RS74A Surface Water and Groundwater Quality Modeling: Mine Site Draft 02

PolyMet Mining Inc.

September 2008

RS74A Surface Water and Groundwater Quality Modeling: Mine Site
Draft 02

PolyMet Mining Inc.

September 2008

4700 West 77th Street
Minneapolis, MN 55435-4803
Phone: (952) 832-2600
Fax: (952) 832-2601

BARR

RS74A Surface Water and Groundwater Quality Modeling of Mine Site – Partridge River Watershed

Draft 02

Table of Contents

List of Tables

List of Figures

List of Appendices

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 (see Figures 1-4 through 1-11). 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, RS74A 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 Partridge 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 (Mine Site-RA1).
- 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 (this 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 (a separate 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 eleven technical memoranda.

1.3 Related Reports

The information on flows and water quality at the Mine 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.

- *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.

- *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 E of this RS74B report.

- *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 flooding 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 E of this RS74B report.

- *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.

- *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.

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 Partridge 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 (RS74A) focuses on the Mine Site and the Partridge watershed. The Plant Site and the Embarrass River watershed are covered in RS74B.

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 Mine Site to the Partridge 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 plan of the Mine Site (Proposed Action and RA1). During post-closure, West Pit overflow to the Partridge River is expected for both the Mine Site-Proposed Action and Mine Site-RA1.

Although there will be no direct discharge during operations or closure, some leakage/seepage to groundwater is anticipated from lean ore and waste rock stockpiles, overburden areas, sumps, and the process water ponds in the Partridge River watershed (see RS23T and RS49) during these periods, and from East Pit and West Pit seepage to groundwater during closure and post-closure for both the Mine Site-Proposed Action and Mine Site-RA1. 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 Partridge River watershed was expanded and redirected.

1.4.2 Surface Water Quality Modeling

The water quality assessment presented in RS74A was conducted using mass-balance models that were developed and calibrated to quantify the impacts of the Mine Site operations on the water chemistry at different locations along the Partridge River (including Colby Lake) under wet, average and dry weather/flow conditions for the Proposed Action and RA1. In general, 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 along groundwater flowpaths; adsorption 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 nonpoint discharges were estimated based on historic and recent monitoring water quality results. The mass-balance models for the Partridge 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 Peter Mitchell Pit of Northshore Mining Company (Northshore) in the Partridge 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 Partridge River, whereas Class 1B (drinking water) and Class 2Bd (recreational purposes and aquatic life; protected as a source of drinking water) Minnesota water quality standards are applicable to Colby Lake.

1.4.3 Groundwater Quality Modeling

Groundwater quality modeling was conducted for RS74A 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 Partridge 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 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:

- Potential future discharges from the projected Mesabi Nugget facility have not been included because the permitted discharge location for the Mesabi Nugget project is to Second Creek (http://www.pca.state.mn.us/hot/mesabi-nugget.html), a watershed that drains toward the Partridge River downstream of Colby Lake, i.e., outside the study area defined in the final SDD for the Partridge River watershed.

- The proposed Cliffs-Erie Railroad Pellet Transfer Facility construction and operation will not involve changes on the discharge volume or discharge quality from its past use, except for TSS. It is assumed here that sedimentation ponds will be constructed to control concentrations of TSS. In addition, the proposed discharge would be to Second Creek, a watershed that drains toward the Partridge River downstream of Colby Lake, i.e., outside the study area defined in the final SDD for the Partridge River watershed.

- Minnesota Power's Laskin Energy Center, a 110 megawatt coal-fired electricity generating facility, is located less than 1 mile northwest of the city of Hoyt Lakes. The Laskin Energy Center withdraws water from Colby Lake and discharges water to the Partridge River downstream of Colby Lake, i.e., outside the study area defined in the final SDD for the Partridge River watershed. Besides, discharges from the Laskin Energy Center under NPDES Permit MN0000990 are basically constrained by a maximum monthly water temperature, and this parameter is not part of the water quality assessment herein; Minnesota

Power submitted a report in June 2007, which concluded that not observable adverse impacts on fish population of species diversity could be attributed to the thermal discharge.

- 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.

- Abandoned flooded taconite pits (Pit 5S and Pit 3) and waste rock stockpiles from LTVSMC past operations drain to the headwaters of Wyman Creek. Two surface water monitoring stations were located in this watershed (see RS76) upstream and downstream of an alternative location for waste rock storage by PolyMet. Monitoring has been discontinued at these sites because PolyMet no longer intends to use this location for stockpiles. Because no changes are anticipated for the LTVSMC mine features, and water quality data used to determine background water quality in the Partridge River watershed (including Colby Lake) corresponds to monitoring in the 2000's hence accounts for the current conditions, there is no need to include these features in the present water quality assessment.

- 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 RS74A report are to:

- Present a summary of background water quality data and calibrate mass-balance models for the Partridge 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 Partridge River watershed to evaluate the potential impact of the NorthMet Project for both the Mine Site-Proposed Action and the Mine Site-RA1 on the water quality of the Partridge River. If the deterministic water quality predictions do not meet the Minnesota water quality standards, propose mitigation and contingency plans to meet the standards.

- Evaluate potential groundwater quality impacts for the aquifers at the Mine Site from the NorthMet Project for both the Mine Site-Proposed Action and the Mine Site-RA1.

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 Partridge 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 Northshore discharges to the Partridge River, the City of Hoyt Lakes – Wastewater Treatment Plant discharge to Whitewater Reservoir, and the future LTVSMC discharge to Colby Lake-Partridge River.

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

- Section 4.0 presents the scenarios (stages of Mine Site development, closure and post-closure) and locations in the Partridge 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, overflow and drainage flows from the Mine Site (liner leakage and seepage from waste rock and lean ore stockpiles, sumps and overburden areas; liner leakage and seepage from the process water ponds and Wastewater Treatment Facility (WWTF) ponds; East Pit and West Pit seepage to groundwater during closure; and West Pit overflow during post-closure) for the Mine Site-Proposed Action and Mine Site-RA1. Only changes with respect to the Mine Site-Proposed Action are presented in the discussion about the Mine Site-RA1.

- Section 5.0 describes the methodology followed to develop the surface water quality mass-balance models for the Partridge 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 Mine Site-Proposed Action is given. The deterministic surface water quality predictions at different locations along the Partridge 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 Mine Site for the Proposed Action. A summary of input data to the groundwater quality model for the Mine Site-Proposed Action is given. Future groundwater quality is predicted along flowpaths from each pertinent Mine Site feature 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 Mine Site-RA1. The deterministic surface water quality predictions at different locations along the Partridge 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 Mine Site-RA1 are compared to those of the Mine Site-Proposed Action.

- Section 8.0 describes the methodology and results for the deterministic groundwater quality impact predictions for the aquifers at the Mine Site for the RA1. A summary of input data to the groundwater quality model for the Mine Site-RA1 is given. Future groundwater quality is predicted along flowpaths from each pertinent Mine Site feature and compared to Minnesota groundwater quality standards.

- Section 9.0 presents the conclusions of the surface water and groundwater quality assessment conducted for the Partridge River watershed.

2.0 Partridge River Watershed

2.1 General Characteristics

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

2.1.1 Location

The Partridge River is a tributary of the St. Louis River. The Partridge River flows southwest to Colby Lake, and continues a short distance from there before joining the St. Louis River south of Aurora. The study watershed for this water quality assessment comprises the watershed starting at the headwaters of the Partridge River and including Colby Lake and Whitewater Reservoir, for a total catchment area of 127.8 square miles (see Figure 1-2). The total length of the Partridge River down to the United States Geological Survey (USGS) gaging station #04015475 - Partridge River above Colby Lake at Hoyt Lakes is approximately 27.7 miles. The terrain ranges from an elevation of 1,609.4 feet above mean sea level (feet-MSL) at its headwaters to an elevation of 1,459.0 feet-MSL near the confluence with Wyman Creek, for a catchment area of 103.4 square miles. The Partridge River varies from sluggish, marshy reaches to large open ponds to steep boulder rapids.

2.1.2 Land Use/Land Cover

The Partridge River watershed is a mix of upland and marshland, with little development. The combined use of the 2001 National Land Cover Dataset (NLCD), the National Wetlands Inventory (NWI) dataset, and the USGS Gap Analysis Program (GAP) dataset indicates that the Partridge River watershed is dominated by wetlands (approximately 40 percent) and upland forests (approximately 50 percent). A detailed description of the available land use data sets for the Partridge River watershed is included in RS73A.

2.1.3 Climate

As indicated in RS73B, the mean annual precipitation for the study area 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 Partridge 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 Partridge 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. Results from the hydrologic/hydraulic model of the Partridge River watershed (see RS73A and RS73B) indicate that the actual total evapotranspiration from the study watershed (including evaporation from open water surfaces) is 16.8 inches per year. This value is very similar to the mean evapotranspiration of 16 inches per year suggested by 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 two stations within the study area of the Partridge River watershed (USGS gage #04015475 – Partridge River above Colby Lake near Hoyt Lakes, and USGS gage #04015455 – South Branch Partridge River near Babbitt). The locations of the two stream gaging stations are shown in Figure 1-2, and the periods of record are presented in RS73A.

RS73A and RS73B presented the development, calibration and use of a hydrologic/hydraulic model of the Partridge River watershed corresponding to USGS gage #04015475. The model was built in XP-SWMM. Use of this model for existing conditions and different stages of the Mine Site development and closure (see Section 4.1.1) allowed estimation of flows at several locations along the Partridge River (see Section 4.1.1). Final estimated values to use in this water quality modeling assessment include:

- Low flow (baseflow) = Average of the 30-day minimum annual flows, based on continuous simulations with XP-SWMM for the period 1978-1988, and percentage reduction of baseflow (with respect to existing conditions) obtained from groundwater modeling of the NorthMet Mine Site using MODFLOW (see Table 2-1; more details about the groundwater model are presented in Appendix B of RS22). The groundwater model developed for the Mine Site has been refined since RS74 Draft-01 to reflect the Mine Site-Proposed Action. As a result of this refinement, new percent reductions in Partridge River baseflow from existing conditions were estimated. The percent reduction in baseflow, presented in Table 2-1, represent the baseflow reduction (in cubic feet per second (cfs)) divided by the existing conditions flow at each location in the Partridge River. The reduction in baseflow at each location in the Partridge River downstream of SW-002 was calculated by summing the incremental baseflow reductions upstream of that location. This method is different than that used for RS74 Draft-01 and was chosen to prevent any “artificial” gaining of baseflow when combining the MODFLOW and XP-SWMM results. The low flow is assumed to represent dry weather/flow conditions. The average of the 30-day minimum annual flows, reduced by the appropriate baseflow reduction, are presented in Table 2-2.

- Average flow = Mean annual flow, based on continuous simulation with XP-SWMM for the period 1978-1988. The average flow is assumed to represent average weather/flow conditions. Results are presented in Table 2-3.

- High flow = Peak flow associated with the 10-yr, 24-hr flood event, based on an event-based simulation with XP-SWMM using a rainfall value of 3.4 inches (Huff and Angel, 1992) to drive the model. The event-based XP-SWMM model was run only for existing conditions. The peak flows occurring during other years of mine operation were calculated by multiplying the existing conditions peak flow by the ratio of the existing conditions average flow to the average flow for a particular stage of Mine Site development or closure (i.e. applying a reduction ratio based on the average flows). The high flow is assumed to represent wet weather/flow conditions. Results are presented in Table 2-4.

The low, average and high flow conditions in the Partridge River considered representative for both the Mine Site-Proposed Action and the Mine Site-RA1. See Section 7.1.3.1 for discussions about the assumptions and implications of this statement.

2.1.5 Quaternary and Bedrock Geology

Geomorphically, the Mine Site is part of the Superior Upland Province and is characterized by bedrock hills and ridges, which are interspersed with peat bogs and wetlands (Olcott and Siegel, 1978). At the Mine Site, the bedrock surface appears to be hummocky. 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 Dunka River basin northeast of the Mine Site 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. At the Mine Site, the sediments average about 12-feet thick, generally less than 25 feet thick, with local depths over 50 feet.

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. Based on test trenches and drill core from the Mine Site (see RS02, RS10 and RS10A), the surficial deposits in this area consist primarily of silty sand, which is interbedded with clay and silt.

The NorthMet mine pits will be located primarily within the Duluth Complex, with the Virginia Formation encountered in some locations along the north-west face of the East Pit. The Biwabik Iron-Formation will not be encountered in the pits.

2.1.6 Hydrogeology

Saturated conditions exist within the unconsolidated deposits at the Mine Site. Groundwater divides in this area generally coincide with surface water divides. However, groundwater flow is interrupted by bedrock outcrops, which force deviations in the groundwater flow field (Siegel and Ericson, 1980). Groundwater flow is generally towards the Partridge River, as shown on Figure 2-1. Because of the shallow nature of the aquifer, flow paths are generally thought to be short.

Groundwater flow within the bedrock units is primarily through fractures and other secondary porosity features, as the rocks have low primary hydraulic conductivity. The Biwabik Iron-Formation is generally considered to be the most permeable unit, locally acting as a water source for residential and community wells, with the Virginia Formation and Duluth Complex being less permeable (Siegel and Ericson, 1980). Aquifer tests were conducted at the Mine Site to determine aquifer properties of the Duluth Complex and the Virginia Formation. Four pumping tests were conducted in monitoring wells constructed within the Virginia Formation. The hydraulic conductivity values measured in these wells ranged from 0.0024 to 1.0 feet per day (ft/day), with a geometric mean of 0.17 ft/day (see RS10). Single well aquifer tests were also conducted within exploratory drill holes completed within the Duluth Complex. Hydraulic conductivity values measured in these boreholes ranged form 0.00026 to 0.041 ft/day, with a geometric mean of 0.0024 ft/day (see RS02).

Near the surface, water in the bedrock is thought to be hydraulically connected with the overlying surficial aquifers, resulting in similar flow directions. Recharge to the bedrock aquifers is by infiltration of precipitation in outcrop areas and leakage from the overlying surficial aquifers (Siegel and Ericson, 1980). The bouldery drift of the Rainy Lobe that covers the Mine Site has an estimated hydraulic conductivity range of 0.1 to 30 ft/day (Siegel and Ericson, 1980). Lab permeameter tests on the silty sand from drill core and test trenches at the Mine Site found the hydraulic conductivity values to be 0.00043 to 0.0081 ft/day, while field testing of the various unconsolidated deposits found a range in hydraulic conductivity values of 0.012 to 31 ft/day (see RS02). The ability of this unit to transmit water is highly dependent on the thickness of the sediments (Adams et al., 2004; Siegel and Ericson, 1980). In general, groundwater flows from northwest to southeast.

2.2 Past and Current Point and Nonpoint Discharges

2.2.1 Northshore Peter Mitchell Pit

As indicated in RS73A, past mining activities have impacted and continue impacting the natural hydrologic regime (and water chemistry) of the Partridge River. One of these impacts is due to Northshore (originally Reserve Mining Company), which began mining operations in the Peter Mitchell Pit located north of the Mine Site (see Figure 1-2) around 1956. Discharges from the Peter Mitchell Pit to the headwaters of the Partridge River have occurred periodically since 1956, but no pumping records are available prior to 1988. (Figure 19 of RS73A shows the approximate locations of past and current Northshore water appropriations from and discharges into the Partridge River.) Inactive portions of the Peter Mitchell Pit have been allowed to fill with water, but pumping from active mining areas and discharges to the Partridge River currently continue. MDNR water appropriation permit 822097 authorized Northshore to withdraw up to 29,700 gallons per minute (gpm) (66.2 cfs) for mine dewatering (referred to as “water level maintenance”) in the Peter Mitchell mine. This permit applies to discharges to both the Partridge River and the Dunka River.

Mine pumping records from Northshore beginning in 1988 are available from the MPCA records (http://www.pca.state.mn.us/data/edaWater/index.cfm) for the period 1999-2005 (see Table 2-5). These mine discharges could be directed to the Partridge River, Second Creek, or Dunka River, but since they depend on the area being mined, they never occur simultaneously to more than one stream. Therefore there are periods in which no discharge occurs from the Peter Mitchell Pit to the Partridge River. The highest reported monthly discharge to the Partridge River was 34 cfs. Low-flow conditions are of particular interest in this report. Additional pumping data for years 2004 and 2006 were provided by Cleveland-Cliffs (email communication from Nancy Smith dated April 5, 2007); the data show that average monthly discharge can be greater than 14 cfs during periods of low flow.

Site PM-1 (see RS76) is located at the Northshore discharge to the Partridge River, upstream of surface water monitoring station SW-001 (see Section 4.1.1 and Figure 1-2). The average baseline water quality data sampled at Site PM-1 reported in RS74 Draft-01included monitoring data from

2004 and 2006. Additional surface water quality monitoring was conducted by PolyMet during 2007 at the monitoring stations PM-1, SW-002, SW-003, SW-004 and SW-005. The 2007 monitoring data was used to update the average baseline concentrations measured in the Partridge River. The results for Site PM-1 are presented in Table 2-6; datasets of water quality data at Site PM-1 are included in RS63 and RS76. Average concentration of arsenic is 0.0065 milligrams per liter (mg/L), of sulfate is 22 mg/L, of copper is 0.00124 mg/L, of nickel is 0.00155 mg/L, and of cobalt is 0.00050 mg/L. Antimony was not measured at PM-1. Therefore, the average concentration of antimony monitored in groundwater in the Partridge River watershed at the Mine Site was used in the model (0.0015 mg/L).

2.2.2 City of Hoyt Lakes Wastewater Treatment Plant

There are municipal discharges from the Wastewater Treatment Plant of the City of Hoyt Lakes (WWTP-Hoyt Lakes) into Whitewater Reservoir, in the Partridge River watershed. Mr. Floyd Nelson, Water and Sewer Supervisor for City of Hoyt Lakes informed Barr during a telephone conversation on April 24, 2007 that the City of Hoyt Lakes has no plans to change or to modify the WWTP-Hoyt Lakes for the next 25 years.

The WWTP-Hoyt Lakes has an installed, operative capacity to treat up to 665,000 gallons per day (gpd) (1.03 cfs), and with a modest amount of maintenance and repair work the treatment capacity could be increased to 1,000,000 gpd (1.55 cfs). The currently treated average flow is 250,000 gpd (0.39 cfs). The installed, operative capacity of 665,000 gpd is considered sufficient to meet foreseeable future needs derived from projected population growth.

In the absence of water quality information for metals from the WWTP-Hoyt Lakes effluent, 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 proxy. The data from Wisconsin covers the period 2002-2007, and it has been screened to include only communities without industrial sources of metals. Characteristic water quality for the WWTP-Hoyt Lakes effluent is presented in Table 2-7 (copper, nickel and zinc).

2.2.3 LTV Steel Mining Company (LTVSMC)

Erie Mining Company (predecessor to LTVSMC) began mining taconite in the Colby Lake watershed in the 1950’s. Five former LTVSMC mine pits (Pit 5S, Pit 3, Pit 2WX, Pit 2W and Pit 2E) are located within the Colby Lake watershed (Adams et al., 2004). Pit 5S and Pit 3 are overflowing now and are included in the model calibration (see discussion in Section 1.4.4). Pit 2WX, Pit 2W and Pit 2E are located within the watersheds of two unnamed creeks north of Colby Lake (see Figure 1-2).

In 2000, the closure of LTVSMC halted active dewatering in these pits and they began to fill with water. The East Range Hydrology Study (Adams et al., 2004) predicts that Pit 2W (and Pit 2E, which discharges to Pit 2W) will begin to overflow sometime between 2014 and 2020, while Pit 2WX will begin to overflow sometime between 2013 and 2017. According to the study by Adams et al. (2004), these pits could have an impact on Colby Lake water levels and the management of Whitewater Reservoir. It is also possible that the water chemistry of pit lake discharges could alter water chemistry within Colby Lake.

The two unnamed creeks drain a combined watershed area of about 5,400 acres. The total watershed area tributary to Colby Lake and Whitewater Reservoir is approximately 81,000 acres. Flows to Colby Lake from the unnamed creeks will not have a significant impact on Colby Lake water levels compared to the inflow from the Partridge River, which drains about 66,000 acres.

The two unnamed creeks are likely to have little impact on Colby Lake water quality based on the location of their outlets to Colby Lake and the bathymetry of the lake itself. The unnamed creek that will receive water from the watershed including Pit 2WX enters Colby Lake less than 1,000 feet from the lake outlet to the Partridge River. The other unnamed creek (which drains an area including Pit 2E and Pit 2W) also enters Colby Lake close to the downstream outlet. At this location, the lake is narrow and shallow. Combined with a hydraulic residence time of less than one month (based on the average flow in the upstream Partridge River of 87.1 cfs and an approximate lake volume of 5,300 acre-feet), the local bathymetry will most often result in flushing of these inflows downstream and inhibit mixing in Colby Lake. While diversions from Colby Lake to Whitewater Reservoir will increase the average hydraulic residence time of the Colby Lake-Whitewater Reservoir system, diversions to Whitewater Reservoir occur only during periods of high flow, when inputs from the unnamed creek will be flushed downstream regardless of the diversion. Because of this, these inputs were not included in the water quality modeling of Colby Lake.

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 Mine Site, Partridge River and Colby Lake.

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

The Minnesota surface water quality standards for the Partridge River and Colby Lake 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.

3.1.8.1 Partridge River

The Partridge 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.

3.1.8.2 Colby Lake

Colby Lake is listed in Minnesota Rules Chapter 7050.0470. Therefore, Class 1B Minnesota surface water quality standards (drinking water), Class 2Bd (recreational purposes and aquatic life; cold or warm water sport or commercial fish; protected as a source of drinking water), and Class 3C (industrial cooling and materials transport) are applicable. Actually, Colby Lake is used by the City of Hoyt Lakes as a source of potable water. 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.

At the Mine Site, deterministic groundwater quality predictions were evaluated at the property boundary, at the Dunka Road and at the Partridge River (i.e., the evaluation locations).

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

4.1 Locations and Scenarios Evaluated

4.1.1 Surface Water

Flows and water chemistry for both the Mine Site-Proposed Action and Mine Site-RA1 are reported/deterministically predicted at the following locations in the Partridge River (see Figure 1-2). These locations and their designations correspond to those used for the proposed monitoring plan as presented in Section 3.1.5.13 of the Detailed Project Description.

- Surface water monitoring station SW-001. This location on the north branch of the Partridge River is upstream of all PolyMet mine facilities (but downstream of the Peter Mitchell Pit discharge), and its watershed area is 6.2 square miles.

- Surface water monitoring station SW-002. This location on the north branch of the Partridge River is northeast of the Mine Site, and its watershed area is 13.3 square miles.

- Surface water monitoring station SW-003. This location on the north branch of the Partridge River is east of the Mine Site, and its watershed area is 15.2 square miles.

- Surface water monitoring station SW-004. This location on the north branch of the Partridge River is immediately upstream of the confluence with the south branch, downstream of 64 percent of the proposed Mine Site facilities by the end of Year 20, and its watershed area is 23.0 square miles.

- Surface water monitoring station SW-004a. This location on the Partridge River is immediately downstream of the confluence of the north and south branches, downstream of 99 percent of the proposed Mine Site facilities by the end of Year 20, and its watershed area is 54.4 square miles.

- Surface water monitoring station SW-005. This location on the Partridge River is at the railway crossing, downstream of 100 percent of the proposed Mine Site facilities by the end of Year 20, and its watershed area is 98.7 square miles. The Mine Site (4.7 square miles) represents less than 5 percent of this watershed.

- USGS gaging station #04015475. This location on the Partridge River is upstream of Colby Lake, and its watershed area is 103.4 square miles.

- Colby Lake.

Locations SW-001, SW-002, SW-003, SW-004 and SW-005 were selected because background water quality data were available (see RS63 and RS76). Location SW-004a was selected because is located downstream of 99 percent of the proposed Mine Site facilities. The USGS gage location was selected because flow data were available.

The following eight scenarios were evaluated for the Partridge River watershed under the Mine Site-Proposed Action, depending on the stage of development or closure of the Mine Site:

- Existing Conditions (i.e., without NorthMet Project).
- Year 1 (end of Mine Site development Year 1).
- Year 5 (end of Mine Site development Year 5).
- Year 10 (end of Mine Site development Year 10).
- Year 15 (end of Mine Site development Year 15).
- Year 20 (end of Mine Site development Year 20; that is, end of mining operations).
- Closure (i.e., during Mine Site closure, which corresponds to the period of West Pit flooding).
- Post-Closure (i.e., after Mine Site closure, which correspond to the period after the West Pit is flooded and begins to overflow to the Partridge River).

The following nine scenarios were evaluated for the Partridge River watershed under the RA1, depending on the stage of development or closure of the Mine Site:

- Existing Conditions (i.e., without NorthMet Project).
- Year 1 (end of Mine Site development Year 1).
- Year 5 (end of Mine Site development Year 5).
- Year 10 (end of Mine Site development Year 10).
- Year 12 (end of Mine Site development Year 12).
- Year 15 (end of Mine Site development Year 15).
- Year 20 (end of Mine Site development Year 20; that is, end of mining operations).
- Closure (i.e., during Mine Site closure, which corresponds to the period of West Pit flooding).
- Post-Closure (i.e., after Mine Site closure, which correspond to the period after the West Pit is flooded and begins to overflow to the Partridge River).

Year 12 is significant for Mine Site-RA1 because East Pit flooding begins in Year 12 and both Category 2/3 Waste Rock and Category 3 Lean Ore stockpiles are still active. See Section 4.3.2.1.1 for more details.

4.1.2 Groundwater

Groundwater quality for both the Mine Site-Proposed Action and Mine Site-RA1 are deterministically predicted downgradient of each waste rock or lean ore stockpile and each mine pit. For each of the pertinent Mine Site features, a groundwater flowpath originating at the feature and ending at the Partridge River was selected for evaluation of potential groundwater impacts. Flowpaths were selected using the hydraulic head distribution at mine closure. When possible, the shortest flowpath from the source to the Partridge River was selected to evaluate a "worst-case" scenario. Figure 4-1 shows the flow paths selected for evaluation of potential impacts from each Mine Site feature. Some of the flowpath models evaluated included multiple sources. For the other sources, there should be very little if any mixing of sources because of the unique flowpaths.

Along each flow path, groundwater concentrations are evaluated at the property boundary and at the Partridge River. For the transient models only, groundwater concentrations are also evaluated at the Dunka Road. If the groundwater flow path did not cross the property boundary prior to reaching the Partridge River, groundwater concentrations were not evaluated at the property boundary. Locations where groundwater concentrations are evaluated are shown on Figure 4-1.

Initial screening level models were used determine potential constituents of concern for each source area using the maximum predicted leakage rate for each stockpile and the maximum predicted concentrations for the stockpile leakage. Transient models were used to further assess constituents of concern identified in the screening level models. Transient models were run for Year 5, Year 10, Year 15, Year 20, Closure and Post-Closure.

4.2 Proposed Action

4.2.1 Description

This section describes the proposed Mine Site facilities with major potential point and nonpoint discharges under the Mine Site-Proposed Action plan that affect the Partridge River. Section 4.3 discusses the major potential point and nonpoint discharges under the Mine Site-RA1 that affect the Partridge River.

4.2.2 Stormwater

The reuse/recycle strategy adopted by PolyMet (see RS21) has resulted in no planned point discharge of process waters to the surface waters of the State during operations (see Figures 1-4 through 1-7 for the Mine Site-Proposed Action and Figures 1-8 through 1-11 for the Mine Site-RA1). However, throughout the NorthMet Project, stormwater runoff produced from natural undisturbed and reclaimed areas (including reclaimed stockpiles) within the Mine Site will be collected and routed to the Partridge River following existing drainage patterns as much as possible (see RS24 and Figure 4-2 of this report). The stormwater chemistry will not differ from the background water chemistry of the natural runoff in the Partridge River watershed (see Section 5.1.3.3). TSS levels in stormwater runoff will be controlled by sedimentation ponds to be constructed at the outlet locations of stormwater off the Mine Site (see RS24). Therefore, stormwater discharges do not represent a significant change on the water quality of the Partridge River and are not addressed as part of this water quality assessment.

4.2.3 Process Water

4.2.3.1 Waste Rock and Lean Ore Stockpiles

4.2.3.1.1 General Description

Five stockpiles will be constructed to accommodate waste rock and lean ore materials produced during the life of the mine in the Mine Site-Proposed Action (see Figure 4-3). These include: the Overburden and Category 1/2 Waste Rock Stockpile, the Category 3 Waste Rock Stockpile, the Category 3 Lean Ore Stockpile, the Category 4 Waste Rock Stockpile, and the Lean Ore Surge Pile (also known as the Category 4 Lean Ore Stockpile). The segregation scheme was based on the results of the geochemical studies presented in RS42/RS53, which served to characterize the waste rock and lean ore materials in terms of their potential for acid rock drainage (ARD) and leaching of heavy metals. Based on these classifications, RS23T and RS49 described different types of bottom liner and top cover systems proposed to manage the unrecoverable stockpile leakage to groundwater and subsequent recharge to the Partridge River (henceforth referred to as liner leakage) according to the material contained in the stockpile.

