MORRISON COPPER/GOLD PROJECT

3rd Party Review Response Report

M09382A04

Klohn Crippen Berger

Canada's 50 Best Managed Companies

ISO 9001:2008 Registered

January 31, 2012

Pacific Booker Minerals Inc.
#1702 - 1166 Alberni Street
Vancouver, British Columbia
V6E 3Z3

Mr. Erik Tornquist
Executive VP and COO

Dear Mr. Tornquist:

Morrison Copper/Gold Project
3rd Party Review Response Report

Please find enclosed our 3rd Party Review Response Report for the Morrison Copper/Gold Project. The report incorporates the scope of work identified by the 3rd Party Review of the project.

We look forward to the success of your project and with working with the Agencies and the Lake Babine Nation in moving forward to the detailed design and permitting stage of the project.

Please advise if you require further information or clarification.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

Harvey McLeod, P.Eng., P. Geo.
Project Director

HM/CA:tc

120131R-3rd Party Review Response.docx
File: M09382A04.730

MORRISON COPPER/GOLD PROJECT

3rd Party Review Response Report

M09382A04 **JANUARY 2012**

EXECUTIVE SUMMARY

This report presents the response to the 3rd Party Review of the Environmental Assessment (EA) for the Morrison Copper/Gold Project. The 3rd Party Review was requested by the Environmental Assessment Office (EAO) and was mainly directed towards the hydrogeology, water balance, geochemistry and aquatic habitat, with respect to the potential for significant adverse effects on Morrison Lake. Morrison Lake is a valuable salmon habitat resource and this report specifically looks at the potential for water quality effects on the lake and salmon spawning habitat.

The review of the hydrogeology, water balance, geochemistry and water quality was carried out by Robertson Geoconsultants Ltd. (RGC) (December 2, 2011) and the review of Morrison Lake aquatic habitat was carried out by Solander Ecological Research Ltd. (November 21, 2011).

Groundwater Modeling and Flows

The 3-D MODFLOW groundwater model was updated to carry out additional sensitivity runs and to quantify potential open pit inflows during operations and closure. The main conclusions of the additional groundwater modeling are:

- Seepage rates from the TSF are similar to previous estimates (which were 50 m^3/hr to 100 m^3/hr). The Expected Case and Upper Bound are 65 m^3/hr and 137 m^3/hr, respectively. The sensitivity analysis for the Expected Case resulted in a range of 20 m^3/hr for a geomembrane lined facility to 109 m^3/hr assuming a higher tailings hydraulic conductivity. PBM has committed to, as a minimum, ensuring a clay till soil liner for the tailings storage facility (TSF) to mitigate seepage. Contaminant transport modeling was carried out to determine the spatial and temporal extent of the seepage plume from the TSF to Morrison Lake and was used to determine the potential water quality in the receiving streams and in the nearby lakebed spawning gravels of Morrison Lake. Seepage from the TSF moves mainly in the direction of stream MCS-7 towards Morrison

Lake and takes in the order of 50 years to reach the lake and then peaks in approximately Year 70, and decreases thereafter.

- The pit dewatering flows are higher than previous estimates (which were 100 m^3/hr to 150 m^3/hr). The maximum flows requiring pumping from the open pit at the full extent of the open pit for the Expected Case and Upper Bound are 368 m^3/hr and 685 m^3/hr, respectively. The seepage rate from Morrison Lake to the open pit, at maximum pit extent, increases from 60 m^3/hr to 133 m^3/hr, and 90 m^3/hr and 320 m^3/hr, for the Expected Case and Upper Bound, respectively.
- The closure pit inflows increase the quantity of water requiring water treatment from 55 m^3/hr to a range of 140 m^3/hr to 170 m^3/hr for the Expected Case and Upper Bound, respectively. However, the seepage of PAG groundwater flows to Morrison Lake reduces to negligible quantities.

The main effect of the increases in pit dewatering flows is a surplus water balance that will need to be mitigated by intercepting groundwater from the pit dewatering wells and discharging the surplus to Morrison Lake during operations. In the Upper Bound case, it may also be necessary to treat a portion of the surplus flow beginning in Year 5. The changes in flows have been incorporated into updated water quality predictions for Morrison Lake.

Closure Considerations

The closure alternative selected is to place the potentially acid generating (PAG) rock back into the open pit and to cover the PAG rock with neutral material and wetland. A water pond would be formed to attenuate seasonal and flood flows to maintain a constant water treatment rate. This alternative was selected over placement of PAG rock into the TSF due to the significantly higher cost (additional $168 million) of transporting PAG rock an additional 6 km and constructing higher dams and haul road. PAG rock would be limed with lime slurry placed in the haul trucks and with lime mixed in with the pit water.

The potential for incomplete mixing has been assessed as described in the following geochemistry review.

A life of mine PAG rock management plan has been developed and the requirements for early or temporary closure have been addressed. Under the early closure scenario, the low grade ore (LGO) would be milled and PAG rock would be placed in the open pit. However, there is a requirement to place some PAG rock into the TSF and this would be carried out while the LGO is being processed.

Temporary closure of the mine requires that surplus water either be treated and discharged to Morrison Lake or stored in the open pit. Water management requires that pit dewatering water continue to be discharged to Morrison Lake. In addition, flows from the water treatment plant would discharge to Morrison Lake. The potential total flows vary from 300 m^3/hr to 510 m^3/hr for the Expected Case and Upper Bound respectively. Water quality predictions for these discharges have been developed and are discussed under the Morrison Lake Effects.

Geochemistry Review

In general, the geochemical source terms used for the assessment remain unchanged. However the following aspects have been addressed:

- The nitrogen species concentrations used are in agreement with several other porphyry copper mines in BC. Nonetheless, the use of the higher concentrations recommended by RGC do not result in any change in exceedances. Nitrite remains elevated in the TSF receiving streams due to naturally high baseline concentrations in the stream surface water, which are approximately 4 times British Columbia Water Quality Guidelines (BCWQGs). Nitrate and ammonia are well below BCWQGs.

- The TSF water quality at end of mining is based on the Equilibrium drainage chemisty model (EDCM) developed from the Bell and Granisle mines. The Bell mine EDCM includes the effect of milling LGO which had been stored up to 20 years. Consequently, there is no need to modify the TSF water quality for milling LGO on closure.

- Sensitivity analyses were carried out for the water quality of the initial closure TSF water pond for the additional load from a deeper leaching zone in the TSF beaches. The sensitivity analysis indicates that concentrations of sulphate, aluminum, arsenic, cadmium and selenium could exceed BCWQGs at the end of Year 3 of closure. The concentrations, however, do meet the preliminary proposed water quality objectives (PPWQOs), discussed in the next section, with the exception of selenium for the upper permutations. The loadings from the tailings beaches will decrease within a few years after Year 3 due to the till cover and the ongoing dilution with surface water.

