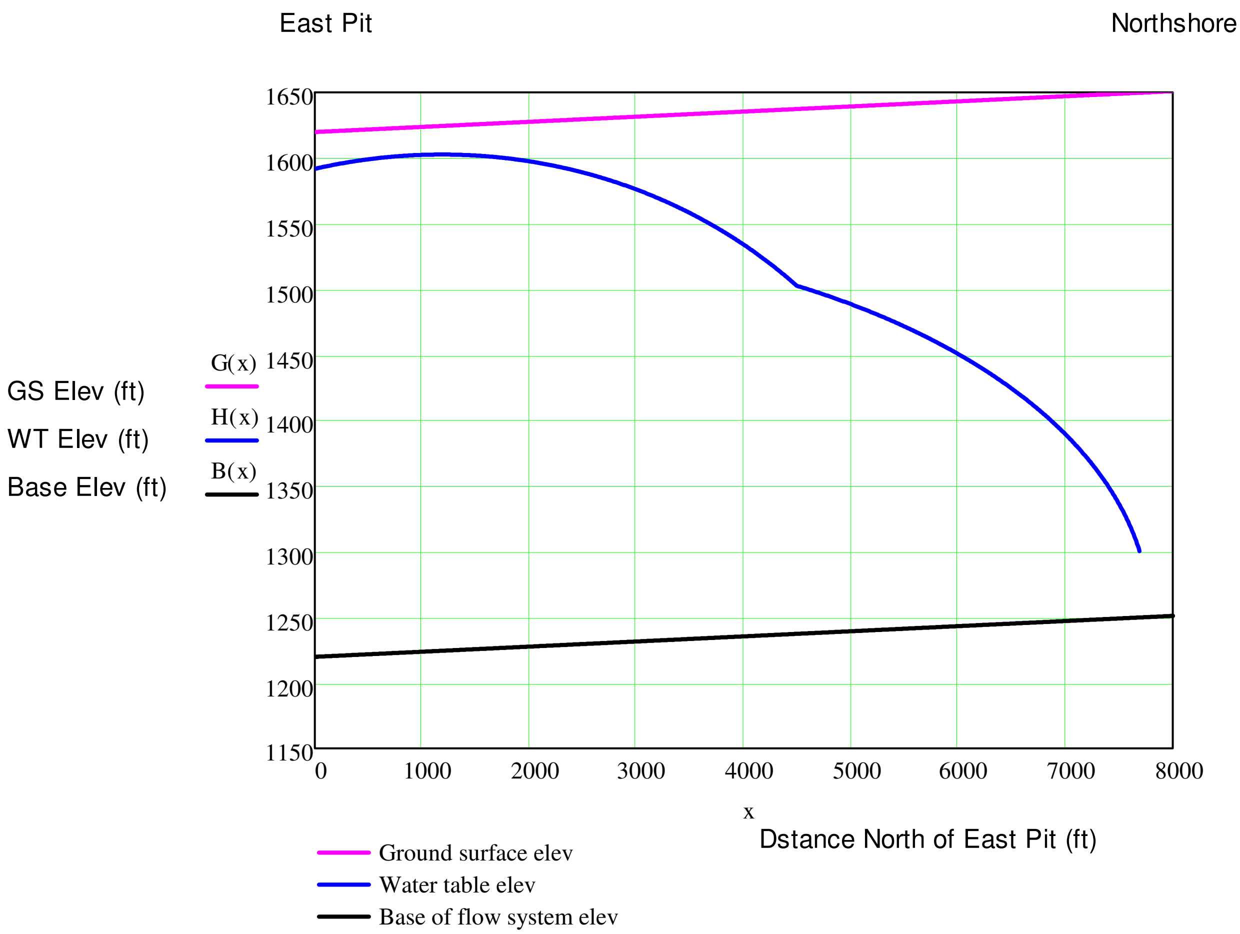
Governing ODE and BC

"Point-and-shoot" solution method

Iterate on QQ_o and/or WW until the head at x = LL is 1300 ft; that is, H(L) = 1300

$H(L) = 1300.1$

This solution is for 1-D horizontal flow and accounts for:
Variable saturated thickness
Uniform downward leakage
Sloping aquifer base


East Pit
Northshore
1650
1600
1550
1500
1450
1400
1350
1300
1250
1200
1150
G(x)
H(x)
B(x)
GS Elev (ft)
WT Elev (ft)
Base Elev (ft)
0
1000
2000
3000
4000
5000
6000
7000
8000
x
Dstance North of East Pit (ft)
Ground surface elev
Water table elev
Base of flow system elev

Subject:	material related to bedrock-wetland connections at Polymet mine site
From:	"john.coleman" <jcoleman@glifwc.org>
Date:	7/29/2015 8:12 AM
To:	bill.johnson@state.mn.us, Sedlacek.Michael@epa.gov, mwatkins@grandportage.com, NancySchuldt@FDLREZ.COM, blatady@boisforte-nsn.gov, esteban@glifwc.org, TKaspar@1 [...]

Following up on the webinar last week, here is some material related to the hydrologic connection between surficial wetlands and the bedrock aquifer.

Throughout the development of the EIS, the applicant and their consultants have made the argument that the surficial deposits, and in particular wetlands such as the 100 Mile Swamp, are not hydrologically well connected to the bedrock aquifer. 8 inches/year of leakage to establish a groundwater mound in the bedrock would require that the 100 Mile Swamp be well connected to the underlying bedrock aquifer. Statements by the applicant claiming a weak to non-existent connection between surficial deposits and the bedrock include:

1) "there may be an unsaturated zone between the surficial deposits and bedrock present in some portions of the site, which would suggest **a minimal degree of hydraulic connection between the surficial aquifer and bedrock**." (WMDP v13, Section 4.3.3.2 Bedrock)
and

2) "As discussed in Section 4.3.3.2, available data indicates that, **although the surficial aquifer and bedrock are likely hydraulically connected to some degree, the connection is believed to be weak or non-existent in many areas of the Mine Site.**" (WMDP v13, Section 5.2.3.1 Groundwater Flow Path Modeling)
and

3) "Because **the dense underlying till acts as an aquitard that restricts downward water flow**, most of the organic and mineral soils in the depressional areas of the site have perched water tables." (page 3, Barr June 2, 2008, Indirect Wetland Impacts at the Mine Site).
and

4) "Figure 4 identifies the moisture content throughout the soil profiles from the soil surface to the bedrock surface (Barr, Overburden Soil Boring Logs - Draft, January 2008). The moisture content was field described as dry, moist or wet. The moisture content changes throughout each soil profile, **indicating the surficial aquifer is not always continuous from the soil surface to the bedrock surface.**" (page 4, Barr June 2, 2008, Indirect Wetland Impacts at the Mine Site).
and

5) "Because of the **lack of interaction between the surficial and bedrock aquifers**, the hydrology of the wetlands at the site is primarily supported by direct precipitation with some variable surficial groundwater component from the uplands." (page 4, Barr June 2, 2008, Indirect Wetland Impacts at the Mine Site).
and

6) "A number of factors contribute to the stable hydrology of the wetlands on the site including: 1) **the lack of continuity between the bedrock and surficial aquifers**; 2) the variability of the hydraulic conductivities within the soil layers causing perched water tables;" (page 12, Barr June 2, 2008, Indirect Wetland Impacts at the Mine Site).
and

7) "**Wetlands generally have a perched surficial water table and no interaction with the bedrock aquifer.**" (page 12, Barr June 2, 2008, Indirect Wetland Impacts at the Mine Site).

8) "Because of the **general lack of interaction between the surficial and bedrock aquifers**, the hydrology of many wetlands at the Mine Site is primarily supported by direct precipitation with some variable surficial groundwater components from the uplands." (PFEIS Page 4-167, lines 191-193)

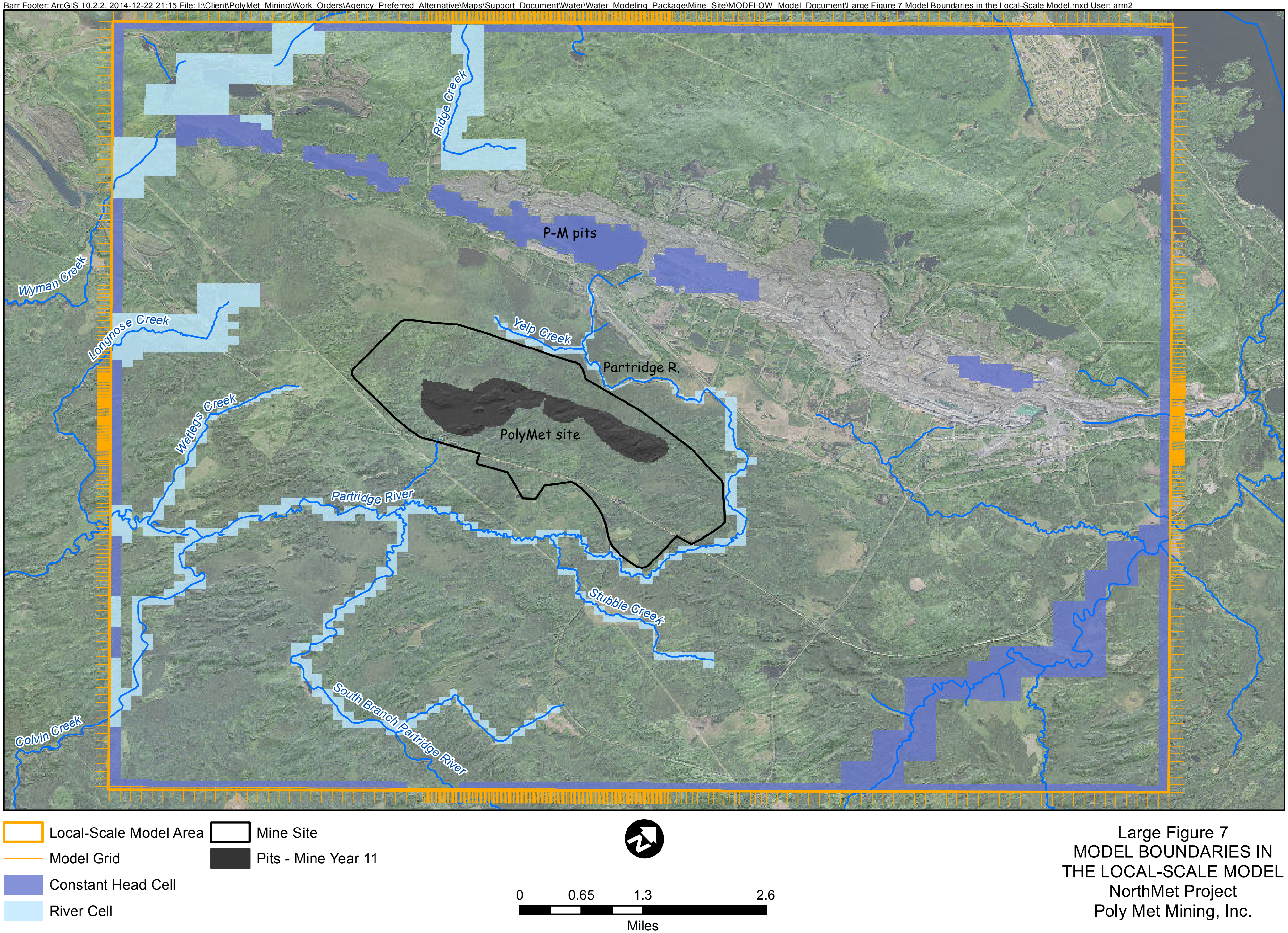
9) "indicating that **the connection between the bedrock, unconsolidated deposits, and wetlands may be be relatively weak.**" (PFEIS, page 4-168, line 246)

The above quotes are a few examples of the many statements in the EIS materials that contend that the surficial aquifer, and in particular wetlands, are isolated from the bedrock.

The sections of the Water Modeling Data Package (WMDP) are available as part of the PFEIS package.
The Barr June 2, 2008, Indirect Wetland Impacts at the Mine Site is available at:
https://app.box.com/s/fj9lfpppml5a1av2himffyi3c0opjia9
and is cited in the PFEIS as Barr 2008h

--
John Coleman, Madison Office of the Great Lakes Indian Fish & Wildlife Commission
U.W.-Madison Land Information and Computer Graphics Facility
550 Babcock Drive, Room B102
Madison, WI 53706
608-263-2873 or 265-5639
jcoleman@glifwc.org

Figure 1



Large Figure 7
MODEL BOUNDARIES IN
THE LOCAL-SCALE MODEL
NorthMet Project
Poly Met Mining, Inc.