The liner yield is defined here as the amount of precipitation that reaches the liner system at the bottom of the stockpile. Part of this liner yield will be collected and evacuated to sumps via the drainage system along the top of the liner, and from there it will be pumped to the WWTF for treatment and reuse in the Tailings Basin-Plant Site (Embarrass River watershed). The liner leakage is defined as a portion of the liner yield that will leak through the liner system to groundwater and potentially flow to the Partridge River. Although the estimated liner leakage rates are several orders of magnitude smaller than the estimated low flows in the Partridge River near the Mine Site, the conservatively predicted concentrations for some metals in the liner leakage are expected to significantly exceed Minnesota water quality standards. This defines the critical condition to be analyzed with the water quality model of the Partridge River during mine operations and closure.

According to Appendix B of RS22 for the Mine Site-Proposed Action:

- Liner leakage from the Category 3 Waste Rock Stockpile will recharge to groundwater, and from there it will recharge the Partridge River upstream of surface water monitoring station SW-003. The assumption used in RS74 Draft-01, which is no longer valid, was that this liner leakage would drain west via groundwater toward the East Pit during the 20 years of mine operations (i.e., leakage would not flow toward the Partridge River) and recharge the Partridge upstream of surface water monitoring station SW-004 after the East Pit is completely flooded by the end of Year 20.

- Liner leakage from Category 3 Lean Ore Stockpile will recharge to groundwater, and from there it will recharge the Partridge River, with 50 percent recharging upstream of surface water monitoring station SW-003 and 50 percent recharging upstream of surface water monitoring station SW-004. The assumption used in RS74 Draft-01, which is no longer valid, was that this liner leakage would flow to the Partridge River, with 100 percent recharging upstream of surface water monitoring station SW-004.

- Liner leakage from the Category 4 Waste Rock Stockpile will flow south/southwest via groundwater toward the Partridge River during mine operations and closure, recharging the Partridge upstream of surface water monitoring station SW-004. (This is the same assumption used in RS74 Draft-01).

- Liner leakage from the Lean Ore Surge Pile will flow south/southwest via groundwater toward the Partridge River during mine operations, recharging the Partridge upstream of surface water monitoring station SW-004. The Lean Ore Surge Pile will be removed at the end of year 20. (This is the same assumption used in RS74 Draft-01).

- (This change was not reported in Appendix B of RS22. It is the result of the preliminary geochemical characterization of the overburden material, and its potential effects on the water quality of downstream watercourses and water bodies. A decision has been made by PolyMet that for this RS74A report the change described below will be modeled. Subsequent environmental studies and permitting will determine if this is acceptable.) The Overburden and Category 1/2 Waste Rock Stockpile will be redesigned, such that the soil liner will extend throughout the entire footprint of the stockpile; that is, the soil liner will include not only the waste rock section, but also the southwest portion covered with overburden material. The assumption used in RS74 Draft-01, which is no longer valid, was that the soil liner would cover only the waste rock section of the stockpile.

- Approximately 20 percent of the liner leakage from the Overburden and Category 1/2 Waste Rock Stockpile is predicted to flow south via groundwater and recharge the Partridge River upstream of the surface water monitoring station SW-004a. This liner leakage will primarily originate from the southwest Overburden portion of the stockpile; depending on the stage of mining, the area occupied by surface overburden material constitutes at least 17.5 percent of the stockpile footprint. During operations, of the remaining 80 percent of the liner leakage from the Overburden and Category 1/2 Waste Rock Stockpile, 60 percent is predicted to flow south via groundwater into the West Pit, and 20 percent is predicted to flow southeast into the East Pit.

Once the East Pit is completely flooded, the leakage to the open pits is predicted to change to 75 percent into the West Pit and 5 percent into the East Pit. (This is the same assumption used in RS74 Draft-01).

Figures 4-4 to 4-7 present schematics of the expected flowpaths of the liner leakage from the five stockpiles during mine operations and closure for the Mine Site-Proposed Action.

The proposed liner systems for the different stockpiles are designed as follows:

- Overburden and Category 1/2 Waste Rock Stockpile. The liner system includes a 12 inch overliner drainage layer, with a permeability of 0.3 centimeters per second (cm/s) and a slope of 0.5 percent; and a 12 inch subgrade soil liner layer, with a permeability of $5x10^{-7}$ cm/s.

- Category 3 Waste Rock Stockpile. The liner system includes a 12 inch overliner drainage layer, with permeability of 0.3 cm/s and slope of 1.0 percent; a low liner density polyethylene (LLDPE) geomembrane, with thickness of 80 mil (0.08 inches); and a 12 inch subgrade material layer, with permeability of $1x10^{-5}$ cm/s.

- Category 3 Lean Ore Stockpile, Category 4 Waste Rock Stockpile, and Lean Ore Surge Pile. The liner system includes a 12 inch overliner drainage layer, with permeability of 0.3 cm/s and slope of 2.0 percent; a low liner density polyethylene (LLDPE) geomembrane, with thickness of 80 mil (0.08 inches); and a 12 inch subgrade material layer, with permeability of $1x10^{-6}$ cm/s.

The proposed cover systems for the different stockpiles are designed as follows:

- Overburden and Category 1/2 Waste Rock Stockpile. 2-foot evapotranspiration (ET) cover.

- Category 3 Waste Rock Stockpile, and Category 3 Lean Ore Stockpile. 3-foot ET cover on the 2.5(H):1(V) regraded outer slopes; and textured geomembrane barrier with an overlying 1.5-foot thick grass vegetated cover soil for the top and bench areas.

- Category 4 Waste Rock Stockpile. Textured geomembrane barrier with an overlying 1.5-foot thick grass vegetated cover soil for the crest, outerslopes and bench areas.

The Lean Ore Surge Pile will be entirely removed and reclaimed at the end of Year 20, but it will not be reclaimed at all during operations.

4.2.3.1.2 Liner Leakage Rates

RS23T and RS49 present an evaluation of the hydrological performance and constructability of different bottom liner and top cover systems for each of the proposed stockpiles. The evaluation is based on the Mine Site-Proposed Action layout shown in RS18, which also provides details about the progressive reclamation (covering) of the different stockpiles (for more details, see Table 4-4 of this report). The comparison of the liner systems is based on simulations with the Hydrologic Evaluation of Landfill Performance (HELP) model, which was developed by the USEPA to estimate drainage from and leakage through the bases of liner systems. HELP was originally designed for landfill systems, but the USEPA also recommends HELP for stockpile systems in Appendix F of the *EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska*. The comparison for the cover systems is based on simulations with the UNSAT-H model, which was developed by the Pacific Northwest National Laboratory to simulate one-dimensional water and heat flow processes. The results presented in these two reports (RS23T and RS49) were used as input for the water quality assessment presented in RS74 Draft-01.

During follow-up discussions over the past year, the Agencies indicated that a range of liner yields from the stockpiles (i.e., the amount of water that reaches the bottom of the stockpile) should be included in RS74 Draft-02 to better account for the uncertainty in stockpile hydrology, and that such range of liner yields should control the estimation of liner leakage rates (i.e., the amount of water that escapes the liner system and flows to groundwater). Several meetings were held between the MDNR, its consultants, and Barr, and consensus was achieved about the methodology and results of estimating stockpiles liner yields. More specifically, high, average and low estimates of liner yield were obtained by analyzing data from test stockpiles in northeast Minnesota where liner yield has been measured, precipitation variability for the 30-year climate normal period (1971-2001), Partridge River flows for the period 1978-1988, and incorporating best professional judgment from MDNR experts about potential infiltration rates into the stockpiles based on the type of cover material. The results of the liner yield analysis are provided in Table 4-1, with the area-weighted values presented in Table 4-5 after accounting for the active and reclaimed areas at the given stage of Mine Site development or closure presented in Table 4-4. In general, this range of liner yields is used as input to the Mine Site water balance including the re-evaluation of liner leakage rates, pit flooding analyses, and as input to the water quality analyses.

Liner leakage rates were thus re-evaluated from those presented in RS74 Draft-01. With the range of liner yields provided in Table 4-1, relevant information from other mine sites, and using the proposed design for the liner systems under the Mine Site-Proposed Action as the base case, 116 additional simulations were conducted with the HELP model by Golder and Associates (see Appendix D). These simulations were intended to complete a sensitivity analysis of liner leakage as a function of the design parameters presented in Table 4-2 as follows:

- Slope of overliner, permeability of soil liner, and liner yield for the Overburden and Category 1/2 Waste Rock Stockpile.

- Slope of overliner, number of installation defects per acre in geomembrane, permeability of subgrade material layer, and liner yield for the Category 3 Waste Rock Stockpile, Category 3 Lean Ore Stockpile, Category 4 Waste Rock Stockpile, and Lean Ore Surge Pile.

The methodology adopted for this evaluation was to use values for the main components of the liner system that, paired with the high, average and low estimates of the liner yield, would favor high, average or low liner leakage rates. For instance, in the case of the Category 3 Lean Ore Stockpile and a target high liner leakage rate, the slope of the overliner was set at 0.5 percent (versus the proposed design of 2.0 percent), the number of installation defects per acre of geomembrane was set at 8 (versus a recommended value of 1 to 2 installation defects per acre for excellent quality of geomembrane installation), and the permeability of the subgrade layer was set at 10^{-5} cm/s (versus the proposed design value of 10^{-6} cm/s).

After agreement was reached between the MDNR, its consultants and Barr for a reasonable (yet conservative when compared to the actual design parameters of the proposed liner systems) average liner leakage rate (see Table 4-3), and accounting for the active and reclaimed areas of the stockpiles at different stages of the Mine Site development and closure (see Table 4-4), area-weighted liner leakage rates were obtained for low, average and high flow conditions (see Table 4-6). These liner leakage rates are different from and more detailed than those provided in RS74 Draft-01. The area-weighted liner yields presented in Table 4-5 for low, average and high flow conditions were then used by SRK to predict the corresponding chemistry of the stockpile leachate (see Section 4.2.3.1.3).

4.2.3.1.3 Chemistry of Leachate

RS53/RS42 and Appendix E present the geochemical characterization of waste rock (including waste rock, lean ore, and ore) and provide estimates of liner drainage chemistry for each of the four stockpiles and surge pile at different stages of Mine Site development and closure. Criteria used for the segregation scheme of waste rock and lean ore materials are presented in Section 6.4.3 of RS53/RS42. Concentrations predicted 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, vanadium and zinc are presented in Tables 4-7 to 4-21. Antimony and vanadium have been added to this list since RS74 Draft-01.

The method used in RS53/RS42 to predict stockpile drainage chemistry involved a combination of a purely empirical approach and a minor use of thermodynamic theory, the latter accounting for a reduction factor in the predicted leachate concentrations from the Category 1/2 Waste Rock Stockpile only. It was conservatively assumed that the Category 3 and 4 stockpiles will oxidize rapidly generating excess heat that will "compensate" for a 17.6°C difference between the mean annual air temperature at the Mine Site and the base temperature used in the Arrhenius equation for determining the reduction factor referred to above. Moreover, it is indicated in RS53/RS42 that "one of the fundamental limitations of the empirical method is that direct scale-up of laboratory test results to full-scale conditions often results in prediction of elevated dissolved metal concentrations because the calculation takes loads indicated by well-flushed laboratory tests and dissolves them in small volumes of water. This does not account for the solubility of secondary minerals which form as a result of weathering of primary minerals or the solubility of the primary minerals themselves. This effect can be evaluated for known major primary and secondary minerals by considering their ideal equilibrium solubility using thermodynamic data. However, for many trace elements, solubility is controlled by small amounts of secondary minerals that cannot be identified directly and must be inferred by evaluation of water chemistry data, or by sorption processes (co-precipitation and adsorption)."

The next paragraphs will highlight why in addition to the issues raised in the previous paragraph, some of the other assumptions and calculations made in RS53/RS42 have led to conservative estimates of the stockpiles' leachate chemistry, in particular for copper, nickel and cobalt concentrations in the liner leakage of the Category 3 Waste Rock, Category 3 Lean Ore and Category 4 Waste Rock Stockpiles and the Lean Ore Surge Pile. It will be demonstrated in Section 5.2.3.1 that even working with such conservative estimates, the deterministically predicted in-stream water quality at different locations of the Partridge River in the vicinity of the Mine Site meets the Minnesota surface water quality standards.

A database of 28,700 water quality records was reviewed as part of the geochemical assessment presented in RS53/RS42. Interpretation and use of the data records was focused on those corresponding to mine sites with geology similar to the NorthMet deposit and in which ARD was not necessarily being released. Nickel and cobalt concentrations are expected to be elevated relative to water quality standards even if acidic conditions do not develop in the NorthMet Project stockpiles. The database included information from all historical Duluth Complex testwork data generated by the MDNR for sites near the NorthMet Project, the kinetic test data generated by the MDNR for Duluth Complex rock similar to NorthMet rock, the kinetic test data generated by PolyMet for the NorthMet Project, and the field measurements for the stockpile drainage from the AMAX test piles. The primary source of information finally used to predict highest metals concentrations in the stockpiles leachate is the set of measurements from the AMAX test piles (Lapakko, 1993; Lapakko et al., 2002;

MDNR, 2004), which provided the lowest pH (acidic conditions) and highest copper, nickel and cobalt concentrations from the database of 28,700 data records referred to above.

The AMAX test piles consisted of six piles of roughly 1,000-tons each that were constructed with rock removed from a test shaft sunk into the Babbitt Deposit. Monitoring of the stockpile leachate took place between 1977 and 1994. Three of the stockpiles did not have any type of cover during the entire monitoring period. The AMAX rock contained sulfur concentrations varying from 0.64 percent to 1.41 percent, copper concentrations of 0.3 percent to 0.4 percent, and nickel concentrations of 0.08 percent to 0.09 percent. Sulfur concentrations of rock in the AMAX test piles are much higher than those expected in the NorthMet Project stockpiles with the exception of Category 4 materials. Copper and nickel content of the rock in the AMAX test piles were at least two to four times greater than those expected in any of the NorthMet Project stockpiles. According to the initial stockpile water chemistry modeling presented in Section 8 of RS53/RS42 (see Table 8-1 of RS53/RS42 for more details), and based on updated information provided in RS67:

- Category 1/2 waste rock has an average sulfur concentration of 0.08 percent, varying from 0.01 percent to 0.31 percent.

- Category 3 waste rock has an average sulfur concentration of 0.22 percent, varying from 0.13 percent to 0.60 percent. Copper and nickel concentrations are higher than Category 1/2 waste rock but concentrations of other elements were comparable.

- Category 3 lean ore is expected to have similar characteristics to Category 3 waste rock, with the exception of higher copper and nickel content.

- Category 4 waste rock has an average sulfur concentration of 2.37 percent, varying from 0.16 percent to 4.75 percent. The effect of including rock from the Virginia Formation is apparent in the lower copper and nickel content but higher arsenic, lead and zinc content compared to Category 1/2 and Category 3 waste rock.

- Lean ore is expected to have similar characteristics to Category 3 lean ore, with exception of higher sulfur concentration and higher copper content.

In principle, it would be reasonable to expect that if measured metal concentrations in the AMAX test piles are higher than those estimated for the NorthMet Project stockpiles, metals concentrations in the leachate from NorthMet Project stockpiles should be less than those measured in the AMAX test piles. However, SRK argues (email communication from Stephen Day dated May 8, 2007) that stockpile configuration and reclamation schedule are also important factors determining the chemistry of the stockpile leachate. Furthermore, as indicated above, nickel and cobalt concentrations are expected to be elevated even if ARD does not develop in the NorthMet Project stockpiles.

Therefore, concentration caps were used to predict highest metals concentrations in the stockpile leachate, which in the case of sulfate, copper, nickel and cobalt corresponded to the highest measured concentrations in the AMAX test piles. More specifically, measurements at one of the AMAX test piles for which the sulfur concentration was 1.41 percent indicated concentrations of sulfate approaching 10,000 mg/L, of copper approaching 200 mg/L, of nickel approaching 800 mg/L, and of cobalt approaching 50 mg/L. The other AMAX test piles constructed from rock containing 0.64 percent-sulfur (i.e., having a greater sulfur content than that of Category 1/2 and Category 3 waste rock and lean ore materials) reached a lowest pH of approximately 5, the maximum sulfate concentration was near 3,000 mg/L, and the maximum nickel concentration was less than 250 mg/L (see Figure 3-1 in RS53/RS42). Reference maximum concentrations used for modeling the impact of the NorthMet Project stockpile leachate under the Mine Site-Proposed Action are 0.71 mg/L, 0.08 mg/L for antimony, 9,600 mg/L for sulfate, 202 mg/L for copper, 762 mg/L for nickel, and 44 mg/L for cobalt.

In addition, the following key assumptions have been used in the stockpile water chemistry modeling presented in RS53/RS42:

- Weathering rates used as input in the stockpile water chemistry modeling corresponded to the calculated 95th percentile rate for each unit, rock type and category grouping (a total of 28 individual rates). These are groups for which it was predicted more than one million tons of rock would be produced.
- All rock is assumed to weather at the same rate without limit to the supply of oxygen. Decrease in oxygen availability was not considered, which is conservative. This may be an important factor when the stockpiles are reclaimed and the cover systems in place.
- The delay to onset of acidic conditions for Category 3 and Category 4 waste rock was an input used to semi-quantitatively determine when leachate from the stockpiles would be acidic. For Category 3, the delay was assumed to be 5 years, based on the AMAX test piles data. For Category 4, the rock was assumed to become acidic immediately upon placement. All rates were assumed to be constant for waste rock stockpiles. In reality, depletion of rock components will result in decreasing rates and this was addressed for the pit walls using evidence from the MDNR's experiments.

Summarizing, information from nearby Duluth Complex sites was particularly important as it provided the basis to determine possible concentration limits for a given chemical element from measured maximum concentrations of that element at a given pH. This in combination with the mine waste rock scheduling – volumes, particle size distribution and chemical characterization- (RS53/RS42), changes to the methodology and/or input data used in RS53/RS42 for prediction of stockpile leachate chemistry (see Appendix E of this report), and liner yields (see Section 4.2.3.1.2) allowed estimation of chemistry predictions for water reporting to the liner for high, average and low flow conditions.

The RS53/RS42 report did not include predicted chemistry for water originating from the overburden stockpile. An overburden drilling program was completed in January 2008 and samples were tested according to a Sampling and Analysis Plan developed through discussion with MDNR. Field observations and subsequent analysis identified four types of overburden based on physical and chemical characteristics:

- Peat. Organic soil.
- Unsaturated Mineral Overburden. This material was found to contain low concentrations of sulfur and leachates from Meteoric Water Mobility Procedures (MWMPs, NDEP 1996) was non-acidic and showed relatively low leachable metal concentrations.
- Saturated Mineral Overburden. A common observation during drilling was that saturated or unoxidized overburden appeared to contain iron sulfide that was not necessarily associated with Duluth Complex rock. Testing of this material confirmed that sulfur concentrations in the fine fraction were elevated compared to its coarse fraction and unsaturated overburden. Based on the association with the fine fraction, it was concluded that the iron sulfide was formed by chemical processes occurring in the overburden after glacial deposition. The presence of chemically-reducing conditions was indicated by low oxidation-reduction potential. It is postulated that sulfate reduction is naturally occurring in these materials allowing iron sulfide to precipitate. MWMP leachates from two samples of this material were acidic (pH 3 to 4) and showed elevated concentrations (in or approaching the mg/L range) of cobalt, copper, nickel and zinc. Sulfate concentrations were near 200 mg/L. These results indicated that weathering of this material might cause it to acidify.
- Overburden Containing Duluth Complex. Some drill hole intersections contained Duluth Complex rock that was visibly mineralized.

Based on these findings, the need to mitigate potential for acid and metal leaching from the saturated mineral overburden was identified. The current plan is to extend the Category 1/2 Waste Rock Stockpile liner to include all of the overburden portion and compact the mixed overburden material as it is being placed to limit oxidation and infiltration and also enhance reaction of any acidic leachate with unsaturated materials. Mitigation measures will be designed so that water originating from the overburden stockpile will be non-acidic and mostly be storm water rather than seepage.

The overburden seepage and overburden liner leakage parameter concentrations presented in Table 4-22 are calculated from the mass-weighted average of the median MWMP leachate chemistry for the overburden groups listed above. Approximately 16 percent of the total overburden volume is anticipated to be peat. Between 13 percent and 27 percent is unsaturated material, and 57 percent to 70 percent of the total volume is anticipated to be saturated material. The peat and unsaturated material, which has generally better leachate water quality than the saturated material, will be placed in the Overburden Storage and Laydown Area, while the saturated material will be placed in the overburden portion of the Overburden and Category 1/2 Waste Rock Stockpile. By this method, parameter concentrations for the seepage from the Overburden Storage and Laydown Area assume a material consisting of 44 percent peat and 56 percent unsaturated overburden. Parameter concentrations for the liner leakage from the overburden portion of the Overburden and Category 1/2 Waste Rock Stockpile were assumed equal to the median of the saturated overburden material.

4.2.3.2 Mine Pits

4.2.3.2.1 General Description

There will not be point discharges of surface waters from the NorthMet Project mine pits to the Partridge River during the twenty years of mining operations. As explained in RS22, while the mine pits are active, the mine pit inflows (direct net precipitation, surface runoff from within the pit footprint, and groundwater inflows) will be directed to sumps within the open pits. At these sumps, process water will be collected and pumped to the WWTF for treatment and then pumped to the Tailings Basin for use as make-up water. However, it is predicted that approximately 45 years (based on for average flow conditions, see Appendix F) after mining activities in the NorthMet Project cease (i.e., around Year 65), overflow from the West Pit will be routed to the Partridge River. Quantification of the flows and water chemistry of this overflow is presented below.

Groundwater within the Mine Site will flow toward the NorthMet Project mine pits during operations while the mine dewatering systems are active and during backfilling of the East and Central Pits (henceforth referred to collectively as the East Pit). In other words, no groundwater flow from the NorthMet Project mine pits to the Partridge River is expected before Year 20 (see Appendix B of RS22). Following completion of all mining activities in the NorthMet Project (i.e., beginning in Year 21), however, groundwater seepage from the constructed wetland in the East Pit to the underlying bedrock are expected. Quantification of the flows and water chemistry of groundwater recharge to the Partridge River is presented below.

4.2.3.2.2 Seepage to Groundwater

4.2.3.2.2.1 East Pit

In about Year 20, following the backfilling of the East Pit, groundwater outflow from the East Pit to the Partridge River is expected to begin. It is predicted that 50 percent will discharge upstream of surface water monitoring station SW-003 and 50 percent will discharge upstream of surface water monitoring station SW-004. (Draft 01 predicted that 100 percent of the East Pit seepage would discharge upstream of surface water monitoring station SW-003). The predicted flow rate is 10 gpm (see Appendix B of RS22). Figures 4-5 to 4-7 have been updated with the East Pit groundwater flowpath.

4.2.3.2.2.2 West Pit

In about Year 65, groundwater outflow from the West Pit to the Partridge River around surface water monitoring station SW-004 is expected to begin. The predicted groundwater outflow rate is 18 gpm (see Appendix B of RS22). The surface water overflow from the West Pit will also begin in about Year 65.

4.2.3.2.3 Chemistry of Pit Waters

4.2.3.2.3.1 East Pit

Water chemistry of the East Pit surface water overflow to the West Pit is characterized in RS31 and updated in Appendix E. Concentrations are predicted 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, vanadium and zinc. Updated high, average and low estimates of this liner leakage rate presented in Table 4-6 were combined with the associated leachate chemistry of Category 1/2 Waste Rock Stockpile presented in Tables 4-7 to 4-9 to produce three sets of predicted East Pit water chemistry presented in Tables 4-23 to 4-25. Updates on the geochemical calculations supporting prediction of the East Pit water chemistry are provided in Appendix E. These concentrations are based on a closure scenario for the East Pit that includes lime/limestone treatment of the Virginia Formation walls while the backfill is being placed, and placement of overburden against the highwall to act as a surface for placement of a low permeability cover over the highwall (see RS52).

The approach followed in RS31 (for both the East Pit and the West Pit) is similar to that described above to characterize the chemistry of liner leakage from stockpiles; that is, it involved a combination of a purely empirical approach and a minor use of thermodynamic theory. More specifically, the approach followed accounts for coupling of the geometry of the pit with the geochemical weathering characteristics of the pit walls and the water balance, including in the latter potential inflows from liner leakage of waste rock stockpiles.

It is important to mention that according to RS31: “Predictions obtained from pit water modeling … accumulate the uncertainties related to each of … individual predictions and data sources”. This limitation is addressed by using reasonable worst case assumptions so that the eventual predictions are conservative with respect to uncertainty.” Furthermore, RS31 indicates that: “the predicted concentrations for the East Pit represent “worst case” and actual concentrations can be expected to be lower than presented.” Put simply, predicted concentrations for the East Pit surface water overflow to the West Pit are conservative.

Following a conservative approach, water chemistry for the recharge of groundwater flow to the Partridge River has been assumed to be the same as that predicted for the surface water overflow from the East Pit to the West Pit.

4.2.3.2.3.2 West Pit

Water chemistry of the West Pit surface water overflow to the West Pit is characterized in RS31 and Appendix E. Concentrations are predicted 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, vanadium and zinc. Updated high, average and low estimates of this liner leakage rate presented in Table 4-6 were combined with the associated leachate chemistry of Category 1/2 Waste Rock Stockpile presented in Tables 4-7 to 4-9 to produce three sets of predicted West Pit water chemistry presented in Tables 4-23 to 4-25. Details about the geochemical calculations supporting prediction of the West Pit water chemistry are provided in Appendix E of this report.

4.2.3.2.4 Pit Flooding

4.2.3.2.4.1 East Pit

Some minor changes to the schedule for East Pit flooding have been made since publication of RS22 and RS74-Draft01. The changes are:

- Groundwater inflows to the East Pit have changed as a result of the refinements to the groundwater model developed for the Mine Site. Changes to the groundwater model are described in Appendix B of RS22.
- WWTF inflows to the East Pit have changed as a result of the updated estimates of liner yields in the different stockpiles as described in Section 4.2.3.1.2.

- Liner leakage from the Category 1/2 Waste Rock Stockpile drains to the East Pit, and such liner leakage is not a small percentage of the liner yield. RS22 assumed all stockpile liner yield would be collected in the stockpile sumps and be routed to the WWTF.
- Liner leakage from the Category 3 Waste Rock Stockpile does not drain to the East Pit.

As indicated in RS22, mining activities will be completed in the East and Central Pit by Year 11 to 13, respectively, prior to the scheduled completion of mining activities in the West Pit by Year 20. Category 1/2 waste rock and water will be used to flood the East Pit, beginning immediately after mining activities have ceased in each of the two pits. More specifically, all Category 1/2 waste rock mined after Year 14 plus approximately half of the total Category 1/2 waste rock from Years 12, 13 and 14 will be placed in the East Pit. Sources of water for East Pit flooding include net precipitation and drainage/runoff from the pit footprint, pumping from the Central Pumping Station (CPS) when needed, and liner leakage from the Category 1/2 Waste Rock Stockpile. The liner leakage from the Category 1/2 Waste Rock Stockpile drains in part to the East Pit; approximately 25 percent of the total liner leakage from the Category 1/2 Waste Rock Stockpile during Years 1 to 20, and about 5 percent of the total liner leakage from the Category 1/2 Waste Rock Stockpile during Closure and Post-Closure. Because the waste rock fills approximately 69 percent of the pit capacity, the rate of East Pit flooding is dictated by the schedule of the waste rock input to the pit. The water level in the East Pit will be maintained within 5 feet of the rock surface during backfilling. Based on the Category 1/2 waste rock schedule and average climate conditions, this will result in net pumping to the pit in some years, and net pumping from the pit in other years. The backfilling operation has been designed for completion at the end of Year 20 with construction of a treatment wetland over the top of the backfilled rock immediately following the completion of the backfilling operation. The updated sources of water and schedule for East Pit flooding are presented in Tables 4-26, 4-27, and 4-28. Tables 4-26, 4-27, and 4-28 present estimates of pit flooding assuming average, low, and high flow values, respectively, for the following inputs: flow from the WWTF, stockpile liner leakage, and stockpile surface runoff. In each case, the East Pit is flooded at the end of Year 20.

Stockpile drainage will continue to require treatment at closure and will continue to be pumped to the WWTF (see RS52). In addition, leachate from the Hydrometallurgical Residue Facility at the Plant Site will no longer be routed back to the hydrometallurgical operations at closure and will also require treatment (see RS65/RS33). Treatment of these flows will be accomplished using the existing WWTF as the primary treatment mechanism with additional treatment when routed through the constructed wetland treatment system built within the backfilled East Pit prior to the East Pit overflowing to the West Pit.

The East Pit is expected to fill around Year 20. An outlet structure and channel will convey the East Pit overflow to the West Pit during and after closure. The drainage area to the East Pit will increase during closure, as pit perimeter dikes are removed and interior drainage ditches are rerouted to direct more water to the pits (to expedite West Pit Flooding). Based on average conditions, annual flow to the East Pit during closure is estimated to be 1,210 acre-feet per year (1.7 cfs) immediately following closure, and decrease to a steady state flow of865 acre-feet per year (1.2 cfs) 14 years into closure. The flows contributing to the East Pit during closure are presented in Table 4-26, 4-27, and 4-28 for cases corresponding to average, low, and high values for flow from the WWTF, stockpile liner leakage, and stockpile surface runoff. The peak overflow rate from the East Pit outlet structure during the 100-year, 24-hour rainfall event (5.2 inches of precipitation) was estimated to be 23 cfs using XP-SWMM. Additional information regarding the East Pit outlet structure, connection to the West Pit, and routing of flood events is provided in Appendix F.

