Tailings Basin-Mitigation Design Water Balance

RS13B
Draft-01

Prepared for
PolyMet Mining, Inc.

September 8, 2008

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Tailings Basin-Mitigation Design
Water Balance
RS13B Draft-01

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(unless noted as updated via * are the same as RS13 Draft-03)

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(Available upon Request)

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RS22	Mine Waste Water management System
RS24	Mine Surface Water Runoff Systems - Runoff Characterization
RS28T	Hydrometallurgical Residue Facility Design and Location
RS36	Stormwater – Volume and Patterns
RS39/40T	Tailings Basin Design and Geotechnical
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RS55T	Tailings Basin Modifications
RS73	Streamflow and Lake Level Changes – Cumulative Impact Report

Executive Summary

PolyMet plans to use the existing LTV Steel Mining Company (LTVSMC) Tailings Basin for flotation tailings disposal from the processing of ore from the NorthMet deposit. A detailed water balance for the PolyMet Plant, which includes the Tailings Basin, was presented in RS13 Draft-03. This water balance was based on the proposed design for the PolyMet Tailings Basin (referred to as the Tailings Basin – Proposed Design). Through the EIS process, geotechnical concerns were raised regarding the proposed design. As a result of the geotechnical concerns with that design, a new design was prepared, referred to as the Tailings Basin – Mitigation Design. The water demand for the project changes as a result redesign of the basin.

This report presents the water balance for the Tailings Basin – Mitigation Design at different stages in the life of the operation. This balance quantifies both the make-up water demand and potential for discharge from the basin in accordance with the requirements outlined in the Final Scoping Decision. The following sources and sinks of water were included in the water balances: entrainment loss, watershed yield (which includes precipitation, evaporation, and runoff), seepage, slurry transport water from the plant and return water to the plant. The water balance tallies the flows of water to and from the Tailings Basin using a monthly time step for a thirty year climate record in order to determine if water will need to be discharged from a water quantity standpoint or if additional water will be needed for plant operations (raw water make-up).

The predicted make-up water demand varies through time as the basins develop, as the yields from the Mine Site change and as a result of climate variability. On an annual average basis, the make-up water demand will likely vary between 600 and 4,000 gpm. However, on a monthly basis, the demand will be more variable, ranging from 3 gpm during wet months (the minimum amount of raw water required for the process) to as much as 7,000 gpm.

1.0 Introduction

PolyMet plans to use the existing LTV Steel Mining Company (LTVSMC) Tailings Basin for flotation tailings disposal from the processing of ore from the NorthMet deposit. A detailed water balance for the PolyMet Plant, which includes the Tailings Basin, was presented in RS13 Draft-03. This water balance was based on the proposed design for the PolyMet Tailings Basin (referred to as the Tailings Basin – Proposed Design). The Tailings Basin – Proposed Design is documented in RS39/40T. Through the EIS process, geotechnical concerns were raised regarding the proposed design. As a result of the geotechnical concerns with that design, a new design was prepared, referred to as the Tailings Basin – Mitigation Design. The Tailings Basin – Mitigation Design will be documented in the forthcoming Permit to Mine and SDS/NPDES Permit applications; however, the aspects that affect the water balance are summarized here in Section 2.

The water balance for the Plant Site, as presented in RS13 Draft-03, changes as a result of the redesign of the basin. This report (referred to as RS13b Draft-01) presents the predicted water balance associated with the Tailings Basin – Mitigation Design. The format of this report is consistent with the format of RS13 Draft-03 in order to help facilitate an easy comparison of the two water balances. The redesign of the Tailings Basin does not affect the design or water balance for the Hydrometallurgical Cells. As such, this report does not discuss these cells any further.

This report is organized into three sections, including this introduction (Section 1). Section 2 presents the Flotation Tailings Basin water balance. Section 3 provides a summary of the data presented in the preceding sections.

2.0 Tailings Basin-Mitigation Design Water Balance

The changes in the design of the Tailings Basin will be documented in detail in the forthcoming Permit to Mine and SDS/NPDES Permit applications. Only the aspects of the design that affect the water balance are presented here. The major changes in the design of the Tailings Basin that are incorporated in the Mitigation Design are as follows:

- Embankments will be constructed with LTVSMC bulk/coarse tailing
- PolyMet tailing will be deposited as bulk tailing
- The footprint of the basin will be slightly different in order to provide additional source for LTVSMC bulk/coarse tailings, maximize the watershed area of the closed tailings basin and provide for the maximum storage capacity for the PolyMet tailings
- There will be no horizontal drains in the LTVSMC north embankment of Cell 2E for dam stability purposes because this function will be provided by rock buttresses at the toe of the LTVSMC dams where required

The Tailings Basin – Mitigation Design will be constructed using LTVSMC tailing for dam construction. The embankments will be constructed in 20 foot lifts, with a 200 foot crest. There will be 625 foot PolyMet bulk tailing beaches in each embankment area. The remainder of the basin will be a pond; an average pond depth of 5 feet was assumed for the work presented here. As a result of the above changes, the stage, area and volume of the pond through time have also changed.

A continuous twenty year water balance was calculated for the Tailings Basin-Mitigation Design in the same manner as was done for the Tailings Basin-Proposed Design. In order to assess the effects of climate variability, the water balance was calculated using climate data from 1971 through 2000 based on the MDNR's recommendations. Thirty iterations of the water balance were calculated, each using a different start date for the climate data. Of these iterations, the water balance starting with climate data from the year 1977 is most similar to average conditions for the 30 water balance iterations and this balance is considered the base case. The remaining iterations are presented in Section 2.3 along with additional sensitivity analysis.

2.1 Water Balance Components

The Tailings Basin-Mitigation Design water balance is broken up into seven different components, as detailed below in Sections 2.1.1 through 2.1.7. A schematic representation of the water balance is shown on Figure 2-1.

2.1.1 Beneficiation Plant Water Balance

Bateman Engineering Pty Ltd (Bateman) calculated a material mass balance for the Beneficiation Plant, which included a plant water balance (Attachment A-2). The water balance was conducted on a process-by-process basis, tallying all of the sources and sinks for water within the plant. A metallurgical simulation software package (MetSim) was used for the process modeling and design. For the beneficiation process, the MetSim model provided the following flows: the volume of water entering the beneficiation plant with the ore, the evaporation from the beneficiation plant processes, the water leaving the beneficiation process as product to the hydrometallurgical process and the amount of water used to transport tailings to the Tailings Basin. In addition, the MetSim model provides the total amount of water that is needed by the Beneficiation Plant from either the Tailings Basin or Colby Lake to meet the demands of the process. The only components that are needed for the water balance for the Tailings Basin are the amount of tailings and water sent to the basin and the Beneficiation Plant water usage. These streams are summarized in Table 2-1.

Table 2-1 Beneficiation Process streams to and from the Tailings Basin

Stream	Mass of Tailing (Tons/Year)	Specific Gravity of Tailing	Vol. of Water (MGAL/Year)	Temp. of Water (°F)
Stream From Plant	11,270,000	2.97	4,595	72
Additional Water to Basin	--	--	11	--
Beneficiation Plant Water Usage	--	--	4,561	--
Raw Water Demand	--	--	1.6	--

Source: Bateman MetSim Model Revision U3, see Attachment A-2.

The tailings production rate is equivalent to an average daily rate of 30,880 ton/day. Note that tons used in this document are short tons of 2,000 pounds each. An average of 4,595 MGAL/year of water will be used to transport the tailings to the basin. It was assumed that there would be no temperature loss in the tailing/water stream from the plant to the Tailings Basin. The Beneficiation Plant requires a minimum of 1.6 MGAL/year of raw water which will be withdrawn from Colby Lake. The remainder of the plant water demand, 4,561 MGAL/year, can be met by either return water from the Tailings Basin, water from the mine site or additional withdrawal from Colby Lake. An additional 11 MGAL/Year of water will be added to the Tailings Basin from the upgraded water treatment plant associated with the sanitary system, flotation OSA flush within the Beneficiation Plant and vehicle wash down. These additional sources of water are discussed in Attachment A-7.

2.1.2 Entrainment Losses

Entrainment loss is the loss of water trapped in the void spaces of the tailings during deposition. It is considered a loss because it is removed from the free water pond and the circulating water system. The entrainment losses estimated for the Tailings Basin-Mitigation Design are lower than for the Proposed Design. For the Mitigation Design, the tailing will be emplaced more densely than was planned for the Proposed Design, which results in a lower porosity and thus less water loss. It was assumed that the porosity of the tailings for the Mitigation Design will be 49% (porosity based on lab testing of bulk tailing under a confining pressure of two tons per square foot). The average flow of tailings sent to the basin will be 1,730 gpm (this is in addition to the 8,737 gpm of water used to transport the tailing). The resulting entrainment loss is expected to be 1,660 gpm.

2.1.3 Active Delta Drainage Losses

Active delta drainage losses result from the infiltration of water used to transport tailings to the basin (i.e. the tailings slurry). During operations, some amount of tailings will be discharged from a spigot located along the outer portion of the beach area. As the tailing and water is discharged to the beach, some of the water used to transport the tailings will infiltrate, with the remaining water reaching the pond located in the center of the basin. Infiltration associated with the tailings slurry was calculated in the same manner as was done for the Proposed Design (documented in RS54/RS46 Draft-01). This calculation is based on the following assumptions:

- The permeability of the tailing is $6.5x10^{-7}$m/s;
- The beach width is 625 ft;
- The delta angle will be 75 degrees; and
- 30% of the delta will have active flow.

Given these assumptions, the active delta drainage loss is predicted to be 90 gpm.

2.1.4 Watershed Yield

The watershed yield component of the water balance is actually the composite of several different flows. These components are illustrated on Figure 2-2 and include direct precipitation and surface water runoff to the basin, evaporation from standing water in the basin, evaporation from active and inactive beaches, infiltration from the beach areas, and seepage from the pond areas.

Unlike other components of the water balance, watershed yield will be the most variable due to natural climatic variability (i.e. winter versus summer and wet year versus dry year). Based on conversations with the MDNR, the thirty-year period from 1971 to 2000 is considered most representative of present conditions. Monthly watershed yields were calculated for this entire period. Watershed yield calculations are described in detail in Attachment A-5. Watershed yield values for the base case are presented below.

Precipitation

Precipitation data from the nearest monitoring location were downloaded from the Minnesota Climatology Group web site (http://climate.umn.edu/doc/historical.htm). The availability of precipitation data changed over time and measurements from the following locations were used: Hoyt Lakes (1971-1982), Babbitt (1982-1986), Tower (1986-1994), and Embarrass (1994-2000). Average precipitation over this period for these locations was 28 inches, resulting in an average flow to the ponds of 1270gpm.

Evaporation

Evaporation rates from the Tailings Basin pond, active beach areas and inactive beach areas were calculated using the Meyer Model, which is described in detail in Attachment A-5. The Meyer Model relates evaporation to wind speed and the difference between the air and water vapor pressures. The vapor pressures depend on air and water temperatures and relative humidity. These calculations are extremely sensitive to the difference between air and water temperatures. The water entering the basin from the plant is warmer than would be found in natural surface water features in the area, resulting in increased evaporation from active beach areas and the pond in the active basin. The predicted evaporation rates are also dependent on the volume of the pond and the amount of beach area in the basin. Predicted evaporation rates and resulting average water losses are presented in Table 2-2.

Table 2-2 Predicted annual evaporation rates for the Flotation Tailings Basin

	Pond in Cell 2E – Years 1-8	Pond in Cell 2E/1E – Years 9-20	Active Beach Area	Dry Beach Area[1]
Predicted Annual Evaporation	33"	31"	46"	15"

[1] Dry Beach evaporation is reported here for comparison, but is not directly included in the water balance as discussed below under "Runoff"

Runoff

Cells 1E and 2E have both active beach areas and upland watershed areas that will contribute surface water runoff. This runoff was predicted using the Meyer Model, which is described in detail in Attachment A-5. Watershed areas were delineated at different time periods based on the Tailings Basin-Mitigation Design presented in the forthcoming Permit to Mine and SDS/NPDES Permit applications. Currently, there is upland area east of Cells 1E and 2E that drains into the Tailings Basin. As the starter dams for Cells 1E and 2E are built up much of this contributing area will be diverted away from the Tailings Basin.

Stormwater runoff from the plant area is addressed in Attachment A-3 *Plant Site Stormwater Volume and Patterns – RS36*. This report supports the watershed areas delineated in Attachment A-5, which indicate that the plant area does not contribute runoff to the Tailings Basin.

Beach runoff is the difference between direct precipitation to the beach areas and infiltration plus evaporation/transpiration plus temporary storage. As such, only beach runoff is included in the actual water balance calculation. Average runoff from the beaches is predicted to be 70gpm. Average runoff from the surrounding watershed is predicted to be 60 gpm.

2.1.5 Seepage from Ponds

Pond seepage from Tailings Basin was calculated using a groundwater flow model of the basin constructed for this purpose. The groundwater model is discussed in detail in Attachment A-6. The groundwater model was used to predict the amount of seepage that will be lost from tailings basin during various stages of basin development. Seepage from Cell 2E is predicted to vary between 1,080 and 2,020 gpm. Seepage from the combined Cell 2E/1E is predicted to vary between 2,770 and 3,390 gpm. Variability is based on the elevation and size of the cells as they develop through time.

2.1.6 Seepage Management

For the Tailings Basin-Mitigation Design, the seepage management system will consist of a seepage barrier/collection system that will be established in the areas south of Cell 1E to contain known seep conditions in this area. This is referred to as the "seepage barrier". The amount of water collected by the seepage barrier was predicted using the groundwater flow model discussed above and described in Attachment A-6. The seepage barrier south of Cell 1E is expected to recover between 370 and 570 gpm. This water will be pumped back to the Tailings Basin. Table 2-3 summarizes Tailings Basin seepage and seepage recovery.

Table 2-3 Summary of Tailings Basin Seepage

	Basin Seepage				Recovered Seepage			
	Seepage from Cell 1E Pond	Seepage from Cell 2E Pond	Drainage of Entrainment Water[e]	Beach Infiltration	Flow to Seepage Barrier	Cell 1E Seeps	Unrecovered Seepage	Percent of Seepage Collected
	(gpm)	(gpm)	(gpm)	(gpm)	(gpm)	(gpm)	(gpm)	(gpm)
Pre-PolyMet Operations (2002)	900[a]	687[a]	4,123[b]	Unknown	550[c]	N/A[d]	5,710	0%
Elev. 1620 Model	1190	1080	240	160	410	--	2,260	15%
Elev. 1660 Model	240	2020	160	170	380	--	2,210	15%
Elev. 1700 Model	3140		170	150	540	140	2,780	20%
Elev. 1720 Model	3340		190	160	570	170	2,950	20%

Notes:

(a) From Adams et al., 2004. East Range Hydrology Project

(b) Seepage from Cell 2W predicted using the groundwater model described in Attachment A-6

(c) Water not collected but listed for comparison to predicted future conditions

(d) Although horizontal drains are present at the basin, the water from them is not being collected

(e) Based on assumption that the percent of tailing that will be deposited on the beaches is proportional to the ratio of beach to pond area and that 50% of this water will become seepage

(f) Based on an assumed infiltration rate of 8 inches a year over entire beach area plus results of Hydrus modeling (see Attachment A-6)

(g) With the exception of Pre-PolyMet Operations, this does not include possible seepage from Cell 2W

PolyMet has committed to collecting all water that immerges as surface seeps from the basin. The groundwater flow model described in Attachment A-6 predicts that there may be some surface seeps on the east side of Cell 1E as the basin develops through time. This water will also be returned to the basin. An addition 5 to 170 gpm (increasing through time) was added to the water balance to account for this seepage and other seeps that may need to be returned to the basin.

2.1.7 Process Water from Mine Site

Process water from the Mine Site will be routed to the Tailings Basin via the Central Pumping Station that will be located at the Mine Site. Process water includes runoff from unreclaimed portions of the stockpiles, liner drainage from all waste rock stockpiles, pit dewatering, and runoff from haul roads, the Lean Ore Surge Pile and the Rail Transfer Hopper. Process water will be treated at the Waste Water Treatment Facility prior to delivery to the Central Pumping Station. All water from the Central Pumping Station will be pumped via the Treated Water Pipeline to the Tailings Basin for use as plant make-up water. The Treated Water Pipeline is described in detail in RS24. The Treated Water Pipeline will transport water into Cell 1E. The flows in this system are expected to be year-round, with lower flows during the winter months and during periods with low precipitation. However, in the water balance presented here, the average annual flows were used, which are summarized in Table 2-4.

Table 2-4 Average Annual Flows from the Mine Site to the Tailings Basin

Year	Flow (gpm)	Year	Flow (gpm)
1	700	11	1,770
2	930	12	740
3	1,170	13	1,370
4	1,400	14	1,540
5	1,640	15	510
6	1,650	16	550
7	1,670	17	580
8	1,680	18	670
9	1,700	19	440
10	1,710	20	370

Flows from the Mine Site will increase through time and peak in Year 11 when both mine pits are being dewatered. Following Year 11, the East Pit will no longer be dewatered and water from the Mine Site will decrease. In Years 13 and 14, there is some excess water from the pits that will be sent to the Tailings Basin. RS22 Draft-02 provides additional information on the Mine Site water balance and the volumes of water that will be sent to the tailings basin.

2.2 Net Balance

The Tailings Basin water balance was calculated on a monthly time step using precipitation and climate data from 1977-1996. For each month, the inputs (precipitation, runoff, returned seepage, water from the Mine Site and slurry transport water from plant) and outputs (entrainment loss, seepage, active delta drainage, and evaporation) were summed to determine the amount of water available for return to the plant. The difference between the amount of available water from the Tailings Basin and the plant demand is the make-up water demand.

Make-up water demand varies through time as the basins develop, as the yields from the Mine Site change and as a result of climate variability. The predicted make-up water demand is shown in Figure 2-3. In general, the largest make up water demand is in Year 8 during the transition from operating just in Cell 2E to operating in the combined Cell 2E/1E and during Years 15 through 20 when water from the Mine Site is the lowest and seepage losses are the greatest. On an annual average basis, the make-up water demand will likely vary between 600 and 4,000 gpm. However, on a monthly basis, the demand will be more variable, ranging from 3 gpm during wet months (the minimum amount of raw water required for the process) to as much as 7,000 gpm.

2.3 Sensitivity Analysis

The sensitivity of the water balance was tested to evaluate parameters that have the greatest uncertainty. The water balance with a start data of January 1977 was used as the base case water balance for the purposes of this sensitivity analysis, except where noted. The water balance sensitivity to the following parameters was tested:

- The variability of the climatic conditions: the 20-year water balance was calculated using a variety of effective “start dates” for the climatic data supplied to the water balance. The base case water balance used a start date of January 1977. An additional 29 water balances were calculated with start dates ranging from January 1971 to January 2000. This range is based on the MDNR’s identification of the 30 year period from 1971-2000 as best representing current conditions. In any given water balance, following the month that used December 2000 climate data, the cycle went back to the beginning and the next month used climate data from January 1971.

- The variability in the production rate: this was tested by increasing and decreasing the rate of tailings and water to the Tailings Basin, and the associated water demand of the beneficiation process, by 10 percent.

- The average porosity of the tailings: the base case water balance assumed an average porosity of 49%. An upper bound of porosity of 53% and a low bound of porosity of 45% were used to test the sensitivity of the water balance to this parameter (i.e. $^{+}$/- 4%).

- The amount of seepage returned to the basin: the base case water balance assumes that the seepage from the seepage management system will be returned to the Tailings Basin. To test the sensitivity, an option of not returning seepage to the Tailings Basin and an option of doubling the amount of seepage collected and returned were used.

- The amount of water pumped from the Mine Site: the amount of water that is predicted to be pumped from the Mine Site comes from a variety of sources that all have some uncertainty in the predicted flows, the largest of which is uncertainty associated with groundwater inflow rates to the pits. To address this uncertainty, the flow to the Tailings Basin was varied by +/- 50%. This variability is consistent with the sensitivity analysis that was performed as part of RS22, which found that groundwater inflow rates to the pits could be as much as double the predicted rate based on uncertainties in hydraulic properties of the rock.

- The effect of heated discharge water from the plant: the base case water balance assumes that there is no temperature loss prior to being discharged to the ponds. For this scenario, the water discharged from the plant was assumed to not be heated.
- Pond seepage: the hydraulic conductivity of the PolyMet tailings was set based on lab permeability tests. The hydraulic conductivity of the tailing affects the amount of seepage lost from the basin ponds. To test the sensitivity of the water balance to uncertainties in the hydraulic conductivity of the tailing, 50% and 150% of the predicted pond seepage were used. No other components that may also be affected by the hydraulic conductivity of the PolyMet tailings (such as seepage recovery and active delta drainage losses) were adjusted.

The results of the sensitivity analysis are presented below and summarized on Figures 2-4 and 2-5. Of the parameters tested, the water balance is most sensitive to the porosity of the flotation tailings, the amount of seepage recovered by the seepage management system, the amount of water coming from the Mine Site and the pond seepage rate. Varying the porosity from 49% (average) to 45% and 53% results in a change in the average make up water demand of -10% to 12% respectively. The variability in the difference between returning or not returning collected seepage to the basin resulted in a change in the average make-up water demand of 24%. Varying the rate of water pumped from the Mine Site by 50% resulted in a 24% change in the average make-up water demand. Changing the pond seepage rate by 50% resulted in a change in the average make-up water demand of 48%. The water balance is relatively insensitive (approximately 7% change in average water demand) to a 10% change in production rate.

3.0 Summary and Conclusions

Detailed water balances were computed for the Beneficiation Plant, which includes the Flotation Tailings Basin. On an average annual basis, the make-up water demand for the beneficiation process, which includes the Tailings Basin, is predicted to vary between 600 and 4600 gpm. In addition, there is a raw water demand of 106 gpm (see Attachment A-7) for potable water and other uses around the Plant Site. There is an additional need for make-up water for the Hydrometallurgical process, which is discussed in RS13 Draft-03. The make-up water for the project will come from Colby Lake. Impacts associated with this withdrawal from Colby Lake are addressed in RS73 Draft-02. Attachment A-8 discusses potential alternative sources of make-up water in the event that an extreme drought prevents withdrawal of water from Colby Lake.

Figure 3-1 shows the average make-up water demand for the Tailings Basin – Mitigation Design compared to the average make-up water demand for the Tailings Basin – Proposed Design. Table 3-1 summarizes the average flows for each water balance component for the two balances. There is very little difference in the needed make-up water demand between these two basins. With the exception of Year 8, the Mitigation Design has a slightly lower water demand. As discussed previously, there will be a large water demand in Year 8 as the two cells merge into one.

Table 3-1 Summary of average water balance component flows for the Proposed Design and the Mitigation Design

Water Balance Term	Proposed Design RS13 Draft-03 (gpm)	Mitigation Design RS13B Draft-01 (gpm)
Flow to Basin From Plant	8760	8760
Water Demand for Plant	8670	8670
Entrainment Losses	1880	1660
Active Delta Drainage	130	90
Precipitation	1250	1270
Evaporation	1300	1390
Runoff	310	120
Seepage From Ponds	2120	2300
Recovered Seepage	770	560
Water from Mine Site	1140	1140
Make-Up Water Demand	2530	2390

Conclusions that can be drawn from this work include:

- The beneficiation process which includes the Tailings Basin will be a net consumer of water.

- The amount of unrecovered deep seepage during PolyMet operation is predicted to be less than occurred during and immediately after LTVSMC operations. The unrecovered seepage is water from both historic operations and proposed PolyMet operations that flows out of the basin as groundwater flow within the till deposits.

- The beneficiation process water system will be a 100% recycle/reuse system except for unrecovered seepage loss to groundwater. Thus there will be no need for a direct point discharge from the tailings basin.

References

Adams, J.T., R.T. Leibfied, and E.S. Herr, 2004. *East Range Hydrology Project – Final Report.* Minnesota Department of Natural Resources, March 2004.

Barr Engineering Company. undated. *Documentation and User's Guide for Meyer Method Watershed Yield Computer Program.*

Barr Engineering Company, 2001. LTV Tailing Basin Interim Water Balance Study. Prepared for LTV Steel Mining Company.

Dunn, I.S., L.R. Anderson, F.W. Kiefer, 1980. Fundamentals of Geotechnical Analysis. John Wiley & Sons, Inc.

Hunt, R. E., 1984. Geotechnical Engineering Investigation Manual. McGraw-Hill, Inc.

Meyer, A. 1947. *Elements of Hydrology*. Chapter 6: Evaporation from Land Areas. John Wiley & Sons, Inc.

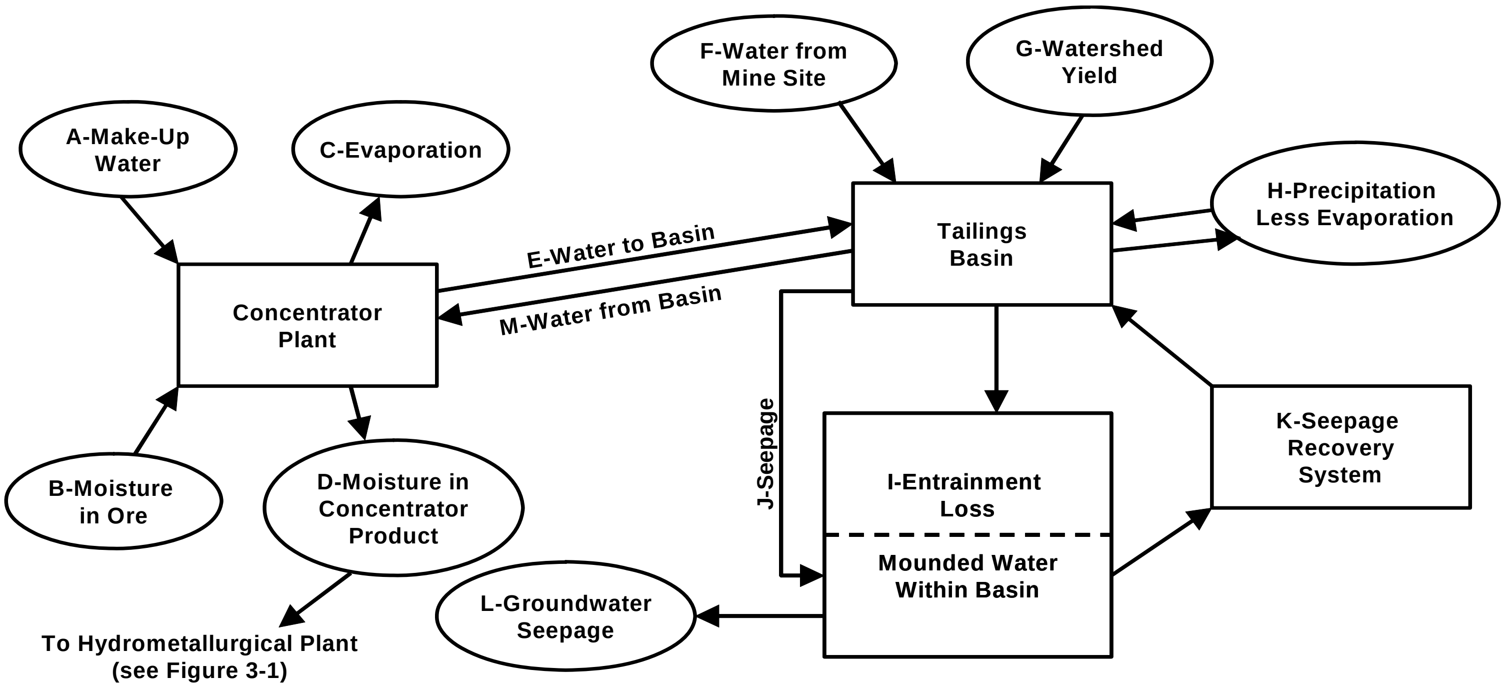
McDonald, M.G., and A.W. Harbaugh, 1988. "A modular three-dimensional finite-difference ground-water flow model," Techniques of Water-Resources Investigations 06-A1, USGS, 576 p.

Figures

Figure 1-1

SITE LAYOUT

NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN



Source of Data

A	Difference between total plant demand and the water from the Tailings Basin (Component M)
B	MetSim Model (Attachment A-2)
C	MetSim Model (Attachment A-2)
D	MetSim Model (Attachment A-2)
E	MetSim Model (Attachment A-2)
F	RS24
G	Meyer Model (Attachment A-5)
H	Meyer Model (Attachment A-5)
I	Calculated using tailings production rate from MetSim model and predicted porosity reported in RS39/40T
J	MODFLOW model (Attachment A-6) and miscellaneous calculations
K	MODFLOW model (Attachment A-6)
L	MODFLOW model (Attachment A-6) and miscellaneous calculations
M	Residual from Water Balance

Figure 2-1 Tailings Basin water balance schematic

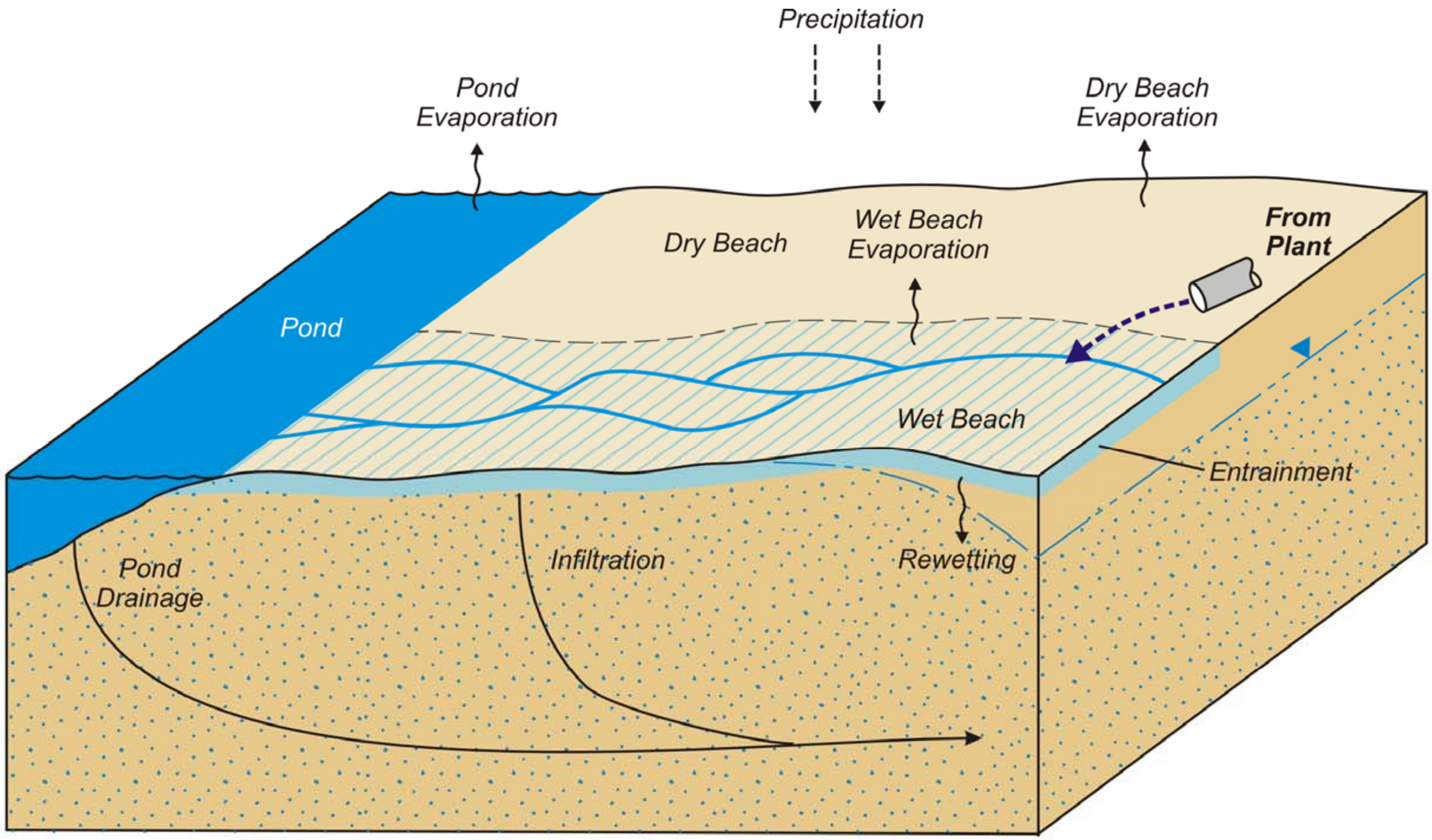


Figure 2-2 Tailings Basin watershed yield components

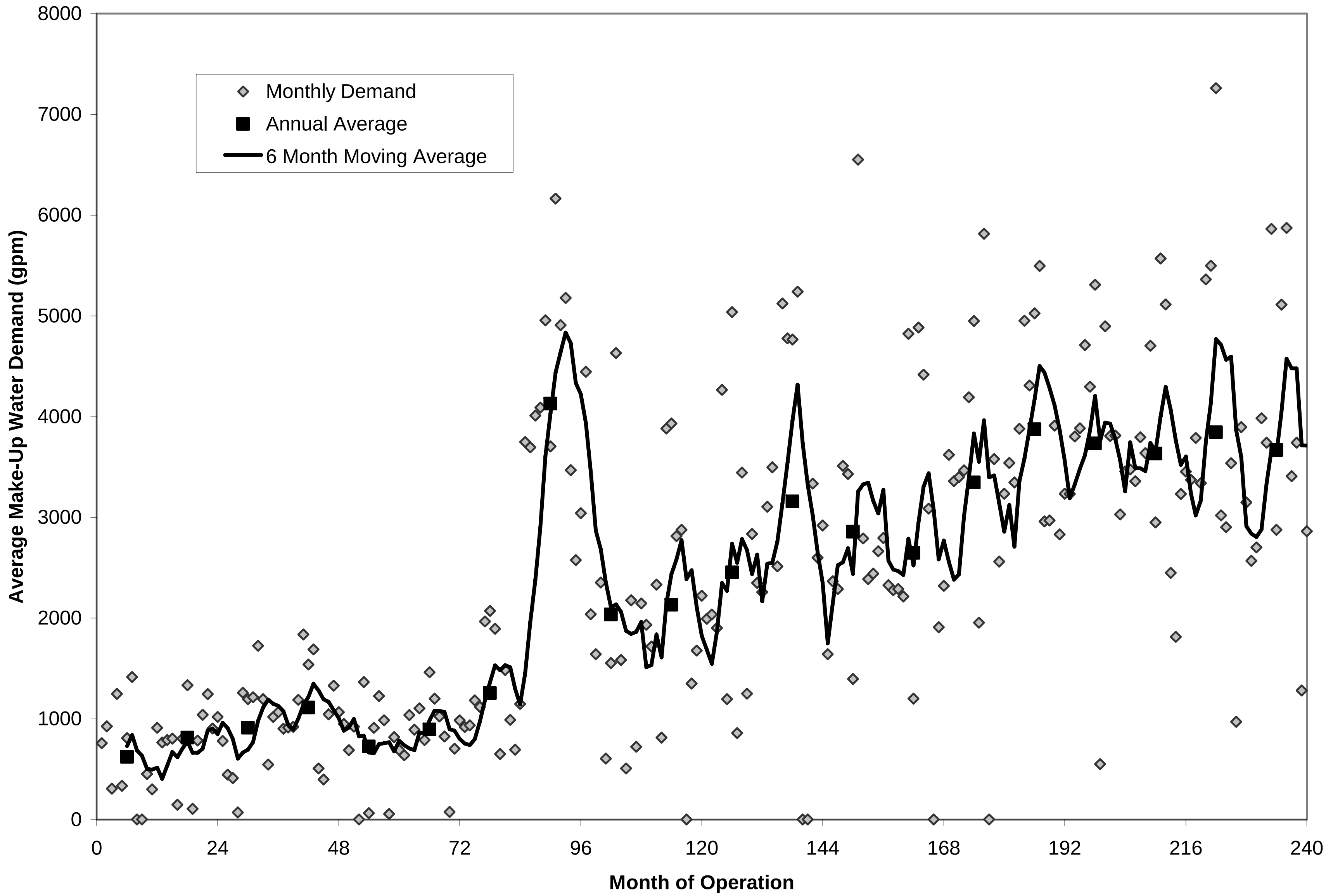


Figure 2-3 Average monthly make-up water demand for the Beneficiation Process

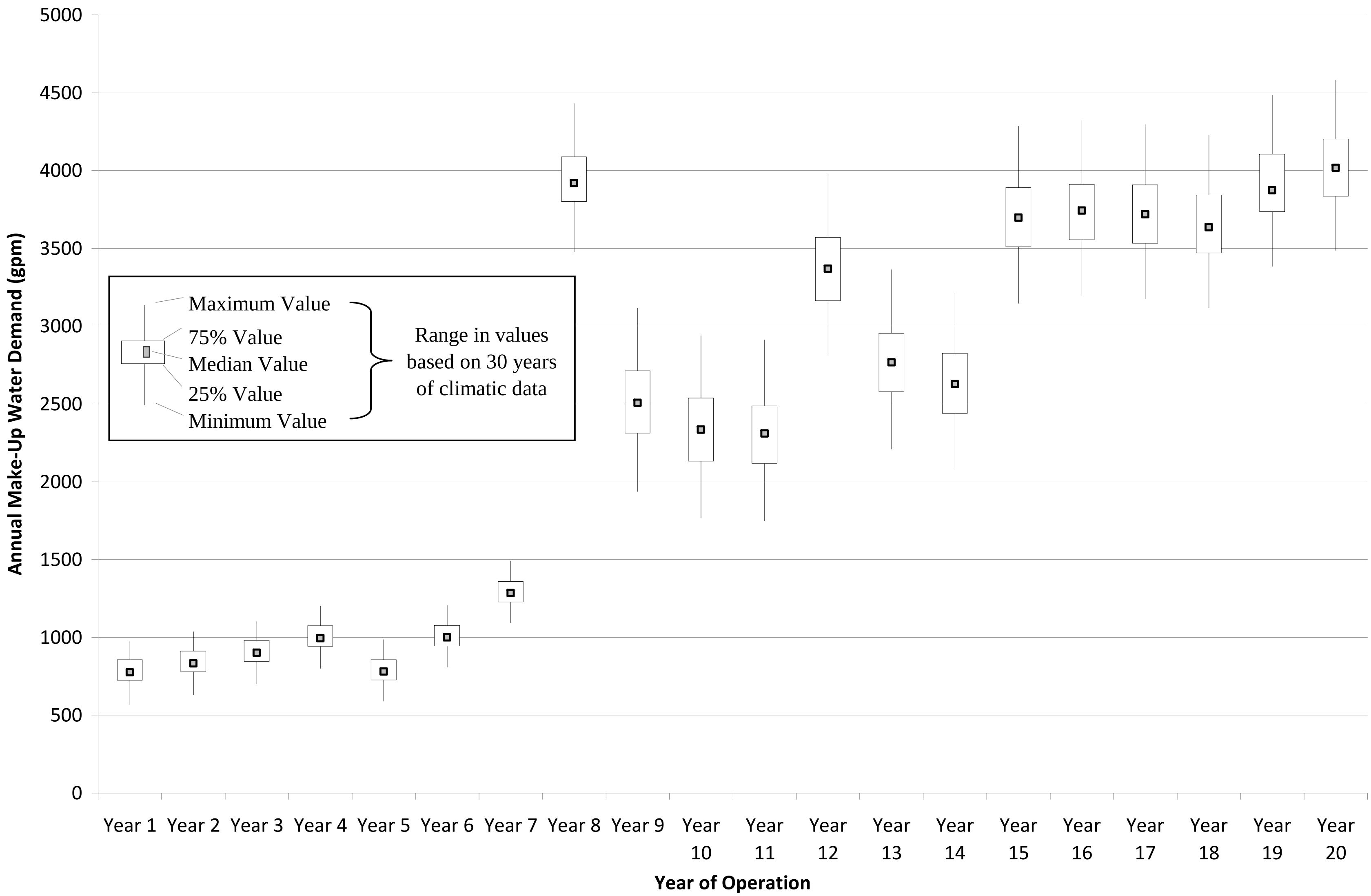


Figure 2-4 Sensitivity of make-up water demand for the Beneficiation Process due to climate variability

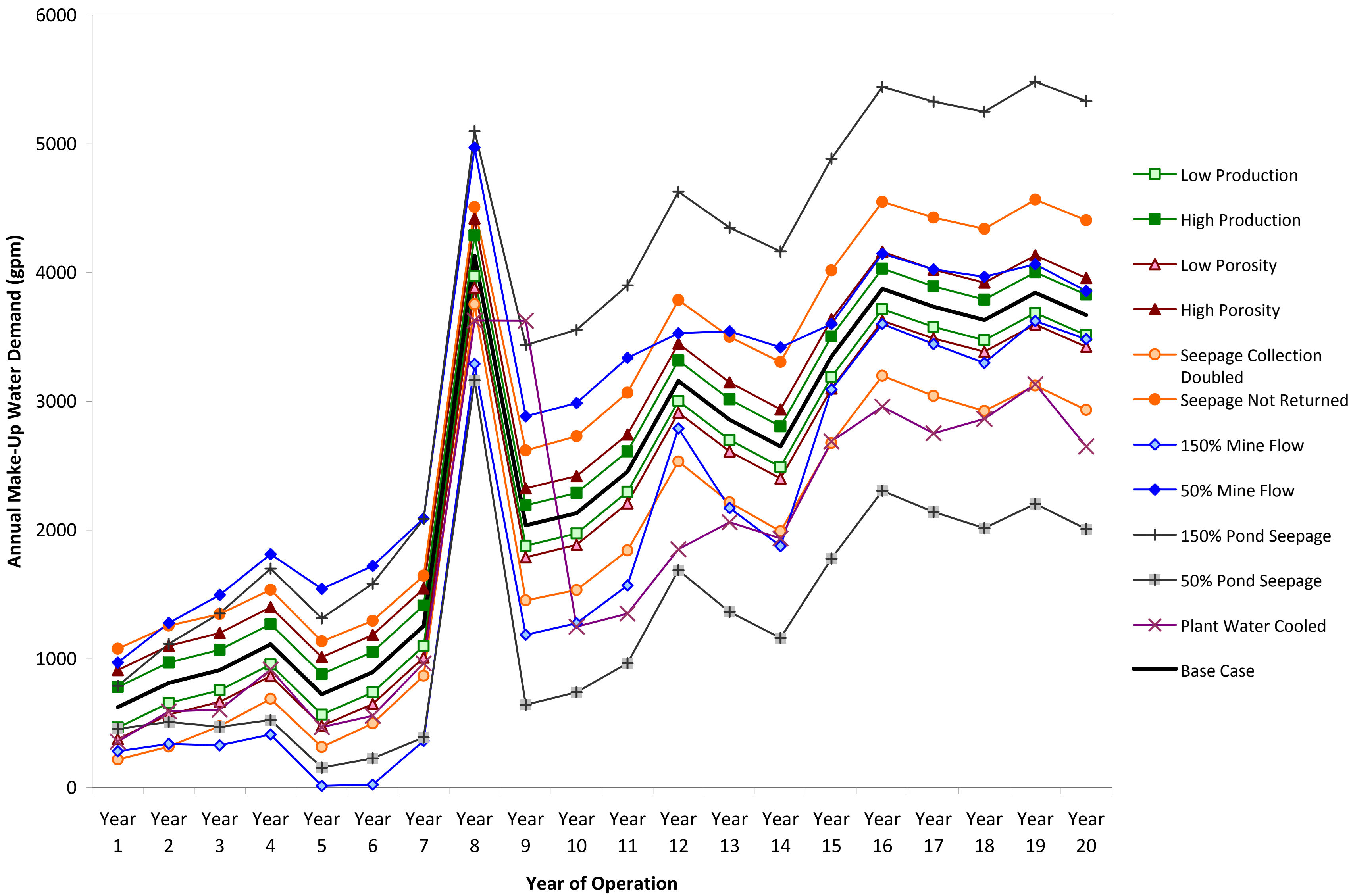


Figure 2-5 Tailings Basin water balance sensitivity analysis

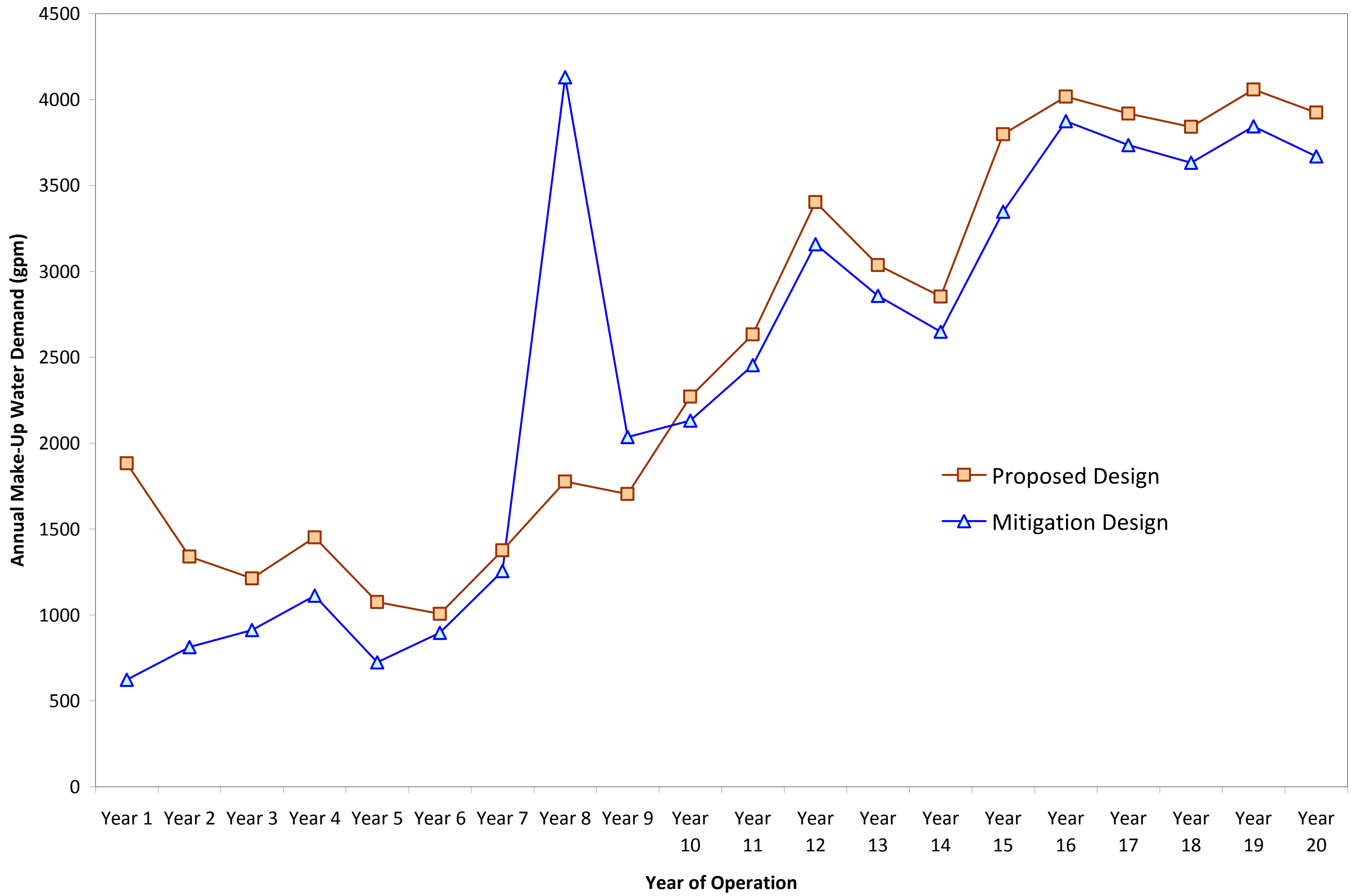


Figure 3-1 Average Annual Make-Up Water Demand for Proposed Design and Mitigation Design

Attachments

Attachment A-1

Tailings Basin Water Balance Work Plan

Tailing Basin Water Balance Work Plan (RS 13)
January 19, 2006

Introduction

Polymet Mining Inc. (PolyMet) is planning to use the former Cliff's Erie tailings basin and plant area north of Hoyt Lake, Minnesota for polymetalic ore processing (Figure 1). The existing tailings facility (also referred to as the LTV basin) will be used to contain tailings products from the NorthMet project. The ore processing procedure produces two types of waste products that will be disposed of at the tailing basin: reactive residue and flotation tailings. These two waste products will be disposed of in separate facilities.

Reactive residue will be stored in a facility made up of smaller containment cells within existing Cell 2W of the tailings basin to hold these wastes. For the first five years of operation (years 0-4), the flotation tailings will be stored in a lined basin located within existing Cell 2W. Beginning in year 5, flotation tailings will be discharged to Cells 1E and 2E. If the floatation tailings are found to be unreactive, Cells 1E and 2E will remain unlined. If the flotation tailings are found to be reactive, these cells will be lined.

Objective

As part of the scoping EAW, a preliminary water balance analysis was conducted for the proposed PolyMet tailing basin. This preliminary water balance analysis found that the average annual make-up water demand would likely be between 2,800 and 4,200 gpm. This analysis was based on the assumption that the flotation tailing cells would be unlined. Under the current plan, this water will come from Colby Lake using an existing water appropriation permit (Appropriation Permit #490135) which is jointly held by Cliffs Erie and Minnesota Power. This permit allows for an annual withdrawal of 6,307 million gallons per year, with a maximum pumping rate of 12,000 gpm. Other sources of water are still being considered and will be addressed in subsequent reports if they are going to be explored further.

The preliminary water balance was conducted at a time when there was little information on the proposed design and operation of the PolyMet tailing basin. In addition, no attempt was made to quantify the effects climatic variability may have on the water balance. Because of this, a more detailed water balance for the plant and tailing basin is needed. As stated in the Final Scoping Decision[1]:

> "The [tailing basin water balance] report will provide an estimate of the water balance for the tailings basin, quantifying both discharge and makeup water demand. The discharge will consist of two parts: 1) the unrecovered seepage through the dams and 2) a permitted discharge from the basin (this could either be on site or pumped to a POTW). The water balance will include precipitation, evaporation, runoff from upland areas, water from the concentrator used to transport tailings, water to the concentrator for reuse, seepage between cells, seepage from the basin and water retained in the tailings. A discussion of the HydroMet plant water balance demonstrating that the plant will be a net water user will be included. Assumptions made and modeling methods will be explained. The water balance will include operation, closure, and post-closure and will include an evaluation of average conditions as well as wet and dry cycles."

This work plan presents the sources and sinks of water that will be included in the water balance and methodologies that will be used to quantify these sources and sinks.

This scope of work is designed to examine the water quantity controls on discharge and makeup water demand. Subsequent reports will address potential water quality controls on discharge and makeup water demand. This aspect of the water balance will not be addressed in this report (RS13). It is assumed that any discharges needed for water quality reasons will need to be balanced by an increased water demand of the same amount. Likewise, any additional water added to the basin (i.e. from a seepage collection system) will reduce the water demand by the same amount.

Available Data

The following information and reports will be used for the Tailing Basin Water Balance:

- Process Design – Plant Water Balance (RS07I): The plant water balance will provide the volumes of water that will be discharged to both the reactive residue cells and the flotation tailing cells from the plant and the total return water demand for the plant. Included in this water balance will be any blowdown that will be sent to the tailing basin.

- Reactive Residue and PolyMet Flotation Tailings Facility Design and Location Technical Design Evaluation Report (RS28): This report will provide design options for the lined reactive residue cells and the lined PolyMet flotation tailing cell(s). The report will discuss location, size, liner and cover design, and water management (during operations,

[1] October 25, 2005, NorthMet Mine and Ore Processing Facilities Project Final Scoping Decision.

closure, and post closure) for both the reactive residue cells and the flotation tailings cells. This report will be used to define wet and/or dry closure conditions for the basin.

- Tailing Basin Geotechnical Technical Design Evaluation Report (RS40T) and Process Design – Tailing Basin Design – Preliminary (RS39): These reports will evaluate tailings basin dam stability and the suitability and benefits of various tailings basin dam designs, basin operations, and provide conceptual sketches and details of the proposed design. Included in this report will be reasonable quantitative measures of dam features, such as dam staged construction, total volume, dam crest elevations, freeboard, plan area of water, volume of water, depth of water and area of beach. This report will present a material mass balance and will examine dam safety requirements as they relate to water levels in the basin.

- Tailing Basin Modifications Technical Design Evaluation Report (RS55): This report will present the modifications that can be made to the existing tailing basin to minimize water release via seepage from the basin through seepage collection and recovery, and seepage prevention. An initial seepage management strategy will be presented in this report.

Based on data presented in the above referenced reports, a "base case" will be defined for use in the tailing basin water balance. This base case will include (1) flotation tailings and reactive residue cell design and operation, (2) closure and post closure scenarios and (3) a seepage collection, recovery and prevention plan. All assumptions associated with the base case will be clearly specified and the sensitivity of the water balance to these assumptions will be discussed. However, a tailing basin water balance will not be conducted for every alternative discussed in the above referenced reports.

Water Balance Components

A conceptual model of the tailing basin water balance is shown on Figure 2. The significant sources and sinks of water for both the reactive residue cells and the flotation tailing basin have been identified. The following sources and sinks of water will be included in the water balance:

- Watershed Yield – Precipitation to and evaporation from the reactive residue cells and the flotation tailing basin and watershed runoff to the flotation tailing basin will be estimated during wet, dry and average climatic conditions. The watershed yield for the first five years will only include that area associated with the lined basin proposed for Cell 2W. Watershed yield during 10, 15 and 20 year periods will include areas associated with Cells 1E and 2E.

- Seepage – Seepage into and out of the reactive residue cells and the flotation tailing basin (either lined or unlined) will be predicted. This analysis will include quantifying the seepage between the various basins or cells, the seepage recovered by the proposed seepage collection system, and the unrecovered seepage through the dams.

- Water to and from the Concentrator – Water from the concentrator used to transport tailings and water to the concentrator for reuse will be provided in the Plant Water Balance (RS07I) prepared by Bateman. Depending on basin operations and climate conditions, the tailing basin may not have adequate storage to provide the return flow to the concentrator required to meet plant needs. Make-up water from an outside source will be required under these conditions.

- Pore volume storage – The volume of water that will be trapped in the voids during tailing deposition will be calculated for both the flotation tailings and the reactive residue.

- Permitted discharge from the basin – The tailing basin water balance will determine if a permitted discharged from the basin will be needed to remove excess water from the system from a water quantity stand point.

In addition, the water balance report will include a discussion of the plant water balance and how it relates to the tailing basin water balance.

Methodology

A spreadsheet model will be constructed using Microsoft Excel as a means to tally all of the flux components for the water balance and provide a water demand or discharge rate for each month. Several other models will be use to feed information into the spreadsheet model, as described below and presented in Table 1.

