RS74B Surface Water and Groundwater Quality Modeling: Plant Site
Draft 02

PolyMet Mining, Inc.

September 2008

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RS74B Surface Water and Groundwater Quality Modeling of the Tailings Basin – Embarrass River Watershed

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1.0 Introduction

1.1 Project Overview

PolyMet Mining, Inc. (PolyMet) is in the process of environmental review for its NorthMet deposit, near Babbitt in northern Minnesota. The NorthMet Project includes two sites: the Mine Site and the Plant Site (see Figure 1-1). The Mine Site refers primarily to the areas considered for open pits, lean ore stockpiles, mine waste rock stockpiles, overburden stockpiles, access roads, and other related facilities and civil works. The Mine Site is located in the Partridge River watershed (see Figure 1-2). The Plant Site includes the existing former LTV Steel Mining Company (LTVSMC) mineral beneficiation processing plant and tailings impoundment, new hydrometallurgical processing plant and hydrometallurgical residue disposal cells. The Plant Site is largely located in the Embarrass River watershed (see Figure 1-3), though a small portion of the seepage from the existing tailings impoundment currently drains to Second Creek, a tributary of the Partridge River that flows into the Partridge River downstream of Colby Lake. The NorthMet Project includes cutoff/collection of this seepage.

PolyMet is proposing to reuse/recycle process water from the Mine Site in the operations at the Plant Site in order to eliminate any direct discharge of process water from the NorthMet Project to the surface waters of the State. In this and other PolyMet submittals "process water" is defined as precipitation runoff and groundwater that has contacted disturbed surfaces and may not meet water discharge limits and hence may require treatment. Some minimum, unrecoverable leakage of process water to groundwater is anticipated, however. On the other hand, stormwater runoff (that is, precipitation runoff that has not contacted disturbed surfaces or precipitation runoff from reclaimed surfaces) will be routed to downstream watercourses without need for treatment other than control for total suspended solids (TSS).

1.2 RS74 Report Overview

As part of the process of environmental review, Barr Engineering Co. (Barr) has been retained by PolyMet to complete a series of support documents required for the Project Description of the NorthMet Project and the related Environmental Impact Study (EIS). This report, RS74B Draft-02, is one of these support documents. Its purpose is to assess the potential impacts of the NorthMet Project on the water quality of groundwater and downstream watercourses in the Embarrass River watershed.

On behalf of PolyMet, Barr submitted the report presenting the Water Quality Modeling (RS74) for the NorthMet Project on July 30, 2007 (RS74, July 2007, hereafter referred to as RS74 Draft-01). RS74 Draft-01 presented the results of the surface water quality model for the Partridge River and Embarrass River watersheds. Deterministic water quality predictions in RS74 Draft-01 were provided based on the best information available at that time. Since RS74 Draft-01 was published, changes have been made to several of the components that are used in the surface water quality models, and alternative plans or mitigation designs have been proposed for both the Mine Site and the Tailings Basin that need to be evaluated. Thus, RS74 Draft-02 includes the evaluation of:

- Mine Site-Proposed Action.
- Mine Site-Reasonable Alternative 1.
- Tailings Basin-Proposed Action.
- Tailings Basin-Geotechnical Mitigation.

In other RS Documents and Technical Memoranda, it is possible that these designs are referred to by other naming conventions such as Mine Site-Proposed Design, Tailings Basin-Proposed Design, Tailings Basin-Mitigation, and Tailings Basin-Mitigation Design, among others; these naming conventions all refer to the same corresponding plans and designs listed above. In addition, Agency/EIS contractor review of RS74 Draft-01 identified a need to conduct a similar assessment of the potential impacts to groundwater quality for both the Mine Site and the Plant Site. The scope of work for RS74 did not include making predictions of downgradient groundwater impacts at these locations, nor was this included in any other RS document.

In order to accommodate the scope of work that was added, RS74 is being divided into two separate reports, RS74A and RS74B. RS74A (a separate report) presents the deterministic surface water and groundwater quality predictions of the impacts associated with the Mine Site on the surrounding groundwater and surface water resources, including the Partridge River and Colby Lake. RS74B (this report) presents the deterministic surface water and groundwater quality predictions of the impacts associated with the Plant Site on the surrounding groundwater and surface water resources, including the Embarrass River.

Following the publishing of RS74 Draft-01 but previous to the preparation of RS74 Draft-02, eleven technical memoranda were prepared and submitted to the Agencies providing updated/new deterministic surface water and groundwater quality predictions of the impacts for the Mine Site and the Plant Site. RS74A and RS74B replace those eight technical memoranda.

1.3 Related Reports

The information on flows and water quality at the Mine Site and Plant Site used in this assessment is based on earlier reports including the following:

- *Hydrogeological - Drill Hole Monitoring and Data Collection - Phase 1* (RS02 Draft-02) published on November 16, 2006 described the initial hydrogeological investigation at the Mine Site, and included baseline monitoring results for water quality parameters of groundwater in the surficial deposits and underlying bedrock (more specifically, in the Duluth Complex) from sampling in March 2005.

- *Hydrogeological - Drill Hole Monitoring and Data Collection - Phase 2* (RS10 Draft-02) published on November 16, 2006 described the second hydrogeological investigation at the Mine Site, and included baseline monitoring results for water quality parameters of groundwater in the underlying bedrock (more specifically, in the Virginia Formation) from sampling in December 2005 and January 2006.

- *Hydrogeological - Drill Hole Monitoring and Data Collection - Phase 3* (RS10A Draft-02) published on March 15, 2007 described the third hydrogeological investigation at the Mine Site, and included baseline monitoring results for water quality parameters of groundwater in the surficial deposits and underlying bedrock (both in the Duluth Complex and Virginia Formation) from sampling in October and November 2006.

- *Tailings Basin and Hydrometallurgical Residue Water Balance* (RS13 Draft-03) published on November 16, 2007 determined the unrecoverable seepage rate that flows out of the Tailings Basin-Proposed Action as groundwater flow through the surficial till deposits for historic operations and during PolyMet operations and closure.

- *Tailings Basin - Mitigation Design Water Balance* (RS13B Draft-01) published on September 8, 2008 determined the unrecoverable seepage rate that flows out of the Tailings Basin-Geotechnical Mitigation as groundwater flow through the surficial till deposits during PolyMet operations and closure.

- *Mine Plan* (RS18 Draft-02) published on September 5, 2007 and updated via Errata on October 23, 2007 provided the locations of the pits, stockpiles, and other mine-related features at different stages of the Mine Site development.

- *Mine Site Water Balance for the PolyMet NorthMet Mine Site* (RS21 Draft-02) published on October 5, 2007 provided estimates of flows and runoff volumes of stormwater that can be expected to flow from the Mine Site to the Partridge River during PolyMet operations. It also provided estimates of flows and runoff volumes of process water that will be pumped from the Mine Site to the Plant Site, and the general water management scheme proposed under PolyMet operations. RS21 summarized the results of the RS22, RS24, and RS25 evaluations.

- *Mine Waste Water Management* (RS22 Draft-02) published on October 17, 2007 defined the areas that will not be contributing runoff to the Partridge River depending of the stage of Mine Site development. The runoff from these areas is treated as process water. Process waters will be collected, treated (if required) and diverted to the Plant Site (Tailings Basin) for use in the processing of ore. *Groundwater Modeling of the NorthMet Mine Site* (Appendix B of RS22) was updated as Draft-03 on August 1, 2008.

- *Reactive Waste Rock and Lean Ore Segregation* (RS23T Draft-02) updated on October 3, 2007 presented the evaluation of the hydrologic performance and constructability of different types of bottom liner and top cover systems for the stockpiles. The systems ultimately selected for each stockpile were based on the geochemical characterization of the waste rock or lean ore material to be contained.

- *Mine Surface Water Runoff Systems* (RS24 Draft-02) published on September 28, 2007 provided estimates of the runoff contribution from natural undisturbed areas and reclaimed stockpiles depending of the stage of Mine Site development. The runoff from these areas is treated as stormwater, and it will be routed to the Partridge River following existing drainage patterns as much as possible.

- *Hydrometallurgical Residue and Flotation Tailings Cell Design and Location* (RS28T Draft-02) published on February 16, 2007 was updated/superseded by three documents:

    - On January 3, 2008 via memorandum with Subject *Hydrometallurgical Residue Facility Design Status Update*, which presented the conceptual design of the liner system for the Hydrometallurgical Residue Facility, hence provided preliminary estimates of leakage rates to groundwater for the proposed facility.

    - On January 18, 2008 via memorandum with Subject *PolyMet NorthMet follow-up to December 19, 2007 Tailings Basin Hydrology/Geochemistry Meeting – Response to Comments*, which responded to specific Agency questions regarding flotation tailings basin and hydrometallurgical residue cell design and performance.

    - On May 30, 2008 via the Barr report titled *Preliminary Geotechnical Evaluation – Flotation Tailings Basin*.

- *Wastewater Treatment Technology* (RS29T Draft-02) published on March 30, 2007 described the process waters generated at the Mine Site and the Plant Site, the treatment technologies that were evaluated, and the preferred treatment methods that are proposed to reuse/recycle the process waters. Further information was provided on November 15, 2007 via supplemental technical memorandum with Subject *Technical Design Evaluation Report, Wastewater Treatment Facility (RS29T), Revisions to the Equalization Ponds*, and on August 28, 2008 via a second technical memorandum with Subject *Revisions to Technical Design Evaluation Report, Wastewater Treatment Facility (RS29T): Response to evaluation of response to DNR comments*.

- *Pit Water Quality Model* (RS31 Draft-01) published on July 20, 2007 presented estimated chemistry of water pumped from the open pits for de-watering during operations, and predicted chemistry of water resulting from flooding of the East and West Pits during and after closure. Subsequent updates to the predictions reported in RS31 Draft-01 have been provided to Barr, and the summary of changes made is presented in SRK Consulting Engineers and Scientists (SRK) memo *Updates to Water Quality Predictions in Support for RS74 (Draft 2)* dated September 12, 2008, which is included as Appendix H of this RS74B report.

- *Hydrometallurgical Residue Characterization and Water Quality Model* (RS33/RS65 Draft-01) published on February 21, 2007 presented the chemical characterization of the leakage from the hydrometallurgical residue cells to groundwater for proposed PolyMet operations and closure plan.

- *Attachment 3 to Appendix A of RS39/RS40T PolyMet Report/Study Plant Site Stormwater - Volume & Patterns* (RS36 Draft-01) published on May 15, 2006 provided estimates of Plant Site flows to Second Creek during storm events.

- *Tailings Basin Geotechnical and Design* (RS39/RS40T Draft-03) published on August 15, 2007 described the existing tailings basin of LTVSMC, and presented PolyMet's tailings disposal plan. Of interest for this report are the estimated seepage rates from the existing tailings basin of LTVSMC as well as from PolyMet's Tailings Basin at different stages of development and closure.

- *Stockpile Conceptual Design* (RS49 Draft-02) updated on October 25, 2007 presented the preliminary design of the stockpile layouts, liner systems, and development concepts. Of interest for this report are the design criteria established to determine the foundation grading that provides for gravity drainage of any drainage from the stockpile to a series of lined collection sumps, from which the drainage will be pumped for treatment, if required, and use at the Plant Site.

- *Mine Closure Plan* (RS52 Draft-01) published on July 20, 2007 presented the concept design for closure and reclamation plans of both the Mine Site and Plant Site facilities. It also provided estimates of Partridge River flows during and after the proposed West Pit water filling operation and it described the post-closure water treatment required including wastewater treatment influent quantity and quality after closure, post-closure treatment facility operations, treatment performance, contingency treatment of West Pit overflow to the Partridge River, and post-closure wastewater treatment monitoring.

- *Waste Rock Characteristics/Waste Water Quality Modelin*g - W*aste Rock and Lean Ore* (RS53/RS42 Draft-01) published on March 9, 2007 presented the physical and geochemical characterization of waste rock (including waste rock, lean ore and ore materials) and provided estimates of rock stockpile drainage chemistry that have been used as input information for the water quality model of the Partridge River watershed during PolyMet operations and closure. Subsequent updates to the predictions reported in RS31 Draft-01 have been provided to Barr, and the summary of changes made by SRK is presented in Appendix H of this RS74B report.

- *Waste Water Modeling - Tailings* (RS54/RS46 Draft-01) published on July 20, 2007 presented the physical and geochemical characterization of existing tailings at the LTVSMC storage facility as well as of new tailings to be generated by the NorthMet Project, and provided estimates of tailings seepage chemistry that have been used as input information for the water quality model of the Embarrass River watershed during PolyMet operations and closure. Subsequent updates to the predictions reported in RS31 Draft-01 have been provided to Barr, and the summary of changes made by SRK is presented in Appendix H of this RS74B report.

- *Tailings Basin Modifications to Eliminate Water Release via Seepage* (RS55T Draft-02) published on February 13, 2007 presented additional information about the measures proposed to minimize the unrecoverable seepage rate that flows out of the Tailings Basin as groundwater flow through the surficial till/peat deposits for PolyMet operations.

- *PolyMet Mining Baseline Surface Water Quality Information* (RS63 Draft-02) published on June 29, 2007 and later updated to include 2007 monitoring data in both the Partridge River and Embarrass River watersheds provided baseline monitoring results for water quality parameters at several locations in the Partridge River and Embarrass River watersheds during the period April through November.

- *Technical Memorandum on Existing Tailings Basin Water Information* (RS64 Draft-01) published on February 7, 2007 provided existing tailings basin water quality data collected from seeps and groundwater wells. This information was later updated to include 2007 monitoring data in seeps and groundwater wells.

- *Streamflow and Lake Level Changes: Model Calibration* (RS73A Draft-03) published on September 12, 2008 presented the methodology and results of calibrating and validating the hydrologic/hydraulic model for the Partridge River watershed.

- *Streamflow and Lake Level Changes: Hydrologic/Hydraulic Modeling Results for the PolyMet NorthMet Mine Site* (RS73B Draft-03) published on September 12, 2008 presented the assessment of impacts of the Mine Site development on the water quantity in the Partridge River and Colby Lake-Whitewater Reservoir.

- *Technical Memorandum on Summary and Interpretation of Surface Water Quality Monitoring Data, PolyMet Mining Company* (RS76 Draft-02) published on June 27, 2007 provided baseline monitoring results for water quality parameters at several locations in the Partridge River and Embarrass River watersheds during the period 1955 to 2004, with most of the older data corresponding to measurements conducted in the 1970s.

- *Preliminary Flotation Tailings Basin Management Plan (TMP) for Operations, Maintenance, and Performance Monitoring – NorthMet Project.* Prepared for PolyMet Mining, Inc. by Barr Engineering Co. March 2008.

When the reports listed above are referenced in the sections below, such reference will not include the draft number. However, it is understood that references correspond to the latest, most updated versions of the reports. For instance, reference to RS22 actually makes reference to RS22 Draft-02 published on October 17, 2007; that is, any previous draft of RS22 should not be considered a valid reference. Also, when related information has been modified subsequent to publication of the reports listed above, a clear note will be made in the section where such modification has been made. In general, when discrepancies in assumptions or values are found, the information presented in RS74A and RS74B supersedes the information presented in the reports listed above.

Information on flows and water quality for the Embarrass River watershed also was obtained from the Minnesota Pollution Control Agency (MPCA) records (http://www.pca.state.mn.us/data/edaWater/index.cfm) or the Minnesota Department of Natural Resources (MDNR) records (http://www.dnr.state.mn.us/). In addition, information provided by third parties (municipalities, mining companies, United States Forest Service (USFS), United States Fish and Wildlife Service (USFWS), etc.) was used to describe foreseeable future actions by other parties in the two study watersheds. Acknowledgement of information sources is provided throughout the report as the information is applied to the study. From this point forward, this report (RS74B) focuses on the Plant Site and the Embarrass River watershed. The Mine Site and the Partridge River watershed are covered in RS74A.

1.4 Scope of Work

1.4.1 Overview

The scope of this study was originally based on the approach that was proposed in the final Scoping Decision Document (SDD) to define cumulative effects of the NorthMet Project for inclusion in the EIS (see Appendix A of this report). The scope has been modified in some respects since publication of the final SDD, based on discussions with the Agencies.

The scope of this study was developed assuming that the NorthMet Project would have direct discharges of process waters from the Plant Site to the Embarrass River. As indicated above, the NorthMet Project is now proposing to reuse/recycle water by collecting and treating process water generated at the Mine Site so that it can be pumped to the Plant Site for use as process make-up water (see RS21). In addition, the water balance of the Tailings Basin will be managed so as to eliminate the need for direct discharge to the Embarrass River (see RS13). Put simply, no point discharges of process waters to surface waters of the State are planned with the NorthMet Project during the twenty years of operations (see RS21) or during closure (see RS52) for either design of the Tailings Basin

(Proposed Action and Geotechnical Mitigation). During post-closure, no point discharge is expected from the Tailings Basin or Hydrometallurgical Residue Facility under either design at the Plant Site except that an emergency overflow will be provided for the Tailings Basin pond.

Although there will be no direct discharge during operations or closure, some leakage/seepage to groundwater is anticipated from tailings impoundments in the Embarrass River watershed (see RS13) regardless of tailings basin design. Groundwater flows through surficial deposits and subsequently flows toward natural watercourses. Thus, the primary potential water quality impacts from the NorthMet Project during operations are indirect impacts to groundwater and subsequent indirect impacts to surface waters via the indirect groundwater impacts. Therefore, the focus of the modeling in the Embarrass River watershed was expanded and redirected.

1.4.2 Surface Water Quality Modeling

The water quality assessment presented in RS74B was conducted using mass-balance models that were developed and calibrated to quantify the impacts of the Plant Site operations on the water chemistry at different locations along the Embarrass River under wet, average and dry weather/flow conditions for the two tailings basin designs (i.e., Proposed Action and Geotechnical Mitigation). Using mass-balance models is conservative. Some features of the physical and chemical phases of the transport of a chemical to or in a watercourse or water body are not considered (e.g., sorption in groundwater flow; sorption from dissolved to particulate forms in surface waters, followed by settling of particulates; loss due to biodegradation, volatilization, photolysis, and other chemical and biochemical reactions in surface waters; etc.). Most of these features, particularly the first two, would likely produce lower concentrations than predicted with mass-balance models.

Background chemical loads from sub-watersheds as well as from point and non point discharges were estimated based on historic and recent monitoring water quality results. The mass-balance models for the Embarrass River watershed were calibrated using this data. It was recognized that this approach would inherently include the effects of past and present actions related to rural and residential developments, existing publicly owned treatment works (POTW), past and current timber harvesting activities, and past and existing taconite mining activities, including the former LTVSMC mining and processing facilities in the Embarrass River watershed. Whenever available, preference was given to the more recent water quality data because they provided a better measure of background water quality without the impacts of the NorthMet Project.

Deterministic water quality predictions during different stages of the NorthMet Project development, closure and post-closure were compared against numeric chronic aquatic toxicity-based Minnesota surface water quality standards (Minnesota Rules Chapter 7050) in addition to those for the Lake Superior Basin (Minnesota Rules Chapter 7052) for the appropriate use classification for the water being analyzed. In general, Class 2B Minnesota water quality standards (recreational purposes and aquatic life; not protected as a source of drinking water) are applicable to the Embarrass River.

The assessment for the Embarrass River included the catchment area upstream of Sabin Lake. The groundwater path from the Tailings Basin to the Embarrass River is estimated to recharge this watercourse in a reach approximately 4 miles upstream of Sabin Lake. Class 2B Minnesota water quality standards are applicable for Sabin Lake. This study area is smaller than the one defined in the final SDD, which considered modeling of the Embarrass River watershed including both Sabin Lake and Wynne Lake, which is immediately located downstream from Sabin Lake. The rationale for the change is that demonstrating compliance with Class 2B Minnesota water quality standards at a location upstream of these two lakes should be sufficient to prove protection of the lakes. The only other flow to Wynne Lake below the study area is existing drainage from stockpiles of the former LTVSMC located north of Area 1 pit, about 3 miles north of the City of Aurora. Precipitation on these stockpiles drains to an unnamed creek and then to Wynne Lake. These stockpiles have been inactive for many years and required reclamation has been completed. Any impact of drainage from the stockpile area is therefore expected to diminish over time.

1.4.3 Groundwater Quality Modeling

Groundwater quality modeling was conducted for RS74B using a two step process. First, sets of "screening level models" were prepared to determine what the constituents of concern are for each source area being evaluated. In the screening level models, the more conservative, simplifying assumptions were made. If the constituents being evaluated were not predicted to exceed groundwater evaluation criteria under these conservative assumptions, they were not carried forward to the next phase of modeling. More detailed modeling was conducted for those constituents that showed potential exceedances of groundwater evaluation criteria using the screening level model.

Groundwater quality impacts were evaluated along flow paths originating at the various source areas being evaluated and ending at the Embarrass River. Potential impacts along each flow path were assessed using simple cross-section groundwater flow and contaminant transport models. Background groundwater concentrations were set using site specific water quality data.

1.4.4 Changes in Scope from final SDD

The final SDD was developed assuming that cumulative impacts to the water quality of streams and water bodies would occur from increases or decreases in surface discharge volume or surface discharge chemistry from the various sub-watersheds. The final SDD assumed that this study would evaluate both the potential impacts associated with the NorthMet Plant Site and also evaluate individual impacts due to other uses/activities. However, some of the uses/activities listed in the final SDD were not addressed in the water quality assessment presented in this report. The reasons for this change included:

- One envisaged change included in the final SDD was the increase in the rate of timber harvesting in the study areas. Information about forest stand information available from both the MDNR and the USFS Superior National Forest (SNF) indicate that only 5.6 percent of the Partridge River watershed has been harvested since 1980, and the corresponding annual rate of timber harvesting is not anticipated to increase in the near future, hence the related impacts on the Partridge River flows are not expected to be significant (Verry et al., 2000). Because the baseline data used for this cumulative impacts analysis already reflects the continuing presence of forest harvesting activities in the Partridge River watershed and significant increases in this activity are not expected, a specific analysis of the effects of these activities was considered not necessary as part of this water quality assessment of cumulative impacts presented in this report. A similar rationale can be followed for the Embarrass River watershed.

- The evaluation of the NorthMet Project potential impacts on mercury levels in the Partridge River and Embarrass River watersheds has not been included in this RS74 Draft-02 report. Such evaluation has already been presented to the Agencies in two separate technical memoranda, with Subject and Date: *NorthMet Project: Assessing Potential Impacts from Sulfate in Seepage and Discharge Water on Total Mercury and Methyl Mercury Concentrations in Offsite Receiving Waters* – April 25, 2008; and *NorthMet Project: Initial comparison of fish mercury concentrations from Hoyt Lakes Area Lakes with fish mercury concentrations from selected lakes in northeast Minnesota* – July 3, 2008.