The re-evaluation of stockpile liner yields discussed in Section 4.2.3.1.2 affects the stockpile water balances, which also affects the quantity of stormwater available from the Category 1/2 and Category 3 stockpiles to aid in flooding the East and West Pits in Closure. With an average annual precipitation of 29.2 inches, an annual evapotranspiration of a mixed forest of 16 inches (MDNR; Baker, 1979), an average liner yield (i.e., infiltration yield) of 10.2 inches for the Category 1/2 stockpile and 3.7 inches for the Category 3 stockpile, the corresponding runoff rates from these stockpiles are 3 and 9.5 inches, respectively. Table 4-29 lists the high, average and low stockpile stormwater yields to the East and West Pits based on this discussion.

4.2.3.2.4.2 West Pit

Some changes to the sources of water and schedule for West Pit flooding during Closure have been made since publication of RS52 and RS74 Draft-01 in July 2007. The changes are:

- Neither surplus water in the Tailings Basin pond by the end of Year 20 nor seepage collected by the Tailings Basin underdrain system will be used for the West Pit flooding.

- Groundwater inflows to the West Pit have changed as a result of the refinements to the groundwater model developed for the Mine Site. Groundwater inflows together with surface runoff from the directly tributary watershed are, by far, the two dominant sources of water for West Pit flooding.

- Stormwater inflows to the West Pit and East Pit in Closure have changed as a result of modifications made to the stockpile water balance during evaluation of the stockpile liner yields (see Section 4.2.3.2.4.1 and Table 4-29).

- WWTF inflows to the West Pit have changed as a result of the updated estimates of liner yields from the different stockpiles.

As indicated in RS52, upon completion of mining operations at the end of Year 20 and after pit dewatering systems are removed, the West Pit will begin to fill naturally with water from groundwater inflows, precipitation and stormwater runoff from the tributary watershed, including surface water overflow from the East Pit. These sources would fill the West Pit in approximately 53 years.

Water may also be diverted from other sources to expedite West Pit flooding. The reasons for evaluating such diversions are related to the potential increase of rock oxidation, acid generation, and metal leaching from the walls of the West Pit. Expedited pit flooding may reduce the potential for oxidation of the material exposed in the pit walls and could therefore minimize the aforementioned risk of generating acid waters from the West Pit after closure.

Appendix F provides a detailed evaluation of potential sources of water for the West Pit flooding and the expected duration of flooding for seven flooding scenarios using different combinations of seven potential sources. The sources investigated included: 1) direct groundwater inflows to the West Pit; 2) surface runoff /stockpile drainage within the Mine Site; 3) seepage collected from the hydrometallurgical residue cells; 4) water from the Tailings Basin, including pond storage and seepage collected from the underdrain system; 5) dewatering discharges from the Peter Mitchell taconite pits; 6) high flows from three locations along the Partridge River (no diversions during baseflow conditions); and 7) water pumped from Colby Lake.

Groundwater inflow to the West Pit (Source 1 above) was estimated as a function of water surface elevation in the West Pit (see Appendix B of RS22) and ranges from 1,307 acre-feet per year (810 gpm) when the pit level is at 920 ft-MSL, and a minimum groundwater inflow of 97 acre-feet per year (60 gpm) when the pit level is at 1,581 ft-MSL.

Source 2 above includes surface runoff from non-stockpile areas the mine site, surface runoff from reclaimed stockpiles, stockpile drainage collected and routed to the East Pit through the WWTF, and liner leakage draining to the pits.

- Non-stockpile Surface Runoff: Surface runoff from the Mine Site was estimated to be 40 percent of annual precipitation (29.2 inches) based on a comparison of precipitation and flow records for the Partridge River. Based on the non-stockpile drainage area tributary to the East Pit (291 acres) and West Pit (288 acres), this equates to an average annual inflow of 287 acre-feet per year (178 gpm) to the East Pit and 284 acre-feet per year (176 gpm) to the

West Pit. The groundwater inflow to the West Pit during each year of pit flooding is presented in Tables 4-26, 4-27, and 4-28.

- Reclaimed Stockpile Surface Runoff: Surface runoff from reclaimed stockpiles was calculated as the remainder of average annual precipitation (29.2 inches) less 16 inches of ET (MDNR; Baker, 1979) less the liner yield (see Table 4-1). This method resulted in low, average, and high stockpile runoff rates in inches per year based on the low, average, and high liner yields. These runoff rates were multiplied by the footprint of each stockpile tributary to the each pit. The resulting annual flows are presented in Tables 4-26, 4-27, and 4-28 for the average, low, and high stockpile runoff estimates, respectively.

- Collected Stockpile Drainage: Stockpile drainage collected in the underdrain system and routed to the East Pit via the WWTF was estimated as the liner yield less the liner leakage, summed for all stockpiles. Low, average, and high estimates of liner yield (see Table 4-1) and liner leakage (see Table 4-6) resulted in low, average, and high estimates of stockpile drainage routed to the East Pit. These flows are included as part of the flow from the WWTF, presented in Tables 4-26, 4-27, and 4-28, for the average, low, and high flow estimates, respectively.

- Liner Leakage: A portion of the liner leakage from the Category 1/2 Waste Rock Stockpile is tributary to the East and West Pits; during West Pit flooding, 91 percent of the Category 1/2 Waste Rock Stockpile footprint is tributary to the West Pit, while 6 percent is tributary to the East Pit. These percentages were applied to the leakage rates presented in Table 4-5 to calculate the flows to the East and West Pits during pit flooding. These flows are presented in Tables 4-26, 4-27, and 4-28, for the average, low and high flow estimates of liner leakage, respectively.

Seepage collected from the Hydrometallurgical Residue Cells (Source 3, above) was estimated to decrease from an average initial rate of 348 acre-feet per year (215 gpm) in Year 21 to zero in Year 34 based on MODFLOW modeling (documented in the forthcoming NPDES/SDS Permit to Mine). This input is included as part of the flow from the WWTF, presented in Tables 4-26, 4-27, and 4-28, for the average, low, and high flow estimates of other inputs (see above), respectively.

After considering the potential impacts of using the various sources and the pit water chemistry resulting from not using some of these additional sources, PolyMet decided to only use direct groundwater inflows (Source 1), surface runoff/stockpile drainage/liner leakage at the Mine Site (Source 2), and seepage from the Hydrometallurgical Residue Cells routed through the WWTF (Source 3) to fill the West Pit. The use of these sources results in flooding the West Pit in 45 years (using average values of stockpile yield, liner leakage, and stockpile runoff) instead of 53 years due to the inclusion of the Hydrometallurgical Residue Facility and drainage collected from the stockpiles. The estimated flooding time drops to 39 years when high estimates of stockpile yield, liner leakage, and stockpile runoff are considered, and increases to 55 years when low flow values are considered for those inputs.

A breakdown of the individual source contributions is presented in Tables 4-26, 4-27, and 4-28, for the average, low, and high flow estimates of the variable inputs mentioned above, respectively. In Tables 4-26, 4-27, and 4-28, stockpile drainage collected and routed to the WWTF and seepage from the Hydrometallurgical Residue Cells are combined as flow from the WWTF to the East Pit.

Table 4-26 includes the percent contribution to West Pit flooding for each source based on average estimates for stockpile yield, stockpile runoff, and liner leakage. Stormwater runoff within the Mine Site (including stockpile and non-stockpile areas) accounts for 31 percent of the West Pit flooding. Net precipitation contributes 15 percent of the flooding volume. Groundwater inflow to the East and West Pits contribute 29 percent of the total volume. Water from the WWTF accounts for 15 percent of the total volume, and the remaining 9 percent comes from liner leakage from the Category 1/2 Waste Rock Stockpile.

When low values of stockpile yield, stockpile runoff, and liner leakage are considered (Table 4-27), the relative contribution of stormwater remains about 32 percent. Due to the longer flooding time, the contributions of groundwater (36 percent) and direct precipitation (18 percent) are both increased. The contribution of liner leakage is 9 percent, while the contribution from the WWTF is reduced to 5 percent.

Table 4-28 includes the percent contribution to West Pit flooding for each source based on high estimates for stockpile yield, stockpile runoff, and liner leakage. The contribution of surface runoff is unchanged at 32 percent. The shorter flooding time reduces the contributions of groundwater to 26 percent and direct precipitation to 13 percent. The contribution of liner leakage is 24 percent, while the contribution from the WWTF is reduced to 5 percent.

In about Year 65, surface water overflow from the West Pit to the Partridge River will begin (based on average flows, see Table 4-26). The West Pit outlet structure will direct overflows into an existing wetland that flows towards Dunka Road and into the Partridge River through an existing natural drainage path, which will have been upgraded as part of mine operations and is referred to as Outlet Structure 5 (OS-5) for this project (see RS24). An existing wetland at that location may be altered during Closure to provide a final stage of treatment before discharge, if necessary. The annual average overflow from the West Pit will be about 2.6 cfs (1,900 acre-feet per year). The peak overflow rate from the East Pit outlet structure during the 100-year, 24-hour rainfall event (5.2 inches of precipitation) was estimated to be 33 cfs using XP-SWMM. Additional information regarding the West Pit outlet structure and routing of flood events is provided in Appendix F.

4.2.3.3 Other Facilities

4.2.3.3.1 General Description

The updated version of the surface water quality model of the Partridge River watershed includes some inputs that were not considered in RS74 Draft-01. These inputs are:

- Overburden Storage and Laydown Area.
- Sumps: Category 1/2 Waste Rock Stockpile Sumps, Category 3 Waste Rock Stockpile Sump, Category 3 Lean Ore Stockpile Sumps, Category 4 Waste Rock Stockpile Sump, and the Lean Ore Surge Pile Sumps.
- Process Water Ponds: Overburden Runoff Process Water Ponds PW-1 and PW-7, Haul Road Runoff Process Water Ponds PW-2 and PW-4, and Rail Transfer Hopper Process Water Pond PW-3. Note that Stockpile Sump Overflow Ponds PW-5 and PW-6 are not included in the model, as discussed below.
- WWTF Equalization Ponds.

4.2.3.3.2 Overburden Storage and Laydown Area

The Overburden Storage and Laydown Area is where the overburden from the mine site will be separated, processed and stockpiled during mining operations for re-use in constructing stockpile liners and covers. This area will be restored and reclaimed at the end of Year 20. The Technical Memorandum "Draft Percolation Estimates for Overburden Stockpiles, PolyMet Project, Minnesota" dated December 21, 2007 by Golder was produced to provide estimates of percolation from the overburden stockpiles, including the stockpile in this area. The Overburden Storage and Laydown Area will not be lined, but percolation from the Overburden Storage and Laydown Area will flow south/southwest via groundwater toward the Partridge River during mine operations (Years 1 through 20), recharging the Partridge upstream of surface water monitoring station SW-004. The Overburden Storage and Laydown Area Stockpile consists of a surge pile (constantly changing) with a maximum height of 40 feet of overburden material constructed without an engineered liner but periodically compacted during placement; therefore an estimated permeability of 1×10^{-5} to 1×10^{-6} centimeters per second was used for this analysis. The resultant liner leakage rate is approximately 535 gallons per acre per day.

The peat and unsaturated overburden material will be placed in the Overburden Storage and Laydown Area, while the saturated material will be placed in the overburden portion of the Overburden and Category 1/2 Waster Rock Stockpile. Geochemistry for the Overburden Storage and Laydown Area has been characterized (see Appendix E). The overburden seepage parameter concentrations (presented in Table 4-22) are derived from the results of humidity cell tests performed on peat and unsaturated overburden material. The calculation of parameter concentrations from these tests is described in Section 4.2.3.1.3.

4.2.3.3.3 Stockpile Sumps

A total of eleven sumps will be constructed for the five stockpiles in order to catch stockpile drainage and then route it to the WWTF, as described in RS22 Draft-02. However, some of the stockpile drainage is expected to leak into groundwater through the sump liner systems. The Technical Memorandum "Draft Percolation Estimates for Drainage Sumps, Process Water Ponds and WWTF Equalization Ponds, PolyMet Project, Minnesota" dated December 17, 2007 by Golder was produced to provide estimates of percolation from the sumps through the sump liners. It was assumed that the stockpile sumps will have an annual average of 6 feet of head for this analysis. The estimates of the sump liner leakage rates are 5 gallons per acre per day for the sumps with Category 1/2 liner types (Category 1/2 Waste Rock Stockpile sumps) and 0.008 gallons per acre per day for sumps with Category 3/4 liner types (Category 3 Waste Rock, Category 3 Lean Ore and Category 4 Waste Rock stockpiles and Lean Ore Surge Pile sumps). Sumps will have similar flow paths as their respective stockpile. The assumptions about the sumps include:

- During mine operations and closure, liner leakage from Sump S-1 of the Category 1/2 Waste Rock Stockpile will recharge the Partridge River upstream of surface water monitoring station SW-004a. During mine operations and closure, liner leakage from Sumps S-2, S-3, and S-4 of the Category 1/2 Waste Rock Stockpile will recharge the West Pit. During the 20 years of mine operations (Years 1 through 20), liner leakage from Sump S-5 of the Category 1/2 Waste Rock Stockpile will recharge the East Pit. After the East Pit is flooded at the end of Year 20, liner leakage from Sump S-5 is assumed to recharge the West Pit.

- During mine operations and closure, liner leakage from Sump S-11 of the Category 3 Waste Rock Stockpile will recharge the Partridge River upstream of surface water monitoring station SW-003.

- During mine operations and closure, liner leakage from Sumps S-9 and S-10 of the Category 3 Lean Ore Stockpile will recharge the Partridge River upstream of surface water monitoring station SW-004.

- During mine operations and closure, liner leakage from Sump S-8 of the Category 4 Waste Rock Stockpile will recharge the Partridge River upstream of surface water monitoring station SW-004.

- During mine operations and closure, liner leakage from Sumps S-6 and S-7 of the Lean Ore Surge Pile will recharge the Partridge River upstream of surface water monitoring station SW-004. The sump will be removed at the end of Year 20 with the rest of the Lean Ore Surge Pile.

Table 4-30 presents the liner leakage rates from the drainage sumps to the Partridge River. It was assumed that the drainage sumps have the same geochemical characterization as their associated stockpile listed in Tables 4-7 to 4-21.

4.2.3.3.4 WWTF Equalization Ponds

The WWTF described in the Mine Site-Proposed Action will treat Mine Site process water to remove dissolved metals and sulfate using a combination of membrane separation (nanofiltration) and chemical precipitation. Outflows from the WWTF during active mining operations will be reused at the Plant Site and for flooding of the East Pit. The overall goal of long-term WWTF operation is to discharge water conforming to Process Water Quality Targets outlined in Table 4-31.

The process water flows to the WWTF will include drainage from the waste rock stockpiles, runoff from process areas (haul roads, rail transfer hopper, and overburden areas) and mine pit dewatering. Because these flows, especially the volume of water removed from the mine pits, will vary significantly over the operation of the Mine Site and within any given year, the WWTF design includes two equalization ponds that will store excess process water from the Mine Site when the WWTF is running at full capacity. It is anticipated that storage of Mine Site process water will be required for approximately one month in the spring when snow that has accumulated over the winter is melting. Large rainfall events would also require storage. During winter months, the flow of process water to the WWTF is expected to be relatively constant and at a reduced rate. For winter operation during active mining at NorthMet, the WWTF ponds will be bypassed, with the process water flows sent directly to the inlet lift stations for the WWTF.

During Closure, the WWTF will also be used to treat drainage from the waste rock stockpiles and the Hydrometallurgical Reactive Residue Cells at the Plant Site. Because these flows are relatively small compared to the pumping of the pits that is required during operations, and because the ponds will be designed to be bypassed in the winter during mining operations, it can be assumed that the WWTF will be able to treat the anticipated process water flows during Closure without storage in the WWTF Equalization Ponds. Therefore, there will be no liner leakage or affects on the Partridge River. During Closure, outflows from the WWTF will be discharged to the wetland treatment system in the East Pit.

The only path for discharge into the environment from the WWTF is liner leakage from the WWTF Equalization ponds. Under Mine Site-Proposed Action, the WWTF is located at the southwest end of the West Pit. The Technical Memorandum "Draft Percolation Estimates for Drainage Sumps, Process Water Ponds and WWTF Equalization Ponds, PolyMet Project, Minnesota" dated December 17, 2007 was produced to provide estimates of percolation from the WWTF equalization ponds. Liner leakage from the WWTF Equalization ponds will flow south/southwest via groundwater toward the Partridge River during mine operations (Years 1 through 20), recharging the Partridge upstream of surface water monitoring station SW-004. Table 4-30 presents the liner leakage rates from the WWTF Equalization ponds to the Partridge River. The parameter concentrations in leachate from the WWTF equalization ponds are assumed to be the Stage 1 influent concentrations presented in Table 13 of the Addendum to RS-29T and are presented in Table 4-32. Stage 1 water quality is characterized with lower pH values and high concentrations of metals and salts than Stage 2 influent.

4.2.3.3.5 Construction Rock

Construction activities at the Mine Site will require rock. Construction Rock uses include:

- In-pit haul roads (10 Million Tons) – water that contacts this rock will be collected and treated by WWTP in operations and most of this rock will be submerged in Closure
- Pit access roads (0.7 MT) – water that contacts this rock will collected by process water system to be treated by WWTP in operations and roads will be reclaimed in Closure
- Rail Transfer Hopper and Ore Handling Area Platform (0.6 MT) – water that contacts this rock will collected by process water system to be treated by WWTP in operations. The Ore Handling Area will be reclaimed and the Rail Transfer Facility will be covered.
- Ore Surge Pile foundation (0.8 MT) – water that contacts this rock will collected by process water system to be treated by WWTP in operations and the facility will be reclaimed in Closure
- Category 1 / 2 Stockpile foundation (7.8 MT) – this rock is below the stockpile liner system so contact to water is limited and some water is collected by the foundation drains
- Category 3 and 4 Stockpile foundations (1.1 MT) – this rock is below the stockpile liner system so contact to water is limited and some water is collected by the foundation drains

Leachate from Construction Rock has not been included in the mass-balance model because the leachate to the environment and Partridge River watershed is limited. In RS18, PolyMet has proposed that mine waste rock with sulphur content less than or equal to 0.12% be approved for use as Construction Rock. This material will not generate ARD but may leach heavy metals and comprises approximately 70 percent of the total waste rock. If the use of Category 1 waste rock is not approved, rock will be obtained from PolyMet owned taconite waste rock stockpiles at Area 5 or by screening/crushing rocks from the overburden at the Mine Site. PolyMet is also investigating purchasing rock from a State owned taconite waste rock stockpile along the Dunka Road. This would result in a shorter haul for the off-site rock. The rock used for covers will be the small pebbles and stones that will remain in the overburden after screening, not what is termed here as Construction Rock.

4.3 Reasonable Alternative 1

4.3.1 Description

This section presents the how the Mine Site-RA1 differs from the Mine Site-Proposed Action plan. Only differences between the two plans are mentioned in this section; therefore, if no difference is mentioned for a certain aspect then the Mine Site-RA1 is the same as the Mine Site-Proposed Action described in Section 4.2 of this report for that aspect. The differences are the result of a change in:

- Type of waste rock or lean ore material to be contained in a stockpile at a given stage of the Mine Site development or closure.
- Total and reclaimed (versus active) footprint areas of the different waste rock and lean ore stockpiles during different stages of the Mine Site development or closure.
- Type of waste rock or lean ore material to be used for backfilling of East Pit.
- The location of Sumps S-9 and S-10 of the Category 3 Lean Ore Stockpile are located on the north side of the stockpile rather than along Dunka Road. This change is to allow gravity drainage to the East Pit after closure.
- The length of time and amount of active treatment expected to be required.

The location of the different inputs to the water quality model of the Partridge River watershed for different stages of the Mine Site development and closure under the Mine Site-RA1 is presented in Figures 4-8 to 4-10. In addition, the footprint areas of the waste rock and lean ore stockpiles for the different stages of the Mine Site development and closure under the Mine Site-RA1 are presented in Figures 4-11 to 4-16.

4.3.2 Process Water

4.3.2.1 Waste Rock and Lean Ore Stockpiles

4.3.2.1.1 General Description

Similar to the waste rock management plan developed for the Mine Site-Proposed Action, the Mine Site-RA1 considers disposal of waste rock and lean ore material in different stockpiles according to their potential to generate ARD or drainage with elevated metal concentrations. The Mine Site-RA1, however, also seeks to eliminate the potential for long term treatment of the leachate collected in the liner system of the different stockpiles. Therefore, according to the Mine Site-RA1 the waste rock and lean ore material with higher reactivity potential (i.e., types Category 2, Category 3 and Category 4) will be temporarily placed on the surface, treated with lime (or limestone) to minimize the acid generation and associated dissolution of metals and sulfate in the stockpile leachate, then used to backfill the East Pit. Because the East Pit will be progressively filled in with water, the oxidation of the waste rock and lean ore material will be effectively halted. Category 1/2 waste rock had been proposed for backfilling of the East Pit under the Mine Site-Proposed Action, whereas Category 1 waste rock will be the only type of material permanently placed on the surface under the Mine Site-RA1. Thus, the main difference between the Mine Site-RA1 and the Mine Site-Proposed Action is the material that will be permanently placed on the surface during Closure and Post-Closure and the associated wastewater treatment. The differences in the waste rock and lean ore stockpiles include:

- Category 1 Waste Rock stockpile:
    - Category 1/2 Waste Rock stockpile according to the Mine Site-Proposed Action will become Category 1 Waste Rock stockpile according to the Mine Site-RA1. In other words, only Category 1 waste rock will be placed in this stockpile; Category 2 waste rock will not be placed in this stockpile. The amount and location of overburden material in this stockpile remains the same.
    - The liner and cover systems for Category 1 Waste Rock Stockpile under the Mine Site-RA1 will be the same considered for Category 1/2 Waste Rock stockpile under the Mine Site-Proposed Action, and the stockpile will be progressively reclaimed at a rate similar to that under the Mine Site-Proposed Action.
    - The footprint area of the stockpile covered by waste rock will be the same 464 acres by the end of Year 20 with both the Mine Site-Proposed Action and Mine Site-RA1.
    - Drainage from the Category 1 Waste Rock stockpile will be treated in the WWTF through at least Year 20. In Year 21 through approximately Year 50 (during West Pit flooding; that is, during Closure) drainage from this stockpile will be treated in the WWTF and transitioned to passive wetland treatment systems that will drain to either the East Pit or the West Pit.
- Category 2/3 Waste Rock stockpile:
    - Category 3 Waste Rock stockpile according to the Mine Site-Proposed Action will become Category 2/3 Waste Rock stockpile according to the Mine Site-RA1. In other words, both Category 2 and Category 3 waste rock will be placed in this stockpile until Year 12, when Category 2 and Category 3 waste rock will be backfilled to the East Pit. By Year 19, Category 2 and Category 3 waste rock will be removed for use

in the backfilling of the East Pit. Category 1 waste rock will be placed in the stockpile after the Category 2 and Category 3 waste rock has been removed.

  - The liner system for Category 2/3 Waste Rock stockpile under the Mine Site-RA1 will be the same considered for Category 3 Waste Rock stockpile under the Mine Site-Proposed Action.

  - The cover system for Category 2/3 Waste Rock stockpile under the Mine Site-RA1 will only include an evapotranspiration (ET) cover over the entire stockpile. Different from what was considered for Category 3 Waste Rock stockpile under the Mine Site-Proposed Action, no geomembrane cover will be considered for the top and benches of the stockpile. The cover system will be implemented after Category 2 and Category 3 waste rock have been removed, and only Category 1 waste rock is in place. In other words, reclamation will not begin until Year 19 when Category 1 waste rock is placed within this footprint.

  - The footprint area of the stockpile will be the same 72 acres by the end of Year 20 with both the Mine Site-Proposed Action and Mine Site-RA1.

  - Category 2 and Category 3 waste rock will be treated with lime or limestone as it is placed in the temporary stockpiles to minimize the generation of acid, and the dissolution of sulfate and metals prior to placement in the East Pit. Sulfate and metals that dissolve into the East Pit during flooding will be treated as described in Section 4.3.2.2.

- Category 3 Lean Ore stockpile:

  - Category 3 lean ore will be placed in this stockpile until Year 12 when Category 3 lean ore will be backfilled to the East Pit. By Year 15, Category 3 lean ore will be removed for use in the backfilling of the East Pit. Category 1 waste rock will be placed in the stockpile after Category 3 lean ore has been removed.

  - The liner system for Category 3 Lean Ore stockpile under the Mine Site-RA1 will be the same considered under the Mine Site-Proposed Action.

  - The cover system for Category 3 Lean Ore stockpile under the Mine Site-RA1 will only include an evapotranspiration (ET) cover over the entire stockpile. Different from what was considered for Category 3 Lean Ore stockpile under the Mine Site-Proposed Action, no geomembrane cover will be considered for the top and benches of the stockpile. The cover system will be implemented after Category 3 lean ore has been removed, and only Category 1 waste rock is in place. In other words, reclamation will not begin until Year 15 when Category 1 waste rock is placed within this footprint.

  - The footprint area of the stockpile will change from 157 acres with the Mine Site-Proposed Action to 124 acres with the Mine Site-RA1 at the end of Year 20.

  - Category 3 lean ore will be treated with lime or limestone as it is placed in the temporary stockpiles to minimize the generation of acid, and the dissolution of sulfate and metals prior to placement in the East Pit. Sulfate and metals that dissolve into the East Pit during flooding will be treated as described in Section 4.3.2.2.

  - The stockpile sumps S-9 and S-10 will be located on the north side of the stockpile for the Mine Site-RA1, rather than along Dunka Road as with the Mine Site-Proposed Action. The reason for this change was to allow gravity flow from the stockpile to the East Pit during and after closure.

- Category 4 Waste Rock stockpile:

  - Different from what was considered under the Mine Site-Proposed Action, under the Mine Site-RA1 the Category 4 Waste Rock stockpile will be removed by the end of Year 20, when all Category 4 waste rock will have been removed for use in the backfilling of the East Pit. No cover will be used for this temporary stockpile.

  - The liner system for Lean Ore stockpile under the Mine Site-RA1 will be the same considered under the Mine Site-Proposed Action.

  - Category 4 waste rock will be treated with lime or limestone as it is placed in the temporary stockpiles to minimize the generation of acid, and the dissolution of sulfate and metals prior to placement in the East Pit. Sulfate and metals that dissolve into the East Pit during flooding will be treated as described in Section 4.3.2.2.

- Lean Ore Surge Pile (also known as the Lean Ore Surge Pile) will be removed under the Mine Site-RA1 by the end of Year 20, similar to the Mine Site-Proposed Action.

4.3.2.1.2 Liner Leakage Rates

The same methodology presented in Section 4.2.3.1.2 for the Mine Site-Proposed Action is valid for the Mine Site-RA1. The only differences are the active versus reclaimed areas at a given stage of the Mine Site development, and the fact that the stockpiles containing the materials with higher potential to generate ARD or elevated concentrations of some metals (Cat 2/3 waste rock, Cat 3 lean ore, Cat 4 waste rock) are not reclaimed until such materials are removed and Cat 1 waste rock is placed instead. Results for liner yields and liner leakage rates are presented in Tables 4-33 to 4-38.

4.3.2.1.3 Chemistry of Leachate

The results of the area-weighted high, average and low estimates of the liner yield for the different stockpiles and stages of Mine Site development and closure under the Mine Site-RA1 presented in

Table 4-35 allows prediction of the corresponding stockpile leachate chemistry. Summaries of the geochemical calculations supporting prediction of the stockpile leachate chemistry are provided in Appendix E. The predictions of the stockpile leachate chemistry are presented in these tables:

- Tables 4-39 to 4-41 for the Category 1 Waste Rock Stockpile;
- Tables 4-42 to 4-44 for the Category 2/3 Waste Rock Stockpile, which account for the treatment with lime of Category 2 and Category 3 waste rock, and placement of Category 1 waste rock in Year 19;
- Tables 4-45 to 4-47 for the Category 3 Lean Ore Stockpile, which account for the treatment with lime of Category 3 lean ore, and placement of Category 1 waste rock in Year 15;
- Tables 4-48 to 4-50 for the Category 4 Waste Rock Stockpile, which account for the treatment with lime of Category 4 waste rock; and,
- Tables 4-51 to 4-53 for the Lean Ore Surge Pile.

The treatment with lime or limestone of Category 2, Category 3 and Category 4 waste rock and Category 3 lean ore while these materials are placed on surface has resulted in maximum concentrations for the stockpile leachate under the Mine Site-RA1 that are, in some cases, a few orders of magnitude smaller than those under the Mine Site-Proposed Action. The over-riding assumption is that the addition of lime and/or limestone will be highly effective in maintaining pH at a high level (pH 8) and limit metal solubility. If the pH is lower than this, metal concentrations can be expected to be greater than those predicted. A summary is provided below for the six main parameters of analysis (i.e., arsenic, antimony, sulfate, copper, nickel and cobalt).

- Maximum concentration of arsenic is the same, 0.71 mg/L, under the Mine Site-Proposed Action and Mine Site-RA1.
- Maximum concentration of antimony is the same, 0.08 mg/L, under the Mine Site-Proposed Action and Mine Site-RA1.
- Maximum concentration of sulfate is 9,600 mg/L under the Mine Site-Proposed Action versus 2,340 mg/L under the Mine Site-RA1.
- Maximum concentration of copper is 202 mg/L under the Mine Site-Proposed Action versus 0.092 mg/L under the Mine Site-RA1.
- Maximum concentration of nickel is 762 mg/L under the Mine Site-Proposed Action versus 0.86 mg/L under the Mine Site-RA1.