- Sensitivity analyses were carried out to include a chemical load from the cyclone sand dam. The upper sensitivity runs potentially result in additional parameters of potential concern that include sulphate, aluminum, arsenic and selenium at exceedances slightly above BCWQGs, but below the PPWQOs.

- Sensitivity analyses were carried out for the PAG porewater in the backfilled PAG rock placed in the open pit. High PAG rock, which will be placed in the base of the open pit, generally has a poorer water quality than the Low PAG rock that will be placed in the main upper portion of the open pit. Not with-standing the potential benefit of placing Low PAG closer to surface, the importance of the PAG porewater has been reduced significantly due to the groundwater modeling that indicates that only a very small portion of PAG porewater will move towards Morrison Lake.

Preliminary Proposed Water Quality Objectives (PPWQOs)

PPWQOs have been developed for sulphate, aluminum, cadmium, cobalt, copper and selenium, following the methodology recommended by BCMOE and CCME. The main methodology, referred to as the “recalculation” method, has been used. In addition, the Biotic Ligand Model and the US EPA guidelines have been used to add further weight of evidence.

PPWQOs are recommended to be used primarily for emergent groundwater that may surface in the TSF receiving streams and the Morrison lakebed. In addition, the baseline water quality of Morrison Lake currently exceeds BCWQGs for total copper and iron and a PPWQO will, therefore, be required for copper and iron and several other parameters (aluminum and cadmium that may be marginally exceeded during operational discharges due to potential higher groundwater flows to the open pit (note that the aluminum and iron concentrations are below CCME guidelines). A summary of the PPWQOs and the corresponding BCWQGs is summarized Table 1.

Table 1 Summary of Recommended PPWQOs and BCWQGs

Parameter	Hardness (mg/L)	PPWQO	BCWQG
Sulphate (mg/L)	100	198	100
	338	360	100
	528	448	100
Aluminum (µg/L)	NA	233	50
Arsenic (µg/L)	NA	55	5
Cadmium (µg/L)	100	0.27	0.033
	338	0.67	0.094
	528	0.93	0.139
Cobalt (µg/L)	NA	45	4
Copper (µg/L)	100	11.9	4
	338	17.8	13.5
	528	18.5	21.1
Selenium (µg/L)	NA	0.0077	0.0022

The PPWQOs have a typical uncertainty (safety) factor of 10 and should be applied to the expected case conditions. The use of the PPWQOs for Upper Bound conditions should consider the likelihood of combining uncertainty factors for different conditions which are not related. Accordingly, final selection of the PPWQOs for specific Upper Bound conditions will be developed in detail during the Permitting stage of the project and will account for the likelihood of combined uncertainty factors.

Morrison Lake Effects

Morrison Lake water quality will be primarily influenced by the diffuser from the water treatment plant and from seepage from the TSF. Modeling of the diffuser flows has addressed the potential for incomplete mixing by assuming mixing only occurs in the hypolimnion during summer and by demonstrating that the diffuser can be designed to maximize mixing with the use of various port designs and areas of discharge. For the Expected Case, TSF seepage is predicted to start to reach Morrison Lake in approximately Year 50, peaking in Year 75 and then declining. For the Upper Bound TSF seepage could start in Year 25 and peak in Year 50, and then decline.

During operations, depending on the actual volumes of pit dewatering flows, there could be a requirement to discharge groundwater from the dewatering wells, and in the Upper Bound case, discharge water treatment water, via a diffuser into Morrison Lake. Water quality predictions indicate potential exceedances of cadmium and copper (which exceeds BCWQGs in the baseline) for the Expected Case with aluminum and iron added for the Upper Bound case. The exceedances are well below the PPWQOs.

After closure, TSF seepage water will begin to emerge in Morrison Lake and the water treatment plant will be treating surplus water from the closed pit lake. For the Expected Case, the predicted lake water quality meets BCWQGs for all parameters except copper and iron, which is exceeded in the baseline water quality. In the Upper Bound, cadmium is marginally above BCWQGs and well below PPWQOs.

For the temporary closure condition there is a surplus of water that would either need to be stored in the open pit or discharged to Morrison Lake. A sensitivity run, assuming that the pit dewatering wells would continue and that surplus open pit water and TSF water would be treated, indicated slight exceedances of aluminum, cadmium, copper and iron.

Emergent Groundwater Effects

An assessment of the potential TSF seepage effects on the receiving streams and the salmon spawning habitat in the vicinity of the TSF was carried out with the contaminant transport modeling, using sulphate as the surrogate parameter. The TSF model was run with a full tailings level and water pond for 25 years, at which time the sulphate concentration in the pond was reduced to reflect the closure pond water quality and concentrations were predicted over time in the receiving streams and the emergent groundwater in Morrison Lake. The Expected Case water quality in the receiving streams meets the PPWQOs for low flow conditions. The Upper Bound groundwater model combined with the Upper Bound geochemical load indicates exceedance of sulphate.

The undiluted emergent groundwater quality entering Morrison Lake is within the PPWQOs for the Expected Case for “Spawn 2”, which is located in an area of identified salmon spawning habitat. Groundwater will flow through the gravels and mix with lake water, further reducing concentrations. The Upper Bound groundwater model, with the Upper Bound geochemical load, in the area of the highest emergent groundwater concentrations (Spawn 4) indicates that sulphate, aluminum and selenium could exceed PPWQOs.

Morrison River Effects

The flow reductions in Morrison River range from 150 m^3/hr during winter low flow up to 307 m^3/hr during the spring to fall period when surface runoff flows are highest. During winter low flow the potential flow reduction in Morrison River is approximately 7% of the 7 day 2 year low flow (7Q2) and 18% of the 7 day 10 year low flow (7Q10) flows. The % flow reduction is less during the fall spawning season. The likelihood of a significant effect on the salmon spawning alevins and emerging fry during winter low flow is low given that the potential reduction in stream flows is within the natural variation of the river. A monitoring program to measure stream flow more accurately during the winter months and to survey the extent of the salmon spawning habitat will be carried out prior to construction of the mine. The Upper Bound water balance case also provides some opportunity to potentially augment flows during low flows by modifying the pit dewatering pumping rate.