1.5 Report Objectives

The objectives of this RS74B report are to:

- Present a summary of background water quality data and calibrate mass-balance models for the Embarrass River watershed to characterize water chemistry of natural surface waters and groundwater as well as existing point and nonpoint discharges.

- Use the mass-balance model calibrated for the Embarrass River watershed to evaluate the impact of the NorthMet Project for both the Tailings Basin-Proposed Action and the Tailings Basin-Geotechnical Mitigation on the water quality of the Embarrass River. If the deterministic water quality predictions do not meet the Minnesota water quality standards, propose plans to meet the standards.

- Evaluate potential groundwater quality impacts for the aquifers at the Plant Site from the NorthMet Project for both the Tailings Basin-Proposed Action and the Tailings Basin-Geotechnical Mitigation.

In addition to the objectives stated above, a secondary objective is to highlight changes made since the original RS74 Draft-01 submittal.

1.6 Report Organization

The remainder of this RS74B Draft-02 report is organized as follows, which has changed since RS74 Draft-01 in order to improve ease of reading and understanding:

- Section 2.0 presents a brief general description of the study area (i.e., the Embarrass River watershed), including location, land use, climate, hydrology, geology and hydrogeology. This section also provides a characterization of flows and water chemistry for past and current point and nonpoint discharges, including the LTVSMC Pit 5NW (also referred to as Area 5 Pit NW in tables and figures of this RS74B report) discharge to the Embarrass River, the former LTVSMC plant site and tailings impoundments discharge/seepage to the Embarrass River, and the City of Babbitt – Wastewater Treatment Plant discharge to the Embarrass River.

- Section 3.0 presents the Minnesota surface water and groundwater quality standards applicable to the Plant Site.

- Section 4.0 presents the scenarios (stages of Plant Site development, closure and post-closure) and locations in the Embarrass River watershed where background water quality, deterministic water quality predictions and Minnesota water quality standards were determined. Section 4.0 also provides a characterization of flows and water chemistry for future point and nonpoint leakage from the Plant Site (Tailings Basin seepage during operations and closure) for the Tailings Basin-Proposed Action and Tailings Basin-Geotechnical Mitigation. Only changes with respect to the Proposed Action are presented in the discussion about the Geotechnical Mitigation.

- Section 5.0 describes the methodology followed to develop the surface water quality mass-balance models for the Embarrass River watershed, including presentation and selection of background flows and water chemistry data that were used to calibrate the water quality models. A summary of input data to the surface water quality mass-balance model for the Tailings Basin-Proposed Action is given. The deterministic surface water quality predictions at different locations along the Embarrass River watershed for the proposed twenty-year period of mining and processing operations as well as for during and after closure of these facilities are given and compared to the Minnesota water quality standards. The results of the culpability and factor to exceed standard analyses are discussed.

- Section 6.0 describes the methodology and results for the deterministic groundwater quality impact predictions for the aquifers at the Tailings Basin for the Proposed Action. A summary of input data to the groundwater quality model for the Tailings Basin-Proposed Action is given. Future groundwater quality is predicted for each year of operations and post-closure and compared to Minnesota groundwater quality standards.

- Section 7.0 provides a summary of input data to the surface water quality mass-balance model for the Tailings Basin-Geotechnical Mitigation. The deterministic surface water quality predictions at different locations along the Embarrass River watershed for the proposed twenty-year period of mining and processing operations as well as for during and after closure of these facilities are given and compared to the Minnesota water quality standards. The results of the culpability and factor to exceed standard analyses are discussed. Finally, the model results from the Tailings Basin-Geotechnical Mitigation are compared to those of the Tailings Basin-Proposed Action.

- Section 8.0 describes the methodology and results for the deterministic groundwater quality impact predictions for the aquifers at the Tailings Basin for the Geotechnical Mitigation. A summary of input data to the groundwater quality model for the Tailings Basin-Geotechnical Mitigation is given. Future groundwater quality is predicted for each year of operations and post-closure and compared to Minnesota groundwater quality standards.

- Section 9.0 presents the conclusions of the water quality assessment conducted for the Embarrass River watershed.

2.0 Embarrass River Watershed

2.1 General Characteristics

The information presented in this section is not intended to provide a complete characterization of the Plant Site study area or the NorthMet Project, but to provide enough information for a general understanding of the Embarrass River watershed characteristics to facilitate a good understanding of the work presented in subsequent sections. Details about the Plant Site study area and the NorthMet Project can be found in the documents listed in Section 1.3.

2.1.1 Location

The Embarrass River also is a tributary of the St. Louis River. The Embarrass River first flows west and then flows southwest before joining the St. Louis River northwest of Makinen, approximately 23.2 miles downstream of the confluence of the Partridge River into the St. Louis River. The study watershed for this water quality assessment comprises the Embarrass River watershed from its headwaters west of Babbitt down to a location 4 miles upstream of Sabin Lake (see discussion in Section 1.4.2), for a total catchment area of 112.1 square miles (see Figure 1-3). The total length of the Embarrass River within the study watershed is approximately 24.8 miles, with terrain ranging from an elevation of 1,464.4 feet above mean sea level (feet-MSL) at its eastern headwaters to an elevation of 1,410.6 feet-MSL at the watershed outlet. The Embarrass River becomes highly sinuous, in particular north of the Plant Site.

2.1.2 Land Use/Land Cover

The Embarrass River watershed is dominated by wetlands in its headwaters, with little development. The combined use of the 2001 National Land Cover Dataset (NLCD) and National Wetlands Inventory (NWI) datasets indicates that the Embarrass River watershed is dominated by wetlands (35 percent), upland forests (50 percent) and shrub/scrub (8 percent).

2.1.3 Climate

As indicated in RS73B, the mean annual precipitation for the study areas is 29.2 inches for the period 1971-2001, which corresponds to the definition of the climate normal by the Climate Prediction Center of the National Weather Service (NWS). Approximately 75 percent of the annual precipitation occurs between May and October, whereas approximately 9 percent of the annual precipitation corresponds to the water equivalent of snowfall between December and February.

The results of the statistical analysis of precipitation data representative of the long-term climatic conditions in the Embarrass River watershed are presented in Appendix B. These results were used to confirm that periods of water quality monitoring in the study watershed included wet and dry weather/flow conditions; precipitation (rather than flow) is used as a proxy to determine wet and dry conditions because available flow data for the Embarrass River (see Section 2.1.4) do not necessarily cover the same periods of water quality monitoring.

As indicated in RS73A, the mean annual evaporation (from open water surfaces) for the study area is 20.0 inches. Pan evaporation measurements from Hoyt Lakes for the period 1966-1983 give no evaporation in the winter months, with a yearly total evaporation of 20.8 inches when a pan correction factor of 0.78 is used. No evaporation is considered during the winter. The mean annual actual evapotranspiration for the study area is 16.0 inches (Baker et al., 1979).

2.1.4 Hydrology

RS73A provided a list of USGS stream gaging stations within the boundaries of the St. Louis River watershed, which included one station within the study area of the Embarrass River watershed (USGS gage #04017000 – Embarrass River at Embarrass). Another station is located in the Embarrass River watershed, but it is downstream of the study area (USGS gage #04018000 – Embarrass River near McKinley). The locations of these two stream gaging stations are shown in Figure 1-3, and the periods of record are presented in Appendix C.

The results of analyzing flow data from the two stream gaging stations referred to above are presented in Appendix C. Table 2-1 provides estimated values for low flow (baseflow), average flow and high flow at the two locations of analysis in the Embarrass River watershed (see Section 4.1.1). There was no need to evaluate flows at different stages of the Plant Site development and closure, as the NorthMet Project does not alter the existing watershed configuration and flows of the Embarrass River. It was assumed that the flows in the Embarrass River would be the same for both the Tailings Basin-Proposed Action and Tailings Basin-Geotechnical Mitigation; the footprint of the Tailings Basin-Geotechnical Mitigation is approximately 13 acres greater than that of the Tailings Basin-Proposed Action, but such difference is negligible in comparison to the total footprint area for the Tailings Basin of more than 3,000 acres. Additionally, the footprint of the Plant Site is very small compared to the watershed upstream of PM-13.

2.1.5 Quaternary and Bedrock Geology

Much of the area is covered by peat bogs or open wetlands, with the remaining area covered by rolling to undulating Wisconsin aged Rainey Lobe drift, lacustrine materials, and outwash. In the region, it appears that only the Embarrass River sub-watershed north of the LTVSMC tailings impoundments has significant quantities of outwash (sand and gravel), with thicknesses greater than 100 feet (Jirsa et al., 2005). Elsewhere, the Quaternary deposits form a thin blanket (0-30 feet) over the bedrock.

Rainey Lobe drift is generally a bouldery till with high clay content. While site-specific geological studies of the drift have not been conducted, information on the quaternary deposits has been gathered during engineering and hydrogeologic investigations in the area. At the Tailings Basin, test pits for preliminary PolyMet engineering studies and informal observations of sumps and other small excavations indicate that the Quaternary geology in this area is similar. Most areas at the Tailings Basin consist of unsorted sand/silt/clay with cobbles and boulders. Boulders on surface can be greater than 10 feet in size and there may be a boulder lag horizon just below the ground surface in some areas. The till has been described as heterogeneous clayey to silty sand with fine to medium grained sand and some gravel and boulders (Sitka, 1995).

In the vicinity of the tailings basins, the uppermost bedrock unit is the Giants Range batholith, including quartz monzonite, monzodiorite and monzogranite. In the southeast corner of Cell 1E in the Tailings Basin, the uppermost bedrock is sedimentary schist with a seam of volcanic schist.

2.1.6 Hydrogeology

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 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.

Regionally, groundwater flows primarily northward, from the Embarrass Mountains to the Embarrass River, as shown on Figure 2-1. At the southern end of the Tailings Basin, there is some flow to the south, forming the headwaters of Second Creek. As the Tailings Basin was built up over time, a groundwater mound formed beneath the basin due to seepage from the various basins, which altered 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 south, west, and north of the basin.

2.2 Past and Current Point and Nonpoint Discharges

2.2.1 Pit 5NW

Area 5 comprises a network of four abandoned mine pits formerly owned by LTVSMC, two of which (named Pit 5NE and Pit 5NW) are located along the southern headwaters of the Embarrass River watershed. The other two abandoned mine pits (named Pit 5SE and Pit 5SW) are located in the Wyman Creek watershed, a tributary of Colby Lake (see Figure 1-1).

Pit 5NW is now substantially controlled by PolyMet. This pit is located in the Biwabik Iron Formation. As of November 2007, the Pit 5NW has a water volume of 5,325 acre-feet and at a water surface elevation of 1,666.5 feet-MSL. Based on bi-monthly flow measurements between June 2001 and December 2007 at Cliffs Erie – Hoyt Lakes Mining Area: Rail Culvert NE of Pit 5N Loadout Pocket, NPDES Permit MN0042536-SD-033, the average surface water discharge from Pit 5NW is 1.99 cubic feet per second -cfs (893 gallons per minute -gpm).

Pit 5NW has a tributary area of approximately 650 acres. Water discharging from Pit 5NW seeps from the pit to a small channel where it travels north approximately 5 miles before joining the Embarrass River downstream of surface water monitoring station PM-12 (see Figure 1-3).

2.2.2 LTVSMC Tailings Basin

The existing LTVSMC tailings basin is unlined and was constructed in stages beginning in 1953. The existing tailings basin was developed by constructing perimeter embankments and placing tailings from the iron ore processing operations directly onto native material (Barr Engineering, 2001). Perimeter embankments were constructed with coarse tailings.

There are three discrete cells in the existing basin: Cells 1E, 2E and 2W (see Figure 2-2). Cell 2W is the largest and highest of the three cells, covering a surface area of approximately 1,450 acres with an average fill height of 200 feet. It is also the driest and has gradually lost the ponded water remaining from taconite processing. Cell 1E is located east of Cell 2W and south of Cell 2E.

Cell 1E covers approximately 980 acres in surface area with an average fill height of 125 feet. Cell 2E is located east of Cell 2W and north of Cell 1E. Cell 2E is the lowest of the three cells and covers approximately 620 acres in surface area. Average fill height is 60 feet. Cells 1E and 2E continue to hold water. The existing basin does not have an overflow or discharge structure. A more complete description of the existing tailings basin is provided in RS39/RS40T.

The LTVSMC tailings basin was shutdown in January 2001 and has been inactive except for closure and reclamation activities consistent with the MDNR approved closure plan. After basin operations ended in 2001, the remaining surface water in Cell 2W drained to Cells 1E and 2E via an outlet structure and into the underlying groundwater system by seepage. Cell 2W has been revegetated by seeding and mulching.

As indicated above, the existing tailings basin is unlined and the perimeter embankments do not have a clay core or cutoff, which allows water to drain from the basin surface to the surrounding wetlands or groundwater aquifers. A portion of the seepage may emerge as surface flow (referred to in this report as “seeps”) on the downstream face of the tailings basin embankment, at or near the embankment toe.

Estimates of seepage have been generated for each of the existing tailings basin cells prior to PolyMet operations. The estimated seepage from all cells is 5,710 gpm (see RS13). Of this amount, 550 gpm drain to Second Creek, which results in a net unrecovered seepage of 5,160 gpm to groundwater flowing toward the Embarrass River. The bulk of this flow is subsurface seepage. All unrecovered seepage is assumed to reach the Embarrass River as groundwater flow during average and high flow conditions.

During low flow conditions, however, measurements taken in the Embarrass River at surface water monitoring station PM-13 (downstream of the existing tailings basin) in 2004 indicate total flows as low as 7.2 cfs (3,390 gpm). This value is less than the expected 5,160 gpm of seepage to the Embarrass River via groundwater. Therefore, during low flow conditions not all of the expected seepage is reaching the Embarrass River. The effective seepage during these periods of low flow has been estimated at 1.2 cfs (540 gpm) based on calibration of the Embarrass River water quality model using sulfate as sample parameter (see Section 5.1.4).

2.2.2.1 Seepage from Cell 1E

Cell 1E still impounds water, but at lower levels than during active LTVSMC basin operations. Seepage monitoring data for seeps at the south end of Cell 1E from May 2002 to October 2006 indicate that surface seepage peaked at 449 gpm around October 2004 and had declined to 199 gpm by October 2006 (see RS55T). Seepage from Cell 1E prior to PolyMet operations has been estimated to be 900 gpm (Adams et al., 2004).

2.2.2.2 Seepage from Cell 2E

Seepage monitoring data for seeps around Cell 2E from May 2002 to October 2006 demonstrate a gradual decrease since closure in 2001 (see RS55T). In October 2006, one active seep remained with a seepage rate of 127 gpm (see RS55T). Seepage from Cell 2E prior to PolyMet operations has been estimated to be 687 gpm (Adams et al., 2004).

2.2.2.3 Seepage from Cell 2W

Following the conclusion of LTVSMC tailings basin operation in 2001, surface water remaining in Cell 2W drained via saturated flow to Cells 1E and 2E and the underlying native material. Cell 2W has since been revegetated. Data from piezometers located in Cell 2W (data is presented in RS39/RS40T) indicate a continual, gradual decrease in piezometric head within the embankments and basin since 2001. Seepage monitoring data for seeps around Cell 2W from May 2002 to October 2006 indicate that the total seepage from active seeps remaining in October 2006 was less than 30 gpm (see RS55T). Subsurface seepage from entrained water in Cell 2W was estimated to be 4,123 gpm in 2002 using a groundwater model described in RS13 Attachment A-6 (see Table 3-11).

2.2.2.4 Water Quality from All Cells

It was deemed that the 2001-2005 groundwater quality monitoring data presented in RS74 Draft-01 was lacking compared to the other inputs to the Embarrass River. Therefore, additional groundwater water quality monitoring was conducted by PolyMet during 2007 at monitoring stations GW-001, SD-002, GW-003, GW-004, GW-005, GW-006, GW-007, GW-008, SD-001, SD-004, SD-006, the West Side Seep, WS-011, WS-012 and WS-013. Parameters analyzed in the 2007 monitoring included alkalinity, boron, calcium, cations, chloride, cobalt, copper, fluoride, hardness, iron, magnesium, manganese, mercury (total), molybdenum, nickel, potassium, salinity, sodium, sulfate, total dissolved solids, total suspended solids, turbidity and zinc. Four groundwater wells (GW-001, GW-006, GW-007 and GW-008) are considered representative of the tailings basin seepage prior to PolyMet operation (see Figure 2-3) and the 2007 monitoring data for water quality of groundwater at these four wells were used to update the chemistry of the seepage from the LTVSMC tailings basin. The data are shown in Table 2-2.

2.2.3 City of Babbitt Wastewater Treatment Plant

There is a municipal discharge from the Wastewater Treatment Plant of the City of Babbitt (WWTP-Babbitt) into Hay pond, in the Embarrass River watershed. Mr. Pete Pastika, City Administrator for City of Babbitt informed Barr during a telephone conversation on April 25, 2007 that the City of Babbitt has no plans to change or to modify the WWTP-Babbitt for the next 25 years. The WWTP-Babbitt is currently operating at one-half its installed capacity.

Similar to WWTP-Hoyt Lakes presented in RS74A, there is no water quality information from the WWTP-Babbitt for metals or other parameters of interest for this RS74B report. Data on copper, nickel and zinc concentrations for discharges of wastewater treatment facilities from small communities in Wisconsin (email communication with Tom Mugan – Wisconsin Department of Natural Resources dated May 22, 2007) were used as an initial estimate for the WWTP-Babbitt effluent is presented in Table 2-3 (copper, nickel and zinc).

3.0 Water Quality Standards

Deterministic water quality predictions during different stages of the NorthMet Project development, closure and post-closure are compared against numeric chronic aquatic toxicity-based Minnesota water quality standards in Sections 5.0, 6.0, 7.0 and 8.0. A discussion of the Minnesota water quality standards is presented here.

3.1 Minnesota Surface Water Quality Standards

3.1.1 Use Classification for Surface Waters

Surface water quality standards vary in the state of Minnesota based on the use classification of the water body in study. Minnesota Rules Chapter 7050.0140 describes the following use classifications:

- Class 1 waters, domestic consumption. Domestic consumption includes all waters of the State that are or may be used as a source of supply for drinking, culinary or food processing use, or other domestic purposes and for which quality control is or may be necessary to protect the public health, safety, or welfare.

- Class 2 waters, aquatic life and recreation. Aquatic life and recreation includes all waters of the State that support or may support fish, other aquatic life, bathing, boating, or other recreational purposes and for which quality control is or may be necessary to protect aquatic or terrestrial life or their habitats or the public health, safety, or welfare.

- Class 3 waters, industrial consumption. Industrial consumption includes all waters of the State that are or may be used as a source of supply for industrial process or cooling water, or any other industrial or commercial purposes, and for which quality control is or may be necessary to protect the public health, safety, or welfare.

- Class 4 waters, agriculture and wildlife. Agriculture and wildlife includes all waters of the State that are or may be used for any agricultural purposes, including stock watering and irrigation, or by waterfowl or other wildlife and for which quality control is or may be necessary to protect terrestrial life and its habitat or the public health, safety, or welfare.

- Class 5 waters, aesthetic enjoyment and navigation. Aesthetic enjoyment and navigation includes all waters of the State that are or may be used for any form of water transportation or navigation or fire prevention and for which quality control is or may be necessary to protect the public health, safety, or welfare.

- Class 6 waters, other uses and protection of border waters. Other uses includes all waters of the State that serve or may serve the uses in Class 1 or Class 5 or any other beneficial uses not listed in this part, including without limitation any such uses in this or any other state, province, or nation of any waters flowing through or originating in this state, and for which quality control is or may be necessary for the declared purposes in this part, to conform with the requirements of the legally constituted state or national agencies having jurisdiction over such waters, or for any other considerations the Agency (MPCA) may deem proper.

- Class 7 waters, limited resource value waters. Limited resource value waters include surface waters of the State that have been subject to a use attainability analysis and have been found to have limited value as a water resource.

These classes are further divided into subclasses which are presented in Sections 3.1.2 through 3.1.7. Minnesota Rules Chapter 7050 is applicable to surface waters of the State. Minnesota Rules Chapter 7052 establishes aquatic life, human health and wildlife (Class 2 only) water quality standards and criteria for Great Lakes Initiative pollutants and is applicable to surface waters of Minnesota within the Lake Superior Basin, which includes the NorthMet Plant Site and Embarrass River.

3.1.2 Class 1 Surface Water Quality Standards

Class 1 Water Use Classification under Minnesota Rules Chapter 7050 is further broken into three subclasses. There are no separate standards for Class 1 Waters under Minnesota Rules Chapter 7052 for the Lake Superior Basin.

- Class 1A waters; direct domestic consumption. The quality of Class 1A waters of the State shall be such that without treatment of any kind the raw waters will meet in all respects both the primary (maximum contaminant levels) and secondary drinking water standards issued by the United States Environmental Protection Agency (USEPA); that is, the USEPA drinking water standards are adopted and incorporated by reference.

- Class 1B waters; treated with simple chlorination for domestic consumption. The quality of Class 1B waters of the State shall be such that with approved disinfection, such as simple chlorination or its equivalent, the treated water will meet both the primary (maximum contaminant levels) and secondary drinking water standards issued by the USEPA; that is, the USEPA drinking water standards are adopted and incorporated by reference.

- Class 1C waters; other treatments for domestic consumption. The quality of Class 1C waters of the State shall be such that with treatment consisting of coagulation, sedimentation, filtration, storage, and chlorination, or other equivalent treatment processes, the treated water will meet both the primary (maximum contaminant levels) and secondary drinking water standards issued by the USEPA; that is, the USEPA drinking water standards are adopted and incorporated by reference.

The water quality standards are not directly provided in Minnesota Rules Chapter 7050.0221, but instead referenced to the USEPA drinking water standards.

3.1.3 Class 2 Surface Water Quality Standards

Class 2 Water Use Classification under Minnesota Rules Chapter 7050 is further broken into five subclasses. These same five subclasses are also applicable under the Minnesota Rules Chapter 7052 for the Lake Superior Basin.

- Class 2A waters; aquatic life and recreation – cold water sport or commercial fish and drinking water. The quality of Class 2A surface waters shall be such as to permit the propagation and maintenance of a healthy community of cold water sport or commercial fish and associated aquatic life, and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface waters is also protected as a source of drinking water.

- Class 2Bd waters; aquatic life and recreation – cold or warm water sport or commercial fish and drinking water. The quality of Class 2Bd surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface waters is also protected as a source of drinking water.

- Class 2B waters; aquatic life and recreation – cold or warm water sport or commercial fish. The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life, and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface water is not protected as a source of drinking water.