Meyer Model

The Meyer Model was developed by Barr Engineering Company, based on work by Adolf Meyer[2]. The model is used to estimate watershed net yield based on watershed characteristics and climatic data. This model will be used to determine net watershed yield from the following flow components:

- Precipitation – Evaporation from open water areas;
- Runoff (Precipitation – Evapotranspiration – Infiltration) from upland areas;

A Meyer Model was constructed for the LTV tailing basin following closure[3]. This model will be used as a starting point and recalibrated to tailings basin pond water level data from the East Range Hydrology Project[4].

Groundwater Flow Model

A groundwater flow model (or a series of models) will be used to help predict the seepage components of the tailing basin water balance. Groundwater flow modeling will be conducted using a three-dimensional MODFLOW[5] model constructed for this purpose. MODFLOW is the industry standard finite-difference code developed by the U.S. Geological Survey. The flotation tailing cells will be simulated using the lake package[6]. The lake package can calculate both steady state and transient lake stages based on a volumetric water balance, which includes precipitation, evaporation, surface water connections, runoff, and groundwater interactions. The exchange of water between a lake and the surrounding aquifer is calculated using Darcy's law with relative heads and hydraulic conductivity of the aquifer and the lakebed sediments.

The groundwater flow model will be based on previous modeling that has been done for the basin, as well as new data that has been collected, including permeability of the various LTV tailings, bulk permeability of the PolyMet tailings, and pre-tailing basin topography. Assumptions will be made on

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[2] Meyer, A. 1947. Elements of Hydrology – Chapter 6: Evaporation from Land Areas. New York: John Wiley & Sons, Inc.
Barr Engineering Company, undated. Documentation and User's Guide for Mey Method Watershed Yield Computer Program.
[3] Barr Engineering Company, 2001. LTV Tailing Basin Interim Water Balance Study. Prepared for LTV Steel Mining Company.
[4] Minnesota Department of Natural Resources, 2004. East Range Hydrology Project.
[5] McDonald, M.G., and A. W. Harbaugh, 1988. A modular, three-dimensional, finite-difference ground-water flow model: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 6, Chap. A1.
[6] Merritt, M.L., and L.F. Konikow, 2000. Documentation of a Computer Program to Simulate Lake-Aquifer Interaction Using the MODFLOW Ground-Water Flow Model and the MOC3D Solute-Transport Model. U.S. Geological Survey Water-Resources Investigations Report 00-4167.

the thickness and permeability of the till, as well as recharge rates. Monitoring well head data and Cell 1E and 2E water level data from 2002-2003 (post-closure) will be used for model calibration.

The groundwater flow model will be used to predict the following flow components:

- Seepage out of Cell 2W (with a liner) and Cells 1E and 2E (with and without liners);
- Groundwater flow between cells (if unlined);
- Groundwater flow into the proposed seepage collection systems; and
- Unrecovered seepage.

The scoping decision, as referenced in the Objectives Section, specified that the RS13 report would provide an estimate of the quantity of unrecovered seepage through the tailing basin dams. It is our understanding that the intent is to quantify the amount of seepage that will not be captured by the proposed seepage collection system and that will be released to the environment. It is this volume that will be reported.

Miscellaneous Calculations

The following components of the tailing basin water balance will be calculated within the spreadsheet model, as described below:

- Seepage out of the reactive residue cells will be calculated using the design permeability for the liner and Darcy's Law. This calculation will provide a conservative estimate of seepage by assuming saturated conditions beneath the cells.

- Pore water storage in tailings (i.e., porosity) will be calculated using an assumed unit weight and the measured specific gravity of the PolyMet tails.

Following the completion of the Tailing Basin Modifications study (RS55T), the Reactive Residue and Flotation Tailings Facility Location and Design Option (RS28T), the Tailing Basin Preliminary Design (RS39), Tailings Basin Geotechnical (RS40T) and the Stormwater Volume and Patterns study (RS36), additional components that need to be added to the tailing basin water balance may be identified. If identified, these components will be added to the water balance and described in detail in the report.

Simulations

A detailed water balance will be calculated for six time periods: Year 0, Year 5, Year 10, Year 20, closure and post-closure. Closure is defined as the period immediately following activities related to closure (i.e. any capping, diking or trenching that may be completed). Post-closure is defined as the period following closure when the system has reached steady-state conditions. Closure and post-closure scenarios will be defined by the Reactive Residue and Flotation Tailings Facility Location and Design Option report (RS28). In addition, a scenario will be run under a hypothetical two year temporary shutdown using the Year 5 base case with both unlined and lined cells.

For each time period, the water balance will be calculated on a monthly time step using 74 years of climatic conditions (1931-2004) recorded at nearby weather stations. This will provide average, minimum and maximum demand and discharge volumes and rates. With the exception of the year 0 scenario, during which floatation tailings will be deposited in a lined pond in cell 2W, each scenario will include calculations with cells 1E and 2E both lined and unlined.

Uncertainties associated with tailing basin design and operation; seepage collection system design, operation and effectiveness; and other water balance components increase with time. That is, there will be more uncertainty in the Year 20 water balance calculations than there will be in the Year 0 water balance calculations. Because of this, more detail will be included in the water balance calculations for the first five years of operation in the lined Cell 2W basin (Year 0 water balance) and the next five years of operation in the lined or unlined Cells 1E and 2E basins (Year 5 water balance). The Year 10, Year 20, closure and post-closure water balances will be discussed in a more general manner, looking primarily at relative changes to the more detailed water balances calculated for Year 0 and Year 5.

In addition to the scenarios described above, a sensitivity analysis will be performed. Parameters such as tailing porosity, seepage recovery volumes and seepage rates will be varied to help predict the uncertainty in the water balance. This information will be used along with the average, minimum and maximum volumes calculated under the different climate conditions to provide a range of demand and discharge volumes and rates that can be expected for the duration of the project. In addition, the sensitivity of the water balance to the production rate will be determined by varying the production rate by +/- 10%.

Table 1
Flow Components of the PolyMet
Tailing Basin Water Balance

Flow Number	Flow Item	Source of Flow Data
1	Waterhsed yield	Meyer Model
2	Pore volume storage	Calculation
3	Water and tailing from flotation process	Plant water balance
4	Return water to flotation process	Plant water balance
5	Seepage	Groundwater flow model
6	Blowdown (Optional)	Plant water balance
7	Permitted discharge (Optional)	Tailing basin water balance
8	Yield from upland areas	Groundwater flow model
9	Water and residue from HydroMet process	Plant water balance
10	Return water to HydroMet process	Plant water balance
11	Seepage from reactive cells	Calculation
12	Pore volume storage	Calculation
13	Groundwater flow not recovered	Groundwater flow model
14	Seepage colleced by seepage recovery system	Groundwater flow model
15	Groundwater collected by seepage recovery system	Groundwater flow model
16	Return flow from seepage recovery system to basin (Optional)	Calculation/Groundwater flow model
17	Make-up water	Residual from Water Balance

Figure 1

TAILINGS BASIN AND PLANT AREA OVERVIEW
Polymet
Hoyt Lakes, MN

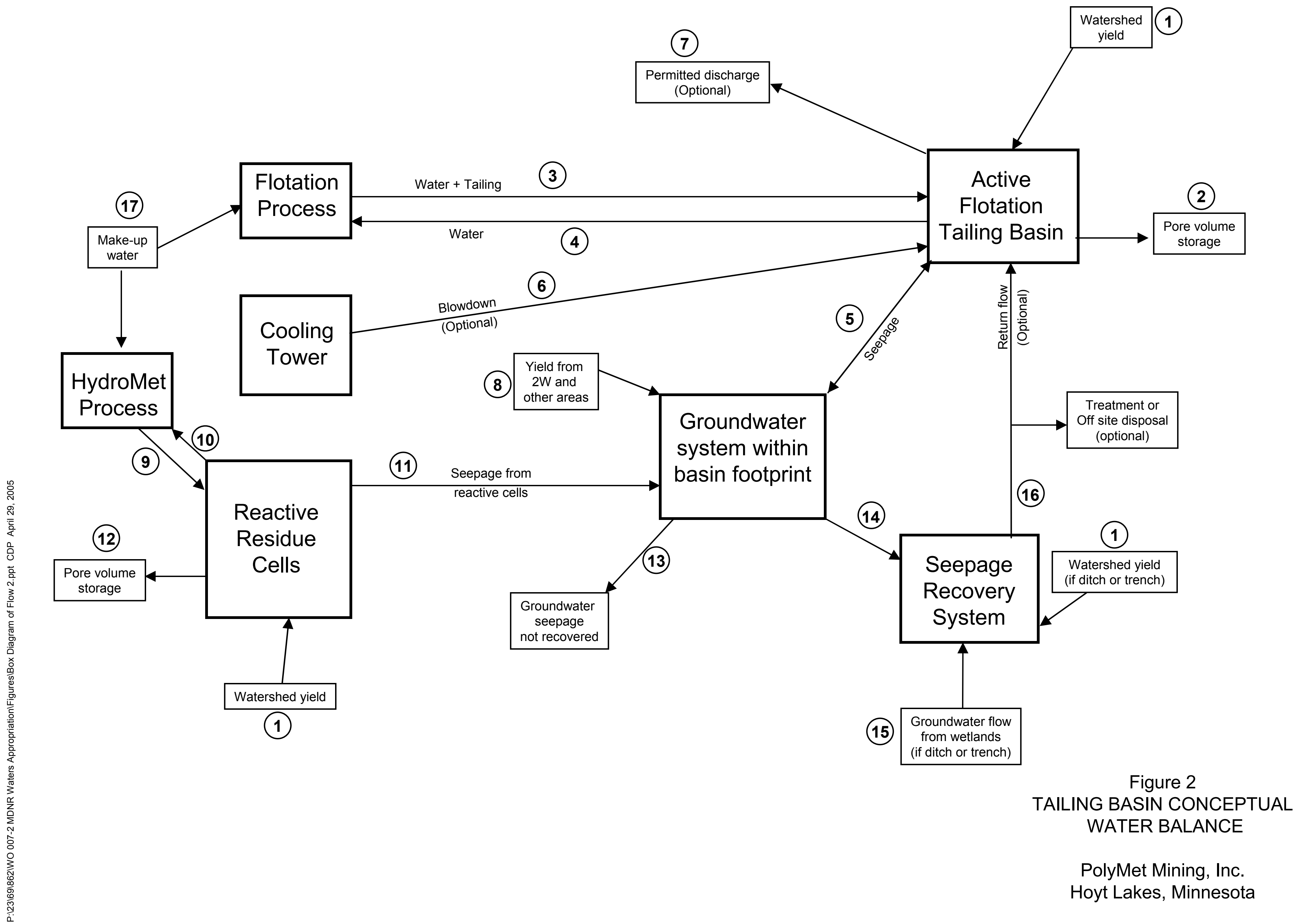

Figure 2
TAILING BASIN CONCEPTUAL WATER BALANCE

PolyMet Mining, Inc.
Hoyt Lakes, Minnesota

Attachment A-2

Plant Water Balance – RS07I

Water Balance Description

Definitive Feasibility Study

PolyMet Mining Corp

NorthMet Project, Minnesota, USA

by

B. Kusnierz
M. Wardell-Johnson

DISCLAIMER

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1.1 INTRODUCTION

The Water Balance for the NorthMet Process Plant is a quantitative description of all input and output flows of water required for the effective operation of the facility. The water used in this facility is physically separated into two distinct plant areas.

1. Concentrator Plant Water Balance
2. Hydrometallurgical Plant Water Balance

The Water Balance data was generated with the metallurgical simulation package MetSim. A detailed mass and energy balance was created for each unit operation incorporated in the facility. The relevant assumptions and calculations used in the simulation process are discussed below. The report is based on MetSim model revision U.

A detailed breakdown of the water balance by circuit can be found in Appendix A

1.2 CONCENTRATOR WATER BALANCE

The Concentrator consists of the follow unit operations:

- Ore Crushing
- Ore Grinding
- Sulphide Flotation and Concentrate Regrinding
- Flotation Tailings Disposal

For a comprehensive description of the facility refer to the Detailed Project Description[1]

A summary of the Concentrator Water Balance is shown in Figure 1.

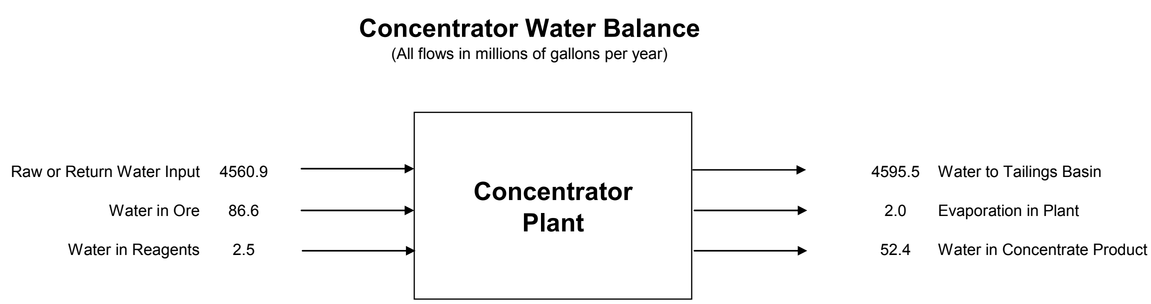


Figure 1 – Concentrator Water Balance

The water inputs to the Concentrator are:

[1] Detailed Project Description, PolyMet January 2007

1.2.1 RAW OR RETURN WATER INPUT

This is the amount of water required to operate the Concentrator. The sources of this water are Colby Lake and return water from the Flotation Tailing Basin. The return water from the Flotaion Tailing Basin includes treated water from the Mine Site, water collected by the seepage collection system, watershed runoff and direct precipitation to the basin, as described in RS13. MetSim calculates this value by summing all of the water flows exiting the Concentrator and subtracting all of the inputs of water to the Concentrator. This ensures the model is balanced.

1.2.2 WATER IN ORE

This is the amount of water naturally contained in the ore fed to the Concentrator. This value is calculated by multiplying the ore tonnage by the ore moisture content. The ore tonnage is 1,343 tonnes per hour as defined in the Design Criteria. The ore moisture content is 3% as determined by laboratory measurement from the samples collected for the pilot plant test work.

1.2.3 WATER IN REAGENTS

This is the amount of water contained in the reagents and process air used in the Concentrator. Flocculent consumption was determined from the pilot test work. The flocculent is assumed to consist completely of water for the purposes of the modelling. The water vapour content of the process air is determined from a standard calculation, which determines the equilibrium saturated water vapour composition (from a steam table) at an estimated air blower discharge temperature of 40 ^{o}C.

The water <u>outputs</u> from the Concentrator are:

1.2.4 WATER TO FLOTATION TAILINGS BASIN

This is the amount of water that is used to transport tailings from the Concentrator Plant to the Flotation Tailing Basin. The water leaves the plant at a temperature of 22.33°C (72.2°F).

1.2.5 EVAPORATION IN PLANT

This is the amount of water evaporated from the flotation cells and thickener. Evaporation from the flotation cells is calculated from the equilibrium saturated water vapour composition of the process air exiting the flotation cells. Evaporation from the thickener is calculated from the slurry temperature, thickener surface area and equilibrium saturated water vapour composition.

1.2.6 WATER IN CONCENTRATE PRODUCT

This is the amount of water contained in the concentrate that is transferred to the Hydrometallurgical Plant. This value is calculated by multiplying the mass flow of slurry by the slurry water content. The slurry mass flow is determined by MetSim and is based on the flotation mass pull. The slurry water content is 35%. This value is calculated by MetSim and is based on the flotation feed percent solids and mass pull, which was determined by the pilot plant test work and by various sources of dilution (ie. launder water).

1.3 HYDROMETALLURGICAL PLANT WATER BALANCE

The Hydrometallurgical Plant consists of the follow unit operations:

- High temperature autoclave leaching of flotation concentrate;

- Gold and platinum group metal (AuPGM) Precipitation;
- Solution Neutralisation;
- Copper Solvent Extraction;
- Copper Electrowinning;
- Raffinate Neutralisation;
- Residual Copper Recovery;
- Mixed Hydroxide Precipitation;
- Magnesium Removal;
- Hydrometallurgical Residue Disposal.

For a comprehensive description of the facility refer to the Detailed Project Description

A summary of the Hydrometallurgical Plant Water Balance is shown in Figure 2.

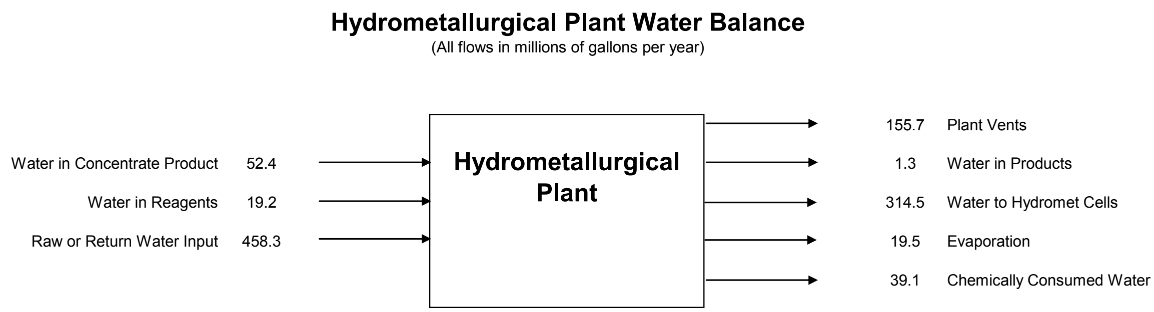


Figure 2 – Hydrometallurgical Plant Water Balance

The water <u>inputs</u> to the Hydrometallurgical plant are:

1.3.1 WATER IN CONCENTRATE PRODUCT

The amount of water contained in the concentrate fed to the Hydrometallurgical plant from the Concentrator as determined from the pilot test work data. An average value of 35% water was used for the process design.

1.3.2 WATER IN REAGENTS

This is the water accompanying the various reagents added to the Hydrometallurgical Plant. Reagent consumption was determined from the pilot test work data. Salient points to note include:

- Flocculent is assumed to consist completely of water;
- Limestone and lime water composition were 63% and 78% respectively, which are based on industry practice;
- The water content of the reagents listed below was obtained from formal discussions with local reagent suppliers;

Reagent	% Water Content
Hydrochloric acid	68
Sulphuric acid	7
Sodium hydrosulphide	70
Caustic soda	50
Coagulant	50
Magnesium hydroxide	70

- The water vapour content of the process air is determined from a standard calculation, which determines the equilibrium saturated water vapour composition (from a steam table) at an estimated air blower discharge temperature of 40 ^{o}C.

1.3.3 RAW OR RETURN WATER INPUT

This is the amount of water required to balance the Hydrometallurgical Plant. The sources of this water are Colby Lake and return water from the Hydrometallurgical Residue Cells. MetSim calculates this value by summing all of the water flows exiting the facility and subtracting all of the inputs of water to the facility.

The water outputs from the Hydrometallurgical Plant are:

1.3.4 PLANT VENTS

This is the amount of water, as vapour, that is vented to the atmosphere from the Final Autoclave Gas Scrubber, Plant Scrubber and Electrowinning Scrubber. This value is calculated from the equilibrium saturated water vapour composition (from a steam table) at the exit gas stream temperature.

1.3.5 WATER IN PRODUCTS

This is the amount of water contained in the various products from the Hydrometallurgical Plant, based on:

- Copper cathode does not contain water;
- Mixed Hydroxide and AuPGM products contain 25 and 20% water respectively after filtration, as determined from filtration tests performed during the pilot plant test work.

1.3.6 WATER TO HYDROMETALLURGICAL CELLS

This is the amount of water that is used to transport residue from the Hydrometallurgical Plant to the Hydrometallurgical Residue Cells. The water leaves the plant at a temperature of 48.32°C (119°F).

1.3.7 EVAPORATION

This is the amount of water evaporated from various thickeners. The plant evaporation is calculated from the slurry temperature, thickener surface area and equilibrium saturated water vapour composition (from a steam table).

1.3.8 CHEMICALLY CONSUMED OR GENERATED WATER

This is the amount of water that is consumed or generated in the various chemical reactions that occur in the Hydrometallurgical Plant. MetSim automatically calculates the amount of water consumed or generated in all reactions. These reactions and their extents were determined by the bench and pilot plant test work An example reaction, involving the neutralisation of sulphuric acid with limestone, is shown below.

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$$

Followed by calcium sulphate precipitation as gypsum, according to:

$$CaSO_4 + 2H_2O \rightarrow CaSO_4.2H_2O$$

1.4 IMPURITY BUILD-UP

The plant facility has a strong emphasis on water recycling. This philosophy, in some processes, can result in a build-up of impurities in the process streams. The simplest measure of impurity build-up in this process is the Hydrometallurgical process water solution concentration. This solution is continuously re-circulated throughout the Hydrometallurgical plant making it the stream most likely to be affected by an impurity build-up. Therefore, if the Product and Residue (output) streams were not sufficient to prevent an impurity build-up, then the equilibrium concentration of the process water stream would exceed plant tolerances.

An analysis of MetSim data has shown an acceptable level of impurities. In particular:

- There is no build-up of chloride ions in the plant. This is explained by considering that the autoclave solution chloride concentration is 9 g/L, and the majority of the water in the Hydrometallurgical Plant eventually becomes process water. As the chloride concentration in the process water is 4.2 gpl, this indicates that the losses of chloride (Hydrometallurgical Residue) exceeds the input of chlorides to the autoclave circuit, and therefore a continuous make-up of hydrochloric acid is required to maintain 9 g/L in the autoclave circuit;
- The Magnesium Removal area provides a sufficient extent of magnesium removal. The magnesium ion concentration in Hydrometallurgical process water is 2 g/L, which is well below saturation levels that could result in unwanted precipitation;
- The input of sodium into the process is minimal as demonstrated by the sodium ion concentration in the Hydrometallurgical process water is less than 1 g/L.

The MetSim calculation engine ensures by repeated iteration that the mass balance has converged and equilibrium has been reached by measuring the change in component flow per iteration. The model calculation is not completed until a tolerance (ie. change per iteration) of $1x10^{-5}$ for every component is achieved.

The mass and energy balance indicates that there is no potential for impurity build-up under normal operating conditions. This is also supported from the absence of impurity build-up during the pilot plant test work. Therefore, it is concluded that there will be no requirement to purge water to control impurity levels in the Hydrometallurgical plant under normal operating conditions.

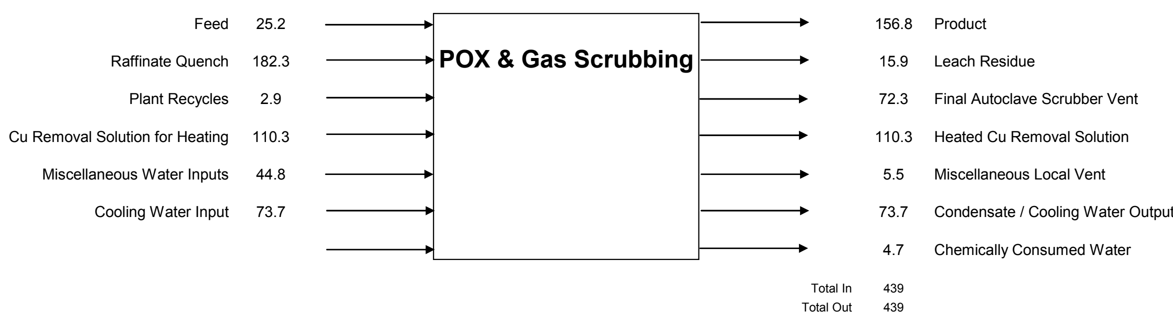
1.5 APPENDIX A

DETAILED WATER BALANCE BY CIRCUIT

Due to the nature of the flowsheet, the individual circuit balances cannot be summed to equal the Concentrator and Hydrometallurgical Plant balances.

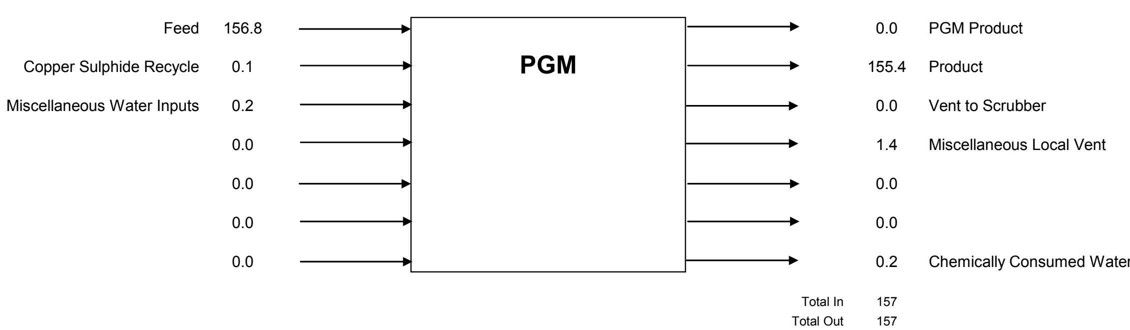
POX Leach and Gas Scrubbing Water Balance

(All flows in tonnes per hour)



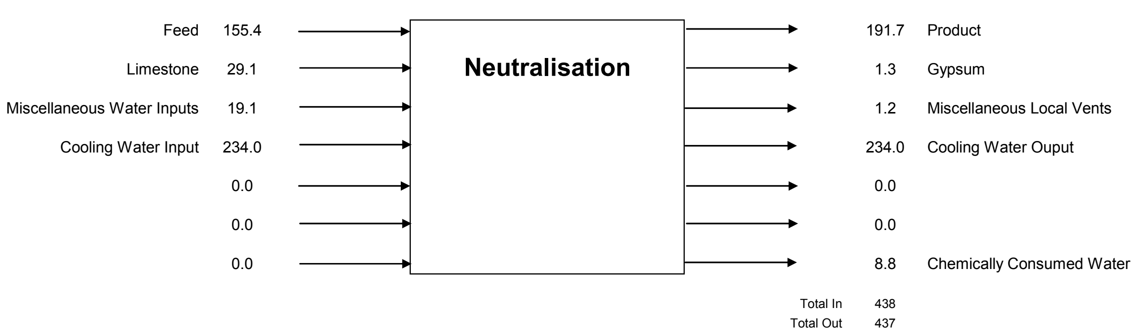
PGM Water Balance

(All flows in tonnes per hour)



Neutralisation Water Balance

(All flows in tonnes per hour)



Copper SX/EW Water Balance

(All flows in tonnes per hour)

Copper SX/EW

Feed	191.7	245.7	Copper Free Solution
Miscellaneous Water Inputs	57.5	2.2	Tankouse Vent
Cooling Water In	198.3	198.3	Cooling Water Out
	0.0	0.0	
	0.0	0.0	
	0.0	0.0	
	0.0	1.2	Chemically Consumed Water

Total In 447
Total Out 447

Raffinate Neutralisation Water Balance

(All flows in tonnes per hour)

Raffinate Neutralisation

Feed	245.7	110.3	Neutralised Solution
Miscellaneous Water Inputs	60.3	182.3	Raffinate to Autoclave
Limestone	17.7	28.3	Raffinate to SX
Scrubber Bleed	3.9	10.3	Gypsum Residue
	0.0	0.8	Miscellaneous Local Vents
	0.0	0.0	
Chemically Generated Water	4.5		

Total In 332
Total Out 332

Copper Removal Water Balance

(All flows in tonnes per hour)

Copper Removal

Feed	110.3	115.2	Cu Free Solution
Miscellaneous Water Inputs	5.6	0.6	CuS Recycle
Steam	0.0	0.0	Plant Scrubber Vent
	0.0	0.1	Miscellaneous Local Vents
	0.0	0.0	
	0.0	0.0	

Total In 116
Total Out 116

Mixed Hydroxide Precipitation Water Balance

(All flows in tonnes per hour)

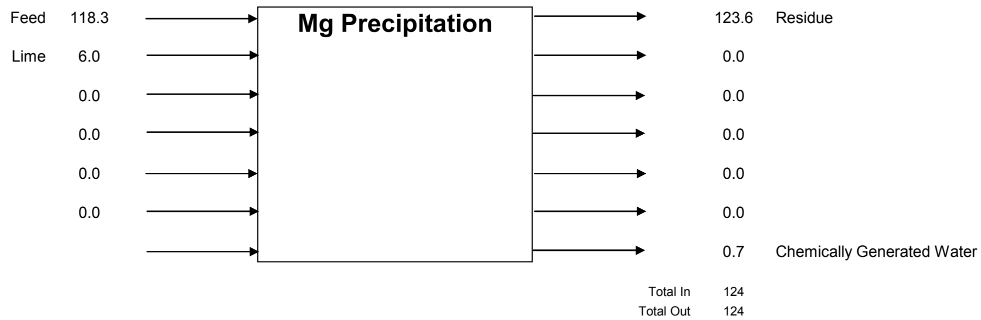
MHP

Feed	115.2	0.6	MHP Product
Magnesium Hydroxide	2.8	0.9	MHP Recycle
Miscellaneous Water Inputs	3.1	118.3	Nickel & Cobalt Free Solution
	0.0	1.3	Miscellaneous Local Vents
	0.0	0.0	
	0.0	0.0	

Total In 121
Total Out 121

Magnesium Precipitation Water Balance

(All flows in tonnes per hour)



Attachment A-3

Plant Site Stormwater Volume and Patterns – RS36

RS36 - Stormwater Volume & Patterns
April 25, 2006

Delivery Package 1A-1
Appendix A – Attachment 3
RS 36
Draft-01
May 15, 2006

Attachment 3 to Appendix A of RS39/40T
PolyMet Report/Study
Plant Site Stormwater – Volume & Patterns
RS36

The purpose of this report is to provide "Stormwater – Volume & Patterns" per PolyMet Mining, Inc.'s Environmental Impact Statement (EIS) Task RS36. Drawing "Stormwater Drainage" shows stormwater drainage areas and patterns in PolyMet Mining, Inc.'s (PolyMet's) plant area (the site), and the approximate location of PolyMet's proposed new structures (building, product load outs, stormwater ponds, etc).

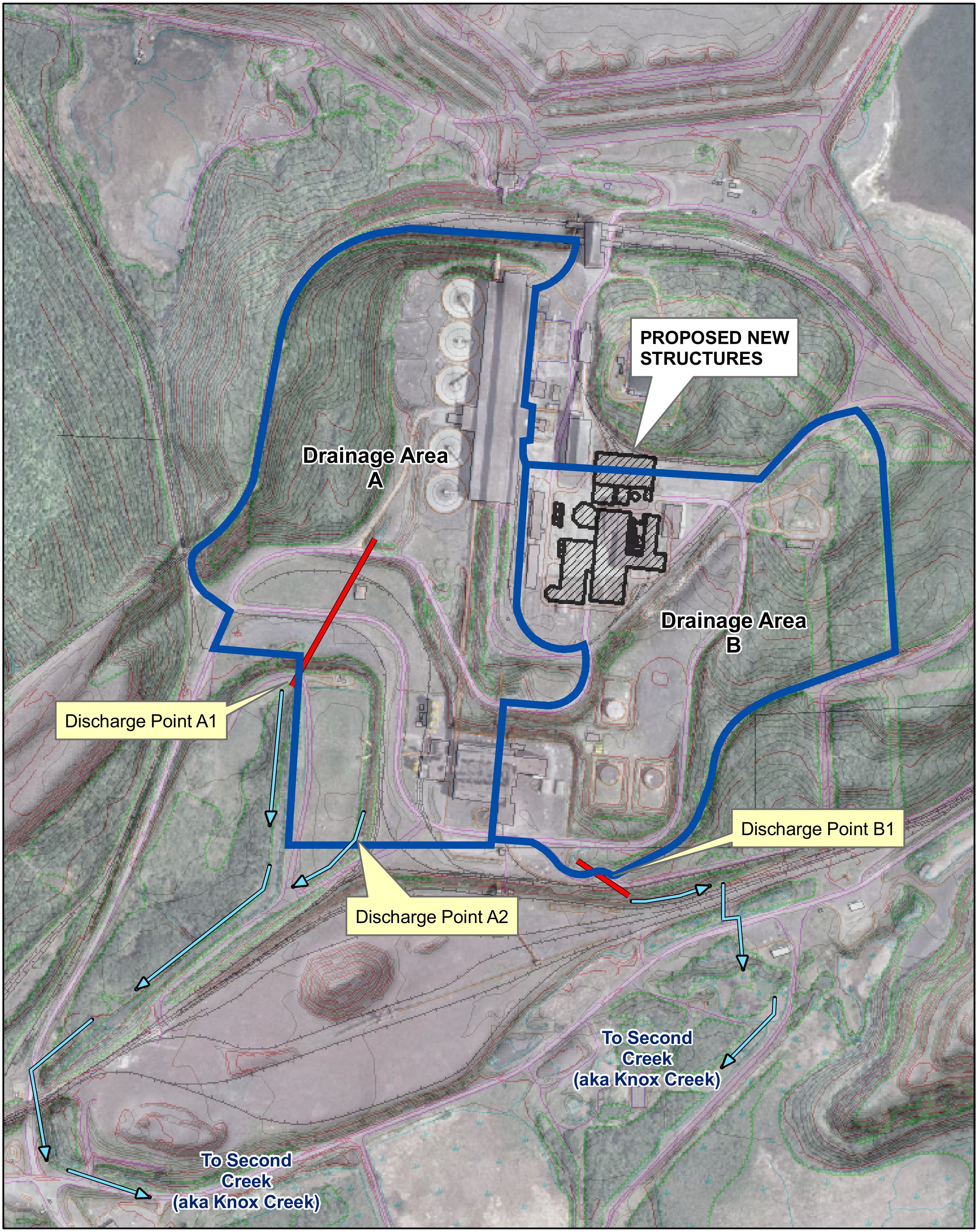
Under LTV Steel Mining Company operation, the Emergency Basin was used to contain the tailings in the tailings thickeners and other in process concentrate and tailings in the event of an emergency shutdown. In addition, some stormwater from roof drains also reported to the Emergency Basin. PolyMet will not use the tailings thickeners and will contain all process concentrate and tailings within the concentrator in an emergency shutdown. Consequently, PolyMet will not discharge water (including stormwater) from the concentrator to the Emergency Basin.

There are two (2) stormwater drainage areas (A and B) from which stormwater flows off-site. The roof drain stormwater will be rerouted to drainage area A. Stormwater flows from drainage areas A and B to Knox Creek drainage via discharges A1, A2 and B1. Knox Creek flows into Second Creek. Stormwater flow onto the site is negligible since the site is located on a topographic high. Drainage areas were determined based on existing stormwater flow patterns and topography. Stormwater drainage on the northern portion of the site is not discussed because it flows north then west into the Emergency Basin, remaining on PolyMet's property. The Emergency Basin is included as part of the Hoyt Lakes Tailings Basin NPDES Permit. Any discharge from the Tailings Basin is expected to be via NPDES permit.

The surface areas of drainage area A and B are approximately 135 acres and 100 acres, respectively. Volumes of stormwater for each drainage area A and B have been calculated to be approximately 39.4 acre-feet and 29.2 acre-feet, respectively, based on a 25 year, 24 hour precipitation event of 3.5 inches. Drainage area acreages were determined using AutoCad drafting software. Drainage area stormwater volumes were calculated by multiplying the 25 year, 24 hour storm event (3.5 inches) precipitation by each drainage area acreage. The 25 year, 24 hour precipitation of 3.5 inches is based on information provided to Minnesota Pollution Control Agency for modification of Cliffs Erie LLC's Hoyt Lakes Mine Area NPDES/SDS Permit MN0042536 (*Water*

Evaluation for the Cliffs Erie LLC Pellet Shipping Project, BARR Engineering Company, February 2005).

In order to control stormwater exiting PolyMet's plant site, two (2) stormwater retention basins may have to be constructed (one for each drainage area) and plant site stormwater drainage system upgrades made. The proximity of PolyMet's property boundary with respect to off-site storm drainage A1, A2, and B1 should be noted. The stormwater retention basins will be included as part of the Stormwater Pollution Prevention Plan for the plant site which in turn is a part of the NPDES/SDS Permit that will be obtained by PolyMet Mining, Inc.



STORMWATER DRAINAGE
Plant Site

Attachment A-4

Water Balance Output Tables

Attachment A-4
Tailings Basin Water Balance

Flotation Tailings Basin

Static Water Budget Components

Volume of Solids to Basin	393	m^3/hr
Volume of Water to Basin	1990	m^3/hr
Water Demand from Plant	1970	m^3/hr
Average Porosity	0.49	
Void Ratio	0.96	
Void Loss	378	m^3/hr

						2E															Total		2E						
Year of Operation	Climate Data Year	Month	Days	Active Cell	Clearwater Cell	Water From Mine Site	Solids from Plant	Water From Plant	Precipitation on Pond	Beach Runoff	Watershed RO	Seepage Returned	Pond Evap	Wet Beach Evap	Entrainment	Rewetting	Pond Seepage	Change in Storage - Pond Growth	Net Balance	Discharge to Plant	Change in Storage - Balance vs Demand	Make-Up Demand	Beach Area	Pond	Forest	Reclaimed TB	Basin Elevation	Pond Volume - Wanted	Pond Volume - Actual
						m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	acres				ft	A-F	A-F
1	1977	1	31	2E	NA	158	393	1990	24	0	0	104	18	4	378	20	60	0	1798	1798	0	173	233	348	86	251	1569	1738.2	1738.2
	1977	2	28	2E	NA	158	393	1990	11	0	0	104	19	4	378	20	60	23	1760	1760	0	210	224	350	86	241	1570	1751	1751
	1977	3	31	2E	NA	158	393	1990	78	33	32	104	35	2	378	20	60	0	1901	1901	0	70	224	350	86	241	1571	1751	1751
	1977	4	30	2E	NA	158	393	1990	57	3	1	104	167	3	378	20	60	0	1687	1687	0	284	224	350	86	241	1572	1751	1751
	1977	5	31	2E	NA	158	393	1990	269	17	40	104	226	2	378	20	60	0	1894	1894	0	77	224	350	86	241	1573	1751	1751
	1977	6	30	2E	NA	158	393	1990	210	20	49	104	284	3	378	20	60	0	1787	1787	0	184	224	350	86	241	1574	1751	1751
	1977	7	31	2E	NA	158	393	1990	159	14	32	103	299	4	378	20	87	21	1649	1649	0	322	215	353	86	231	1575	1763.7	1763.7
	1977	8	31	2E	NA	158	393	1990	387	35	102	103	248	1	378	20	87	0	2042	1970	72	1	215	353	86	231	1576	1763.7	1807.2
	1977	9	30	2E	NA	158	393	1990	313	19	46	103	168	1	378	20	87	0	2049	1970	80	1	215	353	86	231	1577	1763.7	1810.1
	1977	10	31	2E	NA	158	393	1990	101	6	7	103	92	1	378	20	87	0	1868	1868	0	103	215	353	86	231	1578	1763.7	1763.7
	1977	11	30	2E	NA	158	393	1990	165	0	0	103	29	2	378	20	87	0	1902	1902	0	69	215	353	86	231	1579	1763.7	1763.7
	1977	12	31	2E	NA	158	393	1990	65	0	0	102	17	4	378	20	114	21	1763	1763	0	207	206	355	86	222	1580	1776.5	1776.5
2	1978	1	31	2E	NA	212	393	1990	26	0	0	102	18	4	378	20	114	0	1796	1796	0	174	206	355	86	222	1581	1776.5	1776.5
	1978	2	28	2E	NA	212	393	1990	21	0	0	102	19	5	378	20	114	0	1791	1791	0	180	206	355	86	222	1582	1776.5	1776.5
	1978	3	31	2E	NA	212	393	1990	33	0	0	102	36	3	378	20	114	0	1788	1788	0	183	206	355	86	222	1583	1776.5	1776.5
	1978	4	30	2E	NA	212	393	1990	70	105	142	102	170	3	378	20	114	0	1937	1937	0	33	206	355	86	222	1584	1776.5	1776.5
	1978	5	31	2E	NA	212	393	1990	235	13	28	101	231	2	378	20	140	21	1788	1788	0	183	197	358	86	212	1585	1789.2	1789.2
	1978	6	30	2E	NA	212	393	1990	156	13	28	101	291	4	378	20	140	0	1667	1667	0	303	197	358	86	212	1586	1789.2	1789.2
	1978	7	31	2E	NA	212	393	1990	367	30	88	101	303	2	378	20	140	0	1946	1946	0	24	197	358	86	212	1587	1789.2	1789.2
	1978	8	31	2E	NA	212	393	1990	218	18	46	101	251	3	378	20	140	0	1792	1792	0	178	197	358	86	212	1588	1789.2	1789.2
	1978	9	30	2E	NA	212	393	1990	125	7	9	101	170	2	378	20	140	0	1734	1734	0	237	197	358	86	212	1589	1789.2	1789.2
	1978	10	31	2E	NA	212	393	1990	62	3	1	100	94	2	378	20	167	21	1687	1687	0	283	187	360	86	202	1590	1801.9	1801.9
	1978	11	30	2E	NA	212	393	1990	59	0	0	100	30	2	378	20	167	0	1765	1765	0	205	187	360	86	202	1591	1801.9	1801.9

Attachment A-4
Tailings Basin Water Balance

						2E															Total		2E						
Year of Operation	Climate Data Year	Month	Days	Active Cell	Clearwater Cell	Water From Mine Site	Solids from Plant	Water From Plant	Precipitation on Pond	Beach Runoff	Watershed RO	Seepage Returned	Pond Evap	Wet Beach Evap	Entrainment	Rewetting	Pond Seepage	Change in Storage - Pond Growth	Net Balance	Discharge to Plant	Change in Storage - Balance vs Demand	Make-Up Demand	Beach Area	Pond	Forest	Reclaimed TB	Basin Elevation	Pond Volume - Wanted	Pond Volume - Actual
						m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	acres				ft	A-F	A-F
	1978	12	31	2E	NA	212	393	1990	22	0	0	100	17	4	378	20	167	0	1739	1739	0	232	187	360	86	202	1592	1801.9	1801.9
3	1979	1	31	2E	NA	265	393	1990	25	0	0	100	18	4	378	20	167	0	1793	1793	0	177	187	360	86	202	1593	1801.9	1801.9
	1979	2	28	2E	NA	265	393	1990	102	0	0	100	19	5	378	20	167	0	1869	1869	0	101	187	360	86	202	1594	1801.9	1801.9
	1979	3	31	2E	NA	265	393	1990	173	0	0	99	36	3	378	20	194	21	1877	1877	0	94	178	363	86	193	1595	1814.7	1814.7
	1979	4	30	2E	NA	265	393	1990	78	121	168	99	173	3	378	20	194	0	1954	1954	0	16	178	363	86	193	1596	1814.7	1814.7
	1979	5	31	2E	NA	265	393	1990	142	7	10	99	234	4	378	20	194	0	1684	1684	0	287	178	363	86	193	1597	1814.7	1814.7
	1979	6	30	2E	NA	265	393	1990	187	14	33	99	295	4	378	20	194	0	1699	1699	0	272	178	363	86	193	1598	1814.7	1814.7
	1979	7	31	2E	NA	265	393	1990	193	14	35	99	308	4	378	20	194	0	1694	1694	0	276	178	363	86	193	1599	1814.7	1814.7
	1979	8	31	2E	NA	265	393	1990	106	7	11	98	257	4	378	20	221	21	1578	1578	0	392	169	365	86	183	1600	1827.4	1827.4
	1979	9	30	2E	NA	265	393	1990	126	6	7	98	174	2	378	20	221	0	1699	1699	0	272	169	365	86	183	1601	1827.4	1827.4
	1979	10	31	2E	NA	265	393	1990	183	8	16	98	96	1	378	20	221	0	1846	1846	0	124	169	365	86	183	1602	1827.4	1827.4
	1979	11	30	2E	NA	265	393	1990	36	0	0	98	30	3	378	20	221	0	1739	1739	0	232	169	365	86	183	1603	1827.4	1827.4
	1979	12	31	2E	NA	265	393	1990	14	0	0	98	17	4	378	20	221	0	1728	1728	0	243	169	365	86	183	1604	1827.4	1827.4
4	1980	1	31	2E	NA	318	393	1990	48	0	0	97	19	4	378	20	247	21	1766	1766	0	205	160	368	86	173	1605	1840.2	1840.2
	1980	2	28	2E	NA	318	393	1990	25	0	0	97	20	4	378	20	247	0	1763	1763	0	208	160	368	86	173	1606	1840.2	1840.2
	1980	3	31	2E	NA	318	393	1990	40	0	0	97	37	3	378	20	247	0	1761	1761	0	209	160	368	86	173	1607	1840.2	1840.2
	1980	4	30	2E	NA	318	393	1990	27	40	51	97	176	3	378	20	247	0	1701	1701	0	270	160	368	86	173	1608	1840.2	1840.2
	1980	5	31	2E	NA	318	393	1990	33	1	0	97	238	5	378	20	247	0	1553	1553	0	418	160	368	86	173	1609	1840.2	1840.2
	1980	6	30	2E	NA	318	393	1990	177	11	26	96	301	4	378	20	274	22	1621	1621	0	350	151	371	86	163	1610	1852.9	1852.9
	1980	7	31	2E	NA	318	393	1990	144	9	19	96	314	4	378	20	274	0	1586	1586	0	384	151	371	86	163	1611	1852.9	1852.9
	1980	8	31	2E	NA	318	393	1990	307	19	58	96	260	2	378	20	274	0	1855	1855	0	116	151	371	86	163	1612	1852.9	1852.9
	1980	9	30	2E	NA	318	393	1990	283	11	29	96	176	1	378	20	274	0	1880	1880	0	91	151	371	86	163	1613	1852.9	1852.9
	1980	10	31	2E	NA	318	393	1990	91	4	4	96	97	2	378	20	274	0	1733	1733	0	237	151	371	86	163	1614	1852.9	1852.9
	1980	11	30	2E	NA	318	393	1990	18	0	0	95	31	3	378	20	301	22	1669	1669	0	302	142	373	86	154	1615	1865.7	1865.7
	1980	12	31	2E	NA	318	393	1990	44	0	0	95	18	4	378	20	301	0	1728	1728	0	242	142	373	86	154	1616	1865.7	1865.7
5	1981	1	31	2E	NA	372	393	1990	19	0	0	95	19	4	378	20	301	0	1755	1755	0	216	142	373	86	154	1617	1865.7	1865.7
	1981	2	28	2E	NA	372	393	1990	79	0	0	95	20	4	378	20	301	0	1814	1814	0	157	142	373	86	154	1618	1865.7	1865.7
	1981	3	31	2E	NA	372	393	1990	41	0	0	95	37	3	378	20	301	0	1760	1760	0	210	142	373	86	154	1619	1865.7	1865.7
	1981	4	30	2E	NA	372	393	1990	255	44	72	93	178	2	378	20	245	2	2002	1970	32	1	137	373	86	146	1620	1866.6	1885.3
	1981	5	31	2E	NA	372	393	1990	58	2	1	93	241	4	378	20	245	0	1660	1660	0	311	137	373	86	146	1621	1866.6	1866.6
	1981	6	30	2E	NA	372	393	1990	363	20	65	93	303	2	378	20	245	0	1956	1956	0	15	137	373	86	146	1622	1866.6	1866.6
	1981	7	31	2E	NA	372	393	1990	224	12	35	93	316	3	378	20	245	0	1763	1763	0	207	137	373	86	146	1623	1866.6	1866.6
	1981	8	31	2E	NA	372	393	1990	125	7	13	93	262	4	378	20	245	0	1692	1692	0	279	137	373	86	146	1624	1866.6	1866.6
	1981	9	30	2E	NA	372	393	1990	152	5	7	92	179	2	378	20	272	22	1747	1747	0	224	128	376	92.71	136	1625	1879.3	1879.3
	1981	10	31	2E	NA	372	393	1990	243	8	20	92	98	0	378	20	272	0	1957	1957	0	13	128	376	92.71	136	1626	1879.3	1879.3

Attachment A-4
Tailings Basin Water Balance

						2E															Total		2E						
Year of Operation	Climate Data Year	Month	Days	Active Cell	Clearwater Cell	Water From Mine Site	Solids from Plant	Water From Plant	Precipitation on Pond	Beach Runoff	Watershed RO	Seepage Returned	Pond Evap	Wet Beach Evap	Entrainment	Rewetting	Pond Seepage	Change in Storage - Pond Growth	Net Balance	Discharge to Plant	Change in Storage - Balance vs Demand	Make-Up Demand	Beach Area	Pond	Forest	Reclamed TB	Basin Elevation	Pond Volume - Wanted	Pond Volume - Actual
						m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	acres				ft	A-F	A-F
	1981	11	30	2E	NA	372	393	1990	32	1	0	92	31	3	378	20	272	0	1785	1785	0	186	128	376	92.71	136	1627	1879.3	1879.3
	1981	12	31	2E	NA	372	393	1990	50	0	0	92	18	4	378	20	272	0	1813	1813	0	157	128	376	92.71	136	1628	1879.3	1879.3
6	1982	1	31	2E	NA	375	393	1990	61	0	0	92	19	4	378	20	272	0	1825	1825	0	145	128	376	92.71	136	1629	1879.3	1879.3
	1982	2	28	2E	NA	375	393	1990	22	0	0	91	20	4	378	20	299	23	1734	1734	0	236	119	378	99.43	127	1630	1892	1892
	1982	3	31	2E	NA	375	393	1990	48	0	0	91	38	3	378	20	299	0	1768	1768	0	203	119	378	99.43	127	1631	1892	1892
	1982	4	30	2E	NA	375	393	1990	58	35	50	91	181	3	378	20	299	0	1719	1719	0	251	119	378	99.43	127	1632	1892	1892
	1982	5	31	2E	NA	375	393	1990	249	8	20	91	244	2	378	20	299	0	1791	1791	0	180	119	378	99.43	127	1633	1892	1892
	1982	6	30	2E	NA	375	393	1990	163	8	19	91	307	4	378	20	299	0	1638	1638	0	333	119	378	99.43	127	1634	1892	1892
	1982	7	31	2E	NA	375	393	1990	261	11	40	90	323	3	378	20	326	21	1698	1698	0	273	110	381	106.1	117	1635	1904.8	1904.8
	1982	8	31	2E	NA	375	393	1990	232	10	34	90	268	3	378	20	326	0	1738	1738	0	233	110	381	106.1	117	1636	1904.8	1904.8
	1982	9	30	2E	NA	375	393	1990	213	6	14	90	181	2	378	20	326	0	1783	1783	0	187	110	381	106.1	117	1637	1904.8	1904.8
	1982	10	31	2E	NA	375	393	1990	287	8	25	90	100	0	378	20	326	0	1953	1953	0	17	110	381	106.1	117	1638	1904.8	1904.8
	1982	11	30	2E	NA	375	393	1990	111	0	0	90	31	2	378	20	326	0	1811	1811	0	160	110	381	106.1	117	1639	1904.8	1904.8
	1982	12	31	2E	NA	375	393	1990	84	0	0	89	18	4	378	20	352	21	1746	1746	0	224	101	384	112.9	107	1640	1917.5	1917.5
7	1983	1	31	2E	NA	379	393	1990	77	0	0	89	20	4	378	20	352	0	1762	1762	0	209	101	384	112.9	107	1641	1917.5	1917.5
	1983	2	28	2E	NA	379	393	1990	74	0	0	89	21	4	378	20	352	0	1758	1758	0	213	101	384	112.9	107	1642	1917.5	1917.5
	1983	3	31	2E	NA	379	393	1990	34	0	0	89	38	3	378	20	352	0	1702	1702	0	269	101	384	112.9	107	1643	1917.5	1917.5
	1983	4	30	2E	NA	379	393	1990	59	46	89	89	183	3	378	20	352	0	1716	1716	0	254	101	384	112.9	107	1644	1917.5	1917.5
	1983	5	31	2E	NA	379	393	1990	111	3	3	88	249	4	378	20	379	21	1523	1523	0	447	92.1	386	119.6	97	1645	1930.3	1930.3
	1983	6	30	2E	NA	379	393	1990	125	4	9	88	314	5	378	20	379	0	1500	1500	0	471	92.1	386	119.6	97	1646	1930.3	1930.3
	1983	7	31	2E	NA	379	393	1990	166	6	18	88	327	4	378	20	379	0	1540	1540	0	431	92.1	386	119.6	97	1647	1930.3	1930.3
	1983	8	31	2E	NA	379	393	1990	345	12	57	88	271	1	378	20	379	0	1822	1822	0	148	92.1	386	119.6	97	1648	1930.3	1930.3
	1983	9	30	2E	NA	379	393	1990	132	3	4	88	183	2	378	20	379	0	1633	1633	0	337	92.1	386	119.6	97	1649	1930.3	1930.3
	1983	10	31	2E	NA	379	393	1990	201	4	11	87	102	1	378	20	406	21	1745	1745	0	225	83	389	126.3	88	1650	1943	1943
	1983	11	30	2E	NA	379	393	1990	194	0	0	87	32	2	378	20	406	0	1813	1813	0	158	83	389	126.3	88	1651	1943	1943
	1983	12	31	2E	NA	379	393	1990	79	0	0	87	18	4	378	20	406	0	1710	1710	0	261	83	389	126.3	88	1652	1943	1943
8	1984	1	31	2E	NA	382	393	1990	11	0	0	87	23	4	378	20	406	520	1119	1119	0	852	98.3	451	125.9	87	1653	2256.9	2256.9
	1984	2	28	2E	NA	382	393	1990	82	0	0	87	27	4	378	20	406	576	1130	1130	0	840	114	514	125.5	86	1654	2570.8	2570.8
	1984	3	31	2E	NA	382	393	1990	12	0	0	86	58	3	378	20	433	520	1059	1059	0	911	129	577	125.2	85	1655	2884.7	2884.7
	1984	4	30	2E	NA	382	393	1990	110	68	82	86	306	3	378	20	433	538	1041	1041	0	929	144	640	124.8	84	1656	3198.7	3198.7
	1984	5	31	2E	NA	382	393	1990	187	4	2	86	453	4	378	20	433	520	844	844	0	1127	159	703	124.4	83	1657	3512.6	3512.6
	1984	6	30	2E	NA	382	393	1990	598	20	44	86	622	3	378	20	433	538	1129	1129	0	842	175	765	124	82	1658	3826.5	3826.5
	1984	7	31	2E	NA	382	393	1990	161	5	2	86	702	6	378	20	433	520	570	570	0	1401	190	828	123.6	81	1659	4140.4	4140.4
	1984	8	31	2E	NA	382	393	1990	375	13	16	85	626	3	378	20	459	520	855	855	0	1116	205	891	123.3	80	1660	4454.3	4454.3
	1984	9	30	2E	NA	382	393	1990	182	4	1	85	453	3	378	20	459	538	794	794	0	1177	221	954	122.9	79	1661	4768.2	4768.2