Summary

This report addresses a wide range of potential scenarios that could have an effect on Morrison Lake. The main conclusion is that the predicted effects for the Expected Case are within BCWQGs, with the exception of total copper concentrations where existing baseline exceeds BCWQGs. Upper Bound sensitivity runs for geochemical loads, groundwater model flows, water balance flows and operational discharges, indicate potential slight exceedances of aluminum, cadmium, copper and iron – all concentrations are well below PPWQOs. Emergent groundwater flow in the vicinity of salmons spawning habitat downstream of the TSF meets PPWQOs for the Expected Case, assuming no dilution with lake-water. Upper Bound sensitivity runs for geochemical loads and groundwater model flows indicate potential exceedance of the PPWQOs for sulphate, aluminum and selenium, assuming no dilution with lake-water and the highest concentration location at approximately Year 45. However, the combining of multiple Upper Bound conditions is unreasonable as discussed in the following section.

The Upper Bound sensitivity runs, when combined, multiply the applied uncertainty factor, which is not realistic. For example, the PPWQOs have an uncertainty factor of 10, the Upper Bound TSF seepage geochemistry could not be realistically achieved for the entire tailings mass, attenuation of metals will occur along the groundwater flow path, the operating TSF water pond will be managed to be smaller than that used for the TSF seepage modeling, and actual pit water flows are expected to be less than predicted. Therefore, the likelihood of a significant adverse effect is low.

Similarly, the magnitude of the effect is low, the diffuser can be designed to ensure effective mixing in the lake and predicted concentrations are protective of aquatic life.

PBM recognize the fisheries value of Morrison Lake and are committed to ensuring that the design, operation and closure of the facility will have no significant adverse effect. An adaptive management plan is presented in this report and will be further developed in the detail design and permitting stage to ensure that operations will be managed to mitigate potential effects. Additional commitments, which PBM formally commits to include the following:

- Working with the Lake Babine Nation and DFO in measuring sockeye escapement numbers on an annual basis and advancing the knowledge of the fish distribution in Morrison Lake with fish population measurements in various areas of the lake. Additional spawning surveys, particularly in the area downstream of the TSF, along the shoreline and at depth to better quantify the spatial extent of salmon spawning will be carried out.

- The physical behavior of the lake will continue to be monitored with water quality monitoring and temperature and conductivity probes. The design of the diffuser and lake mixing model will be further developed prior to construction.

- Spawning surveys in Morrison River will be carried out to better quantify the potential effect of the reduction in flow due to the mine. This will be combined with more accurate stream gauging stations to ensure that low flow measurements are captured.

TABLE OF CONTENTS

PAGE

EXECUTIVE SUMMARY i
1. INTRODUCTION 1
1.1 General 1
1.2 Scope of the Review Response 2
2. HYDROGEOLOGY 5
2.1 Model Review and Calibration 5
2.2 TSF Hydrogeology 6
2.2.1 General 6
2.2.2 TSF Seepage Predictions and Sensitivity Analysis 7
2.3 Open Pit Hydrogeology 8
2.3.1 General 8
2.3.2 Operations 9
2.3.3 Closure 9
3. GEOCHEMISTRY 10
3.1 General 10
3.2 Nitrogen Species 10
3.3 TSF Water Quality 12
3.3.1 Effect of Milling LGO 12
3.3.2 Effect of PAG Rock Placement in TSF due to Early Closure 12
3.3.3 TSF Pond Water Quality on Closure 12
3.4 PAG Porewater 22
3.5 Water Treatment Plant 25
4. CLOSURE CONSIDERATIONS 27
4.1 General 27
4.2 Life of Mine Plan and Waste Volumes 27
4.3 Temporary Closure Plan 31
4.4 Early Closure Plan 32

TABLE OF CONTENTS
(continued)

4.5 Final Closure - PAG Backfill Plan....33
4.6 Final Closure Cost Estimate....36
5. PRELIMINARY PROPOSED WATER QUALITY OBJECTIVES....38
5.1 General....38
5.2 Copper....39
5.2.1 Background....39
5.2.2 U.S. EPA Biotic Ligand Model....40
5.2.3 Recalculation Based on Toxicity Data for Sockeye Salmon....42
5.3 Cadmium....44
5.3.1 Background....44
5.3.2 U.S. EPA Hardness-Dependent Guideline....45
5.3.3 Recalculation Based on Toxicity Data for Sockeye Salmon....46
5.4 Aluminum....50
5.4.1 Background....50
5.4.2 Recalculation Based on Toxicity Data for Rainbow Trout....50
5.5 Arsenic....53
5.5.1 Background....53
5.5.2 Recalculation Based on Toxicity Data for Rainbow Trout....53
5.6 Sulfate....56
5.6.1 Background....56
5.6.2 Recalculation Based on Toxicity Data for Rainbow Trout....57
5.7 Cobalt....60
5.7.1 Background....60
5.7.2 Recalculation Based on Toxicity Data for Rainbow Trout....60
5.8 Selenium....62
5.8.1 Background....62
5.8.2 U.S. EPA Selenium Guidelines....63

TABLE OF CONTENTS
(continued)

5.8.3 Recalculation Based on Toxicity Data for Oncorhynchus 63
5.9 Summary 66
6. WATER FLOWS AND WATER BALANCE 68
6.1 Water Flow Effects 68
6.1.1 Morrison River Flow Changes 68
6.1.2 Biological Effect of Morrison River Flow Changes 70
6.2 Life of Mine Water Balance 72
6.3 Closure Water Balance 77
6.3.1 TSF Water Balance 77
6.3.2 Mine Area Water Balance – Pit Backfill Stage 77
6.3.3 Mine Area Water Balance – Closure 79
6.3.4 Water Balance Temporary Closure 79
7. WATER QUALITY EFFECTS ASSESSMENT 81
7.1 TSF Effects on Stream Water Quality 81
7.1.1 Methodology 81
7.1.2 Results 82
7.1.3 Summary of Stream Effects 89
7.2 Water Quality Effects on Morrison Lake 89
7.2.1 General 89
7.2.2 Morrison Lake Modeling 90
7.2.3 Potential TSF Seepage Effects to Salmon Spawning Habitat 95
7.2.4 Morrison Lake Effects for Operational Discharges 104
7.2.5 Morrison Lake Effects for Temporary Closure 106
7.3 Summary of Effects Assessment on Morrison Lake and Receiving Streams108
8. UPDATED ADAPTIVE MANAGEMENT PLANS AND TABLE OF COMMITMENTS 111
8.1 General 111

TABLE OF CONTENTS
(continued)