- Maximum concentration of cobalt is 44 mg/L under the Mine Site-Proposed Action versus 0.052 mg/L under the Mine Site-RA1.

Leachate chemistry for the overburden seepage and overburden liner leakage is unchanged relative to the Mine Site-Proposed Action.

4.3.2.2 Mine Pits

4.3.2.2.1 East Pit

The Mine Site-RA1 plan for East Pit flooding varies minimally from the Mine Site-Proposed Action. The type of rock and/or lean ore used for backfilling is different than that described for the Mine Site-Proposed Action. Additionally, the amount of water routed from the WWTF to the East Pit varies somewhat from the Mine Site-Proposed Action both during East Pit flooding and during Closure. The sources of water and schedule for East Pit flooding under the Mine Site-RA1 are presented in Tables 4-54, 4-55, and 4-56, corresponding to average, low, and high estimates of selected inputs (including stockpile runoff, liner yield, and liner leakage). All other hydrologic aspects of East Pit flooding and flood routing in Closure for the Mine Site-RA1 are identical to those presented for the Mine Site-Proposed Action and discussed in Section 4.2.3.2.4, with the exception of the stormwater runoff analysis.

The re-evaluation of stockpile liner yields discussed in Section 4.3.2.1.2 affects the stockpile water balances, which also affects the quantity of stormwater available from the Category 1 and Category 2/3 stockpiles to aid in flooding the East and West Pits in Closure. With an average annual precipitation of 29.2 inches, an annual evapotranspiration of a mixed forest of 16 inches (MDNR; Baker, 1979), an average liner yield (i.e., infiltration yield) of 10.2 inches for the Category 1 stockpile and the Category 2/3 stockpile, the corresponding runoff rate from these stockpiles, which both contain Category 1 rock with an ET cover, is 3 inches. Table 4-57 lists the high, average and low stockpile stormwater yields to the East and West Pits for the Mine Site-RA1 based on this discussion.

As with the Mine Site-Proposed Action, the liner leakage from the westernmost Category 1 Waste Rock Stockpile drains in part to the East Pit; 25% of the liner leakage from the waste rock portion of the stockpile during Years 1 to 20, and 6% of the total waste rock liner leakage during Closure. High, average and low estimates of this liner leakage rate presented in Table 4-38 were combined with the associated leachate chemistry presented in Tables 4-39 to 4-41 to produce three sets of predicted East Pit water chemistry. Summaries of the geochemical calculations supporting prediction of the East Pit water chemistry are provided in Appendix E. The results of these computations under the Mine Site-RA1 are presented in Tables 4-58 to 4-60.

After flooding, the East Pit pore water will have concentrations of metals and sulfate similar to those in the drainage from the waste rock and lean ore stockpiles due to a transient flushing of oxidized chemicals on the surface of the rock that will dissolve into the water. This transient load will be mitigated by pumping East Pit water through the WWTF beginning in Year 21 and continuing through Year 50. Most of the treated water will be cycled back through the East Pit, but a portion of the water, sufficient to maintain an inward groundwater gradient without exposing the waste rock to further oxidation will be discharged through a wetland treatment (polishing) system into the West Pit. When the concentrations of sulfate and other chemicals in the East Pit are reduced, the WWTF will be decommissioned and the only remaining drainage, from the Category 1 Waste Rock Stockpile, will be routed through wetland treatment areas into the West Pit.

The maximum concentrations for the water leaving the East Pit after treatment as described above under the Mine Site-RA1 are of the same order of magnitude and generally smaller than those under the Mine Site-Proposed Action. A summary is provided below for the six main parameters of analysis (i.e., arsenic, antimony, sulfate, copper, nickel and cobalt).

- Maximum concentration of arsenic is 0.0879 mg/L under the Mine Site-Proposed Action versus 0.0177 mg/L under the Mine Site-RA1.
- Maximum concentration of antimony is 0.0812 mg/L under the Mine Site-Proposed Action versus 0.0126 mg/L under the Mine Site-RA1.
- Maximum concentration of sulfate is 324 mg/L under the Mine Site-Proposed Action versus 345 mg/L under the Mine Site-RA1.
- Maximum concentration of copper is 0.0956 mg/L under the Mine Site-Proposed Action versus 0.0115 mg/L under the Mine Site-RA1.
- Maximum concentration of nickel is 0.0845 mg/L under the Mine Site-Proposed Action versus 0.00834 mg/L under the Mine Site-RA1.
- Maximum concentration of cobalt is 0.00851 mg/L under the Mine Site-Proposed Action versus 0.00096 mg/L under the Mine Site-RA1.

4.3.2.2.2 West Pit

The Mine Site-RA1 considers the same plan for West Pit flooding as presented in Section 4.2.3.2.4. The contribution of surface runoff from the Category 2/3 Waste Rock Stockpile (Category 3 stockpile in the Mine Site-Proposed Action) to West Pit flooding is reduced due to the change in the stockpile cover. Consequently, liner yield increases relative to the Mine Site-Proposed Action, increasing the volume of water pumped from the WWTF to the East Pit during West Pit flooding. These changes shorten the time to fill the West Pit by less than a year (for each of the low, average, and high flow cases considered) and do not appreciably alter the relative contributions of each source to West Pit flooding. The sources of water and schedule for West Pit flooding under the Mine Site-RA1 are presented in Table 4-54, Table 4-55, and 4-56 for average, low, and high estimates selected inputs, respectively. All other hydrologic aspects of West Pit flooding and flood routing for the Mine Site-RA1 are identical to those presented for the Mine Site-Proposed Action and discussed in Section 4.2.3.2.4.

High, average and low estimates of this liner leakage rate presented in Table 4-38 were combined with the associated leachate chemistry presented in Tables 4-39 to 4-41 to produce three sets of predicted West Pit water chemistry. Summaries of the geochemical calculations supporting prediction of the West Pit water chemistry are provided in Appendix E. The results of these computations under the Mine Site-RA1 are presented in Tables 4-58 to 4-60.

The maximum concentrations for the West Pit water under the Mine Site-RA1 are of the same order of magnitude and equal to or slightly less than those under the Mine Site-Proposed Action. A summary is provided below for the six main parameters of analysis (i.e., arsenic, antimony, sulfate, copper, nickel and cobalt).

- Maximum concentration of arsenic is 0.1985 mg/L under the Mine Site-Proposed Action versus 0.1880 mg/L under the Mine Site-RA1.
- Maximum concentration of antimony is 0.1201 mg/L under the Mine Site-Proposed Action versus 0.1098 mg/L under the Mine Site-RA1.
- Maximum concentration of sulfate is 247 mg/L under the Mine Site-Proposed Action versus 271 mg/L under the Mine Site-RA1.
- Maximum concentration of copper is 0.006 mg/L under the Mine Site-Proposed Action versus 0.006 mg/L under the Mine Site-RA1.
- Maximum concentration of nickel is 0.0715 mg/L under the Mine Site-Proposed Action versus 0.0608 mg/L under the Mine Site-RA1.
- Maximum concentration of cobalt is 0.00796 mg/L under the Mine Site-Proposed Action versus 0.0069 mg/L under the Mine Site-RA1.

4.3.2.3 Other Facilities

4.3.2.3.1 Overburden Storage and Laydown Area

There is no change to the Overburden Storage and Laydown Area between the Mine Site-RA1 and Mine Site-Proposed Action.

4.3.2.3.2 Stockpile Sumps

Due to the change in the rate of stockpile progression and the lack of reclamation, the stockpile sump sizes have changed between Mine Site-Proposed Action and Mine Site-RA1; however, the direction of liner leakage from the sumps remain the same. Table 4-61 presents the liner leakage rates from the stockpile sumps to the Partridge River for the Mine Site-RA1. The sump leachate chemistry is assumed to be the same as the high, average and low estimates of the chemistry for the different stockpiles and stages of Mine Site development and closure for Mine Site-RA1 presented in Tables 4-39 to 4-53.

4.3.2.3.3 Process Water Ponds

There is no change to the process water ponds for the Haul Roads, Rail Transfer Hopper, or the Overburden runoff between the Mine Site-RA1 and Mine Site-Proposed Action.

In addition to the Stockpile Overflow Ponds PW-5 and PW-6, a third stockpile overflow pond PW-8 has been added to capture the sump overflow water from the Category 3 Lean Ore Stockpile, since the sumps for this stockpile have been modified. As with the Mine Site-Proposed Action, the Mine Site-Reasonable Alternative 1 surface water model does not include these stockpile overflow ponds based on the infrequent use, short duration of time used, and diluted nature of the water in the ponds.

4.3.2.3.4 WWTF Equalization Ponds

In comparison to the Mine Site-Proposed Area, the WWTF facility was moved to a location between the Lean Ore Surge Pile and the Overburden Storage and Laydown Area for Mine Site-RA1. The estimates of percolation from the WWTF equalization ponds under Mine Site-RA1 were obtained based on the design presented in PolyMet NorthMet Mine Site Wastewater Treatment Facility (WWTF) Permitting Support Document-Draft. A temporary WWTF will be manually operated for the first two or three years of mining operation that will remove metals from the Mine Site process water using mobile ion exchange trailers while the process water flows from the Mine Site are relatively low and the quality of the water is still suitable for treatment via ion exchange. The temporary WWTF design will include one 35 acre-feet equalization basin (East Equalization Basin). This basin will receive all Mine Site process water flows prior to treatment in the temporary WWTF. The long-term WWTF operation will be similar to the Mine Site-Proposed Action and will remove of metals and sulfate via a combination of nanofiltration and chemical precipitation. The long-term system will be placed into service in Year 3 of mining operation and will operate until the end of Year 20. During Closure the WWTF will be used to treat process water from waste rock stockpile drainage and will also be used to treat water in the East Pit that has been impacted by the placement of Category 3 and Category 4 waste rock into the pit for subaqueous disposal. As with the Mine Site-Proposed Action, the post closure operation of the WWTF will be at a significantly reduced flow rate. In addition, the flows will be relatively constant and not likely subject to the seasonal changes anticipated during active mining operations. For these reasons, during Closure, the WWTF equalization ponds can be bypassed and will not be full; therefore there will be no liner leakage or affects on the Partridge River.

The overall goal of long-term WWTF operation is to discharge water conforming to Process Water Quality Targets outlined in Table 4-31. Flow rates and water quality vary significantly over the operating period for the long-term WWTF, and removal of both metals and sulfate is required. Therefore, another goal of long-term WWTF operation is flexibility to accommodate changes in water quantity and quality over the operational period. The long-term WWTF will consist of two equalization basins. The East Equalization Basin will be constructed as part of the temporary WWTF and the West Equalization Basin, also sized at 35 acre-feet, will be constructed as part of long-term WWTF construction. Both the East and West Equalization Basins will have a bottom elevation of 1,602 feet, a working depth of 13 feet and 2 feet of freeboard. Side slopes will be 4:1 (H:V). Ramps with slopes of 10:1 will be provided on the south end of the equalization basins to allow equipment access for cleaning and maintenance. The bottom slope will be 0.5 percent towards the outlet to provide positive drainage. The liner will be a composite 60-mil HDPE geomembrane underlain by a geosynthetic clay liner (GCL) inch granular base and overlain by a 12-inch thick sand layer and a 12-inch thick riprap protective layer. In comparison to the Equalization Basins planned in the Mine Site-Proposed Action, the Equalization Basins in Mine Site-RA1 will be larger, therefore shallower with less head, causing less liner leakage.

The only path for discharge into the environment from the WWTF is liner leakage from the WWTF Equalization ponds. In the mass balance model, liner leakage from both ponds is added into one input for the model. Liner leakage from the WWTF Equalization ponds will flow south/southwest via groundwater toward the Partridge River during mine operations (Years 1 through 20), recharging the Partridge upstream of surface water monitoring station SW-004. Table 4-61 presents the liner leakage rates from the WWTF Equalization ponds to the Partridge River. The concentrations of the two basins are expected to be different. The overall concentration from both basins was calculated from adding the total mass loading of each parameter. The parameter concentrations in leachate from the WWTF equalization ponds are presented in Table 4-62. In general, the concentrations of liner leakage under Mine Site-RA1 will be less than Mine Site-Proposed Action because the concentrations from the waste rock will also be less

5.0 Proposed Action – Surface Water Quality Modeling

5.1 Modeling Methods

5.1.1 Overview

Concentrations of the constituents of interest in the Partridge 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 compound. 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 Mine Site-Proposed Action for the surface water quality model.

5.1.2 Model Construct

The Partridge River was subdivided into eight reaches extending from the watershed headwaters near the existing Northshore discharge downstream to Colby Lake. Figure 4-4 shows the Partridge River watershed with the model nodes and the sub-watersheds tributary to each node. Figures 4-5 through 4-7 present the main features of the Mine Site considered for this water quality assessment, including liner leakage from waste rock and lean ore stockpiles and overburden storage, and seepage from the mine pits. More specifically, these figures show the expected flowpath from the Mine Site features to the surface water quality model nodes for different stages of the NorthMet Project under the Mine Site-Proposed Action. Eight nodes were used in the model with nomenclature consistent with the proposed monitoring plan from Section 3.1.5.13 of the Detailed Project Description (see

Section 4.1.1). The eighth reach and node were included to represent Colby Lake and its immediate watershed (including Whitewater Reservoir).

Figure 5-1 shows a schematic view of the Partridge 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 shown 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 (e.g., SW-xxx) are designated by the subscript of that node (e.g., subscript _1 for SW-001). In-river flows and concentrations are designated with subscript _r. A description of all of the variables used in the model is shown in Table 5-1. In RS74 Draft-01, stockpile and overburden liner leakage/seepage were grouped into two general categories: one that recharged the Partridge River upstream of surface water monitoring station SW-004, and the other upstream of surface water monitoring station SW-004a. In addition, in RS74 Draft-01, leakage from the stockpile sumps, process water ponds and the WWTF Equalization Ponds were not included. The modeling for RS74A has been updated to deal separately with each individual source (and different flowpaths), including the additional sources above. . Figure 5-1 and Table 5-1 have been updated with this information.

Flows from sub-watersheds (both surface water flows and groundwater flows) are added to the model at the downstream node of each watershed. For example, the flows from the watershed tributary to the segment of the river between SW-002 and SW-003 are added to the model at the node SW-003. Flows from point sources are added to the model at the downstream node of the appropriate watershed. The location of each point source is described in Section 5.1.3.

5.1.3 Summary of Data Input

5.1.3.1 Partridge River

<u>Flows</u>

In-river flows at the nodes (designated as Q_r) were determined using an XP-SWMM model set up for each stage of Mine Site development and closure. Average annual flows were used to model the average condition. The maximum 24-hour average flow resulting from the 10-year 24-hour precipitation event was used to model the wet condition. The dry condition was modeled by assuming no surface water contribution and calculating flow in the river as the sum of groundwater and Mine Site inputs only. Flows in the Partridge River at nodes SW-001, SW-002, SW-003, SW-004, SW-004a, SW-005, USGS Gage and Colby Lake for these three different conditions are presented in Tables 2-2 through Table 2-4.

Water Quality

The modeled concentrations in the Partridge River at each node (designated as C_r) are the results of the water balance/mass balance model and are discussed in Section 5.2.2. For reference, baseline water quality data for the Partridge River are presented in Table 5-3.

5.1.3.2 Groundwater Recharge from Watershed

Flows

The inflow of groundwater at each node upstream of Colby Lake (designated as Q_g) was estimated based on the 30-day minimum average flow as computed by the XP-SWMM and MODFLOW models (see Section 2.1.4). This flow is similar to the baseflow observed in the Partridge River at the USGS Gage for the period of record 1978-1988. Different values were used for each stage of Mine Site development and closure based on the results of XP-SWMM models designed to simulate that particular stage of Mine Site development. Stockpiles and pits expand, reducing the area contributing to infiltration because those areas are dewatered or have liners. Once the East Pit and/or the West Pit have flooded, their groundwater recharge is subtracted from the groundwater estimate because these areas have been included as contributing areas in the XP-SWMM model (see RS52) simulating conditions in Closure and Post-Closure (otherwise the groundwater recharge would be double-counted). Groundwater flow into Colby Lake (Q_{gcl}) was calculated to be 1.17 cfs based on 0.000075 cfs per acre of drainage area obtained from XP-SWMM results for the lower reach of the Partridge River. This value was assumed constant for average, wet, and dry conditions as well as for all stages of Mine Site development. The inflow of groundwater at each node is presented in Table 2-1.

Water Quality

Groundwater concentrations from tributary sub-watersheds (designated as C_g) were determined from groundwater quality data from 2005-2007 except thallium, for which all 22 samples in the 2005-2007 dataset were reported as below the detection limit. Therefore, the background concentration for thallium was based on the 1992-1996 groundwater quality data reported by the MPCA (http://www.pca.state.mn.us/water/groundwater/gwmap/gwbaseline.html). A single value of C_g was used for all sub-watersheds. Because no additional baseline water quality monitoring data for the water quality of groundwater became available in 2007, the baseline water chemistry for groundwater in the Partridge River watershed presented in RS74 Draft-01 remains valid, with the exception of a few parameters for which typographical errors were found. Values of C_g used in the model are presented in Table 5-2.

With the exception of aluminum, the values presented in Table 5-2 are conservatively based on total concentration of metal. As discussed in the hydrogeologic reports (see RS02, RS10, and RS10a), total aluminum concentration in the NorthMet Mine Site dataset is highly variable (ranging thousands of micrograms per liter). The Regional Copper-Nickel Study (Siegel and Ericson, 1980) provides groundwater quality data for metals (including aluminum) from 58 samples. The data are reported as dissolved concentrations and the reported aluminum concentrations range from 0 to 0.28 mg/L. Similar data are available for the NorthMet data set, and 21 of 23 samples fall within the range reported by Siegel and Ericson, indicating good agreement between the datasets. Therefore, the median concentration of dissolved aluminum from the NorthMet dataset was used in the model for groundwater concentrations from tributary sub-watersheds.

5.1.3.3 Surface Runoff from Watershed

Flows

Surface runoff flows (designated as Q_s) tributary to each node upstream of Colby Lake were computed as the remainder of flow in the river (as computed using an XP-SWMM model) that was not accounted for by groundwater flows, the Northshore discharge, liner leakage and seepage flows from the Mine Site facilities, and the Mine Site surface runoff. Surface runoff to the Colby Lake node for average and wet conditions was calculated as 28 percent of the flow in the river at the USGS Gage (the entrance to Colby Lake) prior to mining operations minus the 1.17 cfs of groundwater flow originating in the Colby Lake-Whitewater Reservoir watershed. The 28 percent is based on a cumulative water balance between Partridge River inflow to Colby Lake and outflows from Colby Lake for the period 2001-2006 (see RS73B for more details about data used).

Water Quality

The concentration of each parameter (designated as C_s) in the surface runoff was estimated by calibrating the model (set up for existing conditions) to the baseline water quality data collected at SW-001, SW-002, SW-003, SW-004 and SW-005 in 2004, 2006 and 2007 (see Table 5-3). The surface runoff concentrations arrived at by this calibration were assumed to be constant for all sub-watersheds and for all flows and stages of Mine Site development. Values of C_s used in the model are presented in Table 5-2.

5.1.3.4 Northshore Discharge from Peter Mitchell Pits

Flows

There is an existing discharge from the Northshore mine site (designated as Q_{sns}) located just upstream of PolyMet's proposed monitoring location at node SW-001. Baseline water quality and flow data were used to estimate the average discharge. Parameters that showed different downstream dilution trends during periods of Northshore discharge were examined to back-calculate what the value of Q_{sns} would have to be to achieve those trends while holding C_s and C_g constant throughout the remainder of the model. The best fit of Q_{sns} = 1 cfs was obtained using sulfate concentration data. A value of $Q_{sns} \approx 2.5$ cfs was obtained using magnesium and calcium concentration data. Calibrations using several other parameters showed that an overall best fit was obtained using a value of Q_{sns} = 1.5 cfs.

Water Quality

Baseline water quality data sampled in 2004 and 2006 (no additional sampling was done in 2007) at PolyMet station PM-1 (which is located at the Northshore discharge, not in the river itself) was used to determine the concentration of each parameter for the Northshore discharge (designated as C_{sns}). Values of C_{sns} used in the model are presented in Table 5-2.

5.1.3.5 NorthMet Project Waste Rock and Lean Ore Stockpiles

Flows

A percentage of the leakage from the stockpile liners at the Mine Site will reach the Partridge River. Approximately 20 percent of the leakage from the Category 1/2 Waste Rock Stockpile and Overburden (Category 1/2) Storage drains south (although most of it is from the southwest overburden portion of the stockpile), entering the Partridge River at node SW-004a (designated as Q_{gC12} and Q_{gO12}, respectively). Nearly 100 percent of liner leakage from the Category 3 Waste Rock Stockpile drains to the Partridge River, entering the river at node SW-003 (designated as Q_{gC3}). Nearly 100 percent of leakage from the Category 3 Lean Ore Stockpile drains to the Partridge River, with 50 percent entering the river upstream of node SW-003 and 50 percent entering the river upstream of node SW-004 (designated as Q_{gC3LO}). Nearly 100 percent of leakage from the Category 4 Waste Rock Stockpile and Lean Ore Surge Pile drains to the Partridge River, entering the river upstream of node SW-004 (designated as Q_{gC4} and Q_{g4LO}, respectively). Leakage reaching the Partridge River is additional to the tributary watershed groundwater flows, as the stockpile areas are considered impervious in the XP-SWMM model and therefore do not contribute to groundwater flow aside from this leakage. In RS74 Draft-01, the leakage rates from the stockpiles were assumed to be the same for average, wet, and dry conditions. In RS74A, high, average and low liner leakage rates (described in Section 4.2.3.1.2 for the Mine Site-Proposed Action) were paired individually with wet, average and dry flow conditions in the Partridge River. Leakage rates from the stockpiles are listed in Table 4-6.

Water Quality

The results of the area-weighted high, average and low estimates of the liner yield for the different stockpiles and Year of Mine Site development or closure allows prediction of the corresponding stockpile leachate chemistry. Water quality concentrations corresponding to high, average and low liner leakage rates for Category 1/2 Waste Rock Stockpile (C_{gC12}) are presented in Tables 4-7 to 4-9; for Category 3 Waste Rock Stockpile (C_{gC3}) in Tables 4-10 to 4-12; for Category 3 Lean Ore Stockpile (C_{gCLO3}) in Tables 4-13 to 4-15; for Category 4 Waste Rock Stockpile (C_{gC4}) in Tables 4-16 to 4-18; and for the Lean Ore Surge Pile (C_{gC4LO}) in Tables 4-19 to 4-21. Water quality concentrations corresponding to the Overburden Areas of the Category 1/2 Waste Rock Stockpile (C_{gO12}) are listed in Table 4-22.

5.1.3.6 NorthMet Project Mine Pits

Flows

During operation, both the East Pit and West Pit pits are constantly dewatered, preventing release of groundwater from the pits to the Partridge River. The water from the de-watering of the mine pits is pumped to the WWTF and then to the Tailings Basin and Plant Site. The pits are flooded in Closure and Post-Closure, however, resulting in a steady flow of groundwater from the pits to the Partridge River. Groundwater recharge from the East Pit in Closure and Post-Closure is estimated to be 10 gpm (or 0.022 cfs), with 50 percent entering the river upstream of node SW-003 and 50 percent entering the river upstream of node SW-004 (designated as Q_{gep}). Groundwater recharge from the West Pit is estimated to be 18 gpm (0.04 cfs) and is added to the Partridge River model at node SW-004 (designated as Q_{gwp}).

No process water from the Mine Site will be discharged to the Partridge River during mining operations. Process water will be pumped to the WWTF and then to the Tailings Basin or to the East

Pit to accelerate flooding (Years 13 through 20). After the West Pit is flooded, however, pit water will overflow to the Partridge River. This input (designated as Q_{sms}) has been added to the model at node SW-004a. The average annual overflow of 1,622 acre-feet per year (2.24 cfs) was used to model the average flow condition. To model the dry condition, the overflow from the West Pit was set equal to the net groundwater inflow to the West Pit (60 acre-feet per year), essentially assuming no surface water runoff. To model the wet condition, the peak overflow resulting from the 10-year 24-hour precipitation event simulated in XP-SWMM was used (14.20 cfs).

Water Quality

Liner leakage from the Category 1/2 Waste Rock Stockpile drains into the East and West Pits. Therefore, the predicted water quality of the East Pit in Closure (C_{gep}) and Post-Closure and the West Pit in Post-Closure (C_{gwp})is based on the corresponding high, average and low leachate chemistry from this stockpile. Water chemistry of seepage from the East Pit and West Pit is presented in Tables 4-23 to 4-25 for low, average and high flow conditions. The predicted water quality of the West Pit overflow is the same as the seepage from the West Pit.

5.1.3.7 NorthMet Project Mine Site Other Facilities

Flows

The updated version of the surface water quality model of the Partridge River watershed presented in this RS74A report includes some inputs that were not considered in RS74 Draft-01. These inputs are:

- Overburden Storage and Laydown Area.
- Sumps: Category 1/2 Waste Rock Stockpile Sumps, Category 3 Waste Rock Stockpile Sumps, Category 3 Lean Ore Stockpile Sumps, Category 4 Waste Rock Stockpile Sumps, and the Lean Ore Surge Pile Sumps.
- Process Water Ponds: Overburden Runoff Process Water Ponds PW-1 and PW-7, Haul Road Runoff Process Water Ponds PW-2 and PW-4, Rail Transfer Hopper Process Water Pond PW-3, and the WWTF Equalization Ponds.

Seepage from the Overburden Storage and Laydown Area will flow south/southwest via groundwater toward the Partridge River during mine operations (Years 1 through 20), recharging the Partridge upstream of surface water monitoring station SW-004 (designated as Q_{gOS}). The estimated seepage rate is 535 gallons per acre per day.

Liner leakage from Category 1/2 Waste Rock Stockpile Sumps, Category 3 Waste Rock Stockpile Sumps, Category 3 Lean Ore Stockpile Sumps, Category 4 Waste Rock Stockpile Sumps, and the Lean Ore Surge Pile Sumps (designated as Q_{gC12s}, Q_{gC3s}, Q_{gC3LOs}, Q_{gC4s}, and Q_{gC4LOs}) are assumed to flow in the same direction as their respective stockpiles.

The Overburden Runoff Process Water Pond PW-1, Haul Road Runoff Process Water Ponds PW-2 and PW-4, and Rail Transfer Hopper Process Water Pond PW-3 (designated as Q_{gOp1}, Q_{gHRp2}, Q_{gHRp4}, and Q_{gRTHp} respectively) will recharge the Partridge River upstream of surface water monitoring station SW-004. The Overburden Runoff Process Water Pond PW-7 (designated as Q_{gOp7}) will recharge the Partridge River upstream of surface water monitoring station SW-004a. The WWTF Equalization Ponds (designated as Q_{gWTFp}) will recharge the Partridge River upstream of surface water monitoring station SW-004.

Table 4-30 presents the liner leakage and seepage rates from the Overburden Storage and Laydown Area, stockpile sumps, the process water ponds and the WWTF Equalization Ponds.

Water Quality

It was assumed that the water chemistry of the Category 1/2 Waste Rock Stockpile Sumps, Category 3 Waste Rock Stockpile Sumps, Category 3 Lean Ore Stockpile Sumps, Category 4 Waste Rock Stockpile Sumps, and the Lean Ore Surge Pile Sumps (designated as C_{gC12s}, C_{gC3s}, C_{gC3LOs}, C_{gC4s}, and C_{gC4LOs}) have the same predicted water chemistry as their associated stockpile listed in Tables 4-7 to 4-21.

The predicted water chemistry of the seepage from Overburden Storage and Laydown Area (designated as C_{gOS}) and the Overburden Area process water ponds (PW-1 and PW-7) (designated as C_{gOp1} and C_{gOp7}) are listed in Table 4-22.

The predicted water chemistry of the liner leakage from the WWTF Equalization Ponds (designated as C_{gWTFp}) is assumed to be the Stage 1 influent concentrations presented in Table 13 of the Addendum to RS-29T and are presented in Table 4-32.

The water chemistry of the Haul Road (PW-2 and PW-4) and the Rail Transfer Pond (PW-3) process water ponds (designated as Q_{gHRp2}, Q_{gHRp4}, and Q_{gRTHp} respectively) have not been predicted; therefore, baseline groundwater chemistry as presented in Table 5-2 was used in the model.

5.1.3.8 Hoyt Lakes Wastewater Treatment Plant

Flows

The Hoyt Lakes-WWTP discharges into Colby Lake. This input (designated as Q_{sHL}) is added at the Colby Lake node. A flow of 0.39 cfs is assumed for all stages of Mine Site development and all flow conditions based on the current average flow (telephone memo with Floyd Nelson, City of Hoyt Lakes, see Section 2.2.2).

Water Quality

Water quality data available for this discharge (designated as C_{sHL}) does not include the concentrations of the relevant parameters in the analysis herein. Concentrations of copper, nickel and zinc have been estimated for this input source based on average WWTP values reported for small community treatment plants (see Section 2.2.2 and Table 2-7). Concentrations for the other water quality parameters were assumed to be equal to the surface runoff concentration (C_s) as presented in Table 5-2.