Attachment A-4
Tailings Basin Water Balance

						2E															Total		2E						
Year of Operation	Climate Data Year	Month	Days	Active Cell	Clearwater Cell	Water From Mine Site	Solids from Plant	Water From Plant	Precipitation on Pond	Beach Runoff	Watershed RO	Seepage Returned	Pond Evap	Wet Beach Evap	Entrainment	Rewetting	Pond Seepage	Change in Storage - Pond Growth	Net Balance	Discharge to Plant	Change in Storage - Balance vs Demand	Make-Up Demand	Beach Area	Pond	Forest	Reclamed TB	Basin Elevation	Pond Volume - Wanted	Pond Volume - Actual
						m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	acres				ft	A-F	A-F
	1984	10	31	2E	NA	382	393	1990	358	8	3	85	266	1	378	20	459	520	1182	1182	0	788	236	1016	122.5	78	1662	5082.1	5082.1
	1984	11	30	2E	NA	382	393	1990	413	0	0	85	88	2	378	20	459	538	1385	1385	0	585	251	1079	122.1	77	1663	5396	5396
	1984	12	31	2E	NA	382	393	1990	257	0	0	85	54	4	378	20	459	520	1280	1280	0	691	267	1142	121.8	76	1664	5710	5710
9	1985	1	31	2E	NA	385	393	1990	63	0	0	130	57	4	378	20	630	520	960	960	0	1011	282	1205	121.4	75	1665	6023.9	6023.9
	1985	2	28	2E	NA	385	393	1990	92	0	0	130	59	4	378	20	630	0	1507	1507	0	463	282	1205	121.4	75	1666	6023.9	6023.9
	1985	3	31	2E	NA	385	393	1990	45	118	66	130	108	3	378	20	630	0	1597	1597	0	373	282	1205	121.4	75	1667	6023.9	6023.9
	1985	4	30	2E	NA	385	393	1990	470	11	4	130	524	2	378	20	630	0	1436	1436	0	535	282	1205	121.4	75	1668	6023.9	6023.9
	1985	5	31	2E	NA	385	393	1990	1044	24	27	130	739	1	378	20	630	0	1833	1833	0	138	282	1205	121.4	75	1670	6023.9	6023.9
	1985	6	30	2E	NA	385	393	1990	959	34	41	134	951	3	378	20	641	-67	1617	1617	0	353	287	1197	109.8	72	1670	5984.7	5984.7
	1985	7	31	2E	NA	385	393	1990	433	15	10	134	1007	5	378	20	641	0	918	918	0	1053	287	1197	109.8	72	1670	5984.7	5984.7
	1985	8	31	2E	NA	385	393	1990	898	32	38	134	826	2	378	20	641	0	1610	1610	0	360	287	1197	109.8	72	1671	5984.7	5984.7
	1985	9	30	2E	NA	385	393	1990	878	21	19	134	532	1	378	20	641	0	1855	1855	0	116	287	1197	109.8	72	1671	5984.7	5984.7
	1985	10	31	2E	NA	385	393	1990	265	6	1	134	265	2	378	20	641	0	1476	1476	0	495	287	1197	109.8	72	1672	5984.7	5984.7
	1985	11	30	2E	NA	385	393	1990	422	0	0	134	85	2	378	20	641	0	1806	1806	0	164	287	1197	109.8	72	1672	5984.7	5984.7
	1985	12	31	2E	NA	385	393	1990	68	0	0	134	52	4	378	20	641	0	1483	1483	0	488	287	1197	109.8	72	1672	5984.7	5984.7
10	1986	1	31	2E	NA	389	393	1990	117	0	0	134	56	4	378	20	641	0	1531	1531	0	440	287	1197	109.8	72	1673	5984.7	5984.7
	1986	2	28	2E	NA	389	393	1990	168	0	0	134	59	4	378	20	641	0	1580	1580	0	391	287	1197	109.8	72	1673	5984.7	5984.7
	1986	3	31	2E	NA	389	393	1990	76	0	0	134	107	3	378	20	641	0	1441	1441	0	530	287	1197	109.8	72	1674	5984.7	5984.7
	1986	4	30	2E	NA	389	393	1990	656	116	62	134	521	2	378	20	641	0	1786	1786	0	185	287	1197	109.8	72	1674	5984.7	5984.7
	1986	5	31	2E	NA	389	393	1990	342	8	2	134	734	4	378	20	641	0	1088	1088	0	882	287	1197	109.8	72	1674	5984.7	5984.7
	1986	6	30	2E	NA	389	393	1990	525	18	15	134	951	4	378	20	641	0	1077	1077	0	894	287	1197	109.8	72	1675	5984.7	5984.7
	1986	7	31	2E	NA	389	393	1990	749	27	27	137	1000	3	378	20	653	-65	1331	1331	0	640	292	1189	98.13	69	1675	5945.6	5945.6
	1986	8	31	2E	NA	389	393	1990	631	23	20	137	820	3	378	20	653	0	1317	1317	0	654	292	1189	98.13	69	1675	5945.6	5945.6
	1986	9	30	2E	NA	389	393	1990	1227	30	30	137	529	0	378	20	653	0	2225	1970	255	1	292	1189	98.13	69	1676	5945.6	6094.3
	1986	10	31	2E	NA	389	393	1990	202	5	0	137	263	2	378	20	653	0	1663	1663	0	307	292	1189	98.13	69	1676	5945.6	5945.6
	1986	11	30	2E	NA	389	393	1990	209	0	0	137	84	2	378	20	653	0	1589	1589	0	381	292	1189	98.13	69	1677	5945.6	5945.6
	1986	12	31	2E	NA	389	393	1990	54	0	0	137	51	4	378	20	653	0	1465	1465	0	505	292	1189	98.13	69	1677	5945.6	5945.6
11	1987	1	31	2E	NA	401	393	1990	99	0	0	137	56	4	378	20	653	0	1518	1518	0	453	292	1189	98.13	69	1677	5945.6	5945.6
	1987	2	28	2E	NA	401	393	1990	91	0	0	137	58	4	378	20	653	0	1508	1508	0	463	292	1189	98.13	69	1678	5945.6	5945.6
	1987	3	31	2E	NA	401	393	1990	118	37	12	137	106	3	378	20	653	0	1538	1538	0	433	292	1189	98.13	69	1678	5945.6	5945.6
	1987	4	30	2E	NA	401	393	1990	42	1	0	137	517	4	378	20	653	0	1001	1001	0	969	292	1189	98.13	69	1679	5945.6	5945.6
	1987	5	31	2E	NA	401	393	1990	910	22	19	137	730	2	378	20	653	0	1699	1699	0	272	292	1189	98.13	69	1679	5945.6	5945.6
	1987	6	30	2E	NA	401	393	1990	284	10	3	137	945	5	378	20	653	0	826	826	0	1145	292	1189	98.13	69	1679	5945.6	5945.6
	1987	7	31	2E	NA	401	393	1990	1203	44	51	137	1000	2	378	20	653	0	1775	1775	0	195	292	1189	98.13	69	1680	5945.6	5945.6
	1987	8	31	2E	NA	401	393	1990	444	16	9	141	815	4	378	20	664	-65	1188	1188	0	783	297	1181	86.5	66	1680	5906.5	5906.5

Attachment A-4
Tailings Basin Water Balance

						2E															Total		2E						
Year of Operation	Climate Data Year	Month	Days	Active Cell	Clearwater Cell	Water From Mine Site	Solids from Plant	Water From Plant	Precipitation on Pond	Beach Runoff	Watershed RO	Seepage Returned	Pond Evap	Wet Beach Evap	Entrainment	Rewetting	Pond Seepage	Change in Storage - Pond Growth	Net Balance	Discharge to Plant	Change in Storage - Balance vs Demand	Make-Up Demand	Beach Area	Pond	Forest	Reclamed TB	Basin Elevation	Pond Volume - Wanted	Pond Volume - Actual
						m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	acres				ft	A-F	A-F
	1987	9	30	2E	NA	401	393	1990	713	18	11	141	525	1	378	20	664	0	1686	1686	0	284	297	1181	86.5	66	1680	5906.5	5906.5
	1987	10	31	2E	NA	401	393	1990	116	3	0	141	262	2	378	20	664	0	1326	1326	0	644	297	1181	86.5	66	1681	5906.5	5906.5
	1987	11	30	2E	NA	401	393	1990	51	1	0	141	83	3	378	20	664	0	1437	1437	0	534	297	1181	86.5	66	1681	5906.5	5906.5
	1987	12	31	2E	NA	401	393	1990	41	0	0	141	51	4	378	20	664	0	1457	1457	0	514	297	1181	86.5	66	1682	5906.5	5906.5
	1988	1	31	2E	NA	168	393	1990	86	0	0	141	56	4	378	20	664	0	1265	1265	0	706	297	1181	86.5	66	1682	5906.5	5906.5
	1988	2	28	2E	NA	168	393	1990	0	0	0	141	58	5	378	20	664	0	1176	1176	0	795	297	1181	86.5	66	1682	5906.5	5906.5
	1988	3	31	2E	NA	168	393	1990	269	0	0	141	105	3	378	20	664	0	1399	1399	0	571	297	1181	86.5	66	1683	5906.5	5906.5
	1988	4	30	2E	NA	168	393	1990	20	49	16	141	514	4	378	20	664	0	807	807	0	1164	297	1181	86.5	66	1683	5906.5	5906.5
	1988	5	31	2E	NA	168	393	1990	364	9	2	141	725	4	378	20	664	0	885	885	0	1086	297	1181	86.5	66	1684	5906.5	5906.5
12	1988	6	30	2E	NA	168	393	1990	557	21	15	141	939	4	378	20	664	0	888	888	0	1083	297	1181	86.5	66	1684	5906.5	5906.5
	1988	7	31	2E	NA	168	393	1990	508	19	13	141	994	4	378	20	664	0	779	779	0	1191	297	1181	86.5	66	1684	5906.5	5906.5
	1988	8	31	2E	NA	168	393	1990	2001	75	87	141	815	-1	378	20	664	0	2587	1970	617	1	297	1181	86.5	66	1685	5906.5	6278.6
	1988	9	30	2E	NA	168	393	1990	606	15	7	145	522	2	378	20	675	-67	2019	1970	49	1	302	1173	74.88	62	1685	5867.4	5896.3
	1988	10	31	2E	NA	168	393	1990	190	4	0	145	260	2	378	20	675	0	1213	1213	0	758	302	1173	74.88	62	1685	5867.4	5867.4
	1988	11	30	2E	NA	168	393	1990	235	0	0	145	83	2	378	20	675	0	1380	1380	0	591	302	1173	74.88	62	1686	5867.4	5867.4
	1988	12	31	2E	NA	168	393	1990	131	0	0	145	51	4	378	20	675	0	1307	1307	0	664	302	1173	74.88	62	1686	5867.4	5867.4
	1989	1	31	2E	NA	312	393	1990	282	0	0	145	55	4	378	20	675	0	1597	1597	0	373	302	1173	74.88	62	1687	5867.4	5867.4
	1989	2	28	2E	NA	312	393	1990	120	0	0	145	57	5	378	20	675	0	1433	1433	0	538	302	1173	74.88	62	1687	5867.4	5867.4
	1989	3	31	2E	NA	312	393	1990	183	0	0	145	105	3	378	20	675	0	1450	1450	0	520	302	1173	74.88	62	1687	5867.4	5867.4
	1989	4	30	2E	NA	312	393	1990	102	152	57	145	510	3	378	20	675	0	1173	1173	0	798	302	1173	74.88	62	1688	5867.4	5867.4
	1989	5	31	2E	NA	312	393	1990	522	13	5	145	720	3	378	20	675	0	1191	1191	0	780	302	1173	74.88	62	1688	5867.4	5867.4
13	1989	6	30	2E	NA	312	393	1990	1131	43	39	145	932	2	378	20	675	0	1653	1653	0	317	302	1173	74.88	62	1689	5867.4	5867.4
	1989	7	31	2E	NA	312	393	1990	97	3	0	145	987	6	378	20	675	0	482	482	0	1489	302	1173	74.88	62	1689	5867.4	5867.4
	1989	8	31	2E	NA	312	393	1990	725	28	21	145	809	3	378	20	675	0	1336	1336	0	634	302	1173	74.88	62	1689	5867.4	5867.4
	1989	9	30	2E	NA	312	393	1990	558	14	5	145	522	2	378	20	675	0	1428	1428	0	543	302	1173	74.88	62	1690	5867.4	5867.4
	1989	10	31	2E	NA	312	393	1990	237	6	1	149	258	2	378	20	686	-65	1416	1416	0	555	307	1166	63.25	59	1690	5828.3	5828.3
	1989	11	30	2E	NA	312	393	1990	83	0	0	149	82	3	378	20	686	0	1365	1365	0	606	307	1166	63.25	59	1691	5828.3	5828.3
	1989	12	31	2E	NA	312	393	1990	23	0	0	149	50	4	378	20	686	0	1335	1335	0	635	307	1166	63.25	59	1691	5828.3	5828.3
	1990	1	31	2E	NA	350	393	1990	95	0	0	149	55	4	378	20	686	0	1442	1442	0	529	307	1166	63.25	59	1691	5828.3	5828.3
	1990	2	28	2E	NA	350	393	1990	109	0	0	149	57	4	378	20	686	0	1453	1453	0	518	307	1166	63.25	59	1692	5828.3	5828.3
	1990	3	31	2E	NA	350	393	1990	151	0	0	149	104	3	378	20	686	0	1450	1450	0	520	307	1166	63.25	59	1692	5828.3	5828.3
	1990	4	30	2E	NA	350	393	1990	496	59	16	149	507	2	378	20	686	0	1467	1467	0	504	307	1166	63.25	59	1692	5828.3	5828.3
	1990	5	31	2E	NA	350	393	1990	184	4	0	149	715	4	378	20	686	0	874	874	0	1096	307	1166	63.25	59	1693	5828.3	5828.3
	1990	6	30	2E	NA	350	393	1990	1140	45	35	149	926	2	378	20	686	0	1698	1698	0	273	307	1166	63.25	59	1693	5828.3	5828.3
14	1990	7	31	2E	NA	350	393	1990	417	16	7	149	980	5	378	20	686	0	861	861	0	1110	307	1166	63.25	59	1694	5828.3	5828.3

Attachment A-4
Tailings Basin Water Balance

						2E															Total		2E						
Year of Operation	Climate Data Year	Month	Days	Active Cell	Clearwater Cell	Water From Mine Site	Solids from Plant	Water From Plant	Precipitation on Pond	Beach Runoff	Watershed RO	Seepage Returned	Pond Evap	Wet Beach Evap	Entrainment	Rewetting	Pond Seepage	Change in Storage - Pond Growth	Net Balance	Discharge to Plant	Change in Storage - Balance vs Demand	Make-Up Demand	Beach Area	Pond	Forest	Reclamed TB	Basin Elevation	Pond Volume - Wanted	Pond Volume - Actual
						m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	acres				ft	A-F	A-F
	1990	8	31	2E	NA	350	393	1990	351	13	4	149	804	4	378	20	686	0	967	967	0	1004	307	1166	63.25	59	1694	5828.3	5828.3
	1990	9	30	2E	NA	350	393	1990	373	9	2	149	518	3	378	20	686	0	1269	1269	0	701	307	1166	63.25	59	1694	5828.3	5828.3
	1990	10	31	2E	NA	350	393	1990	879	23	14	149	258	0	378	20	686	0	2063	1970	93	1	307	1166	63.25	59	1695	5828.3	5884.4
	1990	11	30	2E	NA	350	393	1990	63	0	0	152	82	3	378	20	698	-67	1536	1536	0	434	312	1158	51.63	56	1695	5789.1	5789.1
	1990	12	31	2E	NA	350	393	1990	99	0	0	152	50	4	378	20	698	0	1443	1443	0	528	312	1158	51.63	56	1696	5789.1	5789.1
	1991	1	31	2E	NA	116	393	1990	43	0	0	152	55	4	378	20	698	0	1148	1148	0	823	312	1158	51.63	56	1696	5789.1	5789.1
	1991	2	28	2E	NA	116	393	1990	104	0	0	152	57	4	378	20	698	0	1207	1207	0	763	312	1158	51.63	56	1696	5789.1	5789.1
	1991	3	31	2E	NA	116	393	1990	141	0	0	152	103	3	378	20	698	0	1198	1198	0	772	312	1158	51.63	56	1697	5789.1	5789.1
	1991	4	30	2E	NA	116	393	1990	443	66	16	152	504	2	378	20	698	0	1183	1183	0	788	312	1158	51.63	56	1697	5789.1	5789.1
	1991	5	31	2E	NA	116	393	1990	549	14	5	152	710	3	378	20	698	0	1018	1018	0	953	312	1158	51.63	56	1697	5789.1	5789.1
15	1991	6	30	2E	NA	116	393	1990	572	23	12	152	920	4	378	20	698	0	846	846	0	1125	312	1158	51.63	56	1698	5789.1	5789.1
	1991	7	31	2E	NA	116	393	1990	1253	50	35	152	974	2	378	20	698	0	1526	1526	0	444	312	1158	51.63	56	1698	5789.1	5789.1
	1991	8	31	2E	NA	116	393	1990	275	11	2	152	799	4	378	20	698	0	649	649	0	1322	312	1158	51.63	56	1699	5789.1	5789.1
	1991	9	30	2E	NA	116	393	1990	1279	34	21	152	515	0	378	20	698	0	1983	1970	13	1	312	1158	51.63	56	1699	5789.1	5797
	1991	10	31	2E	NA	116	393	1990	232	6	1	152	256	2	378	20	698	0	1157	1157	0	813	312	1158	51.63	56	1699	5789.1	5789.1
	1991	11	30	2E	NA	116	393	1990	309	0	0	152	82	2	378	20	698	0	1389	1389	0	582	312	1158	51.63	56	1700	5789.1	5789.1
	1991	12	31	2E	NA	116	393	1990	75	0	0	154	50	4	378	20	713	-65	1235	1235	0	735	318	1150	40	53	1700	5750	5750
	1992	1	31	2E	NA	124	393	1990	67	0	0	154	54	4	378	20	713	0	1166	1166	0	805	318	1150	40	53	1701	5750	5750
	1992	2	28	2E	NA	124	393	1990	113	0	0	154	56	4	378	20	713	0	1210	1210	0	761	318	1150	40	53	1701	5750	5750
	1992	3	31	2E	NA	124	393	1990	37	0	0	154	103	3	378	20	713	0	1089	1089	0	882	318	1150	40	53	1701	5750	5750
	1992	4	30	2E	NA	124	393	1990	117	60	14	154	500	3	378	20	713	0	845	845	0	1126	318	1150	40	53	1702	5750	5750
	1992	5	31	2E	NA	124	393	1990	524	14	4	154	706	3	378	20	713	0	991	991	0	979	318	1150	40	53	1702	5750	5750
16	1992	6	30	2E	NA	124	393	1990	557	23	10	154	914	4	378	20	713	0	829	829	0	1142	318	1150	40	53	1703	5750	5750
	1992	7	31	2E	NA	124	393	1990	507	21	9	154	967	5	378	20	713	0	722	722	0	1249	318	1150	40	53	1703	5750	5750
	1992	8	31	2E	NA	124	393	1990	880	36	20	154	793	2	378	20	713	0	1298	1298	0	673	318	1150	40	53	1703	5750	5750
	1992	9	30	2E	NA	124	393	1990	629	17	6	154	511	2	378	20	713	0	1296	1296	0	675	318	1150	40	53	1704	5750	5750
	1992	10	31	2E	NA	124	393	1990	176	4	0	154	255	2	378	20	713	0	1082	1082	0	889	318	1150	40	53	1704	5750	5750
	1992	11	30	2E	NA	124	393	1990	253	0	0	154	81	2	378	20	713	0	1327	1327	0	644	318	1150	40	53	1704	5750	5750
	1992	12	31	2E	NA	124	393	1990	132	0	0	154	50	4	378	20	713	0	1236	1236	0	735	318	1150	40	53	1705	5750	5750
	1993	1	31	2E	NA	132	393	1990	71	0	0	157	54	4	378	20	724	-65	1236	1236	0	735	323	1142	40	43	1705	5710.9	5710.9
	1993	2	28	2E	NA	132	393	1990	9	0	0	157	56	4	378	20	724	0	1107	1107	0	864	323	1142	40	43	1706	5710.9	5710.9
	1993	3	31	2E	NA	132	393	1990	35	0	0	157	102	3	378	20	724	0	1088	1088	0	883	323	1142	40	43	1706	5710.9	5710.9
	1993	4	30	2E	NA	132	393	1990	171	60	11	157	497	3	378	20	724	0	900	900	0	1071	323	1142	40	43	1706	5710.9	5710.9
	1993	5	31	2E	NA	132	393	1990	522	14	3	157	701	3	378	20	724	0	994	994	0	977	323	1142	40	43	1707	5710.9	5710.9
17	1993	6	30	2E	NA	132	393	1990	491	20	7	157	908	5	378	20	724	0	764	764	0	1207	323	1142	40	43	1707	5710.9	5710.9

Attachment A-4
Tailings Basin Water Balance

						2E															Total		2E						
Year of Operation	Climate Data Year	Month	Days	Active Cell	Clearwater Cell	Water From Mine Site	Solids from Plant	Water From Plant	Precipitation on Pond	Beach Runoff	Watershed RO	Seepage Returned	Pond Evap	Wet Beach Evap	Entrainment	Rewetting	Pond Seepage	Change in Storage - Pond Growth	Net Balance	Discharge to Plant	Change in Storage - Balance vs Demand	Make-Up Demand	Beach Area	Pond	Forest	Reclaimed TB	Basin Elevation	Pond Volume - Wanted	Pond Volume - Actual
						m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	acres				ft	A-F	A-F
17	1993	7	31	2E	NA	132	393	1990	1548	65	36	157	961	1	378	20	724	0	1845	1845	0	125	323	1142	40	43	1708	5710.9	5710.9
	1993	8	31	2E	NA	132	393	1990	466	19	6	157	788	4	378	20	724	0	858	858	0	1113	323	1142	40	43	1708	5710.9	5710.9
	1993	9	30	2E	NA	132	393	1990	444	12	2	157	508	3	378	20	724	0	1105	1105	0	865	323	1142	40	43	1708	5710.9	5710.9
	1993	10	31	2E	NA	132	393	1990	196	5	0	157	253	2	378	20	724	0	1104	1104	0	866	323	1142	40	43	1709	5710.9	5710.9
	1993	11	30	2E	NA	132	393	1990	207	0	0	157	81	2	378	20	724	0	1282	1282	0	688	323	1142	40	43	1709	5710.9	5710.9
	1993	12	31	2E	NA	132	393	1990	80	0	0	157	49	4	378	20	724	0	1185	1185	0	786	323	1142	40	43	1709	5710.9	5710.9
	1994	1	31	2E	NA	152	393	1990	60	0	0	157	54	4	378	20	724	0	1180	1180	0	790	323	1142	40	43	1710	5710.9	5710.9
	1994	2	28	2E	NA	152	393	1990	24	0	0	161	55	5	378	20	735	-72	1207	1207	0	763	328	1134	40	33	1710	5671.8	5671.8
	1994	3	31	2E	NA	152	393	1990	41	0	0	161	101	3	378	20	735	0	1108	1108	0	863	328	1134	40	33	1711	5671.8	5671.8
	1994	4	30	2E	NA	152	393	1990	406	55	8	161	493	3	378	20	735	0	1144	1144	0	827	328	1134	40	33	1711	5671.8	5671.8
	1994	5	31	2E	NA	152	393	1990	417	12	1	161	696	4	378	20	735	0	902	902	0	1069	328	1134	40	33	1711	5671.8	5671.8
18	1994	6	30	2E	NA	152	393	1990	973	42	18	161	901	2	378	20	735	0	1300	1300	0	671	328	1134	40	33	1712	5671.8	5671.8
	1994	7	31	2E	NA	152	393	1990	467	20	6	161	954	5	378	20	735	0	705	705	0	1266	328	1134	40	33	1712	5671.8	5671.8
	1994	8	31	2E	NA	152	393	1990	403	17	4	161	782	4	378	20	735	0	808	808	0	1162	328	1134	40	33	1713	5671.8	5671.8
	1994	9	30	2E	NA	152	393	1990	722	20	6	161	504	1	378	20	735	0	1414	1414	0	557	328	1134	40	33	1713	5671.8	5671.8
	1994	10	31	2E	NA	152	393	1990	617	17	4	161	251	1	378	20	735	0	1558	1558	0	412	328	1134	40	33	1713	5671.8	5671.8
	1994	11	30	2E	NA	152	393	1990	144	4	0	161	80	3	378	20	735	0	1236	1236	0	735	328	1134	40	33	1714	5671.8	5671.8
	1994	12	31	2E	NA	152	393	1990	67	0	0	161	49	4	378	20	735	0	1185	1185	0	785	328	1134	40	33	1714	5671.8	5671.8
	1995	1	31	2E	NA	100	393	1990	143	0	0	161	53	4	378	20	735	0	1204	1204	0	767	328	1134	40	33	1714	5671.8	5671.8
	1995	2	28	2E	NA	100	393	1990	50	0	0	161	55	5	378	20	735	0	1109	1109	0	861	328	1134	40	33	1715	5671.8	5671.8
	1995	3	31	2E	NA	100	393	1990	139	0	0	165	101	3	378	20	747	-65	1212	1212	0	759	333	1127	40	22	1715	5632.6	5632.6
	1995	4	30	2E	NA	100	393	1990	74	54	6	165	490	3	378	20	747	0	752	752	0	1219	333	1127	40	22	1716	5632.6	5632.6
	1995	5	31	2E	NA	100	393	1990	296	8	1	165	691	4	378	20	747	0	721	721	0	1250	333	1127	40	22	1716	5632.6	5632.6
19	1995	6	30	2E	NA	100	393	1990	106	4	0	165	895	6	378	20	747	0	321	321	0	1650	333	1127	40	22	1716	5632.6	5632.6
	1995	7	31	2E	NA	100	393	1990	1058	46	18	165	947	2	378	20	747	0	1284	1284	0	686	333	1127	40	22	1717	5632.6	5632.6
	1995	8	31	2E	NA	100	393	1990	923	40	15	165	777	2	378	20	747	0	1311	1311	0	660	333	1127	40	22	1717	5632.6	5632.6
	1995	9	30	2E	NA	100	393	1990	540	15	2	165	501	2	378	20	747	0	1167	1167	0	804	333	1127	40	22	1718	5632.6	5632.6
	1995	10	31	2E	NA	100	393	1990	856	25	7	165	250	0	378	20	747	0	1750	1750	0	221	333	1127	40	22	1718	5632.6	5632.6
	1995	11	30	2E	NA	100	393	1990	56	0	0	165	80	3	378	20	747	0	1085	1085	0	885	333	1127	40	22	1718	5632.6	5632.6
	1995	12	31	2E	NA	100	393	1990	196	0	0	165	49	4	378	20	747	0	1255	1255	0	716	333	1127	40	22	1719	5632.6	5632.6
	1996	1	31	2E	NA	84.7	393	1990	349	0	0	165	53	4	378	20	747	0	1387	1387	0	584	333	1127	40	22	1719	5632.6	5632.6
	1996	2	28	2E	NA	84.7	393	1990	321	0	0	165	55	5	378	20	747	0	1357	1357	0	614	333	1127	40	22	1720	5632.6	5632.6
	1996	3	31	2E	NA	84.7	393	1990	73	0	0	165	101	3	378	20	747	0	1065	1065	0	905	333	1127	40	22	1720	5632.6	5632.6
	1996	4	30	2E	NA	84.7	393	1990	208	221	26	168	487	3	378	20	758	-67	1120	1120	0	850	338	1119	40	12	1720	5593.5	5593.5
	1996	5	31	2E	NA	84.7	393	1990	233	7	0	168	686	4	378	20	758	0	638	638	0	1333	338	1119	40	12	1721	5593.5	5593.5

Attachment A-4
Tailings Basin Water Balance

						2E															Total		2E						
Year of Operation	Climate Data Year	Month	Days	Active Cell	Clearwater Cell	Water From Mine Site	Solids from Plant	Water From Plant	Precipitation on Pond	Beach Runoff	Watershed RO	Seepage Returned	Pond Evap	Wet Beach Evap	Entrainment	Rewetting	Pond Seepage	Change in Storage - Pond Growth	Net Balance	Discharge to Plant	Change in Storage - Balance vs Demand	Make-Up Demand	Beach Area	Pond	Forest	Reclamed TB	Basin Elevation	Pond Volume - Wanted	Pond Volume - Actual
						m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	acres				ft	A-F	A-F
20	1996	6	30	2E	NA	84.7	393	1990	1057	47	15	168	889	2	378	20	758	0	1317	1317	0	654	338	1119	40	12	1721	5593.5	5593.5
	1996	7	31	2E	NA	84.7	393	1990	631	28	7	168	941	4	378	20	758	0	809	809	0	1162	338	1119	40	12	1721	5593.5	5593.5
	1996	8	31	2E	NA	84.7	393	1990	309	14	1	168	772	4	378	20	758	0	636	636	0	1335	338	1119	40	12	1722	5593.5	5593.5
	1996	9	30	2E	NA	84.7	393	1990	588	17	2	168	497	2	378	20	758	0	1196	1196	0	775	338	1119	40	12	1722	5593.5	5593.5
	1996	10	31	2E	NA	84.7	393	1990	274	8	0	168	248	2	378	20	758	0	1121	1121	0	850	338	1119	40	12	1723	5593.5	5593.5
	1996	11	30	2E	NA	84.7	393	1990	672	0	0	168	79	2	378	20	758	0	1679	1679	0	291	338	1119	40	12	1723	5593.5	5593.5
	1996	12	31	2E	NA	84.7	393	1990	284	0	0	168	48	4	378	20	758	0	1320	1320	0	650	338	1119	40	12	1723	5593.5	5593.5

Attachment A-5

Watershed Yield Calculations using the Meyer Model

Attachment A-5
Watershed Yield Calculations
Using the Meyer Model
Tailings Basin – Mitigation Design

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1.0 Introduction

Barr Engineering Company (Barr) prepared a detailed water balance for the Tailings Basin – Mitigation Design. A component of the water balance was watershed yield, which includes precipitation, evaporation, runoff and infiltration. This report documents the methodologies used to predict these components and presents detailed information on the watershed yield values predicted for the Tailings Basin – Mitigation Design.

2.0 Meyer Model

2.1 Model Overview

The Meyer Model is a proprietary computer model developed by Barr Engineering Company that can be used to estimate the "yield" of a watershed during long-term climatic events. Yield is simply the amount of water that reaches the ponds being simulated and groundwater after deducting losses from precipitation—losses such as evaporation from land, water surfaces, and snow, and transpiration from plants. The model is based on work by Adolf Meyer, who presented empirical relationships for evaporation and transpiration in his book, Elements of Hydrology, which was used as a college text from 1916 through the early 1950s. His methods for estimating water surface evaporation were refined and proven during an analysis of 50 years of weather records for the Minnesota Resource Commission in 1942.

The method is still valid because Meyer's work is empirical—he based his relationships on observed data. The formulas he developed for water surface evaporation are similar in form to other accepted formulas. The charts he created for transpiration and snow evaporation are also based on physical measurements. All his empirical relationships have been converted to computerized formulas to simplify their application in the model. Barr has used the method successfully to model water surface elevations on mining reservoirs and tailing basins.

Usually, hydrologic analysis for storm systems uses a short-term, high intensity event (for example, 6 inches of rain in 24 hours). This type of event is useful in determining the required size of storm sewer pipes and calculating pond flood levels. However, where no outlet exists (a landlocked basin), much longer climatic events usually result in higher flood levels. For example, if 12 inches of rain fell in one month, the flood level would likely be higher than it would be from the 6-inch, 24-hour event. The Meyer Model lets us estimate the response of a basin over a wet or dry cycle of many months or years.

2.2 Model Calculations

The watershed area of each basin is divided into upland and water surface areas. The upland and water surface areas are further divided into representative types. For water surface areas, the balance consists of determining the precipitation onto the water surface and evaporation from the water surface. For upland areas, transpiration is included with land evaporation ("evapotranspiration") as a loss, and moisture can be temporarily stored as soil moisture or snow, before it is released as evapotranspiration, runoff, and groundwater.

For water surface areas, evaporation is determined using available climatic data and the Meyer evaporation formula. The Meyer evaporation formula uses the average monthly water temperature, relative humidity, and wind speed to determine each month's evaporation using the following formula:

$$E = C\ (VW - VA)\ (1 + W/10) \tag{1}$$

Where	E	= evaporation, inches per month
	C	= empirical coefficient
	VW	= maximum vapor pressure of water at given temperature
	VA	= vapor pressure of air for given temperature and humidity
	w	= average wind speed, miles per hour

These calculations are extremely sensitive to the difference between air and water temperatures. The Meyer formula uses the difference between the vapor pressures of the water surface and the air to determine evaporation. Water surface vapor pressure is a function of water temperature. The Meyer model determines the water temperature by applying a user-defined adjustment to the monthly air temperature. Lake water temperature correction factors are applied on a monthly basis in the Meyer Model. These are used to account for the "thermodynamic flywheel" behavior of water bodies. For the inactive basins at PolyMet, these water temperature adjustments were taken from values found to be representative for water bodies in the Iron Range region (Barr Engineering, 2001, 1994, 1990, 1986). However, these studies were of lakes and tailing basins ponds under normal temperatures. The process water from the PolyMet plant that will be discharged to the basins will be heated. As such, additional corrections are needed for areas that will be receiving this heated water. This is discussed in Section 2.3. The vapor pressure of the air is a function of air temperature and relative humidity.

For natural upland areas, the Meyer method estimates precipitation losses from curves relating vegetative transpiration to temperature, and land surface evaporation to precipitation and temperature. The losses are adjusted by factors that have been calibrated for other watersheds in the region. For unvegetated or sparsely vegetated upland areas (mining and other developed land use), only land evaporation was subtracted from precipitation since there is no significant vegetation to contribute to transpiration.

2.3 Additional Evaporation Calculations

Estimates of water losses due to evaporation from heated water are needed to complete the water balance calculations for the proposed Tailings Basin. Estimates of open-water evaporation rates can be obtained from:

- historical information on pan evaporation rates from nearby weather stations and the use of an appropriate value of the pan coefficient; or,
- empirical methods based on weather parameters such as solar radiation, air temperature, water temperature, relative humidity, and wind speed.

The open-water evaporation rates obtained will be used as a reference to determine the corresponding evaporation values for the three areas in which the Tailings Basin has been divided for the water balance calculations, i.e.:

- ponded area (A_{ow});
- wet tailings area (A_{wt}); and,
- dry tailings area (A_{dt}).

The only nearby weather station where daily pan evaporation rates have been recorded is Hoyt Lakes, MN – Coop ID 213921. This station is located 1 mile south of the proposed tailings impoundment, and its period of record dates from 1958 to 1983. The monthly values measured in a US Weather Bureau Class A evaporation pan during the months of open-water are presented in Table 2-1. Additional water losses due to sublimation during the period of snow cover could be anticipated, but they are not measured at Hoyt Lakes, MN. These additional losses can be assumed to be negligible; the latent heat of sublimation is approximately 15 percent larger than the latent heat of evaporation, and the net radiation input during winter typically is only 5 to 10 percent the value during summer (Henneman and Stefan, 1999).

As a first approximation, it is reasonable to assume that the pan evaporation rates (E_{pan}) represent an upper bound of the evaporation values for any of the three calculation areas referred to above (A_{ow}, A_{wt} and A_{dt}), if and only if no external inflow of water occurs. They represent an upper bound because the comparable smaller size of the evaporation pan induces a greater heat exchange of the water in the pan with the atmosphere, hence a larger water loss due to evaporation. One simple form to obtain the estimates of the evaporation rates from the ponded area (E_{ow}), for instance, is via the use of a pan coefficient (k_{pan}):

$$E_{ow} = k_{pan} E_{pan} \tag{2}$$

A typical value for k_{pan} is 0.70, although this may vary between 0.55 and 0.80 (based on the average monthly values of wind speed and relative humidity recorded at International Falls, MN) depending on the upwind fetch of the surrounding green crop or dry fallow. Estimates of the evaporation rates for the ponded area (A_{ow}) are presented in Table 2-1, based on (2) and with k_{pan} = 0.70. By applying an additional correction factor to account for the expected direct relation between moisture content of the tailings and the corresponding evaporation rate (Blight, 2002; Fujiyasu et al., 2000; Gibson et al., 1998; Rassam, 2002; Seneviratne et al., 1996), similar estimates of the evaporation rates could be obtained for the wet tailings (A_{wt}) and dry tailings (A_{dt}) areas.

Table 2-1

Monthly Values of Measured Pan Evaporation at Hoyt Lakes, MN (Coop ID 213921) and Estimated Evaporation Rates from Ponded Area

Month	Pan Evaporation (mm)	Evaporation from Ponded Area (mm)
April	32	22
May	125	88
June	143	100
July	160	112
August	128	89
September	74	52
October	17	12

The tailings disposal operation in the proposed basin includes, however, the continuous inflow of heated water with the tailings slurry. The water temperature in any of the three calculation areas referred to above (A_{ow}, A_{wt} and A_{dt}; in particular A_{ow} and A_{wt}) will be greater than the temperature determined by the site-specific weather conditions. The estimates of evaporation given in Table 2-1 do not account for this effect; the values in Table 2-1 just serve as a reference of the order of magnitude of the evaporation rate in the tailings impoundments between April and October, not an upper bound.

The empirical methods used to estimate evaporation rates are normally expressed as a function of the amount of radiative energy provided by the sun (short- and long-wave net radiation), the gradient of vapor pressure between the evaporative surface and the air above (based on the water temperature, air temperature and relative humidity), and the wind speed. The following paragraphs will present more details about the background information required as input for the Meyer evaporation model, which is the empirical relation selected for use in this assessment.

One key factor for the calculations of evaporation is the water temperature at the air-water interface (T_w). The dew point temperature (T_d) is normally assumed as the representative value (i.e., $T_w = T_d$). When T_d is not directly measured, its value can be computed based on the measured values of the air temperature and relative humidity. Recent work by Bogan et al. (2003) shows, however, that the equilibrium temperature (T_e) is a better indicator of T_w (i.e., $T_w = T_e$). The equilibrium temperature is the water temperature at which the sum of all heat fluxes through the air-water interface is zero, hence it accounts for the effects of solar radiation input and evaporative cooling.

The method proposed by Brady et al. (1969) has been followed here to compute the monthly values of T_e, as a function of the incoming solar radiation (H_s), albedo of the evaporative surface (α), air temperature (T_a), wind speed (W) and relative humidity (RH). The relations to use for the calculation of T_e (°C) are:

$$T_e = T_d + \frac{(1-\alpha)H_s}{K} \qquad (3)$$

$$T_d = (RH)^{1/8}(112 + 0.9T_a) - 112 + 0.1T_a \qquad (4)$$

$$K = 4.5 + 0.05T_e + \beta f(W) + 0.47 f(W) \qquad (5)$$

$$f(W) = 9.2 + 0.46W^2 \qquad (6)$$

$$\beta = 0.35 + 0.015T_m + 0.0012T_m^2 \qquad (7)$$

$$T_m = \frac{T_e + T_d}{2} \qquad (8)$$

In the relation above, T_d (°C), α is dimensionless (α = 0.08 for water; Maidment, 1992), H_s (W/m^2), K = bulk surface conductance (W/m^2/°C), RH is dimensionless (fraction, not percent), T_a (°C), and W (m/s). It can be seen in (3) to (8) that the calculation of T_e involves an iterative procedure. In case the value of T_e is negative (below freezing temperature), it has been assumed that the actual water temperature in the ponded area was 1°C (i.e., isothermal conditions with T_e = 1°C).

The historical record used for the four input weather variables correspond to the period 1961 to 1990 at International Falls – Coop ID 214026. This station is located 90 miles northwest of the proposed tailings basin. The results of the computations of T_e for the ponded area A_{ow} ($\alpha = 0.08$), together with the measured monthly values of air temperature T_a and estimated dew point temperature T_d (relation (4); Bras, 1990), are presented in Table 2-2. Similar computations of T_e for the wet A_{wt} and dry A_{dt} tailings areas have been performed using albedos of 0.10 and 0.35, respectively (Maidment, 1992). In case of no external inflow of water, the corresponding value of T_e (i.e., $T_w = T_e$) would be used for the estimates of the evaporation rates; this is the case in the dry tailings area A_{dt}.

The ponded and the wet tailings areas (A_{ow} and A_{wt}, respectively) of the impoundment are, however, continuously receiving a significant amount of hot water from the tailings slurry. Therefore, the actual water temperature T_w at the air-water interface will be higher than the equilibrium temperature T_e. The incoming water is hotter than the water in A_{ow} and A_{wt}. It can be expected that in the case of A_{ow} the mixing of the incoming and ponded waters would be restricted to a surface layer (density stratification). The method proposed by Thomann and Mueller (1987) has been followed here to compute the monthly values of T_w (°C), as follows:

$$T_w = \frac{T_{in} + rT_e}{1 + r} \quad (9)$$

$$r = \frac{KA_s}{\rho C_p Q} \quad (10)$$

In the relation above, T_{in} = temperature of incoming water with tailings slurry (°C), T_e (°C), K (W/m^2/°C), A_s = evaporative surface area (m^2), ρ = density of water (kg/m^3), C_p = specific heat of water (J/kg/°C), Q = inflow of water with tailings slurry (m^3/s). The formulation of the heat balance given by (9) and (10) is based on the assumption that the outflow of water pumped back to the floatation plant is equal to the inflow Q and that the temperature of this recirculated volume of water is the one resulting from the mixing of the receiving water with temperature T_e and the incoming water with temperature T_{in}.

The values of T_w for the ponded area A_{ow} (with $A_s = A_{ow}$) are presented in Table 2-2 for the initial conditions of Cell 2E in the Tailings Basin – Mitigation Design (Years 1-8). Similar calculations were conducted for each of the basins and time periods needed and are presented in Section 3. The input values used for the calculations are A_{ow} = 749,000 m^2, ρ = 1000 kg/m^3, Cp = 4184 J/kg/°C, Q =

0.664 m3/s, T_{in} = 41.1°C. Similar computations of T_w have been carried out for the wet tailings area A_{wt}. In this case, A_{wt} = 749,000 m^2, T_{in} = 41.1°C, and Q_{in} = 0.664 m^3/s. Recall that for the dry tailings area A_{dt}, $T_w = T_e$ (obtained using $\alpha = 0.5$). Average basin areas for Cells 1E and 2E were used in the final calculations. The discharge rate was set equal to the rate of water from the plant that is expected to reach the pond.

Thus, the monthly values of water temperature at the air-water interface have been computed for the three calculation areas A_{ow}, A_{wt} and A_{dt}. These values, together with the recorded values of air temperature, wind speed and relative humidity at International Falls, MN, were used as input in the Meyer evaporation model. Additional assumptions related to amount of open water area in the winter were needed. For the Tailings Basin it was assumed that from April to October the entire water area would be ice free, in March and November 25% of the water area would be ice free, and in December and January 10% of the water area would be ice free. The estimates of average annual evaporation rates for each of the calculation areas are as follows:

- Cell 2E during Years 1-8 = 33 inches per year;
- Cell 1E during Years 1-8 = 19 inches per year;
- Cell 2E/1E during Years 9-20 = 31 inches per year; and
- Active Tailings Basin Beach Areas = 46 inches per year.

Note that the annual estimates are much larger than what is normally predicted for this geographic location. Two factors make the difference in this case: there is an open-water surface all year round, and there is a continuous external input of hot water.

Table 2-2

Monthly Values of Measured Air Temperature at International Falls, MN (Coop ID 214026), and Estimated Dew Point Temperature, Equilibrium Water Temperature and Mixed Water Temperature

Month	Air Temperature (°C)	Dew Point Temperature (°C)	Equilibrium Water Temperature (°C)	Mixed Water Temperature Cell 2E Years 1-8 (°C)	Mixed Water Temperature Cell 2E/1E Years 9-20 (°C)
January	-17.2	-21.2	1.0	2.7	1.6
February	-13.5	-18.4	1.0	2.9	1.7
March	-5.5	-10.9	1.0	2.9	1.7
April	3.9	-3.0	6.3	7.6	6.7
May	11.2	3.9	13.2	13.9	13.4
June	16.3	10.3	19.0	19.3	19.1
July	19.3	13.9	22.2	22.3	22.2
August	17.6	13.1	20.3	20.5	20.4
September	11.9	8.0	13.9	14.5	14.1
October	5.8	1.5	5.8	7.2	6.3
November	-3.9	-7.1	1.0	3.0	1.7
December	-13.8	-17.0	1.0	2.9	1.7

2.4 Weather Data

A variety of weather data are required as input for the Meyer Model. Average wind speed and relative humidity from International Falls were used, as that was the closest inland site for which those data are available. Precipitation and temperature data from the nearest location were downloaded from the MN Climatology Group web site (http://climate.umn.edu/doc/historical.htm). The availability changed over time and observations from the following locations were used: Babbitt (1931-1951 and 1982-1986), Hoyt Lakes (1958-1982), Tower (1986-1994), and Embarrass (1994-2004).

3.0 Watershed Delineation and Land Cover Classification

Watersheds were initially delineated using the Spatial Analyst Toolbox in ArcGIS 9.1 with the Mesabi Range Digital Terrain Model provided by the MN DNR. These watershed delineations were then visually inspected and watersheds were modified as necessary, combining some smaller watersheds if appropriate. A 2000 survey, completed by Barr Engineering Co. for LTV Steel Mining Company, indicated that some changes had occurred before the facility closed within the Tailings Basins. The Tailings Basins watersheds were manually modified based on the contours generated by the 2000 survey. Watershed areas used in this study and the two previous studies area summarized in Table 3-1.

Table 3-1

Watershed Areas for Existing Conditions for the Current Study and Two Previous studies

	Cell 1E (acres)	Cell 2E (acres)	Cell 2W (acres)
Current Study	1591	747	958
Barr LTV Study	1855	749	953
East Range Hydrology Study	1350	746	954

The watershed sizes for Cells 2W and 2E are very similar to the two previous studies. There is some discrepancy in the watershed area for Cell 1E between the studies. The difference is caused by two landlocked areas that may drain to Cell 1E if the water level is high enough. While the upland area tributary to the Tailings Basins is need for the calibration of this model, most of these areas will be blocked from draining to the Tailings Basins in future conditions by the construction of new dikes. Existing watershed boundaries and land cover classification are shown in Figure 3-1. Future watershed boundaries and land cover classification for the Tailings Basin – Mitigation Design were modified as appropriate from the areas that were calculated for the Tailings Basin – Proposed Design (see RS13 Draft-03 Attachment A-5 Figures 3-2 through 3-5).

The land cover data from the PolyMet EAW were used to develop the land cover classification used in the Meyer Model. These data were developed from field surveys conducted by Barr Engineering Co. and a 2003 aerial photo. The data were simplified into two water categories and five upland categories to be used in the Meyer Model as summarized in Table 3-2. Land cover areas are summarized in Table 3-2 for existing watersheds and in Table 3-3 for proposed watersheds based on cell elevations.

Table 3-2

Land Cover Areas for Existing Conditions

Land Cover Classification	Cell 1E (acres)	Cell 2E (acres)	Cell 2W (acres)
Shallow Water[1]	472.1 – 376.1	0	0
Deep Water	0	0	0
Reclaimed Tailings Basin[1]	571.4 – 475.3	634.0	957.7
Developed	21.6	0	0
Grassland/Brushland	21.259	23.7	0
Forest	600.2	89.3	0
Total	1590.5	747.0	957.7

[1] The Shallow Water and Reclaimed Tailings Basin Areas were calculated each month as the water level in the pond went down.

Table 3-3

Land Cover Areas for Future Conditions

Land Use/Cover	Cell 1E Years 1-8 acres	Cell 2E Year 1 acres	Cell 2E Year 8 acres	Cell 2E/1E Year 9 acres	Cell 2E/1E Year 20 acres
Tailings Basin Pond	336	350	765	1197	1119
Active Beach	389	224	175	287	338
Reclaimed Tailings Basin	571.4	241	82	72	12
Forrest/Brush	621.5	86	124	110	40

4.0 Model Calibration

The Meyer Model that was used in this study was calibrated to observed water levels in Cell 1E and Cell 2E from April 2002-September 2003. Water level measurements were collected by the MN DNR for the East Range Hydrology Project (Adams, et. al, 2004). Precipitation measurements made on site from May-October in 2002 and 2003 were combined with precipitation data from Embarrass, Minnesota to create the precipitation record used in the model calibration. Temperature data from Embarrass, Minnesota and wind and humidity data from International Falls, Minnesota completed the climate inputs to the model.

The Meyer Model developed for the LTV study was used as a starting point for calibrating the water balance (Adams, et. al, 2004). This model used a land-use classification that included four upland categories (Crust, Developed, Forbes, and Forest) and two water categories (Shallow Water/Wetland and Deep Water. Since the majority of the Tailings Basin site had been revegetated with alfalfa, one additional category (Reclaimed Tailings Basin) was added for this study; this category incorporated the infiltration characteristics of tailings basin with evapotranspiration for alfalfa ground cover.

Seepage occurs both between the Tailings Basins ponds and out of the ponds through the surrounding dikes. Net seepage was estimated in the East Range Hydrology Project (Adams et. al, 2004) for each pond during the summer of 2002 and the summer of 2003. That study found a decrease in seepage over the two years as the water level in the pond went down. For this study, seepage was assumed to be directly proportional to the water surface elevation (or head) in the pond. Each month the seepage was calculated using linear interpolation of water surface elevation on the two seepage estimates from the East Rangy Hydrology Study, with the two estimates representing the extreme minimum and maximum seepage rates.

The resulting water surface elevations are shown in Figure 4-1. The root mean squared error for the modeled water levels in Cell 1E is 0.5 feet and for Cell 2E it is 0.25 feet.

5.0 Watershed Yield Calculations

The calibrated Meyer Model, with updated evaporation calculations accounting for heated water, was used to predict watershed yields for the Tailings Basin – Mitigation Design. The Meyer Model was used to predict evaporation, infiltration, and runoff from both the inactive cell and the contributing watershed areas. Watershed yields for the basin were calculated for the entire 20-year life of the basin. Meyer Model results are shown in Table 5-1. Model results, reported in inches, were multiplied by the areas of the corresponding land uses to determine runoff volumes for the water balances.

References

Adams, J.L., Leibfried, R.T., and Herr, E.S., 2004. East Range hydrology Project, Minnesota Department of Natural Resources, Final Report, March, 2004.

Barr Engineering Company. 1994. *Twin City—South Mine Pit Lake—Lake Restoration Plan*. Prepared for Minnesota Aquafarms, Inc. 1994.

Barr Engineering Company. 1990. *Laurentian Taconite Mine—Draft Environmental Impact Statement*. Prepared for Inland Steel Mining Company. June.

Barr Engineering Company. 1986. *Hydrologic and Nutrient Budget Analyses of Swan Lake, Itasca County, Minnesota*. Report prepared for M.A. Hanna Company. October.

Barr Engineering Company. undated. *Documentation and User's Guide for Meyer Method Watershed Yield Computer Program.*

Blight, G.E., 2002. Measuring evaporation from soil surfaces for environmental and geotechnical purposes. *Water SA*, 28(4): 381-394.

Bogan, T., Mohseni, O. and Stefan, H.G., 2003. Stream temperature-equilibrium temperature relationship. *Water Resources Research*, 39(9): 12 pp.

Brady, D.K., Graves, W.L. and Geyer, J.C., 1969. Surface heat exchange at power plant cooling lakes. *Edison Electric Institute Publication #69-901*, Res. Project Report RP 49-5, Johns Hopkins University.

Bras, R.L., 1990. *Hydrology: An introduction to hydrologic science*. Addison-Wesley Publishing Company, Reading, MA: 643 pp.

Fujiyasu, Y., Fahey, M. and Newson, T., 2000. Field investigation of evaporation from freshwater tailings. *Journal of Geotechnical and Geoenvironmental Engineering*, 126(6): 556-567.

Gibson, J.J., Reid, R. and Spence, C., 199). A six-year isotopic record of lake evaporation at a mine site in the Canadian subarctic: results and validation. *Hydrological Processes*, 12: 1779-1792.

Henneman, H.E. and Stefan, H.G., 1999. Albedo models for snow and ice on a freshwater lake. *Cold Regions Science and Technology*, 29: 31-48.

Maidment, D.R., 1992. *Handbook of hydrology*. McGraw-Hill, Inc., New York, NY: Chapter 4.

Meyer, A. 1947. *Elements of Hydrology*. Chapter 6: Evaporation from Land Areas. New York: John Wiley & Sons, Inc.

Rassam, 2002. Variation of evaporative and shear strength parameters along a tailings delta. *Canadian Geotechnical Journal*, 39: 32-45.

Seneviratne, N.H., Fahey, M., Newson, T.A. and Fujiyasu, Y., 1996. Numerical modeling of consolidation and evaporation of slurried mine tailings. *International Journal for Numerical and Analytical Methods in Geomechanics*, 20: 647-671.

Thomann, R.V. and Mueller, J.A., 1987. *Principles of surface water quality modeling and control*. Harper Collins Publishers, New York, NY: Chapter 9.

