GoldSim Model Evaluation Work Plan
NorthMet Project, Minnesota

Revised ERM Draft
25 January 2012

1.0 Introduction

The NorthMet Project Supplemental Draft Environmental Impact Statement (SDEIS) will use GoldSim, a proprietary but publically available dynamic system model, to predict project effects on the quality of surface water and groundwater at designated evaluation locations within the Project Area. Two separate models are being developed for the NorthMet SDEIS. The first will evaluate the Mine Site, including mine facilities such as open pits, waste rock stockpiles, overburden storage areas, and waste water treatment plant (WWTP). The second will evaluate the Plant Site, including mine facilities such as process plants, ponds, WWTP, existing and future tailings basins, and groundwater collection wells.

Common to both models will be incorporation of hydrological processes including rainfall, evapotranspiration, surface water runoff, infiltration, surface water flow, groundwater flow, and groundwater storage. Chemical processes will include background water chemistry, chemical leaching from mine waste, groundwater solute transport, and seepage/mixing of groundwater into surface water. The water-quality models for the NorthMet Project are probabilistic, meaning that the uncertainty in the parameters describing the release and transport of chemicals is used to estimate uncertainty in the model predictions.

The model calculations incorporate processes and associated input parameters that affect the release and transport of chemicals from site facilities to natural systems beyond the site boundaries (such as perennial streams). During the period since models were first applied for the 2009 NorthMet Draft Environmental Impact Statement (DEIS), they have undergone extensive revision within an “Impact Assessment Planning” (IAP) process, a collaborative effort in which the project Co-lead agencies (MDNR, USACE, and USFS) plus the MPCA and technical representatives from the Cooperating Agencies (USEPA and the Tribes) who have met regularly to define water quality modeling needs. An important component in the IAP process has been to select ranges and probability distributions for model parameters.

The NorthMet water quality models will incorporate the range of transport processes and the uncertainty ranges of model parameters as agreed to by the Co-lead Agencies in IAP, Model Work Plan, and Model Calibration processes. Further, the models are largely transparent, meaning that all of the information on environmental behavior of the proposed NorthMet Project is presented in technical support documents provided by PolyMet and Barr Engineering. In particular, Mine Site and Plant Site Water Modeling Work Plans describe the conceptual models and list the probability distributions for all

model parameters (PolyMet, 2012a and 2012b). Technical support for the selection of model parameters is presented in the Mine Site and Plant Site Water Modeling Data Packages (PolyMet, 2011a and 2011b).

The GoldSim software contains algorithms that perform unit conversions, track local/global mass balances, and most importantly, automate Monte Carlo simulations for predicting uncertainty. However, most of the governing equations used in the NorthMet dynamic systems model (DSM) will be programmed into the GoldSim software by PolyMet's consultant, Barr Engineering. This programming process may introduce computational errors caused by incorrect equations, incorrect conditional statements, or transcription errors.

This memo describes the proposed review process for verifying that the GoldSim water quality models accurately implement the assumptions, inputs, and fate/transport calculations agreed upon by the Co-lead agencies. This verification will be performed by members of the ERM team who are independent of the Project sponsor (PolyMet) and the GoldSim modeler. This model evaluation work plan would be part of a broader Co-lead agency GoldSim Water Modeling Process (see flow diagram below).

2.0 Review Process

This Model Evaluation Work Plan will occur during the Model True-up and Project Refinement Phases of the GoldSim Water Modeling Process:

- Model Input Review will occur during the Model True-up Phase and will provide assurance to the Co-leads that the approved guidance from the IAP process has been properly incorporated into the models; and

- Model Computation Review will occur during the Project Refinement Phase and will include checking model computations for chemical leaching, groundwater and surface water flow, solute transport, and mixing of groundwater into surface water

The review team will have a separate GoldSim license so the model can be operated independently of Barr. It is expected that Barr will provide a fully functioning version of the GoldSim NorthMet model for ERM evaluation.

For a model of this complexity, it is not feasible to apply *all* verifications to *all* components or calculations performed by the model. The general approach is to perform a reasonable number of initial verifications and then perform additional verifications to model components that are suspect. The verifications depend to some extent on the types of model components being evaluated. Water-related components are relatively straightforward, so emphasis will be placed on inputs, internal computations, and programmed equations. Chemical components are more complex and tend to involve multiple conditional statements in the programming. As a consequence, verification of the chemical components places emphasis on inputs,

local/global mass balances, and comparing GoldSim predictions to cases where the results can be calculated independently.

Model components subjected to independent testing will be selected to include those components most likely to affect the predictions of water quality impacts. Specific examples include the Category 1 waste rock stockpile and the West Pit Lake (these will remain as permanent features after closure), the concentration caps applied to solutes in the waste rock (these can impart large reductions in predicted solute release), and solutes associated with the mine wastes that have water quality limits (e.g., sulfate).

It is our understanding that Barr will provide a document presenting all equations that have been programmed into the GoldSim software. The model evaluation will assess the appropriateness of these equations given the model assumptions and where necessary, check that the equations are properly coded into the software. Resident algorithms in GoldSim, such as the Monte Carlo simulator and solute transport module, will not be reviewed. GoldSim has been extensively checked and debugged over its history of development and the resident algorithms are assumed to be correct.