5.1.3.9 Colby Lake

Volume

Flows to Colby Lake (designated as Q_{sCL}) for average, wet, and dry conditions were computed by adding the flows in the river at the USGS Gage to the groundwater flows and surface water runoff from the Colby-Whitewater Reservoir watershed for each condition.

Flows from the Colby-Whitewater Reservoir watershed were computed for the average and wet scenarios as 28 percent of the respective flows in the Partridge River at the USGS Gage. This percentage was determined based on a cumulative water balance between Partridge River inflow to Colby Lake and outflows from Colby Lake from 2001 to 2006. The dry condition assumes no surface runoff from the Colby-Whitewater Reservoir watershed and includes only the groundwater component from this watershed.

Water Quality

The modeled concentrations in Colby Lake (designated as C_{sCL}) are the results of the water balance/mass-balance model and are discussed in Section 5.2. Average flow conditions were modeled as steady state. For the dry condition, parameter concentrations in Colby Lake were modeled assuming a starting concentration equal to the average flow condition followed by 30-days of low flow calculated for the dry conditions. The wet condition was modeled assuming a starting concentration equal to the average flow condition followed by 24 hours of high flows (i.e. wet conditions).

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 Mine Site 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 SW-002, SW-003, SW-004 and SW-005 (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 Mine Site development and each flow condition (see Appendix G).

5.1.4.2 Discussion of Results

The resulting values of C_s are presented in Table 5-2. However, for some parameters the calibration results in a concentration of 0 mg/L. This was caused by 1) the parameter was not detected during sampling of the Partridge River or 2) the concentration in groundwater samples was significantly higher than in Partridge River samples. Therefore, the surface runoff concentration was set as half the detection limit or the average of the measured concentrations in the Partridge River for silver, arsenic, barium, beryllium, cadmium, cobalt, nickel and selenium. In general, surface runoff concentrations tend to be lower than or equal to groundwater concentrations from areas unaffected by the Mine Site. The exception is thallium for which the surface runoff concentration is 99 times larger than the groundwater concentration. Thallium was not detected in the Partridge River, therefore the surface runoff concentrations were calibrated to half the detection limit; however, it is possible that the concentration in the Partridge River is much lower than half the detection limit which would cause surface runoff concentrations to be conservative. Vanadium was not sampled; therefore a value of 0.0009 mg/L was used based on Hem (1992).

5.1.5 Modeled Flow Conditions

Wet, dry and average conditions were simulated for Years 1, 5, 10, 15 and 20 of Mine 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. Nodes upstream of Colby Lake were modeled assuming steady state conditions. The node corresponding to Colby Lake was modeled as steady state for the average flow condition only. For the dry condition, parameter concentrations in Colby Lake were modeled assuming a starting concentration equal to the average flow condition followed by 30-days of low flow calculated for the dry conditions. The wet condition was modeled assuming a starting concentration equal to the average flow condition followed by 24 hours of high flows (i.e. wet conditions).

5.2 Modeling Results

5.2.1 General

The Partridge River water quality model (see Section 5.1) was used to deterministically predict water chemistry in the Partridge River and Colby Lake during various stages of Mine Site operation and closure (see Section 4.1.1) for the Mine Site-Proposed Action (see Section 4.2). The seven model scenarios were evaluated for conditions representing low, average and high flow conditions (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, vanadium 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 liner leakage/seepage from the Mine Site facilities will reach the Partridge 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 Partridge River (see Sections 1.4.2. and 5.1 for more details).

5.2.2 Water Quality Presentations

5.2.2.1 Discussion of Deterministic Water Quality Predictions

Deterministic water quality predictions for the parameters listed in Section 5.2.1 are presented for the following seven scenarios for the Mine Site-Proposed Action listed in Section 4.1.1: Years 1, 5, 10, 15, 20, Closure, and Post-Closure.

Summary tables (presenting the complete results) and figures (presenting deterministically predicted concentrations of antimony, arsenic, cobalt, copper, nickel and sulfate) were prepared for the Mine Site-Proposed Action, including:

- Tables 5-4 to 5-6 for results at surface water monitoring station SW-001.
- Tables 5-7 to 5-9 and Figure 5-2 for results at surface water monitoring station SW-002.
- Tables 5-10 to 5-12 and Figure 5-3 for results at surface water monitoring station SW-003.
- Tables 5-13 to 5-15 and Figure 5-4 for results at surface water monitoring station SW-004.
- Tables 5-16 to 5-18 and Figure 5-5 for results at surface water monitoring station SW-004a.
- Tables 5-19 to 5-21 and Figure 5-6 for results at surface water monitoring station SW-005.
- Tables 5-22 to 5-24 and Figure 5-7 for results at USGS gaging station #04015475.
- Tables 5-25 to 5-27 and Figure 5-8 for results at Colby Lake.

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 Partridge River was used to determine the corresponding chronic standard consistent with Minnesota Rules Chapters 7050 and 7052. A figure was not prepared for SW-001 because this location is upstream of all Mine Site facilities, therefore concentrations do not vary with scenario of analysis.

In addition, the spatial variation of the deterministic water quality predictions for the six main parameters (antimony, arsenic, cobalt, copper, nickel and sulfate) characterizing the potential impacts of the NorthMet Project Mine Site-Proposed Action on the water quality of downstream watercourses and water bodies are presented at:

- Figure 5-9 for results corresponding to Year 1.
- Figure 5-10 for results corresponding to Year 5.
- Figure 5-11 for results corresponding to Year 10.
- Figure 5-12 for results corresponding to Year 15.
- Figure 5-13 for results corresponding to Year 20.

- Figure 5-14 for results corresponding to Closure.
- Figure 5-15 for results corresponding to Post-Closure.

All calculations and results for the complete set of constituents evaluated here are presented in Appendix H.

5.2.2.2 Parameters with Limited/Poor Data

The results presented in this section for the Partridge River and Colby Lake 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 Mine Site-Proposed Action, which led to decide dropping some parameters from the water quality modeling:

- There has been no monitoring of the chemical composition of the discharge from the Hoyt Lakes-WWTP. However, there is data for copper, nickel and zinc concentrations for discharges of wastewater treatment facilities from small communities in Wisconsin (see Section 2.2.2). The concentrations of all other water quality parameters in the Hoyt Lakes-WWTP discharge were assumed to be equal to the surface runoff concentration values.

- Antimony and vanadium were not monitored at Site PM-1, located at the Northshore discharge to the Partridge River. Therefore, the water quality of the discharge upstream of PM-1 for antimony and vanadium was assumed to be equal to the groundwater concentration values.

- There are no estimates of leachate concentration values from the Haul Road Runoff Process Water Ponds PW-2 and PW-4, Rail Transfer Hopper Process Water Pond PW-3. The water quality of these facilities was assumed to be equal to the groundwater concentration values.

- Chromium was not modeled. Chromium is expected to be hosted by primary magmatic oxides in the Duluth Complex, possibly as trace components of magnetite (Fe_3O_4) and ilmenite ($FeTiO_3$), or as trace amounts of chromite ($FeCr_2O_4$). All three minerals are highly resistant to weathering. For example, Geochemist's Workbench indicated the solubility of chromite to be 5×10^{-9} mg Cr/L at near neutral pH. Kinetic tests mostly indicate concentrations less than the detection limit (0.0002 mg/L) with isolated erratic results above the detection limit. As these concentrations are well below the lowest water quality standards (surface 0.1 mg/L at hardness near 100 mg $CaCO_3$/L) for chromium, modeling of chromium is not needed.

- Phosphate was not modeled. Phosphate probably occurs as apatite ($Ca_5(PO_4)3(OH,Cl,Fe)$). Apatite is also highly resistant to weathering and immobilized by presence. Geochemist's Workbench indicates the solubility of apatite to be 3×10^{-6} mg P/L at near neutral pH. Phosphate is undetected in kinetic test leachates (<0.03 mg PO_4/L).

- The groundwater concentrations from tributary sub-watersheds were determined by averaging 22 groundwater quality data samples from 2005-2007. 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. These parameters include silver, arsenic, barium, beryllium, boron, cadmium, cobalt, copper, lead, nickel, antimony, selenium, thallium, and zinc. (All 22 samples of thallium were below the detection limit so the concentration used in modeling was based on 1992-1996 groundwater water quality reported by the MPCA, see section 5.1.3.2). Vanadium was not sampled; therefore a value of 0.0043 mg/L for groundwater was used based on Hem (1992).

- 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 Partridge 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 each monitoring location. These parameters include silver, barium, beryllium, cadmium, cobalt, lead, antimony, selenium, thallium, and zinc. At least half the samples for other parameters were not detected at certain monitoring locations in the Partridge River; these parameters and locations include arsenic (SW-002, SW-003, SW-004 and SW-005), boron (SW-005), copper (PM-1 and SW-002), and nickel (PM-1 and SW-002). Vanadium was not sampled; therefore a value of 0.0009 mg/L was used for surface runoff based on Hem (1992).

5.2.3 Interpretation of Deterministic Water Quality Predictions

5.2.3.1 Comparison to Water Quality Standards

Partridge River

Deterministic water quality predictions of each constituent of analysis during Years 1, 5, 10, 15, 20, Closure, and Post-Closure in the Partridge River are presented in Tables 5-4 to 5-24 for low, average and high flows in the Partridge River under Mine Site-Proposed Action. 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 0.0069 mg/L at SW-004a in Post-Closure during average flow conditions under Mine Site-Proposed Action. This value is one-fourth of 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 SW-004 is 0.0015 mg/L and at SW-005 is 0.0015 mg/L.

- Arsenic. The highest deterministic water quality prediction of arsenic is 0.0083 mg/L at SW-004a in Post-Closure during low flow conditions under Mine Site-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 SW-004 is 0.0010 mg/L and at SW-005 is 0.0010 mg/L.

- Cobalt. The highest deterministic water quality prediction of cobalt is 0.00207 mg/L at SW-004 in Year 15 during low flow conditions under Mine Site-Proposed Action. This value is less than one-half 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 SW-004 is 0.00050 mg/L and at SW-005 is 0.00060 mg/L.

- Copper. The highest deterministic water quality prediction of copper is 0.00697 mg/L at SW-004 in Year 15 during low flow conditions under Mine Site-Proposed Action. This value is 84 percent of the Minnesota surface water quality standard of 0.00830 mg/L, based on a predicted hardness of 87.3 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at SW-004 is 0.00209 mg/L and at SW-005 is 0.00174 mg/L.

- Nickel. The highest deterministic water quality prediction of nickel is 0.02565 mg/L at SW-004 in Year 15 during low flow conditions under Mine Site-Proposed Action. This value is approximately one-half the Minnesota surface water quality standard of 0.0465 mg/L, based on a predicted hardness of 87.3 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at SW-004 is 0.00190 mg/L and at SW-005 is 0.00207 mg/L.

- Sulfate. The highest deterministic water quality prediction of sulfate is 31.7 mg/L at SW-004a in Post-Closure during low flow conditions under Mine Site-Proposed Action. There is no Minnesota water quality standard for sulfate applicable to the use classification of the Partridge River. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at SW-004 is 10.0 mg/L and at SW-005 is 9.0 mg/L.

All constituents meet minimum in-stream Minnesota water quality standards at all locations in the Partridge River during low, average and high flow conditions for all modeled scenarios under the Mine Site-Proposed Action. In most cases, the deterministic water quality predictions are well below the Minnesota surface water quality standards.

Colby Lake

Colby Lake must conform to different Minnesota surface water quality standards. Deterministic water quality predictions of each constituent of analysis during Years 1, 5, 10, 15, 20, Closure, and Post-Closure in Colby Lake are presented in Tables 5-25 to 5-27 for low, average and high flows under Mine Site-Proposed Action. 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 0.00395 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-Proposed Action. This value is 70 percent of the Minnesota surface water quality standard of 0.0055 mg/L.

- Arsenic. The highest deterministic water quality prediction of arsenic is 0.00515 mg/L in Colby Lake in Post-Closure during high flow conditions under Mine Site-Proposed Action. This value is one-half the Minnesota surface water quality standard of 0.01 mg/L.

- Cobalt. The highest deterministic water quality prediction of cobalt is 0.00081 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-Proposed Action. This value is one-fourth the Minnesota surface water quality standard of 0.0028 mg/L.

- Copper. The highest deterministic water quality prediction of copper is 0.00253 mg/L in Colby Lake in Year 15 during high flow conditions under Mine Site-Proposed Action. This value is one-fourth the Minnesota surface water quality standard of 0.0093 mg/L based on a estimated hardness of 100 mg/L.

- Nickel. The highest deterministic water quality prediction of nickel is 0.00506 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-Proposed Action. This value is one order of magnitude lower than the Minnesota surface water quality standard of 0.052 mg/L based on a predicted hardness of 100 mg/L.

- Sulfate. The highest deterministic water quality prediction of sulfate is 15.3 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-Proposed Action. This value is 6 percent of the Minnesota surface water quality standard of 250 mg/L.

All constituents meet minimum Minnesota surface water quality standards in Colby Lake during low, average and high flow conditions for all modeled scenarios under the Mine Site-Proposed Action except for iron and thallium (see Tables 5-25 to 5-27). This result is not attributable to the NorthMet Project, but rather it is related to the detection limit of the groundwater and to the existing levels in the surface water quality monitoring of the Partridge River. The Class 1B Minnesota water quality standard for iron is a secondary MCL of 0.3 mg/L, which is applicable for Colby Lake. There is no Minnesota water quality standard for iron in the Partridge River. The average concentration of iron from surface water quality monitoring in 2004, 2006 and 2007 at SW-004 is 1.99 mg/L and at SW-005 is 1.34 mg/L at SW-004. The average concentration of iron from groundwater quality monitoring in 2004, 2006 and 2007 at SW-004 is 2.84 mg/L. Therefore, the Minnesota water quality standard for iron would be exceeded even without NorthMet Project.

The deterministic water quality predictions for thallium in the Partridge River did not exceed Minnesota water quality standards under Mine Site-Proposed Action. However, thallium standards are stricter for Class 2Bd waters (0.00028 mg/L) to which Colby Lake must adhere than for Class 2B waters (0.00056 mg/L) which is applicable for the Partridge River. Thallium was only detected once in the Partridge River at PM-1 in August 2004; all the other reported values were below the detection limit of 0.00040 mg/L. By using half the detection limit as the target in the model calibration and an estimated concentration in groundwater that is basically negligible (0.000004 mg/L), an artificially high concentration in surface runoff was obtained. This high concentration dominates the predictions in Colby Lake. Further testing of thallium using a lower detection limit in the Partridge River would be necessary to determine predicted concentrations with a higher certainty.

5.2.3.2 Culpability Analysis

This section presents the culpability analysis (i.e., the degree of a particular Mine Site facility's or natural feature's impact on the overall deterministic water quality predictions in the Partridge River) for the Mine Site-Proposed Action. Six water quality parameters 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 Mine Site facilities) and Mine Site facilities (e.g., seepage from the East Pit, liner leakage from the Lean Ore Surge Pile) were investigated for all scenarios of Mine Site development and closure and for low, average and high flow conditions at the following surface water quality monitoring stations:

- SW-003. This location on the north branch of the Partridge River is east of the Mine Site, and its watershed area is 15.2 square miles. It is the first water quality monitoring station located downstream of the proposed Mine Site facilities.
- SW-004. This location on the north branch of the Partridge River is immediately upstream of the confluence with the south branch, downstream of 64 percent of the proposed Mine Site facilities by the end of Year 20, and its watershed area is 23.0 square miles.
- SW-004a. This location on the Partridge River is immediately downstream of the confluence of the north and south branches, downstream of 99 percent of the proposed Mine Site facilities by the end of Year 20, and its watershed area is 54.4 square miles.

The culpability analysis is completed for two sets of graphs which are presented in Appendix I for Mine Site-Proposed Action:

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

In the figures located in Appendix I, "#N/A" indicates that the mass flux is not applicable during the year of analysis (e.g., the West Pit has no seepage to the Partridge River via groundwater recharge before Post-Closure). In the figures, "-" 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 main results of this analysis are presented below:

Low Flow Conditions – Mine Site-Proposed Action

- Discharges from upstream of PM-1 represent the main input determining concentrations of arsenic, antimony and sulfate at SW-003 and SW-004. (Site PM-1 is upstream of surface water monitoring station SW-001). Seepage to groundwater from the West Pit and overflow from the West Pit also represents an important contribution determining concentrations of arsenic, antimony and sulfate at SW-004 and SW-004a during Post-Closure.

- Discharges from upstream of PM-1 and liner leakage from Category 1/2 Waste Rock Stockpile represent the main input determining concentrations of arsenic at SW-004a.

- Natural groundwater recharge from the watershed represents the main input determining concentrations of antimony and sulfate at SW-004a.

- Liner leakage from Category 3 Waste Rock Stockpile and natural groundwater recharge from the watershed, followed by discharges from upstream of PM-1, represent the main inputs determining concentrations of cobalt at SW-003 and SW-004.

- Natural groundwater recharge from the watershed represents the main input determining concentrations of cobalt at SW-004a. Seepage to groundwater from the West Pit and overflow from the West Pit also represent an important contribution determining concentrations of cobalt at SW-004a during Post-Closure.

- Liner leakage from Category 3 Waste Rock Stockpile represents the main input determining concentrations of copper and nickel at SW-003 and SW-004.

- Natural groundwater recharge from the watershed and liner leakage from Category 3 Waste Rock Stockpile represent the main inputs determining concentrations of copper and nickel at SW-004a.

Average Flow Conditions – Mine Site-Proposed Action

- Surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site) represents the main input determining concentrations of arsenic and sulfate at SW-003, SW-004 and SW-004a.

- Surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site) represents the main input determining concentrations of cobalt and antimony at SW-003, SW-004 and SW-004a. Liner leakage from Category 3 Waste Rock Stockpile also represents an important contribution determining concentrations of cobalt at SW-003 and SW-004.

- Surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site), followed by liner leakage from Category 3 Waste Rock Stockpile, represents the main input determining concentrations of copper at SW-003, SW-004 and SW-004a.

- Liner leakage from Category 3 Waste Rock Stockpile, followed by surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site), represents the main input determining concentrations of nickel at SW-003 and SW-004.

- Surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site), followed by groundwater seepage from the natural watershed and liner leakage from Category 3 Waste Rock stockpile, represents the main input determining concentrations of nickel at SW-004a.

- During Post-Closure, overflow from the West Pit together with surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site) represent the main inputs determining concentrations of arsenic, cobalt, copper, nickel, antimony and sulfate at SW-004a.

<u>High Flow Conditions – Mine Site-Proposed Action</u>

- Surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site) represents the main input determining concentrations of arsenic, cobalt, copper, antimony and sulfate at SW-003, SW-004 and SW-004a. Liner leakage from Category 3 Waste Rock and Category 3 Lean Ore Stockpiles also represent an important contribution determining concentrations of cobalt and copper at SW-003 and SW-004.

- During Post-Closure, overflow from the West Pit represents the main input determining concentrations of arsenic and antimony at SW-004a. This overflow from the West Pit also represents an important contribution determining concentrations of cobalt, nickel and sulfate at SW-004a.

- Liner leakage from Category 3 Lean Ore and Category 3 Waste Rock Stockpiles and surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site) represent the main inputs determining concentrations of nickel at SW-003 and SW-004.

- Surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site) represents the main input determining concentrations of nickel at SW-004a.

5.2.3.3 Factor to Exceed Standards

This section presents the analysis conducted to determine what increase in NorthMet Project's Mine Site liner leakage/seepage chemical concentrations would cause the deterministic water quality predictions in the Partridge River watershed (including Colby Lake) to exceed Minnesota surface water quality standards. Only changes to stockpile leachate chemical concentrations were investigated; changes in flows were not analyzed because a consensus was achieved between Barr Engineering, SRK and MDNR about the methodology to use for determination of the high, average and low estimates of the liner leakage rate for the different stockpiles and conditions. On the other hand, estimated seepage flows from the East Pit and West Pit to the Partridge River as groundwater recharge are considered conservative. Therefore, only changes to mine pits chemical concentrations were investigated; changes in flows were not analyzed.

The predicted chemical concentrations for the leachate from Category 3 Waste Rock Stockpile, Category 3 Lean Ore Stockpile, Category 4 Waste Rock Stockpile and Lean Ore Surge Pile as well as for the seepage from the East Pit and West Pit were multiplied concurrently by a factor. The determination of the factor for a given parameter (antimony, arsenic, cobalt, copper, nickel and sulfate were investigated here) and flow condition (low, average or high) was based on deterministic water quality predictions in the Partridge River or Colby Lake that exceed Minnesota surface water quality standards for that parameter at a given location and stage of the Mine Site development or closure under the Mine Site-Proposed Action. For an explanation of the Minnesota surface water quality standards, see Section 3.1.

Table 5-28 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 Partridge River and Colby Lake. There is no applicable Minnesota surface water quality standard for sulfate given the use classification of the Partridge 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 5-28.

Table 5-29 compares the concentrations of leachate from Category 3 Waste Rock Stockpile, Category 3 Lean Ore Stockpile, Category 4 Waste Rock Stockpile and Lean Ore Surge Pile as well as for the seepage from the East Pit and West Pit (all occurring concurrently) that would cause Partridge River deterministic water chemistry predictions to exceed Minnesota surface water quality standards and the "base case" concentrations of these Mine Site features. Table 5-30 presents the same information for Colby Lake. "Base Case" concentrations are those reasonable worst case concentrations presented in Tables 4-10 to 4-21 and Tables 4-23 to 4-25 and used to deterministically predict the concentrations in the Partridge River presented in Section 5.2.2.1.

The main results of this analysis are presented below:

Partridge River

- Antimony. The smallest factor to exceed the corresponding standard is 6.1 under the Mine Site-Proposed Action.
- Arsenic. The smallest factor to exceed the corresponding standard is 11.8 under the Mine Site-Proposed Action.
- Cobalt. The smallest factor to exceed the corresponding standard is 4.1 under the Mine Site-Proposed Action.
- Copper. The smallest factor to exceed the corresponding standard is 1.6 under the Mine Site-Proposed Action.
- Nickel. The smallest factor to exceed the corresponding standard is 2.3 under the Mine Site-Proposed Action.

Colby Lake

- Antimony. The smallest factor to exceed the corresponding standard is 2.1 under the Mine Site-Proposed Action.
- Arsenic. The smallest factor to exceed the corresponding standard is 3.2 under the Mine Site-Proposed Action.
- Cobalt. The smallest factor to exceed the corresponding standard is 11.3 under the Mine Site-Proposed Action.
- Copper. The smallest factor to exceed the corresponding standard is 10.2 under the Mine Site-Proposed Action.
- Nickel. The smallest factor to exceed the corresponding standard is 19.0 under the Mine Site-Proposed Action.
- Sulfate. The smallest factor to exceed the corresponding standard is 62 under the Mine Site-Proposed Action.

6.0 Proposed Action – Groundwater Quality Modeling

6.1 Introduction to Groundwater Quality Modeling

6.1.1 Previous Modeling of the Mine Site

The work presented here builds off of the modeling of the Mine Site that was presented in Appendix B of RS22. Readers are directed to that report for details of the previous modeling, which is summarized here. The previous modeling focused on quantifying the exchange of water between the pits and the groundwater system during mine operations and closure. The model simulated both the bedrock and the surficial deposits and used data collected during three phases of hydrogeologic investigations (see RS02, RS10 and RS10A) to constrain model parameters.

6.1.1.1 Previous Model Setup

The model had a grid covering an area of approximately 100 square miles. The model was vertically discritized into eight layers; seven layers simulating the various bedrock units and one layer simulating the surficial deposits. Vertical discritization was needed to accurately simulate the footwall and headwall geology of the pits at various stages of pit development. The bottom of Layer 1 was set equal to the bedrock-surface elevation as defined in RS49.

6.1.1.2 Hydraulic Conductivity

Five hydraulic conductivity zones were used to represent the bedrock units in the model: one zone for the Duluth Complex, two zones for the Virginia Formation, one zone for the Biwabik Iron Formation (BIF) and one zone for the Giants Range batholith. For the various layers, the boundary between the zones representing the Virginia Formation and the Duluth Complex and the boundary between the zones representing the Virginia Formation and the BIF was based on the location of these contacts at the elevation of the center of each layer. Two hydraulic conductivity zones were used to represent the surficial deposits in Layer 1: one zone for wetland deposits and one zone for glacial deposits. Boundaries of the wetland deposits were based on the wetland delineation presented in RS14. Hydraulic conductivity values for the zones representing the surficial deposits were allowed to vary during model calibration. For these two zones, hydraulic conductivity was assumed to be laterally isotropic and vertically anisotropic. Values for the remaining zones were based on hydraulic conductivity information presented in Section 2.1.6. Hydraulic conductivity of these zones was assumed to be isotropic. Table 6-1 shows the final hydraulic conductivity values used in the model.

6.1.1.3 Recharge

The same two zones that were used to represent the hydraulic conductivity of the surficial deposits were used to represent recharge in the local-scale model. Recharge was applied to the upper-most active layer. Recharge values were allowed to vary during model calibration. The final recharge values used in the model are as follows: recharge to wetland deposits = 0.3 inches per year; recharge to the glacial deposits = 1.5 inches per year. These recharge rates are consistent with the groundwater recharge rate that was predicted by the XP-SWMM model of the Mine Site area. The XP-SWMM model, which was calibrated using streamflow data from the Partridge River (see RS73A), has an average recharge rate of 0.84 inches per year.

6.1.1.4 Calibration

The model was calibrated to head and flux data using a combination of traditional trial-and-error methods and automated calibration methods. During model calibration, the only parameters that were allowed to vary were hydraulic conductivity of the surficial deposits, recharge, and conductance of the river cells simulating the Partridge River. The model was calibrated to water level data from piezometers completed within the surficial aquifer and exploratory boreholes and wells completed within the bedrock units. In addition to head targets, the model was also calibrated to a prediction of baseflow in the north branch of the Partridge River just upstream of the confluence with the south branch of the Partridge River, monitoring station SW-004.

6.1.1.5 Predictions

The groundwater flow model described in RS22 and summarized above was used to simulate conditions during several periods during mine operations and during Closure and Post-Closure. Closure is defined as the period during which the West Pit is flooding, after which is referred to as Post-Closure. The predicted water table in Post-Closure is shown on Figure 6-1, while Figure 6-2 shows the predicted piezometric surface within the bedrock in Post-Closure. The models were also used to predict flow directions for leakage from the stockpiles, which is summarized in Section 4.1.2.

6.2 General Modeling Methodology

Sources of potential groundwater impacts evaluated in this report include:

- Groundwater outflow from the East/Central and West Pits at the Mine Site; potential impacts could occur in both the surficial aquifer and the bedrock aquifers; and
- Leakage through stockpiles liners from the Category 1/2 - Overburden Stockpile, Category 3 Waste Rock Stockpile, Category 3 Lean Ore Stockpile, Category 4 Waste Rock Stockpile, and Lean Ore Surge Pile; potential impacts to the surficial aquifer were evaluated.

Figure 4-3 shows the locations of the sources that were evaluated at the Mine Site.

For each of the above sources, a groundwater flow path originating at the source and ending at the Partridge River was selected for evaluation of potential groundwater impacts. Flow paths were selected using the hydraulic head distribution at mine closure shown in Figure 6-1. When possible, the shortest path from the source to the Partridge River was selected to evaluate a “worst-case” scenario. Figure 4-1 shows the flow paths selected for evaluation of potential impacts from each source. Some of the flow path models evaluated included multiple sources, as discussed below. For the other sources, there should be very little if any mixing of sources because of the unique flow paths.

Potential impacts along each flow path were assessed using a simple cross-sectional model. Three-dimensional solute transport in groundwater in a one-dimensional flow field is described by the following equation, termed the advection-dispersion-reaction equation:

$$\frac{\partial C}{\partial t} = D_x \frac{\partial^2 C}{\partial x^2} + D_y \frac{\partial^2 C}{\partial y^2} + D_z \frac{\partial^2 C}{\partial z^2} - \frac{q}{n}\frac{\partial C}{\partial x} - R\lambda C \qquad \textbf{(Eq. 6-1)}$$

Where

C = Dissolved concentration [M/L^3]

t = Time [T]

D_x, D_y, D_z = Dispersion coefficients [L^2/T]

q = Darcy flux [L/T]

n = Saturated water content [unitless]

R = Retardation factor [unitless]

λ = Decay coefficient [T^{-1}]

Because the models used in this study are two-dimensional cross-section models (i.e. lateral flow into or out of the cross-section is assumed to be 0), the “y” terms drop out of the equation. In addition, potential decay (i.e. radioactive decay or chemical precipitation) was not accounted for as part of this evaluation. By ignoring these terms, this analysis provides a conservative estimate of groundwater concentrations. Under these assumptions, the advection-dispersion-reaction equation simplifies to the following:

$$\frac{\partial C}{\partial t} = D_x \frac{\partial^2 C}{\partial x^2} + D_z \frac{\partial^2 C}{\partial z^2} - \frac{q}{n}\frac{\partial C}{\partial x} - RC$$ **(Eq. 6-2)**

There are a number of published solutions to the advection-dispersion equation, including analytical and numerical solutions. Analytical solutions are attractive because of their relative simplicity; however, these solutions have more limitations on how the solute source may be represented and generally cannot explicitly simulate seepage into the aquifer from above. For maximum flexibility, a numerical solution to the advection-dispersion equation was utilized for this analysis. Specifically, the program MT3DMS (Zheng and Wang, 1999) was used to numerically solve the advection-dispersion equation. MT3DMS is a modular program that solves the advection-dispersion equation numerically and is designed to work with the industry standard finite-difference groundwater modeling code MODFLOW (McDonald and Harbaugh, 1988). Solute transport modeling was completed in two steps: first, a simple cross-sectional groundwater flow model of each flow path as described above was constructed using MODFLOW. Then, the groundwater flow field generated using MODFLOW was used in MT3DMS to predict solute concentrations downgradient of the source. The graphical user interface (GUI) Groundwater Vistas (version 5.16 Build 11) was used to complete the MODFLOW and MT3DMS modeling.