Figure 2

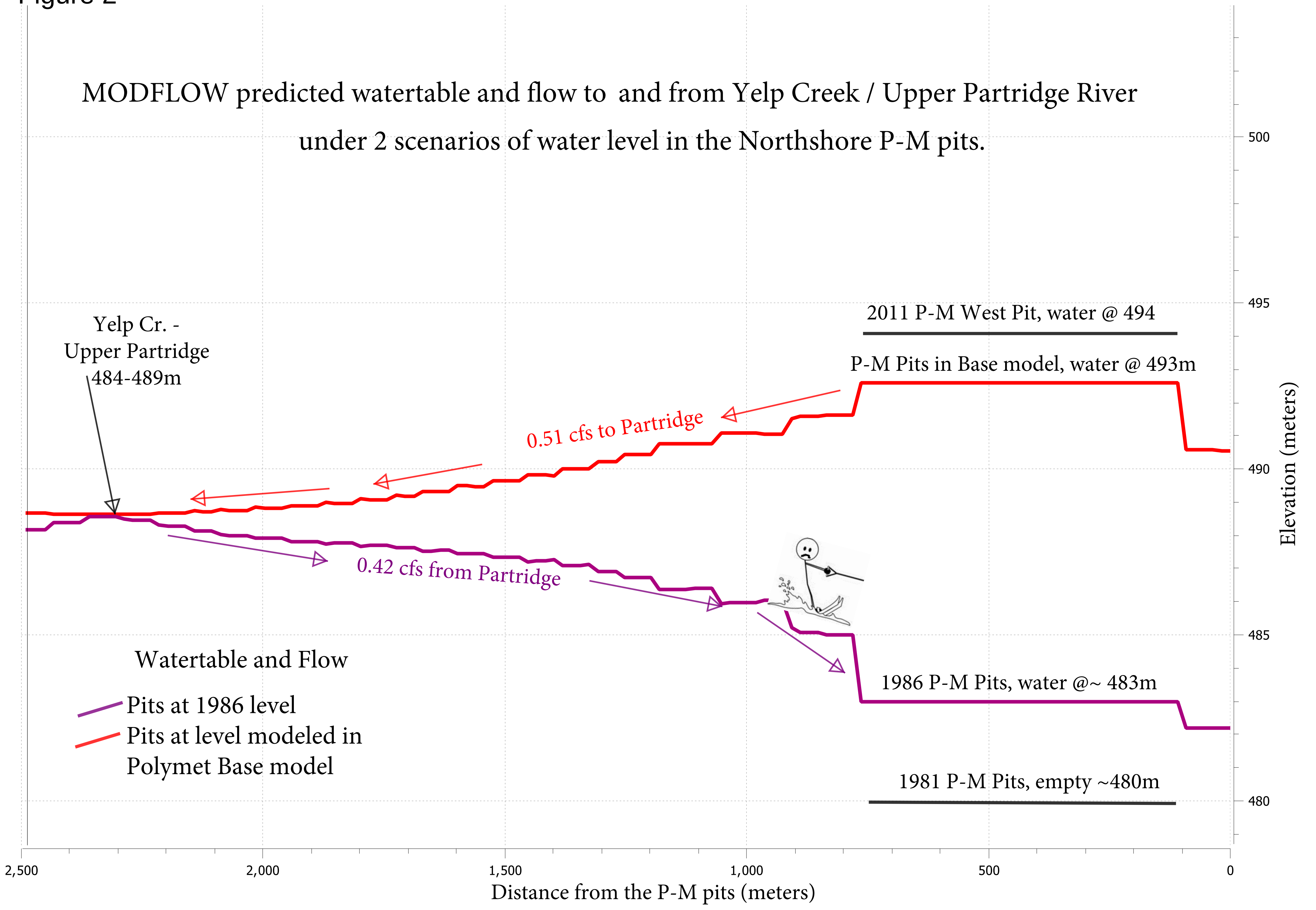
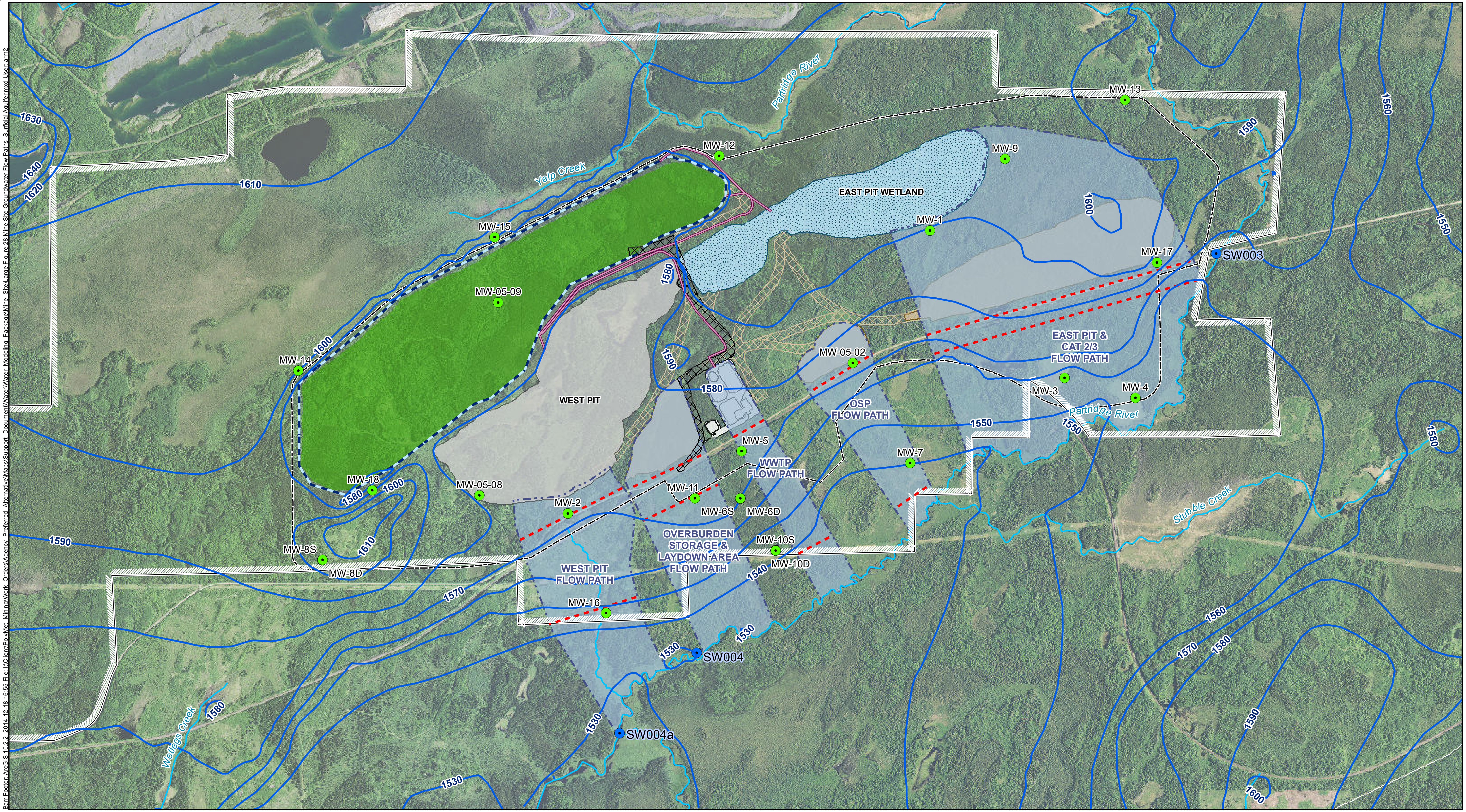

MODFLOW predicted watertable and flow to and from Yelp Creek / Upper Partridge River
under 2 scenarios of water level in the Northshore P-M pits.
Yelp Cr. -
Upper Partridge
484-489m
2011 P-M West Pit, water @ 494
P-M Pits in Base model, water @ 493m
0.51 cfs to Partridge
0.42 cfs from Partridge
1986 P-M Pits, water @~ 483m
1981 P-M Pits, empty ~480m
Watertable and Flow
Pits at 1986 level
Pits at level modeled in
Polymet Base model
500
495
490
485
480
Elevation (meters)
2,500
2,000
1,500
1,000
500
0
Distance from the P-M pits (meters)

Figure 2 - Profile of the water table between the upper Partridge and the P-M pits under 2 scenarios of water level in the pits.
The red stair-step line in the figure is the water table between the upper Partridge R. and the Peter-Mitchel taconite pits when the pits are at 493 meters elevation. Water is flowing from the pits to the upper Partridge R. The purple stair-step line is the water table between the upper Partridge R. and the Peter-Mitchel taconite pits when the pits are at 483 meters elevation (the elevation that they had in 1986). In the 483 meter model run, water is flowing from the upper Partridge R., to the P-M pits.

Figure 3



Mine Features
West Pit
East Pit Wetland
Reclaimed Stockpile
Removed and Reclaimed Stockpile
Haul Roads
Reclaimed Haul Roads

Surface Water Monitoring Location
Groundwater Monitoring Location
Groundwater Containment System
Process Water Pipe
Groundwater Elevation Contours (Ft) at Closure[1]

[1] Inferred water table contours were developed using contours from the Mine Site MODFLOW model.

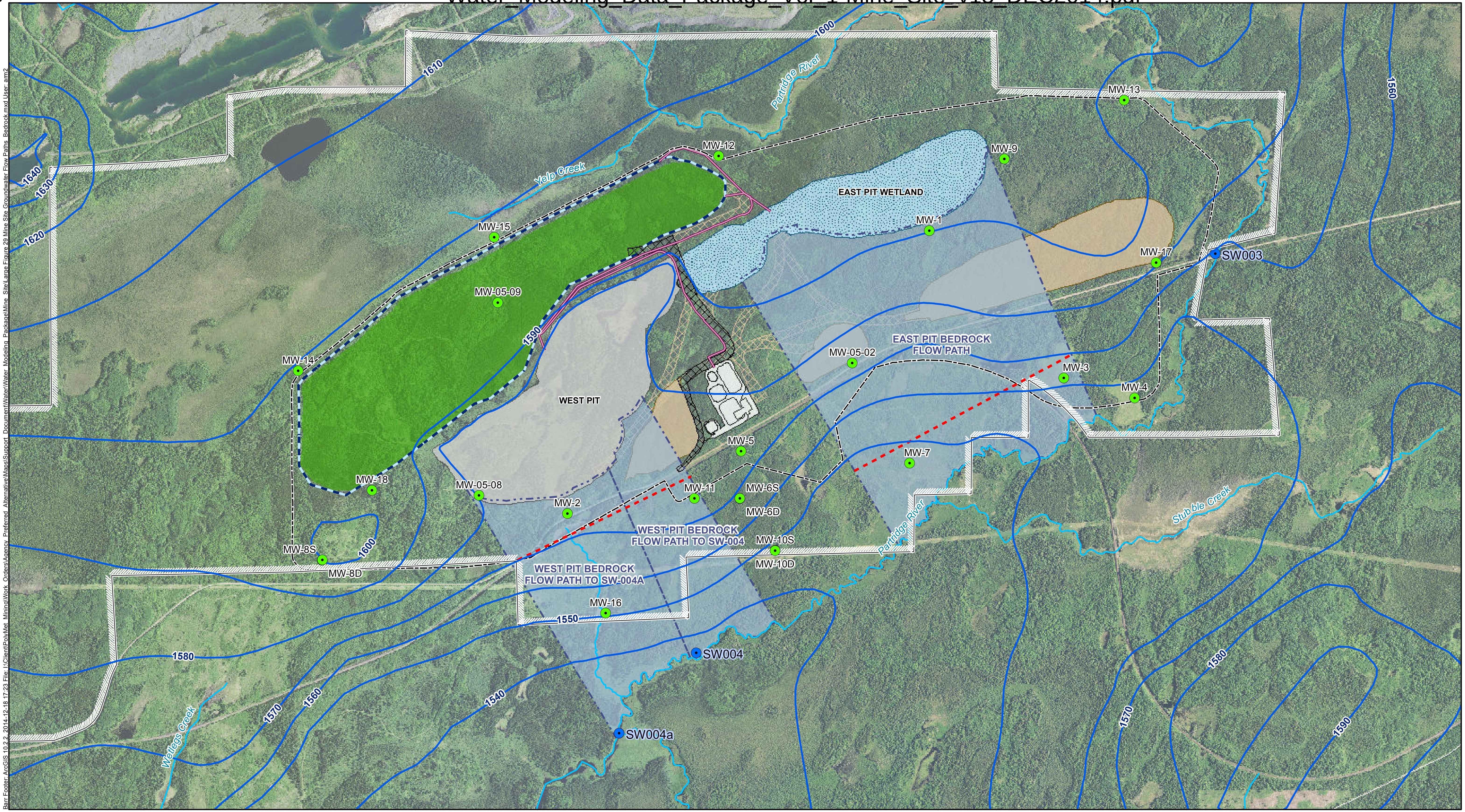
Groundwater Evaluation Distances
Groundwater Flow Path
Mine Site
Extent of Future PolyMet Lands