- Class 2C waters; aquatic life and recreation – indigenous fish. The quality of Class 2C surface waters shall be such as to permit the propagation and maintenance of a healthy community of indigenous fish and associated aquatic life, and their habitats. These waters shall be suitable for boating and other forms of aquatic recreation for which the waters may be usable.

- Class 2D waters; aquatic life and recreation for wetlands – indigenous fish. The quality of Class 2D wetlands shall be such as to permit the propagation and maintenance of a healthy community of aquatic and terrestrial species indigenous to wetlands, and their habitats. Wetlands also add to the biological diversity of the landscape. These waters shall be suitable for boating and other forms of aquatic recreation for which the wetland may be usable.

The water quality standards are provided for many substances in Minnesota Rules Chapter 7050.0222 for State waters and for fewer substances in Minnesota Rules Chapter 7052.0100 for Lake Superior Basin waters. The standard for some substances is dependent on total hardness (cadmium, chromium +3, copper, lead, nickel, and zinc). In cases standards for a given constituent are available from both the Minnesota Rules Chapters 7050 and 7052, the most stringent values will be used.

3.1.4 Class 3 Surface Water Quality Standards

Class 3 Water Use Classification under Minnesota Rules Chapter 7050 is further broken into four subclasses. There are no separate standards for Class 3 Water Use Classifications under Minnesota Rules Chapter 7052 for the Lake Superior Basin.

- Class 3A waters; industrial consumption; no treatment. The quality of Class 3A waters of the State shall be such as to permit their use without chemical treatment, except softening for groundwater, for most industrial purposes, except food processing and related uses, for which a high quality of water is required.
- Class 3B waters; industrial consumption; moderate treatment. The quality of Class 3B waters of the State shall be such as to permit their use for general industrial purposes, except for food processing, with only a moderate degree of treatment.
- Class 3C waters; industrial cooling and materials transport. The quality of Class 3C waters of the State shall be such as to permit their use for industrial cooling and materials transport without a high degree of treatment being necessary to avoid severe fouling, corrosion, scaling, or other unsatisfactory conditions.
- Class 3D waters; wetlands; industrial consumption; moderate treatment. The quality of Class 3D wetlands shall be such as to permit their use for general industrial purposes, except for food processing, with only a moderate degree of treatment.

3.1.5 Class 4 Surface Water Quality Standards

Class 4 Water Use Classification under Minnesota Rules Chapter 7050 is further broken into three subclasses. There are no separate standards for Class 4 Water Use Classifications under Minnesota Rules Chapter 7052 for the Lake Superior Basin.

- Class 4A waters; irrigation use. The quality of Class 4A waters of the State shall be such as to permit their use for irrigation without significant damage or adverse effects upon any crops or vegetation usually grown in the waters or area, including truck garden crops.
- Class 4B waters; livestock and wildlife use. The quality of Class 4B waters of the State shall be such as to permit their use by livestock and wildlife without inhibition or injurious effects.
- Class 4C waters; industrial cooling and materials transport. The quality of Class 4C waters of the State shall be such as to permit their use for irrigation and by wildlife and livestock without inhibition or injurious effects and be suitable for erosion control, groundwater recharge, low flow augmentation, stormwater retention, and stream sedimentation.

3.1.6 Class 5 Surface Water Quality Standards

Class 5 Water Use Classification under Minnesota Rules Chapter 7050 only has one subclass. There are no separate standards for Class 5 Water Use Classifications under Minnesota Rules Chapter 7052 for the Lake Superior Basin.

- Class 5 waters; aesthetic enjoyment and navigation. The quality of Class 5 waters of the State shall be such as to be suitable for aesthetic enjoyment of scenery, to avoid any interference with navigation or damaging effects on property.

3.1.7 Class 6 Surface Water Quality Standards

The numeric and narrative water quality standards in Class 6 Surface Water Quality Standards prescribe the qualities or properties of the waters of the State that are necessary for other designated public uses and benefits. The Agency (MPCA) therefore reserves the right to impose any standards necessary for the protection of this class, consistent with legal limitations.

3.1.8 Surface Water Quality Standards for Embarrass River

The Minnesota surface water quality standards for the Embarrass River are listed in Table 3-1. The most stringent standards, shown in bold, are compared to the results from the water quality model in Sections 5.2.3.1 and 7.2.3.1.

The Embarrass River is not specifically listed in Minnesota Rules Chapter 7050.0470. Therefore, Class 2B Minnesota surface water quality standards (recreational purposes and aquatic life; cold or warm water sport or commercial fish; not protected as a source of drinking water), Class 3C (industrial cooling and materials transport), Class 4A (irrigation use), Class 4B (livestock and wildlife use), Class 5 (aesthetic enjoyment and navigation), and Class 6 (other uses) are applicable. In cases standards for a given constituent are available from both the Minnesota Rules Chapters 7050 and 7052, the most stringent values will be used.

3.2 Minnesota Groundwater Water Quality Standards

The groundwater quality standards that the NorthMet Project will be required to meet and the compliance locations will be established during the permitting process. However, in order to evaluate potential groundwater impacts, it is helpful to compare deterministic groundwater quality predictions to groundwater standards. Groundwater quality standards are promulgated rules that are enforceable by the MPCA. Groundwater quality standards are published in Minnesota Rules 4717.7500 Table of Health Risk Limits (HRLs). If the groundwater were used as a water source for a public water system, then the water delivered to the tap would need to meet the National

Primary Drinking Water Regulations (also known as maximum contaminant levels (MCLs)) published at 40 CFR Part 141.

The USEPA has also established national secondary drinking water regulations that set non-mandatory water quality goals for 15 constituents. These secondary MCLs are not enforceable but are established as guidelines to assist public water system operators in managing their drinking water for aesthetic considerations such as taste, color and odor. The constituents are not considered to present an adverse affect to human health at the secondary MCL. The water quality standards for the constituents being evaluated as part of this study are summarized in Table 3-2. The lower of the groundwater standards referenced above was selected at the target groundwater evaluation criteria for use in this evaluation.

4.0 Description of Major Potential Future Point and Nonpoint Discharges at NorthMet Plant Site

4.1 Locations and Scenarios Evaluated

4.1.1 Surface Water

Flows and water chemistry for both the Tailings Basin-Proposed Action and Tailings Basin-Geotechnical Mitigation are reported/deterministically predicted at the following locations in the Embarrass River (see Figure 1-3).

- Surface water monitoring station PM-12. This location on the Embarrass River is upstream of all Plant Site and Tailings Basin facilities, and its watershed area is 18.9 square miles.
- Surface water monitoring station PM-13. This location on the Embarrass River is downstream of all Plant Site and Tailings Basin facilities, and its watershed area is 111.8 square miles.

Locations PM-12 and PM-13 were selected because background water quality data were available (see RS63 and RS76). The locations and their designations are stations used by PolyMet for baseline monitoring in 2004, 2006 and 2007. PM-12 and PM-13 are the same locations as monitoring locations SW004 and SW005 in the existing tailings basin permit that PolyMet expects to be transferred from Cliffs Erie to PolyMet as part of the permitting process.

The following nine scenarios were evaluated for the Embarrass River watershed under the Tailings Basin-Proposed Action, depending on the stage of development or closure of the Plant Site:

- Existing Conditions (i.e., without NorthMet Project).
- Year 1 (end of Tailings Basin development Year 1).
- Year 5 (end of Tailings Basin development Year 5).
- Year 8 (end of Tailings Basin development Year 8, which is the last year tailings are disposed in Cell 2E only; see Section 4.2.3.1).
- Year 9 (end of Tailings Basin development Year 9, which is the first year tailings are disposed in the merged Cells 1E and 2E; see Section 4.2.3.1).
- Year 15 (end of Tailings Basin development Year 15).
- Year 20 (end of Tailings Basin development Year 20; that is, end of ore processing and Tailings Basin operation).

- Closure (i.e., during the initial stages of closure of the Tailings Basin, and before West Pit overflow in the Mine Site).
- Post-Closure (i.e., long-term closure of the Tailings Basin, when seepage collected from the Tailings Basin becomes negligible and the Tailings Basin is fully reclaimed; see RS52).

The following eight scenarios were evaluated for the Embarrass River watershed under Tailings Basin-Geotechnical Mitigation, depending on the stage of development or closure of the Plant Site:

- Existing Conditions (i.e., without NorthMet Project).
- Year 1 (end of Tailings Basin development Year 1).
- Year 5 (end of Tailings Basin development Year 5).
- Year 10 (end of Tailings Basin development Year 10).
- Year 15 (end of Tailings Basin development Year 15).
- Year 20 (end of Tailings Basin development Year 20; that is, end of ore processing and Tailings Basin operation).
- Closure (i.e., during the initial stages of closure of the Tailings Basin, and before West Pit overflow in the Mine Site).
- Post-Closure (i.e., long-term closure of the Tailings Basin, when seepage collected from the Tailings Basin becomes negligible and the Tailings Basin is fully reclaimed; see RS52).

Years 8 and 9 were reported for the Tailings Basin-Proposed Action but not for the Tailings Basin-Geotechnical Mitigation because maximum deterministic water quality predictions for most parameters in unrecovered seepage from the Tailings Basin to groundwater do not occur in those years. The only exception is nickel, for which, however, the deterministically predicted concentration in Year 10 is 91.4 percent of predicted concentration in Year 8.

4.1.2 Groundwater

Groundwater quality for both the Tailings Basin-Proposed Action and Tailings Basin-Geotechnical Mitigation are deterministically predicted for each year of operation and for post-closure. Predicted groundwater concentrations were evaluated at the toe of the existing LTVSCM tailings basin. Specifically, deterministic water quality predictions presented in this document focus on groundwater flowing north from Cell 2E. This water has the shortest flow path to the environment (as apposed to groundwater that may flow west through Cell 2W) and will have the highest dissolved constituent concentrations of any groundwater leaving the basin. Because of the bedrock topography, virtually all of the groundwater flowing south from the Tailings Basin will be captured by the seepage barrier to be constructed by PolyMet at the headwaters of Second Creek.

4.2 Proposed Action

4.2.1 Description

This section describes the proposed tailings basin site facilities with major potential point and nonpoint discharges under the Tailings Basin-Proposed Action plan that affects the Embarrass River. Section 4.3 discusses the major potential future point and nonpoint discharges under Tailings Basin-Geotechnical Mitigation that affects the Embarrass River.

4.2.2 Stormwater

Stormwater runoff from the Plant Site, excluding the Tailings Basin, is addressed in RS36 (which is Attachment 3 to RS13). As discussed in that report, stormwater from the Plant Site will be routed to Second Creek. Stormwater retention basins may have to be constructed to manage any sediment load associated with this flow. For the Tailings Basin-Proposed Action, water that infiltrates into the LTVSMC tailings material that will be the upper most material of the embankment cover system, will be collected by a subsurface drain system. This water will be routed to sedimentation basins and then discharged. Water that ponds on intermediate benches will discharge to surface water inlets and be transported downslope by the same subsurface drain system that transports infiltrated water down slope. Other stormwater will be allowed to naturally runoff the Tailings Basin embankments. The stormwater chemistry will not differ from the background water chemistry of the existing runoff from the LTVSMC basin. Therefore, stormwater discharges do not represent a significant change to the water quality of the Embarrass River and are not addressed as part of this water quality assessment.

4.2.3 NorthMet Tailings Basin

4.2.3.1 General Description

PolyMet plans to continue development of the former LTVSMC tailings basin for tailings disposal from the processing of NorthMet deposit ore. During PolyMet operations, flotation tailings will be sent to Cells 1E and 2E. The surrounding geology includes native, unconsolidated, surficial deposits consisting of dense silty sand and clayey till. The till is overlain by as much as 10 feet of organic peat in some cases. In the region occupied by the Tailings Basin, groundwater flow is primarily from south to north to the Embarrass River.

The existing tailings basin currently has a surface seepage collection system that was operated by LTVSMC, which consists of a number of horizontal drains, ditches, and sumps. Additional horizontal drains will be installed to effectively eliminate point discharge of surface seepage to the adjacent environment. The intercepted seepage will be routed to sump and pump locations for subsequent return to the Tailings Basin via pipelines. The proposed system is described in RS55T.

Horizontal drains will be installed where current seeps exit along the northern side of Cell 2E and at the northwest corner of Cell 2W. If additional seeps emerge during basin operation, additional horizontal drains will be installed. Drain lengths will vary between approximately 100 and 500 feet, depending on the rate of seepage at each drain location. Additional horizontal drains may be needed along the northern side of Cell 2E for dam stability reasons, as described in RS39/RS40T. (For this work, it was assumed that drains would be installed along the entire north and northeast sides of Cell 2E.) Seepage occurring south of Cell 1E is near the toe of an existing rail embankment, through large waste rock used at this location for embankment construction. At this location, seepage will be recovered using a combination of a seepage barrier, seepage collection trench, and sump and pump system to return recovered seepage to the Tailings Basin.

Additional measures will be taken to reduce seepage rates during operations. During operations, perimeter dikes will be progressively capped with a geomembrane and tailings cover [see *Preliminary Flotation Tailings Basin Management Plan (TMP) for Operations, Maintenance, and Performance Monitoring – NorthMet Project* listed in Section 1.3]. At closure the unsaturated zone of the tailings beach will also be capped with geomembrane and tailings cover.

Seepage from Cells 1E and 2E during PolyMet operations was calculated using a groundwater flow model of the basin constructed for this purpose. A three-dimensional model of the basin was constructed using the industry standard finite-difference code MODFLOW (McDonald and Harbaugh, 1988). The groundwater model is discussed in detail in RS13 Attachment A-6.

The amount of water collected by the seepage management system was predicted using the same groundwater flow model. The groundwater model simulated seepage from the active and inactive cells and the beach areas. It also quantified the amount of water that would be collected by the seepage management system. It was assumed that the seepage management system would be installed prior to basin operation. The additional horizontal drains needed for dam stability were assumed to be installed prior to tailings deposition in Cell 2E, which is expected to begin at the start of operations and continue for approximately eight years. At that time, the splitter dike between Cells 1E and 2E will be overtopped, creating a single tailings cell. Once the single cell is developed tailings deposition will rotate around the cell to develop the dams and effectively fill the cell.

Table 4-1 summarizes Tailings Basin seepage flows to the Embarrass River watershed during operations and closure for the Tailings Basin-Proposed Action.

As the Tailings Basin develops through time, more seepage will be generated from the pond and beach areas due to the increased head differential between the ponds and the surrounding water table. The water collected by the proposed seepage management system, as simulated in the model, is a combination of water that is currently emerging as seeps, as well as water that would eventually reach the till and leave the basin as groundwater flow. The uncollected seepage simulated by the model is composed solely of groundwater flow within the till and peat deposits. It is important to keep in mind that both the collected and unrecovered seepage is a combination of new water added to the basins by PolyMet, and water that is still mounded and ponded in the basin from LTVSMC operations. Groundwater modeling results indicate the following:

- The amount of seepage intercepted by the horizontal drains will increase from an estimated 180 gpm during Year 1 to an estimated 430 gpm during Year 20.
- The seepage barrier south of Cell 1E is expected to recover between 420 and 530 gpm.
- It is estimated that between 24 percent and 30 percent of total basin seepage will be collected. This includes all of the flow from surface seeps plus some of the groundwater flow within the till and peat deposits.
- The total unrecovered seepage from Cells 1E and 2E is estimated to range from 1,430 gpm in Year 1 to 2,680 gpm in Year 20.

A conservative approach for water quality predictions is to assume that all unrecovered seepage will reach the Embarrass River as groundwater flow.

4.2.3.2 Seepage from Cells 1E and 2E

During operational Years 1 through 8 when there are two separate ponds, seepage from Cell 2E is predicted to vary between 530 and 1,960 gpm and seepage from Cell 1E is predicted to vary between 1,030 and 540 gpm. After the two ponds merge in Year 9, the total seepage is predicted to vary between 2,600 and 3,130 gpm. In addition to the pond seepage, there will also be infiltration of water through the beach areas and embankments. These flows are collectively referred to as seepage. Some of the seepage will be collected by the various seepage collection systems that will be installed at the basin prior to operation. The total amount of unrecovered seepage from the basin is shown in Table 4-1. During operations, the total unrecovered seepage is estimated to range from 1,430 to 2,680 gpm. In closure and post-closure, the total seepage is predicted to be 1,100 gpm.

4.2.3.3 Seepage from Cell 2W

Seepage from Cell 2W was estimated to be 4,123 gpm prior to PolyMet operations (see Table 4-1). Flotation tailings will not be deposited in Cell 2W during operations. It is expected that seepage from Cell 2W will decrease to 3,573 gpm during mine operations as water currently entrained in the basin continues to seep (see Table 4-1). During closure and post-closure it is expected that the seepage from Cell 2W will further decrease to 1,510 and 610 gpm, respectively.

4.2.3.4 Water Quality

RS54/RS46 presents the assessment of the overall reactivity of the tailings solids to be produced by the NorthMet Project, and the development of mass-loading rates for input into the deterministic water quality predictions for impact assessment presented in this report. The release ratios, which affect the mass-loading rates, have been updated since the publication of RS54/RS46 to represent more recent waste characterization humidity cell tests. In addition, SRK prepared an updated prediction of pond water chemistry during operations and closure (see Appendix H). The methodology used to predict the resulting concentration of percolate to groundwater from the mass-loading rates and pond chemistry referred to above is discussed in detail in Section 6.0. Table 4-2 summarizes the predicted seepage chemistry for the Tailings Basin Cells 1E and 2E for different stages of development and closure.

4.2.4 NorthMet Hydrometallurgical Residue Cells

4.2.4.1 General Description

Hydrometallurgical residue will be stored in a facility made up of four containment cells within existing Cell 2W of the tailings basin. The design of the cells has been revised from consisting of 70 to 80 foot deep rectangular cells as presented in RS28T to having shallower cells with irregular shapes as presented in the January 3, 2008 Technical Memorandum with Subject *Hydrometallurgical Residue Facility Design Status Update* from Tom Radue (Barr) to Jamie Maszk (MDNR). The updated design will take better advantage of the geotechnical characteristics and configuration of the previously constructed LTVSMC tailings dams. As described in the January 3, 2008 memorandum, each of the four cells will have a depth between approximately 24 and 40 feet with perimeter dikes separating them from one another. The decreased depth of the cells leads to decreased liner leakage rates. Each residue cell is planned to have sufficient capacity for approximately 5 years of operation, with cells constructed successively on approximately a 5-year cycle. The hydrometallurgical residue cell liner system is currently planned to consist of a 60 to 80 mil low density polyethylene (LDPE) geomembrane overlying a geosynthetic clay liner (GCL). The cells will function as large sedimentation basins, with the slurried residue settling out in the cell while the excess liquid is recovered by a pump system and returned to the plant for use. Once a hydrometallurgical cell has been filled to capacity, the cell will be dewatered and cover construction will proceed with increments of cover construction proceeding each year for a 3-year period until cell closure has been completed.

4.2.4.2 Liner Leakage

Some modifications to the design and management plan of the hydrometallurgical residue cells have been made since publication of RS28T. The rate of liner leakage ranges from 0.47 gpm in Year 1 to 8.66 gpm in Year 20. There is zero leakage before Year 1. After Year 26 there is an average annual liner leakage of 0.74 gpm. Although liner area has changed, liner leakage rates for the hydrometallurgical residue cells are still computed using the empirical formulas developed by J.P. Giroud, which are referenced in the RS28T text. Liner leakage is a function of the configuration of the liner system, the thickness of the clay component of the liner system, the quality of the liner system construction, the hydraulic head above the liner system, and several other factors. For the hydrometallurgical residue cells, the combined liner leakage rate is zero when construction of the cells begins, increasing to a maximum five years after construction when hydraulic head on the liner is greatest. The leakage rate then declines as the final cover is placed on the hydrometallurgical residue cells and as drainage from the in-cell residue is collected by the in-cell drainage collection system. The updated unrecoverable leakage rates from the hydrometallurgical residue cells to groundwater are presented in Table 4-1.

4.2.4.3 Water Quality

The water chemistry of the unrecoverable leakage from the hydrometallurgical residue cells is presented in Table 4-3. Table 4-6 of RS74 Draft-01 (source Appendix D.4 of RS46/RS54) only presented concentrations for some of the constituents that are now investigated in RS74B. The concentrations of the remaining needed constituents were obtained from Table 6-2 of RS65/RS33. Predictions for barium, chloride, fluoride and hardness are not available. The concentrations for these constituents were assumed to be the maximum observed value in the waste characterization humidity cell tests.

4.3 Geotechnical Mitigation

4.3.1 Description (only changes with respect to Section 4.2)

This section presents how the Tailings Basin-Geotechnical Mitigation differs from the Tailings Basin-Proposed Action design. Only differences between the two plans are mentioned in this section; therefore, if no difference is mentioned for a certain aspect then the Tailings Basin-Geotechnical Mitigation is the same as the Tailings Basin-Proposed Action described in all the previous sections of this report for that aspect. The major changes and additions to the Tailings Basin design are as follows:

- Embankments will be constructed out of LTVSMC bulk/coarse tailings instead of out of PolyMet coarse tailings. The latter had been considered in the Tailings Basin-Proposed Action. This change has been motivated by uncertainty associated with geotechnical stability of the Tailings Basin-Proposed Action raised by the MDNR.

- The PolyMet tailings particle size will result in the tailings being deposited as bulk tailings in the tailings pond and on the beaches from subaerial spigotting. The latter had been considered in the Tailings Basin-Proposed Action, and as a result of downstream particle size classification would create three different depositional areas (i.e., coarse tailings beach, fine tailings beach, and slimes in the tailings pond).

- The footprint of the Tailings Basin has changed in order to minimize dam construction, to allow for recovery of more LTVSMC coarse tailings, and to increase the watershed contributing to the Tailings Basin pond at closure. Consequently, the stage, area and volume of the pond through time have changed.

- There will be no horizontal drains in the LTVSMC north embankment of Cell 2E. Dam stability will be achieved by providing rock buttresses at the toe of the LTVSMC dams where required. However, all surface seeps will be collected using a variety of methods including vertical wells, seepage collection trenches and sump and pump systems. These systems, along with the seepage barrier south of Cell 1E, make up the seepage management system.

- A pond above much of the tailings will be maintained in closure. The pond will simultaneously prevent oxygen intrusion from the tailings surface, while also providing a controlled amount to seepage water to maintain elevated saturation conditions in tailings below the pond. This measure has been adopted to reduce chemical load generation from PolyMet tailings. To achieve this, the permeability of the tailings at the surface will be modified by bentonite addition; more details are provided in RS13B.