At the Mine Site, predicted groundwater concentrations were evaluated at the property boundary and at the Partridge River and, for the transient models only, the Dunka Road. If the groundwater flow path did not cross the property boundary prior to reaching the Partridge River, groundwater concentrations were not evaluated at the property boundary. Locations where groundwater concentrations are evaluated are shown on Figure 4-1.

6.2.1 Model Domain and Discretization

Figures 6-3 and 6-4 show schematics of each MODFLOW model layout and input parameters. The x-axis is oriented along the groundwater flow path, with the origin located at the upgradient edge of the seepage/leakage source area. Model cell dimensions were set to minimize numerical dispersion and computation time for each scenario. The cell dimensions were used for the simulations are summarized in Table 6-2.

For sources with potential impacts only to the surficial aquifer, the model consisted of 5 layers (simulating an average thickness of 5 meters for the surficial deposits). For sources with potential impacts to the surficial deposits and bedrock, the model consisted of a total of 10 layers (5 layers for the surficial deposits and 5 for the bedrock, representing the upper 100 meters of bedrock).

6.2.2 Hydraulic Conductivity Values

Hydraulic conductivity values were obtained from the groundwater model of the Mine Site presented in RS22 and described in Section 6.1.1. The highest hydraulic conductivity value for the surficial deposits reported in RS22 were used to evaluate a worst-case scenario (a higher hydraulic conductivity value results in a greater Darcy flux and less mixing with recharge prior to reaching a given evaluation location, resulting in a higher predicted concentration). The hydraulic conductivity of the Duluth Complex used in the regional model described in Section 6.1.1 was used for the bedrock hydraulic conductivity. Table 6-3 summarizes the hydraulic conductivity values used in the models.

6.2.3 Boundary Conditions

Constant head boundaries are located at the upgradient and downgradient edges of each flow path model, with heads selected to match the hydraulic gradient predicted by the Mine Site groundwater model described in Section 6.1.1. The upgradient and downgradient constant head boundary values used for each flow path model are shown on Figures 6-3 and 6-4. The actual head values used are arbitrary and were selected to match the predicted hydraulic gradient. The exception to this is the Category 1/2 model. With constant head cells placed at the upgradient and downgradient ends of the model as described above, the addition of the high stockpile leakage rates resulted in mounding in the cross-section model and flow towards both the upgradient and downgradient constant head boundaries. This reversal of flow is not seen in the plan view models presented in RS22 when these same stockpile leakage rates are used. Because the plan view models provide a more accurate representation of the mounding effect, the upgradient constant head cells were removed in the cross-section so that the reversal of flow would not occur in the model. This results in a more conservative estimate of groundwater impacts because the effect of “clean” upgradient water mixing with the stockpile leakage is ignored.

6.2.4 Recharge

The Recharge Package in MODFLOW was used to simulate both the infiltration of precipitation within the model domain outside of the source areas and the leakage to the aquifer from the stockpile source areas, where applicable. Recharge was applied to the uppermost model layer. For the screening level models, the highest liner leakage rates presented in Table 4-6 were used for the recharge rate within each source area. These leakage rates represent the maximum predicted rate for each source, building conservatism into the screening level model results. Time-varying recharge rates were used for the more detailed modeling discussed in Section 6.4. Actual recharge rates for the stockpiles used in each phase of Mine Site modeling are discussed in the subsequent sections. Recharge from precipitation (i.e. outside source areas) was set equal to the recharge value (1.5 inches per year) used in the Mine Site groundwater model presented RS22.

6.2.5 Dispersion

After the flow field was calculated using the MODFLOW model, MT3DMS was used to predict solute fate and transport and concentrations at the evaluation locations. MT3DMS requires values for the dispersion coefficients D_x, D_y, and D_z. Since there was assumed to be no flow in the y-direction (transverse to the flow path), a value for D_y was not required. The following relationships were used to estimate these parameters (Wiedemeier et al., 1999):

$$D_x = 0.83(\log_{10} L_p)^{2.414} \quad \textbf{(Eq. 6-3)}$$

$$D_z = 0.05 D_x \quad \textbf{(Eq. 6-4)}$$

Where

L_p = flow path length (i.e. distance from source to discharge area) [L]

Table 6-4 summarizes the dispersion coefficients used for each model.

6.2.6 Sorption

MT3DMS allows for simulation of retardation due to sorption onto soil particles and decay of constituents. Neither of these was simulated in the screening level model presented in Section 6.3. However, sorption was included in the simulations presented in Section 6.4.

Sorption is the process by which dissolved constituents are removed from solution and immobilized in or on the solid matrix of the porous medium by electrostatic or chemical forces. Sorption includes both adsorption and absorption, which includes both surface adhesion of the constituent and entering of the constituent into the bulk phase (i.e., solid phase). Sorption reactions are commonly included in modeling the potential impacts to surface and groundwater associated with leaching of heavy metals from waste sources. Sorption acts as a sink for heavy metals and is included in the retardation factor of the general advection-dispersive reactive equation (see Eq. 6-1 and 6-2).

Several isotherms have been developed in the research community to describe the ability of a particular constituent to be sorbed onto a particular porous medium. These isotherms include linear, Langmuir, Freundlich, and others. For this analysis, the equilibrium-based sorption and a linear sorption isotherm were assumed. Sorption is controlled by the partition (distribution) coefficient, K_d. K_d is defined by the following equation:

$$K_d = \frac{C_{sorbed}}{C_{solution}} \quad \textbf{(Eq. 6-5)}$$

Where

C_{sorbed} = equilibrium concentration of the constituent sorbed onto the surface of the porous medium

$C_{solution}$ = equilibrium concentration of the constituent remaining in the solution.

Higher partition coefficients represent higher sorption capacity. K_d, which has units of L^3M^{-1}, is dependent on both the nature and concentration of the constituent and the properties of the porous medium. Thus, it is both site-specific and constituent-specific. Sorption parameters used in select cross-section models are discussed in Section 6.4.2. Additional information on the sorption of metals at the Mine Site can be found in the Technical Memorandum “Attenuation of Inorganics in Groundwater at the NorthMet Mine Site,”(Appendix C).

6.2.7 Background/Recharge Concentrations

Background groundwater concentrations were obtained using data collected from monitoring wells located at the Mine Site, presented in RS02 and RS10A. It was assumed that background groundwater concentrations are representative of recharge concentrations and the recharge concentration was set equal to the background concentration in each of the models. When individual well locations were used to calculate average values, non-detect concentrations were set at half the detection limit. Where there was not background data available for a parameter, a concentration of zero was used for the recharge concentration.

Table 6-5 summarizes the source of background/recharge concentration data sources used in each of the models. Actual values used for each screening level model are presented in Tables 6-6 through 6-23.

6.2.8 Source Areas

New predicted concentrations of leakage/seepage presented for high, average and low linear leakage rates (see Section 4.2.3.1.2 for the Mine Site-Proposed Action) were used as source area concentrations for each of the flow path models. For the screening level models presented in Section 6.3, the highest predicted concentrations for each constituent for each source being modeled were used. For the more detailed models presented in Section 6.4, time-varying source area concentrations were incorporated. As discussed in Section 6.2.4, recharge zones were used to represent the stockpile leakage in the models. For these features, concentrations were assigned to these recharge zones. For the models simulating the East Pit and the West Pit, source zone concentrations are applied to the constant head cells that represent the upgradient edge of these sources.

SRK provided two separate water quality predictions for the East Pit that represent different waters. "Pore Water" is a representation of the pore water chemistry in the backfill assuming that all water entering the pit equilibrates with the oxidation products formed in the Category 3 and Category 4 rock while it was stockpiled. These concentrations are constant in time and do not account for the dilution and/or treatment of water in the East Pit that will be taking place during Closure (see Section 2.6.3). "Total East Pit" is the mixed wetland water and stormwater that flows into the wetland area. For the work presented here, the "Pore Water" predictions were used for the water leaving the East Pit via groundwater flow into bedrock and the "Total East Pit" predictions were used for the water leaving the East Pit via groundwater flow into the surficial deposits. Actual concentrations used in the screening level models are shown in Tables 6-6 through 6-23.

6.3 Screening Level Models

6.3.1 Methodology

A set of "screening level models" was prepared to determine what the potential constituents of concern are for each source area being evaluated. In these models, the most conservative assumptions were made; these simulations included only advection and dispersion in a steady-state model using the leakage rate for an open stockpile (higher leakage rate than for the closed stockpile) and the maximum predicted concentrations for the stockpile leakage (corresponding to concentrations during Post-Closure). In the screening level models, the only mechanism for reduction of constituent concentrations prior to reaching the Partridge River is mixing with recharge from precipitation and inflow of groundwater upgradient of the simulated source area(s).

The results from each screening level model were scaled to predict the concentrations of individual constituents, avoiding the need to complete a separate model run for each constituent to be evaluated. The following relationship was used to predict concentrations of individual constituents:

$$C = p_s C_s + p_r C_r + (1 - p_s - p_r) C_b \qquad \textbf{(Eq. 6-6)}$$

Where

C = concentration of constituent of interest

p_s = proportional contribution from source area(s)

C_s = concentration of constituent of interest in source area(s) inflow

p_r = proportional contribution from recharge

C_r = concentration of constituent of interest in recharge inflow

C_b = background concentration of constituent of interest

The proportional contribution from recharge and the source area(s) were determined by completing a model run with the concentration of that component set equal to unity and the concentration of all other components equal to zero and evaluating what percentage of that concentration reached the evaluation point.

Previous modeling of the Category 1/2 – Overburden stockpile predicted that during both operations and closure, seepage from the western 20 percent of the stockpile area will flow south towards the Partridge River. The remaining 80 percent will flow into the East and West Pits. For this reason, overburden will be placed in this western portion of the stockpile and most of the water that flows through the Category 1/2 waste rock will be collected in the pits rather than flowing to the Partridge River. However, it is possible that some seepage from Category 1/2 waste rock will flow to the south along with seepage from the overburden. To account for this, it was assumed that leakage from 25 percent of the stockpile area simulated in the model would be from the Category 1/2 waste rock. This is a very conservative number; the actual percentage will likely be much lower. Leakage from the remaining 75 percent of the area was assigned concentrations equal to predicted overburden seepage concentrations (see Section 4.2.3.1.3).

Three sets of screening level models were run for each flow path:

- one with high liner leakage rates and leakage water quality associated with high flow through the stockpile, referred to as High Leakage model;
- one with average liner leakage rates and leakage water quality associated with average flow through the stockpile, referred to as Average Leakage model; and
- one with low liner leakage rates and leakage water quality associates with low flow through the stockpile, referred to as Low Leakage model.

The exception to this is the Category 1/2 Waste Rock Stockpile. As discussed in Section 6.2.3, the predicted liner leakage rates for Category 1/2 Waste Rock Stockpile resulted in unreasonable mounding in the portion of the model below the stockpile if no underdrains are present. The predicted linear leakage rates are much higher than natural recharge and the modeling results suggest that leakage may be limited by the ability of the aquifer to transport this water away from the stockpile. The HELP model assumes that the permeability of the native soils is greater than that of the soil liner and that the native soil does not impose any constraints on the liner leakage rate. This is likely not the case for the Category 1/2 Waste Rock Stockpile. Groundwater modeling of this stockpile suggests that the maximum leakage rate and average leakage rate for this pile would result in a mound developing beneath the pile that is higher in elevation than the foundation for the stockpile if no underdrains are present. However, there will be an underdrain system beneath the linear that will prevent such a mound from forming. Because of this, only low linear leakage rates were used in the screening model for the Category 1/2 Waste Rock Stockpile model.

Leakage rates are discussed further in Section 4.2.3.1.2. Water quality associated with each of the flow conditions is discussed further in Section 4.2.3.1.3.

6.3.2 Simulation Results

Tables 6-6 through 6-23 summarize the results of the screening level simulations for each flow path and assumed leakage rate. These tables also present the source area and background concentrations used. Predicted groundwater concentrations are compared to groundwater evaluation criteria presented in Section 3.2. The screening level models show that the predicted concentrations in the upper portion of the bedrock aquifer are very similar to the predicted concentrations in the surficial aquifer. With depth, the concentrations in the bedrock are closer to the background concentrations. As such, Tables 6-9 through 6-14 present the concentrations predicted for the upper portion of the bedrock aquifer in order to be conservative. Potential exceedances of the groundwater evaluation criteria under all three linear leakage rate scenarios are highlighted on Tables 6-6 through 6-23 and summarized on Table 6-24.

Predicted beryllium and thallium concentrations exceeded evaluation criteria in each of the screening level simulations. However, this is due to the high background concentrations used in the models. Background concentrations for these parameters were all non-detects and as such one-half the detection limit was used. As a result, the background concentrations used for these constituents exceed the groundwater evaluation criteria. Because of this, these parameters are not shown as potential exceedances on Table 6-24. The background concentrations of aluminum, iron and manganese exceeded the groundwater evaluation criteria in many of the models and these parameters were not carried forward into the subsequent phase of modeling where this occurs. For these and other parameters that were not carried forward into the subsequent phase of modeling, the predicted concentrations shown on Tables 6-6 through 6-23 can be considered the maximum expected concentration.

As shown above, many of the potential contaminants of concern have been eliminated using the simple, conservative screening level models. The following sources and constituents were carried forward to the next phase of modeling:

- Category 1/2 - Overburden Stockpile – arsenic (As), antimony (Sb) and sulfate (SO_4)
- West Pit – arsenic (As), antimony (Sb) and sulfate (SO_4)
- East Pit and Category 4 Waste Rock Stockpile – iron (Fe), manganese (Mn), nickel (Ni), antimony (Sb) and sulfate (SO_4)
- Category 3 Waste Rock Stockpile – arsenic (As), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), antimony (Sb) and sulfate (SO_4)
- Category 3 Lean Ore Stockpile – copper (Cu), iron (Fe), manganese (Mn), nickel (Ni) and sulfate (SO_4)
- Lean Ore Surge Pile – iron (Fe), manganese (Mn), nickel (Ni) and sulfate (SO_4)

6.4 Transient Models

6.4.1 Methodology

An additional phase of groundwater modeling was undertaken to further evaluate the potential contaminants of concern for which potential exceedances of evaluation criteria were identified through use of the screening level models (Section 6.3.2). In this phase of modeling, the previously steady state models were converted to transient models, which allowed for the source area leakage rates and concentrations to vary with time. SRK provided predictions of stockpile leachate concentrations at various times during the project: Year 1, Year 5, Year 10, Year 15, Year 20, Closure and Post-Closure (Section 4.2.3). In addition, stockpile leakage rates will change during operations as new portions of the stockpiles are created and other portions are progressively closed. High, average and low stockpile leakage rates were calculated using the leakage rates for uncovered and covered sections (Section 4.2.3) and the amount of area that will be uncovered versus covered at any given time. Leakage rates calculated in this manner and used in the model are presented in Table 4-5 for Year 5, Year 10, Year 15, Year 20, Closure and Post-Closure. Closure is considered the period during which time the West Pit is flooding. As discussed in Section 6.2.3, the liner leakage rates for Category 1/2 Stockpile resulted in unreasonable mounding in the portion of the model below the stockpile. The predicted linear leakage rates are much higher than natural recharge and the modeling results suggest that leakage may be limited by the ability of the aquifer to transport this water away from the stockpile. Because of this, only low linear leakage rates were used in the transient model for the Category 1/2 Stockpile model.

West pit flooding is predicted to take between 40 and 56 years (Section 4.2.3.2.4.2). For the analysis presented here, it was assumed that Closure conditions would represent the period of West Pit flooding and Post-Closure would represent the period after the West Pit has flooded. Six stress periods were used in the transient models. (A “stress period” is a modeling term for a user specified time period during which no model inputs (such as recharge rates, source term concentrations, or user specified heads) change.) Stress periods are summarized in Table 6-25. Because of the different flooding rates for the West Pit under the different linear leakage rate conditions, the stress period lengths had to be different in the transient models to match the predicted conditions. While all of the cross-section models were set up in this general manner, each model had special considerations that are addressed below. If no model inputs changed between stress periods, the stress periods were combined with the total duration of the model simulation remaining unchanged.

6.4.1.1 Category 1/2 – Overburden Stockpile Model

This model was set up as described above, with water quality data predicted for a given period matched up with leakage rates for that same period. Concentrations used for each model stress period for each constituent for both the Category 1/2 and overburden portions of the stockpile are shown on Tables 6-26 through 6-28.

6.4.1.2 West Pit Model

The West Pit will be dewatered during Years 1 through 20. During Closure, the pit will be flooded with water and is not expected to lose water to groundwater. As such, only Post-Closure conditions were simulated with the West Pit model. Concentrations used for each model stress period are shown on Tables 6-26 through 6-28.

6.4.1.3 East Pit and Category 4 Waste Rock Stockpile Model

The East Pit will be dewatered during Years 1 through 12 and then will be backfilled with waste rock and water. During this period, groundwater will be flowing into the pit. It is only during Closure and Post-Closure that the East Pit is predicted to lose water to groundwater. To simulate this, the constant head cells representing the East Pit in the model are assigned background groundwater concentrations during stress periods 1 through 4. Closure concentrations are used in stress period 5 and Post-Closure concentrations in stress period 6. In this way, leachate from the Category 4 Waste Rock Stockpile is being mixed with background groundwater during operations and with water from the East Pit during Closure and Post-Closure. Concentrations used for each model stress period are shown on Tables 6-26 through 6-28.

6.4.1.4 Category 3 Waste Rock Stockpile Model

This model was set up in the same manner as the East Pit and Category 4 Waste Rock Stockpile model, with the predicted East Pit water quality being used as the up-gradient water quality during Closure and Post-Closure. Predicted concentrations from each time period are matched up with the corresponding leakage rate. Concentrations used for each model stress period for each constituent are shown on Tables 6-26 through 6-28.

6.4.1.5 Category 3 Lean Ore Stockpile Model

This model was set up in the same manner as the Category 1/2 Stockpile model, with predicted concentrations from each time period being matched up with the corresponding leakage rate. Concentrations used for each model stress period for each constituent are shown on Tables 6-26 through 6-28.

6.4.1.6 Lean Ore Surge Pile Model

This model was set up so that predicted concentrations from each time period are matched up with the corresponding leakage rate. This pile will be removed in Closure. Following the model period simulating operations, background water quality was used for all recharge. Concentrations used for each model stress period for each constituent are shown on Tables 6-26 through 6-28.

6.4.2 Sorption

In order to better understand what actual groundwater impacts may be associated with the NorthMet Project Mine Site, the transient cross-sectional models were run both with and without sorption. As discussed in Section 6.2.6, equilibrium-based sorption and a linear sorption isotherm were assumed. Linear isotherms use a partition coefficient (K_d) to relate the concentration of a sorbed constituent to the concentration of the constituent in solution (see Eq. 6-6). General K_d values can be used in screening-level/risk assessment analysis to determine the impact of heavy metals on groundwater in the absence of site-specific geochemical or isotherm data (USEPA, 1996a).

The USEPA published a 2005 report titled *Partition Coefficients for Metals in Surface Water, Soil, and Waste* (USEPA, 2005). The goal of the report was to "develop metal partition coefficients…for screening-level human and ecological risk assessments for chronic exposure to chemicals released from land-based waste management units…" The report summarized a search of published documents on the topic of partition coefficients. It summarized the results of many different studies and provided the ranges of values that were reported for conditions that are likely to represent a natural environment (did not include studies of pure mineral phase or treated soils, very low or high pH, etc.). Also presented in the publication are the values recommended by the USEPA for use in developing risk-based soil screening levels for contaminants in soils (USEPA, 1996b). Table 6-29 summarizes the K_d values presented in the USEPA reports and the values that were used in this analysis. Sorption is only considered for those parameters listed in Table 6-29.

The published sorption coefficients can be used to model attenuation of inorganic compounds in groundwater at the Mine Site, provided the pH, organic carbon content and iron oxide content are within the range of those in the studies used to determine the USEPA-recommended values. The technical memorandum "Attenuation of Inorganics in Groundwater at the NorthMet Mine Site" (Appendix C) presents the geochemical characterization of the surficial deposits at the Mine Site. This memorandum concludes that the pH, organic carbon content and the iron oxide content of the Mine Site soils are within the range of soils used in the development of the USEPA data base (generally are in the lower half of the range) and as such the published values are reasonable for site specific modeling. For the modeling presented here, the USEPA recommended values were used as these values fall within the lower range of the values presented from the literature study. The exception to this is for vanadium, where the USEPA recommended value is higher than the literature range, in which case the mean value was used.

In addition to K_d values, the inclusion of sorption in the transport simulation requires a bulk density for the soil. An average bulk density of 1.27 tons/yd^3 (1.5 kg/L) was used. This value represents the average bulk density for the soils at the Mine Site as reported in the U.S. Department of Agriculture's St. Louis County Soil Survey Geographic Database. Sorption was only simulated in the surficial aquifer. In the bedrock, it was assumed there would be no sorption.

6.4.3 Results

Results from the transient models are presented on Figures 6-5 through 6-48 and are summarized below and in Tables 6-30 through 6-32 (these tables show the predictions at the property boundary or the Partridge River, whichever is closer to the source area for each flowpath). Predictions are also made for concentrations at the Dunka Road for flowpaths that cross the Dunka Road prior to the nearest evaluation point; this includes the West Pit, East Pit and Category 4 Waste Rock Stockpile, and the Lean Ore Surge Pile models. For the Category 1/2 stockpile flowpath, the property boundary is very near the Dunka Road; results are only presented at the property boundary. Results from the screening level model showed that concentrations in the bedrock are very similar to, if not slightly less than, concentrations in the surficial deposits. As such, only concentrations in the surficial aquifer are shown.

6.4.3.1 Category 1/2 – Overburden Stockpile Model

Concentrations are predicted to be above the groundwater evaluation criteria for arsenic and antimony if sorption is not considered. With sorption, predicted concentrations are below the groundwater evaluation criteria. Sulfate is predicted to exceed the secondary MCL criteria for the high linear leakage scenario, but is predicted to be below the secondary MCL criteria for the other two cases.

6.4.3.2 West Pit Model

Concentrations of arsenic and antimony are predicted to be above the groundwater evaluation criteria at the property boundary and at the Dunka Road if sorption is not considered. With sorption, arsenic and antimony concentrations are predicted to be under the evaluation criteria at the property boundary for the period simulated. Sulfate concentrations are predicted to be below 200 mg/L at the property boundary and 125 mg/L at the Dunka Road under all three stockpile leakage rates, which are all below the secondary MCL criteria.

6.4.3.3 East Pit and Category 4 Waste Rock Stockpile Model

Concentrations of iron and manganese are predicted to exceed the secondary MCL criteria for all three cases. Concentrations of nickel are predicted to be below the groundwater evaluation criteria with and without sorption for the average and low linear leakage rates. The predicted concentration of nickel for the high linear leakage rates is predicted to be above the groundwater evaluation criteria with no sorption, but is predicted to be below the criteria at the Partridge River with sorption. Antimony concentrations are predicted to be temporarily over the groundwater evaluation criteria at the Partridge River for all three linear leakage cases when sorption is not simulated. For all cases with sorption included, concentrations are predicted to be below the evaluation criteria. At the Partridge River, sulfate concentrations are predicted to reach a steady-state concentration below 50 mg/L, with a temporary maximum concentration of less than 75 mg/L for all cases, which is well below the secondary MCL criteria.

6.4.3.4 Category 3 Waste Rock Stockpile Model

Concentrations of arsenic, copper, iron, manganese, nickel and antimony are predicted to be over the groundwater evaluation criteria or secondary MCL criteria for one or more of the leakage rate cases with no sorption simulated. Of these, only nickel under the high linear leakage case exceeds evaluation criteria when sorption is considered (sorption is not considered for iron or manganese). Sulfate is predicted to reach peak concentrations of 180, 178, and 280 mg/L and long term concentrations of 128, 114, and 212 mg/L for the low, average and high linear leakage rates respectively, which are all below the secondary MCL criteria.

6.4.3.5 Category 3 Lean Ore Stockpile Model

For the high linear leakage case, predicted concentrations of iron, manganese, and nickel (with and without sorption) are predicted to exceed the respective groundwater evaluation and/or secondary MCL criteria. For the average and low linear leakage cases, the predicted concentration of nickel, only when sorption is not simulated, is predicted to be over the groundwater criterion. There are no other predicted exceedences for the low and average linear leakage cases. Groundwater is predicted to have a long term sulfate concentration of 56 mg/L just upgradient of the Partridge River for the high linear leakage case and is predicted to be essentially equal to background concentrations for the low and average linear leakage cases; all of which are well below the secondary MCL criteria.

6.4.3.6 Lean Ore Surge Pile Model

Iron and manganese concentrations are predicted to temporarily exceed groundwater criteria for the high leakage rate case, but long-term concentrations are predicted to be below criteria. With no sorption simulated, nickel concentrations are predicted to temporary exceed the groundwater criterion for the high linear leakage case. However, with sorption, no exceedence is predicted, nor is it predicted to be exceeded with or without sorption for the low or average linear leakage cases. Sulfate is predicted to be at or below 25 mg/L for the low, average and high linear leakage cases at the Partridge River, which is well below the secondary MCL criteria.

6.5 Interpretation of Results

When sorption is included in the prediction of groundwater concentrations along each flow path, there are only two exceedences of a groundwater standard at the property boundary or the Partridge River: nickel concentrations at the Partridge River down-gradient from the Category 3 Stockpile with high linear leakage rates and nickel concentrations down-gradient from the Category 3 Lean Ore Stockpile with high liner leakage rates.

The secondary MCL criteria for iron and manganese are predicted to be exceeded along several of the flowpaths. The only predicted exceedance of the secondary MCL criteria for sulfate is along the Category 1/2 flowpaths under high liner leakage conditions. It is worth reiterating here that the 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.

7.0 Reasonable Alternative 1 – Surface Water Quality Modeling

7.1 Modeling Methods

7.1.1 Overview

Concentrations of the constituents of interest in the Partridge River and Colby Lake under the Mine Site-RA1 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 Mine Site-Proposed-Action is also valid for the Mine Site-RA1, 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 Mine Site-Proposed-Action, including the schematic view of the model presented in Figure 5-1 and the description of the variables shown in Table 5-1 is also valid for the Mine Site-RA1. However, the Mine Site-RA1 layout is shown in Figures 4-8 to 4-16.

7.1.3 Summary of Data Input

7.1.3.1 Partridge River

<u>Flows</u>

In-river flows at nodes discussed in Section 5.1.3.1 and presented in Tables 2-2 to 2-4 for the Mine Site-Proposed Action are also valid for the Mine Site-RA1.

Baseflow reductions in the Partridge River (see Table 2-1) are primarily determined by the drawdown effect associated with mining of the East Pit and West Pit, and to a significantly lesser degree by the area covered by waste rock or lean ore stockpiles. No changes (with respect to the Mine Site-Proposed Action) to the development of the mine pits are considered with the Mine Site-RA1. Changes in the total or reclaimed footprint of the stockpiles with the Mine Site-RA1 are minimal compared to the Mine Site-Proposed Action; hence their impact on baseflow reductions is negligible. Estimated low flows in the Partridge River under the Mine Site-Proposed Action and Mine Site-RA1 are presented in Table 2-2.

Average and high flows at different locations in the Partridge River are dependent on the stage of development of the mine pits as well as on the rate of growth and reclamation of the waste rock and lean ore stockpiles. This dependence is translated into runoff volumes and flows of stormwater to be routed to the Partridge River versus those of process water to be collected and pumped to the WWTF for treatment and reuse in the Tailings Basin-Plant Site in the Embarrass River watershed. As indicated above, no changes (with respect to the Mine Site-Proposed Action) to the development of the mine pits are considered with the Mine Site-RA1. The rate of growth, and in particular of reclamation, of the waste rock and lean ore stockpiles under the Mine Site-RA1 is different from those under the Mine Site-Proposed Action. However, review of Tables 2-3 and 2-4 indicate that at a given location in the Partridge River, the difference between the maximum (associated with a smaller rate of stockpile reclamation) and minimum (associated with a greater rate of stockpile reclamation) flows for the different stages of Mine Site development is less than 3 percent. Therefore, for practical purposes the average and high flows under the Mine Site-Proposed Action are representative of those under the Mine Site-RA1 and are presented in Tables 2-3 and 2-4.

Water Quality

The concentrations in the Partridge River 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 Partridge River at SW-002, SW-003, SW-004 and SW-005 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 Mine Site-Proposed Action is also valid for the Mine Site-RA1.

Water Quality

The groundwater concentrations discussed in Section 5.1.3.2 and presented in Table 5-2 for the Mine Site-Proposed Action is also valid for the Mine Site-RA1.

7.1.3.3 Surface Runoff from Watershed

Flows

Surface runoff flows discussed in Section 5.1.3.3 for the Mine Site-Proposed Action is also valid for the Mine Site-RA1.

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 Mine Site-Proposed Action is also valid for the Mine Site-RA1.