8.2 Tailings Storage Facility Adaptive Management Plans ... 111
8.2.1 Contingency for Raising the TSF Dam to Store Waste Rock or Water ... 111
8.2.2 Contingency for Storage of Surplus Water Balance ... 112
8.2.3 Contingency for Disposal of PAG Waste Rock and/or LGO for the Early Closure Case ... 112
8.2.4 Contingency Plan for TSF if LGO is not Processed ... 113
8.2.5 Contingency Plan if Rougher Tailings has ARD Potential ... 113
8.3 Mine Rock Adaptive Management Plans ... 113
8.4 Seepage and Groundwater Flows Adaptive Management Plans ... 115
8.4.1 Contingency for Excessive Seepage Losses from the TSF ... 115
8.4.2 Contingency for Excessive Seepage Inflows from Morrison Lake into the Open Pit ... 116
8.4.3 Contingency for Groundwater Flows from PAG Porewater to Morrison Lake – Closure ... 116
8.5 Water Balance Adaptive Management Plans ... 117
8.5.1 Contingency Plan for Surplus Water Balance ... 117
9. OBSERVATIONS ON THE TABLE OF COMMITMENTS ... 119
10. CLOSING ... 123

TABLES

Table 1.1 Summary of 3rd Party Review Issues and PBM Scope of Work to Address the Review ... 2
Table 2.1 Expected Case and Upper Bound Case – Hydrogeologic Parameters ... 5
Table 2.2 Summary of TSF Stages ... 6
Table 2.3 Summary of TSF Seepage Predictions ... 8
Table 2.4 Summary of Open Pit Dewatering/Inflow Predictions ... 9
Table 2.5 Pit Lake Inflows-Outflows on Closure ... 9
Table 3.1 Summary of Nitrogen Species Concentration ... 10

TABLE OF CONTENTS
(continued)

Table 3.2 Stream 7 Water Quality Predictions using RGC Nitrogen Species Concentration 11

Table 3.3 TSF Closure Water Quality Inputs with Sensitivity Analyses 14

Table 3.4 TSF Closure Pond Water Quality at TSF Pond Filling - Beach Loading Sensitivity Lower Bound 16

Table 3.5 TSF Closure Pond Water Quality at TSF Pond Filling – Beach Loading Sensitivity Upper Bound 17

Table 3.6 Humidity Cell Tailings Coarse Fraction (Cyclone Sand) Leachate Quality Over 80 Weeks of Operation 18

Table 3.7 TSF Closure Pond Water Quality at TSF Pond Filling Sensitivity Analyses 20

Table 3.8 Estimated PAG Porewater Quality 24

Table 3.9 Summary of Predicted Effluent Treatment Objectives and RGC Alternate Treatment Concentrations 25

Table 4.1 Summary of Waste Rock and Pit Volumes over Life of Mine 27

Table 4.2 Summary of Annual Waste Volumes 29

Table 4.3 Surplus Water Summary for Temporary Closure 31

Table 4.4 Summary of Annual Early Closure and Closure Waste Volume Allocations 33

Table 4.5 Closure and Reclamation Cost Estimate 37

Table 5.1 Water Quality Guidelines for Copper Based on Biotic Ligand Model 41

Table 5.2 Species-Specific Toxicity Data for Copper (µg/L) 43

Table 5.3 Species-Specific Toxicity Data for Cadmium (µg/L) 47

Table 5.4 Acute-to-Chronic Ratios for Selected Fish Species Exposed to Cadmium (µg/L) 48

Table 5.5 Genus-Specific Toxicity Data for Aluminum (µg/L) 52

Table 5.6 Genus-Specific Toxicity Data for Arsenic (µg/L) 55

Table 5.7 Genus-Specific Toxicity Data for Sulfate (µg/L) 58

Table 5.8 Genus-Specific Toxicity Data for Cobalt (µg/L) 61

TABLE OF CONTENTS
(continued)

Table 5.9 Genus-Specific Toxicity Data for Selenium (µg/L) 66
Table 5.10 Summary of Recommended PPWQOs and BCWQGs............................ 67
Table 6.1 Summary of Surplus Water Management Flow Rates.............................. 74
Table 6.2 Annual Water Balance – Expected Case 75
Table 6.3 Annual Water Balance – Upper Bound 76
Table 6.4 TSF Water Balance on Initial and Full –Closure..................................... 77
Table 6.5 Water and Mass Balance for Pit Infilling – Expected Case...................... 78
Table 6.6 Water and Mass Balance for Pit Infilling – Upper Bound Case............... 78
Table 6.7 Water Balance for Pit Area on Full –Closure – Expected Case 79
Table 6.8 Summary of Surplus Water Management Flow Rates – Temporary Closure – Year 15 80
Table 7.1 Predicted Relative Concentrations of Seepage in TSF Receiving Streams – Expected Case Groundwater Model 81
Table 7.2 Predicted Relative Concentrations of Seepage in TSF Receiving Streams – Upper Bound Groundwater Model 81
Table 7.3 Surface Water Quality in Stream MCS-7 Downstream of the TSF at Low and Average Flow Conditions 83
Table 7.4 Surface Water Quality in Stream MCS-8 Downstream of the TSF at Low and Average Flow Conditions 84
Table 7.5 Surface Water Quality in Stream MCS-10 Downstream of the TSF at Low and Average Flow Conditions 85
Table 7.6 Upper Bound Groundwater Sensitivity Analysis Surface Water Quality in Stream MCS-7 Downstream of the TSF at Low and Average Flow Conditions –... 86
Table 7.7 Upper Bound Groundwater Sensitivity Analysis -Surface Water Quality in Stream MCS-8 Downstream of the TSF at Low and Average Flow Conditions.. 87
Table 7.8 Upper Bound Groundwater Sensitivity Analysis Surface Water Quality in Stream MCS-10 Downstream of the TSF at Low and Average Flow Conditions.. 88

TABLE OF CONTENTS
(continued)

Table 7.9 Sensitivity Run for Upper Bound Concentrations (mg/L) of Key Parameters in Morrison Lake 93
Table 7.10 Peak Groundwater Concentrations in Spawn 2 – Expected Groundwater Model Case 102
Table 7.11 Peak Groundwater Concentrations in Spawn 4 – Sensitivity Run with Upper Bound Groundwater Model and Upper Bound TSF Water Quality 103
Table 7.12 Morrison Lake Water Quality - Expected Case – Operational Discharges – Year 18 105
Table 7.13 Morrison Lake Water Quality - Upper Bound Case – Operational Discharges – Year 18 105
Table 7.14 Morrison Lake Water Quality – Temporary Closure – Year 15 – Expected Case 107
Table 7.15 Morrison Lake Water Quality – Temporary Closure Year 15 - Upper Bound 107

FIGURES

Figure 1.1 General Arrangement Plan – Closure 2
Figure 4.1 Phase I Plan 30
Figure 4.2 Phase II Plan 30
Figure 4.3 Phase III and Phase IV Plan 31
Figure 4.4 High PAG Placement on Closure 34
Figure 4.5 Low PAG Placement on Closure 35
Figure 5.1 Water Quality Guidelines for Copper 44
Figure 5.2 Hardness-Toxicity Relationships for Cadmium in Rainbow Trout 49
Figure 5.3 Water Guidelines for Cadmium 49
Figure 5.4 Water Quality Guidelines for Aluminum 51
Figure 5.5 Water Quality Guidelines for Arsenic 56
Figure 5.6 Hardness-Toxicity Relationships for Sulfate in Rainbow Trout 59
Figure 5.7 Water Quality Guidelines for Sulfate 59