2.1 Model Input Review

The Model Input Review, which will occur during the Model True-up Phase, focuses on checking for correct incorporation of input parameters into the GoldSim model. A Monte Carlo ***simulation*** will typically involve 500 to 1000 transient ***runs*** of the water quality computational model, with each run using a suite of input parameters. During each run, a set of calculations are performed for each ***time step***. This leads to the following types of inputs:

- ***Simulation-deterministic*** parameters are set before the analysis begins and remain constant for all runs and all time steps.

- ***Simulation-uncertain*** parameters are determined at the beginning of the Monte Carlo simulation and remain constant for all runs and time steps. Using a random probability (between 0 and 1), the value for each input is sampled from the associated cumulative probability distribution (cpd) at the beginning of the simulation.

- ***Run-uncertain*** parameters are determined from the associated cpd's at the beginning of a run and remain constant for that run. The values are reset at the beginning of the next run.

- ***Time-step-uncertain*** parameters are determined from the associated cpd's at the beginning of a time step and remain constant for that time step. The values are reset at the beginning of the next time step.

Model input review takes advantage of GoldSim's ability to export tabulated summaries of model parameters, which can be formatted into Excel spreadsheets. Barr will be directed to program the GoldSim model to produce the following spreadsheets:

- ***Simulation Input Spreadsheet*** that tabulates all simulation-deterministic and simulation-uncertain parameters used in the Monte Carlo simulation. For each simulation-uncertain parameter, the compilation will include the random probability that was used to sample the associated cpd.

- ***Run Input Spreadsheet*** that tabulates all run-uncertain parameters. Each line of the spreadsheet will provide the values used for one run, and the parameter values and associated random probabilities will be listed in columns. The overall spreadsheet will have 500 to 1000 lines.

- ***Time-Step Spreadsheet*** will summarize time-step-uncertain inputs and associated random probabilities for a specified number of time steps specified by the user. Fortunately there are not too many inputs that change from time step to time step during a run. Each line of the spreadsheet will contain the uncertain input values associated with one time step. As a working number, 1000 time steps will be randomly selected from a simulation.

Barr will also be requested to reference the source of each input value (e.g., approved by the Geochemistry IAP Final Summary Memo dated 20 June 2011). Input review will involve checking the compiled spreadsheets and comparing the values with input descriptions provided in the approved final versions of the Mine Site Water Modeling Work Plan (including Tables 1-1 thru 1-34) and Plant Site Water Modeling Work Plan (including Tables 1-1 thru 1-50). For uncertain parameters, the random probability will be checked against the associated cpd to ensure that the associated input value was properly sampled. As a guideline, initial input checking will include:

- All values contained in the Simulation Input Spreadsheet

- 50 input types (columns) in the Run Input Spreadsheet

- All inputs in the Time-Step Spreadsheet

If the initial check does not identify any problems with model inputs, the process may be ended at that stage. If problems are identified, additional checks will be performed and any deficiencies will be brought to the attention of the Co-leads and PolyMet. The review process will continue until the reviewers have reasonable confidence that GoldSim is correctly setting and using the model input values.

Fred Marinelli will have lead responsibility for this Model Input Review. Once the spreadsheets identified above are provided, ERM can complete this review in approximately one week. This work can be done remotely as long as the requested spreadsheets can be emailed or posted to an ftp site.

2.2 Model Computation Review – To Be Completed

2.3 Model Evaluation Documentation

ERM will coordinate with Barr and the Co-lead Agencies to correct any input or computational errors uncovered. ERM will submit to the MDNR a summary report at the end of the Model True-up Phase and the Project Refinement Phase documenting the findings resulting from executing the Model Evaluation Work Plan.

3.0 References

PolyMet Mining (2012a). NorthMet Mine Site Water Modeling Work Plan, Ver. 5. January 10, 2012.

PolyMet Mining (2012b). NorthMet Plant Site Water Modeling Work Plan, Ver. 3. January 10, 2012.

PolyMet Mining (2011a). NorthMet Project Water Modeling Data Package, Volume 1 - Mine Site. Ver. 9, December 2, 2011.

PolyMet Mining (2011b). NorthMet Project Water Modeling Data Package, Volume 2 - Plant Site. Ver. 4, December 2, 2011.

PolyMet Mining (2011c). Mine Site Water Quality Model Quality Assurance Project Plan. November 7, 2011.

GoldSim Water Modeling Process 1/20/12

IAP Process

(1) Work plans and data package completion to initiate

Model True-Up

(2) Develop Co-lead QA/QC plan

(3) Implement QA/QC (model inputs check)

(4) Develop model calibration methodology

(5) Incorporate available new mine site groundwater data

(6) Review calibration results (iterative modeling

(7) Approve calibration

(8) Calibrate model

(9) Develop QAPPs

(10) Realistic results review (iterative, comprehensive)

(11) Record/review/approve model inputs and assumptions changes via CDF(s)

(12) Implement QA/QC (model inputs and structure check)

Project Refinement

(15) Possible Ripple Effects Analysis

(14) Record/review/approve Proposed Project changes via CDF(s)

(13) Project refinement (comprehensive, iterative)

(16) Possible analysis of new agency-mitigation or alternative

(17) Final model run and final model QA/QC

(18) Identify preliminary selection of Environmentally Preferred Alternative

Documentation

(19) Produce report

(23) PolyMet updates data packages and work plans per CDFs

(22) PolyMet updates project description per CDFs

(20) Co-lead modeling report review and

(25) Cooperator modeling report

(24) Final high level audit-level review of data packages and work plans for record

(21) PSDEIS chapter preparation