7.1.3.4 Northshore Discharge from Peter Mitchell Pits

Flows

The discharges from the Northshore mine site discussed in Section 5.1.3.4 for the Mine Site-Proposed Action is also valid for the Mine Site-RA1.

Water Quality

Parameter concentrations for this input discussed in Section 5.1.3.4 and presented in Table 5-2 for the Mine Site-Proposed Action is also valid for the Mine Site-RA1.

7.1.3.5 NorthMet Project Waste Rock and Lean Ore Stockpiles

Flows

Similarly to the model for the Mine Site-Proposed Action, the liner leakage from the stockpiles drain to the same Partridge River nodes. Approximately 20 percent of the leakage from the Category 1 Waste Rock Stockpile and Overburden (Category 1) Storage drains south (although most of it is from the overburden portion of the stockpile), entering the Partridge River at node SW-004a (designated as Q_{gC12} and Q_{gO12}, respectively). Leakage from the Category 2/3 Waste Rock Stockpile drains to the Partridge River entering the river at node SW-003 (designated as Q_{gC3}). Nearly 100 percent of leakage from the Category 3 Lean Ore Stockpile drains to the Partridge River, with 50 percent entering the river upstream of node SW-003 and 50 percent entering the river upstream of node SW-004 (designated as Q_{gC3LO}). Nearly 100 percent of leakage from the Category 4 Waste Rock Stockpile and Lean Ore Surge Pile drains to the Partridge River, entering the river upstream of node SW-004 (designated as Q_{gC4} and Q_{g4LO}, respectively). Low, average and high liner leakage rates from the stockpiles are listed in Table 4-38.

Water Quality

The results of the area-weighted high, average and low estimates of the liner yield for the different stockpiles and Year of Mine Site development or closure allows prediction of the corresponding stockpile leachate chemistry. The addition of lime or limestone to the stockpiles results in lower chemistry for Mine Site-RA1 than under Mine Site-Proposed Action. Water quality concentrations corresponding to high, average and low liner leakage rates under Mine Site-RA1 for Category 1 Waste Rock Stockpile (C_{gC12}) are presented in Tables 4-39 to 4-41; for Category 2/3 Waste Rock Stockpile (C_{gC3}) in Tables 4-42 to 4-44; for Category 3 Lean Ore Stockpile (C_{gCLO3}) in Tables 4-45 to 4-47; for Category 4 Waste Rock Stockpile (C_{gC4}) in Tables 4-48 to 4-50; and for the Lean Ore Surge Pile (C_{gC4LO}) in Tables 4-51 to 4-53. Parameter concentrations for the Overburden Areas of the Category 1 Waste Rock Stockpile (C_{gO12}) discussed in Section 5.1.3.5 and presented in Table 4-22 for the Mine Site-Proposed Action are also valid for the Mine Site-RA1.

7.1.3.6 NorthMet Project Mine Pits

Flows

The seepage from the East and West Pit discussed in Section 5.1.3.6 for the Mine Site-Proposed Action is also valid for the Mine Site-RA1.

Water Quality

Water quality has been estimated for the East Pit and West Pit in closure and provides parameter concentrations for these inputs based upon low, average and high liner leakage rates of Category 1 Waste Rock Stockpile and based on the Category 2, Category 3 and Category 4 rock that will be backfilled into the pits during closure. The water quality is presented in Tables 4-58 to 4-60 for the East Pit and the West Pit under Mine Site-RA1. Parameter concentrations for the West Pit overflow are assumed to be the same as seepage from the West Pit under Mine Site-RA1.

7.1.3.7 NorthMet Project Mine Site Other Facilities

Flows

Seepage from Overburden Storage and Laydown Area discussed in Section 5.1.3.7 and presented in Table 4-30 for the Mine Site-Proposed Action is also valid for the Mine Site-RA1.

Leakage from the Overburden Runoff Process Water Ponds PW-1 and PW-7, Haul Road Runoff Process Water Ponds PW-2 and PW-4, Rail Transfer Hopper Process Water Pond PW-3 discussed in Section 5.1.3.7 and presented in Table 4-30 for the Mine Site-Proposed Action is also valid for the Mine Site-RA1.

The stockpile areas, and therefore the liner leakage from the stockpile sumps, are different under Mine Site-RA1 than from Mine Site-Proposed Action. Liner leakage from Category 1 Waste Rock

Stockpile Sumps, Category 2/3 Waste Rock Stockpile Sumps, Category 3 Lean Ore Stockpile Sumps, Category 4 Waste Rock Stockpile Sumps, and the Lean Ore Surge Pile Sumps (designated as Q_{gC12s}, Q_{gC3s}, Q_{gC3LOs}, Q_{gC4s}, and Q_{gC4LOs}) are assumed to flow in the same direction as their respective stockpiles. Liner leakage rates from the drainage sumps are listed in Table 4-61.

The WWTF Equalization Ponds (designated as Q_{gWTFp}) will recharge the Partridge River upstream of surface water monitoring station SW-004. Table 4-62 presents the liner leakage rates from the WWTF equalization ponds to the Partridge River.

Water Quality

It was assumed that the water chemistry of the Category 1 Waste Rock Stockpile Sumps, Category 2/3 Waste Rock Stockpile Sumps, Category 3 Lean Ore Stockpile Sumps, Category 4 Waste Rock Stockpile Sumps, and the Lean Ore Surge Pile Sumps (designated as C_{gC12s}, C_{gC3s}, C_{gC3LOs}, C_{gC4s}, and C_{gC4LOs}) have the same predicted water chemistry as their associated stockpile listed in Tables 4-39 to 4-53.

The parameter concentrations in leachate from the WWTF Equalization Ponds under Mine Site-RA1 are presented in Table 4-62.

Parameter concentrations for leachate concentrations from the Overburden Storage and Laydown Area, Overburden Runoff Process Water Ponds PW-1 and PW-7, Haul Road Runoff Process Water Ponds PW-2 and PW-4, and Rail Transfer Hopper Process Water Pond PW-3 discussed in Section 5.1.3.7 for the Mine Site-Proposed Action are also valid for the Mine Site-RA1.

7.1.3.8 Hoyt Lakes Wastewater Treatment Plant

Flows

Discharge from the Hoyt Lakes WWTP discussed in Section 5.1.3.8 for the Mine Site-Proposed Action is also valid for the Mine Site-RA1.

Water Quality

The concentration of the discharge from the Hoyt Lakes WWTP discussed in Section 5.1.3.8 for the Mine Site-Proposed Action is also valid for the Mine Site-RA1.

7.1.3.9 Colby Lake

Volume

Flows to Colby Lake in discussed Section 5.1.3.9 for the Mine Site-Proposed Action are also valid for the Mine Site-RA1.

Water Quality

The concentrations in Colby Lake are the results of the water balance/mass-balance model and are discussed in Section 7.2.2.

7.1.4 Model Calibration

The model calibration results presented in Section 5.1.4 for the Mine Site-Proposed Action are also valid for the Mine Site-RA1.

7.1.5 Modeled Flow Conditions

The same modeled flow conditions were used under the Mine Site-Proposed Action and Mine Site-RA1 with the exception that an additional year was modeled for the Mine Site-RA1, Year 12. For more details about the modeled flow conditions see Section 5.1.5.

7.2 Modeling Results

7.2.1 General

The Partridge River water quality model (see Section 7.1) was used to deterministically predict water chemistry in the Partridge River and Colby Lake during various stages of Mine Site operation and closure (see Section 4.1.1) for the Mine Site-RA1 (see Section 4.3). The eight model scenarios were evaluated for conditions representing low, average and high flow conditions (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, vanadium 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 liner leakage/seepage from the Mine Site facilities will reach the Partridge 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 Partridge River (see Sections 1.4.2 and 7.1 for more details).

7.2.2 Water Quality Presentations

7.2.2.1 Discussion of Deterministic Water Quality Predictions

Deterministic water quality predictions for the parameters listed in Section 7.2.1 are presented for the following eight modeled scenarios for the Mine Site-RA1 listed in Section 4.1.1: Years 1, 5, 10, 12, 15, 20, Closure, and Post-Closure.

Summary tables (presenting the complete results) and figures (presenting deterministically predicted concentrations of antimony, arsenic, cobalt, copper, nickel and sulfate) were prepared for the Mine Site-RA1, including:

- Tables 7-1 to 7-3 for results at surface water monitoring station SW-001.
- Tables 7-4 to 7-6 and Figure 7-1 for results at surface water monitoring station SW-002.
- Tables 7-7 to 7-9 and Figure 7-2 for results at surface water monitoring station SW-003.
- Tables 7-10 to 7-12 and Figure 7-3 for results at surface water monitoring station SW-004.
- Tables 7-13 to 7-15 and Figure 7-4 for results at surface water monitoring station SW-004a.
- Tables 7-16 to 7-18 and Figure 7-5 for results at surface water monitoring station SW-005.
- Tables 7-19 to 7-21 and Figure 7-6 for results at USGS gaging station #04015475.
- Tables 7-22 to 7-24 and Figure 7-7 for results at Colby Lake.

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 Partridge River was used to determine the corresponding chronic standard consistent with Minnesota Rules Chapters 7050 and 7052. A figure was not prepared for SW-001 because this location is upstream of all Mine Site facilities, therefore concentrations do not vary with scenario of analysis.

In addition, the spatial variation of the deterministic water quality predictions for the six main parameters (antimony, arsenic, cobalt, copper, nickel and sulfate) characterizing the potential impacts of the NorthMet Project Mine Site-RA1 on the water quality of downstream watercourses and water bodies are presented at:

- Figure 7-8 for results corresponding to Year 1.
- Figure 7-9 for results corresponding to Year 5.
- Figure 7-10 for results corresponding to Year 10.
- Figure 7-11 for results corresponding to Year 12.
- Figure 7-12 for results corresponding to Year 15.
- Figure 7-13 for results corresponding to Year 20.
- Figure 7-14 for results corresponding to Closure.
- Figure 7-15 for results corresponding to Post-Closure.

All calculations and results for the complete set of constituents evaluated here are presented in Appendix H.

7.2.2.2 Parameters with Limited/Poor Data

The results presented for the Partridge River and Colby Lake 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 Mine Site-Proposed Action is valid for the Mine Site-RA1.

7.2.3 Interpretation of Deterministic Water Quality Predictions

7.2.3.1 Comparison to Water Quality Standards

Partridge River

Deterministic water quality predictions of each constituent of analysis during Years 1, 5, 10, 12, 15, 20, Closure, and Post-Closure in Partridge River are presented in Tables 7-1 to 7-21 for low, average and high flows in the Partridge River under Mine Site-RA1. 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 0.00633 mg/L at SW-004a in Post-Closure during average flow conditions under Mine Site-RA1. This value is one-fifth of 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 SW-004 is 0.0015 mg/L and at SW-005 is 0.0015 mg/L.

- Arsenic. The highest deterministic water quality prediction of arsenic is 0.00756 mg/L at SW-004a in Post-Closure during low flow conditions under Mine Site-RA1. This value is one-seventh of 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 SW-004 is 0.0010 mg/L and at SW-005 is 0.0010 mg/L.

- Cobalt. The highest deterministic water quality prediction of cobalt is 0.00161 mg/L at the USGS Gage in Post-Closure during low flow conditions under Mine Site-RA1. This value is 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 SW-004 is 0.00050 mg/L and at SW-005 is 0.00060 mg/L.

- Copper. The highest deterministic water quality prediction of copper is 0.00339 mg/L at SW-004a in Year 5 during low flow conditions under Mine Site-RA1. This value is less than half the Minnesota surface water quality standard of 0.00758 mg/L based on a predicted hardness of 78.4 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at SW-004 is 0.00209 mg/L and at SW-005 is 0.00174 mg/L.

- Nickel. The highest deterministic water quality prediction of nickel is 0.01522 mg/L at the USGS Gage in Post-Closure during low flow conditions under Mine Site-RA1. This value is one-third the Minnesota surface water quality standard of 0.04450 mg/L based on a predicted hardness of 82.9 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at SW-004 is 0.00190 mg/L and at SW-005 is 0.00207 mg/L.

- Sulfate. The highest deterministic water quality prediction of sulfate is 33.1 mg/L at SW-004a in Post-Closure during low flow conditions under Mine Site-RA1. There is no Minnesota water quality standard for sulfate applicable to the use classification of the Partridge River. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at SW-004 is 10.0 mg/L and at SW-005 is 9.0 mg/L.

All constituents meet minimum in-stream Minnesota water quality standards at all locations in the Partridge River during low, average and high flow conditions for all modeled scenarios under the Mine Site-RA1. In most cases, the deterministic water quality predictions are well below the Minnesota surface water quality standards.

Colby Lake

Colby Lake must conform to different Minnesota water quality standards than the Partridge River. Deterministic water quality predictions of each constituent of analysis during Years 1, 5, 10, 12, 15, 20, Closure, and Post-Closure in Colby Lake are presented in Tables 7-22 to 7-24 for low, average and high flows under Mine Site-RA1. 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 0.00373 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-RA1. This value is two-thirds the Minnesota surface water quality standard of 0.0055 mg/L.

- Arsenic. The highest deterministically water quality prediction of arsenic is 0.00493 mg/L in Colby Lake in Post-Closure during high flow conditions under Mine Site-RA1. This value is one-half the Minnesota surface water quality standard of 0.01 mg/L.

- Cobalt. The highest deterministic water quality prediction of cobalt is 0.00077 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-RA1. This value is one-fourth the Minnesota surface water quality standard of 0.0028 mg/L.

- Copper. The highest deterministic water quality prediction of copper is 0.00207 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-RA1. This value is one-fourth the Minnesota surface water quality standard of 0.0093 mg/L based on an estimated hardness of 100 mg/L.

- Nickel. The highest deterministic water quality prediction of nickel is 0.00455 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-RA1. This value is one order of magnitude smaller than the Minnesota surface water quality standard of 0.052 mg/L based on an estimated hardness of 100 mg/L.

- Sulfate. The highest deterministic water quality prediction of sulfate is 15.8 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-RA1. This value is one order of magnitude smaller than the Minnesota surface water quality standard of 250 mg/L.

All constituents meet minimum Minnesota water quality standards for Colby Lake during low, average and high flow conditions for all modeled scenarios of the Mine Site development and closure under the Mine Site-RA1 except for iron and thallium (see Tables 7-22 to 7-24). Similar to Mine Site-Proposed Action, these exceedances are related to the detection limit of the groundwater and to the existing levels in the surface water quality monitoring of the Partridge River. See Section 5.2.3.1 for discussion.

7.2.3.2 Culpability Analysis

This section presents the culpability analysis (i.e., the degree of a particular Mine Site facility's or natural feature's impact on the overall deterministic water quality predictions in the Partridge River) for the Mine Site-RA1. Six water quality parameters 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 Mine Site facilities) and Mine Site facilities (e.g., seepage from the East Pit, liner leakage from the Lean Ore Surge Pile) were investigated for all scenarios of Mine Site development and closure and for low, average and high flow conditions at the following surface water quality monitoring stations:

- SW-003. This location on the north branch of the Partridge River is east of the Mine Site, and its watershed area is 15.2 square miles. It is the first water quality monitoring station located downstream of the proposed Mine Site facilities.
- SW-004. This location on the north branch of the Partridge River is immediately upstream of the confluence with the south branch, downstream of 64 percent of the proposed Mine Site facilities by the end of Year 20, and its watershed area is 23.0 square miles.
- SW-004a. This location on the Partridge River is immediately downstream of the confluence of the north and south branches, downstream of 99 percent of the proposed Mine Site facilities by the end of Year 20, and its watershed area is 54.4 square miles.

The culpability analysis is completed for two sets of graphs which are presented in Appendix I for Mine Site-RA1:

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

In the figures located in Appendix I, "#N/A" indicates that the mass flux is not applicable during the year of analysis (e.g., the West Pit has no seepage to the Partridge River via groundwater recharge before Post-Closure). In the figures, "-" 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 main results of this analysis are presented below:

<u>Low Flow Conditions – Mine Site-RA1</u>

- Discharges from upstream of PM-1 represent the main input determining concentrations of arsenic at SW-003 and SW-004. (Site PM-1 is upstream of surface water monitoring station SW-001). Seepage to groundwater from the West Pit represents an important contribution determining concentrations of arsenic at SW-004 during Post-Closure.
- Discharges from upstream of PM-1, followed by natural groundwater recharge from the watershed and liner leakage from Category 1 Waste Rock stockpile, represents the main inputs determining concentrations of arsenic at SW-004a. Overflow from the West Pit represents an important contribution determining concentrations of arsenic at SW-004a during Post-Closure.

- Discharges from upstream of PM-1, followed by natural groundwater recharge from the watershed, represents the main inputs determining concentrations of antimony and sulfate at SW-003 and SW-004. Seepage to groundwater from the West Pit represents an important contribution determining concentrations of antimony and sulfate at SW-004 during Post-Closure.

- Natural groundwater recharge from the watershed, followed by discharges from upstream of PM-1, represents the main input determining concentrations of cobalt at SW-003 and SW-004; of copper at SW-003 only; and of antimony and sulfate at SW-004a. Overflow from the West Pit represents an important contribution determining concentrations of antimony and sulfate at SW-004a during Post-Closure.

- Natural groundwater recharge from the watershed, followed by seepage from the Overburden Storage and Laydown Area and discharges from upstream of PM-1, represents the main input determining concentrations of copper at SW-004 in Years 1 through 20.

- Natural groundwater recharge from the watershed represents the main input determining concentrations of copper at SW-004 in Closure and Post-Closure.

- Natural groundwater recharge from the watershed represents the main input determining concentrations of cobalt and copper at SW-004a.

- Natural groundwater recharge from the watershed represents the main input determining concentrations of nickel at SW-003, SW-004, and SW-004a.

<u>Average Flow Conditions – Mine Site-RA1</u>

- Surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site) represents the main input determining concentrations of arsenic and sulfate at SW-003, SW-004 and SW-004a. Discharges from upstream of PM-1 also represent an important contribution determining concentrations of arsenic and sulfate at SW-003.

- Surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site) represents the main input determining concentrations of antimony, cobalt and copper at SW-003, SW-004 and SW-004a.

- Surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site), followed by natural groundwater recharge from the watershed, represents the main inputs determining concentrations of nickel at SW-003, SW-004 and SW-004a.

- During Post-Closure, overflow from the West Pit together with surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site) represent the main inputs determining concentrations of arsenic, antimony, cobalt, copper, nickel and sulfate at SW-004a.

High Flow Conditions – Mine Site-RA1

- Surface runoff from the natural watershed (i.e., from areas undisturbed by the Mine Site) represents the main input determining concentrations of arsenic, cobalt, copper, nickel and sulfate at SW-003, SW-004 and SW-004a.
- During Post-Closure, overflow from the West Pit represents the main input determining concentrations of arsenic and antimony at SW-004a. This overflow from the West Pit also represents an important contribution determining concentrations of cobalt, nickel and sulfate at SW-004a.

7.2.3.3 Factor to Exceed Standards

This section presents the analysis conducted to determine what increase in NorthMet Project's Mine Site liner leakage/seepage chemical concentrations would cause the deterministic water quality predictions in the Partridge River watershed (including Colby Lake) to exceed Minnesota surface water quality standards under Mine Site-RA1.

The predicted chemical concentrations for the leachate from Category 2/3 Waste Rock Stockpile, Category 3 Lean Ore Stockpile, Category 4 Waste Rock Stockpile and Lean Ore Surge Pile as well as for the seepage from the East Pit and West Pit were multiplied concurrently by a factor. The determination of the factor for a given parameter (antimony, arsenic, cobalt, copper, nickel and sulfate were also investigated here) and flow condition (low, average or high) was based on deterministic water quality predictions in the Partridge River or Colby Lake that exceed Minnesota surface water quality standards for that parameter at a given location and stage of the Mine Site development or closure under the Mine Site-RA1. For an explanation of the Minnesota surface water quality standards, see Section 3.1.

Table 5-28 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 Partridge River and Colby Lake. There is no applicable Minnesota surface water quality standard for sulfate given the use classification of the Partridge 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 5-28.

Table 5-29 compares the concentrations of leachate from Category 2/3 Waste Rock Stockpile, Category 3 Lean Ore Stockpile, Category 4 Waste Rock Stockpile and Lean Ore Surge Pile as well as for the seepage from the East Pit and West Pit (all occurring concurrently) that would cause Partridge River deterministic water chemistry predictions to exceed Minnesota surface water quality standards and the “base case” concentrations of these Mine Site features. Table 5-30 presents the same information for Colby Lake. “Base Case” concentrations are those reasonable worst case concentrations presented in Tables 4-10 to 4-21 and Tables 4-23 to 4-25 and used to deterministically predict the concentrations in the Partridge River presented in Section 5.2.2.1.

The main results of this analysis are presented below:

Partridge River

- Antimony. The smallest factor to exceed the corresponding standard is 6.9 under the Mine Site-RA1.
- Arsenic. The smallest factor to exceed the corresponding standard is 13.5 under the Mine Site-RA1.
- Cobalt. The smallest factor to exceed the corresponding standard is 20.2 under the Mine Site-RA1.
- Copper. The smallest factor to exceed the corresponding standard is 27.0 under the Mine Site-RA1.
- Nickel. The smallest factor to exceed the corresponding standard is 21.6 under the Mine Site-RA1.

Colby Lake

- Antimony. The smallest factor to exceed the corresponding standard is 2.3 under the Mine Site-RA1.
- Arsenic. The smallest factor to exceed the corresponding standard is 3.6 under the Mine Site-RA1.
- Cobalt. The smallest factor to exceed the corresponding standard is 21.1 under the Mine Site-RA1.
- Copper. The smallest factor to exceed the corresponding standard is 59.7 under the Mine Site-RA1.
- Nickel. The smallest factor to exceed the corresponding standard is 51.3 under the Mine Site-RA1.
- Sulfate. The smallest factor to exceed the corresponding standard is 60.2 under the Mine Site-RA1.

7.3 Comparison of Proposed Action and Reasonable Alternative 1 Results

7.3.1 Comparison to Water Quality Standards

<u>Partridge River</u>

The maximum deterministic water quality predictions of selected water quality parameters are summarized below for Mine Site-Proposed Action and Mine Site-RA1 for the Partridge River:

- Antimony. The highest deterministic water quality prediction of antimony is 0.00686 mg/L in Post-Closure at SW-004a during average flow conditions under Mine Site-Proposed Action. This value is 8 percent greater than the highest deterministic water quality prediction for antimony of 0.00633 mg/L at SW-004a in Post-Closure during average flow conditions under Mine Site-RA1. In both cases, however, the maximum predicted values are one-fourth the Minnesota surface water quality standard of 0.031 mg/L.

- Arsenic. The highest deterministic water quality prediction of arsenic is 0.0083 mg/L in Post-Closure at SW-004a during low flow conditions under Mine Site-Proposed Action. This value is 10 percent greater than the highest deterministic water quality prediction for arsenic of 0.00756 mg/L at SW-004a in Post-Closure during low flow conditions under Mine Site-RA1. In both cases, however, the maximum predicted values are almost 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 0.00207 mg/L in Year 15 at SW-004 during low flow conditions under Mine Site-Proposed Action. This value is 29 percent greater than the highest deterministic water quality prediction for cobalt of 0.00161 mg/L at the USGS Gage in Post-Closure during low flow conditions under Mine Site-RA1. In both cases, however, the maximum predicted values are one-third the Minnesota surface water quality standard of 0.005 mg/L.

- Copper. The highest deterministic water quality prediction of copper is 0.00697 mg/L at SW-004 in Year 15 during low flow conditions under Mine Site-Proposed Action. This value is 100 percent greater than the highest deterministic water quality prediction for copper of 0.00339 mg/L at SW-004a in Year 5 during low flow conditions under Mine Site-RA1. The Minnesota surface water quality standard for copper is hardness-depending, being 0.0083 mg/L for the Mine Site-Proposed Action predicted hardness and 0.0076 mg/L for the Mine Site-RA1 predicted hardness. The maximum predicted values are no greater than 80 percent of the corresponding Minnesota surface water quality standard.

- Nickel. The highest deterministic water quality prediction of nickel is 0.02565 mg/L at SW-004 in Year 15 during low flow conditions under Mine Site-Proposed Action. This value is 69 percent greater than the highest deterministic water quality prediction for nickel of 0.01522 mg/L at the USGS Gage in Post-Closure during low flow conditions under Mine Site-RA1. The Minnesota surface water quality standard for nickel is hardness-depending, being 0.0465 mg/L for the Mine Site-Proposed Action predicted hardness and 0.0445 mg/L for the Mine Site-RA1 predicted hardness. The maximum predicted values are no greater than approximately one-half the corresponding Minnesota surface water quality standard.

- Sulfate. The highest deterministic water quality prediction of sulfate is 33.1 mg/L at SW-004a in Post-Closure during low flow conditions under Mine Site-RA1. This value is just slightly greater than the highest deterministic water quality prediction for sulfate of 31.7 mg/L in Post-Closure at SW-004a during low flow conditions under Mine Site-Proposed Action. There is no Minnesota surface water quality standard for sulfate applicable to the use classification of the Partridge River. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at SW-004 is 10.0 mg/L.

All parameters meet minimum in-stream Minnesota water quality standards at all locations in the Partridge River during low flow, average flow, and high flow conditions for all modeled scenarios under the Mine Site-Proposed Action and Mine Site-RA1.

Colby Lake

The maximum deterministic water quality predictions of selected water quality parameters are summarized below for Mine Site-Proposed Action and Mine Site-RA1 for Colby Lake:

- Antimony. The highest deterministic water quality prediction of antimony in Colby Lake is 0.00395 mg/L in Post-Closure during low flow conditions under Mine Site-Proposed Action. This value is 6 percent greater than the highest deterministic water quality prediction for antimony of 0.00373 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-RA1. In both cases, however, the maximum predicted values are less than three-quarters of the Minnesota surface water quality standard of 0.0055 mg/L.

- Arsenic. The highest deterministic water quality prediction of arsenic in Colby Lake is 0.00515 mg/L in Post-Closure during high flow conditions under Mine Site-Proposed Action. This value is 4 percent greater than the highest deterministic water quality prediction for arsenic of 0.00493 mg/L in Colby Lake in Post-Closure during high flow conditions under Mine Site-RA1. In both cases, however, the maximum predicted values are one-half the Minnesota surface water quality standard of 0.01 mg/L.

- Cobalt. The highest deterministic water quality prediction of cobalt in Colby Lake is 0.00081 mg/L in Post-Closure during low flow conditions under Mine Site-Proposed Action. This value is 5 percent greater than the highest deterministic water quality prediction for cobalt of 0.00077 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-RA1. In both cases, however, the maximum predicted values are less than one-third the Minnesota surface water quality standard of 0.0028 mg/L.

- Copper. The highest deterministic water quality prediction of copper in Colby Lake is 0.00253 mg/L in Year 15 during high flow conditions under Mine Site-Proposed Action. This value is 5 percent greater than the highest deterministic water quality prediction for copper of 0.00207 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-RA1. In both cases, however, the maximum predicted values are less than one-quarter the Minnesota surface water quality standard of 0.0093 mg/L based on an estimated hardness of 100 mg/L.

- Nickel. The highest deterministic water quality prediction of nickel in Colby Lake is 0.00506 mg/L in Post-Closure during low flow conditions under Mine Site-Proposed Action. This value is 14 percent greater than the highest deterministic water quality prediction for nickel of 0.00445 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-RA1. In both cases, however, the maximum predicted values are one order of magnitude lower than the Minnesota surface water quality standard of 0.052 mg/L based on an estimated hardness of 100 mg/L.

- Sulfate. The highest deterministic water quality prediction of sulfate in Colby Lake is 15.8 mg/L in Post-Closure during low flow conditions under Mine Site-RA1. This value is 3 percent greater than the highest deterministic water quality prediction for sulfate of 15.3 mg/L in Colby Lake in Post-Closure during low flow conditions under Mine Site-Proposed Action. In both cases, however, the maximum predicted values are one order of magnitude smaller than the Minnesota surface water quality standard of 250 mg/L

All parameters meet minimum in stream Minnesota water quality standards in Colby Lake during low, average and high flow conditions for all modeled scenarios except iron and thallium for both Mine Site-Proposed Action and Mine Site-RA1. See Sections 5.2.3.1 and 7.2.3.1 for explanation of the exceedance of the iron and thallium standards.

7.3.2 Culpability Analysis

When comparing the culpability analysis for the Mine Site-RA1 to the culpability analysis for the Mine Site-Proposed Action, the main conclusion is that stockpile leachate no longer dominates the deterministic water quality prediction for the six parameters evaluated here (due to the effect of the treatment with lime or limestone), and also eliminates long-term treatment of the leachate collected in the liner system of the stockpiles that temporarily contain waste rock and lean ore material with higher reactivity potential (i.e., types Category 2, Category 3 and Category 4) to generate ARD or drainage with elevated metal concentrations. For a full interpretation of culpability analysis for both Mine Site plans see Sections 5.2.3.2 and 7.2.3.2.

7.3.3 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 potential impacts on the water chemistry of the Partridge River and Colby

Lake that might result from implementing the Mine Site-RA1 are smaller than those associated with the Mine Site-Proposed Action. The exception is that the concentrations of sulfate are marginally higher for the Mine Site-RA1. This main conclusion is further justified with the summary of factors to exceed standards presented below.