4.3.2 Stormwater

For the Tailings Basin-Geotechnical Mitigation, stormwater will be allowed to naturally runoff the Tailings Basin embankments (which are constructed of LTVSMC tailing). If there are erosion issues that develop as a result of this runoff, ditching and/or piping can be constructed to route collected water to sedimentation basins and then discharged. The stormwater chemistry will not differ from the background water chemistry of the existing runoff. Therefore, stormwater discharges do not represent a significant change to the water quality of the Embarrass River and are not addressed as part of this water quality assessment

4.3.3 NorthMet Tailings Basin

Seepage and seepage recovery from Cells 1E and 2E during PolyMet operations were calculated using a groundwater flow model of the basin constructed for this purpose. A three-dimensional model of the basin was constructed using the finite-difference code MODFLOW-SURFACT (McDonald and Harbaugh, 1988). The groundwater model is discussed in detail in RS13B Attachment A-6. The groundwater model simulated seepage from the active and inactive cells and the beach and embankment areas. It also quantified the amount of water that would be collected by the seepage management system. Table 4-4 summarizes unrecoverable Tailings Basin seepage flows to the Embarrass River watershed during operations and closure.

As the Tailings Basin develops through time, more seepage will be generated from the pond and beach areas due to the increased head differential between the ponds and the surrounding water table. The water collected by the proposed seepage management system, as simulated in the model, is a combination of water that is currently emerging as seeps, as well as water that would eventually reach the till and leave the basin as groundwater flow. The uncollected seepage simulated by the model is composed solely of groundwater flow within the till and peat deposits. It is important to keep in mind that both the collected and unrecovered seepage is a combination of new water added to the basins by PolyMet, and water that is still mounded and ponded in the basin from LTVSMC operations. Groundwater modeling results indicate the following:

- The seepage barrier south of Cell 1E is expected to recover between 410 and 570 gpm.
- It is estimated that between 15 percent and 20 percent of total basin seepage will be collected, primarily by the seepage barrier located south of Cell 1E. This includes all of the flow from surface seeps plus some of the groundwater flow within the till and peat deposits.
- The total unrecovered seepage from Cells 1E and 2E is estimated to range from 1,600 gpm in Year 1 to 2,900 gpm in Year 20.

A conservative approach for water quality predictions is to assume that all unrecovered seepage will reach the Embarrass River as groundwater flow.

4.3.3.1 Seepage from Cells 1E and 2E

The flow of water leaving the tailings basin during operations includes pond seepage and water that infiltrates through the embankment and beach areas. The unrecovered seepage flows for the Tailings Basin-Geotechnical Mitigation are presented in Table 4-4.

4.3.3.2 Water Quality from Cells 1E and 2E

RS54/RS46 presents the assessment of the overall reactivity of the tailings solids to be produced by the NorthMet Project, and the development of mass-loading rates for input into deterministic water quality predictions for impact assessment presented in this report. The release ratios, which affect the mass-loading rates, have been updated since the publication of RS54/RS46 to represent more recent waste characterization humidity cell tests. The loading rates also needed to be updated to account for the new design of the basin (i.e., the Tailings Basin-Geotechnical Mitigation). In addition, SRK prepared a prediction of pond water chemistry during operations and closure. The methodology used to predict the resulting concentration of percolate to groundwater from the mass-loading rates and pond chemistry presented above is discussed in detail in Section 8.0. Table 4-5 summarizes the predicted seepage chemistry for the Tailings Basin-Geotechnical Mitigation for different stages of development and closure.

4.4 Summary of Main Water Quality Parameters

Antimony, arsenic, cobalt, copper, nickel and sulfate are considered the six main parameters of analysis for this water quality assessment. These parameters were selected by Paul Eger (MDNR), Cory Conrad (Knight Piesold) and Barr (Tina Pint and Miguel Wong) because they are considered the main parameters of analysis for the cumulative water quality impacts assessment of the NorthMet Project; an email was sent on June 3, 2008 to fourteen other people from MDNR, MPCA, ERM and Knight Piesold asking for their input, but no response was obtained. A summary of the deterministically predicted chemical concentrations for these six parameters in the seepage to groundwater from the Tailings Basin is provided below (the complete set of predictions for all constituents of analysis included in this water quality assessment is presented in Table 4-2 for the Tailings Basin-Proposed Action and in Table 4-5 for the Tailings Basin-Geotechnical Mitigation):

- Maximum concentration of antimony is 0.0113 mg/L in Year 15 under the Tailings Basin-Proposed Action versus 0.0117 mg/L in Year 10 under the Tailings Basin-Geotechnical Mitigation.

- Maximum concentration of arsenic is 0.0155 milligrams per liter (mg/L) in Year 15 under the Tailings Basin-Proposed Action versus 0.0279 mg/L in Closure and Post-Closure under the Tailings Basin-Geotechnical Mitigation.

- Maximum concentration of cobalt is 0.00866 mg/L in Year 15 under the Tailings Basin-Proposed Action versus 0.00271 mg/L in Closure and Post-Closure under the Tailings Basin-Geotechnical Mitigation.

- Maximum concentration of copper is 0.02077 mg/L in Year 15 under the Tailings Basin-Proposed Action versus 0.01412 mg/L in Closure and Post-Closure under the Tailings Basin-Geotechnical Mitigation.

- Maximum concentration of nickel is 0.15366 mg/L in Year 15 under the Tailings Basin-Proposed Action versus 0.024818 mg/L in Year 10 under the Tailings Basin-Geotechnical Mitigation.

- Maximum concentration of sulfate is 241.9 mg/L in Year 15 under the Tailings Basin-Proposed Action versus 223.1 mg/L in Year 10 under the Tailings Basin-Geotechnical Mitigation.

5.0 Proposed Action – Surface Water Quality Modeling

5.1 Modeling Methods

5.1.1 Overview

Concentrations of the constituents of interest in the Embarrass River were modeled using a simple water balance and mass-balance model. The river was subdivided into a series of nodes. The surface water and groundwater flows tributary to each node were added to the river flow from the upstream node to compute the flow leaving each node. Similarly, the mass of a constituent entering each node via the surface water contributions, groundwater contributions, and point source contributions was added to the mass of the constituent from the upstream node to compute the mass of a constituent leaving each node. Values of mass and flow were then converted to concentrations.

The mass-balance model is simple; the inputs and outputs are easily schematized/visualized. The flow, mass flux, and concentration formulations are written into a single-page spreadsheet model and are easy to follow. The mass-balance model is flexible, allowing the user to define the values for a host of input flows and concentrations. The model is applicable to any conservative and non-retarded constituent. The model assumes steady-state conditions. Consequently, pulse- or step-loadings cannot be modeled.

Section 5.0 presents the model construct and results from the Tailings Basin-Proposed Action for the surface water quality model.

5.1.2 Model Construct

The Embarrass River was divided into two reaches using two nodes, PM-12 and PM-13. The two nodes are at locations of PolyMet's 2004, 2006 and 2007 water quality monitoring stations on the Embarrass River. Figure 5-1 shows the Embarrass River watershed with the model nodes and the sub-watersheds tributary to each node. Tributary flows and mass loading from each reach are added at the downstream node of that reach.

Figure 5-2 shows a schematic view of the Embarrass River water balance/mass-balance model. The nodes are represented by squares. Flows into each node are shown as Q's and concentrations of flow entering each node are show as C's. Contributions to each node are broken down by surface water contributions (designated with a subscript _s) and groundwater contributions (designated with a subscript _g). Contributions to each node are designated by the subscript of that node (e.g., subscript _12 for PM-12). In-river flows and concentrations are designated with a subscript _r. A description of all of the variables used in the model is shown in Table 5-1.

5.1.3 Summary of Input Data

5.1.3.1 Embarrass River

Flows

In-river flows at the nodes (designated as Q_r) were determined based on data from USGS stream gaging station #04017000 from 1946 to 1964. This gage is located between nodes PM-12 and PM-13 and drains an area of 88.3 square miles. The average annual mean flow, average annual 1-day maximum flow and the average annual 30-day minimum average flow were determined from this record per square mile of drainage area. These values were then multiplied by the drainage area upstream of PM-12 (18.9 square miles) and PM-13 (111.8 square miles) to determine the flows at those locations. Average annual mean flows were used to model the average flow condition. The average annual 1-day maximum flow was used to model the high flow condition. The dry condition was modeled assuming only groundwater contributions (including groundwater seepage from the existing LTVSMC tailings basin, described in Section 5.1.3.5). Flows in the Embarrass River at nodes PM-12 and PM-13 are presented in Table 2-1.

Water Quality

The modeled concentrations in the Embarrass River at PM-12 and PM-13 (designated as C_r) are the results of the water balance/mass-balance model and are discussed in Section 5.2. For reference, baseline water quality data for the Embarrass River at PM-12 and PM-13 are presented in Table 5-3.

5.1.3.2 Groundwater Recharge from Watershed

Flows

The inflow of groundwater at each node (designated as Q_g) was computed based on the 30-day minimum average flow statistic computed from the historical USGS gage record. A significant portion of the USGS record predates the existing LTVSMC tailings basin impact, so those flows would reflect only natural groundwater flows (i.e., before LTVSMC tailings basin seepage). Therefore, existing LTVSMC tailings basin seepage is assumed to be an additional, separate contribution to the river. Section 5.1.3.5 addresses the seepage contributions from the existing LTVSMC tailings basin. The natural groundwater recharge flow is 0.86 cfs to PM-12 and 4.21 cfs to PM-13.

Water Quality

Some groundwater quality data exists for the Embarrass River, but only one station is located beyond the influence of the existing LTVSMC tailings basin, and data from a single upland well at the Plant Site were not considered to adequately represent the groundwater chemistry of the overall Embarrass River watershed. Therefore, the concentration of each parameter in the groundwater (designated as C_g) was taken from the Regional Copper-Nickel Study, when available (Siegel and Ericson, 1980, see Appendix D). If data for that parameter was not included in this study, values were calculated from groundwater data collected in the Embarrass River watershed by the MPCA (MPCA, 1999). However, no antimony data was collected in either of these studies, therefore the groundwater quality of antimony in the Embarrass River watershed was assumed to be the same as in the Partridge River watershed. The groundwater concentrations used in the model are presented in Table 5-2.

5.1.3.3 Surface Runoff from Watershed

Flows

Surface runoff flows (designated as Q_{s12} or Q_{s13}) were computed as the remainder of flow in the river not accounted for by groundwater flows, PolyMet tailings basin seepage flows, LTVSMC tailings basin seepage flows, discharge from Pit 5NW, and discharge from the Babbitt-WWTP. Surface water flows in the Embarrass River were not determined by running storm events over the watershed using XP-SWMM (as was done for the Partridge River watershed) because an XP-SWMM model has not been developed for the Embarrass River.

Water Quality

The concentration of each parameter (designated as C_{s12} and C_{s13}) in the surface runoff was estimated by calibrating the model (set up for existing conditions) to the baseline water quality data collected at PM-12 and PM-13 in 2004, 2006 and 2007 (see Table 5-3). The surface runoff concentrations arrived at by this calibration were assumed to be constant for both sub-watersheds and for all flows and stages of Plant Site development. Values of C_s used in the model are presented in Table 5-2.

5.1.3.4 Pit 5NW Discharge

Flows

There is a discharge from Pit 5NW between PM-12 and PM-13. This discharge is designated as Q_{sPit} and is added to the river at PM-13. Based on bi-monthly flow measurements between June 2001 and December 2007 at Cliffs Erie – Hoyt Lakes Mining Area: Rail Culvert NE of Pit 5N Loadout Pocket, NPDES Permit MN0042536-SD-033, the average surface water discharge from Pit 5NW is estimated to be 1.99 cfs (893 gpm). In the Embarrass River model, this discharge was assumed to be 1.99 cfs for average and wet conditions. During dry conditions, the discharge is assumed to be zero.

Water Quality

Parameter concentrations for this input (C_{sPit}) are based on water quality data for Pit 5NW collected between 2001 and 2007 and are presented in Table 5-2.

5.1.3.5 Tailings Basin Seepage

Flows

There are two inputs from the tailings basin included in the Embarrass River model: seepage from Cell 2W and seepage from Cells 1E/2E. Both existing tailings basin flows are added at node PM-13. For wet and average conditions, 100 percent of the calculated flow is added to the water balance/mass-balance model. During dry conditions, however, a total of 1.2 cfs of total seepage flow is added to the model. During periods of low flow, the total flow in the river is less than the calculated seepage from the existing LTVSMC tailings basin, indicating that not all of the estimated seepage is reaching the Embarrass River. The effective seepage value of 1.2 cfs was determined based on calibration of the Embarrass River model using sulfate as a sample parameter during low flow events.

The first input is from Cell 2W of the existing LTVSMC tailings basin (designated as Q_{2ws}). The seepage rate used for this source was 4,123 gpm (9.18 cfs) prior to mining and processing operations by PolyMet. This value was estimated using a groundwater model (see RS13). It is expected that seepage from Cell 2W will decrease to 3,573 gpm during mining and processing operations by PolyMet as water currently entrained in the basin continues to percolate and the water table drawdowns. During Closure and Post-Closure it is expected that seepage from Cell 2W will further decrease to 1,510 and 610 gpm, respectively. The seepage rates from Cell 2W used in the model are presented in Table 4-1. The total seepage from Cell 2W was added to the model for wet and average conditions. For dry conditions, a total of 1.2 cfs of existing tailings basin seepage was added to the model. The amount of seepage from Cell 2W was based on the ratio of seepage from Cell 2W to the total seepage flow from the tailings basin including Cells 1E/2E.

The second input is from Cells 1E/2E, where PolyMet's flotation tailings will be disposed. Cells 1E and 2E are the active cells during mining and processing operations by PolyMet. The unrecoverable seepage rates for these cells (designated as Q_{fs}) vary over the course of the Plant Site development (see Table 4-1). Prior to the Plant Site development, the combined flow from Cells 1E and 2E is estimated to be 900 gpm (2.01 cfs), it peaks to approximately 2,680 gpm (5.99 cfs) in Year 20, and then it drops to approximately 1,710 gpm (3.82 cfs) in Post-Closure (see Table 4-1). During wet and average conditions, 100 percent of the flotation tailings seepage is used as input to the model. For dry conditions, a total of 1.2 cfs of existing tailings basin seepage was added to the model. The amount of seepage from Cells 1E/2E was based on the ratio of seepage from Cells 1E/2E to the total seepage flow from the tailings basin including Cell 2W.

Water Quality

Water quality data from four groundwater wells (GW-001, GW-006, GW-007 and GW-008) were considered representative of the tailings basin seepage from Cell 2W prior to PolyMet operation (see RS64). Parameter concentrations for this source (C_{s2W}) were obtained from the data collected in 2001-2005 and 2007 for all parameters and are presented in Table 5-2.

Prior to PolyMet operations, parameter concentrations in the flotation tailings seepage are assumed equal to the concentrations estimated for seepage from Cell 2W. Values of C_{fs}, the predicted seepage chemistry for the Tailings Basin Cells 1E and 2E for different stages of development and closure, are summarized in Table 4-2. Details about the methodology used for these predictions are presented in Section 6.0.

5.1.3.6 Hydrometallurgical Residue Cell Leakage

Flows

Also located at the tailings basin is the Hydrometallurgical Residue Facility. Hydrometallurgical residue will be stored in a facility made up of smaller containment cells within the existing Cell 2W of the tailings basin. The leakage is added at node PM-13. The rate of leakage ranges (designated as Q_{rrs}) from 0.47 gpm in Year 1 to 8.66 gpm in Year 20 (see RS28T updated on January 3, 2008 via memorandum with Subject *Hydrometallurgical Residue Facility Design Status Update*). During Closure and Post-Closure there is a liner leakage rate of 0.74 gpm. The rates presented in Table 4-1 were used for wet, average, and dry conditions.

Water Quality

The predicted water chemistry of the unrecoverable leakage from the hydrometallurgical residue cells to groundwater (C_{rrs}) was provided in RS33/RS65, and it is presented here in Table 4-3. Predictions for barium, chloride, fluoride and hardness are not available in RS33/RS65. The concentrations for these constituents were assumed to be the maximum observed value in the waste characterization humidity cell tests (see Appendix H).

5.1.3.7 Babbitt Wastewater Treatment Plant

Flows

The Babbitt-WWTP discharges into Hay Lake upstream of PM-12. This input (designated as Q_{sBab}) is added at the PM-12 node. A flow of 0.33 cfs is assumed for all stages of Plant Site development for average and high flow conditions (see RS27 Part 2). Zero discharge is assumed for low flow conditions for all stages of Plant Site development.

Water Quality

Water quality data available for this discharge does not include the concentrations of the relevant parameters in the analysis herein. On the other hand, assuming the average concentrations of copper, nickel and zinc calculated based on small community treatment plants (see Section 2.2.3) results in estimated river concentrations that are much higher than the concentrations of copper, nickel, and zinc observed at PM-12. Therefore, the concentrations of all water quality parameters in the Babbitt-WWTP discharge (C_{sBab}) were assumed to be equal to the surface runoff concentration (see Section 5.1.3.3).

5.1.4 Model Calibration

5.1.4.1 Methodology

To calibrate the model, the model was set up for the existing conditions (i.e., no PolyMet Tailings Basin and Hydrometallurgical Residue Facility inputs) using all known flow and concentration inputs. There is data for all model inputs except the concentration of each constituent in surface runoff (C_s). Using a process of trial and error, the value of C_s that produced the best fit of the modeled in-river concentrations to the concentrations measured at the water quality monitoring stations (see Table 5-3) was determined. Concentrations measured at the water quality monitoring stations have been updated from those used in RS74 Draft-01 by adding 2007 monitoring data. The concentration which provided the best fit to the existing water quality data was then applied to the model for each stage of Plant Site development and each flow condition (see Appendix E).

5.1.4.2 Discussion of Results

The resulting values of C_s are presented in Table 5-2. In general, surface runoff concentrations tend to be lower than or equal to groundwater concentrations from the areas unaffected by the existing LTVSMC tailings basin. The exceptions include silver, aluminum, beryllium, calcium, chloride, iron, potassium, manganese, thallium, and zinc. Silver, beryllium and thallium were not detected in the Embarrass River, therefore the surface runoff concentrations were calibrated to half the detection limit; however, it is possible that the concentration in the Embarrass River is much lower than half the detection limit which would cause surface runoff concentrations to be conservative. The averaged sampled concentrations of iron and manganese in the Embarrass River were actually higher upstream at PM-12 than downstream at PM-13, resulting in difficulties in producing a reasonable best fit. High concentrations of sulfate in the Pit 5NW discharge (1,046 mg/L) prevented accurate calibration of the model to observed concentrations of sulfate at PM-13 (average monitored in-stream concentration of 36.1 mg/L) regardless of the surface runoff contribution. An appropriate value of C_s for sulfate was determined by calibrating to data at PM-12.

5.1.5 Modeled Flow Conditions

Wet, dry and average conditions were simulated for Years 1, 5, 8, 9, 15 and 20 of Plant Site operation as well as for Closure and Post-Closure. Model inputs were adjusted to model each of these scenarios where appropriate as discussed in the sections above. All of the estimated tailings basin seepage was assumed to reach the Embarrass River for average and wet conditions. For the dry conditions, a total of 1.2 cfs of seepage from the three tailings basin inputs was assumed to reach the Embarrass River (see Section 5.1.3.5). In this latter case, the amount of seepage coming from each Tailings Basin source (i.e., Cells 2W, 1E and 2E) is based on the ratio of each input as calculated for the average and wet conditions.

5.2 Modeling Results

5.2.1 General

The Embarrass River water quality model (see Section 5.1) was used to deterministically predict water chemistry in the Embarrass River during various stages of Plant Site operation and closure (see Section 4.1.1) for the Tailings Basin-Proposed Action (see Section 4.2). The nine model scenarios were evaluated for conditions representing low flow, average flow, and high flow (see Section 2.1.4).

Section 5.2.2 presents the deterministic water quality predictions for silver, aluminum, arsenic, boron, barium, beryllium, calcium, cadmium, chloride, cobalt, copper, fluoride, iron, hardness, potassium, magnesium, manganese, sodium, nickel, lead, antimony, selenium, sulfate, thallium, and zinc.

Deterministic water quality predictions were computed using the best available flow and chemistry data for the various components included in the mass-balance model. When necessary, conservative assumptions were made (e.g., all the seepage from the Tailings Basin and Hydrometallurgical Residue Facility will reach the Embarrass River as groundwater). In addition, the mass-balance model does not account for possible reductions in chemical mass resulting from the transport of the chemical to and within the Embarrass River (see Sections 1.4.2. and 5.1 for more details).

5.2.2 Water Quality Presentations

5.2.2.1 Discussion of Results

Deterministic water quality predictions for the parameters listed in Section 5.2.1 are presented for the following eight modeled scenarios for the Tailings Basin-Proposed Action listed in Section 4.1.1: Years 1, 5, 8, 9, 15, 20, Closure, and Post-Closure.

Tables 5-4 through 5-9 present the complete results for surface water monitoring stations PM-12 and PM-13, respectively, for the Tailings Basin-Proposed Action. Figures 5-3 and 5-4 present the results for antimony, arsenic, cobalt, copper, nickel and sulfate at PM-12 and PM-13 for the Tailings Basin-Proposed Action, respectively. In addition to the mass-balance deterministic water quality predictions, the tables include background surface water quality at the corresponding location (see Table 5-3) and the most stringent of the chronic aquatic toxicity-based Minnesota surface water quality standards (see Table 3-1). Where hardness based standards are applicable, the deterministic water quality predictions at each surface water monitoring station located in the Embarrass River was used to determine the corresponding chronic standard consistent with Minnesota Rules

Chapters 7050 and 7052. All calculations and results for the complete set of constituents evaluated here are presented in Appendix F.

5.2.2.2 Parameters with Limited/Poor Data

The results presented for the Embarrass River in this section use the best available information at this time. However, there are some parameters that have limited or poor data. The following is a list of parameters with limited and/or poor data for the Tailings Basin-Proposed Action:

- There has been no monitoring of the chemical composition of the discharge from the Babbitt-WWTP. Assuming the average concentrations of copper, nickel and zinc calculated based on small community treatment plants (see Section 5.1.3.7) results in estimated river concentrations that are much higher than the concentrations of copper, nickel, and zinc observed at PM-12. Therefore, the concentrations of all water quality parameters in the Babbitt-WWTP discharge were assumed to be equal to the surface runoff concentration.

- Antimony was not monitored in the Regional Copper-Nickel Study (Siegel and Ericson, 1980) nor were antimony samples collected in the Embarrass River watershed by the MPCA (MPCA, 1999). Therefore, the groundwater quality of antimony in the Embarrass River watershed was assumed to be the same as in the Partridge River watershed (see RS74A).