Tables

Table 5-1
Meyer Model Results

						Upland Number 1: Crust					Upland Number 2: Developed					Upland Number 3: Forbes					Upland Number 4: Forest					Upland Number 5: Reclaimed Tailings Basin					Shallow Water
Year	Month	Precip	Temp	Wind	Rel Hum	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Evaporation
		Inches	F			Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
1971	1	0.64	-4.35	9.00	0.68	0.00	0.00	3.46	3.28	0.00	0.00	0.00	3.54	0.07	0.00	0.00	0.00	3.68	0.06	0.00	0.00	0.00	3.68	0.06	0.00	0.00	0.00	3.68	0.06	0.00	0.09
1971	2	1.85	9.60	10.10	0.62	0.00	0.00	5.04	3.05	0.00	0.00	0.00	5.13	0.25	0.00	0.00	0.00	5.32	0.21	0.00	0.00	0.00	5.32	0.21	0.00	0.00	0.00	5.32	0.21	0.00	0.35
1971	3	2.05	19.35	9.60	0.66	0.00	0.00	6.33	2.43	0.00	0.00	0.00	6.47	0.71	0.00	0.00	0.00	6.77	0.60	0.00	0.00	0.00	6.77	0.60	0.00	0.00	0.00	6.77	0.60	0.00	0.55
1971	4	0.83	36.70	11.20	0.63	5.13	1.26	0.00	1.92	0.00	4.32	2.27	0.00	0.71	0.00	4.39	2.58	0.00	0.60	0.00	4.04	2.08	0.00	0.60	0.00	4.93	2.07	0.00	0.60	0.00	1.64
1971	5	3.01	46.90	10.00	0.60	0.29	1.02	0.00	2.94	0.00	0.60	0.83	0.00	1.58	0.00	0.15	0.69	0.00	1.34	0.83	0.00	0.57	0.00	1.34	1.11	0.40	0.44	0.00	1.34	0.83	2.48
1971	6	4.45	62.60	6.60	0.73	0.66	0.80	0.00	3.79	0.00	1.70	0.00	0.00	2.78	0.00	1.25	0.00	0.00	2.35	2.24	1.10	0.00	0.00	2.35	2.93	1.14	0.00	0.00	2.35	2.23	2.46
1971	7	2	60.05	9.60	0.75	0.29	0.14	0.00	4.20	0.00	0.60	0.00	0.00	1.46	0.00	0.15	0.00	0.00	1.23	1.81	0.00	0.00	0.00	1.23	2.24	0.40	0.00	0.00	1.23	1.64	2.82
1971	8	5.4	59.25	8.00	0.74	0.80	1.62	0.00	3.43	0.00	2.13	0.41	0.00	2.76	0.00	1.68	0.00	0.00	2.34	1.38	1.53	0.00	0.00	2.34	1.65	1.42	0.00	0.00	2.34	1.32	2.93
1971	9	4.81	54.45	9.20	0.82	0.47	1.89	0.00	2.08	0.00	1.14	1.39	0.00	2.28	0.00	0.69	0.00	0.00	1.93	1.07	0.54	0.00	0.00	1.93	1.30	0.76	0.00	0.00	1.93	1.08	2.32
1971	10	7.2	45.40	9.70	0.86	0.71	3.80	0.00	1.00	0.00	1.86	2.84	0.00	2.50	0.00	1.41	1.97	0.00	2.12	0.24	1.26	1.01	0.00	2.12	0.32	1.24	2.42	0.00	2.12	0.24	1.50
1971	11	2.17	24.35	9.50	0.90	0.00	0.00	1.52	1.82	0.00	0.00	0.00	1.57	0.60	0.00	0.00	0.00	1.66	0.51	0.00	0.00	0.00	1.66	0.51	0.00	0.00	0.00	1.66	0.51	0.00	0.38
1971	12	0.8	9.65	9.40	0.85	0.00	0.00	2.32	2.98	0.00	0.00	0.00	2.37	0.00	0.00	0.00	0.00	2.46	0.00	0.00	0.00	0.00	2.46	0.00	0.00	0.00	0.00	2.46	0.00	0.00	0.11
1972	1	0.88	-6.00	10.70	0.73	0.00	0.00	3.13	3.28	0.00	0.00	0.00	3.18	0.07	0.00	0.00	0.00	3.29	0.06	0.00	0.00	0.00	3.29	0.06	0.00	0.00	0.00	3.29	0.06	0.00	0.06
1972	2	0.52	2.85	8.60	0.64	0.00	0.00	3.52	3.05	0.00	0.00	0.00	3.58	0.12	0.00	0.00	0.00	3.70	0.10	0.00	0.00	0.00	3.70	0.10	0.00	0.00	0.00	3.70	0.10	0.00	0.19
1972	3	1.23	17.50	8.80	0.62	0.00	0.00	4.14	2.43	0.00	0.00	0.00	4.24	0.57	0.00	0.00	0.00	4.45	0.48	0.00	0.00	0.00	4.45	0.48	0.00	0.00	0.00	4.45	0.48	0.00	0.54
1972	4	1.84	33.80	9.30	0.60	3.49	1.45	0.00	1.92	0.00	3.01	2.10	0.00	0.97	0.00	2.77	2.71	0.00	0.82	0.00	2.42	3.06	0.00	0.82	0.00	3.36	2.12	0.00	0.82	0.00	1.43
1972	5	1.47	55.40	8.60	0.63	0.14	0.16	0.00	2.94	0.00	0.14	0.24	0.00	1.09	0.00	0.00	0.00	0.00	0.92	1.64	0.00	0.00	0.00	0.92	2.15	0.09	0.00	0.00	0.92	1.62	2.92
1972	6	1.56	59.45	8.60	0.59	0.22	0.04	0.00	3.79	0.00	0.40	0.00	0.00	1.20	0.00	0.00	0.00	0.00	1.02	1.81	0.00	0.00	0.00	1.02	2.22	0.27	0.00	0.00	1.02	1.61	3.75
1972	7	4.79	60.90	8.00	0.66	0.71	1.00	0.00	4.20	0.00	1.86	0.03	0.00	2.86	0.00	1.41	0.00	0.00	2.42	1.74	1.26	0.00	0.00	2.42	2.02	1.24	0.00	0.00	2.42	1.55	3.50
1972	8	5.64	61.30	7.70	0.68	0.84	1.59	0.00	3.43	0.00	2.24	0.42	0.00	2.98	0.00	1.79	0.00	0.00	2.52	1.43	1.64	0.00	0.00	2.52	1.62	1.49	0.00	0.00	2.52	1.37	3.65
1972	9	3.27	48.00	10.60	0.66	0.32	1.43	0.00	2.08	0.00	0.68	1.17	0.00	1.42	0.00	0.23	0.00	0.00	1.20	0.43	0.08	0.00	0.00	1.20	0.51	0.45	0.00	0.00	1.20	0.43	3.05
1972	10	1.4	37.35	10.30	0.67	0.13	0.74	0.00	1.00	0.00	0.12	0.79	0.00	0.49	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.42	0.00	0.08	0.00	0.00	0.42	0.00	1.98
1972	11	0.75	23.15	8.70	0.76	0.00	0.00	0.75	1.82	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.65
1972	12	0.89	3.20	8.90	0.64	0.00	0.00	1.64	2.98	0.00	0.00	0.00	1.64	0.00	0.00	0.00	0.00	1.64	0.00	0.00	0.00	0.00	1.64	0.00	0.00	0.00	0.00	1.64	0.00	0.00	0.24
1973	1	0.49	9.50	8.00	0.68	0.00	0.00	1.86	3.28	0.00	0.00	0.00	1.88	0.25	0.00	0.00	0.00	1.92	0.21	0.00	0.00	0.00	1.92	0.21	0.00	0.00	0.00	1.92	0.21	0.00	0.24
1973	2	0.23	12.10	8.80	0.65	0.00	0.00	1.75	3.05	0.00	0.00	0.00	1.79	0.32	0.00	0.00	0.00	1.88	0.27	0.00	0.00	0.00	1.88	0.27	0.00	0.00	0.00	1.88	0.27	0.00	0.35
1973	3	1.2	32.05	8.90	0.68	1.51	0.57	0.00	2.43	0.00	1.10	1.08	0.00	0.81	0.00	0.96	0.59	0.00	0.68	0.00	0.61	0.00	0.00	0.68	0.00	1.30	0.53	0.00	0.68	0.00	1.05
1973	4	1.55	36.25	10.00	0.60	0.15	0.42	0.00	1.92	0.00	0.17	0.47	0.00	0.91	0.00	0.00	0.78	0.00	0.77	0.00	0.00	0.70	0.00	0.77	0.00	0.11	0.67	0.00	0.77	0.00	1.64
1973	5	4.28	48.00	9.90	0.57	0.42	1.61	0.00	2.94	0.00	0.98	1.21	0.00	2.09	0.00	0.53	1.02	0.00	1.77	0.96	0.38	0.85	0.00	1.77	1.28	0.66	0.89	0.00	1.77	0.96	2.76
1973	6	4.73	59.00	9.50	0.60	0.70	1.07	0.00	3.79	0.00	1.83	0.15	0.00	2.75	0.00	1.38	0.00	0.00	2.32	1.98	1.23	0.00	0.00	2.32	2.61	1.22	0.00	0.00	2.32	1.98	3.77
1973	7	4.8	64.00	8.30	0.63	0.71	0.85	0.00	4.20	0.00	1.86	0.00	0.00	3.01	0.00	1.41	0.00	0.00	2.55	2.19	1.26	0.00	0.00	2.55	2.74	1.24	0.00	0.00	2.55	2.18	4.28
1973	8	4.81	64.10	6.70	0.75	0.71	1.11	0.00	3.43	0.00	1.86	0.09	0.00	2.78	0.00	1.41	0.00	0.00	2.35	1.74	1.26	0.00	0.00	2.35	2.05	1.24	0.00	0.00	2.35	1.71	3.12
1973	9	2	50.90	8.80	0.74	0.19	0.73	0.00	2.08	0.00	0.30	0.70	0.00	1.00	0.00	0.00	0.00	0.00	0.85	0.64	0.00	0.00	0.00	0.85	0.73	0.20	0.00	0.00	0.85	0.61	2.55
1973	10	5.5	45.65	9.30	0.72	0.54	2.75	0.00	1.00	0.00	1.35	2.10	0.00	2.05	0.00	0.90	0.11	0.00	1.74	0.27	0.75	0.00	0.00	1.74	0.33	0.90	0.49	0.00	1.74	0.27	2.28
1973	11	0.89	25.25	9.50	0.71	0.00	0.00	0.89	1.82	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.89
1973	12	0.56	9.55	8.70	0.64	0.00	0.00	1.45	2.98	0.00	0.00	0.00	1.45	0.00	0.00	0.00	0.00	1.45	0.00	0.00	0.00	0.00	1.45	0.00	0.00	0.00	0.00	1.45	0.00	0.00	0.36
1974	1	0.79	2.10	8.50	0.60	0.00	0.00	2.13	3.28	0.00	0.00	0.00	2.13	0.11	0.00	0.00	0.00	2.15	0.09	0.00	0.00	0.00	2.15	0.09	0.00	0.00	0.00	2.15	0.09	0.00	0.22
1974	2	0.69	9.30	8.30	0.52	0.00	0.00	2.55	3.05	0.00	0.00	0.00	2.58	0.25	0.00	0.00	0.00	2.63	0.21	0.00	0.00	0.00	2.63	0.21	0.00	0.00	0.00	2.63	0.21	0.00	0.44
1974	3	1.16	18.25	9.90	0.56	0.00	0.00	3.07	2.43	0.00	0.00	0.00	3.14	0.59	0.00	0.00	0.00	3.29	0.50	0.00	0.00	0.00	3.29	0.50	0.00	0.00	0.00	3.29	0.50	0.00	0.71
1974	4	1.45	38.10	9.90	0.59	2.59	0.97	0.00	1.92	0.00	2.13	1.58	0.00	0.89	0.00	1.95	2.03	0.00	0.75	0.00	1.60	1.46	0.00	0.75	0.00	2.41	1.58	0.00	0.75	0.00	1.80
1974	5	4.83	46.30	9.50	0.60	0.47	2.00	0.00	2.94	0.00	1.15	1.49	0.00	2.19	0.00	0.70	1.52	0.00	1.86	0.76	0.55	1.42	0.00	1.86	1.01	0.77	1.45	0.00	1.86	0.76	2.36
1974	6	2.59	58.15	9.00	0.54	0.38	0.35	0.00	3.79	0.00	0.87	0.00	0.00	1.72	0.00	0.42	0.00	0.00	1.46	1.88	0.27	0.00	0.00	1.46	2.48	0.58	0.00	0.00	1.46	1.84	4.10
1974	7	2.61	67.70	9.00	0.62	0.38	0.06	0.00	4.20	0.00	0.87	0.00	0.00	2.01	0.00	0.42	0.00	0.00	1.70	2.29	0.27	0.00	0.00	1.70	2.85	0.58	0.00	0.00	1.70	2.01	5.17
1974	8	4.01	59.60	9.80	0.71	0.59	1.05	0.00	3.43	0.00	1.51	0.03	0.00	2.20	0.00	1.06	0.00	0.00	1.86	1.29	0.91	0.00	0.00	1.86	1.52	1.00	0.00	0.00	1.86	1.12	3.56
1974	9	1.28	46.35	9.00	0.68	0.12	0.52	0.00	2.08	0.00	0.08	0.60	0.00	0.60	0.00	0.00	0.00	0.00	0.51	0.26	0.00	0.00	0.00	0.51	0.29	0.06	0.00	0.00	0.51	0.23	2.53
1974	10	3.1	42.10	9.20	0.66	0.30	1.57	0.00	1.00	0.00	0.63	1.33	0.00	1.15	0.00	0.18	0.00	0.00	0.97	0.00	0.03	0.00	0.00	0.97	0.00	0.42	0.00	0.00	0.97	0.00	2.29
1974	11	1.66	26.75	95.00	0.71	0.00	0.00	1.12	1.82	0.00	0.00	0.00	1.16	0.50	0.00	0.00	0.00	1.24	0.43	0.00	0.00	0.00	1.24	0.43	0.00	0.00	0.00	1.24	0.43	0.00	5.22
1974	12	0.84	16.70	7.90	0.70	0.00	0.00	1.96	2.98	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	2.08	0.00	0.00	0.00	0.00	2.08	0.00	0.00	0.00	0.00	2.08	0.00	0.00	0.43
1975	1	3.28	6.75	8.70	0.64	0.00	0.00	5.03	3.28	0.00	0.00	0.00	5.08	0.20	0.00	0.00	0.00	5.19	0.17	0.00	0.00	0.00	5.19	0.17	0.00	0.00	0.00	5.19	0.17	0.00	0.25
1975	2	1.25	9.90	8.40	0.59	0.00	0.00	6.00	3.05	0.00	0.00	0.00	6.07	0.26	0.00	0.00	0.00	6.22	0.22	0.00	0.00	0.00	6.22	0.22	0.00	0.00	0.00	6.22	0.22	0.00	0.37
1975	3	1.16	15.70	10.50	0.56	0.00	0.00	6.63	2.43	0.00	0.00	0.00	6.74	0.49	0.00	0.00	0.00	6.97	0.42	0.00	0.00	0.00	6.97	0.42	0.00	0.00	0.00	6.97	0.42	0.00	0.63
1975	4	0.68	33.20	9.60	0.61	5.36	1.21	0.00	1.92	0.00	4.51	2.23	0.00	0.68	0.00	4.53	1.83	0.00	0.58	0.00	4.18	1.37	0.00	0.58	0.00	5.07	1.25	0.00	0.58	0.00	1.39
1975	5	2.16	54.60	8.90	0.63	0.21	0.43	0.00	2.94	0.00	0.35	0.40	0.00	1.41	0.00	0.00	0.00	0.00	1.20	1.60	0.00	0.00	0.00	1.20	2.11	0.23	0.00	0.00	1.20	1.58	2.88
1975	6	5.45	59.85	7.90	0.77	0.81	1.31	0.00	3.79	0.00	2.15	0.20	0.00	3.10	0.00	1.70	0.00	0.00	2.62	2.00	1.55	0.00	0.00	2.62	2.53	1.44	0.00	0.00	2.62	1.97	2.05
1975	7	4.45	68.55	8.00	0.68	0.66	0.52	0.00	4.20	0.00	1.70	0.00	0.00	3.04	0.00	1.25	0.00	0.00	2.57	2.29	1.10	0.00	0.00	2.57	2.68	1.14	0.00	0.00	2.57	2.15	4.32
1975	8	2.93	61.35	8.20	0.75	0.43	0.59	0.00	3.43	0.00	1.02	0.00	0.00	1.77	0.00	0.57	0.00	0.00	1.50	1.34	0.42	0.00	0.00	1.50	1.45	0.68	0.00	0.00	1.50	1.15	3.09
1975	9	3.34	49.70	7.90	0.79	0.32	1.40	0.00	2.08	0.00	0.70	0.98	0.00	1.50	0.00	0.25	0.00	0.00	1.27	0.55	0.10	0.00	0.00	1.27	0.63	0.47	0.00	0.00	1.27	0.51	2.02
1975	10	1.63	44.15	9.10	0.74	0.15	0.74	0.00	1.00	0.00	0.19	0.76	0.00	0.69	0.00	0.00	0.00	0.00	0.58	0.10	0.00	0.00	0.00	0.58	0.12	0.13	0.00	0.00	0.58	0.10	2.03
1975	11	1.6	28.10	8.50	0.76	0.00	0.00	1.09	1.82	0.00	0.00	0.00	1.13	0.47	0.00	0.00	0.00	1.20	0.40	0.00	0.00	0.00	1.20	0.40	0.00	0.00	0.00	1.20	0.40	0.00	0.86
1975	12	0.94	8.55	7.40	0.78	0.00	0.00	2.03	2.98	0.00	0.00	0.00	2.07	0.00	0.00	0.00	0.00	2.14	0.00	0.00	0.00	0.00	2.14	0.00	0.00	0.00	0.00	2.14	0.00	0.00	0.16
1976	1	1.29	1.25	9.10	0.72	0.00	0.00	3.23	3.28	0.00	0.00	0.00	3.27	0.09	0.00	0.00	0.00	3.36	0.08	0.00	0.00	0.00	3.36	0.08	0.00	0.00	0.00	3.36	0.08	0.00	0.11
1976	2	0.56	16.85	8.70	0.70	0.00	0.00	3.26	3.05	0.00	0.00	0.00	3.34	0.49	0.00	0.00	0.00	3.50	0.41	0.00	0.00	0.00	3.50	0.41	0.00	0.00	0.00	3.50	0.41	0.00	0.38
1976	3	2.48	19.20	10.10	0.67	0.00	0.00	4.98	2.43	0.00	0.00	0.00	5.12	0.70	0.00	0.00	0.00	5.39	0.59	0.00	0.00	0.00	5.39	0.59	0.00	0.00	0.00	5.39	0.59	0.00	0.53
1976	4	1.07	42.85	8.90	0.62	4.08	1.12	0.00	1.92	0.00	3.39	2.00	0.00	0.79	0.00	3.42	0.59	0.00	0.67	0.34	3.07	0.00	0.00	0.67	0.46	3.91	0.23	0.00	0.67	0.34	1.90
1976	5	0.73	51.50	9.10	0.55	0.06	0.00	0.00	2.94	0.00	0.00	0.06	0.00	0.67	0.00	0.00	0.00	0.00	0.57	1.29	0.00	0.00	0.00	0.57	1.67	0.00	0.00	0.00	0.57	1.27	3.16
1976	6	6.69	64.60	9.00	0.73	0.99	1.44	0.00	3.79	0.00	2.71	0.08	0.00	3.90	0.00	2.26	0.00	0.00	3.30	2.25	2.11	0.00	0.00	3.30	2.78	1.81	0.00	0.00	3.30	2.28	3.02
1976	7	1.47	64.45	7.00	0.71	0.21	0.00	0.00	4.20	0.00	0.36	0.00	0.00	1.24	0.00	0.00	0.00	0.00	1.05	1.83	0.00	0.00	0.00	1.05	2.01	0.24	0.00	0.00	1.05	1.62	3.24
1976	8	0.47	63.50	6.80	0.70	0.06	0.00	0.00	3.43	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.36	1.18	0.00	0.00	0.00	0.36	1.01	0.00	0.00	0.00	0.36	0.83	3.55
1976	9	0.99	51.55	7.50	0.69	0.09	0.19	0.00	2.08	0.00	0.00	0.34	0.00	0.57	0.00	0.00	0.00	0.00	0.48	0.45	0.00	0.00	0.00	0.48	0.37	0.00	0.00	0.00	0.48	0.33	2.75
1976	10	1.41	34.90	7.30	0.71	0.13	0.78	0.00	1.00	0.00	0.12	0.82	0.00	0.46	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.39	0.00	0.08	0.00	0.00	0.39	0.00	1.40
1976	11	0.15	18.45	9.20	0.71	0.00	0.00	0.15	1.82	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.59
1976	12	0.71	0.20	8.40	0.72	0.00	0.00	0.86	2.98	0.00	0.00	0.00	0.86	0.00	0.00	0.00	0.00	0.86	0.00	0.00	0.00	0.00	0.86	0.00	0.00	0.00	0.00	0.86	0.00	0.00	0.13
1977	1	0.51	-4.10	7.50	0.71	0.00	0.00	1.30	3.28	0.00	0.00	0.00	1.31	0.07	0.00	0.00	0.00	1.32	0.06	0.00	0.00	0.00	1.32	0.06	0.00	0.00	0.00	1.32	0.06	0.00	0.07
1977	2	0.21	12.90	8.80	0.69	0.00	0.00	1.14	3.05	0.00	0.00	0.00	1.17	0.34	0.00	0.00	0.00	1.24	0.29	0.00	0.00	0.00	1.24	0.29	0.00	0.00	0.00	1.24	0.29	0.00	0.31
1977	3	1.61	30.75	9.50	0.70	1.06	0.73	0.00	2.43	0.00	0.79	1.10	0.00	0.89	0.00	0.51	0.00	0.00	0.75	0.00	0.16	0.00	0.00	0.75	0.00	0.90	0.00	0.00	0.75	0.00	0.94
1977	4	1.15	43.70	8.20	0.64	0.11	0.16	0.00	1.92	0.00	0.05	0.28	0.00	0.82	0.00	0.00	0.00	0.00	0.70	0.37	0.00	0.00	0.00	0.70	0.46	0.03	0.00	0.00	0.70	0.37	1.80
1977	5	5.57	59.55	8.70	0.64	0.55	1.65	0.00	2.94	0.00	1.37	1.07	0.00	3.13	0.00	0.92	0.00	0.00	2.65	1.91	0.77	0.00	0.00	2.65	2.37	0.91	0.00	0.00	2.65	1.93	3.32
1977	6	4.21	60.75	7.30	0.74	0.62	0.80	0.00	3.79	0.00	1.60	0.02	0.00	2.59	0.00	1.15	0.00	0.00	2.20	1.80	1.00	0.00	0.00	2.20	2.11	1.06	0.00	0.00	2.20	1.78	2.31
1977	7	3.27	65.25	8.20	0.76	0.48	0.31	0.00	4.20	0.00	1.17	0.00	0.00	2.30	0.00	0.72	0.00	0.00	1.95	1.77	0.57	0.00	0.00	1.95	1.90	0.78	0.00	0.00	1.95	1.58	3.02
1977	8	7.94	57.05	7.70	0.80	1.18	2.90	0.00	3.43	0.00	3.27	0.88	0.00	3.59	0.00	2.82	0.00	0.00	3.03	1.10	2.67	0.00	0.00	3.03	1.25	2.18	0.00	0.00	3.03	1.21	2.19
1977	9	6.21	52.75	7.60	0.88	0.61	2.70	0.00	2.08	0.00	1.56	1.95	0.00	2.70	0.00	1.11	0.00	0.00	2.28	0.94	0.96	0.00	0.00	2.28	1.12	1.04	0.04	0.00	2.28	0.99	1.60
1977	10	2.08	42.40	9.10	0.72	0.20	1.03	0.00	1.00	0.00	0.32	0.96	0.00	0.80	0.00	0.00	0.27	0.00	0.67	0.00	0.00	0.00	0.00	0.67	0.00	0.22	1.19	0.00	0.67	0.00	2.00

Table 5-1
Meyer Model Results

						Upland Number 1: Crust					Upland Number 2: Developed					Upland Number 3: Forbes					Upland Number 4: Forest					Upland Number 5: Reclaimed Tailings Basin					Shallow Water
Year	Month	Precip	Temp	Wind	Rel Hum	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Evaporation
		Inches	F			Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
1977	11	3.28	25.50	9.00	0.81	0.00	0.00	2.50	1.82	0.00	0.00	0.00	2.55	0.73	0.00	0.00	0.00	2.67	0.62	0.00	0.00	0.00	2.67	0.62	0.00	0.00	0.00	2.67	0.62	0.00	0.63
1977	12	1.33	7.00	8.50	0.68	0.00	0.00	3.62	2.98	0.00	0.00	0.00	3.69	0.19	0.00	0.00	0.00	3.83	0.16	0.00	0.00	0.00	3.83	0.16	0.00	0.00	0.00	3.83	0.16	0.00	0.26
1978	1	0.52	-0.10	8.00	0.54	0.00	0.00	4.07	3.28	0.00	0.00	0.00	4.15	0.07	0.00	0.00	0.00	4.30	0.06	0.00	0.00	0.00	4.30	0.06	0.00	0.00	0.00	4.30	0.06	0.00	0.23
1978	2	0.39	3.95	6.70	0.51	0.00	0.00	4.31	3.05	0.00	0.00	0.00	4.39	0.14	0.00	0.00	0.00	4.57	0.12	0.00	0.00	0.00	4.57	0.12	0.00	0.00	0.00	4.57	0.12	0.00	0.30
1978	3	0.67	20.95	7.90	0.53	0.00	0.00	4.31	2.43	0.00	0.00	0.00	4.45	0.62	0.00	0.00	0.00	4.72	0.52	0.00	0.00	0.00	4.72	0.52	0.00	0.00	0.00	4.72	0.52	0.00	0.80
1978	4	1.38	36.85	9.50	0.59	3.58	1.18	0.00	1.92	0.00	3.02	1.94	0.00	0.87	0.00	2.95	2.41	0.00	0.73	0.00	2.60	1.91	0.00	0.73	0.00	3.46	1.90	0.00	0.73	0.00	1.68
1978	5	4.76	54.30	8.10	0.55	0.47	1.55	0.00	2.94	0.00	1.13	1.09	0.00	2.54	0.00	0.68	0.34	0.00	2.15	1.59	0.53	0.00	0.00	2.15	2.11	0.75	0.27	0.00	2.15	1.59	3.32
1978	6	3.06	59.10	9.00	0.61	0.45	0.46	0.00	3.79	0.00	1.08	0.00	0.00	2.00	0.00	0.63	0.00	0.00	1.69	1.96	0.48	0.00	0.00	1.69	2.58	0.72	0.00	0.00	1.69	1.93	3.59
1978	7	7.43	63.55	8.20	0.73	1.10	1.84	0.00	4.20	0.00	3.04	0.20	0.00	4.17	0.00	2.59	0.00	0.00	3.53	2.20	2.44	0.00	0.00	3.53	2.75	2.03	0.00	0.00	3.53	2.23	3.16
1978	8	4.4	62.65	9.00	0.80	0.65	1.04	0.00	3.43	0.00	1.68	0.21	0.00	2.52	0.00	1.23	0.00	0.00	2.13	1.67	1.08	0.00	0.00	2.13	1.97	1.12	0.00	0.00	2.13	1.67	2.85
1978	9	2.45	56.50	9.70	0.83	0.24	0.74	0.00	2.08	0.00	0.44	0.65	0.00	1.37	0.00	0.00	0.00	0.00	1.16	1.13	0.00	0.00	0.00	1.16	1.28	0.29	0.00	0.00	1.16	1.07	2.47
1978	10	1.25	42.35	9.60	0.75	0.12	0.58	0.00	1.00	0.00	0.08	0.66	0.00	0.52	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.44	0.00	0.05	0.00	0.00	0.44	0.00	1.90
1978	11	1.15	22.65	9.10	0.77	0.00	0.00	0.62	1.82	0.00	0.00	0.00	0.65	0.50	0.00	0.00	0.00	0.73	0.42	0.00	0.00	0.00	0.73	0.42	0.00	0.00	0.00	0.73	0.42	0.00	0.62
1978	12	0.45	3.25	8.20	0.74	0.00	0.00	1.07	2.98	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.00	1.18	0.00	0.00	0.00	0.00	1.18	0.00	0.00	0.00	0.00	1.18	0.00	0.00	0.15
1979	1	0.5	-3.75	7.00	0.68	0.00	0.00	1.50	3.28	0.00	0.00	0.00	1.54	0.07	0.00	0.00	0.00	1.62	0.06	0.00	0.00	0.00	1.62	0.06	0.00	0.00	0.00	1.62	0.06	0.00	0.09
1979	2	1.85	3.40	8.60	0.64	0.00	0.00	3.20	3.05	0.00	0.00	0.00	3.26	0.13	0.00	0.00	0.00	3.36	0.11	0.00	0.00	0.00	3.36	0.11	0.00	0.00	0.00	3.36	0.11	0.00	0.20
1979	3	3.45	22.00	10.10	0.69	0.00	0.00	5.75	2.43	0.00	0.00	0.00	5.86	0.84	0.00	0.00	0.00	6.10	0.71	0.00	0.00	0.00	6.10	0.71	0.00	0.00	0.00	6.10	0.71	0.00	0.59
1979	4	1.51	34.15	9.50	0.65	4.74	1.56	0.00	1.92	0.00	4.05	2.44	0.00	0.89	0.00	3.92	1.18	0.00	0.75	0.00	3.57	0.33	0.00	0.75	0.00	4.53	0.87	0.00	0.75	0.00	1.29
1979	5	2.83	46.25	9.60	0.62	0.27	0.95	0.00	2.94	0.00	0.55	0.79	0.00	1.49	0.00	0.10	0.72	0.00	1.26	0.75	0.00	0.57	0.00	1.26	1.00	0.37	0.45	0.00	1.26	0.75	2.25
1979	6	3.61	58.40	8.70	0.66	0.53	0.68	0.00	3.79	0.00	1.32	0.06	0.00	2.23	0.00	0.87	0.00	0.00	1.89	1.92	0.72	0.00	0.00	1.89	2.53	0.88	0.00	0.00	1.89	1.90	3.01
1979	7	3.85	64.65	6.60	0.79	0.57	0.51	0.00	4.20	0.00	1.43	0.00	0.00	2.58	0.00	0.98	0.00	0.00	2.18	2.18	0.83	0.00	0.00	2.18	2.72	0.96	0.00	0.00	2.18	2.06	2.41
1979	8	2.1	60.30	7.70	0.81	0.31	0.39	0.00	3.43	0.00	0.65	0.00	0.00	1.31	0.00	0.20	0.00	0.00	1.11	1.37	0.05	0.00	0.00	1.11	1.60	0.43	0.00	0.00	1.11	1.16	2.36
1979	9	2.42	53.50	8.50	0.81	0.23	0.83	0.00	2.08	0.00	0.43	0.72	0.00	1.26	0.00	0.00	0.00	0.00	1.07	0.85	0.00	0.00	0.00	1.07	0.98	0.28	0.00	0.00	1.07	0.73	2.24
1979	10	3.63	39.85	8.40	0.81	0.35	1.96	0.00	1.00	0.00	0.79	1.62	0.00	1.22	0.00	0.34	0.00	0.00	1.04	0.00	0.19	0.00	0.00	1.04	0.00	0.53	0.00	0.00	1.04	0.00	1.36
1979	11	0.69	24.65	8.20	0.80	0.00	0.00	0.69	1.82	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.59
1979	12	0.27	17.30	8.20	0.76	0.00	0.00	0.96	2.98	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.36
1980	1	0.95	5.10	6.50	0.69	0.00	0.00	1.73	3.28	0.00	0.00	0.00	1.75	0.16	0.00	0.00	0.00	1.77	0.14	0.00	0.00	0.00	1.77	0.14	0.00	0.00	0.00	1.77	0.14	0.00	0.16
1980	2	0.45	9.15	7.40	0.64	0.00	0.00	1.92	3.05	0.00	0.00	0.00	1.95	0.24	0.00	0.00	0.00	2.02	0.21	0.00	0.00	0.00	2.02	0.21	0.00	0.00	0.00	2.02	0.21	0.00	0.28
1980	3	0.78	17.65	8.50	0.58	0.00	0.00	2.12	2.43	0.00	0.00	0.00	2.20	0.54	0.00	0.00	0.00	2.34	0.45	0.00	0.00	0.00	2.34	0.45	0.00	0.00	0.00	2.34	0.45	0.00	0.60
1980	4	0.52	41.90	9.00	0.51	1.74	0.27	0.00	1.92	0.00	1.33	0.80	0.00	0.59	0.00	1.29	0.49	0.00	0.50	0.23	0.94	0.00	0.00	0.50	0.30	1.61	0.00	0.00	0.50	0.23	2.40
1980	5	0.64	55.90	7.70	0.52	0.05	0.00	0.00	2.94	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.55	1.64	0.00	0.00	0.00	0.55	2.11	0.00	0.00	0.00	0.55	1.59	3.71
1980	6	3.35	59.00	8.70	0.64	0.49	0.46	0.00	3.79	0.00	1.21	0.00	0.00	2.13	0.00	0.76	0.00	0.00	1.80	1.74	0.61	0.00	0.00	1.80	2.14	0.81	0.00	0.00	1.80	1.60	3.30
1980	7	2.81	66.40	7.20	0.63	0.41	0.15	0.00	4.20	0.00	0.96	0.00	0.00	2.09	0.00	0.51	0.00	0.00	1.77	1.90	0.36	0.00	0.00	1.77	2.15	0.64	0.00	0.00	1.77	1.54	4.43
1980	8	6	63.10	7.80	0.70	0.89	1.61	0.00	3.43	0.00	2.40	0.11	0.00	3.25	0.00	1.95	0.00	0.00	2.75	1.40	1.80	0.00	0.00	2.75	1.53	1.60	0.00	0.00	2.75	1.30	3.71
1980	9	5.35	52.05	9.10	0.83	0.53	2.30	0.00	2.08	0.00	1.31	1.70	0.00	2.35	0.00	0.86	0.00	0.00	1.99	0.77	0.71	0.00	0.00	1.99	0.91	0.87	0.00	0.00	1.99	0.79	2.09
1980	10	1.78	37.75	9.20	0.80	0.17	0.97	0.00	1.00	0.00	0.23	0.95	0.00	0.60	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.51	0.00	0.16	0.00	0.00	0.51	0.00	1.36
1980	11	0.34	26.85	7.80	0.86	0.00	0.00	0.34	1.82	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.52
1980	12	0.86	7.90	8.70	0.77	0.00	0.00	1.20	2.98	0.00	0.00	0.00	1.20	0.00	0.00	0.00	0.00	1.20	0.00	0.00	0.00	0.00	1.20	0.00	0.00	0.00	0.00	1.20	0.00	0.00	0.18
1981	1	0.36	8.85	7.30	0.74	0.00	0.00	1.30	3.28	0.00	0.00	0.00	1.32	0.24	0.00	0.00	0.00	1.36	0.20	0.00	0.00	0.00	1.36	0.20	0.00	0.00	0.00	1.36	0.20	0.00	0.16
1981	2	1.38	15.35	8.20	0.74	0.00	0.00	2.16	3.05	0.00	0.00	0.00	2.22	0.49	0.00	0.00	0.00	2.33	0.41	0.00	0.00	0.00	2.33	0.41	0.00	0.00	0.00	2.33	0.41	0.00	0.28
1981	3	0.8	27.70	8.50	0.68	0.00	0.00	2.20	2.43	0.00	0.00	0.00	2.31	0.70	0.00	0.00	0.00	2.53	0.59	0.00	0.00	0.00	2.53	0.59	0.00	0.00	0.00	2.53	0.59	0.00	0.81
1981	4	4.79	39.15	9.60	0.65	2.23	2.78	0.00	1.92	0.00	2.55	2.72	0.00	1.84	0.00	2.11	2.71	0.00	1.56	0.00	1.61	2.25	0.00	1.56	0.00	2.51	2.87	0.00	1.56	0.00	1.60
1981	5	1.13	50.90	7.50	0.57	0.10	0.10	0.00	2.94	0.00	0.04	0.23	0.00	0.86	0.00	0.00	0.00	0.00	0.73	1.26	0.00	0.00	0.00	0.73	1.66	0.03	0.00	0.00	0.73	1.25	2.74
1981	6	6.82	59.95	8.10	0.70	1.01	1.83	0.00	3.79	0.00	2.77	0.36	0.00	3.69	0.00	2.32	0.00	0.00	3.12	2.01	2.17	0.00	0.00	3.12	2.57	1.85	0.00	0.00	3.12	2.04	2.72
1981	7	4.34	65.60	7.10	0.67	0.64	0.62	0.00	4.20	0.00	1.65	0.00	0.00	2.86	0.00	1.20	0.00	0.00	2.42	2.15	1.05	0.00	0.00	2.42	2.56	1.10	0.00	0.00	2.42	2.15	3.81
1981	8	2.43	64.70	6.50	0.78	0.36	0.32	0.00	3.43	0.00	0.79	0.00	0.00	1.63	0.00	0.34	0.00	0.00	1.38	1.58	0.19	0.00	0.00	1.38	1.73	0.53	0.00	0.00	1.38	1.40	2.90
1981	9	2.84	51.95	8.50	0.80	0.27	1.07	0.00	2.08	0.00	0.55	0.73	0.00	1.39	0.00	0.10	0.00	0.00	1.18	0.69	0.00	0.00	0.00	1.18	0.78	0.37	0.00	0.00	1.18	0.62	2.19
1981	10	4.68	39.50	9.90	0.80	0.46	2.60	0.00	1.00	0.00	1.10	2.07	0.00	1.50	0.00	0.65	0.00	0.00	1.27	0.00	0.50	0.00	0.00	1.27	0.00	0.74	0.09	0.00	1.27	0.00	1.52
1981	11	0.6	33.40	8.30	0.80	0.05	0.30	0.00	1.82	0.00	0.00	0.37	0.00	0.23	0.00	0.00	0.24	0.00	0.20	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.41	0.00	0.20	0.00	0.97
1981	12	0.97	12.25	7.10	0.85	0.00	0.00	0.97	2.98	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.97	0.00	0.00	0.13
1982	1	1.17	-7.75	9.30	0.66	0.00	0.00	2.07	3.28	0.00	0.00	0.00	2.08	0.07	0.00	0.00	0.00	2.09	0.06	0.00	0.00	0.00	2.09	0.06	0.00	0.00	0.00	2.09	0.06	0.00	0.09
1982	2	0.38	7.25	8.50	0.72	0.00	0.00	2.23	3.05	0.00	0.00	0.00	2.25	0.21	0.00	0.00	0.00	2.29	0.18	0.00	0.00	0.00	2.29	0.18	0.00	0.00	0.00	2.29	0.18	0.00	0.17
1982	3	0.92	21.35	10.10	0.74	0.00	0.00	2.44	2.43	0.00	0.00	0.00	2.51	0.66	0.00	0.00	0.00	2.66	0.55	0.00	0.00	0.00	2.66	0.55	0.00	0.00	0.00	2.66	0.55	0.00	0.47
1982	4	1.07	35.70	9.40	0.63	2.05	0.62	0.00	1.92	0.00	1.57	1.24	0.00	0.78	0.00	1.51	1.56	0.00	0.66	0.00	1.16	1.25	0.00	0.66	0.00	1.86	1.21	0.00	0.66	0.00	1.46
1982	5	4.76	55.30	8.20	0.72	0.47	1.51	0.00	2.94	0.00	1.13	1.04	0.00	2.59	0.00	0.68	0.22	0.00	2.19	1.67	0.53	0.00	0.00	2.19	2.23	0.75	0.14	0.00	2.19	1.67	2.19
1982	6	3.01	55.05	8.10	0.73	0.44	0.59	0.00	3.79	0.00	1.05	0.12	0.00	1.84	0.00	0.60	0.00	0.00	1.56	1.64	0.45	0.00	0.00	1.56	2.15	0.70	0.00	0.00	1.56	1.62	2.09
1982	7	4.95	66.15	7.20	0.79	0.73	0.78	0.00	4.20	0.00	1.93	0.00	0.00	3.19	0.00	1.48	0.00	0.00	2.70	2.35	1.33	0.00	0.00	2.70	2.91	1.29	0.00	0.00	2.70	2.28	2.62
1982	8	4.4	60.80	7.10	0.81	0.65	1.14	0.00	3.43	0.00	1.68	0.13	0.00	2.42	0.00	1.23	0.00	0.00	2.05	1.49	1.08	0.00	0.00	2.05	1.75	1.12	0.00	0.00	2.05	1.42	2.37
1982	9	3.92	53.10	8.90	0.86	0.38	1.53	0.00	2.08	0.00	0.88	1.18	0.00	1.87	0.00	0.43	0.00	0.00	1.58	0.91	0.28	0.00	0.00	1.58	1.08	0.58	0.00	0.00	1.58	0.89	1.92
1982	10	5.45	45.90	9.10	0.83	0.54	2.71	0.00	1.00	0.00	1.34	2.06	0.00	2.05	0.00	0.89	0.81	0.00	1.74	0.29	0.74	0.00	0.00	1.74	0.39	0.89	1.03	0.00	1.74	0.29	1.68
1982	11	2.05	25.15	8.10	0.84	0.00	0.00	1.42	1.82	0.00	0.00	0.00	1.47	0.58	0.00	0.00	0.00	1.56	0.49	0.00	0.00	0.00	1.56	0.49	0.00	0.00	0.00	1.56	0.49	0.00	0.52
1982	12	1.59	19.10	9.10	0.83	0.00	0.00	2.41	2.98	0.00	0.00	0.00	2.49	0.56	0.00	0.00	0.00	2.67	0.48	0.00	0.00	0.00	2.67	0.48	0.00	0.00	0.00	2.67	0.48	0.00	0.30
1983	1	1.45	14.10	8.70	0.79	0.00	0.00	3.39	3.28	0.00	0.00	0.00	3.51	0.44	0.00	0.00	0.00	3.75	0.37	0.00	0.00	0.00	3.75	0.37	0.00	0.00	0.00	3.75	0.37	0.00	0.19
1983	2	1.26	20.40	7.80	0.81	0.00	0.00	3.91	3.05	0.00	0.00	0.00	4.09	0.68	0.00	0.00	0.00	4.44	0.58	0.00	0.00	0.00	4.44	0.58	0.00	0.00	0.00	4.44	0.58	0.00	0.25
1983	3	0.65	27.55	9.40	0.74	0.00	0.00	3.84	2.43	0.00	0.00	0.00	4.07	0.67	0.00	0.00	0.00	4.52	0.57	0.00	0.00	0.00	4.52	0.57	0.00	0.00	0.00	4.52	0.57	0.00	0.67
1983	4	1.08	37.95	8.80	0.59	3.17	0.91	0.00	1.92	0.00	2.66	1.71	0.00	0.78	0.00	2.81	2.13	0.00	0.66	0.00	2.46	2.25	0.00	0.66	0.00	3.25	1.68	0.00	0.66	0.00	1.69
1983	5	2.09	50.30	9.10	0.60	0.20	0.51	0.00	2.94	0.00	0.33	0.48	0.00	1.28	0.00	0.00	0.00	0.00	1.08	1.23	0.00	0.00	0.00	1.08	1.63	0.22	0.00	0.00	1.08	1.22	2.69
1983	6	2.26	60.75	8.80	0.74	0.33	0.19	0.00	3.79	0.00	0.72	0.00	0.00	1.62	0.00	0.27	0.00	0.00	1.37	2.05	0.12	0.00	0.00	1.37	2.62	0.48	0.00	0.00	1.37	1.92	2.56
1983	7	3.12	68.85	7.50	0.79	0.46	0.14	0.00	4.20	0.00	1.10	0.00	0.00	2.34	0.00	0.65	0.00	0.00	1.98	2.24	0.50	0.00	0.00	1.98	2.62	0.74	0.00	0.00	1.98	1.83	2.99
1983	8	6.47	68.55	6.30	0.79	0.96	1.41	0.00	3.43	0.00	2.61	0.00	0.00	3.81	0.00	2.16	0.00	0.00	3.23	1.79	2.01	0.00	0.00	3.23	1.93	1.74	0.00	0.00	3.23	1.59	3.09
1983	9	2.39	54.80	8.40	0.84	0.23	0.78	0.00	2.08	0.00	0.42	0.33	0.00	1.29	0.00	0.00	0.00	0.00	1.09	0.82	0.00	0.00	0.00	1.09	0.87	0.28	0.00	0.00	1.09	0.70	2.14
1983	10	3.75	43.85	8.40	0.83	0.37	1.86	0.00	1.00	0.00	0.83	1.51	0.00	1.42	0.00	0.38	0.00	0.00	1.20	0.07	0.23	0.00	0.00	1.20	0.09	0.55	0.00	0.00	1.20	0.07	1.50
1983	11	3.49	29.00	9.40	0.86	0.00	0.00	2.61	1.82	0.00	0.00	0.00	2.67	0.82	0.00	0.00	0.00	2.80	0.69	0.00	0.00	0.00	2.80	0.69	0.00	0.00	0.00	2.80	0.69	0.00	0.67
1983	12	1.48	-0.65	8.30	0.77	0.00	0.00	4.02	2.98	0.00	0.00	0.00	4.09	0.07	0.00	0.00	0.00	4.22	0.06	0.00	0.00	0.00	4.22	0.06	0.00	0.00	0.00	4.22	0.06	0.00	0.09
1984	1	0.17	3.85	8.60	0.72	0.00	0.00	4.04	3.28	0.00	0.00	0.00	4.12	0.14	0.00	0.00	0.00	4.28	0.12	0.00	0.00	0.00	4.28	0.12	0.00	0.00	0.00	4.28	0.12	0.00	0.13
1984	2	1.04	22.35	7.40	0.79	0.00	0.00	4.34	3.05	0.00	0.00	0.00	4.48	0.68	0.00	0.00	0.00	4.74	0.58	0.00	0.00	0.00	4.74	0.58	0.00	0.00	0.00	4.74	0.58	0.00	0.32
1984	3	0.15	18.20	7.90	0.61	0.00	0.00	3.97	2.43	0.00	0.00	0.00	4.14	0.49	0.00	0.00	0.00	4.47	0.41	0.00	0.00	0.00	4.47	0.41	0.00	0.00	0.00	4.47	0.41	0.00	0.56
1984	4	1.2	42.60	9.20	0.51	3.28	0.98	0.00	1.92	0.00	2.75	1.76	0.00	0.84	0.00	2.78	0.34	0.00	0.71	0.31	2.43	0.00	0.00	0.71	0.41	3.25	0.20	0.00	0.71	0.31	2.47
1984	5	1.93	49.15	8.40	0.64	0.18	0.46	0.00	2.94	0.00	0.28	0.46	0.00	1.19	0.00	0.00	0.00	0.00	1.01	1.10	0.00	0.00	0.00	1.01	1.44	0.19	0.00	0.00	1.01	1.10	2.26
1984	6	5.47	61.75	8.40	0.75	0.81	1.21	0.00	3.79	0.00	2.16	0.11	0.00	3.20	0.00	1.71	0.00	0.00	2.71	2.18	1.56	0.00	0.00	2.71	2.74	1.44	0.00	0.00	2.71	2.17	2.45
1984	7	1.41	64.90	7.30	0.74	0.20	0.00	0.00	4.20	0.00	0.33	0.00	0.00	1.21	0.00	0.00	0.00	0.00	1.03	2.07	0.00	0.00	0.00	1.03	2.31	0.22	0.00	0.00	1.03	1.85	3.10
1984	8	3.05	66.90	7.30	0.74	0.45	0.30	0.00	3.43	0.00	1.07	0.00	0.00	2.05	0.00	0.62	0.00	0.00	1.73	1.70	0.47	0.00	0.00	1.73	1.72	0.72	0.00	0.00	1.73	1.34	3.71