0 1,000 2,000 4,000
Feet

Large Figure 28
MINE SITE GROUNDWATER
FLOW PATHS - SURFICIAL AQUIFER
NorthMet Project
Poly Met Mining Inc.
Hoyt Lakes, MN

Figure 4

Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf



Mine Features
- West Pit
- East Pit Wetland
- Reclaimed Stockpile
- Removed and Reclaimed Stockpile
- Haul Roads
- Reclaimed Haul Roads

- Surface Water Monitoring Location
- Groundwater Monitoring Location
- Groundwater Containment System
- Process Water Pipe
- Groundwater Elevation Contours (Ft) at Closure[1]

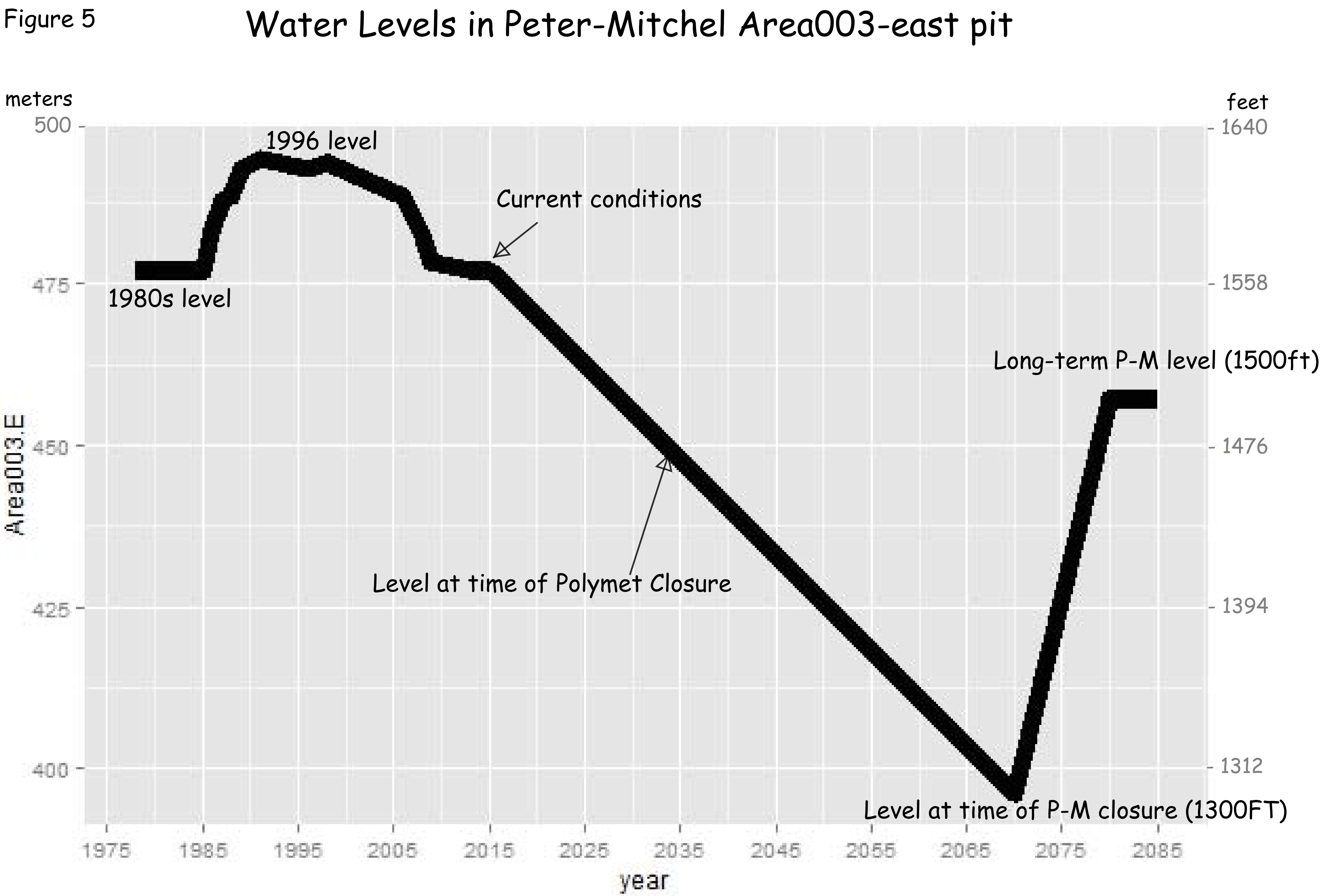
[1] Inferred water table contours were developed using contours from the Mine Site MODFLOW model.

- Groundwater Evaluation Distances
- Groundwater Flow Path
- Mine Site
- Extent of Future PolyMet Lands

0 1,000 2,000 4,000
Feet

Large Figure 29
MINE SITE GROUNDWATER FLOW PATHS - BEDROCK
NorthMet Project
Poly Met Mining Inc.
Hoyt Lakes, MN

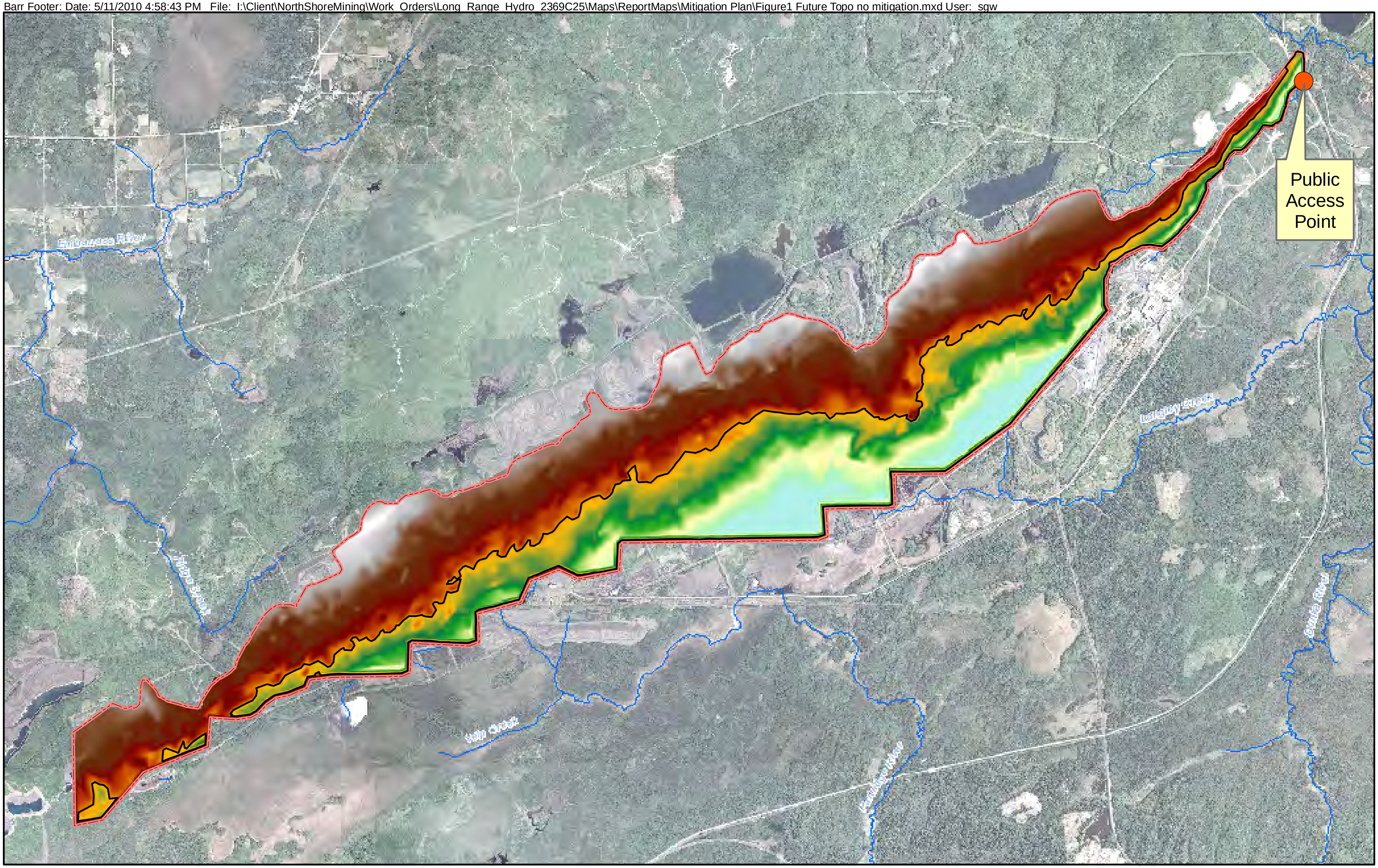
Figure 5



Water Levels in Peter-Mitchel Area003-east pit
meters
feet
500
475
450
425
400
1640
1558
1476
1394
1312
Area003.E
1996 level
Current conditions
1980s level
Long-term P-M level (1500ft)
Level at time of Polymet Closure
Level at time of P-M closure (1300FT)
1975
1985
1995
2005
2015
2025
2035
2045
2055
2065
2075
2085
year

Figure 6

Barr Footer: Date: 5/11/2010 4:58:43 PM File: I:\Client\NorthShoreMining\Work_Orders\Long_Range_Hydro_2369C25\Maps\ReportMaps\Mitigation Plan\Figure1 Future Topo no mitigation.mxd User: sgw



1500 ft contour

Mine Site Boundary

Streams

Future Topography (no mitigation)

Elevation (feet)

High : 1785.95

Low : 1195.2

N

Kilometers

1 0 1 2 3

Miles

1 0 1 2

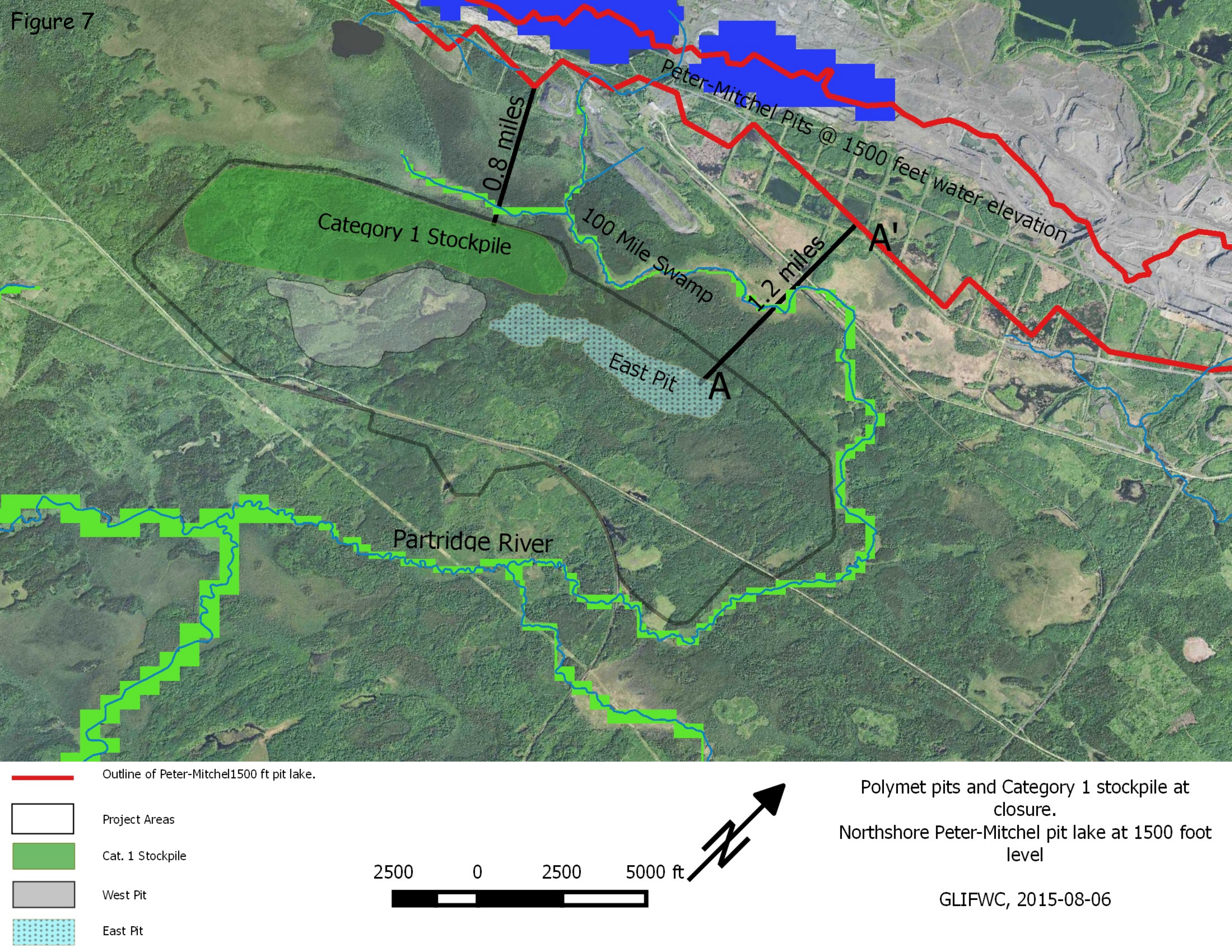
Figure 1

BARR

Ultimate Topography of the PMP
(without Mitigation)
Peter Mitchell Pit Mitigation Plan
North Shore Mining
Babbitt, Minnesota

Figure from the Northshore Watershed Mitigation Plan of 2011. - A map of the Peter-Mitchel pit final lake water elevation from the Feb. 11, 2011 report titled "Watershed Mitigation Plan" (MDNR 2011s.pdf) which contains the May 2010 BARR Engineering document titled: "Peter Mitchell Pit Concept Mitigation Plan". That plan identifies the final status of the P-M pits as being connected into a long east-west pit that will be allowed to fill to a water elevation of 1500 ft (457 meters). The recreational lake formed by this filling is scheduled to passively discharge to a tributary of the Dunka River in the north-east. While the ultimate water level in the reflooded P-M pits is expected to be 1500 feet, in the interim, the taconite pit bottoms continue to be deepened to an elevation of approximately 1300 ft (396 meters). In 2011 the bottoms of the P-M pits ranged down to an elevation of 1394 feet (425 meters).