- Vanadium results are not presented in RS74B, but they are presented in RS74A. Vanadium can be expected to occur as oxides or as a trace component of primary oxides such as magnetite. The solubility of V_2O_3 at near neutral pH is 0.0023 mg V/L, which is comparable to the maximum sustained concentrations leaching from PolyMet tailings in humidity cells (0.0021 mg/L). As these concentrations are well below the groundwater standard of 0.05 mg/L and there is no Minnesota surface water quality standard, modeling of vanadium is not needed.

- Predictions of unrecoverable leakage from the hydrometallurgical residue cells to groundwater for barium, chloride, fluoride and hardness were assumed to be the maximum observed value in the waste characterization humidity cell tests.

- The concentration of seepage from Cell 2W was determined by averaging water quality monitoring data from four groundwater wells. If a parameter was not detected, half the detection limit was used to calculate the average. However, for some parameters, half or more of the samples were not detected. These parameters include silver, beryllium, cadmium, lead, antimony, selenium, thallium and zinc.

- The concentration of seepage from the Pit 5NW discharge was determined by averaging water quality data samples from monitoring station SD-033. If a parameter was not detected, half the detection limit was used to calculate the average. However, for some parameters, half or more of the samples were not detected. These parameters include silver, aluminum, arsenic, barium, beryllium, cadmium, cobalt, copper, molybdenum, nickel, lead, antimony, selenium, thallium, and zinc. If multiple detection limits exist for parameters not detected, the smallest detection limit was used to compute the average parameter concentration, omitting the non-detections with higher detection limits.

- The surface runoff concentrations from tributary sub-watersheds were determined by using a process of trial and error that results in the best fit of modeled in-river concentrations to the average of the concentrations measured at the water quality monitoring stations taken in the Embarrass River in 2004, 2006 and 2007. If a parameter was not detected, half the detection limit was used to calculate the average. However, for some parameters, at least half of the samples were not detected at both monitoring locations PM-12 and PM-13. These parameters include silver, arsenic, beryllium, cadmium, cobalt, molybdenum, lead, antimony, selenium, thallium and zinc. At least half the samples of boron were not detected at PM-12, but only one-quarter of the samples were not detected at PM-13.

5.2.3 Interpretation of Results

5.2.3.1 Comparison to Water Quality Standards

Deterministic water quality predictions at PM-12

Deterministic water quality predictions of each constituent of analysis during Years 1, 5, 8, 9, 15, 20, Closure, and Post-Closure at surface water monitoring location PM-12 are presented in Tables 5-4 to 5-6 for low, average and high flows under Tailings Basin-Proposed Action. PM-12 is located upstream of all mining related inputs to the Embarrass River model. Therefore, no changes in water quality are observed between model scenarios (see Figure 5-3). The maximum deterministic water quality predictions of some key water quality parameters (see Section 4.4) are summarized below:

- Antimony. The highest deterministic water quality prediction of antimony is 0.00150 mg/L at PM-12 during low flow conditions under Tailings Basin-Proposed Action. This value is one order of magnitude smaller than the Minnesota surface water quality standard of 0.031 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-12 is 0.00150 mg/L.

- Arsenic. The highest deterministic water quality prediction of arsenic is 0.00273 mg/L at PM-12 during low flow conditions under Tailings Basin-Proposed Action. This value is one order of magnitude smaller than the Minnesota surface water quality standard of 0.053 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-12 is 0.00100 mg/L.

- Cobalt. The highest deterministic water quality prediction of cobalt is 0.00110 mg/L at PM-12 during low flow conditions under Tailings Basin-Proposed Action. This value is about one-fifth the Minnesota surface water quality standard of 0.005 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-12 is 0.00058 mg/L.

- Copper. The highest deterministic water quality prediction of copper is 0.00400 mg/L at PM-12 during low flow conditions under Tailings Basin-Proposed Action. This value is about one-half the Minnesota surface water quality standard of 0.00832 mg/L, based on a hardness of 87.5 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-12 is 0.00153 mg/L.

- Nickel. The highest deterministic water quality prediction of nickel is 0.00700 mg/L at PM-12 during low flow conditions under Tailings Basin-Proposed Action. This value is one order of magnitude smaller than the Minnesota surface water quality standard of 0.04659 mg/L based on a hardness of 87.5 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-12 is 0.00194 mg/L.

- Sulfate. The highest deterministic water quality prediction of sulfate is 8.5 mg/L at PM-12 during low flow conditions under Tailings Basin-Proposed Action. There is no Minnesota surface water quality standard for sulfate applicable to the Use Classification of the Embarrass River. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-12 is 4.6 mg/L.

All parameters listed in Section 5.2.1 meet minimum in-stream Minnesota water quality standards at PM-12 during low, average and high flows for all modeled scenarios under Tailings Basin-Proposed Action (see Tables 5-4 to 5-6). In most cases, the deterministic water quality predictions are well below the Minnesota surface water quality standards.

<u>Deterministic Water Quality Predictions at PM-13</u>

Deterministic water quality predictions of each constituent of analysis during Years 1, 5, 8, 9, 15, 20, Closure, and Post-Closure at surface water monitoring location PM-13 are presented in Tables 5-7 to 5-9 for low, average and high flows under Tailings Basin-Proposed Action. PM-13 is located downstream of the Tailings Basin. The maximum deterministic water quality predictions of some key water quality parameters are summarized below:

- Antimony. The highest deterministic water quality prediction of antimony is 0.00209 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Proposed Action. This value is one order of magnitude smaller than the Minnesota surface water quality standard of 0.031 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00150 mg/L.

- Arsenic. The highest deterministic water quality prediction of arsenic is 0.00393 mg/L at PM-13 in Post-Closure during low flow conditions under Tailings Basin-Proposed Action. This value is one order of magnitude smaller than the Minnesota surface water quality standard of 0.053 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00100 mg/L.

- Cobalt. The highest deterministic water quality prediction of cobalt is 0.00172 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Proposed Action. This value is about one-third the Minnesota surface water quality standard of 0.005 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00050 mg/L.

- Copper. The highest deterministic water quality prediction of copper is 0.00579 mg/L at PM-13 in Post-Closure during low flow conditions under Tailings Basin-Proposed Action. This value is less than one-half the Minnesota surface water quality standard of 0.0116 mg/L, based on a hardness of 130.7 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00200 mg/L.

- Nickel. The highest deterministic water quality prediction of nickel is 0.01829 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Proposed Action. This value is about one-fifth the Minnesota surface water quality standard of 0.0804 mg/L based on a hardness of 166.7 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00207 mg/L.

- Sulfate. The highest deterministic water quality prediction of sulfate is 63.4 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Proposed Action. There is no Minnesota surface water quality standard for sulfate applicable to the Use Classification of the Embarrass River. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 36.1 mg/L.

All constituents meet minimum in-stream Minnesota water quality standards at PM-13 during low, average and high flow conditions for all modeled scenarios under the Tailings Basin-Proposed Action except for aluminum (see Tables 5-7 to 5-9). In most cases, the deterministic water quality predictions are well below the Minnesota surface water quality standards. The water quality standard for aluminum of 0.125 mg/L is exceeded at PM-13 for all scenarios of Plant Site development and closure for low and average flow conditions. The maximum deterministic water quality prediction for aluminum is 0.24649 mg/L under low flow conditions and 0.23718 mg/L under average flow conditions. The exceedances are in part explained by the fact that the average monitored concentration of aluminum in the Embarrass River at PM-13 in 2004, 2006 and 2007 (0.1916 mg/L) also exceeds the Minnesota surface water quality standard. The maximum deterministic water quality prediction of aluminum is an increase of 29 percent over existing conditions.

The deterministic model predicts sulfate concentrations at PM-13 that are above the average measured concentration of 36.1 mg/L. This is in part due to the difficulties of the sulfate calibration (see Section 5.1.4.2). The high concentrations of sulfate in the Pit 5NW discharge (1,046 mg/L) result in a significant load to the Embarrass River, as the deterministic model assumes conservation of mass. Including the load from the Pit 5NW discharge, the model calibration resulted in predicted sulfate concentrations (51 mg/L for average flow conditions) higher than the average measured concentration even without any additional mining inputs. Therefore, while the model-predicted sulfate concentrations for average flows are higher than the average measured concentration, the increase relative to model calibration (i.e., pre-PolyMet) is smaller than might be considered when comparing to the average measured sulfate concentration of 36.1 mg/L at PM-13. This is apparent in the culpability analysis for sulfate (see Section 5.2.3.2), where the Pit 5NW appears as the primary source for average flow conditions. This situation does not occur during low flows, for which the discharge from the Pit 5NW is assumed to be zero.

5.2.3.2 Culpability Analysis

This section presents the culpability analysis (i.e., the degree of a particular Plant Site facility's or natural feature's impact on the overall deterministic water quality predictions in the Embarrass River) for the Tailings Basin-Proposed Action. The six water quality parameters (see Section 4.4) were selected for the culpability analysis: antimony, arsenic, cobalt, copper, nickel and sulfate. All upstream impacts, including those from both natural features (i.e., groundwater recharge and surface runoff from areas that will not be disturbed by the Plant Site facilities) and Tailings Basin facilities (e.g., hydrometallurgical residue cells liner leakage, Cells 1E/2E seepage) were investigated for all scenarios of Plant Site development and closure and for low, average and high flow conditions at the PM-13 surface water quality monitoring stations.

The culpability analysis is completed for two sets of graphs which are presented in Appendix G for Tailings Basin-Proposed Action:

- Mass flux of upstream impacts (concentration of the feature multiplied by the flow of the feature).
- Percent contributions at a certain location (mass flux of each feature divided by total mass flux at PM-13).

In Appendix G, "-" indicates that the mass flux is zero (e.g., there is no surface runoff during low flow conditions), whereas "0.00" indicates that the mass flux is very small. The 288 figures in Appendix G present the full set of results of the culpability analysis for the Tailings Basin-Proposed Action. The main results of this analysis are presented below:

Low Flow Conditions – Tailings Basin-Proposed Action

- Natural groundwater recharge from the watershed, followed by seepage from Cell 2W in Year 1 and seepage from Cells 1E/2E of the Tailings Basin in all other years, represents the main input determining concentrations of arsenic, cobalt and copper.
- Natural groundwater recharge from the watershed represents the main input determining concentrations of nickel in Year 1.
- Natural groundwater recharge from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of nickel in Years 5, 8, 9, Closure and Post-Closure; and of antimony in all years.
- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of nickel in Years 15 and 20.
- Seepage from Cell 2W, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Year 1.
- Seepage from Cell 2W, followed by liner leakage from the Hydrometallurgical Residue Cells and seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Years 5, 8 and 9.
- Liner leakage from the Hydrometallurgical Residue Cells, followed by seepage from Cells 1E/2E of the Tailings Basin and from Cell 2W, represents the main input determining concentrations of sulfate in Years 15 and 20.
- Seepage from Cell 2W, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Closure.
- Seepage from Cells 1E/2E of the Tailings Basin, followed by seepage from Cell 2W, represents the main input determining concentrations of sulfate in Post-Closure.

Average Flow Conditions – Tailings Basin-Proposed Action

- Natural surface water runoff from the watershed, followed by seepage from Cell 2W, represents the main input determining concentrations of arsenic, cobalt, and copper in Year 1.
- Natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of arsenic and copper in Years 5, 8, 9, Closure and Post-Closure.
- Natural surface water runoff from the watershed represents the main input determining concentrations of cobalt in Years 5, 8, 9, Closure and Post-Closure.

- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of arsenic, cobalt, and copper in Years 15 and 20.

- Natural surface water runoff from the watershed, followed by seepage from Cell 2W, represents the main input determining concentrations of nickel in Year 1.

- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of nickel in Years 5, 8, and 9.

- Seepage from Cells 1E/2E of the Tailings Basin represents the main input determining concentrations of nickel in Years 15 and 20.

- Natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of nickel in Closure and Post-Closure.

- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of antimony in Year 1 and in Closure and Post-Closure.

- Seepage from Cells 1E/2E of the Tailings Basin represents the main input determining concentrations of antimony in Years 5, 8, 9, 15 and 20.

- Discharge from Pit 5NW, followed by seepage from Cell 2W and seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Years 1, 5, 8, and 9.

- Discharge from Pit 5NW, followed by seepage from Cells 1E/2E of the Tailings Basin and seepage from Cell 2W, represents the main input determining concentrations of sulfate in Years 15 and 20.

- Discharge from Pit 5NW represents the main input determining concentrations of sulfate in Closure and Post-Closure.

<u>High Flow Conditions – Tailings Basin-Proposed Action</u>

- Natural surface water runoff from the watershed represents the main input determining concentrations of arsenic, cobalt and copper in all years.

- Natural surface water runoff from the watershed represents the main input determining concentrations of nickel in Years 1, 5, 8, 9, Closure and Post-Closure.

- Natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of antimony in Years 1, Closure and Post-Closure; and of nickel in Years 15 and 20.

- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of antimony in Years 5, 8, 9, 15, and 20.
- Natural surface water runoff from the watershed, followed by discharge from Pit 5NW, represents the main input determining concentrations of sulfate in all years.

5.2.3.3 Factor to Exceed Standards

This section presents the analysis conducted to determine what increase in NorthMet Project's Tailings Basin seepage chemical concentrations would cause the deterministic water quality predictions in the Embarrass River watershed to exceed Minnesota surface water quality standards. Only changes to Tailings Basin features' leachate chemical concentrations, not to seepage flows, were investigated in order to be consistent with RS74A.

The predicted chemical concentrations for the leachate from the PolyMet Tailings Basin (Cells 1E/2E) and Hydrometallurgical Residue Facility were multiplied concurrently by a factor. The determination of the factor for a given parameter (antimony, arsenic, cobalt, copper and nickel were also investigated here, see Section 4.4) and flow condition (low, average or high) was based on deterministic water quality predictions in the Embarrass River that exceed Minnesota surface water quality standards for that parameter at PM-13 and a given stage of the Tailings Basin development or closure under the Tailings Basin-Proposed Action. For an explanation of the Minnesota surface water quality standards, see Section 3.1.

Table 5-10 presents the smallest factors, along with the location and scenario that would cause the deterministic water quality predictions to exceed Minnesota surface water quality standards in the Embarrass River at PM-13. There is no applicable Minnesota surface water quality standard for sulfate given the use classification of the Embarrass River. However, there is emerging interest in sulfate, and so the corresponding sulfate concentration for the smallest factors referred to above is also presented in Table 5-10.

Table 5-11 compares the concentrations of leachate from PolyMet Tailings Basin (Cells 1E/2E) and Hydrometallurgical Residue Facility (all occurring concurrently) that would cause Embarrass River deterministic water chemistry predictions to exceed Minnesota surface water quality standards and the "base case" concentrations of these Tailings Basin features. "Base Case" concentrations are those reasonable worst case concentrations presented in Tables 4-2 and 4-3 and used to deterministically predict the concentrations in the Embarrass River presented in Section 5.2.2.1.

The main results of this analysis are presented below:

- Antimony. The smallest factor to exceed the corresponding standard is 33.0 under the Tailings Basin-Proposed Action.
- Arsenic. The smallest factor to exceed the corresponding standard is 34.0 under the Tailings Basin-Proposed Action.
- Cobalt. The smallest factor to exceed the corresponding standard is 5.7 under the Tailings Basin-Proposed Action.
- Copper. The smallest factor to exceed the corresponding standard is 3.6 under the Tailings Basin-Proposed Action.
- Nickel. The smallest factor to exceed the corresponding standard is 6.1 under the Tailings Basin-Proposed Action.

6.0 Proposed Action – Groundwater Quality Modeling

6.1 Modeling Methodology – (Operations and Closure)

6.1.1 Background and Introduction

In order to help predict both the quality of water that leaves the Tailings Basin as groundwater and the Tailings Basin pond water quality, groundwater flow and contaminant transport modeling was conducted, as reported in RS13 and RS54/RS46. This modeling was performed using MODFLOW and MODPATH. The transport of dissolved constituents through the Tailings Basin is complicated by many factors, including changing pond elevation, unsaturated flow conditions and numerous source areas with very different seepage travel times from each area. It was difficult to know *a priori* which of these factors would be important in the predictions that were to be made. Because of this, the first round of modeling (presented in the previously mentioned reports) attempted to simulate many of these complexities. The result was a complicated set of models that were difficult for the EIS contractor to validate and would be nearly impossible for the general public reviewing the EIS to understand. In order to provide for more transparent predictions, a second round of conservative modeling was undertaken for the Tailings Basin-Proposed Action.

This section (Section 6.0) documents the methodology used to predict the concentration of dissolved constituents in seepage leaving the Tailings Basin and seepage collected by the proposed seepage collection system, and presents the results of these predictions for the Tailings Basin-Proposed Action. The work presented here supersedes the work documented in RS13 and RS54/RS46 that was conducted in order to make these same predictions. Specifically, it replaces Section 5.3.2 of RS13 Attachment A-6 and Sections 7.2.7 and 7.2.8 of RS54/RS46.

The primary objective of the work presented here is to provide a conservative prediction of the quality of the seepage water leaving the Tailings Basin. To do this, a conservative prediction of the quality of the water collected by the seepage collection system was also prepared, as this is part of the prediction of tailings pond water quality which in turn feeds into the prediction of water quality for groundwater leaving the basin. A primary driver in the selection of a methodology used to meet the objective was the desire for the prediction to be transparent and easy to follow. However, because this is a complex system that integrates both hydrogeology and geochemistry, it may still be difficult for a lay person to understand.

As discussed previously, transport of dissolved constituents through the Tailings Basin is complex. It is not practical to simulate all possible processes and factors that ultimately affect concentrations of dissolved constituents in groundwater at the toe of the Tailings Basin. Knowledge gained during the first round of modeling, along with a general understanding of transport modeling, allow simplifying assumptions, that will not understate the predictions, to be made. It was determined that two of the complexities that need to be retained for the deterministic water quality predictions are the varying mass loading of constituents from the different source areas and the different transport times through the basin for waters starting at each source area. In addition, it was decided that transport through the unsaturated zone could not be ignored.

The deterministic water quality predictions presented in this section focus on groundwater flowing north from Cell 2E. This water has the shortest flow path to the environment (as opposed to groundwater that may flow west through Cell 2W) and will have the highest dissolved constituent concentrations of any groundwater leaving the basin. Because of the bedrock topology, virtually all of the groundwater flowing south from the Tailings Basin will be captured by the seepage barrier constructed at the headwaters of Second Creek.

6.1.2 MODFLOW-SURFACT Modeling

Travel times through the basin were computed using MODFLOW-SURFACT. MODFLOW-SURFACT is a fully integrated flow and transport code that is based on MODFLOW. MODFLOW-SURFACT includes the ability to simulate unsaturated flow, which is why it was chosen for this application. For the Tailings Basin-Proposed Action, the model considered the following source areas: embankments (both capped and uncapped), the coarse beach areas, the fine beach areas, and the pond(s) (see Figures 6-1 through 6-4). The contribution from each source area to the concentration of dissolved constituents in groundwater leaving the basin at the toe of the embankment was predicted under steady-state conditions. Flow conditions for Years 1, Year 8, Year 9, Year 20 and Closure were used in this analysis. (Closure actually refers to Post-Closure in Section 4.1.1.) That is, the exact same Years 1, Year 8, Year 9, Year 20 and Closure models that were used for the Tailings Basin water balance were used as the basis of the transport models (see RS13 for documentation of these flow models). For each source area being examined, MODFLOW-SURFACT was used to predict the contribution from that source at down-gradient locations using a unit source concentration.

Transport through the basin considered only advection. Dispersion, retardation and degradation were not simulated. Unsaturated flow was simulated using pseudo-soil relations (see MODFLOW-SURFACT manual for discussion of the simulation of unsaturated flow). The transport equation was solved using the fully upstream transport scheme with an implicit time weighting scheme.

For each source area being evaluated, a model run was completed with the concentration of that component set equal to unity and the concentration of all other components equal to zero. For the beach and embankment areas, the concentration was applied to the recharge zone simulating these features. For the pond, the concentration was applied to the constant head cells simulating the pond. This was done using each model (Year 1, Year 8, Year 9, Year 20 and Closure models). For each model run, concentrations were tracked forward in time until equilibrium was achieved or for 1,000 years.

The result of this contaminant transport modeling was a series of breakthrough curves for each source area considered for each flow condition simulated. The breakthrough curves were predicted at a hypothetical well location in the center of the toe of the LTVSMC Cell 2E embankment. These curves are shown in Figures 6-5 through 6-16. Figure 6-5 shows the breakthrough curves for the source areas in Cell 2E under Year 1 flow conditions. For the water that infiltrates through the coarse tailings on the beach under these flow conditions, 10 percent reaches the toe of the embankment in approximately 0.8 years, while 50 percent of the water has reached the toe within 5 years. In general, water from the coarse tailings beach areas appears at the toe of the embankment first, which is to be expected since the material has the highest saturated hydraulic conductivity and the shortest flowpath. However, because much of the coarse beach area is unsaturated, the average travel time for this water is slower than for the water originating in the pond, which has a flowpath through fully saturated conditions. Figures 6-17 through 6-21 show the percent of the source concentration that reaches the toe of the embankment.

6.1.3 Source Term Load Predictions

SRK provided mass load terms for each source area for each year of operations and for closure. This report is not intended to describe how these loads were computed; that will be done either in a revision to RS54/RS46 or in a separate technical memorandum provided by SRK. However, it can be stated that the methodology used to predict the mass loads is consistent with the methodology presented in Section 7.2.8 of RS54/RS46 (note however that the release ratios have been updated to represent more recent waste characterization humidity cell tests). That report presented the pore water concentrations in Table 7-15 and Appendix D.3. For the work presented here, it was necessary to have the mass loads and flows for these sources rather than just the pore water concentrations. The load and flow values used in this work that were provided by SRK are shown in Tables 6-1 through 6-5.

6.1.4 Spreadsheet Model

A spreadsheet model was developed to predict the concentration of dissolved constituents for water collected by the seepage collection system and water released to the environment using the results from the MODFLOW-SURFACT modeling and the transient SRK loads. The spreadsheet model assumed plug flow for each source area (embankment, coarse beach, fine beach and pond) and used the travel times presented under Section 6.1.2 for the transport times of the plugs. An example of how the travel time data was interpreted is presented below:

> Figure 6-14 shows the time it takes for water infiltrating the fine beach area of Cell 2E to reach the toe of the LTVSMC embankment. Data is presented as a series of breakthrough curves, with each curve representing a different flow condition (i.e., conditions during Year 1, Year 8, Year 9 and Year 20). For this work, the average 10 percent breakthrough time was used. Figure 6-14 shows that the 10 percent breakthrough times vary between approximately 1.5 and 2.5 years. For the fine beach area, an average travel time of 2 years was used. For the embankment areas, the travel times for the open embankments, 5 years, were used (see Figure 6-13). A travel time of 2 years was used for the coarse beach areas (see Figure 6-15) and for the pond a travel time of 3 years was used (see Figure 6-16).