TABLE OF CONTENTS
(continued)

Figure 5.8 Water Quality Guidelines for Cobalt ... 61
Figure 5.9 Water Quality Guidelines for Selenium ... 65
Figure 6.1 Morrison River – Flows ... 69
Figure 6.2 TSF Water Pond Volume – Expected Case ... 73
Figure 6.3 TSF Water Pond Volume – Upper Bound ... 73
Figure 7.1 Temporal Distribution of Loading Sources to Morrison Lake ... 91
Figure 7.2 Morrison Lake Water Quality with Time – Expected Case – Cadmium ... 91
Figure 7.3 Morrison Lake Water Quality with Time – Upper Bound - Cadmium ... 92
Figure 7.4 Illustration of Morrison Lakebed Spawning Habitat ... 96
Figure 7.5 Sockeye Spawning Locations – Morrison Lake ... 97
Figure 7.6 Plan of Sulphate Plume at Year 75 – Expected Case ... 98
Figure 7.7 Morrison Lake Salmon Spawning Groundwater Observation Locations ... 99
Figure 7.8 Sulphate Concentrations at Morrison Lake – Spawn 1 Location ... 100
Figure 7.9 Sulphate Concentrations at Morrison Lake – Spawn 2 Location ... 100
Figure 7.10 Sulphate Concentrations at Morrison Lake – Spawn 3 Location ... 101
Figure 7.11 Sulphate Concentrations at Morrison Lake – Spawn 4 Location ... 101

APPENDICES

Appendix I Groundwater Model Report
Appendix II Hydrogeology Work Plan for Detailed Design
Appendix III SGS Letter on Water Treatment
Appendix IV Water Balance Tables
Appendix V Morrison Lake Water Quality Model, Dr. Greg Lawrence
Appendix VI Baseline Water Quality, Morrison Lake, Mine Area Groundwater

1. INTRODUCTION

1.1 General

This report presents the response to the 3rd Party Review of the Environmental Assessment (EA) for the Morrison Copper/Gold Project. The 3rd Party Review was requested by the Environmental Assessment Office (EAO) and was specifically directed towards the following components:

- Hydrogeology assessment and effects of seepage into the open pit and out of the tailings storage facility (TSF).
- Water balance.
- Geochemistry and water quality effects on Morrison Lake and the receiving streams.
- Effects on aquatic habitat in Morrison Lake.

The review of the hydrogeology, water balance, geochemistry and water quality effects was carried out by Robertson Geoconsultants Ltd. (RGC) (December 2, 2011) and the review of Morrison Lake aquatic habitat effects was carried out by Solander Ecological Research Ltd. (November 21, 2011). A General Arrangement Plan of the Mine is shown on Figure 1.1.

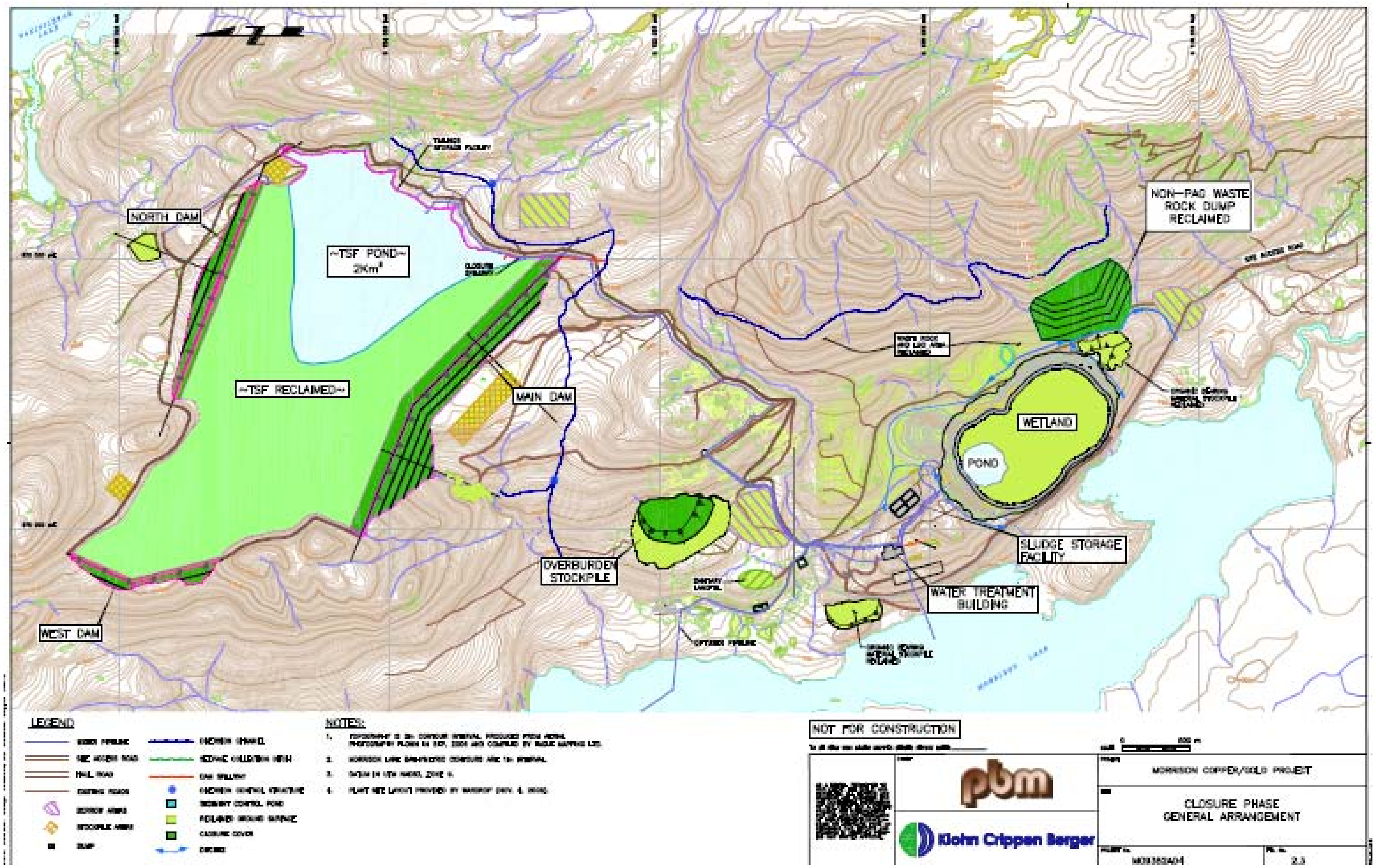


Figure 1.1 General Arrangement Plan – Closure

1.2 Scope of the Review Response

A meeting was held with EAO, CEAA, RGC and Pacific Booker Minerals Inc. (PBM) on December 16, 2011 to clarify the key issues and the scope of work required to address them. PBM issued a letter dated December 20, 2011, which referenced the key issues outlined by RGC and the Proponent's proposed scope of work to address the issues. These are summarized in Table 1.1 and the corresponding section of this report that addresses the issues/concerns is presented in the table.