Table 5-1
Meyer Model Results

						Upland Number 1: Crust					Upland Number 2: Developed					Upland Number 3: Forbes					Upland Number 4: Forest					Upland Number 5: Reclaimed Tailings Basin					Shallow Water
Year	Month	Precip	Temp	Wind	Rel Hum	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Evaporation
		Inches	F			Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
1984	9	1.34	50.60	8.20	0.76	0.12	0.46	0.00	2.08	0.00	0.10	0.33	0.00	0.70	0.00	0.00	0.00	0.00	0.60	0.50	0.00	0.00	0.00	0.60	0.48	0.07	0.00	0.00	0.60	0.39	2.35
1984	10	2.55	45.95	9.80	0.81	0.25	1.15	0.00	1.00	0.00	0.47	1.01	0.00	1.08	0.00	0.02	0.00	0.00	0.91	0.24	0.00	0.00	0.00	0.91	0.26	0.31	0.00	0.00	0.91	0.21	1.86
1984	11	2.68	27.15	8.80	0.79	0.00	0.00	1.97	1.82	0.00	0.00	0.00	2.02	0.66	0.00	0.00	0.00	2.12	0.56	0.00	0.00	0.00	2.12	0.56	0.00	0.00	0.00	2.12	0.56	0.00	0.76
1984	12	1.63	11.15	8.20	0.75	0.00	0.00	3.29	2.98	0.00	0.00	0.00	3.37	0.29	0.00	0.00	0.00	3.51	0.24	0.00	0.00	0.00	3.51	0.24	0.00	0.00	0.00	3.51	0.24	0.00	0.24
1985	1	0.38	3.60	8.90	0.73	0.00	0.00	3.53	3.28	0.00	0.00	0.00	3.61	0.14	0.00	0.00	0.00	3.78	0.11	0.00	0.00	0.00	3.78	0.11	0.00	0.00	0.00	3.78	0.11	0.00	0.12
1985	2	0.5	8.75	7.80	0.73	0.00	0.00	3.77	3.05	0.00	0.00	0.00	3.88	0.24	0.00	0.00	0.00	4.08	0.20	0.00	0.00	0.00	4.08	0.20	0.00	0.00	0.00	4.08	0.20	0.00	0.18
1985	3	0.27	29.10	10.20	0.68	3.04	0.35	0.00	2.43	0.00	2.50	1.03	0.00	0.61	0.00	2.50	0.00	0.00	0.52	0.00	2.15	0.00	0.00	0.52	0.00	2.91	0.00	0.00	0.52	0.00	0.96
1985	4	2.73	41.55	10.70	0.68	0.26	1.03	0.00	1.92	0.00	0.52	0.88	0.00	1.34	0.00	0.07	0.31	0.00	1.13	0.19	0.00	0.00	0.00	1.13	0.24	0.35	0.00	0.00	1.13	0.18	1.70
1985	5	6.27	55.20	8.60	0.66	0.62	2.23	0.00	2.94	0.00	1.58	1.51	0.00	3.18	0.00	1.13	0.78	0.00	2.69	1.67	0.98	0.00	0.00	2.69	2.22	1.05	0.63	0.00	2.69	1.67	2.66
1985	6	5.61	55.80	8.50	0.71	0.83	1.60	0.00	3.79	0.00	2.23	0.43	0.00	2.95	0.00	1.78	0.00	0.00	2.50	1.72	1.63	0.00	0.00	2.50	2.27	1.48	0.00	0.00	2.50	1.72	2.31
1985	7	2.62	64.30	7.40	0.71	0.38	0.17	0.00	4.20	0.00	0.88	0.00	0.00	1.92	0.00	0.43	0.00	0.00	1.63	2.26	0.28	0.00	0.00	1.63	2.82	0.59	0.00	0.00	1.63	2.22	3.35
1985	8	5.43	60.00	8.20	0.80	0.80	1.59	0.00	3.43	0.00	2.14	0.29	0.00	2.82	0.00	1.69	0.00	0.00	2.38	1.51	1.54	0.00	0.00	2.38	1.79	1.43	0.00	0.00	2.38	1.51	2.49
1985	9	5.14	52.65	8.90	0.80	0.50	2.15	0.00	2.08	0.00	1.24	1.59	0.00	2.31	0.00	0.79	0.00	0.00	1.95	0.95	0.64	0.00	0.00	1.95	1.15	0.83	0.00	0.00	1.95	0.97	2.29
1985	10	1.6	42.95	9.80	0.74	0.15	0.75	0.00	1.00	0.00	0.18	0.77	0.00	0.65	0.00	0.00	0.26	0.00	0.55	0.00	0.00	0.00	0.00	0.55	0.00	0.12	0.53	0.00	0.55	0.00	2.01
1985	11	2.47	17.55	7.50	0.83	0.00	0.00	1.88	1.82	0.00	0.00	0.00	1.92	0.55	0.00	0.00	0.00	2.01	0.46	0.00	0.00	0.00	2.01	0.46	0.00	0.00	0.00	2.01	0.46	0.00	0.32
1985	12	0.41	2.15	9.20	0.82	0.00	0.00	2.29	2.98	0.00	0.00	0.00	2.33	0.00	0.00	0.00	0.00	2.42	0.00	0.00	0.00	0.00	2.42	0.00	0.00	0.00	0.00	2.42	0.00	0.00	0.07
1986	1	0.71	9.90	8.90	0.81	0.00	0.00	2.72	3.28	0.00	0.00	0.00	2.79	0.26	0.00	0.00	0.00	2.91	0.22	0.00	0.00	0.00	2.91	0.22	0.00	0.00	0.00	2.91	0.22	0.00	0.10
1986	2	0.92	11.80	6.80	0.81	0.00	0.00	3.29	3.05	0.00	0.00	0.00	3.38	0.33	0.00	0.00	0.00	3.55	0.28	0.00	0.00	0.00	3.55	0.28	0.00	0.00	0.00	3.55	0.28	0.00	0.11
1986	3	0.46	27.20	9.20	0.70	0.00	0.00	3.07	2.43	0.00	0.00	0.00	3.20	0.63	0.00	0.00	0.00	3.48	0.54	0.00	0.00	0.00	3.48	0.54	0.00	0.00	0.00	3.48	0.54	0.00	0.76
1986	4	3.84	43.95	10.00	0.64	2.83	2.17	0.00	1.92	0.00	2.89	2.39	0.00	1.77	0.00	2.49	2.85	0.00	1.50	0.48	1.99	2.30	0.00	1.50	0.63	3.03	2.32	0.00	1.50	0.48	2.02
1986	5	2.07	54.60	8.80	0.64	0.20	0.40	0.00	2.94	0.00	0.32	0.38	0.00	1.37	0.00	0.00	0.00	0.00	1.16	1.60	0.00	0.00	0.00	1.16	2.11	0.21	0.00	0.00	1.16	1.58	2.79
1986	6	3.07	61.00	8.40	0.68	0.45	0.39	0.00	3.79	0.00	1.08	0.00	0.00	2.07	0.00	0.63	0.00	0.00	1.75	2.01	0.48	0.00	0.00	1.75	2.52	0.72	0.00	0.00	1.75	1.87	3.10
1986	7	4.56	65.80	7.40	0.75	0.67	0.68	0.00	4.20	0.00	1.75	0.00	0.00	2.98	0.00	1.30	0.00	0.00	2.52	2.04	1.15	0.00	0.00	2.52	2.38	1.17	0.00	0.00	2.52	1.81	3.05
1986	8	3.84	55.30	7.30	0.75	0.57	1.20	0.00	3.43	0.00	1.43	0.23	0.00	1.93	0.00	0.98	0.00	0.00	1.63	0.95	0.83	0.00	0.00	1.63	1.08	0.95	0.00	0.00	1.63	0.86	2.38
1986	9	7.23	49.65	8.40	0.82	0.71	3.48	0.00	2.08	0.00	1.87	2.54	0.00	2.82	0.00	1.42	0.00	0.00	2.39	0.67	1.27	0.00	0.00	2.39	0.83	1.25	0.24	0.00	2.39	0.67	1.91
1986	10	1.23	40.90	7.90	0.78	0.11	0.59	0.00	1.00	0.00	0.07	0.67	0.00	0.49	0.00	0.00	0.54	0.00	0.41	0.00	0.00	0.00	0.00	0.41	0.00	0.05	0.77	0.00	0.41	0.00	1.53
1986	11	1.23	19.85	9.40	0.79	0.00	0.00	0.64	1.82	0.00	0.00	0.00	0.68	0.55	0.00	0.00	0.00	0.76	0.47	0.00	0.00	0.00	0.76	0.47	0.00	0.00	0.00	0.76	0.47	0.00	0.50
1986	12	0.33	14.05	8.70	0.83	0.00	0.00	0.97	2.98	0.00	0.00	0.00	1.01	0.00	0.00	0.00	0.00	1.09	0.00	0.00	0.00	0.00	1.09	0.00	0.00	0.00	0.00	1.09	0.00	0.00	0.19
1987	1	0.6	11.65	8.10	0.81	0.00	0.00	1.23	3.28	0.00	0.00	0.00	1.29	0.32	0.00	0.00	0.00	1.43	0.27	0.00	0.00	0.00	1.43	0.27	0.00	0.00	0.00	1.43	0.27	0.00	0.12
1987	2	0.5	23.05	8.90	0.77	0.00	0.00	1.07	3.05	0.00	0.00	0.00	1.18	0.61	0.00	0.00	0.00	1.41	0.52	0.00	0.00	0.00	1.41	0.52	0.00	0.00	0.00	1.41	0.52	0.00	0.41
1987	3	0.72	29.05	9.40	0.64	0.92	0.12	0.00	2.43	0.00	0.62	0.59	0.00	0.70	0.00	0.64	0.90	0.00	0.59	0.00	0.29	0.74	0.00	0.59	0.00	0.91	0.63	0.00	0.59	0.00	1.02
1987	4	0.25	44.90	8.70	0.52	0.02	0.00	0.00	1.92	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.40	0.57	0.00	0.00	0.00	0.40	0.76	0.00	0.00	0.00	0.40	0.56	2.60
1987	5	5.54	52.90	9.00	0.63	0.54	1.91	0.00	2.94	0.00	1.36	1.19	0.00	2.77	0.00	0.91	0.11	0.00	2.35	1.46	0.76	0.00	0.00	2.35	1.95	0.91	0.12	0.00	2.35	1.46	2.76
1987	6	1.67	61.85	7.90	0.65	0.24	0.02	0.00	3.79	0.00	0.45	0.00	0.00	1.31	0.00	0.00	0.00	0.00	1.11	2.15	0.00	0.00	0.00	1.11	2.71	0.30	0.00	0.00	1.11	2.05	3.35
1987	7	7.32	66.25	7.40	0.75	1.09	1.61	0.00	4.20	0.00	2.99	0.00	0.00	4.29	0.00	2.54	0.00	0.00	3.63	2.26	2.39	0.00	0.00	3.63	2.65	2.00	0.00	0.00	3.63	2.23	3.15
1987	8	2.72	61.30	7.30	0.77	0.40	0.53	0.00	3.43	0.00	0.92	0.08	0.00	1.66	0.00	0.47	0.00	0.00	1.41	1.42	0.32	0.00	0.00	1.41	1.55	0.62	0.00	0.00	1.41	1.28	2.80
1987	9	4.23	54.70	6.60	0.78	0.41	1.60	0.00	2.08	0.00	0.97	1.20	0.00	2.06	0.00	0.52	0.00	0.00	1.74	1.00	0.37	0.00	0.00	1.74	1.14	0.65	0.00	0.00	1.74	0.95	2.30
1987	10	0.71	37.35	8.90	0.72	0.06	0.34	0.00	1.00	0.00	0.00	0.42	0.00	0.29	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.24	0.00	1.66
1987	11	0.3	30.70	8.60	0.79	0.02	0.14	0.00	1.82	0.00	0.00	0.17	0.00	0.13	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.11	0.00	0.91
1987	12	0.25	18.55	7.50	0.88	0.00	0.00	0.25	2.98	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.17
1988	1	0.53	-0.80	8.30	0.79	0.00	0.00	0.71	3.28	0.00	0.00	0.00	0.72	0.07	0.00	0.00	0.00	0.73	0.06	0.00	0.00	0.00	0.73	0.06	0.00	0.00	0.00	0.73	0.06	0.00	0.04
1988	2	0	1.55	9.10	0.69	0.00	0.00	0.61	3.05	0.00	0.00	0.00	0.62	0.10	0.00	0.00	0.00	0.64	0.08	0.00	0.00	0.00	0.64	0.08	0.00	0.00	0.00	0.64	0.08	0.00	0.14
1988	3	1.65	22.00	10.30	0.72	0.00	0.00	1.45	2.43	0.00	0.00	0.00	1.52	0.75	0.00	0.00	0.00	1.66	0.63	0.00	0.00	0.00	1.66	0.63	0.00	0.00	0.00	1.66	0.63	0.00	0.54
1988	4	0.12	36.60	8.90	0.56	1.17	0.00	0.00	1.92	0.00	0.86	0.29	0.00	0.50	0.00	0.81	0.00	0.00	0.42	0.00	0.46	0.00	0.00	0.42	0.00	1.10	0.00	0.00	0.42	0.00	1.75
1988	5	2.23	55.70	9.30	0.56	0.21	0.33	0.00	2.94	0.00	0.37	0.39	0.00	1.48	0.00	0.00	0.00	0.00	1.25	1.59	0.00	0.00	0.00	1.25	1.91	0.25	0.00	0.00	1.25	1.49	3.68
1988	6	3.3	64.00	7.50	0.65	0.49	0.36	0.00	3.79	0.00	1.19	0.00	0.00	2.28	0.00	0.74	0.00	0.00	1.93	1.98	0.59	0.00	0.00	1.93	2.24	0.79	0.00	0.00	1.93	1.73	3.58
1988	7	3.11	67.05	6.80	0.69	0.46	0.20	0.00	4.20	0.00	1.10	0.00	0.00	2.28	0.00	0.65	0.00	0.00	1.93	1.77	0.50	0.00	0.00	1.93	1.77	0.73	0.00	0.00	1.93	1.31	3.72
1988	8	12.26	63.00	7.50	0.79	1.83	4.83	0.00	3.43	0.00	5.22	1.41	0.00	5.20	0.00	4.77	0.00	0.00	4.40	1.67	4.62	0.00	0.00	4.40	1.90	3.48	0.00	0.00	4.40	1.92	2.76
1988	9	3.62	53.25	8.40	0.78	0.35	1.38	0.00	2.08	0.00	0.79	1.08	0.00	1.75	0.00	0.34	0.00	0.00	1.48	0.90	0.19	0.00	0.00	1.48	1.04	0.52	0.00	0.00	1.48	1.01	2.42
1988	10	1.17	37.35	8.90	0.75	0.11	0.60	0.00	1.00	0.00	0.05	0.69	0.00	0.43	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.36	0.00	0.03	0.00	0.00	0.36	0.00	1.54
1988	11	1.4	26.80	9.20	0.86	0.00	0.00	0.91	1.82	0.00	0.00	0.00	0.94	0.46	0.00	0.00	0.00	1.01	0.39	0.00	0.00	0.00	1.01	0.39	0.00	0.00	0.00	1.01	0.39	0.00	0.57
1988	12	0.81	8.45	8.90	0.82	0.00	0.00	1.72	2.98	0.00	0.00	0.00	1.75	0.00	0.00	0.00	0.00	1.82	0.00	0.00	0.00	0.00	1.82	0.00	0.00	0.00	0.00	1.82	0.00	0.00	0.13
1989	1	1.74	10.00	8.80	0.82	0.00	0.00	3.18	3.28	0.00	0.00	0.00	3.23	0.26	0.00	0.00	0.00	3.34	0.22	0.00	0.00	0.00	3.34	0.22	0.00	0.00	0.00	3.34	0.22	0.00	0.09
1989	2	0.67	-1.25	9.70	0.70	0.00	0.00	3.78	3.05	0.00	0.00	0.00	3.84	0.07	0.00	0.00	0.00	3.96	0.06	0.00	0.00	0.00	3.96	0.06	0.00	0.00	0.00	3.96	0.06	0.00	0.11
1989	3	1.13	16.40	8.70	0.72	0.00	0.00	4.35	2.43	0.00	0.00	0.00	4.45	0.52	0.00	0.00	0.00	4.65	0.44	0.00	0.00	0.00	4.65	0.44	0.00	0.00	0.00	4.65	0.44	0.00	0.33
1989	4	0.61	34.80	9.30	0.66	3.53	0.72	0.00	1.92	0.00	2.91	1.50	0.00	0.66	0.00	2.91	0.63	0.00	0.55	0.00	2.56	0.00	0.00	0.55	0.00	3.34	1.36	0.00	0.55	0.00	1.29
1989	5	3.22	50.45	7.70	0.62	0.31	1.00	0.00	2.94	0.00	0.67	0.78	0.00	1.77	0.00	0.22	0.26	0.00	1.50	1.24	0.07	0.00	0.00	1.50	1.66	0.44	0.04	0.00	1.50	1.24	2.41
1989	6	6.75	58.75	7.70	0.71	1.00	1.89	0.00	3.79	0.00	2.74	0.43	0.00	3.59	0.00	2.29	0.00	0.00	3.04	1.98	2.14	0.00	0.00	3.04	2.60	1.83	0.00	0.00	3.04	1.98	2.50
1989	7	0.6	66.25	6.20	0.73	0.08	0.00	0.00	4.20	0.00	0.00	0.00	0.00	0.68	0.00	0.00	0.00	0.00	0.58	2.24	0.00	0.00	0.00	0.58	2.67	0.00	0.00	0.00	0.58	2.24	3.14
1989	8	4.47	62.55	7.00	0.78	0.66	0.97	0.00	3.43	0.00	1.71	0.14	0.00	2.54	0.00	1.26	0.00	0.00	2.15	1.54	1.11	0.00	0.00	2.15	1.72	1.14	0.00	0.00	2.15	1.50	2.78
1989	9	3.33	52.35	8.50	0.74	0.32	1.28	0.00	2.08	0.00	0.70	1.03	0.00	1.60	0.00	0.25	0.00	0.00	1.36	0.79	0.10	0.00	0.00	1.36	0.91	0.47	0.00	0.00	1.36	0.77	2.64
1989	10	1.47	42.45	8.00	0.69	0.14	0.69	0.00	1.00	0.00	0.14	0.74	0.00	0.59	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.50	0.00	0.09	0.00	0.00	0.50	0.00	2.05
1989	11	0.5	20.85	9.60	0.77	0.00	0.00	0.50	1.82	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.58
1989	12	0.14	-2.60	8.40	0.76	0.00	0.00	0.57	2.98	0.00	0.00	0.00	0.58	0.07	0.00	0.00	0.00	0.59	0.06	0.00	0.00	0.00	0.59	0.06	0.00	0.00	0.00	0.59	0.06	0.00	0.08
1990	1	0.59	13.55	9.30	0.81	0.00	0.00	0.75	3.28	0.00	0.00	0.00	0.79	0.38	0.00	0.00	0.00	0.85	0.32	0.00	0.00	0.00	0.85	0.32	0.00	0.00	0.00	0.85	0.32	0.00	0.14
1990	2	0.61	7.45	9.70	0.68	0.00	0.00	1.14	3.05	0.00	0.00	0.00	1.19	0.21	0.00	0.00	0.00	1.29	0.18	0.00	0.00	0.00	1.29	0.18	0.00	0.00	0.00	1.29	0.18	0.00	0.23
1990	3	0.94	26.10	10.50	0.65	0.00	0.00	1.31	2.43	0.00	0.00	0.00	1.41	0.71	0.00	0.00	0.00	1.63	0.60	0.00	0.00	0.00	1.63	0.60	0.00	0.00	0.00	1.63	0.60	0.00	0.90
1990	4	2.98	37.50	10.40	0.69	1.34	1.53	0.00	1.92	0.00	1.37	1.70	0.00	1.32	0.00	0.93	1.22	0.00	1.12	0.00	0.44	0.59	0.00	1.12	0.00	1.46	1.02	0.00	1.12	0.00	1.38
1990	5	1.14	46.30	8.50	0.62	0.10	0.14	0.00	2.94	0.00	0.04	0.26	0.00	0.83	0.00	0.00	0.00	0.00	0.71	0.76	0.00	0.00	0.00	0.71	1.00	0.03	0.00	0.00	0.71	0.75	2.16
1990	6	6.85	60.45	8.40	0.71	1.02	1.81	0.00	3.79	0.00	2.78	0.34	0.00	3.73	0.00	2.33	0.00	0.00	3.16	2.10	2.18	0.00	0.00	3.16	2.73	1.86	0.00	0.00	3.16	2.12	2.72
1990	7	2.59	62.60	7.40	0.72	0.38	0.22	0.00	4.20	0.00	0.87	0.00	0.00	1.85	0.00	0.42	0.00	0.00	1.57	2.03	0.27	0.00	0.00	1.57	2.47	0.58	0.00	0.00	1.57	1.99	3.02
1990	8	2.18	63.15	7.10	0.70	0.32	0.31	0.00	3.43	0.00	0.68	0.00	0.00	1.44	0.00	0.23	0.00	0.00	1.22	1.57	0.08	0.00	0.00	1.22	1.78	0.45	0.00	0.00	1.22	1.38	3.57
1990	9	2.24	53.70	7.70	0.78	0.21	0.75	0.00	2.08	0.00	0.37	0.61	0.00	1.18	0.00	0.00	0.00	0.00	1.00	0.83	0.00	0.00	0.00	1.00	0.92	0.25	0.00	0.00	1.00	0.72	2.40
1990	10	5.46	37.95	8.30	0.71	0.54	3.17	0.00	1.00	0.00	1.34	2.50	0.00	1.63	0.00	0.89	0.28	0.00	1.38	0.00	0.74	0.00	0.00	1.38	0.00	0.89	0.42	0.00	1.38	0.00	1.66
1990	11	0.38	27.30	9.90	0.74	0.00	0.00	0.38	1.82	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.95
1990	12	0.62	6.00	9.30	0.77	0.00	0.00	1.00	2.98	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.16
1991	1	0.27	-0.90	8.80	0.76	0.00	0.00	1.20	3.28	0.00	0.00	0.00	1.21	0.07	0.00	0.00	0.00	1.22	0.06	0.00	0.00	0.00	1.22	0.06	0.00	0.00	0.00	1.22	0.06	0.00	0.06
1991	2	0.59	13.55	8.60	0.71	0.00	0.00	1.38	3.05	0.00	0.00	0.00	1.42	0.38	0.00	0.00	0.00	1.48	0.32	0.00	0.00	0.00	1.48	0.32	0.00	0.00	0.00	1.48	0.32	0.00	0.29
1991	3	0.88	24.70	9.80	0.66	0.00	0.00	1.52	2.43	0.00	0.00	0.00	1.61	0.69	0.00	0.00	0.00	1.78	0.58	0.00	0.00	0.00	1.78	0.58	0.00	0.00	0.00	1.78	0.58	0.00	0.76
1991	4	2.68	41.90	9.60	0.60	1.48	1.30	0.00	1.92	0.00	1.42	1.54	0.00	1.33	0.00	0.95	2.16	0.00	1.12	0.23	0.55	1.75	0.00	1.12	0.31	1.52	1.59	0.00	1.12	0.23	2.00
1991	5	3.43	54.45	8.80	0.68	0.33	0.94	0.00	2.94	0.00	0.73	0.70	0.00	2.00	0.00	0.28	0.00	0.00	1.70	1.60	0.13	0.00	0.00	1.70	2.13	0.49	0.00	0.00	1.70	1.60	2.50
1991	6	3.46	62.50	8.70	0.68	0.51	0.47	0.00	3.79	0.00	1.26	0.00	0.00	2.30	0.00	0.81	0.00	0.00	1.95	2.20	0.66	0.00	0.00	1.95	2.80	0.84	0.00	0.00	1.95	2.11	3.28

Table 5-1
Meyer Model Results

						Upland Number 1: Crust					Upland Number 2: Developed					Upland Number 3: Forbes					Upland Number 4: Forest					Upland Number 5: Reclaimed Tailings Basin					Shallow Water
Year	Month	Precip	Temp	Wind	Rel Hum	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Evaporation
		Inches	F			Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
1991	7	7.83	62.55	7.60	0.73	1.16	2.06	0.00	4.20	0.00	3.22	0.23	0.00	4.28	0.00	2.77	0.00	0.00	3.62	2.08	2.62	0.00	0.00	3.62	2.50	2.15	0.00	0.00	3.62	2.10	2.95
1991	8	1.72	63.85	6.30	0.68	0.25	0.18	0.00	3.43	0.00	0.47	0.05	0.00	1.20	0.00	0.02	0.00	0.00	1.02	1.65	0.00	0.00	0.00	1.02	1.82	0.32	0.00	0.00	1.02	1.49	3.67
1991	9	7.74	50.55	9.50	0.77	0.76	3.72	0.00	2.08	0.00	2.02	2.69	0.00	3.03	0.00	1.57	0.00	0.00	2.56	0.76	1.42	0.00	0.00	2.56	0.92	1.35	0.15	0.00	2.56	0.76	2.40
1991	10	1.45	37.55	9.60	0.76	0.14	0.77	0.00	1.00	0.00	0.14	0.81	0.00	0.51	0.00	0.00	0.62	0.00	0.43	0.00	0.00	0.00	0.00	0.43	0.00	0.09	0.93	0.00	0.43	0.00	1.54
1991	11	1.87	19.50	10.20	0.82	0.00	0.00	1.22	1.82	0.00	0.00	0.00	1.27	0.61	0.00	0.00	0.00	1.36	0.51	0.00	0.00	0.00	1.36	0.51	0.00	0.00	0.00	1.36	0.51	0.00	0.44
1991	12	0.47	11.05	9.30	0.81	0.00	0.00	1.69	2.98	0.00	0.00	0.00	1.74	0.00	0.00	0.00	0.00	1.83	0.00	0.00	0.00	0.00	1.83	0.00	0.00	0.00	0.00	1.83	0.00	0.00	0.18
1992	1	0.42	10.25	8.60	0.82	0.00	0.00	1.82	3.28	0.00	0.00	0.00	1.89	0.27	0.00	0.00	0.00	2.02	0.23	0.00	0.00	0.00	2.02	0.23	0.00	0.00	0.00	2.02	0.23	0.00	0.09
1992	2	0.64	15.90	8.00	0.69	0.00	0.00	1.96	3.05	0.00	0.00	0.00	2.07	0.46	0.00	0.00	0.00	2.27	0.39	0.00	0.00	0.00	2.27	0.39	0.00	0.00	0.00	2.27	0.39	0.00	0.37
1992	3	0.23	23.45	9.10	0.81	0.00	0.00	1.58	2.43	0.00	0.00	0.00	1.73	0.57	0.00	0.00	0.00	2.02	0.48	0.00	0.00	0.00	2.02	0.48	0.00	0.00	0.00	2.02	0.48	0.00	0.35
1992	4	0.71	34.75	9.60	0.72	1.32	0.23	0.00	1.92	0.00	1.00	0.76	0.00	0.68	0.00	1.06	1.09	0.00	0.58	0.00	0.71	0.80	0.00	0.58	0.00	1.36	0.79	0.00	0.58	0.00	1.08
1992	5	3.3	53.40	9.30	0.63	0.32	0.92	0.00	2.94	0.00	0.69	0.70	0.00	1.91	0.00	0.24	0.00	0.00	1.62	1.51	0.09	0.00	0.00	1.62	2.01	0.46	0.00	0.00	1.62	1.51	2.82
1992	6	3.39	55.65	8.00	0.69	0.50	0.71	0.00	3.79	0.00	1.23	0.14	0.00	2.03	0.00	0.78	0.00	0.00	1.72	1.69	0.63	0.00	0.00	1.72	2.19	0.82	0.00	0.00	1.72	1.65	2.39
1992	7	3.19	56.70	6.50	0.77	0.47	0.59	0.00	4.20	0.00	1.14	0.08	0.00	1.98	0.00	0.69	0.00	0.00	1.67	1.69	0.54	0.00	0.00	1.67	2.09	0.76	0.00	0.00	1.67	1.57	2.00
1992	8	5.54	57.30	5.70	0.77	0.82	1.80	0.00	3.43	0.00	2.19	0.64	0.00	2.71	0.00	1.74	0.00	0.00	2.30	1.35	1.59	0.00	0.00	2.30	1.63	1.46	0.00	0.00	2.30	1.33	2.17
1992	9	3.83	50.65	8.50	0.77	0.37	1.60	0.00	2.08	0.00	0.85	1.26	0.00	1.72	0.00	0.40	0.00	0.00	1.46	0.77	0.25	0.00	0.00	1.46	0.95	0.57	0.00	0.00	1.46	0.77	2.32
1992	10	1.11	38.85	6.60	0.73	0.10	0.55	0.00	1.00	0.00	0.03	0.65	0.00	0.43	0.00	0.00	0.41	0.00	0.36	0.00	0.00	0.00	0.00	0.36	0.00	0.02	0.34	0.00	0.36	0.00	1.50
1992	11	1.54	24.00	6.80	0.84	0.00	0.00	0.97	1.82	0.00	0.00	0.00	1.01	0.53	0.00	0.00	0.00	1.10	0.45	0.00	0.00	0.00	1.10	0.45	0.00	0.00	0.00	1.10	0.45	0.00	0.45
1992	12	0.83	10.30	8.00	0.82	0.00	0.00	1.80	2.98	0.00	0.00	0.00	1.84	0.00	0.00	0.00	0.00	1.93	0.00	0.00	0.00	0.00	1.93	0.00	0.00	0.00	0.00	1.93	0.00	0.00	0.15
1993	1	0.45	4.30	7.80	0.76	0.00	0.00	2.09	3.28	0.00	0.00	0.00	2.15	0.15	0.00	0.00	0.00	2.25	0.13	0.00	0.00	0.00	2.25	0.13	0.00	0.00	0.00	2.25	0.13	0.00	0.09
1993	2	0.05	8.50	7.50	0.69	0.00	0.00	1.90	3.05	0.00	0.00	0.00	1.97	0.23	0.00	0.00	0.00	2.10	0.20	0.00	0.00	0.00	2.10	0.20	0.00	0.00	0.00	2.10	0.20	0.00	0.21
1993	3	0.22	23.00	7.80	0.70	0.00	0.00	1.51	2.43	0.00	0.00	0.00	1.62	0.57	0.00	0.00	0.00	1.85	0.48	0.00	0.00	0.00	1.85	0.48	0.00	0.00	0.00	1.85	0.48	0.00	0.53
1993	4	1.05	34.85	6.30	0.61	1.30	0.42	0.00	1.92	0.00	0.94	0.96	0.00	0.77	0.00	0.94	1.30	0.00	0.66	0.00	0.59	0.94	0.00	0.66	0.00	1.24	1.00	0.00	0.66	0.00	1.25
1993	5	3.31	46.55	6.80	0.65	0.32	1.18	0.00	2.94	0.00	0.69	0.94	0.00	1.68	0.00	0.24	0.86	0.00	1.42	0.79	0.09	0.75	0.00	1.42	1.05	0.46	0.64	0.00	1.42	0.79	1.80
1993	6	3.01	54.20	7.20	0.71	0.44	0.62	0.00	3.79	0.00	1.05	0.15	0.00	1.81	0.00	0.60	0.00	0.00	1.53	1.56	0.45	0.00	0.00	1.53	2.07	0.70	0.00	0.00	1.53	1.55	2.03
1993	7	9.81	60.50	6.30	0.78	1.46	3.17	0.00	4.20	0.00	4.12	0.88	0.00	4.81	0.00	3.67	0.00	0.00	4.07	2.12	3.52	0.00	0.00	4.07	2.76	2.74	0.09	0.00	4.07	2.13	2.13
1993	8	2.95	61.65	5.90	0.78	0.43	0.59	0.00	3.43	0.00	1.03	0.13	0.00	1.79	0.00	0.58	0.00	0.00	1.52	1.78	0.43	0.00	0.00	1.52	2.17	0.69	0.00	0.00	1.52	1.83	2.48
1993	9	2.72	45.50	9.40	0.81	0.26	1.25	0.00	2.08	0.00	0.52	1.08	0.00	1.13	0.00	0.07	0.00	0.00	0.95	0.25	0.00	0.00	0.00	0.95	0.30	0.34	0.09	0.00	0.95	0.25	1.79
1993	10	1.24	34.85	10.10	0.74	0.11	0.67	0.00	1.00	0.00	0.07	0.75	0.00	0.42	0.00	0.00	0.67	0.00	0.36	0.00	0.00	0.00	0.00	0.36	0.00	0.05	0.84	0.00	0.36	0.00	1.52
1993	11	1.27	20.15	10.10	0.79	0.00	0.00	0.67	1.82	0.00	0.00	0.00	0.71	0.56	0.00	0.00	0.00	0.80	0.47	0.00	0.00	0.00	0.80	0.47	0.00	0.00	0.00	0.80	0.47	0.00	0.52
1993	12	0.51	9.95	8.30	0.83	0.00	0.00	1.18	2.98	0.00	0.00	0.00	1.22	0.00	0.00	0.00	0.00	1.31	0.00	0.00	0.00	0.00	1.31	0.00	0.00	0.00	0.00	1.31	0.00	0.00	0.13
1994	1	0.38	-10.55	8.40	0.71	0.00	0.00	1.49	3.28	0.00	0.00	0.00	1.54	0.07	0.00	0.00	0.00	1.63	0.06	0.00	0.00	0.00	1.63	0.06	0.00	0.00	0.00	1.63	0.06	0.00	0.04
1994	2	0.14	1.25	8.80	0.67	0.00	0.00	1.53	3.05	0.00	0.00	0.00	1.59	0.09	0.00	0.00	0.00	1.70	0.08	0.00	0.00	0.00	1.70	0.08	0.00	0.00	0.00	1.70	0.08	0.00	0.15
1994	3	0.26	25.20	10.00	0.67	0.00	0.00	1.16	2.43	0.00	0.00	0.00	1.26	0.59	0.00	0.00	0.00	1.46	0.50	0.00	0.00	0.00	1.46	0.50	0.00	0.00	0.00	1.46	0.50	0.00	0.77
1994	4	2.51	35.05	10.50	0.61	1.17	1.26	0.00	1.92	0.00	1.13	1.50	0.00	1.15	0.00	0.68	2.32	0.00	0.97	0.00	0.32	2.27	0.00	0.97	0.00	1.25	1.75	0.00	0.97	0.00	1.56
1994	5	2.66	49.25	9.80	0.61	0.26	0.79	0.00	2.94	0.00	0.50	0.66	0.00	1.50	0.00	0.05	0.23	0.00	1.27	1.11	0.00	0.00	0.00	1.27	1.48	0.33	0.00	0.00	1.27	1.11	2.65
1994	6	6.01	59.95	8.10	0.72	0.89	1.52	0.00	3.79	0.00	2.41	0.26	0.00	3.34	0.00	1.96	0.00	0.00	2.83	2.07	1.81	0.00	0.00	2.83	2.72	1.60	0.00	0.00	2.83	2.08	2.53
1994	7	2.98	60.50	8.70	0.77	0.44	0.38	0.00	4.20	0.00	1.04	0.00	0.00	2.01	0.00	0.59	0.00	0.00	1.70	1.95	0.44	0.00	0.00	1.70	2.42	0.69	0.00	0.00	1.70	1.92	2.54
1994	8	2.57	57.40	7.90	0.79	0.38	0.63	0.00	3.43	0.00	0.86	0.19	0.00	1.45	0.00	0.41	0.00	0.00	1.23	1.23	0.26	0.00	0.00	1.23	1.47	0.57	0.00	0.00	1.23	1.14	2.36
1994	9	4.46	53.35	7.60	0.81	0.44	1.78	0.00	2.08	0.00	1.04	1.34	0.00	2.09	0.00	0.59	0.00	0.00	1.76	0.98	0.44	0.00	0.00	1.76	1.19	0.69	0.00	0.00	1.76	0.96	2.15
1994	10	3.94	42.90	9.50	0.77	0.38	2.01	0.00	1.00	0.00	0.88	1.62	0.00	1.44	0.00	0.43	1.01	0.00	1.22	0.00	0.28	0.11	0.00	1.22	0.00	0.59	0.92	0.00	1.22	0.00	1.82
1994	11	0.89	29.40	10.60	0.79	0.08	0.81	0.00	1.82	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.95
1994	12	0.43	19.20	8.40	0.72	0.00	0.00	0.43	2.98	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.48
1995	1	0.91	7.85	8.80	0.79	0.00	0.00	1.11	3.28	0.00	0.00	0.00	1.12	0.22	0.00	0.00	0.00	1.16	0.19	0.00	0.00	0.00	1.16	0.19	0.00	0.00	0.00	1.16	0.19	0.00	0.10
1995	2	0.29	4.60	10.00	0.71	0.00	0.00	1.23	3.05	0.00	0.00	0.00	1.26	0.16	0.00	0.00	0.00	1.32	0.13	0.00	0.00	0.00	1.32	0.13	0.00	0.00	0.00	1.32	0.13	0.00	0.17
1995	3	0.89	25.00	10.50	0.72	0.00	0.00	1.38	2.43	0.00	0.00	0.00	1.46	0.69	0.00	0.00	0.00	1.62	0.58	0.00	0.00	0.00	1.62	0.58	0.00	0.00	0.00	1.62	0.58	0.00	0.64
1995	4	0.46	32.15	9.80	0.68	1.14	0.01	0.00	1.92	0.00	0.81	0.47	0.00	0.64	0.00	0.79	0.76	0.00	0.54	0.00	0.44	1.11	0.00	0.54	0.00	1.07	0.48	0.00	0.54	0.00	1.12
1995	5	1.9	48.65	8.10	0.66	0.18	0.46	0.00	2.94	0.00	0.27	0.46	0.00	1.17	0.00	0.00	0.00	0.00	0.99	1.04	0.00	0.00	0.00	0.99	1.38	0.18	0.00	0.00	0.99	1.04	2.07
1995	6	0.66	65.65	8.70	0.69	0.09	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.72	0.00	0.00	0.00	0.00	0.61	2.30	0.00	0.00	0.00	0.61	2.87	0.00	0.00	0.00	0.61	2.14	3.60
1995	7	6.8	63.85	7.90	0.76	1.01	1.48	0.00	4.20	0.00	2.76	0.07	0.00	3.91	0.00	2.31	0.00	0.00	3.31	1.95	2.16	0.00	0.00	3.31	2.27	1.84	0.00	0.00	3.31	1.89	2.88
1995	8	5.93	64.80	7.70	0.73	0.88	1.47	0.00	3.43	0.00	2.37	0.24	0.00	3.32	0.00	1.92	0.00	0.00	2.81	1.64	1.77	0.00	0.00	2.81	1.82	1.58	0.00	0.00	2.81	1.65	3.59
1995	9	3.36	51.60	9.50	0.75	0.33	1.33	0.00	2.08	0.00	0.71	1.07	0.00	1.59	0.00	0.26	0.00	0.00	1.34	0.70	0.11	0.00	0.00	1.34	0.80	0.47	0.00	0.00	1.34	0.70	2.64
1995	10	5.5	40.25	10.60	0.79	0.54	3.06	0.00	1.00	0.00	1.35	2.39	0.00	1.76	0.00	0.90	0.58	0.00	1.49	0.00	0.75	0.00	0.00	1.49	0.00	0.90	1.21	0.00	1.49	0.00	1.65
1995	11	0.35	14.50	8.50	0.78	0.00	0.00	0.35	1.82	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.35
1995	12	1.26	3.00	9.00	0.80	0.00	0.00	1.48	2.98	0.00	0.00	0.00	1.49	0.12	0.00	0.00	0.00	1.51	0.10	0.00	0.00	0.00	1.51	0.10	0.00	0.00	0.00	1.51	0.10	0.00	0.09
1996	1	2.24	-12.25	7.50	0.71	0.00	0.00	3.65	3.28	0.00	0.00	0.00	3.67	0.07	0.00	0.00	0.00	3.69	0.06	0.00	0.00	0.00	3.69	0.06	0.00	0.00	0.00	3.69	0.06	0.00	0.03
1996	2	1.86	0.60	10.00	0.68	0.00	0.00	5.43	3.05	0.00	0.00	0.00	5.45	0.08	0.00	0.00	0.00	5.49	0.07	0.00	0.00	0.00	5.49	0.07	0.00	0.00	0.00	5.49	0.07	0.00	0.14
1996	3	0.47	11.00	8.60	0.80	0.00	0.00	5.58	2.43	0.00	0.00	0.00	5.63	0.29	0.00	0.00	0.00	5.71	0.25	0.00	0.00	0.00	5.71	0.25	0.00	0.00	0.00	5.71	0.25	0.00	0.12
1996	4	1.3	29.70	7.40	0.75	4.59	1.41	0.00	1.92	0.00	3.82	2.29	0.00	0.82	0.00	3.65	2.67	0.00	0.70	0.00	3.30	2.69	0.00	0.70	0.00	4.19	2.12	0.00	0.70	0.00	0.66
1996	5	1.51	44.05	7.70	0.61	0.14	0.34	0.00	2.94	0.00	0.15	0.40	0.00	0.96	0.00	0.00	0.21	0.00	0.81	0.49	0.00	0.05	0.00	0.81	0.65	0.10	0.11	0.00	0.81	0.49	1.94
1996	6	6.62	58.20	6.80	0.80	0.98	1.87	0.00	3.79	0.00	2.68	0.44	0.00	3.50	0.00	2.23	0.00	0.00	2.96	1.93	2.08	0.00	0.00	2.96	2.56	1.79	0.00	0.00	2.96	1.93	1.58
1996	7	4.08	58.55	7.20	0.75	0.60	0.84	0.00	4.20	0.00	1.54	0.10	0.00	2.45	0.00	1.09	0.00	0.00	2.07	1.89	0.94	0.00	0.00	2.07	2.40	1.02	0.00	0.00	2.07	1.92	2.38
1996	8	2	60.85	6.80	0.76	0.29	0.34	0.00	3.43	0.00	0.60	0.13	0.00	1.28	0.00	0.15	0.00	0.00	1.08	1.59	0.00	0.00	0.00	1.08	1.91	0.40	0.00	0.00	1.08	1.54	2.76
1996	9	3.68	51.45	6.40	0.81	0.36	1.49	0.00	2.08	0.00	0.80	1.18	0.00	1.70	0.00	0.35	0.00	0.00	1.44	0.80	0.20	0.00	0.00	1.44	0.97	0.54	0.00	0.00	1.44	0.79	1.85
1996	10	1.77	38.30	10.60	0.76	0.17	0.95	0.00	1.00	0.00	0.23	0.93	0.00	0.61	0.00	0.00	0.07	0.00	0.51	0.00	0.00	0.00	0.00	0.51	0.00	0.15	0.01	0.00	0.51	0.00	1.67
1996	11	4.21	16.15	8.30	0.82	0.00	0.00	3.68	1.82	0.00	0.00	0.00	3.72	0.50	0.00	0.00	0.00	3.79	0.42	0.00	0.00	0.00	3.79	0.42	0.00	0.00	0.00	3.79	0.42	0.00	0.31
1996	12	1.84	4.60	7.70	0.83	0.00	0.00	5.36	2.98	0.00	0.00	0.00	5.41	0.15	0.00	0.00	0.00	5.51	0.13	0.00	0.00	0.00	5.51	0.13	0.00	0.00	0.00	5.51	0.13	0.00	0.07
1997	1	0.29	-1.05	8.90	0.76	0.00	0.00	5.58	3.28	0.00	0.00	0.00	5.63	0.07	0.00	0.00	0.00	5.74	0.06	0.00	0.00	0.00	5.74	0.06	0.00	0.00	0.00	5.74	0.06	0.00	0.06
1997	2	0.25	6.10	7.70	0.76	0.00	0.00	5.63	3.05	0.00	0.00	0.00	5.70	0.18	0.00	0.00	0.00	5.84	0.16	0.00	0.00	0.00	5.84	0.16	0.00	0.00	0.00	5.84	0.16	0.00	0.11
1997	3	1.78	18.00	7.90	0.72	0.00	0.00	6.73	2.43	0.00	0.00	0.00	6.85	0.63	0.00	0.00	0.00	7.08	0.53	0.00	0.00	0.00	7.08	0.53	0.00	0.00	0.00	7.08	0.53	0.00	0.36
1997	4	0.78	32.70	8.50	0.64	5.45	1.29	0.00	1.92	0.00	4.58	2.34	0.00	0.71	0.00	4.61	2.65	0.00	0.60	0.00	4.26	2.04	0.00	0.60	0.00	5.16	2.10	0.00	0.60	0.00	1.18
1997	5	2.54	41.35	8.90	0.60	0.24	0.93	0.00	2.94	0.00	0.46	0.81	0.00	1.27	0.00	0.01	1.29	0.00	1.08	0.16	0.00	1.25	0.00	1.08	0.22	0.31	0.99	0.00	1.08	0.16	1.89
1997	6	4.36	59.90	7.00	0.70	0.64	0.89	0.00	3.79	0.00	1.66	0.07	0.00	2.63	0.00	1.21	0.00	0.00	2.22	2.05	1.06	0.00	0.00	2.22	2.69	1.11	0.00	0.00	2.22	2.04	2.55
1997	7	2.26	60.80	6.90	0.77	0.33	0.19	0.00	4.20	0.00	0.72	0.00	0.00	1.62	0.00	0.27	0.00	0.00	1.37	1.91	0.12	0.00	0.00	1.37	2.38	0.48	0.00	0.00	1.37	1.77	2.32
1997	8	2.68	55.85	6.80	0.75	0.39	0.72	0.00	3.43	0.00	0.91	0.24	0.00	1.45	0.00	0.46	0.00	0.00	1.23	1.08	0.31	0.00	0.00	1.23	1.30	0.60	0.00	0.00	1.23	0.96	2.36
1997	9	2.16	51.65	8.20	0.75	0.21	0.78	0.00	2.08	0.00	0.35	0.72	0.00	1.09	0.00	0.00	0.00	0.00	0.92	0.75	0.00	0.00	0.00	0.92	0.89	0.23	0.00	0.00	0.92	0.67	2.47
1997	10	2.47	37.65	9.20	0.76	0.24	1.37	0.00	1.00	0.00	0.44	1.23	0.00	0.80	0.00	0.00	0.00	0.00	0.68	0.00	0.00	0.00	0.00	0.68	0.00	0.29	0.00	0.00	0.68	0.00	1.52
1997	11	1.68	19.95	7.60	0.80	0.00	0.00	1.03	1.82	0.00	0.00	0.00	1.08	0.60	0.00	0.00	0.00	1.17	0.51	0.00	0.00	0.00	1.17	0.51	0.00	0.00	0.00	1.17	0.51	0.00	0.43
1997	12	0.42	18.35	7.00	0.82	0.00	0.00	1.45	2.98	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00	1.59	0.00	0.00	0.00	0.00	1.59	0.00	0.00	0.00	0.00	1.59	0.00	0.00	0.26
1998	1	0.75	10.15	6.90	0.84	0.00	0.00	1.92	3.28	0.00	0.00	0.00	1.98	0.27	0.00	0.00	0.00	2.12	0.23	0.00	0.00	0.00	2.12	0.23	0.00	0.00	0.00	2.12	0.23	0.00	0.06
1998	2	1.19	24.50	7.10	0.82	0.00	0.00	2.32	3.05	0.00	0.00	0.00	2.44	0.73	0.00	0.00	0.00	2.69	0.62	0.00	0.00	0.00	2.69	0.62	0.00	0.00	0.00	2.69	0.62	0.00	0.30
1998	3	1.04	22.10	8.20	0.67	0.00	0.00	2.63	2.43	0.00	0.00	0.00	2.81	0.68	0.00	0.00	0.00	3.16	0.58	0.00	0.00	0.00	3.16	0.58	0.00	0.00	0.00	3.16	0.58	0.00	0.58
1998	4	1.37	39.65	7.90	0.59	2.23	0.83	0.00	1.92	0.00	1.86	1.44	0.00	0.87	0.00	1.86	1.72	0.00	0.74	0.00	1.51	1.04	0.00	0.74	0.00	2.29	0.86	0.00	0.74	0.00	1.72

Table 5-1
Meyer Model Results

						Upland Number 1: Crust					Upland Number 2: Developed					Upland Number 3: Forbes					Upland Number 4: Forest					Upland Number 5: Reclaimed Tailings Basin					Shallow Water
Year	Month	Precip	Temp	Wind	Rel Hum	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Runoff	Infiltration	Storage	Evaporation	Transperation	Evaporation
		Inches	F			Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
1998	5	2.81	53.80	8.20	0.67	0.27	0.71	0.00	2.94	0.00	0.54	0.57	0.00	1.70	0.00	0.09	0.00	0.00	1.44	1.54	0.00	0.00	0.00	1.44	2.04	0.36	0.00	0.00	1.44	1.53	2.40
1998	6	3.09	55.90	7.10	0.76	0.45	0.59	0.00	3.79	0.00	1.09	0.10	0.00	1.90	0.00	0.64	0.00	0.00	1.61	1.69	0.49	0.00	0.00	1.61	2.17	0.73	0.00	0.00	1.61	1.62	1.77
1998	7	2.08	60.95	6.30	0.75	0.30	0.14	0.00	4.20	0.00	0.64	0.00	0.00	1.53	0.00	0.19	0.00	0.00	1.29	1.91	0.04	0.00	0.00	1.29	2.32	0.42	0.00	0.00	1.29	1.65	2.42
1998	8	4.59	62.55	6.30	0.78	0.68	1.12	0.00	3.43	0.00	1.77	0.15	0.00	2.60	0.00	1.32	0.00	0.00	2.20	1.61	1.17	0.00	0.00	2.20	1.86	1.18	0.00	0.00	2.20	1.40	2.62
1998	9	2.46	54.00	6.80	0.78	0.24	0.83	0.00	2.08	0.00	0.44	0.73	0.00	1.29	0.00	0.00	0.00	0.00	1.09	0.91	0.00	0.00	0.00	1.09	1.03	0.29	0.00	0.00	1.09	0.78	2.27
1998	10	4.06	40.85	8.70	0.84	0.40	2.17	0.00	1.00	0.00	0.92	1.75	0.00	1.39	0.00	0.47	0.00	0.00	1.18	0.00	0.32	0.00	0.00	1.18	0.00	0.61	0.00	0.00	1.18	0.00	1.30
1998	11	1.92	24.45	7.70	0.86	0.00	0.00	1.30	1.82	0.00	0.00	0.00	1.35	0.57	0.00	0.00	0.00	1.44	0.49	0.00	0.00	0.00	1.44	0.49	0.00	0.00	0.00	1.44	0.49	0.00	0.44
1998	12	0.83	11.00	7.70	0.80	0.00	0.00	2.13	2.98	0.00	0.00	0.00	2.18	0.00	0.00	0.00	0.00	2.27	0.00	0.00	0.00	0.00	2.27	0.00	0.00	0.00	0.00	2.27	0.00	0.00	0.17
1999	1	0.87	2.55	7.50	0.75	0.00	0.00	2.88	3.28	0.00	0.00	0.00	2.93	0.12	0.00	0.00	0.00	3.04	0.10	0.00	0.00	0.00	3.04	0.10	0.00	0.00	0.00	3.04	0.10	0.00	0.09
1999	2	0.64	15.30	9.20	0.71	0.00	0.00	3.04	3.05	0.00	0.00	0.00	3.13	0.44	0.00	0.00	0.00	3.30	0.37	0.00	0.00	0.00	3.30	0.37	0.00	0.00	0.00	3.30	0.37	0.00	0.33
1999	3	0.8	23.15	8.30	0.68	0.00	0.00	3.14	2.43	0.00	0.00	0.00	3.27	0.66	0.00	0.00	0.00	3.55	0.56	0.00	0.00	0.00	3.55	0.56	0.00	0.00	0.00	3.55	0.56	0.00	0.60
1999	4	1.62	38.80	7.60	0.63	2.66	1.08	0.00	1.92	0.00	2.27	1.68	0.00	0.95	0.00	2.13	2.15	0.00	0.80	0.00	1.78	1.43	0.00	0.80	0.00	2.64	1.43	0.00	0.80	0.00	1.48
1999	5	3.81	51.20	9.60	0.68	0.37	1.24	0.00	2.94	0.00	0.84	0.92	0.00	2.05	0.00	0.39	0.38	0.00	1.73	1.31	0.24	0.09	0.00	1.73	1.75	0.56	0.21	0.00	1.73	1.31	2.28
1999	6	4.2	57.20	7.70	0.74	0.62	0.95	0.00	3.79	0.00	1.59	0.17	0.00	2.44	0.00	1.14	0.00	0.00	2.07	1.82	0.99	0.00	0.00	2.07	2.41	1.06	0.00	0.00	2.07	1.82	2.09
1999	7	10.63	64.25	7.00	0.76	1.59	3.22	0.00	4.20	0.00	4.48	0.74	0.00	5.41	0.00	4.03	0.00	0.00	4.57	2.39	3.88	0.00	0.00	4.57	3.07	2.99	0.00	0.00	4.57	2.43	2.73
1999	8	5.12	58.90	6.20	0.80	0.76	1.53	0.00	3.43	0.00	2.00	0.49	0.00	2.63	0.00	1.55	0.00	0.00	2.23	1.53	1.40	0.00	0.00	2.23	1.86	1.34	0.00	0.00	2.23	1.61	2.14
1999	9	4.99	50.25	6.90	0.84	0.49	2.21	0.00	2.08	0.00	1.20	1.67	0.00	2.13	0.00	0.75	0.32	0.00	1.80	0.73	0.60	0.00	0.00	1.80	0.95	0.80	1.50	0.00	1.80	0.73	1.65
1999	10	2.44	35.30	8.10	0.76	0.23	1.41	0.00	1.00	0.00	0.43	1.27	0.00	0.74	0.00	0.00	1.82	0.00	0.63	0.00	0.00	0.93	0.00	0.63	0.00	0.29	1.53	0.00	0.63	0.00	1.31
1999	11	0.22	29.30	7.80	0.75	0.01	0.21	0.00	1.82	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.91
1999	12	0.43	12.20	7.90	0.79	0.00	0.00	0.43	2.98	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.21
2000	1	0.55	0.30	7.20	0.77	0.00	0.00	0.90	3.28	0.00	0.00	0.00	0.91	0.07	0.00	0.00	0.00	0.92	0.06	0.00	0.00	0.00	0.92	0.06	0.00	0.00	0.00	0.92	0.06	0.00	0.05
2000	2	0.6	13.05	7.80	0.71	0.00	0.00	1.11	3.05	0.00	0.00	0.00	1.15	0.36	0.00	0.00	0.00	1.21	0.31	0.00	0.00	0.00	1.21	0.31	0.00	0.00	0.00	1.21	0.31	0.00	0.26
2000	3	1.77	28.45	8.30	0.66	0.00	0.00	1.93	2.43	0.00	0.00	0.00	2.03	0.89	0.00	0.00	0.00	2.23	0.75	0.00	0.00	0.00	2.23	0.75	0.00	0.00	0.00	2.23	0.75	0.00	0.88
2000	4	1.96	34.40	8.40	0.64	1.73	1.08	0.00	1.92	0.00	1.50	1.49	0.00	1.00	0.00	1.21	2.13	0.00	0.85	0.00	0.86	2.48	0.00	0.85	0.00	1.72	1.63	0.00	0.85	0.00	1.26
2000	5	3.12	49.45	8.20	0.68	0.30	0.99	0.00	2.94	0.00	0.64	0.79	0.00	1.70	0.00	0.19	0.36	0.00	1.44	1.14	0.04	0.13	0.00	1.44	1.52	0.42	0.12	0.00	1.44	1.14	1.98
2000	6	5.71	51.05	8.60	0.75	0.85	1.92	0.00	3.79	0.00	2.27	0.70	0.00	2.74	0.00	1.82	0.28	0.00	2.32	1.30	1.67	0.00	0.00	2.32	1.73	1.51	0.59	0.00	2.32	1.30	1.68
2000	7	4.97	59.95	6.70	0.75	0.74	1.12	0.00	4.20	0.00	1.94	0.14	0.00	2.90	0.00	1.49	0.00	0.00	2.45	2.06	1.34	0.00	0.00	2.45	2.71	1.29	0.00	0.00	2.45	2.06	2.39
2000	8	4.5	58.15	7.20	0.79	0.67	1.32	0.00	3.43	0.00	1.73	0.44	0.00	2.33	0.00	1.28	0.00	0.00	1.98	1.47	1.13	0.00	0.00	1.98	1.88	1.15	0.00	0.00	1.98	1.49	2.29
2000	9	1.99	46.60	7.60	0.76	0.19	0.86	0.00	2.08	0.00	0.30	0.82	0.00	0.88	0.00	0.00	0.00	0.00	0.74	0.36	0.00	0.00	0.00	0.74	0.45	0.20	0.00	0.00	0.74	0.36	1.94
2000	10	3.01	39.85	7.20	0.76	0.29	1.60	0.00	1.00	0.00	0.60	1.37	0.00	1.04	0.00	0.15	1.62	0.00	0.88	0.00	0.00	0.92	0.00	0.88	0.00	0.40	1.47	0.00	0.88	0.00	1.48
2000	11	0.94	21.65	7.80	0.84	0.00	0.00	0.94	1.82	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.40
2000	12	0.81	-4.75	6.50	0.78	0.00	0.00	1.68	2.98	0.00	0.00	0.00	1.69	0.07	0.00	0.00	0.00	1.70	0.06	0.00	0.00	0.00	1.70	0.06	0.00	0.00	0.00	1.70	0.06	0.00	0.05
2001	1	1.01	9.15	7.30	0.83	0.00	0.00	2.43	3.28	0.00	0.00	0.00	2.45	0.24	0.00	0.00	0.00	2.50	0.21	0.00	0.00	0.00	2.50	0.21	0.00	0.00	0.00	2.50	0.21	0.00	0.06
2001	2	1.37	-1.55	8.00	0.73	0.00	0.00	3.73	3.05	0.00	0.00	0.00	3.76	0.07	0.00	0.00	0.00	3.81	0.06	0.00	0.00	0.00	3.81	0.06	0.00	0.00	0.00	3.81	0.06	0.00	0.07
2001	3	0.75	16.55	7.80	0.71	0.00	0.00	3.95	2.43	0.00	0.00	0.00	4.01	0.49	0.00	0.00	0.00	4.15	0.42	0.00	0.00	0.00	4.15	0.42	0.00	0.00	0.00	4.15	0.42	0.00	0.34
2001	4	4.63	35.60	8.60	0.72	3.61	3.19	0.00	1.92	0.00	3.69	3.30	0.00	1.65	0.00	3.19	4.19	0.00	1.40	0.00	2.69	4.69	0.00	1.40	0.00	3.69	3.69	0.00	1.40	0.00	1.04
2001	5	6.88	49.05	8.50	0.70	0.68	2.93	0.00	2.94	0.00	1.76	2.07	0.00	3.04	0.00	1.31	1.90	0.00	2.57	1.09	1.16	1.69	0.00	2.57	1.45	1.18	2.04	0.00	2.57	1.09	1.86
2001	6	2.6	57.55	7.80	0.69	0.38	0.38	0.00	3.79	0.00	0.87	0.02	0.00	1.71	0.00	0.42	0.00	0.00	1.45	1.84	0.27	0.00	0.00	1.45	2.42	0.58	0.00	0.00	1.45	1.80	2.53
2001	7	2.6	60.45	6.70	0.75	0.38	0.29	0.00	4.20	0.00	0.87	0.00	0.00	1.80	0.00	0.42	0.00	0.00	1.52	1.89	0.27	0.00	0.00	1.52	2.38	0.58	0.00	0.00	1.52	1.71	2.43
2001	8	5.91	62.00	6.60	0.77	0.88	1.65	0.00	3.43	0.00	2.36	0.34	0.00	3.14	0.00	1.91	0.00	0.00	2.66	1.63	1.76	0.00	0.00	2.66	1.96	1.57	0.00	0.00	2.66	1.56	2.70
2001	9	1.69	50.10	6.10	0.80	0.16	0.62	0.00	2.08	0.00	0.21	0.64	0.00	0.84	0.00	0.00	0.00	0.00	0.71	0.59	0.00	0.00	0.00	0.71	0.69	0.14	0.00	0.00	0.71	0.55	1.78
2001	10	3.54	37.65	8.30	0.82	0.34	1.99	0.00	1.00	0.00	0.76	1.66	0.00	1.12	0.00	0.31	0.04	0.00	0.95	0.00	0.16	0.00	0.00	0.95	0.00	0.51	0.05	0.00	0.95	0.00	1.21
2001	11	2.02	33.95	8.70	0.82	0.19	1.19	0.00	1.82	0.00	0.31	1.12	0.00	0.60	0.00	0.00	1.52	0.00	0.51	0.00	0.00	0.65	0.00	0.51	0.00	0.20	1.31	0.00	0.51	0.00	0.92
2001	12	0.74	15.90	9.00	0.82	0.00	0.00	0.74	2.98	0.00	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.24
2002	1	0.37	9.95	7.10	0.80	0.00	0.00	0.83	3.28	0.00	0.00	0.00	0.85	0.26	0.00	0.00	0.00	0.89	0.22	0.00	0.00	0.00	0.89	0.22	0.00	0.00	0.00	0.89	0.22	0.00	0.10
2002	2	0.32	15.25	8.80	0.71	0.00	0.00	0.70	3.05	0.00	0.00	0.00	0.75	0.42	0.00	0.00	0.00	0.86	0.35	0.00	0.00	0.00	0.86	0.35	0.00	0.00	0.00	0.86	0.35	0.00	0.33
2002	3	1.42	10.95	9.10	0.64	0.00	0.00	1.80	2.43	0.00	0.00	0.00	1.87	0.30	0.00	0.00	0.00	2.02	0.25	0.00	0.00	0.00	2.02	0.25	0.00	0.00	0.00	2.02	0.25	0.00	0.34
2002	4	0.66	33.15	8.80	0.68	1.49	0.23	0.00	1.92	0.00	1.10	0.75	0.00	0.68	0.00	1.07	1.04	0.00	0.57	0.00	0.72	1.39	0.00	0.57	0.00	1.37	0.74	0.00	0.57	0.00	1.09
2002	5	1.93	42.90	8.60	0.64	0.18	0.56	0.00	2.94	0.00	0.28	0.55	0.00	1.10	0.00	0.00	0.65	0.00	0.93	0.35	0.00	0.54	0.00	0.93	0.47	0.19	0.47	0.00	0.93	0.35	1.78
2002	6	4.04	60.50	8.30	0.71	0.60	0.74	0.00	3.79	0.00	1.52	0.02	0.00	2.51	0.00	1.07	0.00	0.00	2.12	2.09	0.92	0.00	0.00	2.12	2.74	1.01	0.00	0.00	2.12	2.07	2.71
2002	7	4.07	65.40	6.60	0.73	0.60	0.55	0.00	4.20	0.00	1.53	0.00	0.00	2.72	0.00	1.08	0.00	0.00	2.30	2.19	0.93	0.00	0.00	2.30	2.71	1.02	0.00	0.00	2.30	2.08	3.07
2002	8	4.73	61.45	7.70	0.79	0.70	1.23	0.00	3.43	0.00	1.83	0.12	0.00	2.60	0.00	1.38	0.00	0.00	2.20	1.48	1.23	0.00	0.00	2.20	1.74	1.22	0.00	0.00	2.20	1.41	2.64
2002	9	2.48	54.95	7.30	0.80	0.24	0.81	0.00	2.08	0.00	0.44	0.71	0.00	1.33	0.00	0.00	0.00	0.00	1.13	0.97	0.00	0.00	0.00	1.13	1.11	0.30	0.00	0.00	1.13	0.89	2.27
2002	10	2.39	30.30	7.30	0.80	0.23	1.51	0.00	1.00	0.00	0.42	1.37	0.00	0.61	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.52	0.00	0.28	0.00	0.00	0.52	0.00	0.92
2002	11	0.69	18.80	7.70	0.80	0.00	0.00	0.69	1.82	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.40
2002	12	0.84	13.35	8.20	0.81	0.00	0.00	1.53	2.98	0.00	0.00	0.00	1.53	0.00	0.00	0.00	0.00	1.53	0.00	0.00	0.00	0.00	1.53	0.00	0.00	0.00	0.00	1.53	0.00	0.00	0.20
2003	1	0.23	1.50	8.80	0.74	0.00	0.00	1.66	3.28	0.00	0.00	0.00	1.67	0.09	0.00	0.00	0.00	1.68	0.08	0.00	0.00	0.00	1.68	0.08	0.00	0.00	0.00	1.68	0.08	0.00	0.09
2003	2	0.26	0.70	8.20	0.66	0.00	0.00	1.83	3.05	0.00	0.00	0.00	1.85	0.08	0.00	0.00	0.00	1.87	0.07	0.00	0.00	0.00	1.87	0.07	0.00	0.00	0.00	1.87	0.07	0.00	0.15
2003	3	0.76	16.65	8.10	0.68	0.00	0.00	2.06	2.43	0.00	0.00	0.00	2.11	0.50	0.00	0.00	0.00	2.21	0.42	0.00	0.00	0.00	2.21	0.42	0.00	0.00	0.00	2.21	0.42	0.00	0.39
2003	4	1.49	33.95	9.40	0.57	1.78	0.81	0.00	1.92	0.00	1.41	1.30	0.00	0.88	0.00	1.20	0.95	0.00	0.75	0.00	0.85	0.18	0.00	0.75	0.00	1.61	0.52	0.00	0.75	0.00	1.56
2003	5	2.26	45.85	8.20	0.58	0.22	0.68	0.00	2.94	0.00	0.38	0.61	0.00	1.27	0.00	0.00	0.48	0.00	1.07	0.70	0.00	0.25	0.00	1.07	0.94	0.25	0.23	0.00	1.07	0.70	2.27
2003	6	3.9	54.05	6.40	0.71	0.58	0.96	0.00	3.79	0.00	1.46	0.25	0.00	2.19	0.00	1.01	0.00	0.00	1.86	1.56	0.86	0.00	0.00	1.86	2.06	0.97	0.00	0.00	1.86	1.56	1.92
2003	7	4.84	58.85	6.00	0.75	0.72	1.12	0.00	4.20	0.00	1.88	0.17	0.00	2.79	0.00	1.43	0.00	0.00	2.36	1.92	1.28	0.00	0.00	2.36	2.47	1.25	0.00	0.00	2.36	1.93	2.20
2003	8	1.45	60.75	6.40	0.76	0.21	0.20	0.00	3.43	0.00	0.35	0.13	0.00	0.97	0.00	0.00	0.00	0.00	0.82	1.57	0.00	0.00	0.00	0.82	1.87	0.24	0.00	0.00	0.82	1.46	2.64
2003	9	6.52	50.55	8.20	0.81	0.64	3.01	0.00	2.08	0.00	1.66	2.20	0.00	2.66	0.00	1.21	0.00	0.00	2.25	0.76	1.06	0.00	0.00	2.25	0.97	1.10	0.16	0.00	2.25	0.76	1.99
2003	10	1.51	37.55	7.50	0.80	0.14	0.81	0.00	1.00	0.00	0.15	0.83	0.00	0.52	0.00	0.00	1.04	0.00	0.44	0.00	0.00	0.00	0.00	0.44	0.00	0.10	0.97	0.00	0.44	0.00	1.23
2003	11	1.64	19.05	8.60	0.81	0.00	0.00	1.03	1.82	0.00	0.00	0.00	1.07	0.57	0.00	0.00	0.00	1.16	0.48	0.00	0.00	0.00	1.16	0.48	0.00	0.00	0.00	1.16	0.48	0.00	0.41
2003	12	0.68	12.45	7.40	0.83	0.00	0.00	1.71	2.98	0.00	0.00	0.00	1.75	0.00	0.00	0.00	0.00	1.84	0.00	0.00	0.00	0.00	1.84	0.00	0.00	0.00	0.00	1.84	0.00	0.00	0.15
2004	1	1.27	-6.50	10.20	0.69	0.00	0.00	2.91	3.28	0.00	0.00	0.00	2.96	0.07	0.00	0.00	0.00	3.06	0.06	0.00	0.00	0.00	3.06	0.06	0.00	0.00	0.00	3.06	0.06	0.00	0.08
2004	2	0.69	10.30	7.40	0.75	0.00	0.00	3.31	3.05	0.00	0.00	0.00	3.38	0.27	0.00	0.00	0.00	3.52	0.23	0.00	0.00	0.00	3.52	0.23	0.00	0.00	0.00	3.52	0.23	0.00	0.17
2004	3	1.29	21.65	9.50	0.71	0.00	0.00	3.85	2.43	0.00	0.00	0.00	3.97	0.70	0.00	0.00	0.00	4.21	0.59	0.00	0.00	0.00	4.21	0.59	0.00	0.00	0.00	4.21	0.59	0.00	0.52
2004	4	1.58	32.85	9.00	0.58	3.22	1.23	0.00	1.92	0.00	2.74	1.91	0.00	0.90	0.00	2.60	2.44	0.00	0.76	0.00	2.25	2.71	0.00	0.76	0.00	3.13	1.91	0.00	0.76	0.00	1.43
2004	5	3.78	40.40	9.60	0.70	0.37	1.67	0.00	2.94	0.00	0.83	1.33	0.00	1.62	0.00	0.38	1.98	0.00	1.37	0.05	0.23	2.11	0.00	1.37	0.06	0.56	1.81	0.00	1.37	0.05	1.42
2004	6	1.08	50.95	8.30	0.68	0.15	0.02	0.00	3.79	0.00	0.19	0.06	0.00	0.84	0.00	0.00	0.00	0.00	0.71	1.26	0.00	0.00	0.00	0.71	1.66	0.12	0.00	0.00	0.71	1.24	2.11
2004	7	2.78	57.25	6.50	0.73	0.41	0.44	0.00	4.20	0.00	0.95	0.03	0.00	1.80	0.00	0.50	0.00	0.00	1.52	1.71	0.35	0.00	0.00	1.52	2.18	0.63	0.00	0.00	1.52	1.60	2.30
2004	8	3.06	51.90	7.00	0.72	0.45	1.01	0.00	3.43	0.00	1.08	0.50	0.00	1.48	0.00	0.63	0.00	0.00	1.26	0.82	0.48	0.00	0.00	1.26	1.02	0.72	0.00	0.00	1.26	0.76	2.26
2004	9	4.88	54.50	8.70	0.69	0.48	1.92	0.00	2.08	0.00	1.16	1.41	0.00	2.31	0.00	0.71	0.00	0.00	1.95	1.16	0.56	0.00	0.00	1.95	1.48	0.78	0.00	0.00	1.95	1.15	3.26
2004	10	2.73	39.45	8.80	0.71	0.26	1.46	0.00	1.00	0.00	0.52	1.28	0.00	0.93	0.00	0.07	1.44	0.00	0.79	0.00	0.00	0.58	0.00	0.79	0.00	0.35	0.97	0.00	0.79	0.00	1.81
2004	11	0.32	26.40	7.70	0.71	0.00	0.00	0.32	1.82	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.86
2004	12	1.7	4.15	8.60	0.74	0.00	0.00	1.87	2.98	0.00	0.00	0.00	1.88	0.14	0.00	0.00	0.00	1.90	0.12	0.00	0.00	0.00	1.90	0.12	0.00	0.00	0.00	1.90	0.12	0.00	0.16