Partridge River

- Antimony. The smallest factor to exceed the corresponding standard is 6.1 under the Mine Site-Proposed Action versus 6.9 under the Mine Site-RA1.
- Arsenic. The smallest factor to exceed the corresponding standard is 11.8 under the Mine Site-Proposed Action versus 13.5 under the Mine Site-RA1.
- Cobalt. The smallest factor to exceed the corresponding standard is 4.1 under the Mine Site-Proposed Action versus 20.2 under the Mine Site-RA1.
- Copper. The smallest factor to exceed the corresponding standard is 1.6 under the Mine Site-Proposed Action versus 27.0 under the Mine Site-RA1.
- Nickel. The smallest factor to exceed the corresponding standard is 2.3 under the Mine Site-Proposed Action versus 21.6 under the Mine Site-RA1.

Colby Lake

- Antimony. The smallest factor to exceed the corresponding standard is 2.1 under the Mine Site-Proposed Action versus 2.3 under the Mine Site-RA1.
- Arsenic. The smallest factor to exceed the corresponding standard is 3.2 under the Mine Site-Proposed Action versus 3.6 under the Mine Site-RA1.
- Cobalt. The smallest factor to exceed the corresponding standard is 11.3 under the Mine Site-Proposed Action versus 21.1 under the Mine Site-RA1.
- Copper. The smallest factor to exceed the corresponding standard is 10.2 under the Mine Site-Proposed Action versus 59.7 under the Mine Site-RA1.
- Nickel. The smallest factor to exceed the corresponding standard is 19.0 under the Mine Site-Proposed Action versus 51.3 under the Mine Site-RA1.
- Sulfate. The smallest factor to exceed the corresponding standard is 62.0 under the Mine Site-Proposed Action versus 60.2 under the Mine Site-RA1.

8.0 Reasonable Alternative 1 – Groundwater Quality Modeling

8.1 Introduction to Groundwater Quality Modeling

The same general modeling approach is used for the evaluation of the Mine Site-RA1 as was used for the Mine Site-Proposed Action (Section 6.0). A set of "screening level models" was prepared to determine what the dissolved constituents of concern were for each source being evaluated. In the screening level models, the most conservative simplifying assumptions were made. If the dissolved constituents being evaluated were not predicted to exceed groundwater evaluation criteria under these assumptions, they were not carried forward to the next phase of modeling. More detailed modeling was conducted for those constituents that showed potential exceedences of groundwater evaluation criteria using the screening level models. Because of the heightened concern regarding sulfate concentration as it relates to mercury, sulfate was carried forward to the next phase of modeling regardless of whether the screening level models predicted groundwater concentrations in excess of criteria.

Groundwater flow conditions and final stockpile footprint configurations in the vicinity of the flow paths do not significantly change between the Mine Site-Proposed Action and the Mine Site-RA1; as such, the same cross section models presented in Section 6.0 were used for the work presented here for Mine Site-RA1.

8.2 General Modeling Methodology

8.2.1 Parameters Unchanged from Proposed Action Modeling

The general modeling methodology is the same as that presented in Section 6.2 for the Mine Site-Proposed Action with the exception of source area concentrations. Source area concentrations used for Mine Site-RA1 are presented in Section 8.2.3.

8.2.2 Background/Recharge Concentrations

Background groundwater concentrations were obtained using data collected from monitoring wells located at the Mine Site, presented in RS02 and RS10A. It was assumed that background groundwater concentrations are representative of recharge concentrations and the recharge concentration was set equal to the background concentration in each of the models. When individual well locations were used to calculate average values, non-detect concentrations were set at half the detection limit. Where there was not background data available for a parameter, a concentration of zero was used for the recharge concentration.

Table 8-1 summarizes the source of background/recharge concentration data sources used in each of the models. Actual values used for each model are presented in Tables 8-2 through 8-7.

8.2.3 Source Areas

New predicted concentrations of leakage/seepage presented for high, average and low liner leakage rates for the Mine Site-RA1 (see Section 4.3.2.1.2) were used as source area concentrations for each of the flow path models. For the screening level models presented in Section 8.3, the highest predicted concentrations for each constituent for each source being modeled were used. For the more detailed models presented in Section 8.4, time-varying source area concentrations were incorporated. As discussed in Section 6.2.4, recharge zones were used to represent the stockpile leakage in the models. For these features, concentrations were assigned to these recharge zones. For the models simulating the East Pit and the West Pit, source zone concentrations are applied to the constant head cells that represent the upgradient edge of these sources.

SRK provided two separate water quality predictions for the East Pit that represent different waters. “Pit Water” is a representation of the pore water chemistry in the backfill assuming that all water entering the pit equilibrates with the oxidation products formed in the Category 2, 3 and 4 rock while it was stockpiled. These concentrations are constant in time and do not account for the dilution and/or treatment of water in the East Pit that will be taking place during Closure (see RS52). “Total East Pit” is the mixed wetland water and stormwater that flows into the wetland area. For the work presented here, the “Pit Water” predictions were used for the water leaving the East Pit via groundwater flow into bedrock and the “Total East Pit” predictions were used for the water leaving the East Pit via groundwater flow into the surficial deposits. Actual concentrations used in the models are shown in Tables 8-2 through 8-19.

8.3 Screening Level Models

8.3.1 Methodology

The same screening level models used for the Proposed Action, presented in Section 6.3.1, were used for the RA1, with the only change being the recharge rates used. As was done for the Proposed Action, three sets of screening level models were run for each flow path:

- one with high liner leakage rates and leakage water quality associated with high flow through the stockpile, referred to as High Leakage model;

- one with average liner leakage rates and leakage water quality associated with average flow through the stockpile, referred to as Average Leakage model; and

- one with low liner leakage rates and leakage water quality associated with low flow through the stockpile, referred to as Low Leakage model.

Leakage rates are discussed and documented in Section 4.3.2.1.2. Water quality associated with each of the flow conditions are discussed and documented in Section 4.3.2.1.3. Liner leakage rates are presented in Table 4-31. For the screening level models, leakage rates from Year 5 were used.

8.3.2 Simulation Results

Tables 8-2 through 8-19 summarize the results of the screening level simulations for each flow path and assumed leakage rate. These tables also present the source area and background concentrations used for the screening level models. Predicted groundwater concentrations are compared to groundwater evaluation criteria presented in Section 3.2. The screening level models show that the predicted concentrations in the upper portion of the bedrock aquifer are very similar to the predicted concentrations in the surficial aquifer. With depth, the concentrations in the bedrock are closer to the background concentrations. As such, Tables 8-5 through 8-10 present the concentrations predicted for the surficial aquifer and the upper portion of the bedrock aquifer in order to be conservative. Potential exceedances of the groundwater evaluation criteria are highlighted on Tables 8-2 through 8-19 and summarized below.

Predicted beryllium and thallium concentrations exceed evaluation criteria in each of the screening level simulations. However, this is due to the high background concentrations used in the models. Background concentrations for the parameters were all non-detects and as such one-half the detection limit was used. As a result, the background concentrations used for these constituents exceed the groundwater evaluation criteria. These parameters are not shown as potential exceedences on Table 8-20. The background concentrations of aluminum, iron and manganese exceeded the groundwater evaluation criteria in many of the models and these parameters were not carried forward into the subsequent phase of modeling where this occurs. For these and other parameters that were not carried forward into the subsequent phase of modeling, the predicted concentrations shown on Tables 8-2 through 8-19 can be considered the maximum expected concentration.

As shown above, many of the potential contaminants of concern have been eliminated using the simple, conservative screening level models. The following sources and constituents were carried forward to the next phase of modeling:

- Category 1 Stockpile – arsenic (As), antimony (Sb), nickel (Ni) and sulfate (SO_4)
- West Pit – arsenic (As), antimony (Sb) and sulfate (SO_4)
- East Pit and Category 4 Waste Rock Stockpile – Iron (Fe) and sulfate (SO_4)
- Category 2/3 Waste Rock Stockpile – Arsenic (As), antimony (Sb), iron (Fe), manganese (Mn), and sulfate (SO_4)
- Category 3 Lean Ore Stockpile – sulfate (SO_4)
- Lean Ore Surge Pile – iron (Fe), manganese (Mn), and sulfate (SO_4)

8.4 Transient Models

8.4.1 Methodology

An additional phase of groundwater modeling was undertaken to further evaluate the potential contaminants of concern for which potential exceedances of evaluation criteria were identified through use of the screening level models (Section 8.3.2). In this phase of modeling, the previously steady state models were converted to transient models, which allowed for the source area leakage rates and concentrations to vary with time. SRK provided predictions of stockpile leachate concentrations at various times during the project: Year 1, Year 5, Year 10, Year 15, Year 20, Closure and Post-Closure.

In addition, stockpile leakage rates will change during operations as new portions of the stockpiles are created and other portions are progressively closed (for the Mine Site-RA1, this applies to Category 1 Stockpile only). High, average and low stockpile leakage rates were calculated using the leakage rates for uncovered and covered sections (see Section 4.3.2.1.2) and the amount of area that will be uncovered versus covered at any given time. Leakage rates used in the model are presented in Table 4-32 for Year 5, Year 10, Year 15, Year 20, Closure and Post-Closure. As discussed in Section 6.2.3, the liner leakage rates for Category 1 resulted in unreasonable mounding in the portion of the model below the stockpile. The predicted liner leakage rates are much higher than natural recharge and the modeling results suggest that leakage may be limited by the ability of the aquifer to transport this water away from the stockpile. Because of this, only low liner leakage rates predicted by the HELP model (documented in Golder's May 20, 2008 memorandum "Draft HELP Runs for Sensitivity Analysis of Liner Leakage Rates") were used in the transient model for the Category 1 Stockpile model.

The same model stress periods used for the Proposed Action, presented in Table 6-25 are used for the RA1.

8.4.1.1 Category 1 Stockpile Model

This model was set up as described above, with water quality data predicted for a given period matched up with leakage rates for that same period. Concentrations used for each model stress period for each constituent for both the Category 1 and overburden portions of the stockpile are shown on Tables 8-21 through 8-23.

8.4.1.2 West Pit Model

The West Pit will be dewatered during Years 1 through 20. During Closure, the pit will be flooding with water and is not expected to lose water to groundwater. As such, only Post-Closure conditions were simulated with the West Pit model. Concentrations used for each model stress period are shown on Tables 8-21 through 8-23.

8.4.1.3 East Pit and Category 4 Waste Rock Stockpile Model

The East Pit will be dewatered during Years 1 through 12 and then will be backfilled with Category 2, Category 3 and Category 4 waste rock and water. During this period, groundwater will be flowing into the pit. During Closure, water from the backfilled East Pit will be pumped, treated and discharged back into the East Pit. This will be done in a manner that minimizes the potential for groundwater outflow from the pit. It is only during Post-Closure that the East Pit is predicted to lose water to groundwater (see Section 4.3.2.2.1). To simulate this, the constant head cells representing the East Pit in the model are assigned background groundwater concentrations during stress periods 1 through 4. Closure concentrations are used in stress period 5 and Post-Closure concentrations are used in stress period 6. Before the end of mining operations, the Category 4 Waste Rock Stockpile will be removed, with the rock being placed in the East Pit. No stockpile will exist in this location during Post-Closure. The recharge area representing the pit is removed from the model in stress periods 5 and 6 and the recharge rate and concentrations of this area return to background levels. Concentrations used for each model stress period are shown on Tables 8-21 through 8-23.

8.4.1.4 Category 2/3 Waste Rock Stockpile Model

This model was set up in the same manner as the East Pit and Category 4 Waste Rock Stockpile model, with the predicted East Pit water quality being used as the up-gradient water quality during Post-Closure. Predicted concentrations from each time period are matched up with the corresponding leakage rate. Concentrations used for each model stress period for each constituent are shown on

Tables 8-21 through 8-23. Beginning in Year 19 there will be Category 1 waste rock in the stockpile. This is reflected in the input concentration data sown on Tables 8-21 through 8-23.

8.4.1.5 Category 3 Lean Ore Stockpile Model

This model was set up in the same manner as the Category 1 Stockpile model, with predicted concentrations from each time period being matched up with the corresponding leakage rate. Concentrations used for each model stress period for each constituent are shown on Tables 8-21 through 8-23. Beginning in Year 15 there will be Category 1 waste rock in the stockpile. This is reflected in the input concentration data sown on Tables 8-21 through 8-23.

8.4.1.6 Lean Ore Surge Pile Model

This model was set up so that predicted concentrations from each time period are matched up with the corresponding leakage rate. This pile will be removed in Closure. Following the model period simulating operations, background water quality was used for all recharge. Concentrations used for each model stress period for each constituent are shown on Tables 8-21 through 8-23.

8.4.2 Sorption

The same sorption related parameters used in the modeling for the Proposed Action, discussed in Section 6.4.2, are used modeling for the RA1.

8.4.3 Results

Results from the transient models are presented on Figures 8-1 through 8-27 and are summarized below and in Tables 8-24 through 8-26 (these tables show the predictions at the property boundary or the Partridge River, whichever is closer to the source area for each flowpath).. Predictions are also made for concentrations at the Dunka Road for flowpaths that cross the Dunka Road prior to the nearest evaluation point; this includes the West Pit, East Pit and Category 4 Waste Rock Stockpile, and the Lean Ore Surge Pile models. For the Category 1 stockpile flowpath, the property boundary is very near the Dunka Road; results are only presented at the property boundary. Results from the screening level model showed that concentrations in the bedrock are very similar to, if not slightly less than, concentrations in the surficial deposits. As such, only concentrations in the surficial aquifer are shown. Concentrations in the bedrock will be lower than those presented for the surficial aquifer.

8.4.3.1 Category 1 Stockpile Model:

Concentrations are predicted to be above the groundwater evaluation criteria for arsenic (all three liner leakage rates) and nickel (high liner leakage rate only) if sorption is not considered. With sorption, predicted concentrations are below the groundwater evaluation criteria. Sulfate is predicted to exceed the secondary MCL criteria for the high liner leakage scenario, but is predicted to be below the secondary MCL criteria for the other two cases.

8.4.3.2 West Pit Model

Concentrations of arsenic and antimony are predicted to be above the groundwater evaluation criteria at the property boundary and at the Dunka Road if sorption is not considered. With sorption, arsenic and antimony concentrations are predicted to be under the evaluation criteria at the property boundary for the period simulated. Sulfate concentrations are predicted to be below 150 mg/L at the property boundary and 200 mg/L at the Dunka Road for all three liner leakage rates, which are below the secondary MCL criteria of 250 mg/L.

8.4.3.3 East Pit and Category 4 Waste Rock Stockpile Model

Sulfate is predicted to have a long term concentration of less than 50 mg/L at the Partridge River for the high, average, and low liner leakage case and a long term concentration of 50 mg/L at the Dunka Road for all three cases; all of which are well below the secondary MCL criteria.

8.4.3.4 Category 2/3 Waste Rock Stockpile Model

Concentrations of arsenic are predicted to be over the groundwater evaluation criteria for all of the leakage rate cases with no sorption simulated and under the criteria with sorption. Concentrations of iron are predicted to be above groundwater criteria for the low, average and high leakage. Manganese concentrations are predicted to be below criteria for the low leakage cases and above criteria for the average and high leakage case. Concentrations of antimony are predicted to be below the groundwater evaluation criteria with and without sorption simulated. Sulfate is predicted to reach peak concentrations between approximately 150 and 225 mg/L for the low, average and high liner leakage rates, which are all below the secondary MCL criteria.

8.4.3.5 Category 3 Lean Ore Stockpile Model

Sulfate is predicted to have a long term concentration of 27 mg/L at the Partridge River for the high liner leakage case and is predicted to be below 15 mg/L for the low and average liner leakage cases; all of these predicted concentrations are well below the secondary MCL criteria.

8.4.3.6 Lean Ore Surge Pile Model

Concentrations of iron and manganese are predicted to exceed the secondary MCL criteria during an approximately 40 year window in Closure and Post-Closure with high liner leakage. Under low and average liner leakage conditions, neither secondary MCL is predicted to be exceeded. Sulfate is predicted to be at or below 30 m/L for the low, average and high liner leakage cases at the Partridge River, which is well below the secondary MCL criteria.

8.5 Interpretation of Results

The secondary MCL criteria for iron and manganese are predicted to be exceeded along several of the flow paths. Predicted concentrations of sulfate are over the secondary MCL criteria along the Category 1 Stockpile flowpath under the high linear leakage case. No other groundwater evaluation criteria are predicted to be exceeded when sorption is considered in the predictions. It is worth reiterating here that the 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.

8.6 Comparison of Proposed Action and Reasonable Alternative 1 Results

The predicted concentrations for the key dissolved constituents for the Proposed Action and the Reasonable Alternative 1 are discussed below:

- Antimony. For the Proposed Action, potential exceedances were identified using the screening level models for the Category 1/2 – Overburden Stockpile and the West Pit. The detailed models for these flowpaths showed that no exceedances are predicted when sorption is considered. For the RA1, potential exceedances were identified using the screening level models for the Category 1 Stockpile and the West Pit. The detailed models for these flowpaths showed that no exceedances are predicted when sorption is considered.

- Arsenic. For the Proposed Action, potential exceedances were identified using the screening level models for the Category 1/2 – Overburden Stockpile, the West Pit and the Category 3 Waste Rock Stockpile. The detailed models for these flowpaths showed that no exceedances are predicted when sorption is considered. For the RA1, potential exceedances were identified using the screening level models for the Category 1 Stockpile, the West Pit and the Category 2/3 Waste Rock Stockpile. The detailed models for these flowpaths showed that no exceedances are predicted when sorption is considered.

- Copper. For the Proposed Action, a potential exceedance was identified using the screening level model for the Category 3 Waste Rock Stockpile. The detailed model for this flowpath showed that no exceedances are predicted when sorption is considered. For the RA1, no potential exceedances were identified using the screening level models.

- Nickel. For the Proposed Action, potential exceedances were identified using the screening level models for the East Pit and Category 4 Waste Rock Stockpile, the Category 3 Waste Rock Stockpile, the Category 3 Lean Ore Stockpile and the Lean Ore Surge Pile. The detailed models for these flowpaths showed that when sorption is considered, the groundwater evaluation criteria for nickel along the Category 3 Waste Rock Stockpile and the Category 3 Lean Ore Stockpile flowpaths under high liner leakage conditions may be exceeded, but exceedences are not expected for the low or average linear leakage conditions along either flowpath. For the RA1, a potential exceedance was identified using the screening level model for the Category 1 Stockpile. The detailed model for this flowpath showed that no exceedances are predicted.

- Sulfate. For the Proposed Action, potential exceedances were identified using the screening level models for the Category 1/2 – Overburden Stockpile and the Category 3 Waste Rock Stockpile. The detailed models for these flowpaths showed that the secondary MCL criteria for sulfate along the Category 1/2 flowpath under high liner leakage conditions may be exceeded, but exceedances are not expected for the low or average linear leakage conditions or for the Category 3 Waste Rock stockpile flowpath. For the RA1, a potential exceedance was identified using the screening level model for the Category 1 Stockpile. The detailed model for this flowpath showed that the secondary MCL criteria for sulfate along the Category 1 Stockpile flow path under high liner leakage conditions may be exceeded, but exceedances are not expected for the low or average linear leakage conditions.

In addition to the parameters discussed above, both the Proposed Action and the Reasonable Alternative 1 are predicted to have several exceedances of the iron, manganese and aluminum secondary MCL criteria. However, background concentrations at the Mine Site for these constituents are near or above the secondary MCL criteria.

9.0 Conclusion

This RS74A report presents the assessment of potential impacts of the NorthMet Project on the water quality of groundwater and downstream watercourses and water bodies in the Partridge River (including Colby Lake) watershed.

In terms of surface water, 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 Partridge River watersheds. 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 Mine Site. The estimated concentrations were compared against the most stringent numeric chronic aquatic toxicity-based Minnesota surface water quality standards (Minnesota Rules Chapters 7050 for Minnesota waters and 7052 for the Lake Superior Basin) for the appropriate use classification for the Partridge River and Colby Lake.

In terms of groundwater, deterministic water quality predictions were made for the NorthMet Project along flow paths originating at the various source areas being evaluated and ending at the Partridge River. Potential impacts along each flow path were assessed using simple cross-section groundwater flow and contaminant transport models. The estimated concentrations were compared against the most stringent groundwater standards that may be applicable (MCL, sMCL or HRL).

RS74 Draft-01 for the NorthMet Project was submitted in July 2007. This Draft 02 of RS74 incorporates the following changes and additions from RS74 Draft-01.

- Inclusion of both surface and groundwater water quality modeling.
- Modeling two Mine Site plans, Mine Site-Proposed Action and Mine Site-RA1.
- Incorporation of liner leakage and seepage from stockpile sumps, overburden areas, process water ponds and the WWTF Equalization Ponds.
- Updates to the groundwater model for the Mine Site which affects the percent reduction in Partridge River baseflow, and the flowpath of leakage from stockpiles and seepage from mine pits.
- Additional surface water quality monitoring data of the Partridge River.

- Incorporation of high, average and low liner leakage rates and associated chemistry values from the Waste Rock and Lean Ore stockpiles.

- Changes to the schedule of East Pit flooding and to the modeling of West Pit overflows in Post-Closure, and incorporation of high, average and low leachate chemistry values from both pits.

- Recognition that some overburden has the potential to be reactive and a resultant mitigation of not using the potentially reactive overburden for construction, compacting the potentially reactive overburden as it is stockpiled and extending the liner of the Category 1/2 Waste Rock Stockpile beneath the overburden portion of the stockpile.

The chemical load contribution from the Mine Site's leakage/seepage was based on geochemical evaluations of mine waste rock stockpile leachate, and mine pit water seepage to groundwater. It should be highlighted that these geochemical evaluations used conservative assumptions so that the eventual deterministic water quality predictions were conservative with respect to uncertainty. Using mass-balance models for the surface water quality assessment of the Partridge River watershed 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 Reasonable Alternative 1, all deterministic surface water quality predictions meet minimum in-stream Minnesota water quality standards at all locations in the Partridge River during low, average and high flow conditions for all modeled scenarios.

For the Proposed Action and Reasonable Alternative 1, all deterministic surface water quality predictions meet minimum Minnesota water quality standards in Colby Lake during low, average and high flow conditions for all modeled scenarios, with the exception of:

- Iron. The Class 1B Minnesota water quality standard for iron is a secondary MCL of 0.3 mg/L, which is applicable for Colby Lake. There is no Minnesota water quality standard for iron in the Partridge River. The average concentration of iron from surface water quality monitoring in 2004, 2006 and 2007 at SW-004 is 1.99 mg/L and at SW-005 is 1.34 mg/L at SW-004. The average concentration of iron from groundwater quality monitoring in 2004, 2006 and 2007 at SW-004 is 2.84 mg/L. Therefore, the Minnesota water quality standard for iron would be exceeded even without NorthMet Project.

- Thallium. The Class 2Bd Minnesota water quality standard for thallium is 0.00028 mg/L, is applicable for Colby Lake. Thallium was only detected once in the Partridge River at PM-1 in August 2004; all the other reported values were below the detection limit of 0.00040 mg/L. By using half the detection limit as the target in the model calibration and an estimated concentration in groundwater that is basically negligible (0.000004 mg/L), an artificially high concentration in surface runoff was obtained. This high concentration dominates the predictions in Colby Lake. Further testing of thallium using a lower detection limit in the Partridge River would be necessary to determine predicted concentrations with a higher certainty.

For the Proposed Action, all groundwater criteria are predicted to be met at the evaluation locations (the Partridge River or the property boundary, whichever is nearest to the source area), with the exception of the following:

- Nickel concentrations at the Partridge River down-gradient from the Category 3 Stockpile with high linear leakage rates and nickel concentrations down-gradient from the Category 3 Lean Ore Stockpile with high liner leakage rates. In both cases, the concentration is not predicted to exceed the criteria until more than 1,000 years after Closure. Further, the concentrations are predicted to be below the criteria under the low and average linear leakage conditions which are more reasonable assessments of liner leakage. That is, the high linear leakage condition is very conservative.

- Sulfate concentrations at the property boundary down-gradient from the Category 1/2 flowpath under high liner leakage conditions. The concentrations are predicted to be below the criteria under the low and average linear leakage conditions which are more reasonable assessments of liner leakage.

- Secondary MCL criteria for iron and manganese are predicted to be exceeded along several of the flowpaths. However, background concentrations for these constituents are currently near or above the secondary MCL criteria at the Mine Site.

For the Reasonable Alternative 1, all groundwater criteria are predicted to be met at the evaluation locations (the Partridge River or the property boundary, whichever is nearest the source area), with the exception of the following:

- Sulfate concentrations at the property boundary down-gradient from the Category 1 flowpath under high liner leakage conditions. The concentrations are predicted to be below the criteria under the low and average linear leakage conditions which are more reasonable assessments of liner leakage.

- Secondary MCL criteria for iron and manganese are predicted to be exceeded along several of the flowpaths. However, background concentrations for these constituents are currently near or above the secondary MCL criteria at the Mine Site.

Because conservatively deterministic water quality predicted impacts to the Partridge River watershed studied do not result in measurable exceedance of the appropriate in-stream Minnesota water quality standards, further refinements of the NorthMet Project do not seem warranted.

10.0References

Adams, J.L., Leibfried, R.T., and Herr, E.S. 2004. East Range Hydrology Project. Division of Lands and Minerals and Division of Waters – Minnesota Department of Natural Resources.

Baker, D.G., Nelson, W.W., and Kuehnast, E.L. 1979. Climate of Minnesota: Part XII – The hydrologic cycle and soil water. *Technical Bulletin 322*, Agricultural Experiment Station, University of Minnesota, 23 pp.

Barr, 2008b. "Water Quality Model of the Partridge River Watershed – PolyMet RS-74, Mine Site-Reasonable Alternative 1 (RA1)." External Memorandum to Jim Scott, PolyMet, dated June 2, 2008.

Hem, J.D., 1992. Study and interpretation of the chemical characteristics of natural water. US Geological Survey Paper 2254.

Huff, F.A., and Angel, J.R. 1992. Rainfall frequency atlas of the Midwest. Bulletin 71 (MCC Research Report 92-03). Midwestern Climate Center – National Oceanic and Atmospheric Administration, and Illinois State Water Survey – Illinois Department of Energy and Natural Resources.

Jirsa, M.A., Setterholm, D.R., Bloomgrem, B.A., Bauer, E.J., and R.S. Lively. 2005. Bedrock Geology, Database, Bedrock Topography, and Depth to Bedrock Maps of the Western Half of the Mesabi Iron Range, Northern Minnesota: Minnesota Geological Survey, Miscellaneous Map M-158, scale 1:100,000.

Lapakko, K.A. 1993. Laboratory Dissolution of Blast Hole Samples of Duluth Complex Rock. Report to the US Bureau of Mines, Salt Lake City Research Center. MN Dept. Natural Resources, Division of Minerals, St. Paul, MN. 44p.

Lapakko, K.A., Antonson, D., Folman, J. and Johnson, A. 2002. Assessment of Test Methods for Waste Rock Dissolution and Laboratory Drainage Quality from Duluth Complex Rock. Report on Contract BLM JSP012002 to the U.S. Bureau of Land Management, Salt Lake City Office. MN Dept. Natural Resources, Division of Minerals, St. Paul, MN. 63p.

McDonald, M.G. and A.W. Harbaugh, 1988. *A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model*: U.S. Geological Survey Techniques of Water-Resources Investigations Report, Book 6, Ch. A1.

Minnesota Department of Natural Resources. 2004. *Duluth Complex Mine Waste Drainage*. MN Dept. Natural Resources, Division of Lands and Minerals, Reclamation Section, St. Paul, MN. March 2004.

Minnesota Pollution Control Agency. 1999. Baseline Water Quality of Minnesota's Principal Aquifers – Region 1, Northeastern Minnesota." MPCA Environmental Outcomes Division, Environmental Monitoring and Analysis Section, Ground Water and Toxics Monitoring Unit, February, 1999.

Mugan, Tom. 2007. E-mail communication with Tom Mugan – Wisconsin Department of Natural Resources dated May 22, 2007.

Nelson, Floyd. 2007. Telephone memo with Floyd Nelson, City of Hoyt Lakes on April 24, 2007.

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

Smith, Nancy. 2007. E-mail Communication from Nancy Smith of Cleveland Cliffs, Dated April 5, 2007.

Verry, E.S, J.W Hornbeck, A.H. Todd. 2000. Watershed research and management in the Lakes States and northeastern United States, in the Proceedings from Land Stewardship in the 21st Century: The contributions of watershed Management, March 13-20, Tucson, AZ.

U.S. EPA, 1996a. *Soil Screening Guidance: User's Guide,* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington D.C., EPA/540/R-96/018.

U.S. EPA, 1996b. *Soil Screening Guidance: Technical Barckground Document,* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington D.C., EPA/540/R-95/128.

U.S. EPA, 2003, *EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska*, U.S. Environmental Protection Agency, Region 10, Seattle, Washington.

U.S. EPA, 2005. *Partition Coefficients for Metals in Surface Water, Soil, and Waste*, U.S. Environmental Protection Agency, Office of Research and Development, Washington D.C., EPA/600/R-05/074.

Wiedemeier, T.H., H.S. Rifai, C.J. Newell, and J.T. Wilson, 1999.*Natural Attenuation Fuels and Chlorinated Solvents in the Subsurface.* John Wiley and Sons, Inc.

Zheng C. and P. P. Wang, 1999. *MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide*. U.S. Army Corps of Engineers Contract Report SERDP-99-1.