Table 1.1 Summary of 3rd Party Review Issues and PBM Scope of Work to Address the Review

AREA	NO.	ISSUE / CONCERN	RGC REC.#	PBM SCOPE	REPORT SECTION
Hydrogeology	1.1	Open pit inflows	10	Confirm EAC 3-D model – calibrate and improve the model. Carry out sensitivity study to vary: recharge, k & faults. Determine Expected Case (EC) and Upper Bound (UB) pit inflows during operations. Determine EC and UB pit inflow rates for water treatment design. Determine PAG porewater flows for Morrison Lake assessment.	2
	1.2	TSF seepage	3	Confirm EAC 3-D model – calibrate and improve the model. Carry out sensitivity study to vary k's, and lined portions. TSF seepage mitigation design / works to meet receiving water quality requirements (e.g. site specific water quality objectives that are protective of the aquatic environment). Assess solute transport and temporal loadings. Determine EC and UB solute concentrations in streams and Morrison Lakebed over time.	2

Table 1.1 Summary of 3rd Party Review Issues and PBM Scope of Work to Address the Review (cont'd)

AREA	NO.	ISSUE / CONCERN	RGC REC.#	PBM SCOPE	REPORT SECTION
Geochemistry Source Terms	2.1	Nitrogen species	5	Document: Bell, Granisle, Kemess, Gibraltar and baseline concentrations.	3.2
	2.2	TSF pond water on closure	6	Carry out additional sensitivity calculations to vary depth, load factor and sand loads.	3.3.3
	2.3	TSF porewater quality for seepage effects		Source terms used are suitable – no additional work required.	
	2.4	PAG/LGO effects on TSF	4	EDCM already includes milling LGO (e.g. Bell Mine-20 year old LGO). PBM has already committed to only place non-acidic PAG in TSF for the expected mine life case. No additional work required.	3.3.1
	2.5	PAG porewater	8	Recalculate High PAG porewater at base of pit where it is co-disposed with the Cleaner tailings. Recalculate low PAG porewater for remainder. For both cases assume that 20% of rock is only limed to an intermediate pH.	3.4
	2.6	Water treatment plant concentrations	9	Provide additional support for the sulphate and magnesium concentrations. This is to be provided by SGS based on their operating experience with water treatment plants.	3.5
Closure Considerations	3.1	Early closure PAG backfill plan	12	Management plan for bonding: early closure will require milling of LGO (up to 37 Mt) and placement of Cleaner tailings into the open pit. Surplus Low PAG (maximum 25 Mt) will be placed in the TSF where it will be encapsulated with Rougher tailings. Early closure plan to be detailed.	4.4
	3.2	Temporary closure surplus water	12	Water treatment and diffuser for a portion of the surplus, remainder to be stored in open pit. Requirement to store, treat and potentially pipe to Babine Lake on mine restart. Options for management will be described for the EC and UB water cases.	4.3
	3.3	Lime mixing plan	7	Describe backfill procedures and lime mixing procedures.	4.5
	3.4	PAG backfill plan	7	Describe placement in approximately 75 m thick lifts. Do a case for UB water inflows. Update the cost estimate if required.	4.5
	3.5	Post closure water management in open pit	7	Add more description concerning storage, attenuation of flows and management of upset events.	6.3

Table 1.1 Summary of 3rd Party Review Issues and PBM Scope of Work to Address the Review (cont'd)

AREA	NO.	ISSUE / CONCERN	RGC REC.#	PBM SCOPE	REPORT SECTION
Water Balance	4.1	Spreadsheet error - makeup water double accounted	1	Revise tables.	Appendix IV
	4.2	Concern with year 19-21	1	Tables have been aligned – tailing flows to TSF and Pit are accounted for.	Appendix IV
	4.3	Underestimation of flows to TSF and overestimate of flows to open pit.	1	Flows balance out. For the UB water case describe use of pit groundwater wells to provide clean water for pump gland water and flocculent mixing water. No additional work required.	Appendix IV
	4.4	Closure water balance Diversion ditch efficiency PAG backfill moisture content	1	Updated water balance to include changes.	6.3
Water Balance	4.5	UB fresh water makeup		Describe use of pit groundwater wells for makeup water for the UB water case.	6.3
	4.6	Fresh water makeup-lake withdrawal		Update if there are any changes.	6.2
	4.7	Water balance update	1	Update water balance with corrections and all changes to the project.	6.2
	4.8	Morrison River low flow effect	2	Calculate low flow reductions and describe biological effect of the flow reduction. Consider if there are any operational controls that could mitigate low flow.	6.1
Water Quality Effects	5.1	TSF seepage water quality effects	11	Re-run model with revised % solutes from seepage modeling.	7.1
	5.2	TSF seepage effects on streams and Morrison Lake spawning beds - "hotspots"		Develop Preliminary Proposed Site Specific Water Quality Objectives (PPWQOs): (1) Salmon Alevins in spawning beds downstream of TSF; and (2) aquatic habitat in local streams (7, 8 & 10). Develop PPWQOs for the Expected and Upper Bound cases.	7.2
	5.3	Morrison Lake water quality	11	Re-run UBC seasonal lake model – sensitivity model to vary: TSF seepage, PAG porewater and water treatment plant flow. Confirm EC and UB predictions. Update the UBC report to include all changes.	7.2
General	6.1	Not enough detail in Adaptive Management Plans (AMPs)	12	More detail will be provided.	8

2. HYDROGEOLOGY

2.1 Model Review and Calibration

The 3-D MODFLOW groundwater flow model that was used for the EAC Application was reviewed and recalibrated to reflect the updated assessment of hydrogeologic parameters. The update included a review of groundwater level data, stream flow data, recharge rates and hydraulic conductivity test results. Expected Case and Upper Bound groundwater hydrogeologic parameters were developed to assess potential effects during operations and closure. In addition, sensitivity analysis was carried out for a number of key variable parameters. Appendix I presents the hydrogeology report, which includes details of the model and model results. A preliminary scope of work for detail design for hydrogeology is included in Appendix II.