Figures

Watershed Divides

Current Land Cover

- Brush; Grassland
- Road
- Tailings Basin Active
- Reclaimed Tailings
- Tailings Basin Open Water/Pond
- Wetland
- Wooded/Forest

N

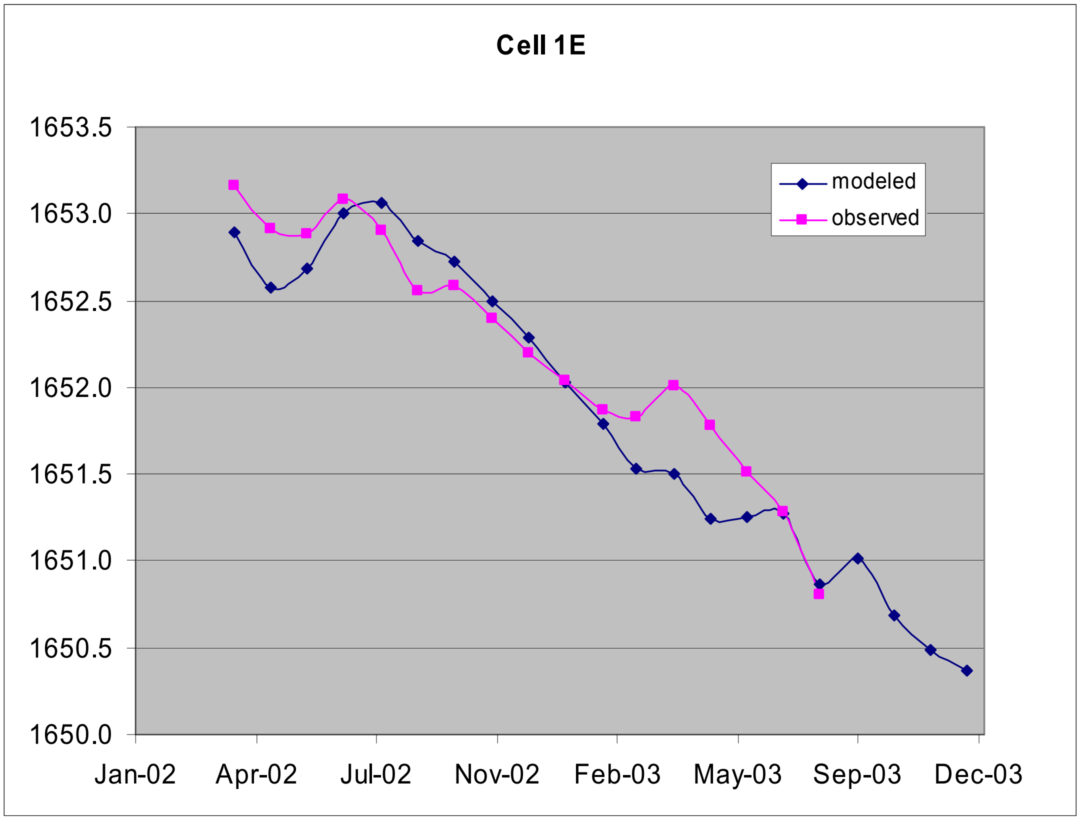
Feet

2,500   0   2,500

Figure 3-1

CURRENT LAND USE IN EXISTING WATERSHEDS

NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN



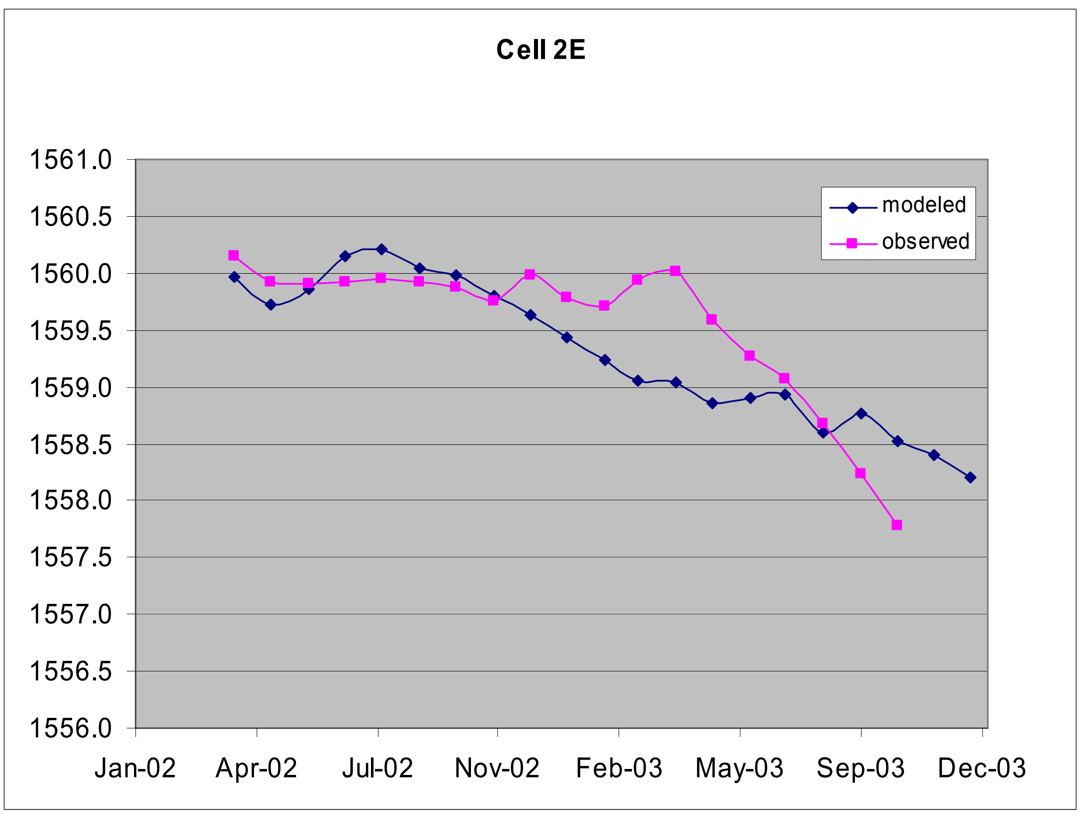


Figure 4-1 Modeled and observed water levels in Cells 1E and 2E for the period of calibration

Attachment A-6

Groundwater Flow Modeling of the PolyMet Tailings Basin-Mitigation Design

Attachment A-6 to RS13b
Groundwater Flow Modeling of the PolyMet Tailings Basin-Mitigation Design

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1 Introduction

1.1 Project Scope and Objectives

Barr Engineering Company (Barr) prepared a detailed water balance for the Tailings Basin-Mitigation Design in support of the NorthMet Mine and Ore Processing Facilities Project (the Project) Environmental Impact Statement (EIS). Two main components of the water balance for the Tailings Basin-Mitigation Design are seepage and seepage recovery. Seepage refers to the water lost to the groundwater flow system from the pond(s) that will be present in the Tailings Basin. This report documents the methodologies used to predict these components of the water balance and provides detailed information of the values predicted for the Tailings Basin-Mitigation Design at various stages of operations and closure.

1.2 Tailings Basin Overview

There are three discrete cells in the existing tailings basin, Cells 1E, 2E, and 2W, as shown on Figure 1-1. Cell 2W is the largest (1,447 acres) and has the highest elevation of the three cells with an average fill height of 200 feet. Cell 2W is currently the driest of the cells and has gradually lost the ponded water remaining from taconite processing. Cell 1E is approximately 980 acres and rises approximately 125 feet above the surrounding ground level; Cell 2E is about 620 acres and has the lowest elevation of all of the existing cells, rising approximately 60 feet above surrounding ground level. Cells 1E and 2E currently have water in them. The existing basin does not have an overflow or discharge structure.

Ore processing associated with the Project will produce two types of solid waste: hydrometallurgical residue and flotation tailings. These two wastes will be disposed of in separate facilities. Hydrometallurgical residue will be stored in the Hydrometallurgical Residue Facility made up of smaller containment cells located within the existing Cell 2W. The flotation tailings will be sent to existing Cells 1E and 2E. This report deals only with the flotation tailings. The Hydrometallurgical Residue Facility is described in RS28T.

Development of the Tailings Basin-Mitigation Design will be documented in detail in the Permit to Mine and SDS/NPDES Permit applications and is summarized here. When considering the effect of the basin design on the groundwater modeling and water balance, the Tailings Basin-Mitigation Design differs from the Proposed Design in three key areas. For the Mitigation Design:

- The perimeter embankments will be constructed with LTVSMC coarse tailing;

- PolyMet Tailing will be deposited in a manner that results in no significant segregation of tailing by particle size; and
- There will be no cap or cover system installed on the embankments or beach areas
- There will be no horizontal drains on the north dam of Cell 2E for the purposes of dam stability (This function will be performed by a rock buttress where necessary along the toe of the existing LTVSMC dams)

Other than these changes, the operation of the Tailings Basin will be similar for the Mitigation Design as was proposed for the Proposed Design.

Tailings deposition will begin in Cell 2E in the first year of operation and will last for approximately seven years. Tailing will be deposited both on the exposed beaches and within the pond. Tailings will be deposited from the exterior embankment along the northern and northeastern edges of Cell 2E. During this period, Cell 1E will likely be used as a clear water basin and was modeled as such.

After approximately seven years of depositing tailings in Cell 2E, the elevation of the cell will reach the elevation of Cell 1E and the two will merge. From approximately Year 8 through the life of the Project, tailings will be disposed of in the merged cells. Tailings will again be deposited from both the exterior embankments (along the northern and northeastern edge of Cell 2E and along the southern and southeastern edge of Cell 1E) and within the pond. Beaches will not be formed along the western edge of Cell 1E or Cell 2E or along the much of the eastern edge of the cells.

The embankments will be constructed out of LTVSMC coarse tailing in approximately 20 foot lifts with a 200 foot crest. At each embankment location, there will be a 625 foot beach consisting of PolyMet bulk tailing that will be the transition area between the LTVSMC coarse tailings embankments on the perimeter of the basin and the edge of the pond within the Tailings Basin. The remainder of the basin will be a pond.

Preliminary water quality modeling of closure conditions indicated that achievement of water quality objectives at the basin in closure will depend in part on maintaining proper moisture conditions and oxygen exclusion in the PolyMet tailings. This will be accomplished by maintenance of a pond above much of the PolyMet tailings after basin closure. The pond with simultaneously prevent oxygen intrusion from the tailings surface, while also providing seepage water to maintain elevated saturation conditions in tailings below the pond. Since the seepage through the PolyMet tailings in combination with the small area providing surface water runoff to the basin may make it difficult to maintain a pond during some portions of the year, the permeability of the tailings at the surface will be modified by bentonite addition as needed to reduce the hydraulic conductivity of the tailings. The reduced hydraulic conductivity will limit seepage through the tailings and will result in maintenance of a pond above the tailings after basin closure.

As was planned for the Proposed Design, the Tailings Basin-Mitigation Design includes a seepage barrier/collection system that will be established in the area south of Cell 1E to contain seepage that is known to be present in the area (i.e. the headwaters of Knox Creek). Water from this seepage barrier will be pumped back to the basin.

2 Hydrogeology of Project Area

2.1 Hydrogeologic Setting

The Rainy Lobe drift forms the major surficial aquifer in the region that encompasses the Tailings Basin. Underlying the drift deposits are Precambrian crystalline and metamorphic bedrock. This material is assumed to have a significantly lower value of hydraulic conductivity (i.e., several orders of magnitude) than the drift and as such, acts as an aquitard. In some locations, peat deposits have been encountered between the tailings and the drift. These deposits are likely discontinuous and can be ignored at the scale at which the Tailings Basin is being evaluated for this analysis. On top of the drift deposits are numerous wetlands and minor surface-water drainages. These features are assumed to represent surficial expressions of the water table. Cross sections through the basin are shown on Figures 2-1 and 2-2.

2.3 Hydrogeologic Conceptual Model

The *hydrogeologic conceptual model* is a schematic description of how water enters, flows, and leaves the groundwater system. In the development of a conceptual model, it is necessary to simplify real-life complexities into a system that can be numerically simulated. The hydrogeologic conceptual model is both scale-dependent (i.e. local conditions may not be identical to regional conditions) and dependent upon the questions being asked.

Regionally, groundwater flows primarily northward, from the Embarrass Mountains to the Embarrass River (Siegel and Ericson, 1980). Gradients in the area are reported to vary between 0.12 ft/ft near the Embarrass Mountains to 0.0009 ft/ft beneath wetlands (Siegel and Ericson, 1980). At the southern end of the Tailings Basin, there is some flow to the south, forming the headwaters of Second Creek (also known as Knox Creek). As the Tailings Basin was built up over time, a groundwater mound formed beneath the basin due to seepage from the basin ponds, altering local flow directions and rates. Seeps have been identified on the south, west, and north sides of the Tailings Basin. The east side of the Tailings Basin is bounded by low-permeability bedrock uplands and there is likely little or no water that seeps out in this direction. In addition to the visible seeps, groundwater likely flows out from beneath the tailing basin into the surrounding drift to the west and north of the basin.

3 Hydrologic Model Selection

3.1 MODFLOW-SURFACT

Groundwater modeling for this work was conducted using MODFLOW-SURFACT (HydroGeoLogic, Inc., 1996), a flow and transport code based on the U.S. Geological Survey groundwater modeling software MODFLOW (McDonald and Harbaugh, 1988). MODFLOW-SURFACT simulates saturated and unsaturated subsurface flow and contaminant fate and transport. This document focuses only of the flow components of the code that were used; contaminant fate and transport modeling is document in RS74 (to be released after release of this report).

MODFLOW-SURFACT was selected for this work because it was determined that unsaturated flow may be important in the transport of dissolved constituents from the beach areas of the PolyMet Tailings Basin. MODFLOW-SURFACT simulates the three-dimensional movement of water in a variably saturated system using the following equation:

$$\frac{\partial}{\partial x}\left(K_{xx}k_{rw}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}k_{rw}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}k_{rw}\frac{\partial h}{\partial z}\right)-W=\Phi\frac{\partial S_w}{\partial t}+S_wS_s\frac{\partial h}{\partial t}$$

Where:

- x ,y, and z are Cartesian coordinates (L);
- K_{xx}, K_{yy}, K_{zz} are the principal components of hydraulic conductivity along the x, y, and z axes, respectively (LT^{-1});
- K_{rw} is the relative permeability, which is a function of water saturation;
- h is the hydraulic head (L);
- W is a volumetric flux per unit volume and represents source and/or sinks of water (T^{-1});
- Φ is the drainable porosity taken to be equal to the specific yield, S_y;
- S_w is the degree of saturation of water, which is a function of the pressure head:
- S_s is the specific storage of the porous material (L-1); and
- t is time (T).

For the work presented here, pseudo-soil relations were used to define the relative permeability (Krw) and the degree of saturation (Sw).

3.3 Groundwater Vistas

The MODFLOW model was developed using the graphical user interface (GUI) Groundwater Vistas (Version 5) (Environmental Simulations, Inc., 2004). Most model input parameters can be imported into Groundwater Vistas as ESRI shapefiles.

4 Groundwater Flow Model

The conceptual model of the Tailings Basin outlined in Section 2 was used to develop numerous numerical model realizations for this study. The same model realization that simulates historical conditions that was presented in RS13 Draft-03 was used as the base case for the work presented here, with the exception of minor changes as discussed in Section 4.6. Separate predictive realizations (i.e., forward simulations) were created for several future condition of interest. These model variants were used to predict groundwater-flow directions, the amount of seepage from basins, the amount of seepage recovered by the seepage collection system, and the amount of seepage not recovered by the seepage collection system. All model simulations are steady-state.

4.1 Purpose and Scope of Simulations

The groundwater flow model was used to answer two main types of questions:

1) Water Balance Related Questions: What will be the seepage loss from the active ponds in the Tailings Basin and how much seepage will be recovered from the seepage collections system?

2) Water Quality Related Questions: What is the fate and transport time for water that infiltrates the beach areas on the active ponds or is lost as seepage from the active ponds in the Tailings Basin?

Five model realizations were constructed to answer these questions. Realizations were constructed to simulate conditions at four different stages of basin development (as defined by the top elevation of the basin) and closure:

- Elevation 1620 ft, which will occur in approximately Year 4
- Elevation 1660 ft, which will occur in approximately Year 7
- Elevation 1700 ft, which will occur in approximately Year 15
- Elevation 1720 ft, which will occur in approximately Year 20
- Closure, which is the same essential design as the Elevation 1720 ft Model

This document deals with the water balance related questions. Groundwater modeling conducted to answer water quality related questions will be documented in the forthcoming RS74 Draft-02.

4.2 Model Domain

The active zone of the finite-difference grid covers approximately 18 square miles (Figure 4-1), extending from the Embarrass River in the north and west to the south and east of the former LTVSMC mine pits (i.e., south of LTVSMC Pits 1, 2, 3 and 2WX and east of LTVSMC Pits 5S and 5N). The lateral extent of the model area is sufficiently large and distant from the area of interest, so that the model boundaries do not meaningfully affect the model results at the Tailings Basin. The model grid is irregular, with larger cells away from the basin and smaller cells covering the basin. The aspect ratio for the change in cell spacing between adjacent cells was set at approximately 1.5:1.

4.3 Vertical Discretization

The base model simulating initial conditions, presented in detail in RS13 Draft-03 Attachment A-6, has two layers: Layer 1 represents the LTVSMC tailings and Layer 2 represents the native unconsolidated material (drift and peat). Portions of Layer 1 outside of the footprint of the Tailings Basin were inactivated (i.e. converted to no-flow cells). The bedrock was assumed to have a significantly lower value of hydraulic conductivity than the native material and, as such, was treated as a no-flow boundary. An exception to this is described below.

The top elevation for Layer 1 was defined using the current topography of the basin. The bottom elevation for Layer 1 (equal to the top of Layer 2) was defined as the pre-mining topography. The bottom elevation for Layer 2 was defined as the top of bedrock. Topographic information from the Minnesota Geological Survey was used to define the elevations of the pre-mining and bedrock surfaces. The exception to this was in the area of the Embarrass Mountains, where the water table is likely located within the bedrock hills. In this area, the bottom of Layer 2 was lowered and the bedrock was simulated as a zone of low hydraulic conductivity. This was necessary to prevent dry cells in Layer 2.

Additional model layers were added to the base model realization to represent the PolyMet tailings. In the Elev. 1620 Model, two additional layers were added, resulting in a total of four model layers. For the Elev. 1660 Model, as additional model layer was added to the Elev. 1620 Model (total of 5 layers). In the Elev. 1700 Model, two additional model layers were added to the Elev. 1660 Model (total of 7 layers). One additional layer was added to the Elev. 1700 Model for the final realizations (the Elev. 1720 Model and the Closure Model), bringing the total number of layers to eight. For each new model layer added in all realizations, the extent of active cells was defined based on the tailings basin design that will be presented in the Permit to Mine and the SDS/NPDES Permit applications and is shown on Figures 4-2 to 4-5. Two cross-sections through the model, showing the general layout of the model layers are shown on Figure 4-6.

4.3 Boundary Conditions

Internal boundaries were used to represent surface-water features within the model domain (shown in Figure 4-1). Streams and rivers were simulated as constant-head boundaries with elevations obtained from USGS 7.5' quadrangle maps. The River Package in MODFLOW was used to simulate area wetlands as head-dependent boundaries, where water is allowed to flow into and out of the boundary, with the flux dependent on the head gradient between the boundary (a constant, user-specified head) and the aquifer and a user-specified conductance. Wetland areas were based on the USGS's countywide lake shapefile. Wetland elevations were set equal to existing ground surface elevations.

The pools of water in Cells 1E and 2E were simulated as constant-head boundaries. For the base model realization, the heads were set using water levels reported in the East Range Hydrology Study (Adams et al., 2004). Cell 1E was set at 1653 ft mean sea level (MSL) and Cell 2E was set at 1560 ft MSL. For the future conditions realizations, heads were set using the Tailing Basin design that will be presented in the Permit to Mine and the SDS/NPDES Permit applications. Water levels were assumed to be four feet lower than the top of the dams. That is, for the Elev. 1720 ft realization, the pond elevation was set equal to 1716 ft. For each realization, the extent of the pond was determined based on basin design presented in Figures 4-2 through 4-5.

A seepage barrier will be constructed to collect the water currently emerging as seepage south of Cell 1E. This water will be collected and pumped back to the Tailings Basin. This barrier was simulated using the drain package and the horizontal-flow barrier package. A horizontal-flow barrier was set south of the seep area, with drain cells placed just north of the barrier to remove water that would otherwise build up behind the barrier. The elevation of the drain cells was set equal to the current elevation of the seeps at that location.

4.4 Hydraulic Conductivity Values

Seven different hydraulic conductivity zones were used in the groundwater flow models, as described here. Two zones were used to represent the tailings in the current LTVSMC basin, two zones were used to represent native material (one for the unconsolidated deposits and one for bedrock), one zone was used to represent the future embankments that will be constructed out of LTVSMC bulk tailing, and two zones were used to represent the PolyMet tailing (one for shallow tailing and one for deep tailing). Figure 4-7 shows the hydraulic conductivity zones used in the model of the basin at Elevation 1720 ft. Table 4-1 summarizes the hydraulic conductivity values used for each material in the groundwater models. In addition, a technical memorandum, "PolyMet Tailings Basin Permeabilities"(Attachment A-6-B) that summarizes the existing information on the permeabilities of material associated with the existing LTVSMC Tailings Basin, the predicted permeabilities of material associated with the PolyMet Tailings Basin and the permeability values used in the various modeling efforts was prepared.

4.4.1 LTVSMC Basin Materials

Hydraulic conductivity values for the LTVSMC tailings were selected to be consistent with the SEEP/W modeling that is being done for the Tailings Basin-Mitigation Design, which will be described in the Permit to Mine and the SDS/NPDES Permit applications. Two zones were used to represent the LTVSMC tailings—one for the slimes and one for the coarse and fine tailings beach areas. The SEEP/W modeling used three zones to represent the LTVSMC tailings: coarse tailing, fine tailing and slimes. For the groundwater modeling presented here the coarse and fine tailings were grouped. Because the majority of the area where coarse tailings are found are currently unsaturated, a permeability representative of fine tailing was used for the grouped coarse and fine tailing area in the groundwater model.

4.4.2 Native Materials

One zone was used to represent the native unconsolidated material and one zone was used to represent the bedrock hills, as discussed above. The hydraulic conductivity of the native drift is higher than would be expected given that it consists primarily of silty sand. Hydraulic conductivity values estimated for the area ranged from about 10 to 3,500 ft/day for sand and gravel deposits and 0.01 to 30 ft/day for Rainy lobe till deposits (Siegel and Ericson, 1980). Slug tests conducted within the glacial till performed along the north dam of Cell 2W found a range of permeabilities of 0.24 to 2.0 ft/day (Attachment A-6-B). Because the thickness of Layer 1 was not allowed to vary during model calibration, the transmissivity of the layer (hydraulic conductivity times the layer thickness) was the operational parameter that was optimized during calibration. Little information exists on the actual thickness of the surficial deposits over much of the model area. It may be that the deposits are thicker than was simulated in the model (generally 5 meters) or that the upper portion of the bedrock is sufficiently fractured such that it acts as an extension of the surficial aquifer. In either case, a thicker aquifer would result in having a lower hydraulic conductivity in order to have the same aquifer transmissivity.

4.4.3 PolyMet Basin Materials

For the Mitigation Design, tailings will be placed in a manner that precludes segregation of the material into fine and coarse fractions. As such, the permeability of the bulk tailings was deemed to be representative of all PolyMet tailings. To account for variability in permeability with confining stress, two different permeabilities were used for the PolyMet tailings; a higher value for the tailings near the surface and a lower value for the tailings at depth in the basin. This is consistent with the material testing presented in Attachment A-6-B. A permeability representative of LTVSMC bulk tailings was used for the embankments of the PolyMet basin which will be constructed out of LTVSMC tailings.

In closure, the permeability of the beach and pond area will be lowered via bentonite augmentation. It was assumed that the bentonite augmented layer would be 18 inches thick and would have a permeability of $1x10^{-6.5}$ cm/sec. Permeability values used for the groundwater modeling of the Mitigation Design are shown in Table 4-1.

Table 4-1 Hydraulic Conductivity Values used in the Groundwater Models

Material	Hydraulic Conductivity ft/sec	Hydraulic Conductivity cm/sec
LTVSMC Embankment	2.67E-06	8.14E-05
PolyMet Bulk - Shallow	1.14E-05	3.47E-04
PolyMet Bulk - Deep	2.13E-06	6.50E-05
LTVSMC Coarse Beach	1.77E-06	5.39E-05
LTVSMC Fine Beach	1.77E-06	5.39E-05
LTVSMC Slimes	3.64E-07	1.11E-05
Glacial Till	7.59E-04	2.31E-02
Bedrock	2.81E-09	8.56E-08

The LTVSMC tailings, PolyMet tailings and the bedrock were assumed to be isotropic (i.e. $K_x = K_y = K_z$). The drift was assumed to have a vertical anisotropy ratio (K_x / K_z) of 10. Hydraulic conductivity zones are shown on Figure 4-7.

4.5 Recharge

The Recharge Package for MODFLOW was used to simulate the infiltration of precipitation within the model domain. Recharge was applied to the uppermost active layer. Zones of high recharge were used above Cell 2W in order to reproduce the groundwater mound beneath the basin, with the recharge rates determined during model calibration presented in RS13 Draft-03. Two recharge zones were used for areas outside of the Tailings Basin, one zone where bedrock is the uppermost unit and one zone where surficial deposits are present. For the predictive realizations, two new recharge zones were added to the model: one zone representing infiltration through the PolyMet beach areas; and one zone representing infiltration through the LTVSMC embankment areas. Recharge zones are shown on Figure 4-8.

Table 4-2 presents the recharge rates used in the various model realizations. During operations, some amount of tailings will be discharged from a spigot located along the outer portion of the beach area. As the tailing and water is discharged to the beach, some of the water used to transport the tailings will infiltrate, with the remaining water reaching the pond located in the center of the basin. Infiltration associated with the tailings slurry was calculated in the same manner as was done for the Proposed Design (documented in RS54/RS46 Draft-01). This calculation is based on the following assumptions:

- The permeability of the tailing is $6.5x10^{-7}$m/s;
- The beach width is 625 ft;
- The delta angle will be 75 degrees; and
- 30% of the delta will have active flow.

Predicted infiltration rates associated with the tailings slurry were added to natural infiltration rates predicted by the Meyer Model (8 inches per year, as described in Attachment A-5) to determine average basin-wide infiltration rates during various stages of tailings basin development.

Table 4-2 Recharge Rates Used in Predictive Realizations

	Infiltration through PolyMet Beach Areas	**Infiltration through Embankment Areas**
	inches/year	**inches/year**
Elev. 1620 Model	25.7	8.0
Elev. 1660 Model	26.2	8.0
Elev. 1700 Model	15.4	8.0
Elev. 1720 Model	14.9	8.0
Closure Model	3.6	8.0

In closure, the surface of the PolyMet tailing will be modified with a bentonite mixture. To help determine what the infiltration will be through this modified layer, the model HELP was used. The results of this modeling are presented in Attachment A-6-A.

4.6 Model Calibration

The base model[1] was not fully recalibrated, since only minor changes were made to the model from the calibrated base model used for the Tailings Basin – Proposed design as presented in RS13 Draft-03 Attachment A-6. Changes to the base model are presented here, along with the final calibration results.

4.6.1 Changes to Base Model

Some changes were made to the base model used for this work from the base model that was presented in RS13 Draft-03 Attachment A-6 in order to incorporate additional data on the basin that has been collected since the work in RS13 Draft-03 was completed. Additional information on the permeability of the LTVSMC tailing was collected and analyzed as part of the geotechnical evaluation of the basin. As a result, the permeability values used for the Tailings Basin – Mitigation Design models are slightly different than were used for the Tailings Basin – Proposed Design models. This can be seen by comparing the values in Table 4-1 in this report with the values in Table 4-1 of RS13 Draft-03 Attachment A-6. As a result of changing the permeability of the LTVSMC tailing, the permeability of the native material also needed to change slightly in order to maintain an acceptable calibration.

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 resulting zones of hydraulic conductivity can be seen on Figure 4-7.

4.6.2 Calibration Results

The small changes in parameter values to the base model did not significantly change the calibration statistics for the model. Calibration statistics are shown below in Table 4-3 and on Figure 4-9. The model calibration was determined to be acceptable, given the modeling objectives, using the following rationale. For groundwater modeling conducted as part of well head protection plans in

[1] The term "base model" refers to the model that simulates existing conditions. This model is also referred to as the "calibration model" since it is the model that is used for calibration.

the state of Minnesota, the Department of Health deems the model calibration acceptable if the absolute residual mean (ARM) is less than 10% of the observed range in heads across the model domain (Steve Roberson, personal communication). As shown in Table 4-3, the ARM is less than 4% of the observed range in heads.

Table 4-3 Calibration Results

Head Targets		
Residual Mean	-3.7 ft	
Absolute Residual Mean	10.7 ft	
Total range in observed heads	302 ft	
Flux Targets	*Target*	*Simulated*
Seepage out from Cell 1E	2.0 cfs	1.9 cfs
Seepage out from Cell 2E	1.5 cfs	1.6 cfs
Seeps south of Cell 1E	554 gpm	470 gpm

4.7 Model Predictions

The groundwater flow model realizations were used to predict the seepage loss from the ponds in the Tailings Basin and to predict the amount of seepage that will be collected by the seepage collection system. Model results are presented in Table 4-4. Predicted heads from the Elev. 1720 Model are shown on Figure 4-10.

Table 4-4 Summary of Predicted Seepage and Seepage Collection Rates

	Seepage from Cell 1E Pond (gpm)	Seepage from Cell 2E Pond (gpm)	Flow to Seepage Barrier (gpm)	Cell 1E Seeps (gpm)
Elev. 1620 Model	1190	1080	410	--
Elev. 1660 Model	240	2020	380	--
Elev. 1700 Model	3140		540	140
Elev. 1720 Model	3340		570	170

As was the case for the Tailings Basin – Propose Design, the groundwater model predicts that there will be some surface seeps along the Cell 1E east embankment. The seepage rate is shown above on Table 4-4 as “Cell 1E Seeps”. For the water balance, it was assumed that this water would be returned to the basin.

4.8 Sensitivity Analysis

An analysis was performed to assess the sensitivity of the model predictions to uncertainties in model parameters. For this analysis, the Elevation 1720 Model realization was used as it represents the condition with the largest seepage rates and seepage recovery rates. The following parameters were adjusted in the sensitivity analysis:

- Hydraulic conductivity values of the PolyMet bulk tailing: The base case model used a hydraulic conductivity value measured from bulk PolyMet tailings. For the sensitivity analysis, the average value measured for the oversized (i.e. coarse) fraction of the tailing and the average value for the undersized (i.e. fine) tailing were used. These hydraulic conductivity values were applied to the entire thickness of PolyMet tails in the model.

- Hydraulic conductivity values of the till: The base case model used a hydraulic conductivity value for the till that is on the upper end of the expected range of values for the material. For the sensitivity analysis, the hydraulic conductivity of the till was decreased by one order of magnitude. It is important to note that this change results in a model that is not calibrated and significantly under predicts both historic seepage losses from the basin and observed flow at the seeps south of Cell 1E.

- Recharge rate in Cell 2W: In the base case model, the recharge rate over Cell 2W is higher than expected infiltration rates in order to mimic the mound that is currently found beneath this cell. For the sensitivity analysis, the infiltration rate was set to 8 inches per year, effectively eliminating the mound beneath the cell.

Results of the sensitivity analysis are presented in Table 4-5. In general, the higher the value of hydraulic conductivity of the PolyMet tailings, the more water is lost via seepage and the more water is collected by the seepage collection system. Changing the recharge rate over Cell 2W increased pond seepage (12%) while having little effect on seepage collection rates. Changing the permeability of the till significantly reduced both the pond seepage and the seepage collection rates.

Table 4-5 Sensitivity Analysis

	Hydraulic Conductivity			Seepage Collected	
	PolyMet Tailing	Till	Pond Seepage	Cell 1E Seeps	Seepage Barrier
	cm/sec	cm/sec	gpm	gpm	gpm
Base Case	6.5e-05	2.3e-02	3340	170	570
High PolyMet Tailing K	1.2e-03	2.3e-02	4084	190	640
Low PolyMet Tailing K	1.9e-05	2.3e-02	2930	150	540
Low Till K	6.5e-05	2.3e-03	300	120	100
No Mound in Cell 2W	6.5e-05	2.3e-02	3740	170	550

References Cited

Adams, J.T., R.T. Leibfried, and E.S. Herr, 2004. *East Range Hydrology Project – Final Report.* Minnesota Department of Natural Resources, March 2004.

Barr Engineering, 2008. "PolyMet Tailings Basin Permeabilities", Technical Memorandum to Paul Eger, MDNR, from Tina Pint and Bill Dehler dated August 28, 2008.

Environmental Simulations, Inc., 2004. Guide to using Groundwater Vistas, Version 4, Environmental Simulations Inc.

Harbaugh, A.W., E.R. Banta, M.C. Hill, and M.G. McDonald, 2000. *MODFLOW-2000, the U.S. Geological Survey modular ground-water model – user guide to modularization concepts and the ground-water flow process.* U.S. Geological Survey Open-File Report 00-92.

McDonald, M.G., and A.W. Harbaugh, 1988. A Modular Three-Dimensional Finite-Difference Groundwater Flow Model, U.S. Geological Survey Techniques of Water Resource Investigations, TWRI 6-A1, 575 p.

Pollock, D.W., 1989, Documentation of computer programs to compute and display pathlines using results from the U.S. Geological Survey modular three-dimensional finite-difference ground-water flow model, USGS Open File Report 89-391, 188 pp.

Siegel, D.I., and D. W. Ericson, 1980. *Hydrology and Water Quality of the Copper-Nickel Study Region, Northeastern Minnesota*. U.S. Geological Survey Water-Resources Investigations 80-739.

Figures

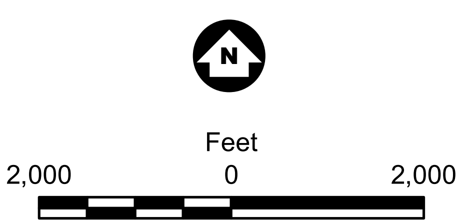
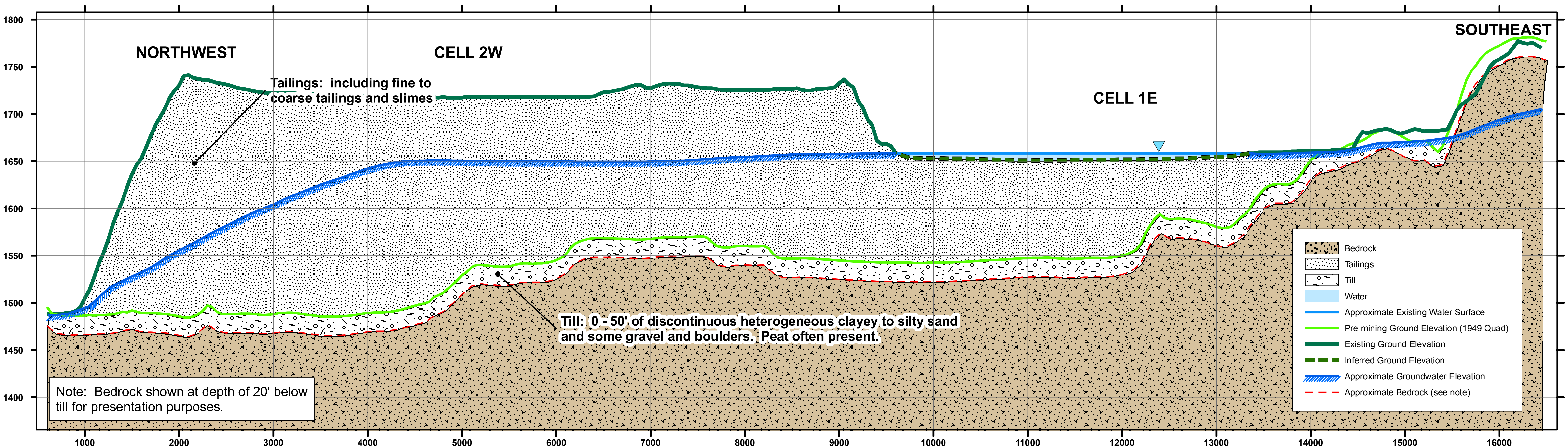
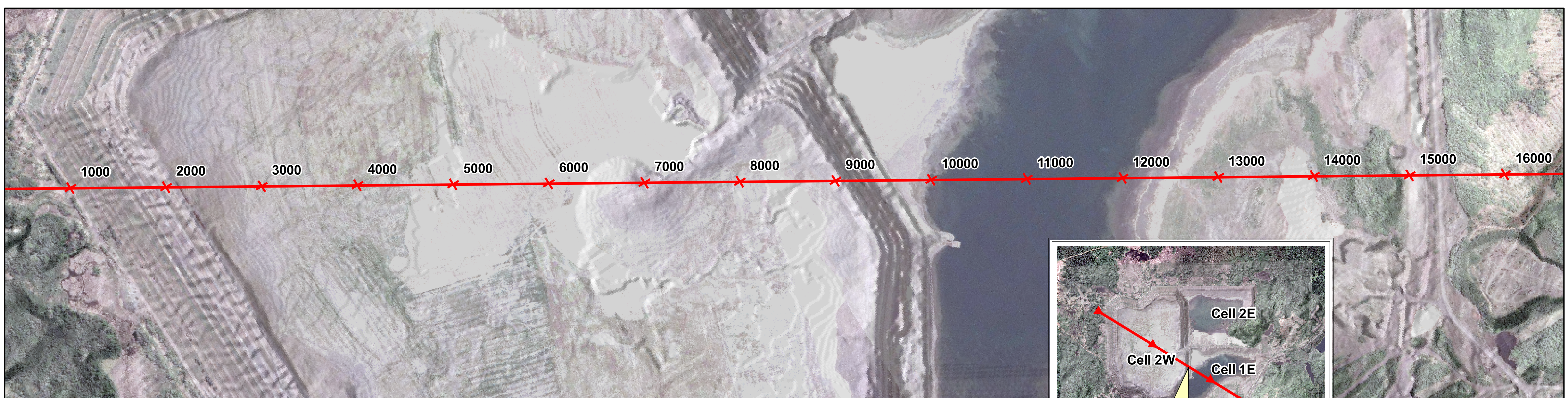


Figure 1-1

SITE LAYOUT

NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN





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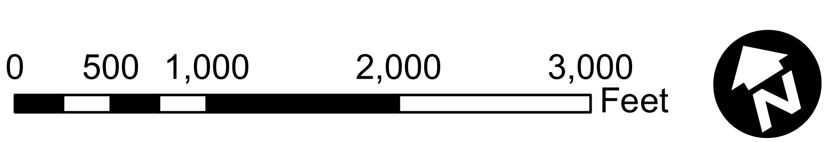
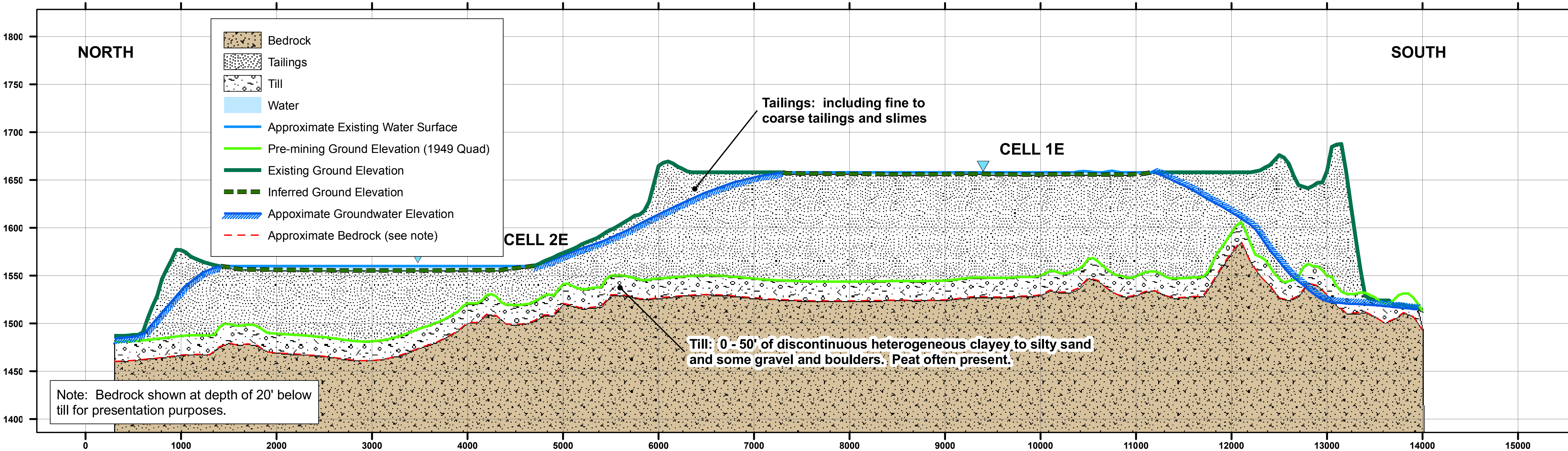
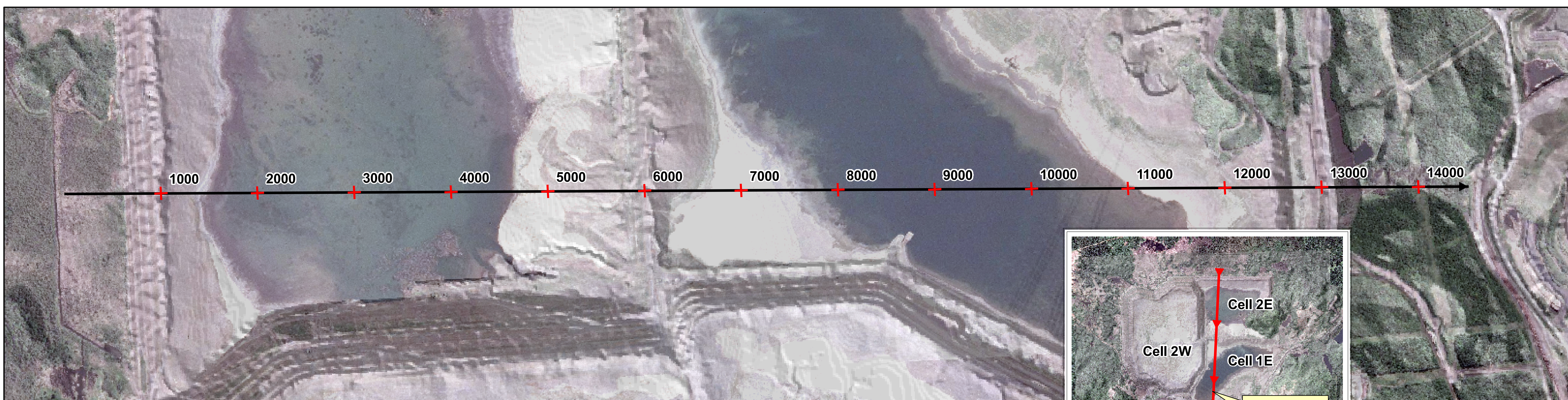


Figure 2-1
WEST TO EAST PROFILE
OF TAILINGS BASIN
NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN





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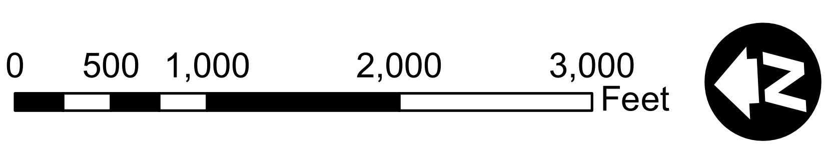


Figure 2-2
NORTH TO SOUTH PROFILE OF TAILINGS BASIN
NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN

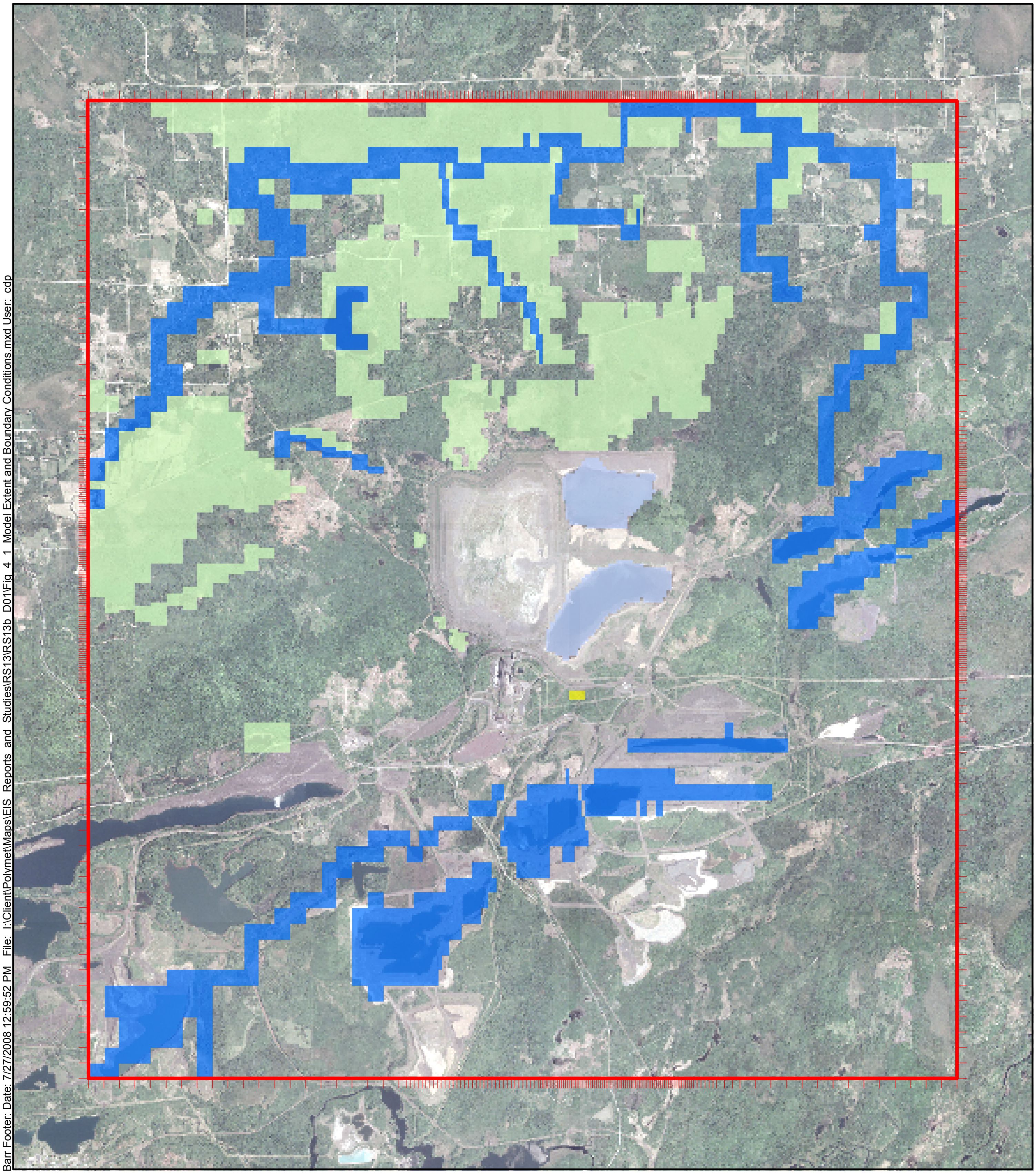
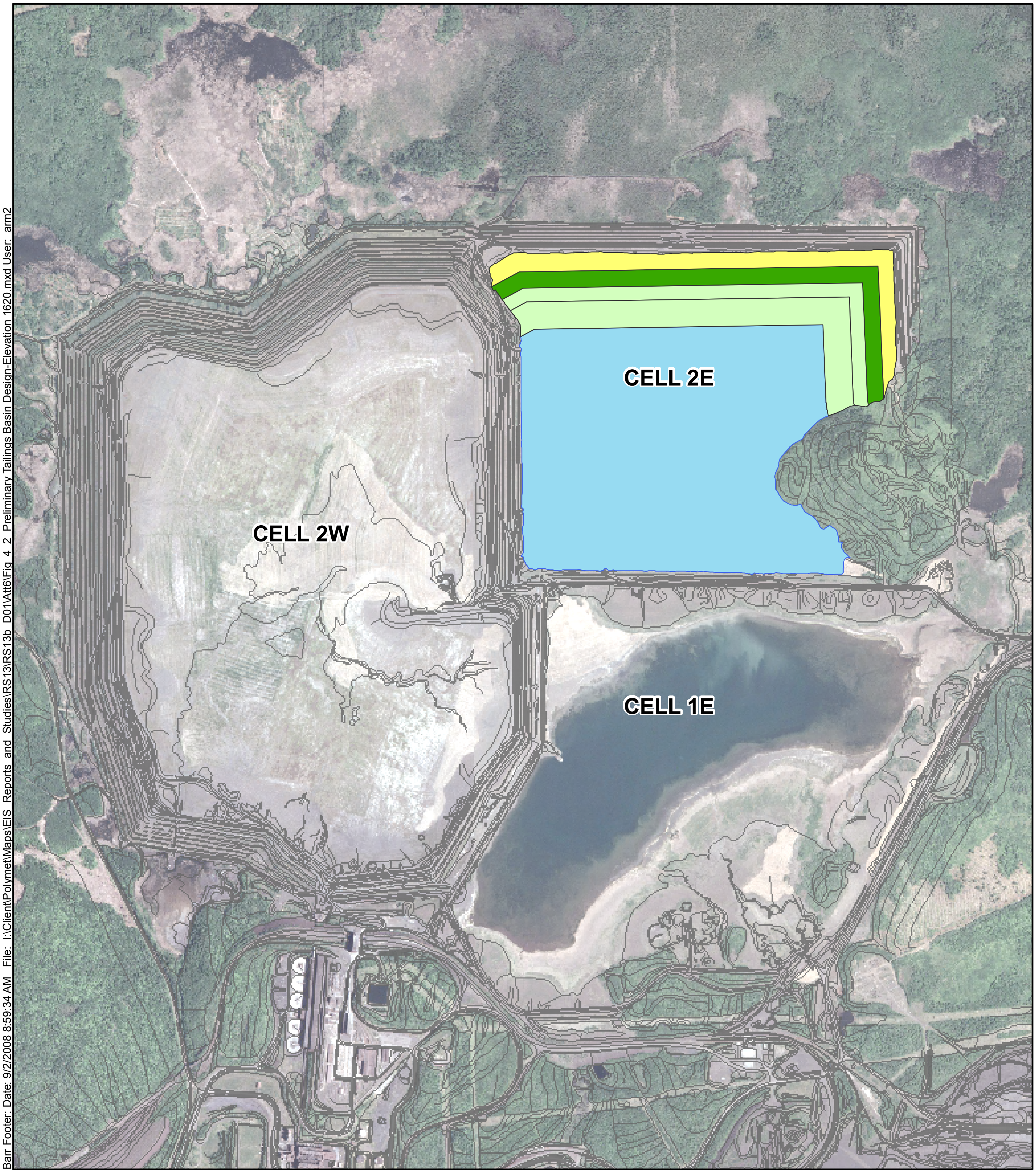


Figure 4-1

MODEL EXTENT AND BOUNDARY CONDITIONS

NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN



Embankment
LTV Beach
PolyMet Beach
Pond

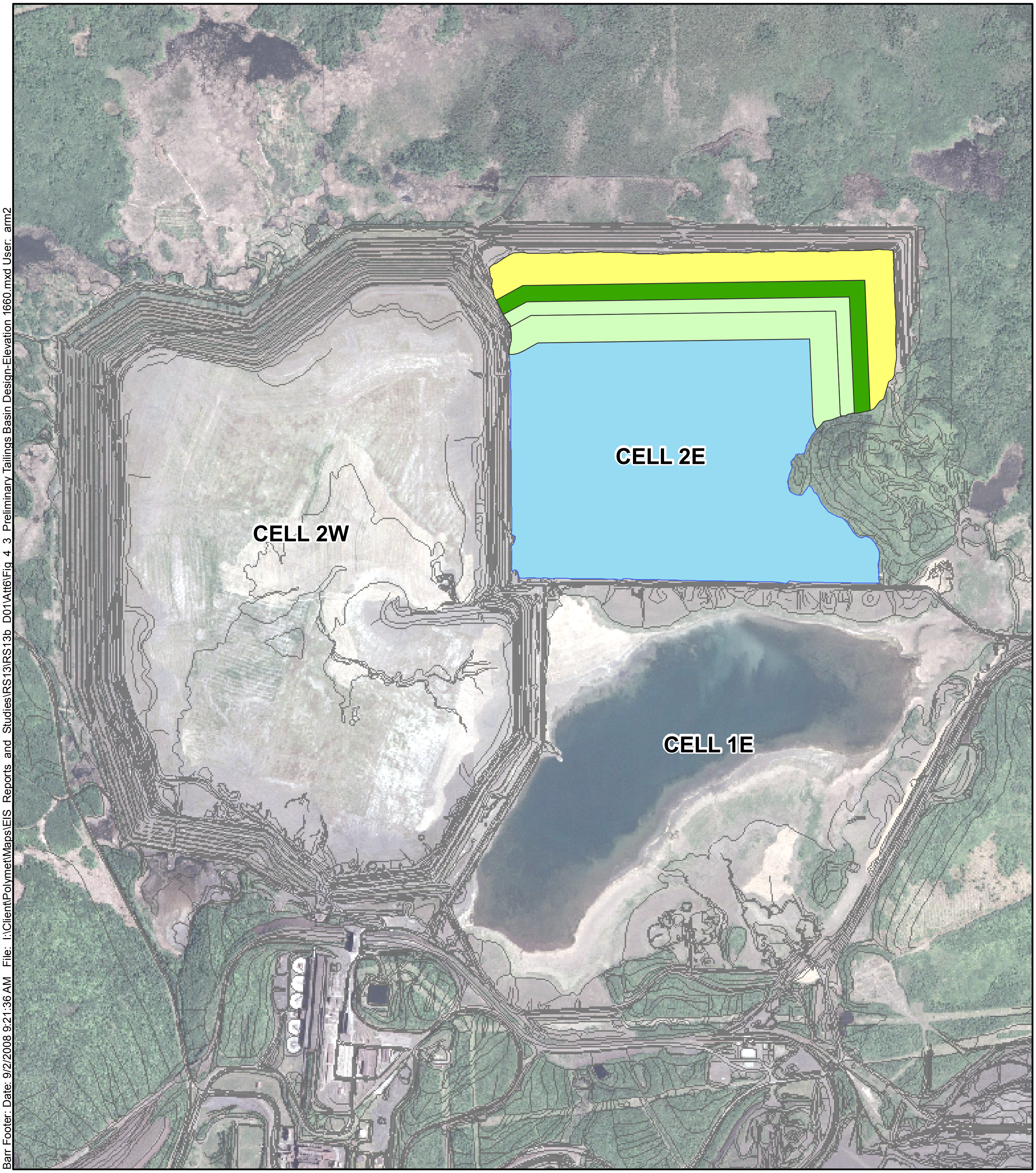
N

Feet
2,000 0 2,000

Figure 4-2

PRELIMINARY TAILINGS BASIN DESIGN-ELEVATION 1620

NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN



Embankment
LTV Beach
PolyMet Beach
Pond

N

Feet
2,000 0 2,000

Figure 4-3

PRELIMINARY TAILINGS BASIN
DESIGN-ELEVATION 1660

NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN

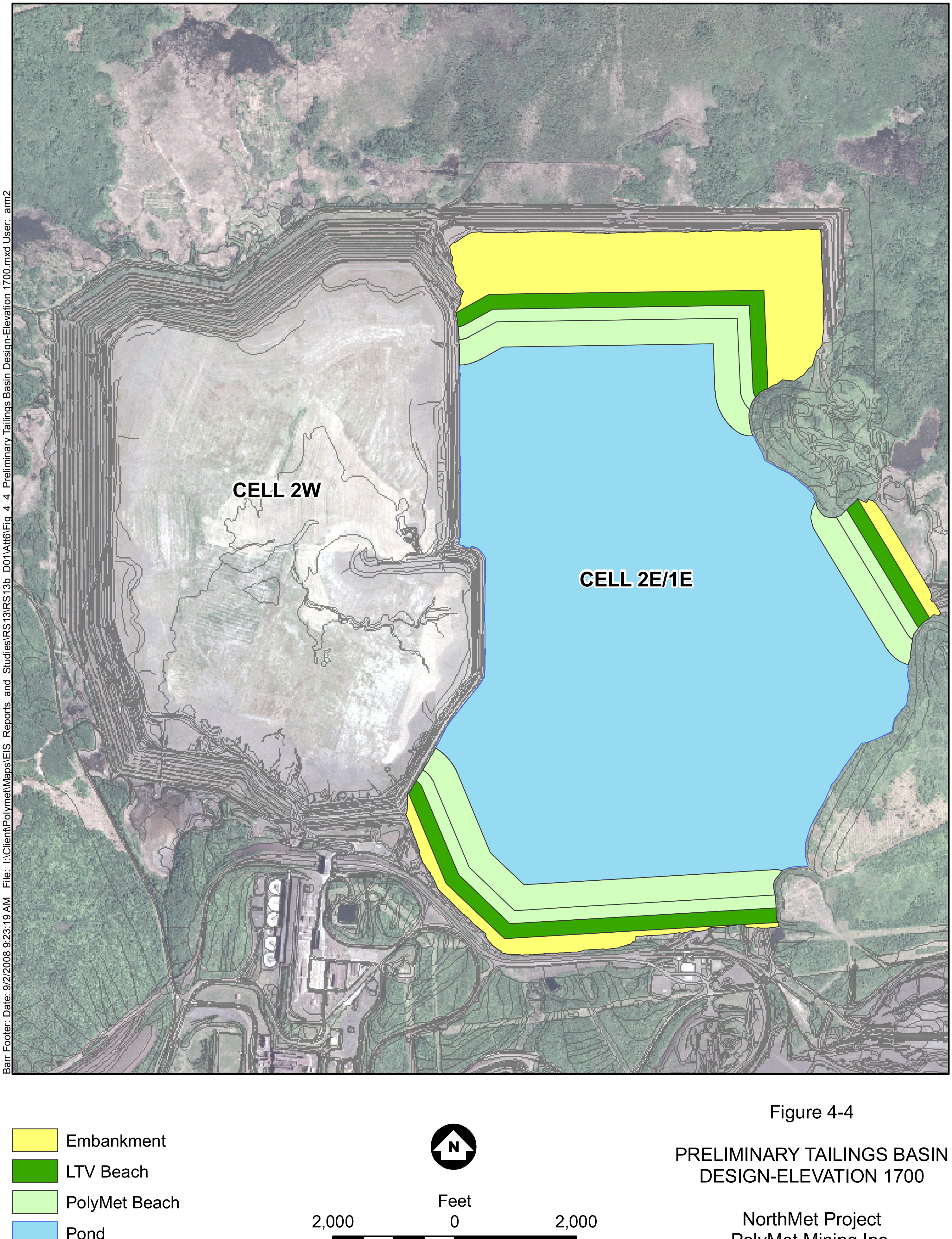


Figure 4-4

PRELIMINARY TAILINGS BASIN DESIGN-ELEVATION 1700

NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN

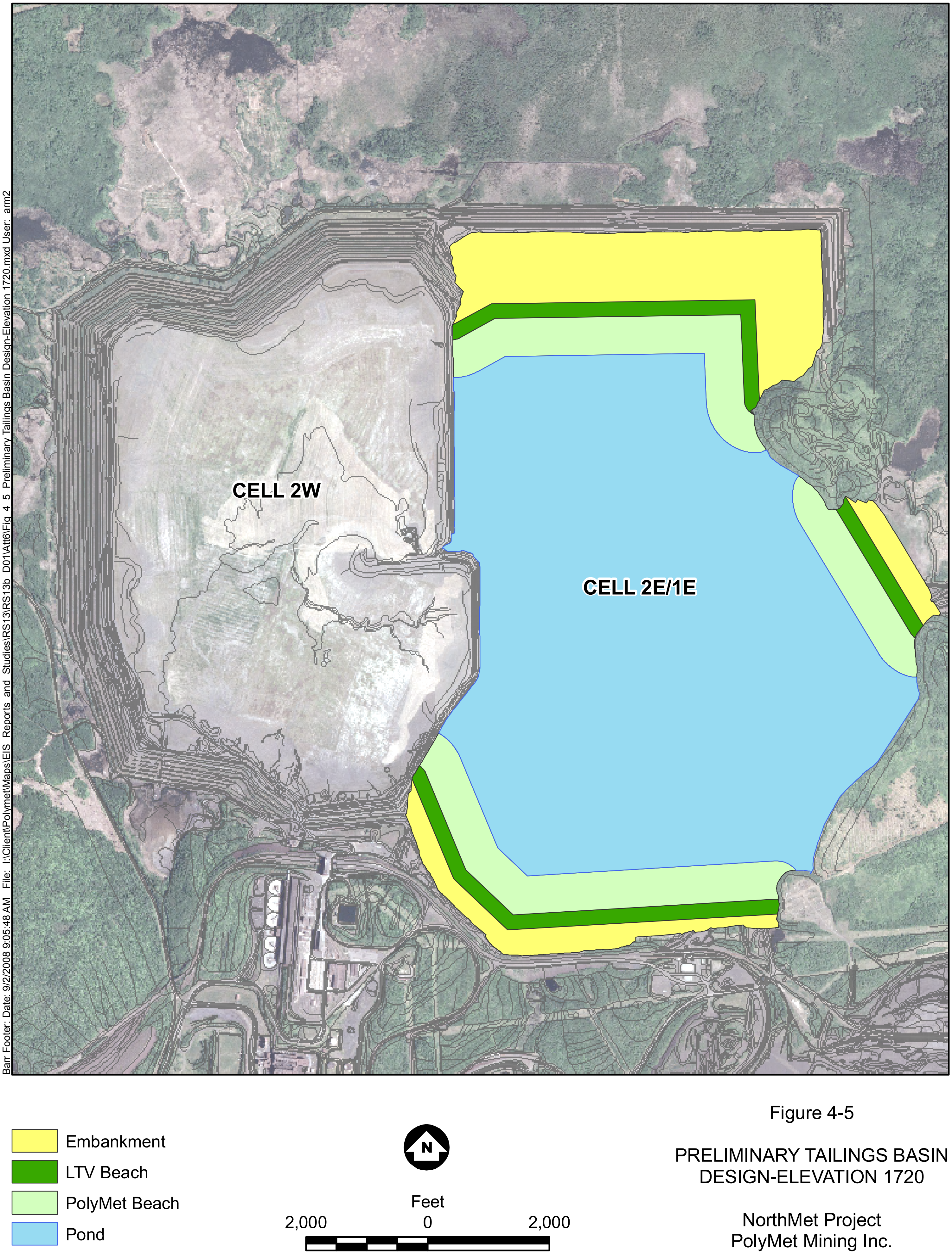
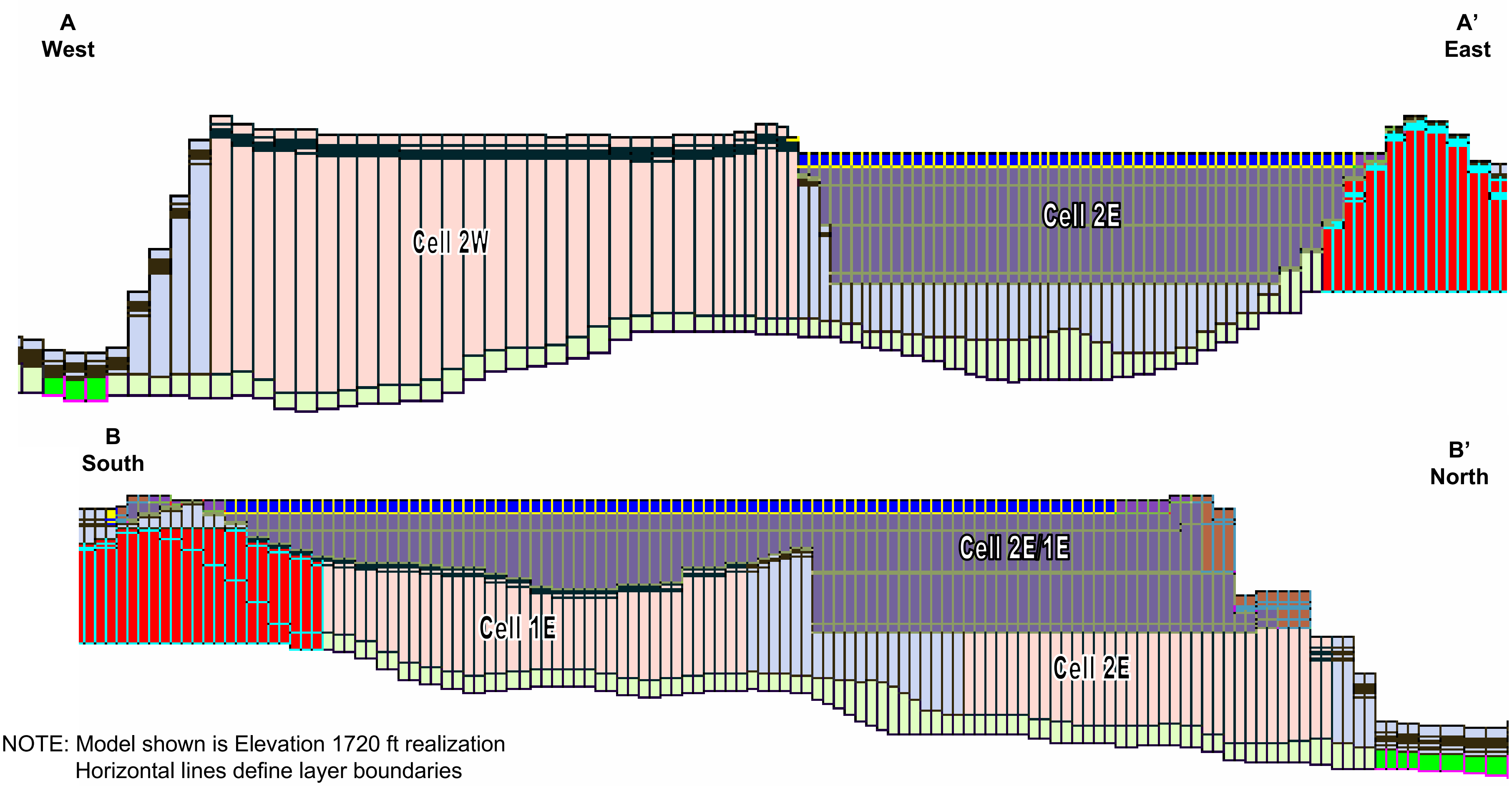


Figure 4-5

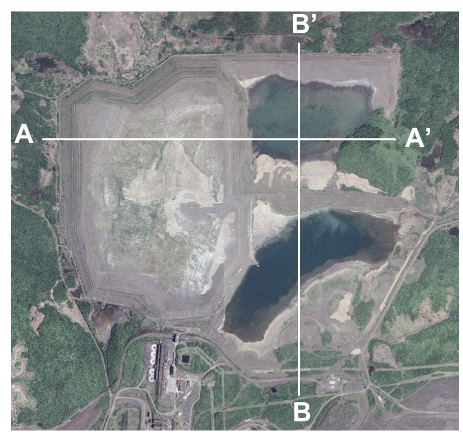
PRELIMINARY TAILINGS BASIN
DESIGN-ELEVATION 1720

NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN



NOTE: Model shown is Elevation 1720 ft realization
Horizontal lines define layer boundaries
Vertical lines show grid spacing

- PolyMet Tailings
- LTVSMC Embankment
- LTVSMC Slimes
- LTVSMC Fine/Coarse Tailing
- Native Unconsolidated Deposits
- Bedrock
- River Cells representing wetlands
- Constant Head Cells representing Tailings Basin Pond

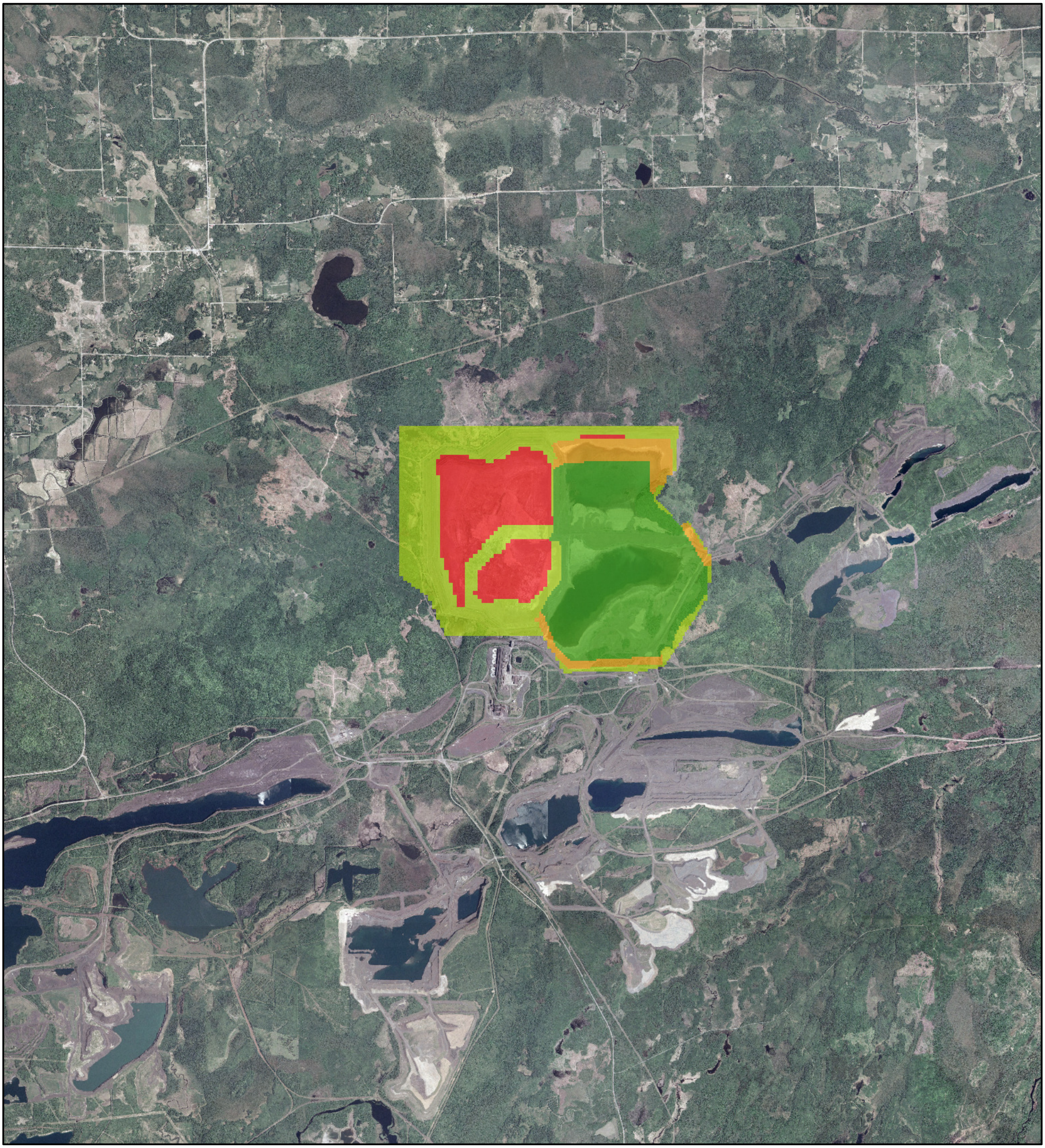


Approximate Cross Section Locations

1,000 ft
Vertical Exaggeration = 10x

Figure 4-6
MODEL CROSS-SECTIONS

NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN



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Hydraulic Conductivity (cm/sec)

Model Layer 1

- 1.1 x 10^-5
- 5.4 x 10^-5
- 8.2 x 10^-5
- 3.5 x 10^-4

Feet

5,000 0 5,000

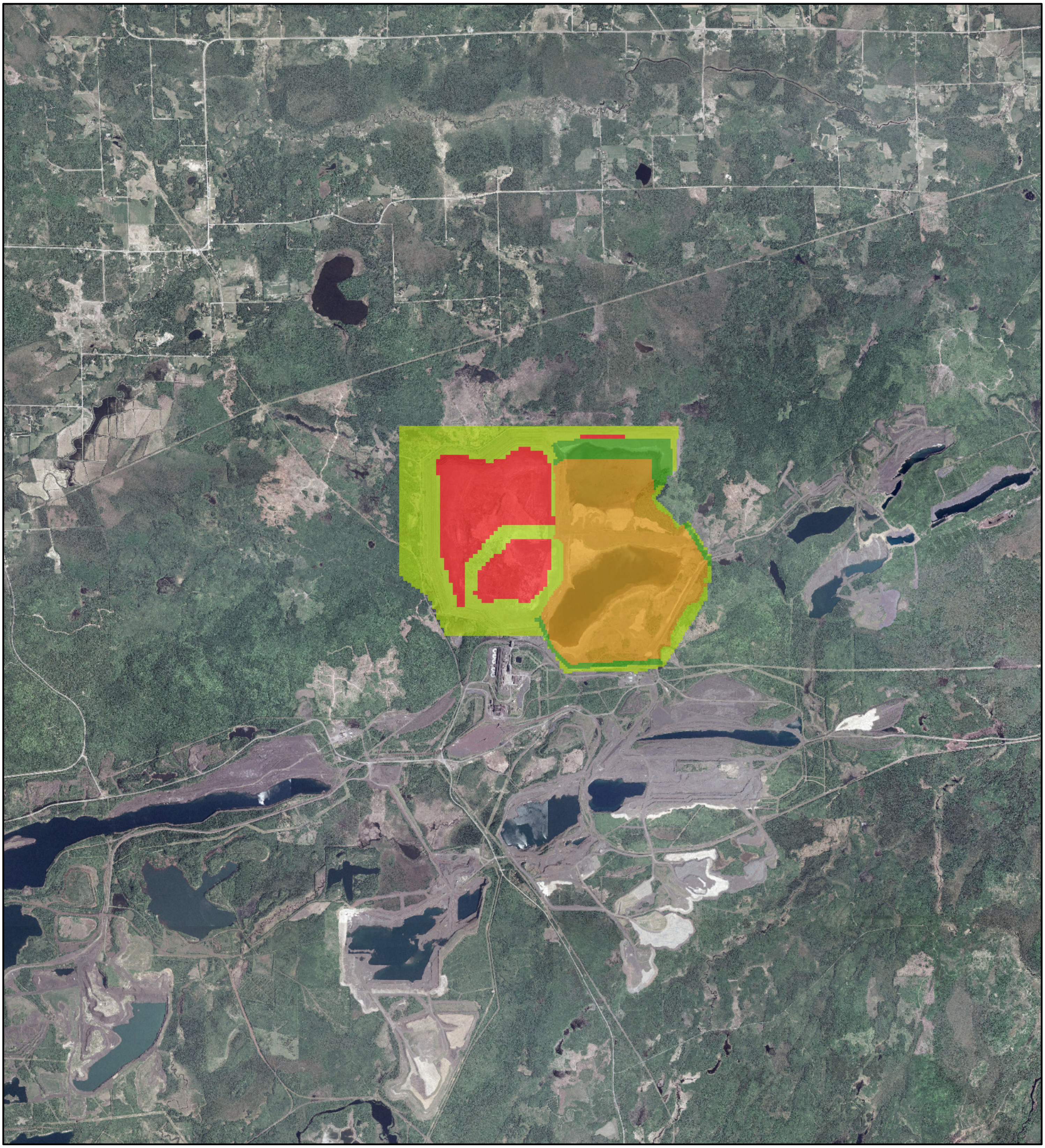
Meters

2,000 0 2,000

Figure 4-7a

HYDRAULIC CONDUCTIVITY
LAYER 1
(Elev 1720 ft Model)

NorthMet Project
PolyMet Mining, Inc.
Hoyt Lakes, MN



Hydraulic Conductivity (cm/sec)

Model Layer 2

- 1.1 x 10^-5
- 4.7 x 10^-5
- 6.5 x 10^-5
- 8.1 x 10^-5

N

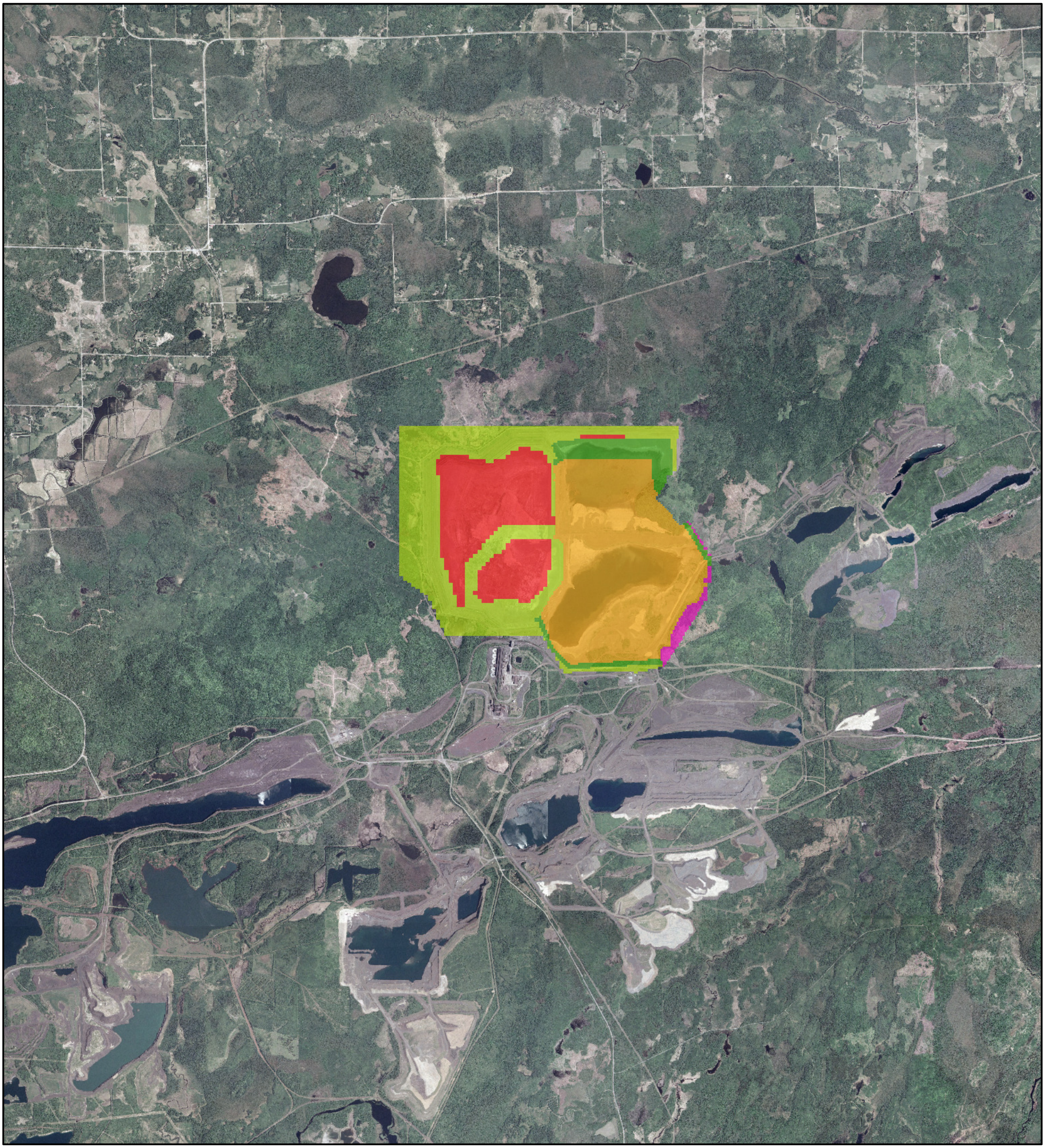
Feet
5,000 0 5,000

Meters
2,000 0 2,000

Figure 4-7b

HYDRAULIC CONDUCTIVITY
LAYER 2
(Elev 1720 ft Model)

NorthMet Project
PolyMet Mining, Inc.
Hoyt Lakes, MN



Hydraulic Conductivity (cm/sec)

Model Layer 3

- 8 x 10^-9
- 1.1 x 10^-5
- 5.4 x 10^-5
- 6.5 x 10^-5
- 8.1 x 10^5

N

Feet

5,000 0 5,000

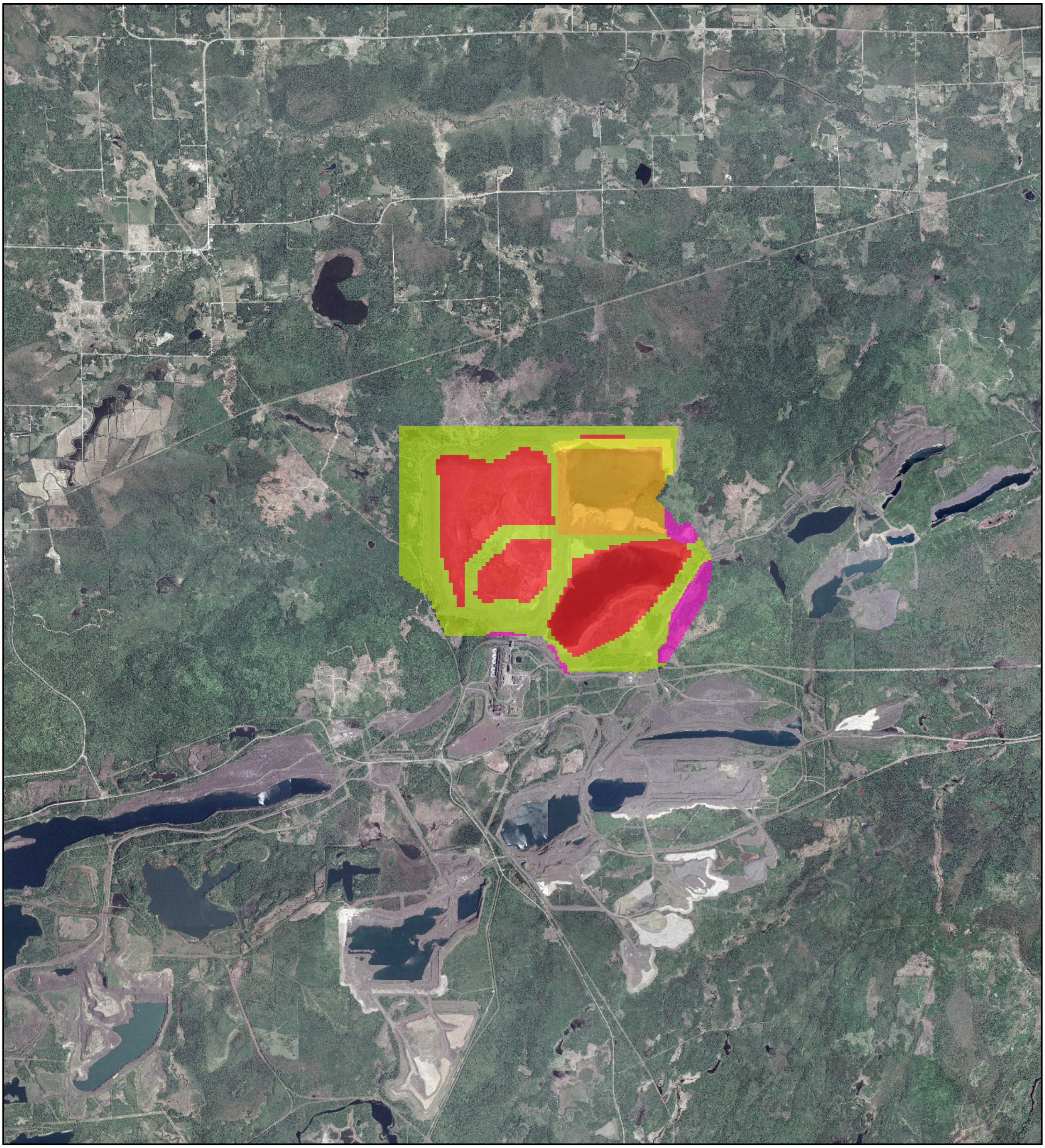
Meters

2,000 0 2,000

Figure 4-7c

HYDRAULIC CONDUCTIVITY
LAYER 3
(Elev 1720 ft Model)

NorthMet Project
PolyMet Mining, Inc.
Hoyt Lakes, MN



Hydraulic Conductivity (cm/sec)

Model Layer 4

- 8.0 x 10^-9
- 1.1 x 10^-5
- 5.4 x 10^-5
- 6.5 x 10^-5
- 8.1 x 10^-5

N

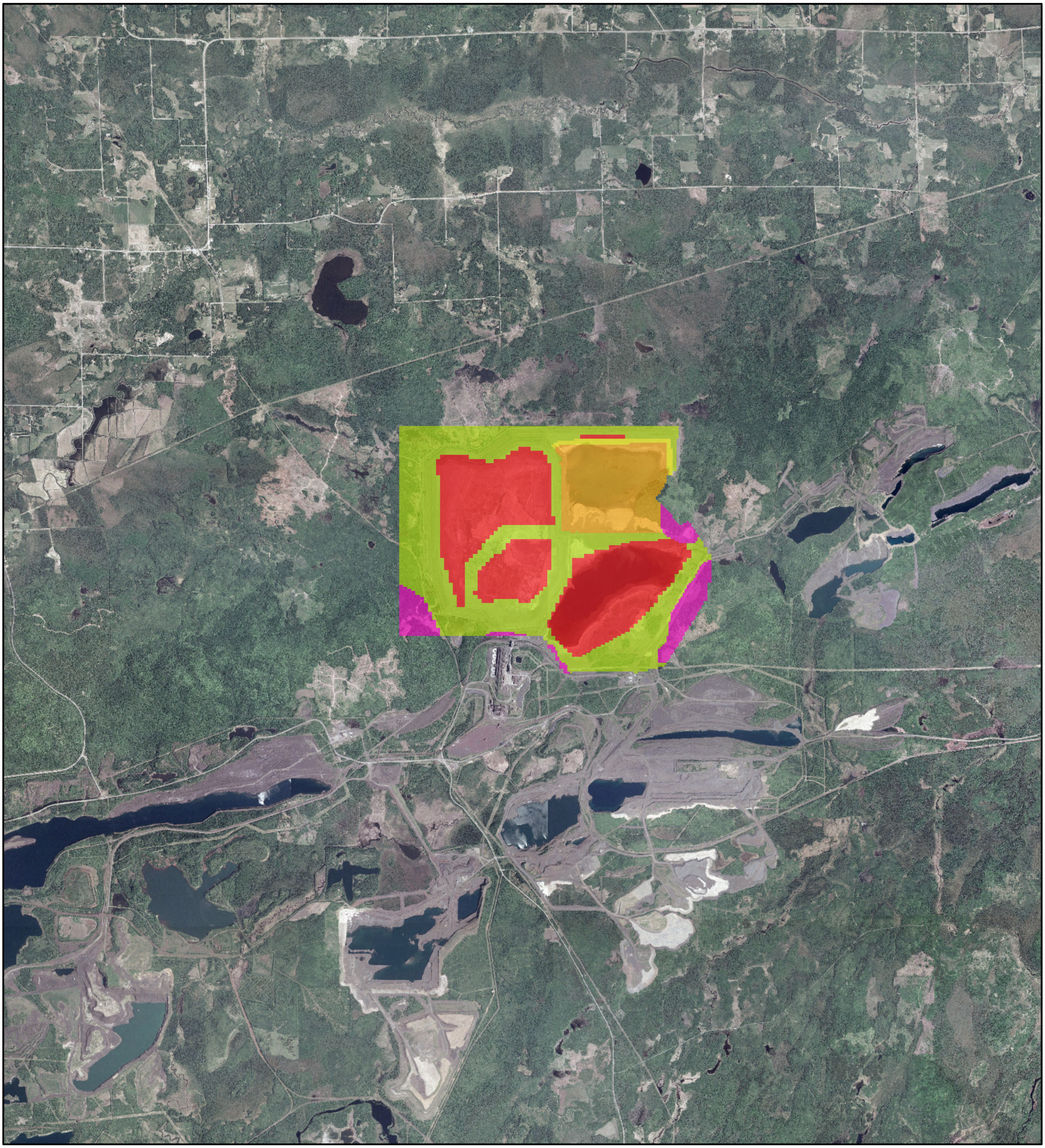
Feet
5,000 0 5,000

Meters
2,000 0 2,000

Figure 4-7d

HYDRAULIC CONDUCTIVITY
LAYER 4
(Elev 1720 ft Model)

NorthMet Project
PolyMet Mining, Inc.
Hoyt Lakes, MN



Hydraulic Conductivity (cm/sec)

Model Layer 5

- 8.0 x 10^-9
- 1.1 x 10^-5
- 5.4 x 10^-5
- 6.5 x 10^-5
- 8.1 x 10^-5

N

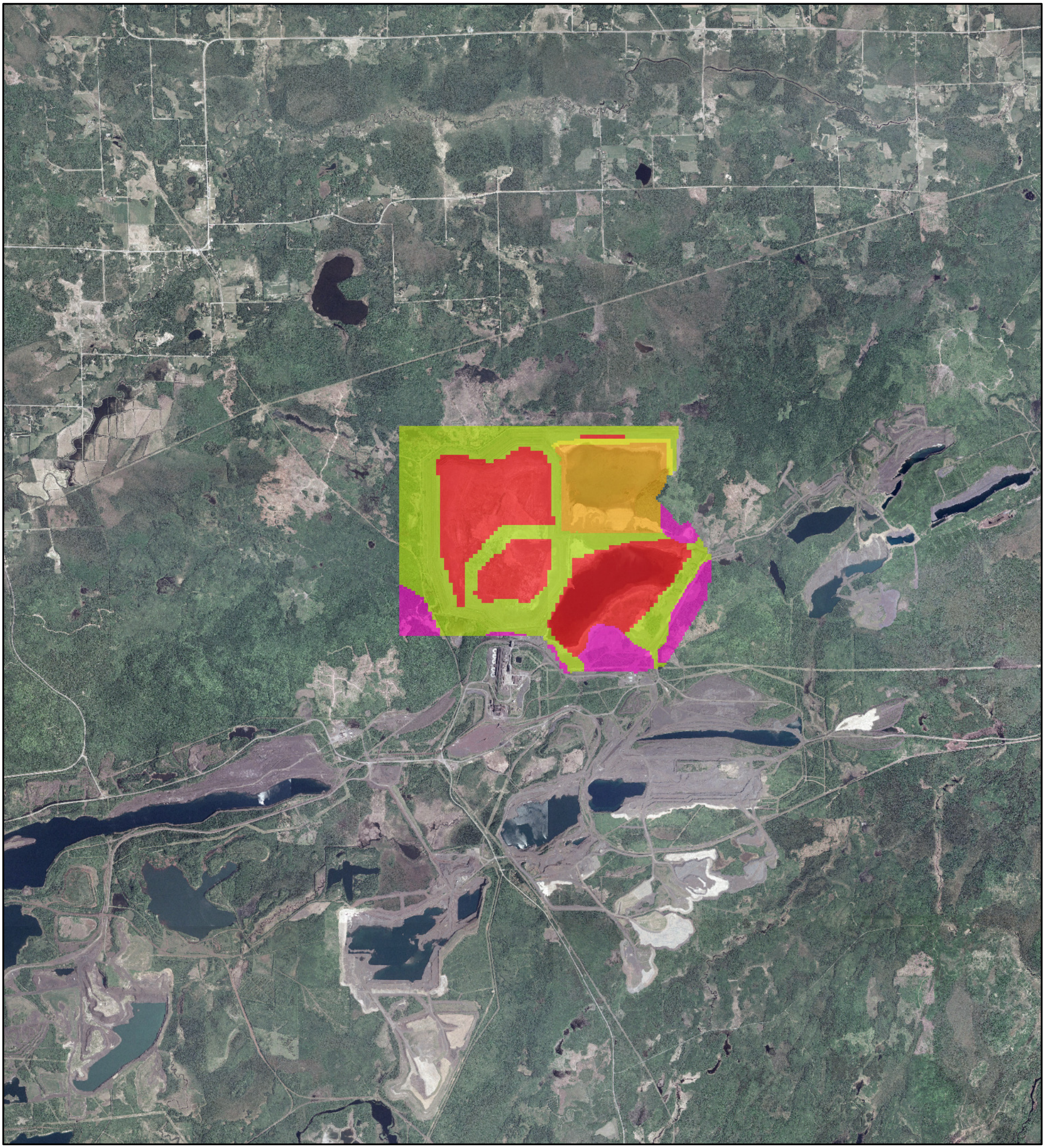
Feet
5,000 0 5,000

Meters
2,000 0 2,000

Figure 4-7e

HYDRAULIC CONDUCTIVITY
LAYER 5
(Elev 1720 ft Model)

NorthMet Project
PolyMet Mining, Inc.
Hoyt Lakes, MN



Hydraulic Conductivity (cm/sec)

Model Layer 6

- 8.0 x 10^-9
- 1.1 x 10^-5
- 5.4 x 10^-5
- 6.5 x 10^-5
- 8.1 x 10^-5

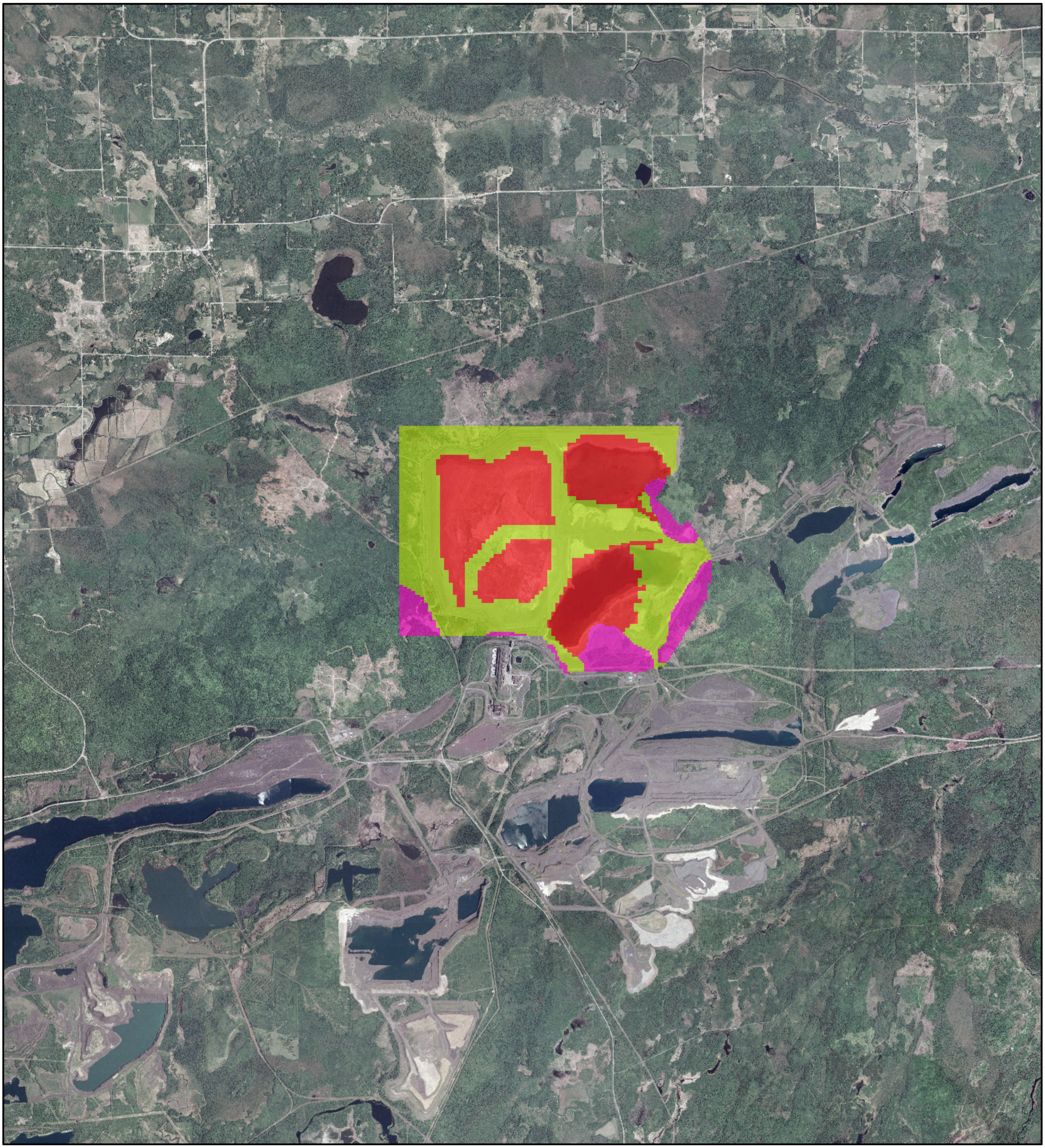
Feet
5,000 0 5,000

Meters
2,000 0 2,000

Figure 4-7f

HYDRAULIC CONDUCTIVITY
LAYER 6
(Elev 1720 ft Model)

NorthMet Project
PolyMet Mining, Inc.
Hoyt Lakes, MN



Hydraulic Conductivity (cm/sec)

Model Layer 7

- 8.0 x 10^-9
- 1.1 x 10^-5
- 5.4 x 10^-5

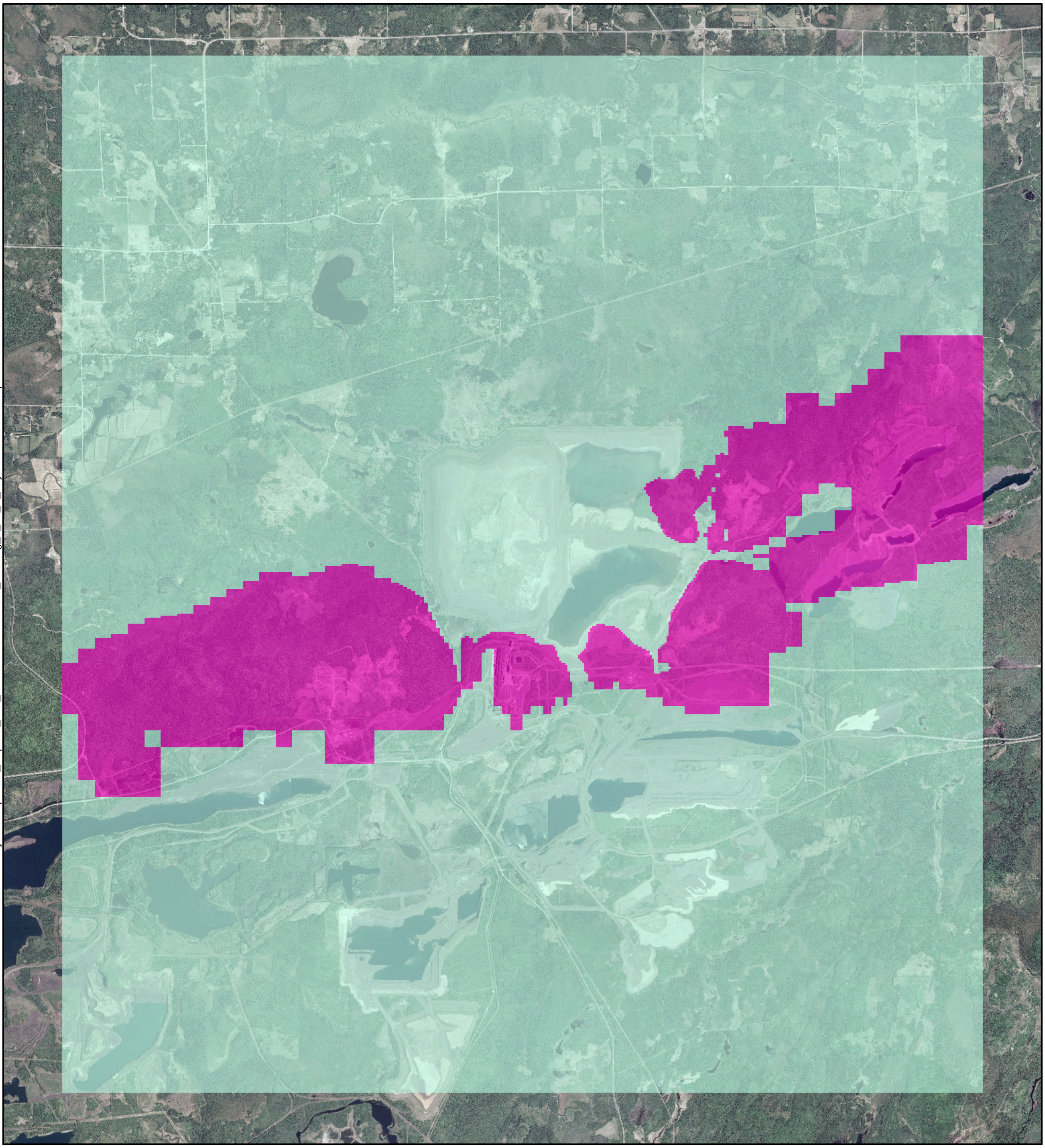
Feet
5,000 0 5,000

Meters
2,000 0 2,000

Figure 4-7g

HYDRAULIC CONDUCTIVITY
LAYER 7
(Elev 1720 ft Model)

NorthMet Project
PolyMet Mining, Inc.
Hoyt Lakes, MN



Hydraulic Conductivity (cm/sec)