Figure 7



Polymet pits and Category 1 stockpile at closure.
Northshore Peter-Mitchel pit lake at 1500 foot level

GLIFWC, 2015-08-06

Figure 8 Flow of particles when P-M pits are at closure levels (457 meters).

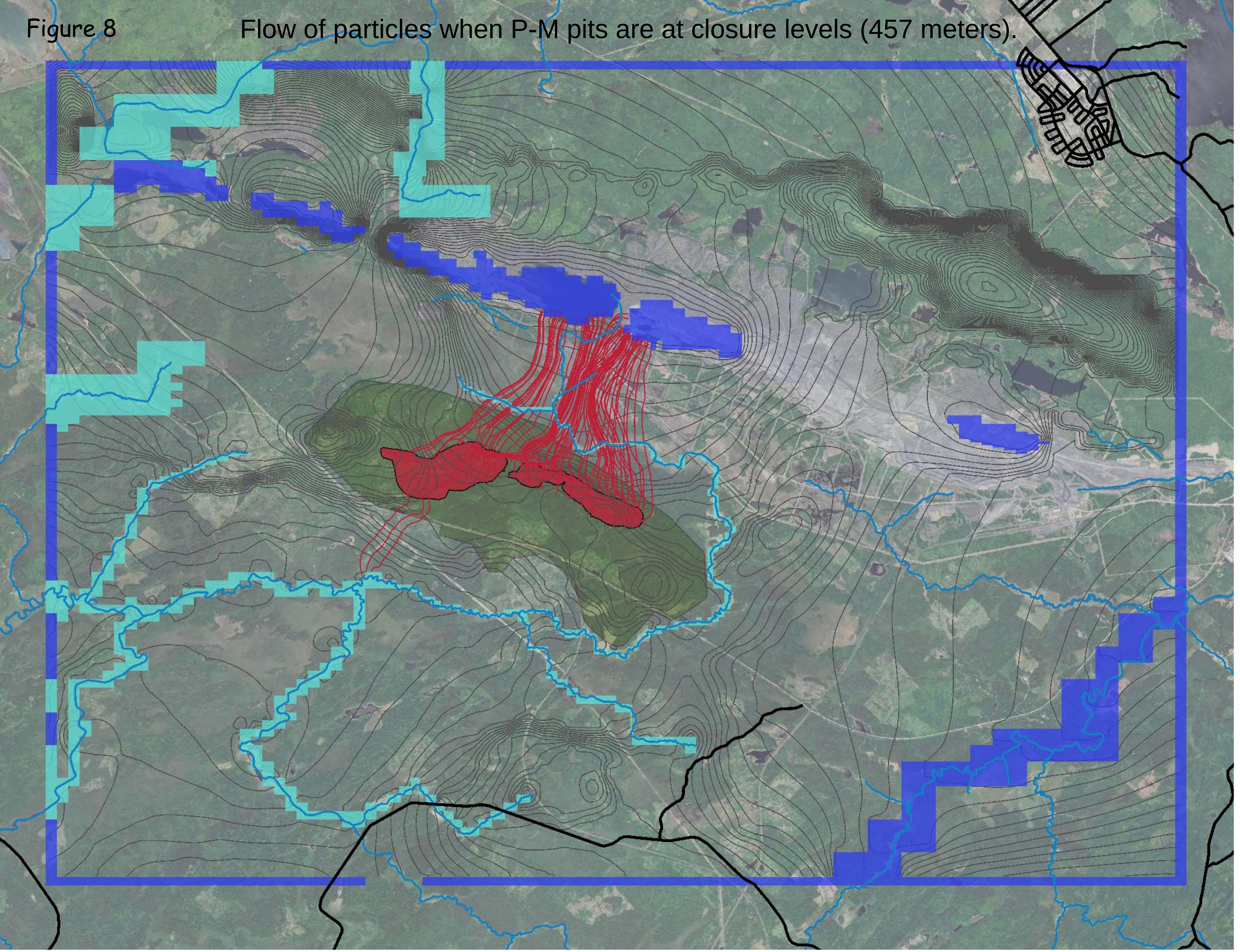
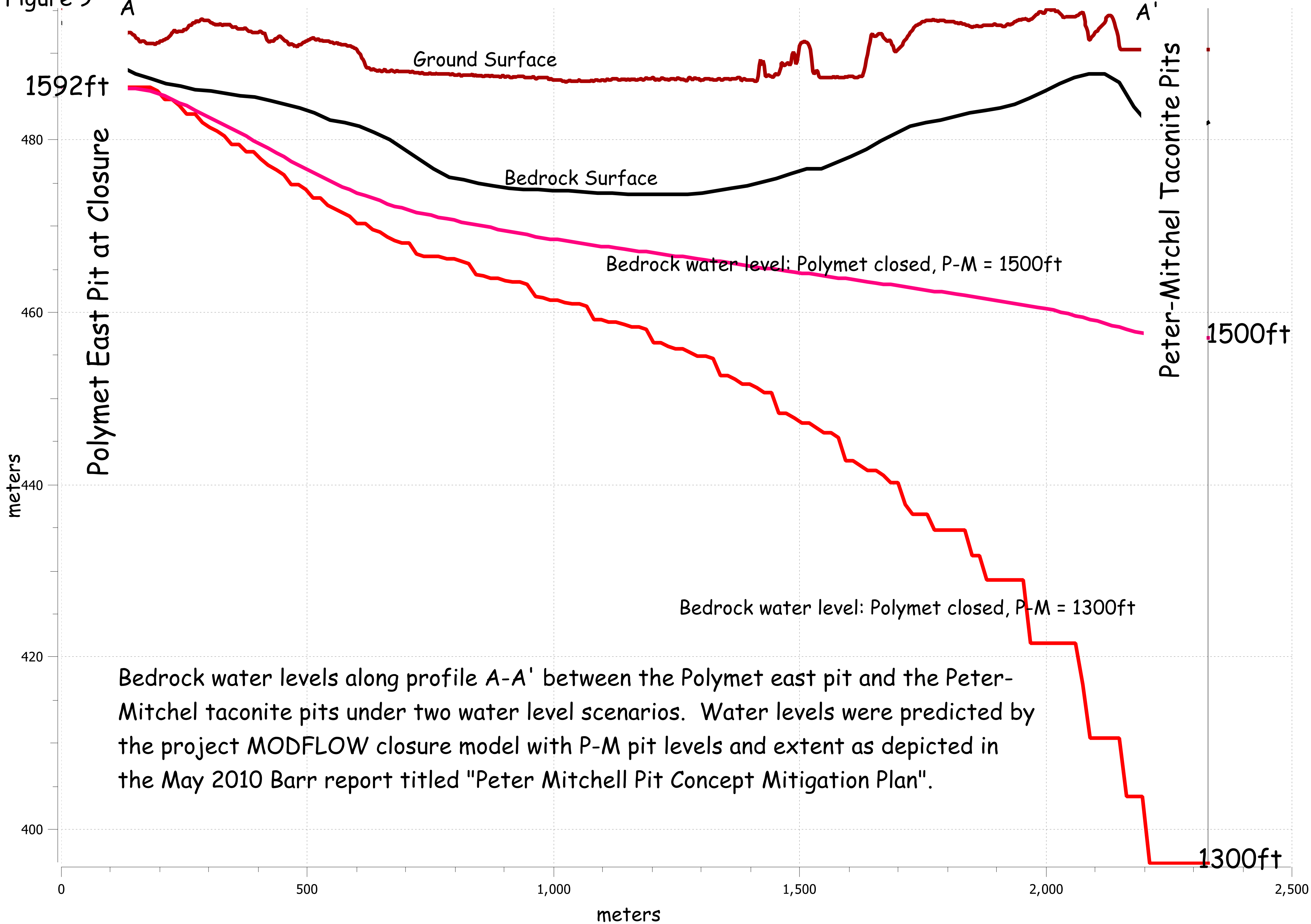


Figure 8 - A map of particles (water) moving from the Polymet pit areas to the P-M pits. This scoping level modeling used the Polymet base MODFLOW model with P-M pits set to their long-term level of 457 meters (1500 ft). Because the upper Partridge River would be unable to supply unlimited water to the aquifer, discharge from the upper Partridge River to the groundwater system is prevented in this model run.

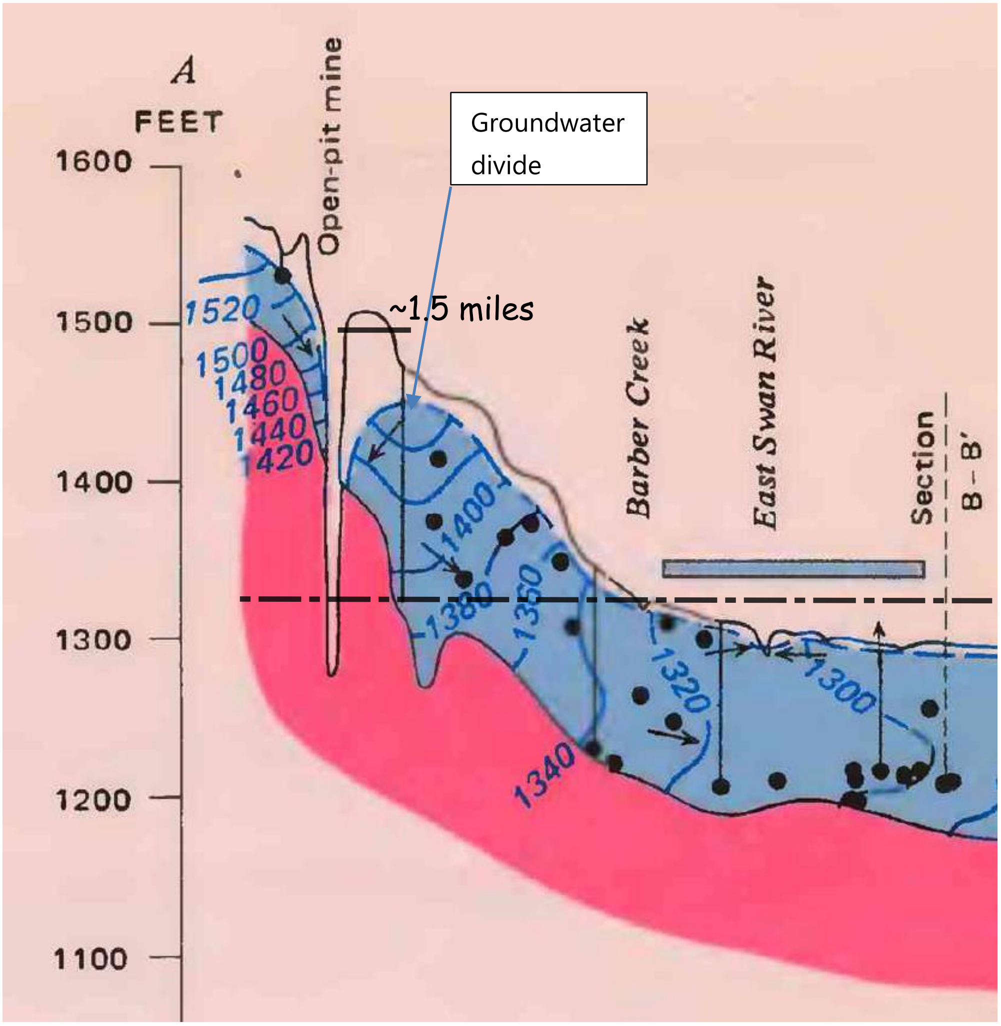
Particles were added to the surficial aquifer and allowed to travel in the direction that the aquifer carried them. These particle tracks originate in the area of the proposed Polymet pits and end at the P-M taconite pits. A few particles leave the Polymet west pit area and travel to the Partridge River because the S-W corner of the Polymet west pit is on the south side of the watertable divide.