A summary of the Expected Case and Upper Bound case hydrogeologic parameters, hydraulic conductivity and recharge, is presented in Table 2.1.

Table 2.1 Expected Case and Upper Bound Case – Hydrogeologic Parameters

Parameter	Expected Case	Upper Bound
K_{Faults} in pit – m/s	1.5×10^{-6}	3×10^{-6}
K_{Faults} outside of open pit – m/s	8×10^{-7}	1×10^{-6}
K – Ashman Formation – m/s	3.3×10^{-7}	1×10^{-6}
K – Eocene –m/s	1×10^{-8}	2×10^{-7}
K_H Tailings –m/s	1.5×10^{-7}	5×10^{-7}
K_V Tailings – m/s	1.5×10^{-8}	1×10^{-7}
K – High elevation till – m/s	2.75×10^{-8}	1×10^{-7}
K – Low elevation till – m/s	6×10^{-8}	2×10^{-7}
Recharge – high elevations	67 mm/yr	74 mm/yr
Recharge – low elevations	83 mm/yr	89 mm/yr

2.2 TSF Hydrogeology

2.2.1 General

The tailings facility will be raised over the life of the mine to progressively store tailings and a summary of TSF areas, water pond areas, and maximum dam heights are summarized in Table 2.2.

Table 2.2 Summary of TSF Stages

Phase	Tailings Elevation (m)	Main Dam Height (m)	TSF Area (km^2)	TSF Water Pond Area (km^2)
Year 2	970	40	2.9	0.3
Year 7	984	54	4	1
Year 11	993	63	4.4	1
Year 18	1006	80	5.2	1
Post Closure	1008	82	5.2	1.7

For groundwater modeling purposes and seepage estimates the full TSF and a water pond of 1.7 km^2 was used for both operations and closure. This recognizes that water management upsets may occur during operations and that water may need to be temporarily stored in the TSF.

Contaminant transport modeling has been carried out to assess the temporal and spatial extent of the groundwater plume from the TSF to Morrison Lake. For contaminant transport modeling, the Expected Case and Upper Bound groundwater models were run for the full TSF model for 25 years with the Expected Case water quality source terms. The groundwater plume concentrations were then input into the closure model run (Year 25 to steady state (approximately Year 100)). The closure model run utilized a sulphate concentration of 50 mg/L in the closure TSF pond. The models were run for the Expected Case and Upper Bound groundwater model conditions. The results of the contaminant transport modeling are reported in Section 7.1.3 of this report.

Contaminant transport modeling for the receiving streams was based on the Expected Case and Upper Bound case groundwater models run to the steady state condition, assuming the TSF tailings water quality during operations. An average percent solute was calculated for the various stream sections to determine a % solute for water quality predictions. The results are reported in Section 7.1 of this report.

2.2.2 TSF Seepage Predictions and Sensitivity Analysis

The results of the seepage modeling are included in Appendix III and summarized in the following sections. The Expected Case and Upper Bound case models were run for two conditions:

- Operations: Full height impoundment run for 25 years; and
- Closure: Full height impoundment run from year 25 to steady state conditions.

An assessment of the benefit of various seepage mitigation measures was made to provide future guidance and a sensitivity analysis was carried out for the Expected Case to assess the sensitivity of the results to several hydrogeologic parameters, and the results are summarized in Table 2.3.

Table 2.3 Summary of TSF Seepage Predictions

Condition	Variable	Total TSF Seepage (m^3/hr)	
		Expected Case	Upper Bound
Base Case	No mitigation measures	65	137
Mitigation Measures	Full glacial till liner (k=10^{-8}m/s)	64	128
	Partial geomembrane liner (till veneer areas: 2.5 km^2)	60	132
	Partial geomembrane liner (till veneer & colluviums areas: 2.6 km^2)	55	127
	Full geomembrane liner	20	46
Sensitivity with Base Case	Higher tailings hydraulic conductivity 10 x's	109	
	Lower tailings hydraulic conductivity div. 10	23	
	Smaller water pond A= 0.5 km^2	26	
	Larger water pond A = 2.5 km^2	89	
Sensitivity with full glacial till liner	Higher till hydraulic conductivity k = 10^{-9} m/s	67	
	Lower till liner hydraulic conductivity k = 10^{-9} m/s	49	

Note: Shaded line has been used for contaminant transport modeling predictions

2.3 Open Pit Hydrogeology

2.3.1 General

The open pit will be developed in four stages as described in Section 4.2 of this report. The initial phase, over the first half of the mine life, includes pit development to approximately 150 m below the elevation of Morrison Lake. The open pit is then deepened to approximately 250 m below lake level. During mining, the open pit slopes will be dewatered with a combination of horizontal drains and dewatering wells to maintain the stability of the pit wall slopes.

Upon closure, the open pit will be backfilled with Cleaner tailings and PAG waste rock and capped with glacial till and wetlands, with an associated storage pond for collection and treatment of surplus water that can become contaminated by acid rock drainage from the final exposed pit walls above the closure pit lake elevation.

The groundwater model for the open pit is combined with the TSF and updates to the model are described in Section 2.1 of this report.

2.3.2 Operations

During operations the pit will be dewatered with a combination of groundwater dewatering wells and horizontal drains. The drawdown in the open pit has been modeled for various pit elevations and the results are summarized in Table 2.4.

Table 2.4 Summary of Open Pit Dewatering/Inflow Predictions

Condition	Pit Elevation (m)	Expected Case (m^3/hr)	Upper Bound (m^3/hr)
Phase I, Year 1	780	33	48
Phase II, Year 5	648	152	271
Phase III, Year 12	576	260	464
Phase IV, Year 18.5	480	368	685

Inflows from Morrison Lake to the pit have been modeled for Year 19 and indicate 133 m^3/h and 320 m^3/hr for the Expected Case and Upper Bound, respectively.

2.3.3 Closure

The potential groundwater inflows into the pit lake on closure were assessed for the Expected and Upper Bound cases, and for varying pit lake water levels, and the results are summarized in Table 2.5. The selected design case is a pit lake elevation of 732 m.

Table 2.5 Pit Lake Inflows-Outflows on Closure

Pit Lake Elevation (m)	Expected Case (m^3/hr)		Upper Bound (m^3/hr)	
	Flow to Pit	Flow to Morrison Lake	Flow to Pit	Flow to Morrison Lake
732	95	0.1	127	0.4
735	92	0.2	122	1
737	91	0.4	120	1.8
745	81	2.8	107	8

3. GEOCHEMISTRY

3.1 General

The RGC review indicated several geochemical loading sources which required further clarification or sensitivity analysis to provide upper bound limits on the potential loading sources. The main items identified include:

- Nitrogen species concentrations in TSF porewater.
- Upper bound loading sources for the TSF water pond post-closure coming from the tailings beaches and the cyclone sand dam.
- Upper bound PAG pore water quality for the backfilled open pit due to incomplete mixing.
- Technology of the water treatment plant to meet sulphate and magnesium water quality objectives.