The travel time data was used to determine when water would show up at the toe of the embankment. For example, water that infiltrates through the coarse beach in Year 5 would show up at the toe of the embankment in Year 7 (a 2 year travel time). Table 6-6 shows the source year of water that shows up at the toe of the embankment for each year of operation for each source:

The water that shows up at the toe of the embankment in Year 15 is a combination of the water that infiltrated through the fine and coarse beach areas in Year 13, the water that infiltrated through the embankment in Year 10 and the water that was lost as seepage from the pond in Year 12. Therefore, when making the concentration predictions at the toe of the embankment for Year 15, the Year 13 Coarse Beach Load, the Year 13 Fine Beach Load, the Year 10 Embankment Load and the Year 12 Pond Load is used. The total loads from Cell 2E were applied to the predicted flow out of the basin to the north. The flows used in this calculation came from the MODFLOW-SURFACT model and are presented in Table 6-7.

It should be noted that the flows in Table 6-7 are different from the flows in Table 4-1. Table 4-1 presents the total seepage losses from the Tailings Basin whereas Table 6-7 presents the seepage losses to the north of Cell 2E. These flows are very similar during the early years of operation when most, if not all of, the unrecovered seepage flows to the north. In the later years, as the head in the Tailings Basin pond increases, more pond seepage flows to the west through Cell 2W. By using the flows in Table 6-7 for the calculation of concentrations, all of the beach and embankment loads are mixed with only the pond seepage flowing north, thus providing a reasonable yet conservative prediction of concentrations. However, these predicted concentrations are applied to all of the unrecovered seepage, which is conservative since the pond water quality is better than the quality of the predicted seepage.

For each parameter, for each year, three sets of predictions were made. The first prediction was for completely mixed water. That is, the entire mass load from Cell 2E was mixed with the entire volume of water leaving the basin as groundwater flow ("Total Water"). This represents a scenario where no water is collected in the horizontal drains that will be placed in the LTVSMC dams.

In reality, the horizontal drains will capture some water and the water captured will be a higher percent of water from the embankment and coarse beach areas, due to the placement of the drains relative to these source areas. The MODFLOW-SURFACT model was used to predict an upper bound for the amount of embankment (80 percent), coarse tailing (50 percent) and fine tailing (20 percent) source water that the drains could collect. These values were agreed to by Agency staff as a reasonable upper bound for the amount of water captured. The flow to the horizontal drains based on these collection efficiencies ("Captured Water") was used to predict the concentration of dissolved constituents in the water collected by the horizontal drains by dividing the contaminant load from a source between Captured Water and Uncaptured Water (see below) on the same basis as the water from the source was divided, totaling that load and mixing it with the volume of Captured Water. Under this scenario, the groundwater flow leaving the basin ("Uncaptured Water") is "Total Water" minus "Captured Water". The quantity of captured water that was used for these calculations came from RS13.

During closure, only the Total Water scenario was predicted because it is likely that the horizontal drains will collect very little water as seepage flow diminishes to eventual long term conditions. In closure, the embankment and coarse beach areas will be capped, the pond edge will move away from the crest of the embankment and the horizontal drains collect much less water. It is likely that the water that is collected will be better mixed than during operations.

6.2 Deterministic Groundwater Quality Predictions – (Operations and Closure)

Deterministic water quality predictions for the Total Water, the Captured Water and the Uncaptured Water are shown in Tables 6-8 through 6-10 and on Figures 6-22 through 6-29. Predicted concentrations of Total Water (labeled Total Concentration), Captured Water and Uncaptured Water are shown on all plots. Because relatively high capture efficiency for the horizontal drains was assumed, the predicted Captured Water quality represents the upper bound for the water that will actually be captured and, therefore, conservatively represents the maximum contaminant load returned back to the tailings basin pond. The Total Water likewise represents the lower bound for the water that will be captured by the horizontal drains (it assumes that the drains do not preferentially capture water from the embankment or beach areas). For water that will leave the basin footprint as groundwater flow, the Total Water represents an upper bound of contaminant concentrations, while the Uncaptured Water represents the lower bound.

The prediction of pond chemistry is dependent on the prediction of Captured Water concentrations because this water is pumped back into the pond. Likewise, the prediction of Captured Water concentrations is dependent on the prediction of pond chemistry. The data presented in Section 6.1 and the results presented in Section 6.2 are the result of several iterations of modeling that were performed in order to synchronize these predictions.

Figures 6-22 though 6-29 show the major constituents of concern and are discussed below (note that closure concentrations and standards are in Table 6-8):

- Figure 6-22 shows the predicted sulfate concentrations. Both the upper and lower bound of water leaving the basin as groundwater are below the secondary drinking water standard of 250 mg/L. In closure, the concentration is predicted to be 110 mg/L.

- Figure 6-23 shows the predicted concentrations of silver. Both the upper and lower bound for the water leaving the basin as groundwater are temporarily above the surface water standard of 0.001 mg/L but below the groundwater standard of 0.03 mg/L (i.e. groundwater standard not shown on Figure 6-23 because of scaling). In closure, the concentration is predicted to be 0.00097 mg/L, slightly below the surface water standard and well below the groundwater standard.

- Figure 6-24 shows the predicted concentrations of antimony. Both the upper and lower bound for the water leaving the basin as groundwater are above both the surface water standard (0.031 mg/L) and the groundwater standard (0.006 mg/L). In closure, the concentration is predicted to be 0.0054 mg/L, slightly below the groundwater standard and well below the surface water standard.

- Figure 6-25 shows the predicted concentrations of arsenic. Both the upper and lower bound for the water leaving the basin as groundwater are temporarily above the groundwater standard of 0.01 mg/L but below the surface water standard. In closure, the concentration is predicted to be 0.012 mg/L, slightly above the groundwater standard but below the surface water standard.

- Figure 6-26 shows the predicted concentrations of cobalt. Both the upper and lower bound for the water leaving the basin as groundwater are temporarily above the surface water standard of 0.005 mg/L. In closure, the concentration is predicted to be 0.0014 mg/L, below the standard. There is no groundwater standard for cobalt.

- Figure 6-27 shows the predicted concentrations of copper. Both the upper and lower bound for the water leaving the basin as groundwater are below the surface water standard of 0.025 mg/L and the groundwater standard of 1 mg/L (i.e. groundwater standard not shown on Figure 6-27 because of scaling). In closure, the concentration is predicted to be 0.018 mg/L, below both standards.

- Figure 6-28 shows the predicted concentrations of nickel. Both the upper and lower bound for the water leaving the basin as groundwater are temporarily above the groundwater standard of 0.1 mg/L and the upper bound is predicted to be above the surface water standard (hardness dependent). In closure, the concentration is predicted to be 0.015 mg/L, below both standards.

- Figure 6-29 shows the predicted concentrations of zinc. Both the upper and lower bound for the water leaving the basin as groundwater are below the surface water and groundwater standard (i.e. groundwater standard of 2 mg/L not shown on Figure 6-29 because of scaling). In closure, the concentration is predicted to be 0.020 mg/L which is below the surface water standard of 0.295 mg/L and the groundwater standard of 2 mg/L.

6.3 Interpretation of Results

6.3.1 Comparison to Water Quality Standards

During operations, the groundwater leaving the tailings basin has predicted sulfate, antimony, arsenic and nickel concentrations that temporarily exceed groundwater standards. The process of predicting the quality of the water leaving the tailings basin as groundwater is necessarily conservative; that is, it is intended to error in the direction of predicting higher contaminant concentrations. It is anticipated that permitting will include groundwater monitoring and a requirement to develop and submit compliance plans if groundwater standards are exceeded. There are mitigations that can be applied after operations commence. For example, the coarse beaches are a primary source of contaminants - temporary spray on covers systems could be applied to inactive beaches and neutralizing agents could be injected into tailings deposited on active beaches.

During operations, the groundwater leaving the tailings basin has predicted silver, antimony, cobalt and nickel that temporarily exceed surface water standards. There is no surface water discharge from the tailings basin. Some groundwater could emerge at the surface into adjacent wetlands at dispersed locations. It is anticipated that permitting will include surface water monitoring and a requirement to develop and submit compliance plans if surface water problems develop. As described above, there are mitigations that can be applied after operations commence.

In closure, the groundwater leaving the tailings basin has a predicted arsenic concentration of 0.012 mg/L which is above the groundwater standard of 0.01 mg/L. It should be noted that the predicted concentrations are at the toe of the embankment. Modest reductions in concentrations would be expected as this water flows away from the basin and mixes with natural recharge.

Because MDNR has decided that the Tailings Basin-Proposed Action has sufficient geotechnical uncertainty to determine that the Proposed Action should not be pursued further, PolyMet decided to not further refine models and develop mitigations that could be modeled so as to demonstrate no exceedances of standards. It is likely that a combination of refined model and modeled mitigations could demonstrate no exceedances.

6.3.2 Culpability Analysis

This section presents the culpability analysis of the Tailings Basin (i.e., the degree of a particular Tailings Basin feature's impact on the overall water quality of the Tailings Basin seepage) for the Tailings Basin-Proposed Action. Six parameters were selected for the culpability analysis: antimony, arsenic, cobalt, copper, nickel and sulfate (see Section 4.4). There are four features that contribute to the overall water quality of the Tailings Basin seepage under the Tailings Basin-Proposed Action: the Tailings Basin pond, fine beach, coarse beach and embankment. All impacts from the Tailings Basin were investigated for Years 1, 5, 8, 9, 15, 20 and Closure. The culpability analysis is completed for two sets of graphs which are presented in Appendix G for Tailings Basin-Proposed Action:

- Mass flux of impacts (concentration of the feature multiplied by the flow of the feature).
- Percent contribution of impacts (mass flux of each feature divided by total mass flux).

The 84 figures in Appendix G present the results of the culpability analysis of the Tailings Basin for the Tailings Basin-Proposed Action. The main results of this analysis are presented below:

- Seepage from the Tailings Basin pond represents the only input determining concentrations of sulfate, antimony, arsenic, cobalt, copper and nickel in Year 1.
- Seepage from the Tailings Basin pond represents the main input determining concentrations of sulfate in Years 5, 8, 9, and Closure; antimony in Years 5, 8, 9, and Closure; cobalt in Closure; copper in Closure; and nickel in Closure.
- Seepage from the coarse beach represents the main input determining concentrations of nickel in Year 15.
- Seepage from the Tailings Basin pond, followed by seepage from the coarse beach, represents the main inputs determining concentrations of antimony in Years 15 and 20; sulfate in Years 15 and 20; arsenic in Years 5, 8 and 9; cobalt in Years 5, 8 and 9; copper in Years 5, 8, 9 and 20; and nickel in Years 5 and 20.
- Seepage from the coarse beach, followed by seepage from the Tailings Basin pond, represents the main inputs determining concentrations of arsenic in Years 15 and 20; cobalt in Years 15 and 20; copper in Year 15; and nickel in Years 5 and 20.
- Seepage from the Tailings Basin pond, followed by seepage from the fine beach, represents the main inputs determining concentrations of arsenic in Closure.

7.0 Geotechnical Mitigation – Surface Water Quality Modeling

7.1 Modeling Methods

7.1.1 Overview

Concentrations of the constituents of interest in the Embarrass River under the Tailings Basin-Geotechnical Mitigation were modeled using a simple water balance and mass-balance model. The overview of the mass-balance model described in Section 5.1.1 for the Tailings Basin-Proposed Action is also valid for the Tailings Basin-Geotechnical Mitigation, including model layout and assumptions.

7.1.2 Model Construct

The construct of the mass-balance model described in Section 5.1.2 for the Tailings Basin-Proposed Action, including the schematic view of the model presented in Figure 5-2 and the description of the variables shown in Table 5-1, is also valid for the Tailings Basin-Geotechnical Mitigation.

7.1.3 Summary of Input Data

7.1.3.1 Embarrass River

Flows

In-river flows at nodes PM-12 and PM-13 discussed in Section 5.1.3.1 and presented in Table 2-1 for the Tailings Basin-Proposed Action are also valid for the Tailings Basin-Geotechnical Mitigation.

The footprint of the Tailings Basin-Geotechnical Mitigation is approximately 13 acres greater than that of the Tailings Basin-Proposed Action, but such difference is negligible in comparison to the total footprint area for the Tailings Basin of more than 3,000 acres. Additionally, the footprint of the Plant Site is very small compared to the watershed upstream of PM-13, so assuming the flows in the Embarrass River for the Tailings Basin-Geotechnical Mitigation will not change with respect to those used in the Tailings Basin-Proposed Action is reasonable.

Water Quality

The concentrations in the Embarrass River at PM-12 and PM-13 are the results of the water balance/mass-balance model and are discussed in Section 7.2.2. For reference, baseline water quality data for the Embarrass River at PM-12 and PM-13 are presented in Table 5-3.

7.1.3.2 Groundwater Recharge from Watershed

Flows

The inflow of groundwater at each node presented in Section 5.1.3.2 for the Tailings Basin-Proposed Action is also valid for the Tailings Basin-Geotechnical Mitigation.

Water Quality

The groundwater concentrations discussed in Section 5.1.3.2 and presented in Table 5-2 for the Tailings Basin-Proposed Action are also valid for the Tailings Basin-Geotechnical Mitigation.

7.1.3.3 Surface Runoff from Watershed

Flows

Surface runoff flows discussed in Section 5.1.3.3 for the Tailings Basin-Proposed Action are also valid for the Tailings Basin-Geotechnical Mitigation.

Water Quality

The concentration of each constituent in the surface runoff discussed in Section 5.1.3.3 and presented in Table 5-2 for the Tailings Basin-Proposed Action is also valid for the Tailings Basin-Geotechnical Mitigation.

7.1.3.4 Pit 5NW Discharge

Flows

The discharges from Pit 5NW between PM-12 and PM-13 discussed in Section 5.1.3.4 for the Tailings Basin-Proposed Action are also valid for the Tailings Basin-Geotechnical Mitigation.

Water Quality

Parameter concentrations for this input discussed in Section 5.1.3.4 and presented in Table 5-2 for the Tailings Basin-Proposed Action are also valid for the Tailings Basin-Geotechnical Mitigation.

7.1.3.5 Tailings Basin Seepage

Flows

Similarly to the model for the Tailings Basin-Proposed Action, there are two inputs from the tailings basin included in the Embarrass River model for the Tailings Basin-Geotechnical Mitigation: seepage from Cell 2W and seepage from Cells 1E/2E. Seepage rates from Cell 2W discussed in Section 5.1.3.5 and presented in Table 4-1 for the Tailings Basin-Proposed Action are also valid for the Tailings Basin-Geotechnical Mitigation. The unrecoverable seepage rates from Cells 1E/2E for the Tailings Basin-Geotechnical Mitigation are taken from RS13B and vary over the course of Plant Site development (see Table 4-4).

Water Quality

Water quality data of seepage from Cell 2W that was discussed in Section 5.1.3.5 and presented in Table 5-2 for the Tailings Basin-Proposed Action is also valid for the Tailings Basin-Geotechnical Mitigation. Values of C_{fs}, the predicted seepage chemistry for the Tailings Basin Cells 1E and 2E for the Tailings Basin-Geotechnical Mitigation, are summarized in Table 4-5. Details about the methodology used for these predictions are presented in Section 8.0.

7.1.3.6 Hydrometallurgical Residue Cell Leakage

Flows

Hydrometallurgical residue leakage discussed in Section 5.1.3.6 and presented in Table 4-1 for the Tailings Basin-Proposed Action is also valid for the Tailings Basin-Geotechnical Mitigation.

Water Quality

The water chemistry of the unrecoverable leakage from the hydrometallurgical residue cells to groundwater discussed in Section 5.1.3.6 and presented in Table 4-3 for the Tailings Basin-Proposed Action is also valid for the Tailings Basin-Geotechnical Mitigation.

7.1.3.7 Babbitt Wastewater Treatment Plant

Flows

The Babbitt-WWTP discharges discussed in Section 5.1.3.7 for the Tailings Basin-Proposed Action are also valid for the Tailings Basin-Geotechnical Mitigation.

Water Quality

The methodology to characterize water quality for this discharge discussed in Section 5.1.3.7 for the Tailings Basin-Proposed Action is also valid for the Tailings Basin-Geotechnical Mitigation. Therefore, the concentrations of all water quality parameters in the Babbitt-WWTP discharge were assumed to be equal to the surface runoff concentration (see Section 7.1.3.3).

7.1.4 Model Calibration

The model calibration results presented in Section 5.1.4 for the Tailings Basin-Proposed Action are also valid for the Tailings Basin-Geotechnical Mitigation.

7.1.5 Modeled Flow Conditions

Wet, dry and average conditions were simulated for Years 1, 5, 10, 15 and 20 of Plant Site operation as well as Closure and Post-Closure under the Tailings Basin-Geotechnical Mitigation. As explained in Section 4.1.1, Years 8 and 9 were reported for the Tailings Basin-Proposed Action but not for the Tailings Basin-Geotechnical Mitigation because maximum deterministic water quality predictions for most parameters in unrecovered seepage from the Tailings Basin to groundwater do not occur in those years. The only exception is nickel, for which, however, the deterministically predicted concentration in Year 10 is 91.4 percent of predicted concentration in Year 8.

7.2 Modeling Results

7.2.1 General

The Embarrass River water quality model (see Section 7.1) was used to deterministically predict water chemistry in the Embarrass River during various stages of Plant Site operation and closure (see Section 4.1.1) for the Tailings Basin-Geotechnical Mitigation (see Section 4.3). The eight model scenarios were evaluated for conditions representing low, average and high flow (see Section 2.1.4).

Section 7.2.2 presents the deterministic water quality predictions for silver, aluminum, arsenic, boron, barium, beryllium, calcium, cadmium, chloride, cobalt, copper, fluoride, iron, hardness, potassium, magnesium, manganese, sodium, nickel, lead, antimony, selenium, sulfate, thallium, and zinc.

Deterministic water quality predictions were computed using the best available flow and chemistry data for the various components included in the mass-balance model. When necessary, conservative assumptions were made (e.g., all the seepage from the Tailings Basin and Hydrometallurgical Residue Facility will reach the Embarrass River as groundwater). In addition, the mass-balance model does not account for possible reductions in chemical mass resulting from the transport of the chemical to and within the Embarrass River (see Sections 1.4.2 and 7.1 for more details).

7.2.2 Water Quality Presentations

7.2.2.1 Discussion of Results

Deterministic water quality predictions for the parameters listed in Section 7.2.1 are presented for the following seven modeled scenarios for the Tailings Basin-Geotechnical Mitigation listed in Section 4.1.1: Years 1, 5, 10, 15, 20, Closure, and Post-Closure.

Tables 7-1 through 7-6 present the complete results for surface water monitoring stations PM-12 and PM-13, respectively, for the Tailings Basin-Geotechnical Mitigation. Figures 7-1 and 7-2 present the results for antimony, arsenic, cobalt, copper, nickel and sulfate at PM-12 and PM-13 for the Tailings Basin-Geotechnical Mitigation, respectively. In addition to the mass-balance deterministic water quality predictions, the tables include background surface water quality at the corresponding location (see Table 5-3) and the most stringent of the chronic aquatic toxicity-based Minnesota surface water quality standards (see Table 3-1). Where hardness based standards are applicable, the deterministic water quality predictions at each surface water monitoring station located in the Embarrass River was used to determine the corresponding chronic standard consistent with Minnesota Rules Chapters 7050 and 7052. All calculations and results for the complete set of constituents evaluated here are presented in Appendix F.

7.2.2.2 Parameters with Limited/Poor Data

The results presented for the Embarrass River in this section use the best available information at this time. However, there are some parameters that have limited or poor data. The same list of parameters with limited and/or poor data presented in Section 5.2.2.2 for the Tailings Basin-Proposed Action is valid for the Tailings Basin-Geotechnical Mitigation.

7.2.3 Interpretation of Results

7.2.3.1 Comparison to Water Quality Standards

<u>Deterministic Water Quality Predictions at PM-12</u>

Deterministic water quality predictions of each constituent during Years 1, 5, 10, 15, 20, Closure, and Post-Closure at surface water monitoring location PM-12 are presented in Tables 7-1 to 7-3 for low, average, and high flows under Tailings Basin-Geotechnical Mitigation. PM-12 is located upstream of all mining related inputs to the Embarrass River model. Therefore, no changes in water quality are observed between model scenarios (see Figure 7-1). The maximum deterministic water quality predictions presented for the Tailings Basin-Proposed Action in Section 5.2.3.1 is valid for the Tailings Basin-Geotechnical Mitigation.

All parameters listed in Section 7.2.1 meet minimum in-stream Minnesota water quality standards at PM-12 during low flows, average flows, and high flows for all modeled scenarios under Tailings Basin-Geotechnical Mitigation (see Tables 7-1 to 7-3). In most cases, the deterministic water quality predictions are well below the Minnesota surface water quality standards.

Deterministic Water Quality Predictions at PM-13

Deterministic water quality predictions of each constituent during Years 1, 5, 10, 15, 20, Closure, and Post-Closure at surface water monitoring location PM-13 are presented in Tables 7-4 to 7-6 for low, average and high flows under Tailings Basin-Geotechnical Mitigation. PM-13 is located downstream of the Tailings Basin. The maximum deterministic water quality predictions of some key water quality parameters (see Section 4.4) are summarized below:

- Antimony. The highest deterministic water quality prediction of antimony is 0.00217 mg/L at PM-13 in Year 10 during low flow conditions under Tailings Basin-Geotechnical Mitigation. This value is one order of magnitude smaller than the Minnesota surface water quality standard of 0.031 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00150 mg/L.

- Arsenic. The highest deterministic water quality prediction of arsenic is 0.00545 mg/L at PM-13 in Post-Closure during low flow conditions under Tailings Basin-Geotechnical Mitigation. This value is one order of magnitude smaller than the Minnesota surface water quality standard of 0.053 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00100 mg/L.

- Cobalt. The highest deterministic water quality prediction of cobalt is 0.00131 mg/L at PM-13 in Post-Closure during low flow conditions under Tailings Basin-Geotechnical Mitigation. This value is about one-fourth the Minnesota surface water quality standard of 0.005 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00050 mg/L.

- Copper. The highest deterministic water quality prediction of copper is 0.00513 mg/L at PM-13 in Post-Closure during low flow conditions under Tailings Basin-Geotechnical Mitigation. This value is about one-third the Minnesota surface water quality standard of 0.01278 mg/L, based on a hardness of 152.8 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00200 mg/L.