Figure 9



Bedrock water levels along profile A-A' between the Polymet east pit and the Peter-Mitchel taconite pits under two water level scenarios. Water levels were predicted by the project MODFLOW closure model with P-M pit levels and extent as depicted in the May 2010 Barr report titled "Peter Mitchell Pit Concept Mitigation Plan".

Figure 10. From Barr 2015-07-04 memo titled: Response to Cooperating Agency Comments Related to Peter Mitchell Pit – Version 3



Note: Polymet E. pit is 1.2 miles from P-M

Figure 2 Portion of a Cross Section Showing Hydraulic Head Contours in the Drift Aquifer Adjacent to an Open-pit Mine (from Cross-section A-A' of Reference (2)). ***The portion shown has a length of approximately 17 miles***

Figure 11. From Barr 2015-07-04 memo titled: Response to Cooperating Agency Comments Related to Peter Mitchell Pit – Version 3

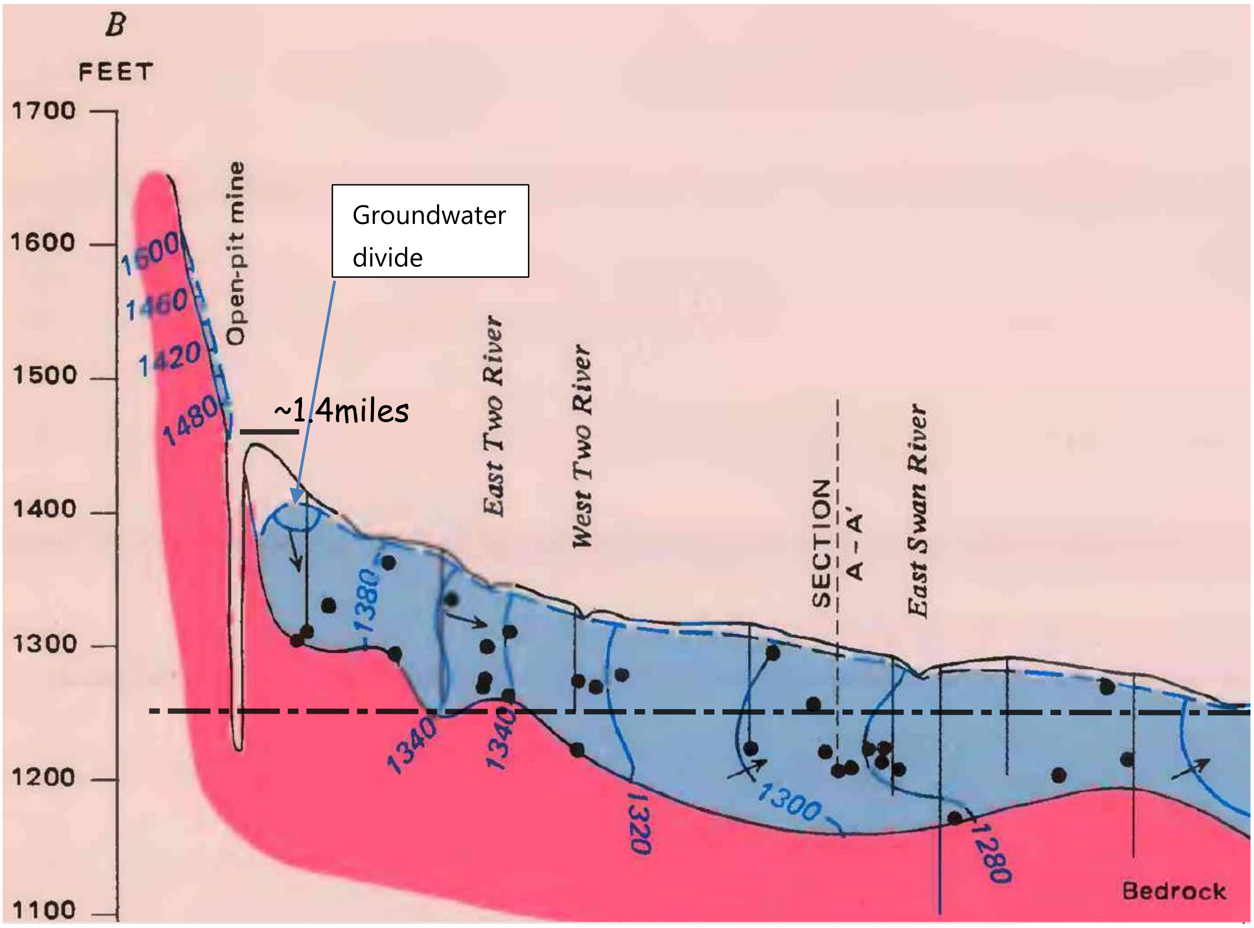
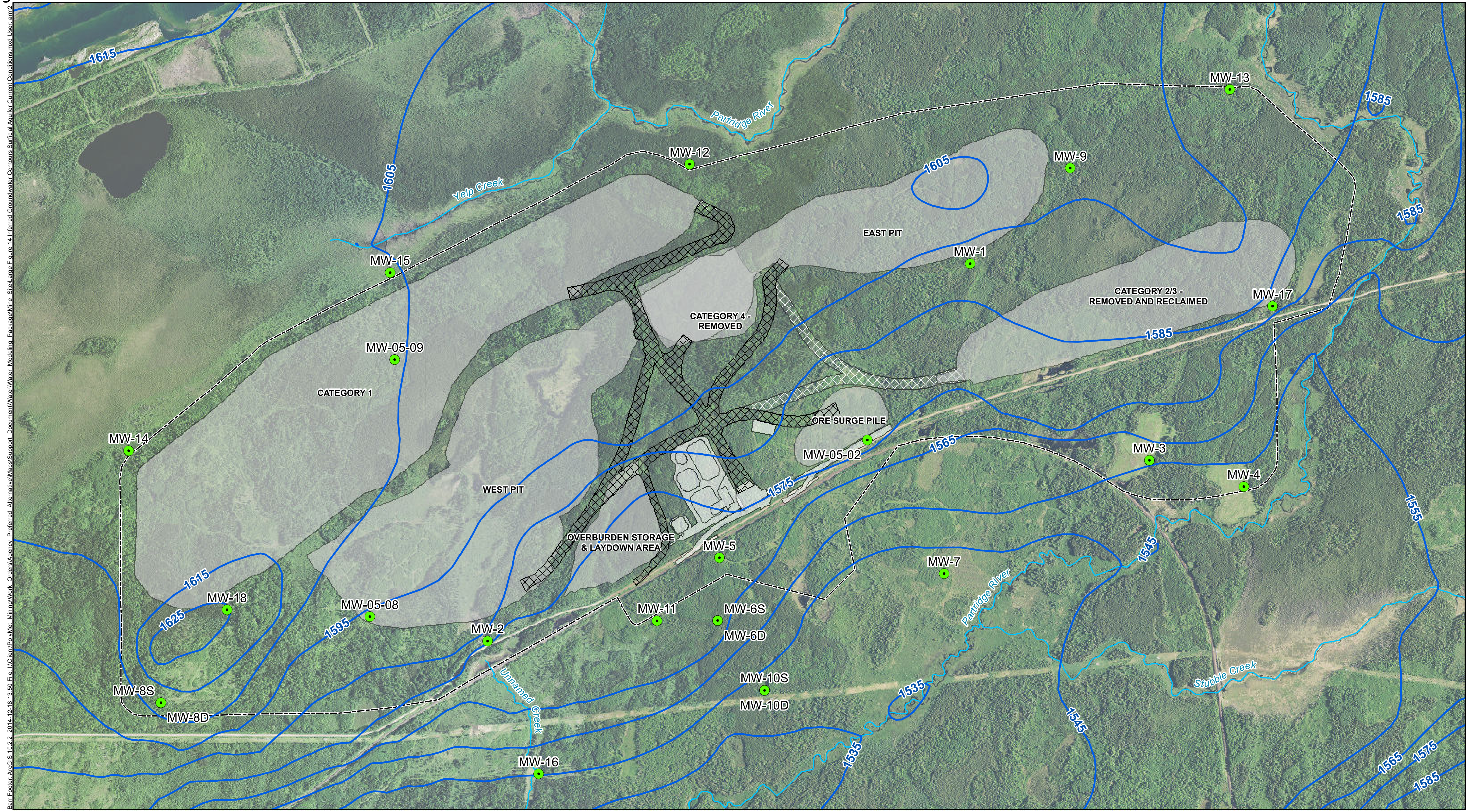


Figure 3 Portion of a Cross Section Showing Hydraulic Head Contours in the Drift Aquifer Adjacent to an Open-pit Mine (from Cross-Section B-B' of Reference (2)]). ***The portion shown has a length of approximately 22 miles***

Figure 12



Monitoring Well

Groundwater Elevation Contours (Ft)[1]

Streams/Rivers

Mine Site

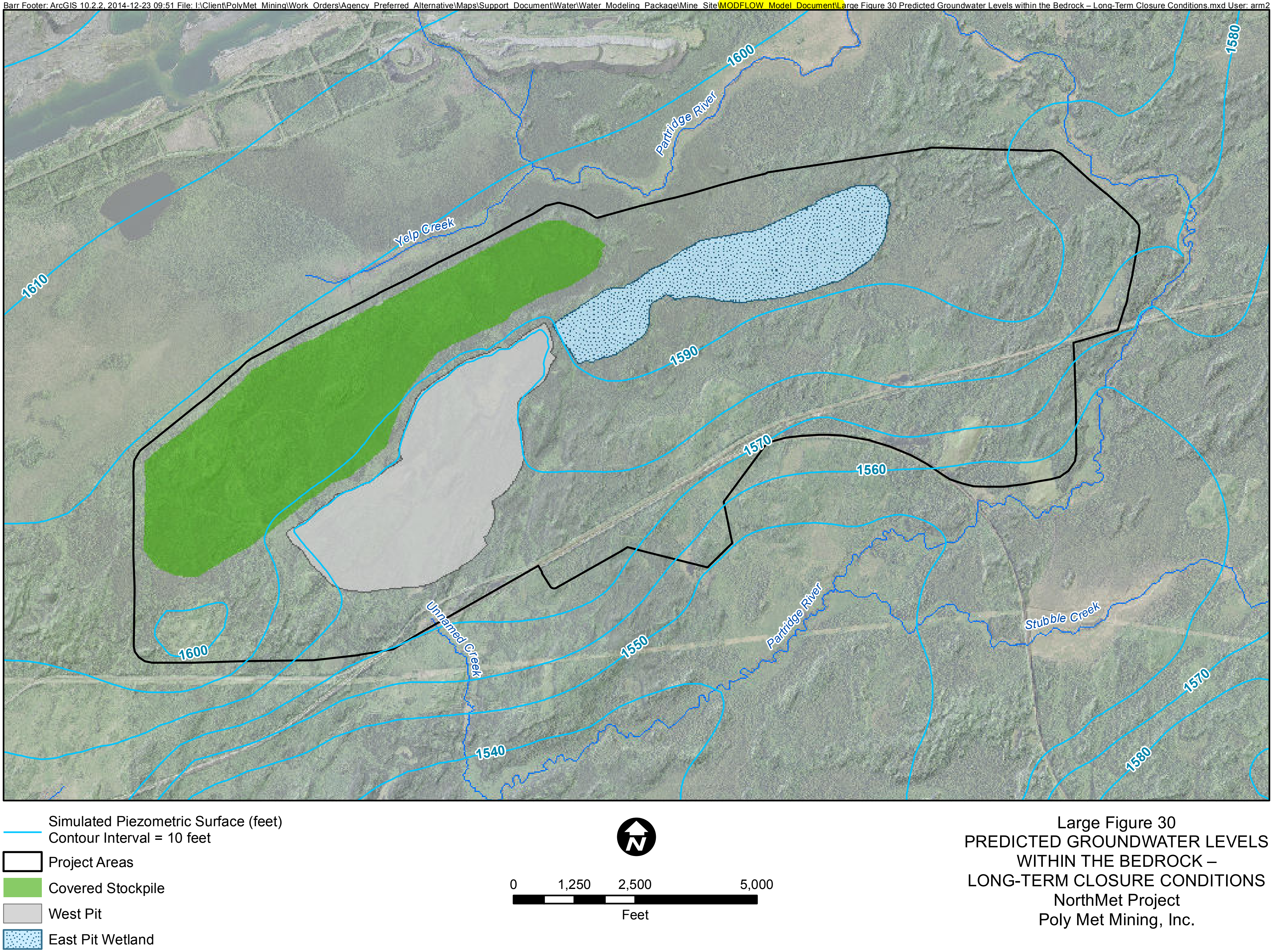
[1]Inferred water table contours were developed using a combination of measured groundwater elevations in site monitoring wells and contours from the Mine Site MODFLOW model.