Model Layer 8

- 8.0 x 10^-9
- 2.3 x 10^-2

N

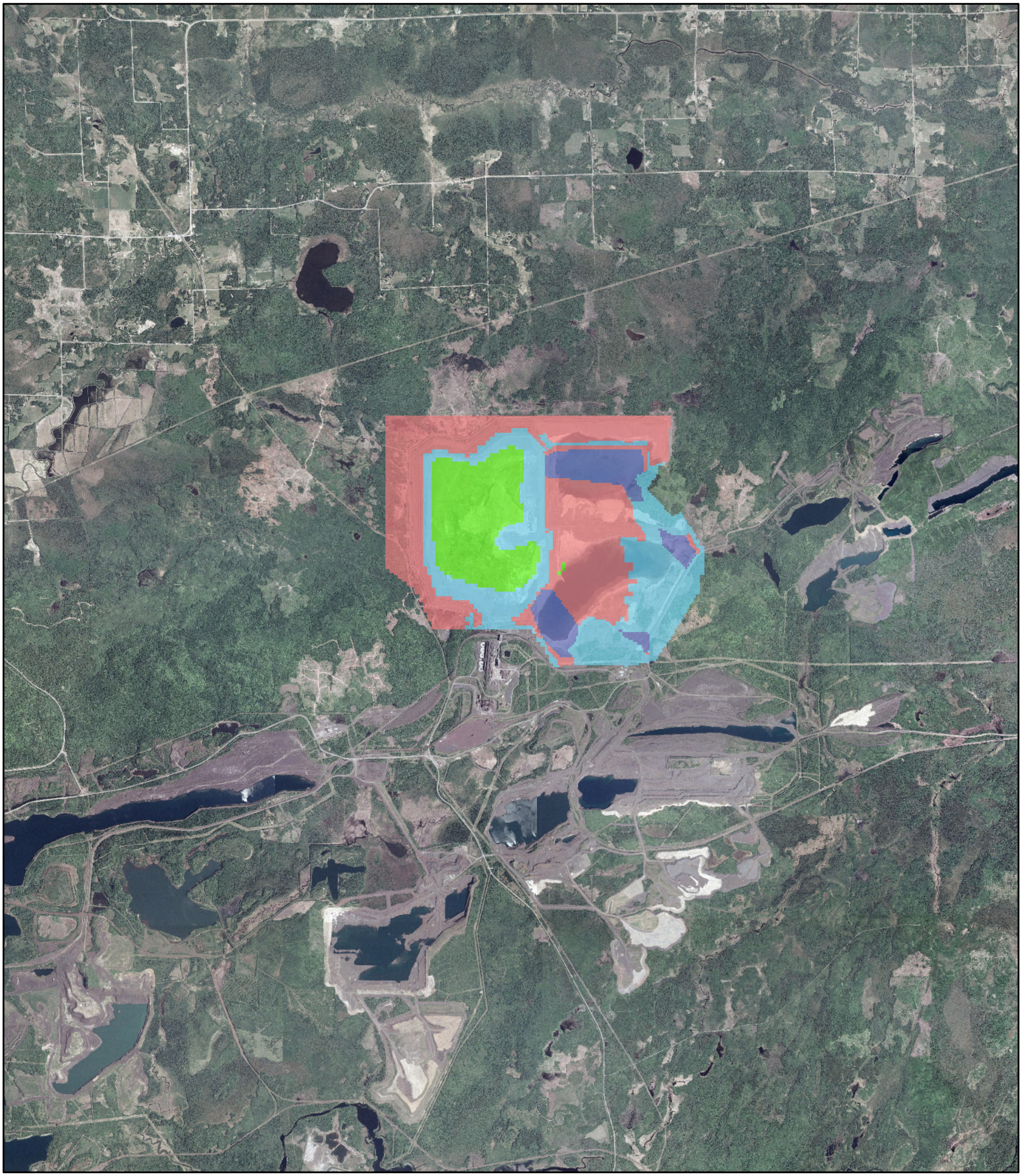
Feet
5,000 0 5,000

Meters
2,000 0 2,000

Figure 4-7h

HYDRAULIC CONDUCTIVITY
LAYER 8
(Elev 1720 ft Model)

NorthMet Project
PolyMet Mining, Inc.
Hoyt Lakes, MN



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Recharge Rates

Model Layer 1

- 0" per year
- 8" per year
- 15" per year
- 56" per year

N

Feet

5,000 0 5,000

Meters

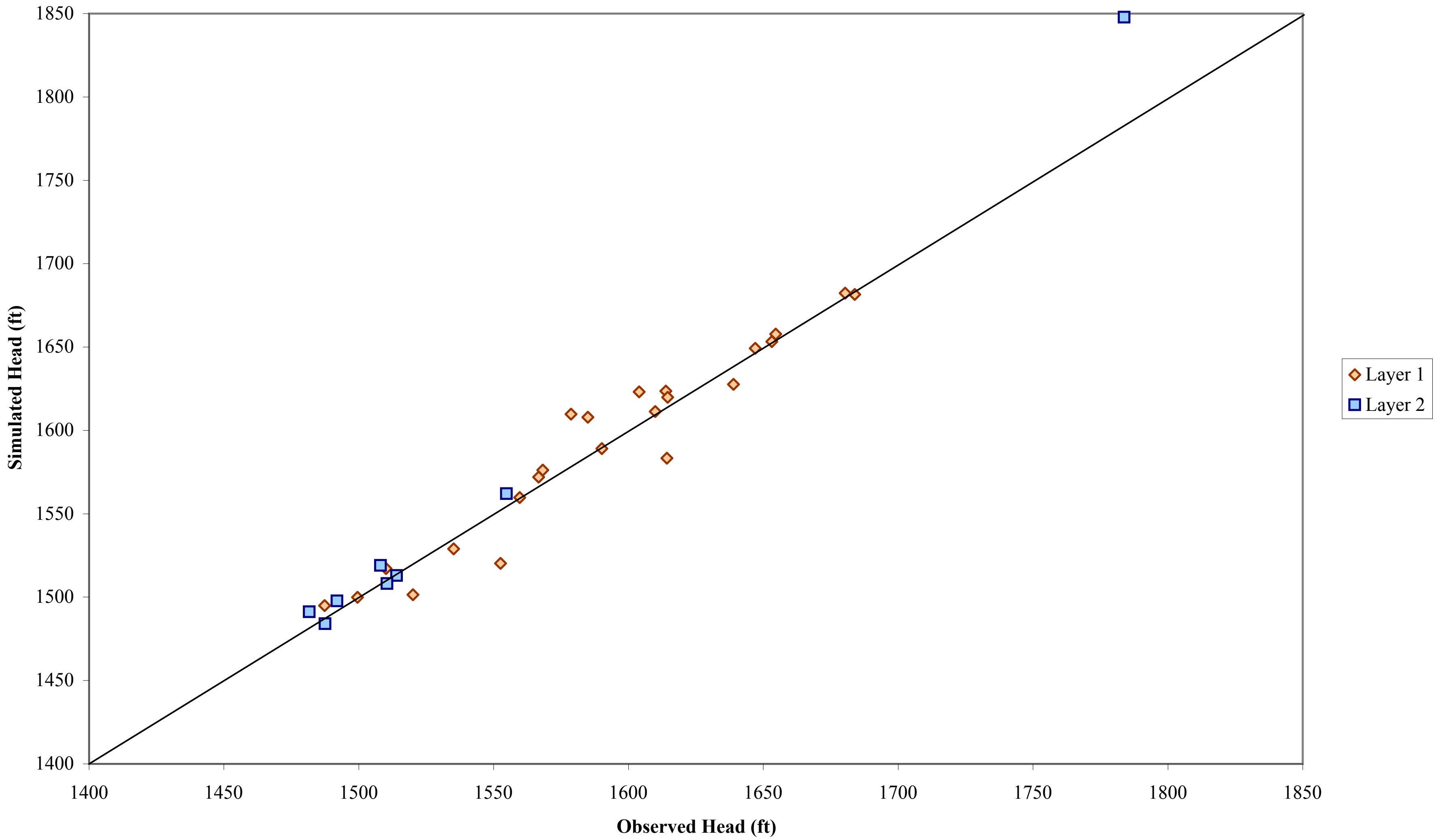
2,000 0 2,000

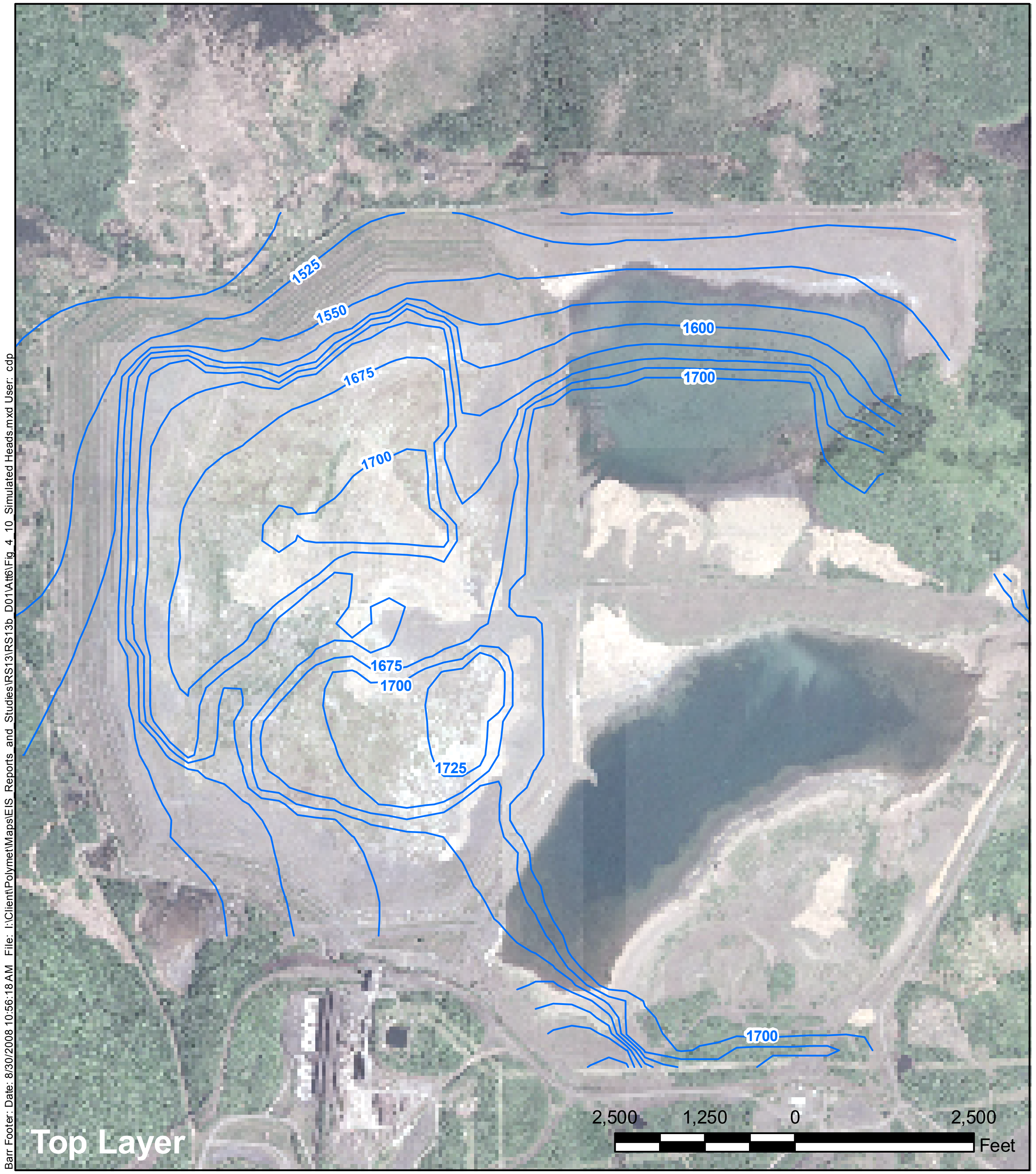
Figure 4-8

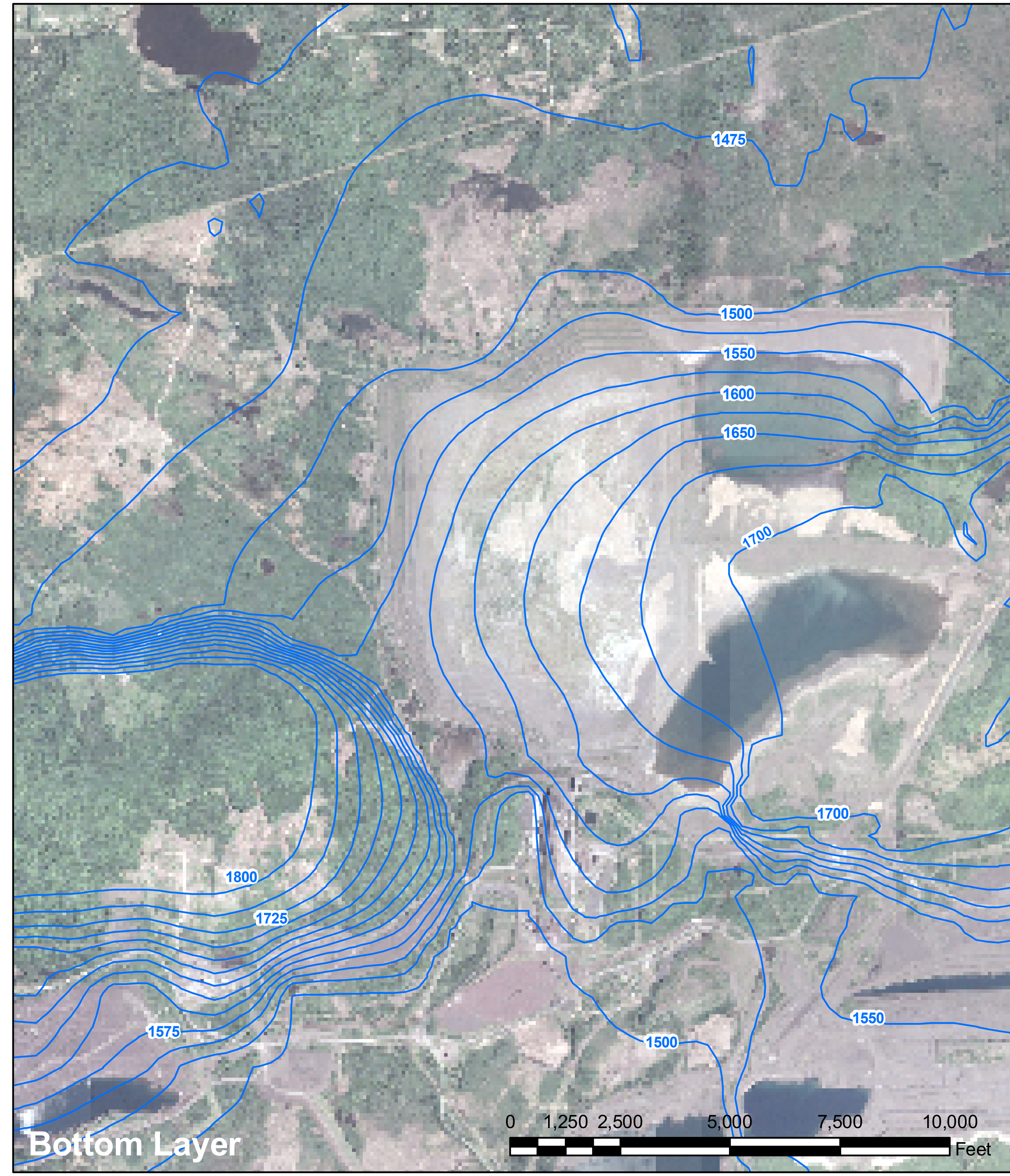
RECHARGE RATES
(Elev 1720 ft Model)

NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN

Figure 4-9
Model Calibration Results







Ground Water Contour (contour interval = 25ft)

Figure 4-10

SIMULATED HEADS FROM
ELEVATION 1720 MODEL

NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN

Attachment A-6-A

HELP Modeling Results for Infiltration During Closure

Attachment A-6-A

HELP Modeling Results for Infiltration during Closure

The HELP model is a water balance model that routes precipitation (that portion that does not runoff or evapotranspire) through a waste disposal facility. The HELP model was utilized to evaluate cover system performance as part of RS28T and is discussed in greater detail in that report. While not a part of the information presented in RS28T, the HELP model was also used to evaluate infiltration through the proposed bentonite modified layer in closure at the Tailings Basin.

The bentonite modified layer proposed for the Tailings Basin – Mitigation Design in closure is as follows:

- 12 inches of unmodified tailings,
- 24 inches of bentonite modified tailings with an average permeability of $10^{-6.5}$ cm/sec.

Using these assumptions, it is predicted that the infiltration through the bentonite modified layer will be 3.6 inches. This is the value that was used for the groundwater modeling presented in RS13b Attachment A-6 and water quality modeling that will be presented in RS74 Draft-02.

The remainder of this attachment presents the model output for the HELP run referenced above.

Attachment A-6-B

Technical Memorandum
“PolyMet Tailings Basin Permeabilities”

Barr Engineering Company
4700 West 77th Street • Minneapolis, MN 55435-4803
Phone: 952-832-2600 • Fax: 952-832-2601 • www.barr.com *An EEO Employer*

Minneapolis, MN • Hibbing, MN • Duluth, MN • Ann Arbor, MI • Jefferson City, MO

Technical Memorandum

To: Paul Eger, MDNR
From: Tina Pint, Bill Dehler
Subject: PolyMet Tailings Basin Permeabilities
Date: August 28, 2008
Project: 23/69-862 006 001
c: Jim Scott, PolyMet Mining

This memorandum presents information on the permeabilities of material associated with the existing LTVSMC Tailings Basin (Section 1), the predicted permeability of material associated with the PolyMet Tailings Basin (Section 2) and the permeability values used in the various modeling efforts that have been conducted in support of the EIS (Section 3).

In order to help facilitate an easier understanding of the various permeability data and values used in the models that are described herein, the following terminology/nomenclature related to the PolyMet tailings will be used throughout this memorandum:

Bulk Tailings: The term "bulk tailings" is used to refer to the PolyMet tailings that are discharged from the beneficiation process. This represents the entire spectrum of tailings that will be sent to the Tailings Basin.

Undersized Tailings: The term "undersized tailings" is used to refer to the finer grained tailings that would be segregated from bulk tailings by use of a cyclone. As described later in this memorandum, an assumed gradation is used for the undersized tailings.

Oversized Tailings: The term "oversized tailings" is used to refer to the coarser grained tailings that would be segregated from bulk tailings by use of a cyclone. As described later in this memorandum, an assumed gradation is used for the oversized tailings.

Fine Beach: The term "fine beach" is used to refer to the portion of the PolyMet tailings basin beach that will in general be composed of finer grained material that will result from the hydraulic segregation caused by the spigoting of tailings.

Coarse Beach: The term "coarse beach" is used to refer to the portion of the PolyMet tailings basin beach that will in general be composed of coarser grained material that will result from the hydraulic segregation caused by the spigoting of tailings.

The terms "fine tailings" and "coarse tailings" have purposely been avoided when referring to PolyMet flotation tailings. These terms have been applied to the LTVSMC tailings to represent specific ranges in grain size distributions.

1.0 LTVSMC Tailings Basin Permeabilities

The main parameter associated with seepage analysis is the hydraulic conductivity of the tailings and tailings dam materials. In geotechnical practice, the term permeability is often used to describe the hydraulic conductivity parameter, and that term will be used in the remainder of this text. Table 1-1 summarizes the permeabilities used by previous investigators for seepage analysis and was compiled through a review of reports discussing the stability of the Erie Mining Company and LTVSMC tailings basin.

Many of the values are estimates based on grain size distribution and experience of previous investigators. In fact, many previous studies (pre-2000) used monitoring data from piezometers to create a phreatic surface for stability analyses to calculate pressure heads rather than incorporating permeability into the seepage models.

Table 1-1: Permeability Postulated by Previous Investigators

Unit	Sitka Corp. - Mar. 1995	Barr Engineering Co. - Jan. and Mar. 2000
	Permeability [cm/s]	**Permeability [cm/s]**
LTVSMC Coarse Tailings	1.00E-03	1.00E-02
LTVSMC Fine Tailings	1.00E-04	1.50E-06 to 2.50E-05
LTVSMC Slimes	1.00E-05	8.40E-07 to 5.80E-06
Virgin Peat	1.00E-02 to 1.00E-04	1.00E-03 to 1.00E-07
Compressed Peat	1.00E-06 to 1.00E-07	-
Till	1.00E-02 to 1.00e-04	4.30E-04 to 5.40E-03

The following report sections describe the updated permeability values and how they were developed through the recent testing program.

1.1 LTVSMC Coarse Tailings

No evidence of previous permeability testing for support of previous LTVSMC coarse tailings design parameters was uncovered in the review of published data. Therefore the LTVSMC coarse tailings were tested for permeability by two methods: in-situ dissipation testing performed during cone penetration tests and laboratory permeability testing on remolded samples. The coarse, granular nature of these tailings generally results in quick dissipation of excess pore-water pressure during cone advancement and therefore makes interpretation of the in situ permeability difficult. Therefore, the resulting LTVSMC coarse tailings permeability used in the current modeling is based upon six remolded laboratory specimens created from bulk samples obtained from test pits performed in Cell 2W. The specimens were remolded to dry densities ranging from 96.4 to 114.9 pcf and tested using the constant head – rigid wall permeability test method (ASTM D5856). Table 1-2 shows the range in values interpreted from the test results.

Table 1-2: Range of Permeability of LTVSMC Coarse Tailings

	k (ft/min)	k (ft/sec)	k (cm/sec)
Minimum	3.20E-03	5.33E-05	1.62E-03
Maximum	6.90E-03	1.15E-04	3.51E-03
Average	5.03E-03	8.39E-05	2.56E-03
St Dev	1.65E-03	2.76E-05	8.41E-04
GeoMean	4.80E-03	8.00E-05	2.44E-03

1.2 LTVSMC Fine Tailings

No evidence of previous permeability testing for support of old LTVSMC fine tailings design parameters was uncovered while reviewing published data. During the recent explorations, the LTVSMC fine tailings were tested for permeability by in-situ dissipation testing performed during cone penetration tests. However, similar to the coarse tailings, the interpretation of the dissipation testing was found to be difficult at the locations tested. Difficulty in interpretation is likely due to the low piezometric levels within the tailings basin leading to minimal pore water pressure response during cone advancement and subsequent dissipation. The majority of the tailings have dewatered at the locations tested, reducing the pore-water pressure response during cone advancement. The relative coarseness of the fine tailings also hinders the ability to measure pore-water pressure dissipation because the tailings are fairly permeable and any pressure created during cone penetration testing dissipates fairly quickly.

Laboratory analysis of LTVSMC fine tailings for permeability was not performed due to lack of sufficient undisturbed samples of representative grain size distribution. Upon review of all of the materials encountered on the site, the grain size distributions of the LTVSMC fine and PolyMet bulk tailings were found to be similar. The PolyMet bulk tailings are characterized as the overall bulk tailings to be produced at the plant and pumped to the tailings basin. The average grain size distribution of the PolyMet bulk tailings was determined during previous studies when testing was performed to evaluate change in permeability of the material with change in overburden pressure. A permeability of 1.77 x 10^{-6} ft/sec (1.16 x 10^{-4} cm/sec) was used as a basis for current seepage analyses and is equivalent to an effective overburden pressure of 2.75 tsf as discussed further in Section 2.1. This overburden pressure was selected for four reasons:

1) 2.75 tsf is approximately equivalent to the minimum pressure exerted on the LTVSMC fine tailings beneath the crest of the existing dam (assuming a unit weight of 90 pcf for approximately 60 feet of overlying soil).

2) 2.75 tsf is equivalent to the minimum pressure exerted on the LTVSMC fine tailings beneath the proposed PolyMet dam between the basin and existing crest zones (assuming a unit weight of 120 pcf for the approximate minimum 45 feet of overlying soil beneath the first lift of the proposed dam).

3) At an effective overburden pressure of 2.75 tsf, the corresponding permeability is within the same range as the high permeability slimes (for which tests are available), with which the LTVSMC fine tailings are intermingled in the area of the existing basin.

4) Following construction of approximately 60 feet of the proposed tailings basin raises, the LTVSMC fine tailings will be under at least 2.75 tsf overburden pressure within the area of the existing basin (assuming a conservative overburden unit weight of 90 pcf).

1.3 LTVSMC Slimes

The LTVSMC slimes are generally found within the interior portion of the tailings basin or located in isolated areas under the existing dams. Attempts were made to test the permeability of the slimes by two methods: in-situ dissipation testing performed during cone penetration tests and laboratory permeability testing on undisturbed samples. The in-situ dissipation testing was performed at 46 locations and depths within Cells 1E and 2E. The time to reach 50 % of the peak pore-water pressure, t_{50}, was determined. Published correlation charts for piezocone analyses were used to obtain the estimated permeability values (Lunne, Robertson and Powell, 1997). Falling head, flexible wall, laboratory permeability testing of six undisturbed samples obtained form thin-wall (Shelby) tubes at three boring locations showed permeability values within the same range as those determined from dissipation testing. The laboratory values appeared to be slightly lower, possibly due to slight disturbance during sampling or the variability between horizontal permeability as measured by CPTu and vertical permeability as measured in the lab.

Table 1-3: Range of Permeability of LTVSMC Slimes

	k (ft/min)	k (ft/sec)	k (cm/sec)
Minimum	1.80E-07	3.00E-09	9.14E-08
Maximum	1.38E-04	2.30E-06	7.01E-05
Average	2.18E-05	3.64E-07	1.11E-05
St Dev	2.65E-05	4.42E-07	1.35E-05
GeoMean	1.098E-05	1.83E-07	5.58E-06

1.5 Glacial Till

Based upon a review of previous reports, the permeability of the glacial till had apparently never been measured. The values used in previous analyses appear to be generalized permeabilities for sandy to clayey till soils. To better evaluate the seepage characteristics of the foundation tills, a sampling program was implemented to retrieve till samples on which laboratory testing could be performed. Although the sampling program used Pitcher barrel sampling methods, which uses a cutting head and retractable thin-wall sampling tube for relatively undisturbed sampling, sufficient samples could not be obtained due to the nature of the formation. The till contained not only varying amounts of clay and sand but also cobbles and boulders that could not be penetrated, even with the cutting teeth of the sampling device. An alternate method, slug testing, was then employed to estimate the permeability of the formation.

The in situ slug tests, performed in standpipe piezometers installed in August, 2007, were performed along the north dam of Cell 2W. The slug testing consisted of preparing a standpipe piezometer by first flushing it of all soils and then filling it with a volume of water. The water was allowed to dissipate and drain from the piezometer into the till and the depth to water was recorded over a measured period of time until equilibrium was reached. The range of values obtained from the testing program is reported in Table 5.

Table 1-5: Range of Permeability of Glacial Till from Slug Tests

	k (ft/min)	k (ft/sec)	k (cm/sec)
Minimum	1.72E-04	1.17E-05	3.57E-04
Maximum	1.44E-03	2.40E-05	7.32E-04
Average	1.03E-03	1.72E-05	5.24E-04
St Dev	3.75E-04	6.24E-06	1.90E-04
GeoMean	9.90E-04	1.65E-05	5.03E-04

1.6 Peat

Organic matter consisting of peat occurs throughout the tailings basin perimeter and just outside the current toe of the dams. Many areas within Cell 2E contain peat deposits covered by years of tailings deposition. In areas along the toe of the tailings basin, natural (uncompressed) peat, relatively unaltered by the construction of the tailings basin, still exists.

Permeability of the compressed peat was determined using two methods to represent permeabilities of the peat in the vertical and horizontal directions. The vertical permeability was determined from falling head, flexible wall permeability tests of four relatively undisturbed peat samples tested at confining stresses ranging from 1.5 to 6.0 tsf, while the horizontal permeability was measured using in situ pore pressure dissipation testing. The difference in permeability between the horizontal and vertical directions is attributed to the way in which peat is formed and varies highly with confining pressure, with horizontal to vertical permeability ratios as high as 15 reported under 180 kPa confining pressure (Ajlouni, 2000). The confining pressures at the PolyMet site are significantly higher and significantly higher ratios of horizontal to vertical permeability should be expected. The permeability of the virgin peat (north of the dam), is unknown. However, peat permeabilities ranging from 10^{-2} to 10^{-4} cm/sec were previously recommended by Sitka and are consistent with this site (Sitka, 1995). The range in permeability for the peat material is shown in Table 1-6.

Table 1-6: Range of Permeability for Compressed Peat Material

Vertical	k (ft/min)	k (ft/sec)	k (cm/sec)
Minimum	2.50E-08	4.17E-10	1.27E-08
Maximum	2.30E-07	3.83E-09	1.17E-07
Average	8.53E-08	1.42E-09	4.33E-08
St Dev	9.79E-08	1.63E-09	4.97E-08
GeoMean	5.47E-08	9.12E-10	2.78E-08

Horizontal	k (ft/min)	k (ft/sec)	k (cm/sec)
Minimum	3.46E-06	5.76E-08	1.76E-06
Maximum	1.45E-05	2.41E-07	7.35E-06
Average	8.96E-06	1.49E-07	4.54E-06
St Dev	7.78E-06	1.30E-07	3.96E-06
GeoMean	7.07E-06	1.18E-07	3.60E-06

1.7 Rock Starter Dam

On the north side of Cell 2E, a rock starter dam constructed over the peat deposit was utilized to facilitate future dam construction. The permeability of the rock starter dam was based upon the published grain size distribution (Ebasco, 1977). Due to the size of the material, samples of the rock could not be obtained in any manner that would allow permeability testing. Therefore, an approximation of the permeability was made using the Hazen equation so that the seepage characteristics of the toe of the dam could be modeled:

$$K = cD_{10}^2$$

Where:

K = hydraulic conductivity (permeability) (cm/sec)

c = constant (assumed equal to 1)

D_{10} = diameter of which 10% of the sample by weight is smaller (mm)

The resulting permeability was found to range from 1.3 x 10^{-3} to 94 x 10^{-3} ft/sec (0.034 to 2.865 cm/sec), based upon the grain size distribution selected, with D_{10} ranging from approximately 0.2 to 2 mm and within the acceptable range for use of the Hazen equation (Lindeburg 2006).

2.0 PolyMet Tailings Basin Permeabilities

Laboratory permeability testing has been performed on three different PolyMet grain size distributions: bulk tailings, oversized tailings and undersized tailings. The data from these tests are summarized below.

2.1 PolyMet Bulk Tailings

The permeability of the PolyMet bulk tailings was determined from falling head, flexible wall, laboratory permeability testing performed as a part of the preparation of Technical Design Evaluation Report RS 39/40T by Barr Engineering (Barr, 2007). Six specimens were remolded to dry densities ranging from 89.3 to 100.7 pcf and tested at confining stresses of 0.25 to 7.0 tsf. The results of the laboratory testing on the bulk tailings are shown in Table 2-1.

Table 2-1: Range of Permeability for the PolyMet Bulk Tailings

	k (ft/min)	k (ft/sec)	k (cm/sec)
Minimum	3.90E-05	6.50E-07	1.98E-05
Maximum	9.50E-04	1.58E-05	4.82E-04
Average	4.19E-04	6.99E-06	2.13E-04
St Dev	4.19E-04	6.98E-06	2.13E-04
GeoMean	2.29E-04	3.81E-06	1.16E-04

Plotting the permeability versus confining stress reveals a strong correlation (Figure 1).

2.2 PolyMet Oversized Tailings

The permeability of the PolyMet oversized tailings was determined from laboratory testing performed as a part of the preparation of report RS 39/40T by Barr Engineering (Barr, 2007). The specimens were remolded to dry densities of 88.6 to 104.8 pcf prior to testing at confining pressures ranging from 0.25 to 10.0 tsf. The results of the laboratory testing on the oversized fraction of the tailings are shown in Table 2-2.

Table 2-2: Range of Permeability for the PolyMet Oversized Tailings

	k (ft/min)	k (ft/sec)	k (cm/sec)
Minimum	1.20E-03	2.00E-05	6.10E-04
Maximum	3.40E-03	5.67E-05	1.73E-03
Average	2.27E-03	3.78E-05	1.15E-03
St Dev	8.02E-04	1.34E-05	4.08E-04
GeoMean	0.002271	3.78E-05	1.15E-03

2.3 PolyMet Undersized Tailings

The permeability of the PolyMet undersized tailings was also determined from laboratory testing performed as a part of the preparation of report RS 39/40T by Barr Engineering (Barr, 2007). Six specimens were remolded to dry densities ranging from 85.1 to 99.9 pcf and tested at confining stresses of 0.25 to 10.0 tsf. The results of the laboratory testing on the fine tailings are shown in Table 2-3.

Table 2-3: Range of Permeability for the PolyMet Undersized Tailings

	k (ft/min)	k (ft/sec)	k (cm/sec)
Minimum	1.80E-05	3.00E-07	9.14E-06
Maximum	8.90E-05	1.48E-06	4.51E-05
Average	3.79E-05	6.32E-07	1.93E-05
St Dev	2.67E-05	4.44E-07	1.35E-05
GeoMean	3.79E-05	6.32E-07	1.93E-05

2.4 PolyMet Tailings Basin Dams (LTVSMC Bulk Tailings)

The LTVSMC coarse tailings to be excavated for use in construction of the shell along the downstream slope of the future tailings basin dam will likely have minor inclusions of LTVSMC fine tailings and slimes in addition to the coarse tailings that will be targeted for excavation. As a conservative approach, to account for possible minor inclusions of slimes and fine tailings in the excavated coarse tailings, four tailings mixtures were prepared from bulk samples obtained during test pitting in Cell 2W. Each of the mixtures was tested for permeability using the constant head, rigid wall, method (ASTM D5856) with the resulting range of values as shown in Table 2-4.

Table 2-4: Range of Permeability of LTVSMC Bulk Mixtures

	k (ft/min)	k (ft/sec)	k (cm/sec)
Minimum	1.30E-04	2.17E-06	6.61E-05
Maximum	2.00E-04	3.33E-06	1.01E-04
Average	1.60E-04	2.67E-06	8.14E-05
St Dev	3.16E-05	5.27E-06	1.61E-04
GeoMean	1.58E-04	2.63E-06	8.02E-05

3.0 Permeabilities used in Various Models

Different permeability values have been used at different times for different purposes. This section summarizes the values used for each modeling effort and gives the basis for selection of the values that were used.

3.1 Geotechnical Modeling

Permeability values used in the seepage analyses for dam stability modeling for the Tailings Basin-Mitigation Design were selected from the ranges described in Sections 1.0 and 2.0. For the LTVSMC coarse tailings and slimes the average permeabilities of 8.39×10^{-5} ft/sec (2.44×10^{-3} cm/sec) and 3.64×10^{-7} ft/sec (1.11×10^{-5} cm/sec), respectively, were used. A permeability of 1.77×10^{-6} ft/sec (1.16×10^{-4} cm/sec) was used for the LTVSMC fine tailings and is associated with an effective overburden pressure of 2.75 tsf as discussed in Section 1.2. The LTVSMC bulk tailings represent mixtures of the slimes, fine, and coarse tailings as a conservative approximation of the largely coarse tailings to be used to construct the shell along the downstream slope of the future tailings basin dam. An average value of 2.67×10^{-6} ft/sec (8.14×10^{-5} cm/sec) was used for preliminary design. Permeability values for this portion of the analysis will be modified in future analysis if it is confirmed by visual observation of tailings excavation for dam construction that inclusions of slimes and fine tailings with coarse tailings are minor. A permeability of 1.72×10^{-5} ft/sec (5.24×10^{-4} cm/sec) was selected as representative of the glacial till. Permeabilities of the compressed and virgin peat zones were selected to best represent the structure of the peat and the direction of seepage. The permeability of the PolyMet bulk tailings is strongly correlated to confining stress (Section 2.1). Accordingly, three representative values of permeability were selected for use in modeling. 1.13×10^{-5} ft/sec (3.44×10^{-4} cm/sec) for PolyMet bulk tailings under less than 0.45 tsf effective overburden (average for 10 feet of soil with a unit weight of 90 pcf), 3.68×10^{-6} ft/sec (1.12×10^{-4} cm/sec) for tailings under 1.35 tsf effective overburden (average for 30 feet of soil with unit weight of 90 pcf), and 2.14×10^{-6} ft/sec (6.52×10^{-5} cm/sec) for tailings under greater than 2.29 tsf effective overburden (average for approximately 50 feet of soil with unit weight of 90 pcf).

The previous sections provided a summary of the analyses used to determine the range in permeability values for the materials encountered in the Tailings Basin. The values selected for design purposes are summarized in Table 3-1. An important component in modeling of tailings basins is calibration of the materials, parameters, and configuration with monitoring data to evaluate the seepage behavior and compare the performance to reality. Deposition of tailings on the beaches as well as separation and compaction using earth moving equipment can yield a wide range in permeability for the materials. The values in Table 3.1 are estimates expected to cover a range of material types and were used as the starting point for the geotechnical model calibration phase of the project.

Table 3-1 –Permeabilities for Stability Models

Material	Permeability (ft/s)	Permeability (cm/s)
LTVSMC Coarse Tailings	8.39×10^{-5}	2.56×10^{-3}
LTVSMC Fine Tailings	1.77×10^{-6}	5.39×10^{-5}
LTVSMC Slimes	3.64×10^{-7}	1.11×10^{-5}
Rock Starter Dam	50×10^{-3}	1.52
Compressed Peat	1.42×10^{-9}	4.33×10^{-8}
Virgin Peat	3.28×10^{-3}	1.00×10^{-1}
Glacial Till	1.72×10^{-5}	5.24×10^{-4}
PolyMet Bulk Tailings	1.13×10^{-5} to 2.14×10^{-6}	6.52×10^{-5} to 3.44×10^{-4}
LTVSMC Bulk Tailings	2.67×10^{-6}	8.14×10^{-5}

3.2 Groundwater Flow Modeling – Proposed Design

Permeability values used in the groundwater flow models that were constructed for the Proposed Design are documented in RS13 Draft-03 Attachment A-6 Table 4-1 and Section 5.2.3 and are summarized here. Permeability values for the LTVSMC tailings were selected to be consistent with the geotechnical modeling that was being conducted simultaneously. Permeability of the native materials, the till and bedrock, were allowed to vary during model calibration within expected ranges. The resulting high permeability value of the till was needed in order to match predicted seepage losses from the basin.

For the Proposed Design, tailings would be spigoted along the perimeter of the dikes which would result in a gradation of grain sizes from course to fine away from the dams. The coarse fractions would be reworked and used for dam construction. For the groundwater modeling, it was assumed that the permeability of the bulk tailings would be representative of the embankment and the portion of the beach nearest the embankment (i.e. the coarse beach) and the permeability of the undersized tailings would be representative of the portion of the beach nearest the pond (i.e. the fine beach) and the material within the pond itself. Permeability values used for the groundwater modeling of the Proposed Design are shown in Table 3-2.

Table 3-2 –Permeabilities used in the Groundwater Models for the Proposed Design

Material	ft/sec	cm/sec
PolyMet Coarse Beach	6.56×10^{-6}	2.00×10^{-4}
PolyMet Fine Beach	5.60×10^{-7}	1.71×10^{-5}
PolyMet Pond/Slimes	5.60×10^{-7}	1.71×10^{-5}
LTVSMC Coarse Beach	1.60×10^{-6}	4.88×10^{-5}
LTVSMC Fine Beach	3.30×10^{-7}	1.01×10^{-5}
LTVSMC Slimes	3.30×10^{-7}	1.01×10^{-5}
Glacial Till	9.26×10^{-4}	2.82×10^{-2}

3.3 Groundwater Flow Modeling – Mitigation Design

Permeability values used in the groundwater flow models that were constructed for the Mitigation Design will be documented in RS13b Draft-01 Attachment A-6 and are summarized here. Permeability values for the LTVSMC tailings were selected to be consistent with the geotechnical modeling that was being conducted simultaneously. These values are different from the values used for the models of the Proposed Design because additional data was collected and analyzed between modeling efforts. The permeability of the till changed slightly in response to changes in permeability of the LTVSMC tailings in order to maintain an acceptable model calibration.

For the Mitigation Design, tailings would be placed in a manner that precludes segregation of the material into fine and coarse fractions. As such, the permeability of the bulk tailings was deemed to be representative of all PolyMet tailings. To account for variability in permeability with confining stress, two different permeabilities were used for the PolyMet tailings; a higher value for the tailings near the surface and a lower value for the tailings at depth in the basin. This is consistent with the material testing presented in Section 2.1. A permeability representative of LTVSMC bulk tailings was used for the embankments of the PolyMet basin which will be constructed out of LTVSMC tailings. In closure, the permeability of the beach and pond area will be lowered via bentonite augmentation. It was assumed that the bentonite augmented layer would be 18 inches thick and would have a permeability of $1\text{x}10^{-6.5}$ cm/sec. Permeability values used for the groundwater modeling of the Mitigation Design are shown in Table 3-3.

Table 3-3 –Permeabilities used in the Groundwater Models for the Mitigation Design

Material	ft/sec	cm/sec
LTVSMC Embankment	2.67E-06	8.14E-05
PolyMet Bulk - Shallow	1.14E-05	3.47E-04
PolyMet Bulk - Deep	2.13E-06	6.50E-05
LTVSMC Coarse Beach	1.77E-06	5.39E-05
LTVSMC Fine Beach	1.77E-06	5.39E-05
LTVSMC Slimes	3.64E-07	1.11E-05
Glacial Till	7.59E-04	2.31E-02
Bedrock	2.81E-09	8.56E-08

3.4 Geochemical Modeling – Proposed Design

The permeability of the PolyMet tailings is used in two different portions of the geochemical modeling: to assess the rate of infiltration associated with the tailings slurry on the beaches and to determine the unsaturated zone moisture profiles needed for water quality predictions (the Hydrus-2D modeling). For the prediction of infiltration in the active delta area, a permeability of $3.9x10^{-5}$ ft/sec ($1.19 x10^{-3}$ cm/sec) was used for the PolyMet coarse beach (representative of oversized tailings) and $7.4x10^{-7}$ ft/sec ($2.26 x10^{-5}$ cm/sec) was used for the PolyMet fine beach (representative of undersized tailings). These values are reported in RS54/RS46 on page 70.

Hydrus-2D modeling was conducted to estimate moisture profiles which were used in the prediction of porewater chemistry. For this work, a permeability of $6.6x10^{-6}$ ft/sec ($2.01 x10^{-4}$ cm/sec) was used for the PolyMet inactive coarse beach and embankment areas and $7.2x10^{-7}$ ft/sec ($2.19 x10^{-5}$ cm/sec) was used for the PolyMet fine beach, which are representative of bulk tailings and undersized tailings respectively, which is consistent with the groundwater flow modeling that is discussed in Section 3.2. These values are reported in RS54/RS46 Appendix D.1 page 1.

3.5 Geochemical Modeling – Mitigation Design

For the prediction of infiltration in the active delta area of the Tailings Basin-Mitigation Design, a permeability of $2.67x10^{-6}$ ft/sec ($8.14 x10^{-5}$ cm/sec) was used for the LTVSMC embankment crest area and $2.14x10^{-6}$ ft/sec ($6.52 x10^{-5}$ cm/sec) was used for the PolyMet bulk tailings. These values are consistent with the values used for the groundwater modeling that is discussed in Section 3.3.

For the proposed mitigation design Hydrus-2D modeling was also undertaken to predict moisture profiles which were used in the prediction of porewater chemistry. For this work, a permeability of $1.78x10^{-6}$ ft/sec ($5.41x10^{-5}$ cm/sec) was used for the PolyMet beach representative of bulk tailings. A permeability of $3.9x10^{-5}$ ft/sec ($1.2x10^{-3}$ cm/sec) was adopted for the LTVSMC coarse tailings to be used in the construction of the embankment, which is representative of the PolyMet oversized tailings.

4.0 References

Public Publications

Ajlouni, M.A. Geotechnical Properties of Peat and Related Engineering Problems, PhD Thesis, University of Illinois at Urbana-Champaign, 2000.

Lindeburg, M.R. Civil Engineering Referente Manual for the PE Exam. Belmont, California: Professional Publications, Inc., 2006.

Lunne, T., P.K. Robertson, and J.J.M. Powell. Cone Penetration Testing in Geotechnical Practice. New York, New York: Routledge, 1997.

Site-Specific Publications

Ebasco Services Inc. Erie Mining Company Tailing Dam Investigations and Analysis Engineering Report. 1977.

Sitka Corporation. Geotechnical Assessment of Tailings Impoundment Phase 1. 1995.

Sitka Corporation. Phase 2 Geotechnical Assessment of Tailings Basin. 1995.

Barr Engineering Co. LTVSMC Tailings Dam Field Exploration and Analyses. 2000.

Barr Engineering Co. Technical Design Evaluation Report RS39/40T for Tailings Basin Geotechnical and Design. 2007.

Attachment A-7

Water Balance – Process Plant – Non MetSim Water Uses

Attachment A-7

Process Plant Water Balance - Non MetSim Water Uses

The water balance provided by Bateman and described in RS07I is based on the output from the MetSim metallurgical process simulation software. Some water uses in the process plant are not directly related to the metallurgical process and therefore were not included in the water balance presented in RS07I. This document describes the Process Plant water uses that were not included in RS07I.

Table 1 lists the water uses not considered in RS07I with their flows and fate.

Table 1 Water Uses Not Considered in MetSim		
Use	**GPM**	**Fate**
Potable Water	17	10 GPM to Tailings Basin 7 GPM to Area 1 and 2 Shops Sanitary Systems
Hydrometallurgical Plant		
Agitator Seals	4	to Residue Facility
Cathode Wash and Spray	20	to Residue Facility
Beneficiation Plant		
Flotation OSA Flush	6	to Tailings Basin
Vehicle Wash Down	8	to Tailings Basin
Oxygen Plant	40	lost to atmosphere
Boiler Water	2	lost to atmosphere
Grounds and Plant Maintenance	6	lost to stormwater
Fire Water	4	lost to leakage
Total	**106**	

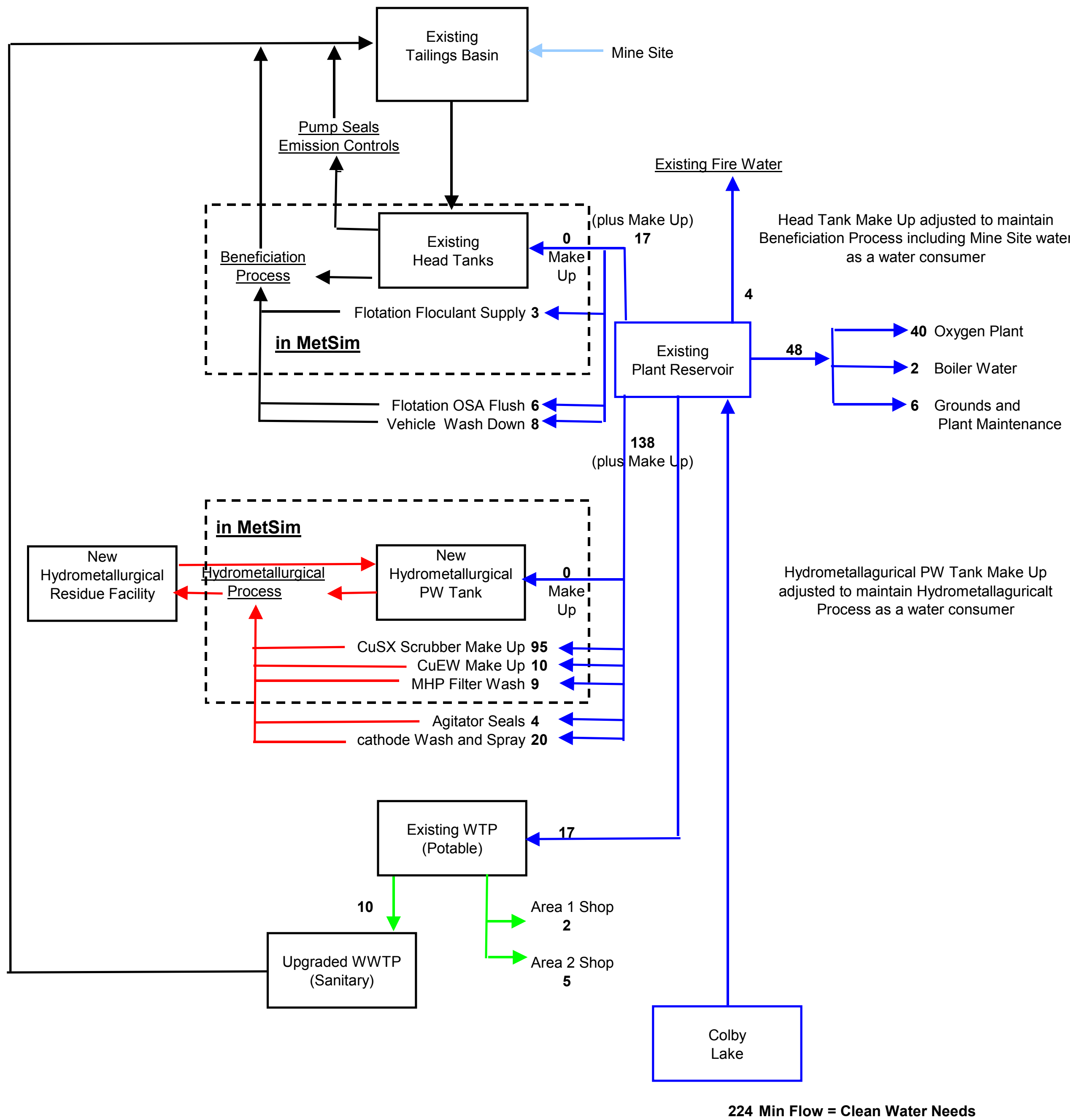
In addition to these quantified flows, pump seals and beneficiation plant emission controls (water to slurrify the dust collected in the baghouses) were not considered in RS07I. These do not require raw water and will use mill process water from the tailings basin. This water will be discharged back to the Tailings Basin without any loss, so no additional raw water is required.

Figure 1 is a simplified diagram of PolyMet's water systems with a focus on raw water requirements and the water uses not considered in MetSim. Note that the Head Tank Make Up Water and Hydrometallurgical PW Tank Make Up Water requirements on Figure 1 do not consider water gains or losses from the Tailings Basin and Hydrometallurgical Residue Facility nor water from the Mine Site. Evaluation of these factors will determine the actual make up water requirements.

The minimum raw water requirement from Colby Lake is 224 gpm. This includes the 106 gpm shown in Table 1, plus a raw water requirement of 114 gpm for the Hydrometallurgical Process and 3 gpm for the Flotation Process, both of which are included in the MetSim model. Additional requirements for water that do not have to be raw water can be met by:

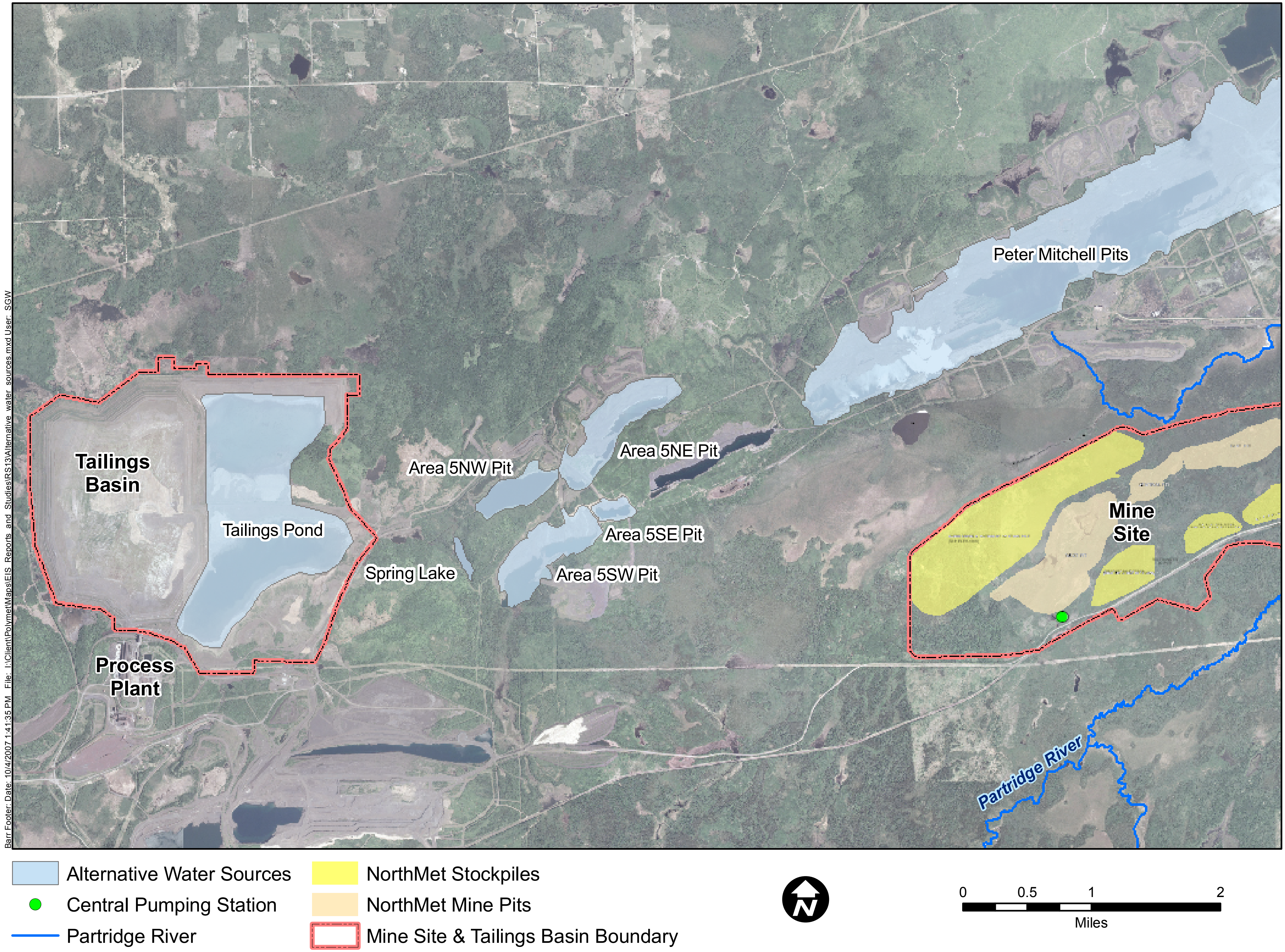
1. additional withdrawal from Colby Lake;
2. water from the Mine Site; or
3. in the case of the Integrated Alternative, from Area 5NW Mine Pit overflow.

Figure 1 – Water Systems Simplified
(values in GPM and show minimum flow from Colby Lake)



Attachment A-8

Tailings Basin Make-Up Water: Alternative Sources



Peter Mitchell Pits
Area 5NE Pit
Area 5NW Pit
Tailings Basin
Tailings Pond
Area 5SE Pit
Spring Lake
Area 5SW Pit
Mine Site
Process Plant
Partridge River
Alternative Water Sources
Central Pumping Station
Partridge River
NorthMet Stockpiles
NorthMet Mine Pits
Mine Site & Tailings Basin Boundary
N
0
0.5
1
2
Miles
Barr Footer: Date: 10/4/2007 1:41:35 PM File: I:\Client\Polymet\Maps\EIS Reports and Studies\RS13\Alternative water sources.mxd User: SGW