- Nickel. The highest deterministic water quality prediction of nickel is 0.00868 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Geotechnical Mitigation. This value is one order of magnitude smaller than the Minnesota surface water quality standard of 0.07829 mg/L based on a hardness of 161.6 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00207 mg/L.

- Sulfate. The highest deterministic water quality prediction of sulfate is 61.6 mg/L at PM-13 in Year 10 during low flow conditions under Tailings Basin-Geotechnical Mitigation. There is no Minnesota surface water quality standard for sulfate applicable to the Use Classification of the Embarrass River. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 36.1 mg/L.

All constituents meet minimum in-stream Minnesota water quality standards at PM-13 during low, average and high flow conditions for all modeled scenarios of the Plant Site development and closure under the Tailings Basin-Geotechnical Mitigation except for aluminum (see Tables 7-4 to 7-6). In most cases, the deterministic water quality predictions are well below the Minnesota surface water quality standards.

Similar to the Tailings Basin-Proposed Action, the water quality standard for aluminum of 0.125 mg/L is exceeded at PM-13 for all scenarios for low and average flow conditions. The maximum deterministic water quality prediction for aluminum is 0.25975 mg/L under low flow conditions and 0.21950 mg/L under average flow conditions. This is in part explained by the fact that the average monitored concentration of aluminum in the Embarrass River at PM-13 in 2004, 2006 and 2007 (0.1916 mg/L) also exceeds the Minnesota surface water quality standard. The maximum deterministic water quality prediction of aluminum is an increase of 36 percent over existing conditions.

7.2.3.2 Culpability Analysis

This section presents the culpability analysis (i.e., the degree of a particular Plant Site facility’s or natural feature’s impact on the overall deterministic water quality predictions in the Embarrass River) for the Tailings Basin-Geotechnical Mitigation. Six parameters were selected for the culpability analysis: antimony, arsenic, cobalt, copper, nickel and sulfate (see Section 4.4). All upstream impacts, including those from both natural features (i.e., groundwater recharge and surface runoff from areas that will not be disturbed by the Plant Site facilities) and Tailings Basin facilities (e.g., hydrometallurgical residue cells liner leakage, Cells 1E/2E seepage) were investigated for all scenarios and flow conditions at the PM-13 surface water quality monitoring stations.

The culpability analysis is completed for two sets of graphs which are presented in Appendix G for Tailings Basin-Geotechnical Mitigation:

- Mass flux of upstream impacts (concentration of the feature multiplied by the flow of the feature).
- Percent contributions at PM-13 (mass flux of each feature divided by total mass flux at a certain location).

In Appendix G, "-" indicates that the mass flux is zero (e.g., there is no surface runoff during low flow conditions), whereas "0.00" indicates that the mass flux is very small. The 252 figures in Appendix G present the full set of results of the culpability analysis for the Tailings Basin-Geotechnical Mitigation. The main results of this analysis are presented below:

Low Flow Conditions – Tailings Basin-Geotechnical Mitigation

- Natural groundwater recharge from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of arsenic in Years 1, 5, 10, 15, 20 and Closure.
- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of arsenic in Post-Closure.
- Natural groundwater recharge from the watershed, followed by seepage from Cell 2W, represents the main input determining concentrations of cobalt in Years 1, 5, 10, 15 and Closure.
- Natural groundwater recharge from the watershed, followed seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of cobalt in Years 20 and Post-Closure.
- Natural groundwater recharge from the watershed in all years, followed by seepage from Cells 1E/2E of the Tailings Basin in Years 20 and Post-Closure, represents the main input determining concentrations of copper.
- Natural groundwater recharge from the watershed in all years, followed by seepage from Cells 1E/2E of the Tailings Basin in Years 1, 5, 10, 15, and 20, represents the main input determining concentrations of nickel and antimony.
- Seepage from Cell 2W, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Years 1 and Closure.

- Seepage from Cell 2W, followed by liner leakage from the Hydrometallurgical Residue Cells and seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Year 5.

- Liner leakage from the Hydrometallurgical Residue Cells, followed by seepage from Cells 1E/2E of the Tailings Basin and seepage from Cell 2W, represents the main input determining concentrations of sulfate in Years 10, 15 and 20.

- Seepage from Cells 1E/2E of the Tailings Basin, followed by seepage from Cell 2W, represents the main input determining concentrations of sulfate in Post-Closure.

Average Flow Conditions – Tailings Basin-Geotechnical Mitigation

- Natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of arsenic in all years.

- Natural surface water runoff from the watershed represents the main input determining concentrations of cobalt in all years.

- Natural surface water runoff from the watershed in all years, followed by seepage from Cells 1E/2E of the Tailings Basin in Years 15 and 20, represents the main input determining concentrations of copper.

- Natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin and seepage from Cell 2W, represents the main input determining concentrations of nickel in Year 1.

- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed and seepage from Cell 2W, represents the main input determining concentrations of nickel in Years 5, 10, 15 and 20.

- Natural surface water runoff from the watershed, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of nickel in Closure and Post-Closure.

- Seepage from Cells 1E/2E of the Tailings Basin in all years represents the main input determining concentrations of antimony in Years 1, 5, 10, 15 and 20.

- Natural groundwater recharge from the watershed represents the main input determining concentrations of antimony in Closure and Post-Closure.

- Discharge from Pit 5NW, followed by seepage from Cell 2W and seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Years 1, 5, 10, 15 and 20.

- Discharge from Pit 5NW represents the main input determining concentrations of sulfate in Closure and Post-Closure.

High Flow Conditions – Tailings Basin-Geotechnical Mitigation

- Natural surface water runoff from the watershed represents the main input determining concentrations of arsenic, cobalt, copper, and nickel in all years.
- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of nickel in Years 1, 5, 10, 15 and 20.
- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of antimony in Years 1, 5, 10, 15 and 20.
- Natural surface water runoff from the watershed, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of antimony in Closure.
- Natural surface water runoff from the watershed represents the main input determining concentrations of antimony in Post-Closure.
- Natural surface water runoff from the watershed, followed by discharge from Pit 5NW, represents the main input determining concentrations of sulfate in all years.

7.2.3.3 Factor to Exceed Standards

This section presents the analysis conducted to determine what increase in NorthMet Project's Tailings Basin seepage chemical concentrations would cause the deterministic water quality predictions in the Embarrass River watershed to exceed Minnesota surface water quality standards under Tailings Basin-Geotechnical Mitigation.

The predicted chemical concentrations for the leachate from the PolyMet Tailings Basin (Cells 1E/2E) and Hydrometallurgical Residue Facility were multiplied concurrently by a factor. The determination of the factor for a given parameter (antimony, arsenic, cobalt, copper and nickel were also investigated here, see Section 4.4) and flow condition (low, average or high) was based on deterministic water quality predictions in the Embarrass River that exceed Minnesota surface water quality standards for that parameter at PM-13 and a given stage of the Tailings Basin development or closure under the Tailings Basin-Geotechnical Mitigation. For an explanation of the Minnesota surface water quality standards, see Section 3.1.

Table 5-10 presents the smallest factors, along with the location and scenario that would cause the deterministic water quality predictions to exceed Minnesota surface water quality standards in the Embarrass River at PM-13. There is no applicable Minnesota surface water quality standard for sulfate given the use classification of the Embarrass River. However, there is emerging interest in sulfate, and so the corresponding sulfate concentration for the smallest factors referred to above is also presented in Table 5-10.

Table 5-11 compares the concentrations of leachate from PolyMet Tailings Basin (Cells 1E/2E) and Hydrometallurgical Residue Facility (all occurring concurrently) that would cause Embarrass River deterministic water chemistry predictions to exceed Minnesota surface water quality standards and the "base case" concentrations of these Tailings Basin features. "Base Case" concentrations are those reasonable worst case concentrations presented in Tables 4-3 and 4-5 and used to deterministically predict the concentrations in the Embarrass River presented in Section 7.2.2.1.

The main results of this analysis are presented below:

- Antimony. The smallest factor to exceed the corresponding standard is 32.0 under the Tailings Basin-Geotechnical Mitigation.
- Arsenic. The smallest factor to exceed the corresponding standard is 16.9 under the Tailings Basin-Geotechnical Mitigation.
- Cobalt. The smallest factor to exceed the corresponding standard is 13.7 under the Tailings Basin-Geotechnical Mitigation.
- Copper. The smallest factor to exceed the corresponding standard is 6.1 under the Tailings Basin-Geotechnical Mitigation.
- Nickel. The smallest factor to exceed the corresponding standard is 31.1under the Tailings Basin-Geotechnical Mitigation.

7.3 Comparison of Proposed Action and Geotechnical Mitigation

7.3.1 Comparison to Water Quality Standards

<u>Deterministic Water Quality Predictions at PM-12</u>

PM-12 is located upstream of all mining related inputs to the Embarrass River model. Therefore, the maximum deterministic water quality predictions presented for the Tailings Basin-Proposed Action are the same as for the Tailings Basin-Geotechnical Mitigation.

Deterministic Water Quality Predictions at PM-13

PM-13 is located downstream of the Tailings Basin. The maximum deterministic water quality predictions of selected water quality parameters are summarized below for Tailings Basin-Proposed Action and Tailings Basin-Geotechnical Mitigation:

- Antimony. The highest deterministic water quality prediction of antimony is 0.00217 mg/L at PM-13 in Year 10 during low flow conditions under Tailings Basin-Geotechnical Mitigation. This value is slightly greater than the highest deterministic water quality prediction for antimony of 0.00209 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Proposed Action. In both cases, however, the maximum predicted values are one order of magnitude smaller than the Minnesota surface water quality standard of 0.031 mg/L.

- Arsenic. The highest deterministic water quality prediction of arsenic is 0.00545 mg/L at PM-13 in Post-Closure during low flow conditions under Tailings Basin-Geotechnical Mitigation. This value is 39 percent greater than the highest deterministic water quality prediction for arsenic of 0.00393 mg/L in Post-Closure and during low flow conditions under Tailings Basin-Proposed Action. In both cases, however, the maximum predicted values are one order of magnitude smaller than the Minnesota surface water quality standard of 0.053 mg/L.

- Cobalt. The highest deterministic water quality prediction of cobalt is 0.00172 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Proposed Action. This value is 31 greater than the highest deterministic water quality prediction for cobalt of 0.00131 mg/L under Tailings Basin-Geotechnical Mitigation. In both cases, however, the maximum predicted values are no greater than one-third the Minnesota surface water quality standard of 0.005 mg/L.

- Copper. The highest deterministic water quality prediction of copper is 0.00579 mg/L at PM-13 in Post-Closure during low flow conditions under Tailings Basin-Proposed Action. This value is 13 percent greater than the highest deterministic water quality prediction for copper of 0.00513 mg/L at PM-13 in Post-Closure during low flow conditions under Tailings Basin-Geotechnical Mitigation. The Minnesota surface water quality standard for copper is hardness-depending, being 0.0116 mg/L for the Tailings Basin-Proposed Action estimated hardness and 0.0128 mg/L for the Tailings Basin-Geotechnical Mitigation estimated hardness. The maximum predicted values are no greater than one-half the corresponding Minnesota surface water quality standard.

- Nickel. The highest deterministic water quality prediction of nickel is 0.01829 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Proposed Action. This value is 110 percent greater than the highest deterministic water quality prediction for nickel of 0.00868 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Geotechnical Mitigation The Minnesota surface water quality standard for nickel is hardness-depending, being 0.0804 mg/L for the Tailings Basin-Proposed Action estimated hardness and 0.0783 mg/L for the Tailings Basin-Geotechnical Mitigation estimated hardness. The maximum predicted values are no greater than one-fourth the corresponding Minnesota surface water quality standard.

- Sulfate. The highest deterministic water quality prediction of sulfate is 63.4 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Proposed Action. This value is slightly greater than the highest deterministic water quality prediction for sulfate of 61.6 mg/L at PM-13 in Year 10 during low flow conditions under Tailings Basin-Geotechnical Mitigation. There is no Minnesota surface water quality standard for sulfate applicable to the Use Classification of the Embarrass River. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 36.1 mg/L.

All parameters meet minimum in stream Minnesota water quality standards at PM-13 during low, average and high flow conditions for all modeled scenarios except aluminum for both Tailings Basin-Proposed Action and Tailings Basin-Geotechnical Mitigation. See Sections 5.2.3.1 and 7.2.3.1 for explanation of the exceedance of the aluminum standard.

7.3.2 Culpability Analysis

The culpability analysis for the Tailings Basin-Geotechnical Mitigation and Tailings Basin-Proposed Action provide very similar results. The main difference is that seepage from Cells 1E/2E of the Tailings Basin is much more significant in Years 15 and 20 for the Tailings Basin-Proposed Action. For a full interpretation of culpability analysis for both Tailings Basin plans see Sections 5.2.3.2 and 7.2.3.2 and Appendix G.

7.3.3 Multiplication Factor to Exceed Standards

A comparison of the deterministic surface water quality predictions presented in Sections 5.2.2 and 7.2.2 clearly indicate that, except for arsenic and somewhat for antimony, potential impacts on the water chemistry of the Embarrass River that might result from implementing the Tailings Basin-Geotechnical Mitigation are smaller than those associated with the Tailings Basin-Proposed Action. This main conclusion is further justified with the summary of factors to exceed standards presented below.

- Antimony. The smallest factor to exceed the corresponding standard is 33.0 under the Tailings Basin-Proposed Action versus 32.0 under the Tailings Basin-Geotechnical Mitigation.
- Arsenic. The smallest factor to exceed the corresponding standard is 34.0 under the Tailings Basin-Proposed Action versus 16.9 under the Tailings Basin-Geotechnical Mitigation.
- Cobalt. The smallest factor to exceed the corresponding standard is 5.7 under the Tailings Basin-Proposed Action versus 13.7 under the Tailings Basin-Geotechnical Mitigation.
- Copper. The smallest factor to exceed the corresponding standard is 3.6 under the Tailings Basin-Proposed Action versus 6.1 under the Tailings Basin-Geotechnical Mitigation.
- Nickel. The smallest factor to exceed the corresponding standard is 6.1 under the Tailings Basin-Proposed Action versus 31.1 under the Tailings Basin-Geotechnical Mitigation.

8.0 Geotechnical Mitigation – Groundwater Quality Modeling

8.1 Modeling Methodology – Operations

Transport of dissolved constituents through the Tailings Basin-Geotechnical Mitigation is complex. It is not practical to simulate all possible processes and factors that ultimately affect concentrations of dissolved constituents in groundwater at the toe of the Tailings Basin. Knowledge gained during the modeling of the Proposed Action, along with a general understanding of transport modeling, allow simplifying assumptions, that will not understate the predictions, to be made. It was determined that two of the complexities that need to be retained for the deterministic water quality predictions are the varying mass loading of constituents from the different source areas and the different transport times through the basin for waters starting at each source area. In addition, it was decided that transport through the unsaturated zone could not be ignored.

8.1.1 MODFLOW-SURFACT Modeling

Travel times through the basin were computed using MODFLOW-SURFACT. MODFLOW-SURFACT is a fully integrated flow and transport code that is based on MODFLOW. MODFLOW-SURFACT includes the ability to simulate unsaturated flow, which is why it was chosen for this application. For the Tailings Basin-Geotechnical Mitigation, the model considered the following source areas: embankments (which consist of LTVSMC tailing overlaying PolyMet Tailing), LTVSMC embankment crests, PolyMet beaches, and the pond (see Figure 8-1 through 8-4). The contribution from each source area to the concentration of dissolved constituents in groundwater leaving the basin at the toe of the LTVSMC embankment was predicted under steady-state conditions. Flow conditions for Year 4, Year 7, Year 15 and Year 20 were used in this analysis. These time periods were selected because they represent significant basin stages from a design standpoint (Year 4 = basin elevation 1,620 feet-MSL, Year 7 = basin elevation 1,660 feet-MSL, Year 15 = basin elevation 1,700 feet-MSL, Year 20 = basin elevation 1,720 feet-MSL). The exact same models that were used for the Tailings Basin-Geotechnical Mitigation water balance were used as the basis of the transport models (see RS13B for documentation of these flow models). For each source area being examined, MODFLOW-SURFACT was used to predict the contribution from that source at down-gradient locations using a unit source concentration.

Transport through the basin considered only advection. Dispersion, retardation and degradation were not simulated. Unsaturated flow was simulated using pseudo-soil relations (see MODFLOW-SURFACT manual for discussion of the simulation of unsaturated flow). The transport equation was solved using the adaptive TVD transport scheme with an automatic time weighting scheme.

For each source area being evaluated, a model run was completed with the concentration of that component set equal to unity and the concentration of all other components equal to zero. For the beach and embankment areas, the concentration was applied to the recharge zone simulating these features. For the pond, the concentration was applied to the constant head cells simulating the pond. This was done using each model (Years 4, Year 7, Year 15, Year 20). For each model run, concentrations were tracked forward in time until equilibrium was achieved or for 1,000 years.

The result of this contaminant transport modeling was a series of breakthrough curves for each source area considered for each flow condition simulated. The breakthrough curves were predicted at a hypothetical well located in the center of the LTVSMC Cell 2E embankment. These curves are shown in Figures 8-5 through 8-11. Figure 8-5 shows the breakthrough curves for the source areas in Cell 2E under Year 4 flow conditions. For the water that infiltrates through the PolyMet tailings on the beach under these flow conditions, 10 percent reaches the toe of the embankment in 3 to 4 years, while 50 percent of the water has reached the toe within 8 years. Figures 8-12 through 8-15 show the percent of the source concentration that reaches the toe of the LTVSMC embankment.

8.1.2 Source Term Load Predictions

SRK Consulting provided mass load terms for each source area for each year of operations. This report is not intended to describe how these loads were computed, that will be done either in a revision to RS54/RS46 or in a separate technical memorandum provided by SRK. However, it can be stated that the methodology used to predict the mass loads is consistent with the methodology presented in Section 7.2.8 of RS54/RS46 (note however that the release ratios have been updated to represent more recent waste characterization humidity cell tests). The load and flow values for the Tailings Basin-Geotechnical Mitigation that are used in this work that were provided by SRK are shown in Tables 8-1 through 8-5.

8.1.3 Spreadsheet Model

A spreadsheet model was developed to predict the concentration of dissolved constituents for water released to the environment using the results from the MODFLOW-SURFACT modeling and the transient SRK loads. The spreadsheet model assumed plug flow for each source area (embankment, LTVSMC Crest, PolyMet Tailings and pond) and used the travel times presented under Section 8.1.1 for the transport times of the plugs. An example of how the travel time data was interpreted is presented below:

> Figure 8-9 shows the time it takes for water infiltrating the LTVSMC Dam Crest area of Cell 2E to reach the toe of the LTVSMC embankment. Data is presented as a series of breakthrough curves, with each curve representing a different flow condition (i.e. conditions during Year 4, Year 7, Year 15 and Year 20). For this work, the average 10 percent breakthrough time was used. Figure 3-5 shows that the 10 percent breakthrough times vary between approximately 10 years for the Year 4 and Year 7 conditions and 30 years for the Year 15 conditions. In order to be conservative, for the LTVSMC dam crest area, an average travel time of 10 years was used. This same travel time was used for the embankment areas. A travel time of 7 years was used for the PolyMet tailings beach areas (see Figure 8-10) and for the pond a travel time of 5 years was used (see Figure 8-11).

The travel time data was used to determine when water would show up at the toe of the LTVSMC embankment. For example, water that infiltrates through the PolyMet tailings beach in Year 5 would show up at the toe of the embankment in Year 12 (a seven year travel time). Table 8-6 shows the source year of water that shows up at the toe of the embankment for each year of operation for each source.

The water that shows up at the toe of the embankment in Year 15 is a combination of the water that infiltrated through the LTVSMC crest and embankment in Year 5, the water that infiltrated through the PolyMet beach in Year 8 and the water that was lost as seepage from the pond in Year 10. Therefore, when making the concentration predictions at the toe of the embankment for Year 15, the Year 5 LTVSMC Crest load, the Year 15 embankment load, the Year 8 PolyMet beach load and the Year 10 pond load is used. The total loads from Cell 2E were applied to the predicted flow out of the basin to the north. The flows used in this calculation came from the MODFLOW-SURFACT model and are presented in Table 8-7. In this manner, the concentration of each dissolved constituent at each year of operation was predicted.

It should be noted that the flows in Table 8-7 are different from the flows in Table 4-4. Table 4-4 presents the total seepage losses from the Tailings Basin where as Table 8-7 presents the seepage losses to the north of Cell 2E. These flows are very similar during the early years of operation when most, if not all of, the unrecovered seepage flows to the north. In the later years, as the head in the Tailings Basin pond increases, more pond seepage flows to the west through Cell 2W. By using the flows in Table 8-7 for the calculation of concentrations, all of the beach and embankment loads are mixed with only the pond seepage flowing north, thus providing a reasonable yet conservative prediction of concentrations. However, these predicted concentrations are applied to all of the unrecovered seepage, which is conservative since the pond water quality is better than the quality predicted seepage.

8.2 Deterministic Groundwater Quality Predictions – Operations

Deterministic water quality predictions for the water leaving the toe of the LTVSMC embankment flowing north are shown in Table 8-8 and on Figures 8-16 through 8-23. Figures 8-16 though 8-23 show the major constituents of concern and are discussed below (note that standards are listed in Table 8-8):

- Figure 8-16 shows the predicted sulfate concentrations. The concentration of sulfate in water leaving the basin as groundwater is below the secondary drinking water standard of 250 mg/L. A peak concentration of 245 mg/L is predicted in Year 11.
- Figure 8-17 shows the predicted concentrations of silver. The concentration of silver in water leaving the basin as groundwater is below the surface water standard of 0.001 mg/L and well below the groundwater standard of 0.03 mg/L (groundwater standard not shown on Figure 8-17 because of scaling). A peak concentration of 0.00099 mg/L is predicted in Year 17.
- Figure 8-18 shows the predicted concentrations of antimony. The concentration of antimony in water leaving the basin as groundwater is above the groundwater standard (0.006 mg/L) but below the surface water standard (0.031 mg/L). A peak concentration of 0.012 mg/L is predicted in Year 12.
- Figure 8-19 shows the predicted concentrations of arsenic. The concentration of arsenic in water leaving the basin as groundwater is temporarily above the groundwater standard of 0.01 mg/L but below the surface water standard. A peak concentration of 0.012 mg/L is predicted in Year 11.
- Figure 8-20 shows the predicted concentrations of cobalt. The concentration of cobalt in water leaving the basin as groundwater is below the surface water standard of 0.005 mg/L. A peak concentration of 0.0025 mg/L is predicted in Year 16. There is no groundwater standard.