0 750 1,500 3,000
Feet

Large Figure 14
INFERRED GROUNDWATER CONTOURS
SURFICIAL AQUIFER, CURRENT CONDITIONS
NorthMet Project
Poly Met Mining Inc.
Hoyt Lakes, MN

Figure 13

Barr Footer: ArcGIS 10.2.2, 2014-12-23 09:51 File: I:\Client\PolyMet_Mining\Work_Orders\Agency_Preferred_Alternative\Maps\Support_Document\Water\Water_Modeling_Package\Mine_Site\MODFLOW_Model_Document\Large Figure 30 Predicted Groundwater Levels within the Bedrock – Long-Term Closure Conditions.mxd User: arm2



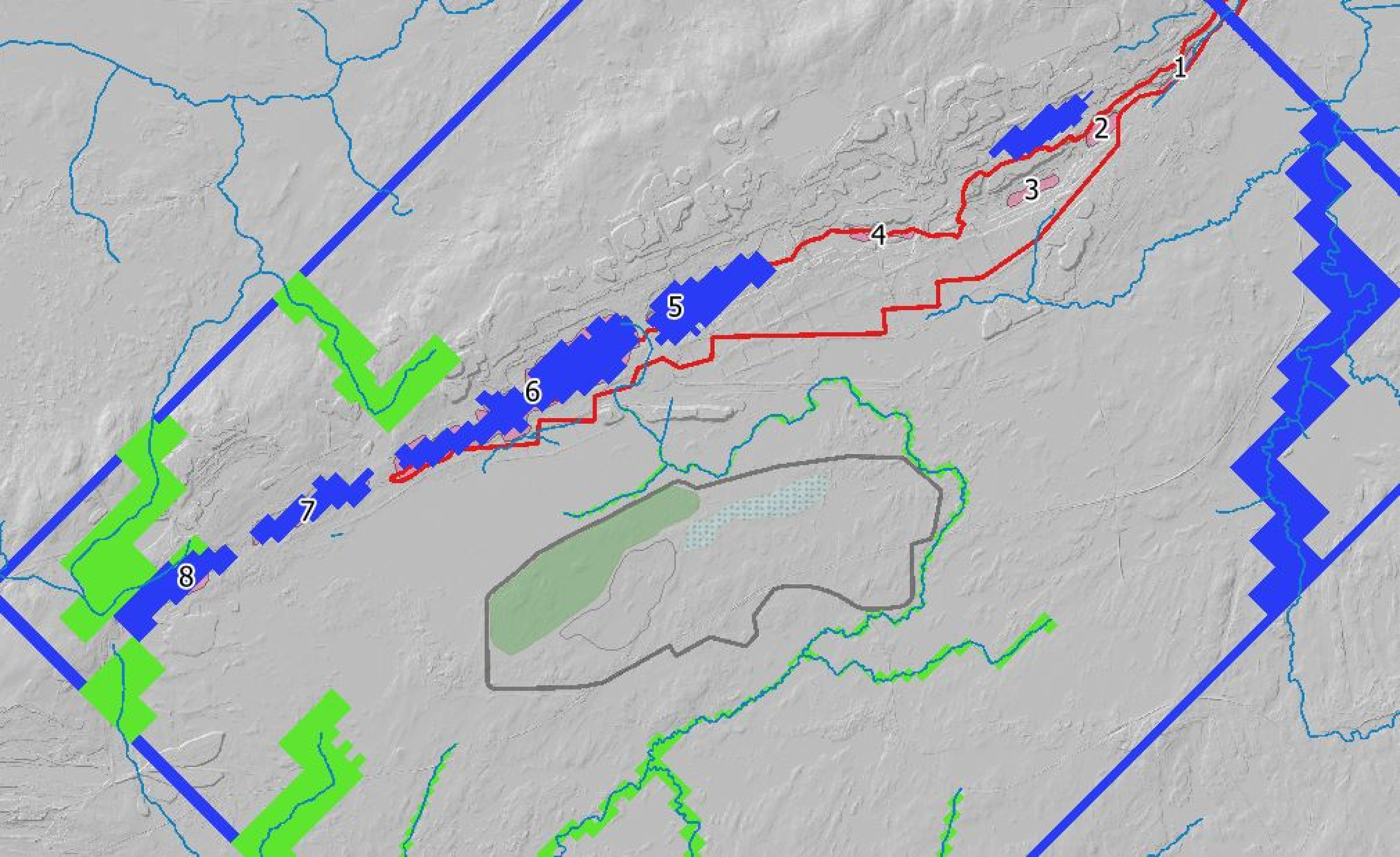
Large Figure 30
PREDICTED GROUNDWATER LEVELS WITHIN THE BEDROCK – LONG-TERM CLOSURE CONDITIONS
NorthMet Project
Poly Met Mining, Inc.

Table 1. Peter-Mitchel pit water levels.

The pit number correspond to the pits in the attached map.

	<-west			pit				east->
	8	7	6*Area3-West	5*Area3-East	4 Area2	3	2	1
year		SD011-12	SD008-10	SD006-7	SD005	SD004		SD002
1978/09		empty	~empty	**empty**	empty	empty	empty	
1979/09		empty	empty	**empty**	empty	empty	empty	
1980/10		empty	empty	**~empty**	empty	empty	empty	
1985/10		~empty	~empty	**<477.9**	~empty	~empty	~empty	~empty
1986/11				**483.4**				
1987/09				**487.7**				
1988/04				488.3				
1989/10				492.6	492.6			
1991/09		499.0	494.0	494.4	492.6			
2011/05	498.74	499.50	494.4	477.6	460.0	425.1	452.3	432.7
Barr MODFLOW runs (1996)	488.3	500.1	492.6	492.6	missing	475.5	475.5	
Partridge @ SW001			489.7					
confluence of Yelp and Partridge			487.0					
Partridge & RR grade (SW002)			486.8					

*headwaters of Partridge River/Yelp Cr.



1
2
3
4
5
6
7
8

horizontal hydraulic conductivity was 4.5 x 10^{-4} feet/day, estimated from the five borehole tests conducted south of the proposed pits, away from the Virginia Formation contact.

3.2.5.5 Calibration Results

Optimized hydraulic conductivity values are summarized in Table 3-4. Because the horizontal hydraulic conductivity of the unconsolidated deposits varies by cell, the range of values and mean value in each zone resulting from the calibration are shown. Large Figure 18 shows the calibrated hydraulic conductivity distribution in Layer 1 for the area of interest, including the average hydraulic conductivity for each of the GoldSim groundwater flow path areas. Table 3-5 provides a comparison between the estimated and calibrated hydraulic conductivity values at locations where prior information was included in the calibration. Calibrated hydraulic conductivity values generally compare well with the estimated values.

Table 3-4 Optimized Hydraulic Conductivity Values

Model Parameter	Value (feet/day)
Horizontal hydraulic conductivity – Upland deposits	Range: 0.056 - 167 Mean: 19.2
Horizontal hydraulic conductivity – Wetland deposits	Range: 0.003 - 224 Mean: 23.7
Vertical hydraulic conductivity – Upland and wetland deposits (1)	0.0028 (1)
Hydraulic conductivity – Giants Range granite	$K_{xx} = K_{yy} = 0.029$ $K_{zz} = 0.0029$
Hydraulic conductivity – Biwabik Iron Formation	$K_{xx} = K_{yy} = 0.87$ $K_{zz} = 0.087$
Hydraulic conductivity – Virginia Formation, Upper Portion	$K_{xx} = K_{yy} = 0.31$ $K_{zz} = 0.031$
Hydraulic conductivity – Duluth Complex	$K_{xx} = K_{yy} = 4.4\text{x}10^{-4}$ $K_{zz} = 4.4\text{x}10^{-5}$
Hydraulic conductivity – Virginia Formation, Lower Portion	$K_{xx} = K_{yy} = 0.079$ $K_{zz} = 0.0079$
Vertical hydraulic conductivity term of Partridge River Reach 1	41.0
Vertical hydraulic conductivity term of Partridge River Reach 2	32.8
Vertical hydraulic conductivity term of Partridge River Reach 3	25.6
Vertical hydraulic conductivity term of Partridge River Reach 4	18.5
Vertical hydraulic conductivity term of Partridge River Reach 5	13.2
Vertical hydraulic conductivity term of Partridge River Reach 6	10.4
Vertical hydraulic conductivity term of Partridge River Reach 7	8.8
Vertical hydraulic conductivity term of Partridge River Reach 8	10.0

(1) Parameter not allowed to vary during calibration

Table 3. MODFLOW modeling results used for Goldsim modeling of contaminant transport as reported in the water modeling report "Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf".

Establish general groundwater head distribution (e.g. watertable):	Section 5.2.3.7 of Water Modeling Data Package Volume 1 - Mine Site (.pdf page 124 of Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf and Large Figs. 14 of Water Modeling Data Package Volume 1 - Mine Site (.pdf page 492 of Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf)
Establishing contaminant flow paths:	Section 5.2.3 and Large Figs. 28-29 of Water Modeling Data Package Volume 1 - Mine Site (.pdf page 114 and 511 of Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf) and Section 5.2.3.7 of Water Modeling Data Package Volume 1 - Mine Site (.pdf page 124 of Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf)
Establishing gradients along contaminant flow paths:	Section 5.2.3.1 of Water Modeling Data Package Volume 1 - Mine Site (.pdf page 118 Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf)
Establishing hydraulic conductivity along contaminant flow paths:	Section 5.2.3.7 of Water Modeling Data Package Volume 1 - Mine Site (.pdf page 125 of Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf) and Section 3.2.5.5 and Large Fig. 18 of Attachment B Groundwater Modeling of the NorthMet Mine Site (.pdf page 662 and 702 of Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf)
"Infiltration" along contaminant flowpaths for calculation of baseflow:	Section 5.2.4.3.5 of Water Modeling Data Package Volume 1 - Mine Site (.pdf page 141 of Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf)

Pit inflows used for "overall water balance in the probabilistic model" (contaminant transport model):	Section 5.2.3.7 of Water Modeling Data Package Volume 1 - Mine Site (.pdf page 125 of Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf) and Section 6.1.2.3.2 of Water Modeling Data Package Volume 1 - Mine Site (.pdf page 177 of Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf)
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Table 4. Parameters used in GoldSim modeling. from the Water_Modeling_Data_Package_Vol_1-Mine_Site_v13_DEC2014.pdf

Table 1-1 **Input Variables for the Mine Site Model**

Variable Name	Units	Deterministic/ Uncertain	Sampling/ Calculation Frequency	Distribution	Mean or Mode	Standard Deviation	Minimum	Maximum	Description	Source of Input Data	Modeling Package Section
Grey cells indicate changes from the previously published version											
Climatic Variables											
Annual_Precip_Cuberoot	[$in^{1/3}$]	Uncertain	Annual	Trunc. Normal	3.05	0.16	0	N/A	Cube root of the annual precipitation	HiDen Climate network for Mine Site (1980-2010 climate normal)	Water Section 5.2.1 *Climate Inputs*
Monthly_Precip_Factors	[%]	Deterministic	N/A	Constant	Vector by month. Reference Table 1-11				Factors for partitioning annual precipitation to monthly	HiDen Climate network for Mine Site (1980-2010 climate normal)	Water Section 5.2.1 *Climate Inputs*
Annual_Evap	[in/yr]	Uncertain	Annual	Normal	20.8	1.33	N/A	N/A	Annual evaporation from open water	HiDen Climate network for Mine Site (1980-2010 climate normal); Baker (1979)	Water Section 5.2.1 *Climate Inputs*
Monthly_Evap_Factors	[%]	Deterministic	N/A	Constant	Vector by month. Reference Table 1-11				Factors for partitioning annual open water evaporation to monthly	Baker (1979) for partitioning ratios	Water Section 5.2.1 *Climate Inputs*
Snowmelt	[--]	Deterministic	N/A	Constant	4	N/A	N/A	N/A	Month when snowmelt occurs	USGS Gage Data	Water Section 6.1.3.3 *Water Balance, Mine Pits*
Freezeup	[--]	Deterministic	N/A	Constant	11	N/A	N/A	N/A	Month when freezeup occurs, consistent with WWTF design team definition	USGS Gage Data	Water Section 6.1.3.3 *Water Balance, Mine Pits*
Background Chemistry											
GW_Conc_Surf	[mg/L]	Uncertain	Realization	Transformed Normal	Vector by Constituent. Reference Table 1-12				Surficial groundwater concentrations in the Partridge River watershed	Analysis of PolyMet background water quality data	Water Section 5.3.1 *Background Groundwater*
GW_Conc_Bed	[mg/L]	Uncertain	Realization	Transformed Normal	Vector by Constituent. Reference Table 1-12				Bedrock groundwater concentrations in the Partridge River watershed	Analysis of PolyMet background water quality data	Water Section 5.3.1 *Background Groundwater*
SW_Conc_RO	[mg/L]	Uncertain	Month	Lognormal	Vector by Constituent. Reference Table 1-13				Calibrated surface runoff concentrations in the Partridge River watershed	Calibration of model to baseline conditions	Water Section 5.3.1 *Background Surface Runoff*
SW_Conc_PMP	[mg/L]	Deterministic	N/A	Constant	Vector by Constituent. Reference Table 1-13				Concentration leaving the Peter Mitchell Pits	2004-2007 WQ modeling at SW-001	Water Section 5.5.3.1 *Other (Non-Project) Loads*
Flow_PMP	[cfs]	Deterministic	N/A	Constant	2.6	N/A	N/A	N/A	Flow from Peter Mitchell Pit dewatering to SW-001	Calibration of model to baseline conditions	Water Section 5.5.3.1 *Other (Non-Project) Loads*
Flow_PMP_end	[yr]	Deterministic	N/A	Constant	55	N/A	N/A	N/A	Mine Year when flow from Peter Mitchell Pit ends, equivalent to year 2070	Northshore Mine Plan	Water Section 5.5.3.1 *Other (Non-Project) Loads*
SW_Conc_Partridge	[mg/L]	Deterministic	N/A	Constant	Matrix by Constituent and location. Reference Table 1-14				Baseline existing chemistry in Partridge River used to evaluate model	2004-2010 Monitoring Data of Partridge River	Water Section 4.4.4.1 *Water Quality ,Partridge River*
Load_Colby	[kg/yr]	Deterministic	N/A	Constant	Vector by Constituent. Reference Table 1-13				Calibrated additional loading to Colby Lake	Calibration of model to baseline conditions	Water Section 5.5.3.1 *Other (Non-Project) Loads*
Groundwater Flowpath Characteristics											
I_ops	[--]	Uncertain	Realization	Uniform	Vector by flowpath. Reference Table 1-15				Average hydraulic gradient along aquifer	Mine Site MODFLOW model	Water Section 5.4.1 *Groundwater Flowpath Modeling*
I_close	[--]	Uncertain	Realization	Uniform	Vector by flowpath. Reference Table 1-15				Average hydraulic gradient along aquifer in closure	Mine Site MODFLOW model	Water Section 5.4.1 *Groundwater Flowpath Modeling*
Thick	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Aquifer thickness	Assumed value	Water Section 5.4.1 *Groundwater Flowpath Modeling*
EL_Pit	[ft]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Pit surficial outflow elevation	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
Width	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Flowpath width	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
L_Upstream	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Length upstream of stockpile	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
L_Stock	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Source (stockpile) length	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
L_Eval_1	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Length to Evaluation Point #1	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
L_Eval_2	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Length to Evaluation Point #2	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
L_Eval_3	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Length to Evaluation Point #3	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*
L_Total	[m]	Deterministic	N/A	Constant	Vector by flowpath. Reference Table 1-15				Total flowpath length	GIS data/calculations	Water Section 5.4.1 *Groundwater Flowpath Modeling*

Table 4, continued.

Table 1-1 **Input Variables for the Mine Site Model**

Variable Name	*Units*	*Deterministic/ Uncertain*	*Sampling/ Calculation Frequency*	*Distribution*	*Mean or Mode*	*Standard Deviation*	*Minimum*	*Maximum*	*Description*	*Source of Input Data*	*Modeling Package Section*
Grey cells indicate changes from the previously published version											
Groundwater Flow Variables											
Bedrock_Porosity	[--]	Deterministic	N/A	Constant	0.05	N/A	N/A	N/A	Porosity of the bedrock flowpaths	Mine Site MODFLOW model (Bedrock units)	Water Section 5.4.1 *Groundwater Flowpath Modeling*
Surficial_Porosity	[--]	Deterministic	N/A	Constant	0.3	N/A	N/A	N/A	Porosity of the surficial flowpaths	Assumed value, e.g. Fetter, 2001	Water Section 5.4.1 *Groundwater Flowpath Modeling*
K_Flowpath	[m/d]	Uncertain	Realization	Triangular	Vector by flowpath. Reference Table 1-15				Hydraulic conductivity of the surficial and bedrock material	Mine Site MODFLOW model (Duluth Complex), constraints discussed in Water Section 5.4.1	Water Section 5.4.4 *Groundwater Transport in GoldSim*
Recharge_min	[in/yr]	Deterministic	N/A	Constant	0.36	N/A	N/A	N/A	Minimum allowed recharge in surficial aquifer (for checking calculated value)	Mine Site MODFLOW model	Water Section 5.4.1 *Groundwater Flowpath Modeling*
Recharge_max	[in/yr]	Deterministic	N/A	Constant	1.8	N/A	N/A	N/A	Maximum allowed recharge in surficial aquifer (for checking calculated value)	Mine Site MODFLOW model	Water Section 5.4.1 *Groundwater Flowpath Modeling*
Surficial_Density	[kg/m3]	Deterministic	N/A	Constant	1,500	N/A	N/A	N/A	Dry (bulk) Density of the surficial deposits	USDA St. Louis County Soil Survey Database	Water Section 5.4.1 *Groundwater Flowpath Modeling*
Kd_Surficial	[L/kg]	Deterministic	N/A	Constant	Vector by Constituent. Reference Table 1-16				Sorption coefficients for the surficial aquifer (As, Sb, Cu, Ni)	EPA screening-level values	Water Section 5.4.3 *Sorption*
Stream Reach Characteristics											
Segment_Area	[m^2]	Deterministic	N/A	Constant	Vector by location. Reference Table 1-17				Cross sectional area of each segment upstream of each node	RS26 geomorphic surveys	Water Section 5.5 *Surface Water Modeling*
Segment_Length	[m]	Deterministic	N/A	Constant	Vector by location. Reference Table 1-17				Length of river upstream of each node	GIS data	Water Section 5.5 *Surface Water Modeling*
Colby_Volume	[acre-ft]	Deterministic	N/A	Constant	5,300	N/A	N/A	N/A	Colby Lake storage volume from RS73B	DNR bathymetric maps (summarized in RS73B)	Water Section 6.1.5 *Water Balance, Colby Lake*
Contributing_Area	[acre]	Deterministic	N/A	Time Series	Matrix by location and year. Reference Table 1-18				Contributing watershed area to each river node (incremental), used to calculate recharge	XPSWMM Model GIS analysis	Water Section 5.6.4 *Modeling Future Conditions*
Stream Flow Variables											
Streamflow_SW006_(Month)	[cfs]	Uncertain	Timestep	User-defined	Imported from worksheet. Reference Table 1-19				Randomly sampled daily streamflow at SW-006 for each month	USGS gage data (corrected for PMP dewatering)	Water Section 5.6.5 *Developing Probabilistic Model Inputs*
Inc_Flow_Factor_(Month)	[--]	Deterministic	N/A	Time Series	Imported from worksheet. Reference Table 1-20a through 1-20l				Factor to multiply Q at SW006 to get the incremental inflow between nodes for each month	XP-SWMM model results (relative differences)	Water Section 5.6.5 *Developing Probabilistic Model Inputs*
GW_Inc_Baseflow	[cfs]	Deterministic	N/A	Time Series	Imported from worksheet. Reference Table 1-21				Baseflow adding to evaluation points via natural groundwater	XP-SWMM model results scaled to observed baseflow at SW-006	Water Section 5.6.5 *Developing Probabilistic Model Inputs*

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● MEMBER TRIBES ●

MICHIGAN
Bay Mills Community
Keweenaw Bay Community
Lac Vieux Desert Band

WISCONSIN
Bad River Band
Lac Courte Oreilles Band
Lac du Flambeau Band
Red Cliff Band
St. Croix Chippewa
Sokaogon Chippewa

MINNESOTA
Fond du Lac Band
Mille Lacs Band

Via Electronic Mail / Original by Mail

June 18, 2015

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Division of Ecological Services
500 Lafayette Road

Re: PolyMet mine site groundwater model calibration and predictions.

NorthMet EIS Co-lead Agency Project Managers:

I am writing to reiterate GLIFWC staff's concerns that the hydrologic characterization of the mine site of the proposed NorthMet project is flawed. This letter follows up on our emails of February 26, April 10 and April 20 of 2015 to the EIS lead agencies of February 26, April 10 and April 20 of 2015. Since before 2008, GLIFWC staff have consistently raised concerns about the quality and validity of the groundwater modeling at the mine site. Most recently it has come to our attention that the mine site MODFLOW model was incorrectly calibrated and unlikely to provide the hydrologic characterization of the site that is needed in order to perform adequate project impact evaluations.

GLIFWC is acting in coordination with our member tribes, including the Fond du Lac Band, to review and contribute to the PolyMet EIS process. As you may know, GLIFWC is an organization exercising delegated authority from 11 federally recognized Ojibwe (or Chippewa) tribes in Wisconsin, Michigan and Minnesota.[1] Those tribes have reserved hunting, fishing and gathering rights in territories

1 GLIFWC member tribes are: in Wisconsin -- the Bad River Band of the Lake Superior Tribe of Chippewa Indians, Lac du Flambeau Band of Lake Superior Chippewa Indians, Lac Courte Oreilles Band of Lake Superior Chippewa Indians, St. Croix Chippewa Indians of Wisconsin, Sokaogon Chippewa Community of the Mole Lake Band, and Red Cliff Band of Lake Superior Chippewa

ceded in various treaties with the United States. GLIFWC's mission is to assist its member tribes in the conservation and management of natural resources and to protect habitats and ecosystems that support those resources. The proposed PolyMet mine is located within the territory ceded by the Treaty of 1854.

Mine-site MODFLOW model incorrectly calibrated:

The existing Peter-Mitchell (P-M) taconite mine pits on the north side of the PolyMet project area play a significant role in the groundwater hydrology of the project site. In the applicant's groundwater model of 2014 (and earlier modeling versions), documented in the "Water Modeling Data Package Vol 1-Mine Site v13 DEC2014.pdf" (WMDPv13), those pits supply approximately 90% of the groundwater baseflow to the upper Partridge River (see GLIFWC email of 4/20/2015). It is not surprising that those taconite pits play a significant role in the local groundwater hydrology since they are positioned high in the local terrain, at times contain large volumes of water, and sit in relatively high conductivity bedrock (Biwabik Iron Formation or BIF). Because they play a dominant role in the local hydrology it is critical that they be correctly incorporated into the project hydrologic modeling.

Unfortunately, the existing project MODFLOW model for the PolyMet mine site was calibrated using P-M taconite pit water levels that were approximately10 meters too high. The project model incorporates the P-M pits as constant-head-cell boundary conditions (Large Figure 7 of Attachment B of the WMDPv13, attached). The project model sets the P-M pit lakes as constant-head-cells approximately 5 meters above the level of the upper Partridge River, yet pit lakes in 1986-88 were actually below the elevation of the upper Partridge. Because of this error, the calibration model has the local direction of groundwater flow 180 degrees reversed from the actual conditions during the calibration period. The model predicts that in 1986-88 water was flowing from the hydrologic high at the P-M pits to the hydrologic low at the upper Partridge River, when in fact, because the pits were partly empty, water would have been flowing from the upper Partridge River to the P-M pits.

Attached is a figure that shows the predicted water tables and groundwater flow between the upper Partridge and the P-M pits when the P-M pits are set at different levels (Figure 1, attached). In red are the project model results used in recent and past project reports. In those models the P-M pits are assumed to be at their 1996 elevation of 493 meters. The 483 meter model (in purple) is the same as the project model except that the water levels in the P-M pits, that are adjacent to the upper Partridge, are set to 483 meters. A water elevation of 483-488 meters appears to be the correct elevation for the calibration period of 1986-88 (Table 1, attached). Calibration and use of the MODFLOW model with the P-M pits erroneously set to the conditions in 1996 (493 meters) is a problem for the following reasons:

- The baseflow used in formulating (calibrating) the PolyMet project MODFLOW mine site model was calculated from flow conditions in late 1986 through early 1988. During calibration, the MODFLOW model was adjusted until the baseflow it predicted matched the 0.51 cfs baseflow target at station SW003, where the Dunka Road crosses the Partridge River.