- Figure 8-21 shows the predicted concentrations of copper. The concentration of copper in water leaving the basin as groundwater is below the surface water standard of 0.025 mg/L and the groundwater standard of 1 mg/L (groundwater standard not shown on Figure 8-21 because of scaling). A peak concentration of 0.011 mg/L is predicted in Year 20.

- Figure 8-22 shows the predicted concentrations of nickel. The concentration of nickel in water leaving the basin as groundwater is below the groundwater standard of 0.1 mg/L and the surface water standard (hardness dependent). A peak concentration of 0.026 mg/L is predicted in Year 16.

- Figure 8-23 shows the predicted concentrations of zinc. The concentration of zinc in water leaving the basin as groundwater is below the surface water and groundwater standard (groundwater standard of 2 mg/L not shown on Figure 8-23 because of scaling). A peak concentration of 0.082 mg/L is predicted in Year 16.

As shown on Table 8-8, groundwater standards are predicted to be exceeded for fluoride in Years 1 through 6. Due to the conservative manner in which these predictions are made, for these years, the predicted quality of water leaving the basin is equal to the quality of water in the pond in Year 1 (i.e. there are no other source areas included). The pond water quality at start-up is essentially equal to the current water quality in the LTVSMC ponds, which has elevated fluoride concentrations (RS64). High fluoride concentrations are also observed in down-gradient monitoring wells (see analytical data for wells GW-006 and GW-007 in Table 8-9). During PolyMet operations, the fluoride concentration in the pond is predicted to decrease, and by Year 2 is predicted to be below the surface water standard (pond water quality predictions are shown in Table 8-5 and will be discussed in detail in a subsequent SRK memorandum or report). As such, the high fluoride concentrations should be considered a remnant of LTVSMC operation that will improve through time.

8.3 Modeling Methodology - Closure

8.3.1 MODFLOW-SURFACT Modeling

The MODFLOW-SURFACT model of Year 20 conditions was modified to simulate closure conditions. (Closure actually refers to Post-Closure in Section 4.1.1.) The hydraulic conductivity of the beach areas was decreased to account for the bentonite augmentation that is being proposed. The pond was kept at the same size as during operations and was simulated using MODFLOW River Cells with a vertical leakance (i.e. hydraulic conductivity times thickness of layer) equal to 1.5×10^{-5} cm^2/sec.

Transport through the basin considered only advection. Dispersion, retardation and degradation were not simulated. Unsaturated flow was simulated using pseudo-soil relations (see MODFLOW-SURFACT manual for discussion of the simulation of unsaturated flow). The transport equation was solved using the adaptive TVD transport scheme with an automatic time weighting scheme. For each source area being examined, MODFLOW-SURFACT was used to predict the contribution from that source at down-gradient locations using a unit source concentration. Source areas are discussed under Section 8.3.2 and include embankments (which consist of LTVSMC tailing overlaying PolyMet Tailing), LTVSMC embankment crests, PolyMet beaches, and the pond. For each source area, the recharge zone simulating the area (or in the case of the pond, the River Cells) was given a concentration of unity. The result is a series of two-dimensional grids showing contribution of the source concentration to the total predicted concentration within the surficial deposits. These grids are shown in Figures 8-24 through 8-35. It should be noted that wetlands in the model are simulated using model River Cells, as discussed in RS13B. As a result, the wetlands act as a source of dilution for water leaving the basin. This effect of this portion of the model design on the predicted concentrations will be evaluated during the forthcoming uncertainty analysis.

8.3.2 Source Term Load Predictions

SRK Consulting provided maximum mass load terms for each source area during closure. The source areas include the following:

- The embankment in Cell 2E, Cell 1E east side and Cell south side;
- The LTVSMC tailing embankment crest (LTVSMC Crest) in Cell 2E, Cell 1E east side and Cell 1E south side;
- The PolyMet tailing beach in Cell 2E, Cell 1E east side and Cell 1E south side; and
- The pond.

This report is not intended to describe how these loads were computed, that will be done either in a revision to RS54/RS46 or in a separate technical memorandum provided by SRK.

The maximum mass loads were converted to pore water concentrations using the assumed appropriate flow rates. Along with the prediction of maximum concentrations, the time and duration of the peaks was also provided. Using only the peak concentrations, regardless of when they occur, results is a very conservative prediction of water quality. As a result, the deterministic water quality predictions presented in the memorandum for closure should be considered the upper limits, with the likely observed concentrations being lower than the values presented here.

In addition to these PolyMet source areas, the other concentrations that were considered are the concentration of water that infiltrates through Cell 2W and regional groundwater concentrations.

Cell 2W water and regional groundwater quality are presented in Table 1 of the May 29, 2008 memorandum “Changes to Water Quality Model of the Embarrass River Watershed – PolyMet RS74, Tailings Basin-Proposed Action” were used for this work. The concentrations for all source areas included in this work are provided in Table 8-10.

8.3.3 Deterministic Groundwater Quality Predictions

In order to predict the groundwater quality during closure, the grids described in Section 8.3.1 and the concentrations described in Section 8.3.2 were combined using ArcGIS. This was done for all dissolved constituents with a surface water or groundwater standard except where background water quality is over the standards (this applies to aluminum, beryllium, manganese), with the exceptions discussed below. Concentrations were not predicted for chloride, barium, lead, and zinc because all of the source term concentrations were below the standard (see Table 8-10). For each constituent, each source area grid was multiplied by the appropriate source concentration and then all grids were summed to provide the final predicted concentrations.

8.4 Deterministic Groundwater Quality Predictions – Closure

Predicted groundwater qualities within the surficial deposits during closure are shown in Figures 8-36 through 8-47. For several of the parameters (sulfate, fluorite, boron), there is a small area close to the southeast of the Cell 1E southern embankment where either groundwater or surface water criteria are predicted to be exceeded. This is in an area that appears to be bound to the east, south and west by bedrock, which results in water flowing to the north. The area adjacent to the Cell 1E east embankment also shows greater concentrations for several parameters. Flow in this area is vertical through the Tailings Basin and then to the west once the water has entered the native material. The concentrations shown just east of the embankment are likely the result of numerical dispersion (a modeling artifact) and as such should not be considered an environmental concern. In addition to showing the overall concentration distribution, the figures also note the highest concentrations to the northeast of the Cell 2E embankment (where concentrations are often highest) and at the headwaters of Second Creek. The areas of exceedance are between the facility boundary (toe of the LTVSMC dams) and the PolyMet property boundary and closer to the facility boundary than the property boundary.

The following exceedences of groundwater or surface water standards are predicted:

- Sulfate: Figure 8-36 shows the predicted sulfate concentrations. There is a small area northeast of the Cell 2E embankment that is predicted to be over the secondary drinking water standard (250 mg/L). This area is between the basin and the boundary of property owned or leased by PolyMet. There is also a small area directly west of the Cell 1E south embankment that is over 250 mg/L.

- Fluoride: Figure 8-37 shows the predicted fluoride concentrations. There is a very small area directly west of the Cell 1E south embankment that is over the groundwater standard of 2 mg/L. This area is between the basin and the boundary of property owned by PolyMet. In all other areas, the predicted concentration is below the standard.

- Arsenic: Figure 8-39 shows the predicted arsenic concentrations. Areas north, northeast, south and southwest of the Tailings Basin Mitigation are above the groundwater standard of 0.01 mg/L, but all areas (with the exception of the area previously discussed southeast of Cell 1E) are below the surface water standard of 0.053 mg/L. There are no exceedances at the boundary of property owned by PolyMet.

- Iron: Figure 8-44 shows the predicted iron concentrations. There are large areas that exceed the groundwater standard for iron of 0.3 mg/L. This is related to the background concentration applied to recharge to the existing LTVSMC basin (4.6 mg/L) and not to PolyMet's operation of the basin.

- Selenium: Figure 8-46 shows the predicted selenium concentrations. There are small areas west of the Cell 1E southern embankment and east of the Cell 2E embankment that are predicted to exceed the surface water standard of 0.005 mg/L. However, the concentrations are well below the standard at the boundary of property owned by PolyMet. Concentrations are below the groundwater standard (0.03 mg/L).

- Silver: Figure 8-47 shows the predicted silver concentrations. There are small areas west of the Cell 1E southern embankment and east of the Cell 2E embankment that are predicted to exceed the surface water standard of 0.001 mg/L. However, the concentrations are well below the standard at the boundary of property owned by PolyMet. Concentrations are below the groundwater standard (0.03 mg/L).

8.5 Interpretation of Results

8.5.1 Comparison to Water Quality Standards

During operations, there are predicted to be temporary exceedences of the groundwater standard for antimony, arsenic, and fluoride in groundwater at the toe of the dam. The surface water and groundwater standards for aluminum and the groundwater standard for iron and beryllium are predicted to be exceeded during operations at the toe of the dam, however, the groundwater in the area of the basin currently exceeds these standards. During closure, concentrations of sulfate, arsenic, fluoride, selenium and silver in groundwater are predicted to exceed either groundwater or surface water standards in very limited areas immediately adjacent to the Tailings Basin. Similarly, iron is predicted to exceed the groundwater standard, however, this relates to existing conditions and not proposed PolyMet operations. It is PolyMet's understanding that for the purpose of describing potential water quality impacts to groundwater, the property boundary or the point where groundwater discharges to the Embarrass River, whichever occurs closest to the proposed project will be the point of evaluation. For the Tailings Basin-Geotechnical Mitigation, there are no predicted exceedances of groundwater or surface water criteria in closure at the PolyMet property boundary. Based on the modeling results for closure conditions, it can be inferred that the amount of dilution available in the watershed via wetland between the toe of the Tailings Basin and the property boundary will also result in no exceedances of groundwater standards at the property boundary or the Embarrass River during operations. This can be further evaluated during the forthcoming uncertainty analysis for the Tailings Basin-Geotechnical Mitigation.

8.5.2 Culpability Analysis

This section presents the culpability analysis of the Tailings Basin (i.e., the degree of a particular Tailings Basin feature's impact on the overall water quality of the Tailings Basin seepage) for the Tailings Basin-Geotechnical Mitigation. Six parameters were selected for the culpability analysis: antimony, arsenic, cobalt, copper, nickel and sulfate (see Section 4.4). There are four features that contribute to the overall water quality of the Tailings Basin seepage under the Tailings Basin-Geotechnical Mitigation during operations: the Tailings Basin pond, PolyMet beach, LTVSMC crest and embankment. In closure there are five features that contribute to the overall water quality of the Tailings Basin seepage under the Tailings Basin-Geotechnical Mitigation: the Tailings Basin pond, LTVSMC crest, PolyMet Cell 2E beach, PolyMet Cell 1E beach and embankment. All impacts from the Tailings Basin were investigated for Years 1, 5, 10, 15, 20 and Closure. The culpability analysis is completed for two sets of graphs which are presented in Appendix G for Tailings Basin-Geotechnical Mitigation:

- Mass flux of impacts (concentration of the feature multiplied by the flow of the feature).
- Percent contribution of impacts (mass flux of each feature divided by total mass flux).

The 72 figures in Appendix G present the results of the culpability analysis of the Tailings Basin for the Tailings Basin-Geotechnical Mitigation. The main results of this analysis are presented below:

- Seepage from the Tailings Basin pond represents the only input determining concentrations of sulfate, antimony, arsenic, cobalt, copper and nickel in Years 1 and 5.

- Seepage from the Tailings Basin pond represents the main input determining concentrations of sulfate, antimony, cobalt, copper and nickel in Years 10, 15, and 20.
- Seepage from the Tailings Basin pond, followed by seepage from the PolyMet beach, represents the main inputs determining concentrations of arsenic in Years 10, 15 and 20.
- Seepage from the embankment, followed by seepage from the LTVSMC crest and PolyMet Cell 1E beach, represents the main inputs determining concentrations of sulfate, copper and nickel in Closure.
- Seepage from the PolyMet Cell 1E beach, followed by seepage from the PolyMet Cell 2E beach, represents the main inputs determining concentrations of antimony in Closure.
- Seepage from the embankment, followed by seepage from the PolyMet Cell 1E beach and LTVSMC crest, represents the main inputs determining concentrations of arsenic in Closure.
- Seepage from the embankment, followed by seepage from the LTVSMC crest, represents the main inputs determining concentrations of cobalt in Closure.

8.6 Comparison of Proposed Action and Geotechnical Mitigation

The maximum predicted concentrations during operations and closure for the key dissolved constituents for the Proposed Action and the Geotechnical Mitigation are discussed below. For this comparison, concentrations predicted at the toe of the Cell 2E embankment are compared. For the Proposed Action, the "Total Concentration" values are used.

- Antimony: For the Proposed Action, a maximum antimony concentration of 0.016 mg/L is predicted during operations, compared to a maximum concentration of 0.012 mg/L for the Geotechnical Mitigation. In closure, the average antimony concentration for the Proposed Action is predicted to be 0.0054 mg/L. For the Geotechnical Mitigation, a maximum local concentration of 0.0018 mg/L is predicted. For both designs, the predicted concentrations are over the groundwater standard (0.006 mg/L) during operations but below the groundwater standard in closure and below the surface water standard (0.031 mg/L) for operations and closure.
- Arsenic: For the Proposed Action, a maximum arsenic concentration of 0.016 mg/L is predicted during operations, compared to a maximum concentration of 0.012 mg/L for the Geotechnical Mitigation. In closure, the average arsenic concentration for the Proposed Action is predicted to be 0.012 mg/L. For the Geotechnical Mitigation, a maximum local concentration of 0.045 mg/L is predicted. For both designs, the concentrations are predicted to be temporarily over the groundwater standard (0.01 mg/L) during operations but well below the surface water standard (0.053 mg/L). For the Geotechnical Mitigation only, concentrations are predicted to be over the groundwater standard in closure.

- Cobalt: For the Proposed Action, a maximum cobalt concentration of 0.0092 mg/L is predicted during operations, compared to a maximum concentration of 0.0025 mg/L for the Geotechnical Mitigation. In closure, the average cobalt concentration for the Proposed Action is predicted to be 0.0014 mg/L. For the Geotechnical Mitigation, a maximum local concentration of 0.0047 mg/L is predicted. For the Proposed Action, the predicted concentration is temporarily above the surface water standard of 0.005 mg/L. All other concentrations are below the standard. There is no groundwater standard for cobalt.

- Copper: For the Proposed Action, a maximum copper concentration of 0.022 mg/L is predicted during operations, compared to a maximum concentration of 0.011 mg/L for the Geotechnical Mitigation. In closure, the average copper concentration for the Proposed Action is predicted to be 0.018 mg/L. For the Geotechnical Mitigation, a maximum local concentration of 0.021 mg/L is predicted. All predicted concentrations are below the groundwater standard (1 mg/L) and the surface water standard (0.023 mg/L).

- Nickel: For the Proposed Action, a maximum nickel concentration of 0.16 mg/L is predicted during operations, compared to a maximum concentration of 0.026 mg/L for the Geotechnical Mitigation. In closure, the average nickel concentration for the Proposed Action is predicted to be 0.015 mg/L. For the Geotechnical Mitigation, a maximum local concentration of 0.0083 mg/L is predicted. For the Proposed Action, the concentration is predicted to be temporarily over the groundwater standard (0.1 mg/L) and the surface water standard (0.127 mg/L). For the Geotechnical Mitigation, groundwater and surface water standards are not predicted to be exceeded.

- Sulfate: For the Proposed Action, a maximum sulfate concentration of 246 mg/L is predicted during operations, compared to a maximum concentration of 245 mg/L for the Geotechnical Mitigation. In closure, the average sulfate concentration for the Proposed Action is predicted to be 110 mg/L. For the Geotechnical Mitigation, a maximum local concentration of 270 mg/L is predicted. With the exception of the local maximum concentration in closure for the Geotechnical Mitigation, all concentrations are predicated to be below the secondary drinking water standard of 250 mg/L.

- Zinc: For the Proposed Action, a maximum zinc concentration of 0.085 mg/L is predicted during operations, compared to a maximum concentration of 0.082 mg/L for the Geotechnical Mitigation. In closure, the average zinc concentration for the Proposed Action is predicted to be 0.020 mg/L. For the Geotechnical Mitigation, zinc concentrations were not predicted for closure because the concentrations of all source terms were below the standards. For both designs, predicted concentrations are below the groundwater standard (2 mg/L) and the surface water standard (0.295 mg/L).

9.0 Conclusions

This RS74B report presents the assessment of potential impacts of the NorthMet Project on the water quality of downstream watercourses and water bodies in the Embarrass River watershed.

In terms of surface water quality modeling, the assessment includes a summary of background flow and water quality data for natural surface waters and groundwater as well as existing point and nonpoint discharges, development and calibration of mass-balance models, and use of these models to deterministically predict water chemistry at different locations in the study watershed as a result of the NorthMet Project development and closure. Estimated concentrations for different water quality parameters under wet, average and dry weather/flow conditions were determined for several stages in the development and closure of the Plant Site. The estimated concentrations were compared against the most stringent numeric chronic aquatic toxicity-based Minnesota surface water quality standards (Minnesota Rules Chapters 7050 and 7052) for all Minnesota waters and the Lake Superior Basin for the appropriate use classification for the watercourse or water body being analyzed.

In terms of groundwater quality modeling, the assessment considered loads from the embankment, beach and pond areas of the Tailings Basin in order to predict the concentration of water leaving the toe of the existing dams. Estimated concentrations for numerous dissolved constituents were predicted for each year of operation and closure. The estimated concentrations in groundwater leaving the toe of the Cell 2E embankment were compared against the most stringent groundwater standards (MCL, sMCL or HRL).

RS74 Draft-02 incorporates the following main changes and additions from RS74 Draft-01.

- Inclusion of both surface and groundwater water quality modeling.
- Modeling two designs for the basin, Tailings Basin-Proposed Action and Tailings Basin-Geotechnical Mitigation.
- Additional surface water quality monitoring data of the Embarrass River and groundwater quality monitoring of Cell 2W of the Tailings Basin.
- Updates to the chemistry of the Hydrometallurgical Residue Facility.

The NorthMet Project proposes to reuse/recycle water by collecting and treating process water generated at the Mine Site (in the Partridge River watershed) so that it can be pumped to the Plant Site (in the Embarrass River watershed) for use as process make up water. In addition, the water balance of the Tailings Basin will be managed so as to eliminate the need for direct discharge. In other words, no point discharges of process waters to surface waters of the State are planned from the NorthMet Project during the twenty years of mining and processing operations or during near term closure. However, some flow to groundwater is anticipated - seepage from the flotation tailings impoundment and liner leakage from the hydrometallurgical residue cells in the Embarrass River watershed. Thus, the primary potential water quality impacts from the NorthMet Project during operations are indirect impacts to groundwater and subsequent indirect impacts to surface waters via the indirect groundwater impacts. Therefore, the focus of the modeling in the Embarrass River watershed was expanded and redirected from what was previously proposed.

The chemical load contribution from the Plant Sites' leakage/seepage to the Embarrass River was based on geochemical evaluations of hydrometallurgical residue cells leachate and flotation tailings impoundment seepage to groundwater. It should be highlighted that these geochemical evaluations used conservative assumptions so that the eventual predictions were conservative with respect to uncertainty. Using mass-balance models for the water quality assessment of the Embarrass River is conservative because these models do not account for some features of the physical and chemical phases of the transport of a chemical to or in a watercourse or water body that would result in lower concentrations than those presented in this report, in particular for sulfate, copper, nickel and cobalt.

For the Proposed Action and Geotechnical Mitigation, the consistently conservative assumptions and model approach used in the surface water quality assessment, predict that concentrations for all water quality parameters evaluated will meet appropriate Minnesota water quality standards at different locations along the Embarrass River. The exceptions are aluminum in the Embarrass River under Tailings Basin-Proposed Action and Tailings Basin-Geotechnical Mitigation. The average monitored concentration of aluminum in the Embarrass River at PM-13 already exceeds the standards even without project aspects added. Data collected in the Partridge River above Colby Lake also demonstrates aluminum exceedances in the 1970s and 2000s, including a sample taken from the South Branch of the Partridge River, a watershed without mining impacts.

For the Proposed Action, several groundwater standards (sulfate, antimony, arsenic and nickel) and surface water standards (silver, antimony, cobalt and nickel) are predicted to be temporarily exceeded in the groundwater leaving the toe of the Cell 2E embankment during operations. For this design, the only standard predicted to be exceeded (but below the surface water standard) is arsenic. Because of geotechnical concerns with this design, no additional time was spent trying to further refine the predictive models or developing mitigations that could be modeled so as to demonstrate no exceedances of standards.

For the Geotechnical Mitigation, during operations and closure, concentrations of some pollutants in groundwater are predicted to exceed either groundwater or surface water standards in very limited areas immediately adjacent to the Tailings Basin. It is PolyMet's understanding that for the purpose of describing potential water quality impacts to groundwater, the property boundary or the point where groundwater discharges to surface water, whichever occurs closest to the proposed project will be the point of evaluation. For the Tailings Basin-Geotechnical Mitigation, there are no predicted exceedences of groundwater or surface water criteria in closure at the PolyMet property boundary or at the Embarrass River. Based on the modeling results for closure conditions, it can also be inferred that the amount of dilution available in the watershed via the wetlands between the toe of the tailings basin and the property boundary will result in no exceedances of groundwater standards at the property boundary or the Embarrass River during operations. This will be further evaluated during the forthcoming uncertainty analysis for the Tailings Basin-Geotechnical Mitigation.

In summary, for the Tailings Basin-Geotechnical Mitigation conservatively deterministically predicted project water quality impacts to the Embarrass River and its watershed beyond PolyMet's property boundary do not result in measurable exceedances of the appropriate Minnesota surface and groundwater quality standards. This conclusion will be further evaluated as part of the forthcoming uncertainty analysis. Finally, it is expected that the rigorous monitoring of groundwater near the Tailings Basin and water in the Embarrass River will be conducted during operations and closure as specified in the required regulatory permits. The results of this monitoring will be used to confirm the deterministic water quality predictions. In the event that monitoring indicates a projected trend beyond the predictions, several mitigation options are available to control unpredicted adverse water quality impacts, including:

- A water treatment facility could be constructed and operated to control the dissolved pollutant load in the tailings pond, a major source of flow to groundwater.
- Additional cleaning steps could be added to the flotation and concentrating process to reduce the pollutant load to the Tailings Basin.
- A variety of Tailings Basin water recovery systems could be installed to recover groundwater near the perimeter of the basin to accommodate treatment and reuse of the recovered water.

- A variety of barrier systems could be installed to control the release of Tailings Basin groundwater to the surrounding environment.
- A variety of passive treatment systems could be installed in problematic areas to control the release of Tailings Basin groundwater to the surrounding environment.

10.0 References

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