- The water level in the P-M pits used in formulating (calibrating) the project model was assumed to be 493 meters elevation, the water elevation in 1996.

- The water level in the P-M pits, when the baseflow at SW003 was 0.51 cfs (i.e. in late 1986 to

Indians; in Minnesota -- Fond du Lac Chippewa Tribe, and Mille Lacs Band of Chippewa Indians; and in Michigan -- Bay Mills Indian Community, Keweenaw Bay Indian Community, and Lac Vieux Desert Band of Lake Superior Chippewa Indians.

early 1988), was actually approximately 10 meters lower, at 483 meters.

As the diagram shows, with the actual pit water levels that occurred in November of 1986 (i.e. ~483 meters), the upper Partridge would have been losing water to the pits and have no baseflow. In plan-view, the resulting model map (Figure 2, attached) shows that the water table would slope down northward from the Partridge River toward the P-M taconite pits. This is because the riverbed of the upper Partridge River is at 486-489 meters elevation, whereas the water levels in the adjacent P-M pits were at approximately 483 meters elevation in 1986.

The significance of this is that the MODFLOW model was calibrated (adjusted to fit reality) to baseflow in 1986-88, yet the P-M pit water levels used as boundary conditions in calibration were those that occurred in 1996, not those that occurred in 1986-88. A fundamental requirement of model calibration is that the calibration targets (i.e. baseflows) and the model boundary conditions (i.e. the water levels in the taconite pits) must be from the same time period, e.g. one can't calibrate a model with taconite pit water levels from 1850 and baseflows from 1950. Although not as extreme as 1850 vs. 1950, the problem of using 1996 pit water levels and 1986-88 river baseflows is similar, the hydrologic system in 1996 was significantly different from the system in 1986-88 because the water levels in the pits were so different. The result of this mis-match of boundary conditions and calibration targets is that **the model is incorrectly calibrated and can not be expected to produce accurate predictions**. The model gives the impression of generating reasonable results but is based on conditions that never existed at the same point in time.

Alternate source for baseflow:

Without the the P-M pits supplying baseflow water to upper Partridge River, the 1986-88 baseflow in the Partridge (0.51 cfs at SW003) had to come from some other source. The most likely alternative source was recharge. Since 2008, we have been arguing that the recharge values used in the groundwater modeling are unrealistic. Without the P-M pits being as large an input to the groundwater system, higher recharge values would be needed to calibrate the model. As pointed out in previous comments by Grand Portage (emails of 2015-02-10 and 2015-02-18) and others, the recharge used in the groundwater modeling (0.36 to 1.8 in/yr) falls well below the recharge estimates made by the USGS for the watershed (6-10 in/yr). Higher recharge numbers are supported by recent work done by Barr Engineering for the Northshore project (Barr 2008_Northshore-Long-Range-Hydro-Study). In that document, Barr estimated that 1.3 cfs to 3.2 cfs of groundwater discharges from the 2,310 acre watershed. Assuming steady state, this implies a groundwater recharge rate of 4.9 to 12.0 inches/year. Use of the higher recharge rates suggested by the USGS or by the Barr work could make up for the loss of water from the model if the P-M pits were incorporated at their actual 1986 level.

Appropriate recharge rates should be determined by recalibration of the MODFLOW model with the water in the P-M pits set at their correct 1986-88 levels. To the extent that XP-SWMM was used to calculate site recharge rates, it suffers from the same problem as the MODFLOW modeling, a lack of consideration of the loss of groundwater northward, due to low water levels in the P-M pits in 1986-88.

Project model predicts contaminant flow to the north at closure of P-M pits:

The project mine site MODFLOW model distributed to cooperating agencies on January 5, 2015 was used by the applicant to predict that contaminants would flow from the mine site at closure to the south and south-east (for example: Large Figures 28 & 29 of the WMDPv13, attached). In those project model runs, the water levels in the P-M taconite pits were assumed to remain at the level found in 1996.

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In the project predictive models the adjacent taconite pits to the Polymet project site were set to have a water elevation of 1616 feet or 493 meters. However, the P-M taconite pit water levels expected at closure are 1500 feet or 457 meters (see figure from the Northshore Watershed Mitigation Plan of 2011, attached). Given the large effect that the project groundwater model indicates the water in the taconite pits has on the local hydrology (90% of upper Partridge River baseflow comes from the taconite pits), one would expect that a large change in the elevation of the water in the taconite pits would have a significant impact on the local hydrology. In fact, additional runs of the project model indicate that the groundwater flow direction between the PolyMet project and the taconite pits would be reversed if the taconite pits had the correct closure water elevation of 457 meters. Model runs of the project model, showing particle tracking, but with the water levels in the P-M taconite pits set at the correct closure water elevation of 457 meters, show that water would flow from the area of the PolyMet mine pits northward to the P-M taconite pits (Figure 3, attached).

This result indicates that the contaminant transport modeling, which assumes contaminant flow paths to the south and south-east, is incorrect because it is based on the incorrect assumption of 1996 era water levels in the taconite pits even during closure. Using the project model with the correct closure water elevations indicates that water flows to the north at closure.

Importance of groundwater hydrology in prediction of project impacts:

Adequate characterization of the groundwater system at a proposed mine site is essential to understanding most of the potential impacts from the project. The amount of water entering the groundwater system, be it precipitation or discharge from the bed of lakes, rivers or mine pits, determines the direction of flow and dilution of contaminants, and dictates points of compliance. The horizontal and vertical conductivity of the soil and bedrock materials determines how the groundwater system responds to stresses and the rate at which the groundwater flows horizontally and vertically. The character of interaction between surface water features and the groundwater system, whether it is loss of water from rivers or wetlands to the groundwater system, or discharge from the groundwater system to the surface water features, determines predicted impacts to surface water features by stresses such as mine dewatering. Estimating water budgets and quantities of water that must be treated requires an adequate understanding of the groundwater system. None of the above effects of a mine project can be predicted accurately if there is not an adequate characterization of the groundwater system. Without an integrated model of the groundwater system, one would be left with only professional judgment to determine the value of the many interrelated parameters that are used for impact prediction. Professional judgment is useful in checking the reasonableness of the predictions from a groundwater model but, by itself, can not adequately integrate the complex site specific information, all pieces of which must fit together like a complex puzzle.

The essential role of groundwater system characterization, characterization that integrates information from the available sources into a coherent model, is demonstrated by the myriad of uses that the project groundwater model has been put to during impact evaluation. We have compiled, from the text in the WMDPv13, references to the use of the groundwater modeling to predict impacts from the project. In particular, the GoldSim contaminant transport modeling uses many outputs from the MODFLOW groundwater modeling. A table (Table 2) of the documented ways that GoldSim modeling uses outputs from the mine site MODFLOW modeling is attached. These extend far beyond the original purpose of the groundwater model; which was to predict pit inflow.

The project MODFLOW model was used to characterize the general nature of the groundwater system such as mine site head distribution (e.g. watertable, Large Figure 14 of the WMDPv13, attached), groundwater levels at closure (Large Figure 30 of Attachment B of WMDPv13, attached) and contaminant flow paths (Large Figures 28 & 29 of the WMDPv13, attached). In addition, the MODFLOW model was used to supply the numeric input parameters to the GoldSim model that is used for prediction of contaminant flow and contaminant concentrations (WMDPv13, Table 1-1). That table, attached, identifies approximately 12 critical GoldSim input parameters that are outputs from the mine site MODFLOW groundwater model. Of those twelve, approximately 6 parameters are related to mine pit inflow; the rest of the 12 parameters relate to the groundwater system across the entire mine site. Those parameters include contaminant flowpath conductivity (K_flowpath), flowpath gradients (I_ops), bedrock porosity (Bedrock_Porosity), recharge (Recharge_min and Recharge_max) and flowpath gradients at closure (I_close).

It is clear that without the conceptual (flow directions etc.) and numeric (bedrock conductivity etc.) outputs from the MODFLOW model, the GoldSim model could not be run. Because of the dependence of the GoldSim modeling of contaminant transport on MODFLOW model outputs it is essential that the MODFLOW outputs be valid. Because the MODFLOW model was incorrectly calibrated to baseflow from 1986-88 and taconite pit water levels from 1996 it is very unlikely that the MODFLOW outputs are valid.

Technical review of the MODFLOW modeling under the project QAPP

One might expect that previous technical review of the groundwater modeling would have detected these problems with calibration and specification of the MODFLOW model boundary conditions. The project technical review of the MODFLOW modeling is documented in the WMDPv13 beginning on page 2969. It is unclear if the review conducted and documented in the review checklist was thorough because of several factual errors in that review. For example: the reviewer identifies the model as a 7 layer model, when it is an 8 layer model; the reviewer identifies the software version as MODFLOW-NWT, when the base calibration modeling was done with MODFLOW-2000 and the PCG2 solver, and the reviewer states that the effects of boundary conditions were evaluated when there was no evaluation of the effect of the P-M pit constant-head boundary conditions. These factual errors are apparent with even a cursory examination of the modeling reports and modeling files.

In summary:

- The project mine site groundwater flow model (MODFLOW) was calibrated to multiple conditions that did not exist simultaneously, i.e. boundary conditions in the form of taconite pit water levels from 1996 and river baseflows from 1986-88. This means that the mine site model is not correctly configured and, therefore, very unlikely to generate accurate predictions.

- The project model, as configured and used by the applicant as a basis for contaminant transport predictions, predicts that contaminants would flow from the PolyMet site south to the Partridge River at project closure. However, if the model is configured with correct closure boundary conditions in the form of taconite pit water levels at their closure level of 457 meters, contaminants are predicted to flow to the north toward the P-M pits. This contaminant flow direction (to the P-M pits) is opposite the direction assumed for the current project contaminant transport modeling.

- The conceptual model of the site hydrology is in conflict with the integrated groundwater model. The conceptual model used for the basis of many of the conclusions in project reports and in the DEIS text is that the taconite pits have little influence on the surrounding aquifer, regardless of whether they are full of water or pumped dry. On the other hand, the mine site MODFLOW model, used by the applicant, indicates that the taconite pits have a profound impact on the aquifer. This makes sense because of the relatively high conductivity of the bedrock in which the taconite pits sit and their elevation in the landscape. In the project groundwater model, the water levels in the taconite pits *determine* if there is any baseflow in the Partridge River and what direction contaminants would flow from the PolyMet pits at closure.

There appear to be two options to resolve these fundamental errors:

Calibrate the MODFLOW model to 1986-88 conditions, with the P-M pits set at their correct late 1986 to early 1988 levels, and use the 0.51 cfs baseflow rate at SW003 (and other 1986-88 baseflows at other stations) as targets. This would result in a very different hydrologic model for the site so as to account for the loss of groundwater to the P-M pits. This appears to be a poor option because of the significant uncertainty about the baseflow in the Partridge River in 1986-88 and uncertainty about the exact level of water in the P-M pits.

or

Calibrate the MODFLOW model to 2011 conditions, with the multiple P-M pits at their known 2011 water levels of 483 to 499m (pit water elevations are available for that year), and use estimates of baseflow at SW003 based on current data. There is more certain information for both the water levels in the taconite pits and the baseflow in the Partridge River. The December 2013 DNR analysis of 2011-12 flows at SW003 indicate that "minimum winter base flows" in the range of 1.3 to 1.8 cfs are reasonable.

Recalibration of the model under either of the above scenarios will result in substantially different calibrated MODFLOW parameters. Those parameters would then be used in the GoldSim modeling of contaminant transport. And finally, the predictive modeling for the post closure period must use the correct closure water elevations for the P-M pits. A simple thought exercise (i.e. the PolyMet pit water levels are higher than the P-M pit water levels at closure; water usually flows downhill) and current groundwater modeling with correct P-M pit closure water levels of 457 meters, both strongly suggest that at closure contaminants may flow north rather than the southward direction currently assumed by project reports.

Since we first raised this issue in February of this year we have looked forward to discussion of technical details and possible resolutions. We continue to look forward to that discussion.

Sincerely,

John Coleman, GLIFWC Environmental Section Leader

cc: Randall Doneen, . Environmental Review Unit Supervisor, MN-DNR
Brenda Halter, Forest Supervisor, Superior National Forest
Tamera Cameron, Chief, Regulatory Branch, St Paul District of the Army Corps of Engineers
Kenneth Westlake, NEPA Coordinator, USEPA Region 5
Nancy Schuldt, Water Projects Coordinator, Fond du Lac Environmental Program
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