3.2 Nitrogen Species

Predicted nitrogen species concentration for various porphyry copper mines and the predicted TSF concentrations are summarized in Table 3.1.

Table 3.1 Summary of Nitrogen Species Concentration

Parameter	Morrison TSF Porewater	Bell	Granisle	Kemess	Gibraltar	RGC
Nitrite (mg/L)	0.03	< 0.6	< 0.15	< .002	0.04	0.1
Nitrate(mg/L)	0.33	< 2	< 1.5	< .002	1.3	3.5
Ammonia (mg/L)	0.096	< 2		0.028	0.23	1.4

Water quality predictions for Stream 7, using the RGC recommended concentrations are presented in Table 3.2. Nitrite exceeds BCWQGs for the average flow condition due to the elevated nitrite concentration in the baseline surface water quality, which is 4x's the BCWQG.

Table 3.2 Stream 7 Water Quality Predictions using RGC Nitrogen Species Concentration

Parameter (mg/L, except pH) (Total Concentrations, except Al)	TSF Porewater		Baseline Water Quality		Expected Case Water Quality MCS-7		Upper Bound Water Quality MCS-7		BCWQG's Expected Case		BCWQGs Upper Bound	
	EC	UB	Groundwater	Surface	Low	Average	Low	Average	Low	Average	Low	Average
Nitrite-NO_2	0.030	0.10	0.0018	0.088	0.0097	0.083	0.0293	0.084	0.069	0.020	0.030	0.020
Nitrate-NO_3	0.33	3.50	0.016	0.51	0.10	0.49	0.991	0.54	13	13	13	13
Ammonia-NH_3	0.096	1.40	0.073	0.0054	0.079	0.0097	0.444	0.0310	1.6	1.6	1.6	1.6

3.3 TSF Water Quality

3.3.1 Effect of Milling LGO

The low grade ore (LGO) will be milled prior to mine closure and has the potential to modify the tailings water quality due to the oxidized materials within the ore. However, the EDCM model includes the contribution of acidic drainage from the LGO and pit slopes during the mine life. In addition, on closure, the Bell Mine processed LGO which had been stored up to 20 years and, therefore, the Bell EDCM model already accounts for degradation in water quality due to milling LGO. Consequently, the processing of the LGO ore should not significantly modify the "end of mining" water quality that has been used for the water quality predictions.

3.3.2 Effect of PAG Rock Placement in TSF due to Early Closure

The mass balance assessment for mine rock is presented in Table 4.2 and indicates that up to 25 Mt of Low PAG rock may need to be placed in the TSF in the event of an early closure of the mine. A percentage of the Low PAG rock may become acidic during the life of the mine, which is estimated to be in the order of 30%, based on expected lag times, or 7.5 Mt. Similarly to the effects of milling LGO discussed in the previous section, we do not anticipate that placement of low PAG will significantly modify the "end of mining" water quality that has been used for the water quality predictions.

3.3.3 TSF Pond Water Quality on Closure

3.3.3.1 General

Sensitivity analysis has been run for the following conditions:

1. Available volume equivalent to 1.0 m and 1.5 m tailings beach above water depth.

2. Load availability factors of 10% and 20%.
3. Sand dam contribution of 50% and 100% of volume, with load factors of 10% and 20%. Sand dam loadings are expected to report directly to the streams when the water quality meets guidelines. Until that time they will report to the TSF pond and have therefore been included for the calculation.

3.3.3.2 Sensitivity of Beach Geochemical Loads – Post Closure

Table 3.3 shows the beach infiltration source terms at the lower and upper permutations based on the first and second sensitivity variables above. Solubility constraints were not applied and show that the source terms, especially the upper sensitivity, may be unrealistic at alkaline conditions (e.g., sulphate, aluminum).

Table 3.4 and Table 3.5 show the results of the sensitivity scenarios and indicate potential parameters of interest Sulphate, aluminum, arsenic, cadmium, and selenium in the TSF pond at Year 3 after closure.

Table 3.3 TSF Closure Water Quality Inputs with Sensitivity Analyses

Parameter (mg/L unless noted)	Final Morrison Prediction Water Quality for Initial TSF Pond	Tailings Infiltration Average Bound Water Quality Reporting to TSF Pond	Tailings Infiltration Upper Water Quality Reporting to TSF Pond	Tailings Infiltration Average Water Quality Reporting to TSF Pond Sensitivity - 1 m Tailings Volume with 10% Load Factor	Tailings Infiltration 95th Percentile Water Quality Reporting to TSF Pond Sensitivity - 1.5 m Tailings Volume with 20% Load Factor	Baseline Surface Runoff Water Quality
pH (pH units)	7.9					7.9
Acidity (as $CaCO_3$)	23	58	58	155	491	2.2
Alkalinity (as $CaCO_3$)	100	2782	3368	7422	28555	72
TDS	2000					86
Sulphate	1700	443	697	1165	5914	8.8
Fluoride	0.55					0.064
Chloride	5.9					<0.25
Ammonia	NA					0.0044
Nitrite	NA					0.00057
Nitrate	NA					0.15
Dissolved						
Aluminum	0.39	2.0	2.8	5.2	22	0.036
Antimony	0.042	0.08	0.22	0.21	1.5	<0.000050
Arsenic	0.036	0.058	0.138	0.15	1.1	0.00026
Barium	0.58	17	20	44	164	0.025
Beryllium	0.000076	0.00080	0.0012	0.0021	0.0095	<0.00025
Bismuth	0.26	0.00041	0.00058	0.0011	0.0049	<0.00025
Cadmium	0.0016	0.0008	0.0017	0.0020	0.014	<0.000010
Calcium	260	836	1,205	2192	8983	21
Chromium	<0.0005	0.0135	0.0145	0.036	0.12	<0.00025

Table 3.3 TSF Closure Water Quality Inputs with Sensitivity Analyses (cont'd)

Parameter (mg/L unless noted)	Final Morrison Prediction Water Quality for Initial TSF Pond	Tailings Infiltration Average Bound Water Quality Reporting to TSF Pond	Tailings Infiltration Upper Water Quality Reporting to TSF Pond	Tailings Infiltration Average Water Quality Reporting to TSF Pond	Tailings Infiltration 95th Percentile Water Quality Reporting to TSF Pond	Baseline Surface Runoff Water Quality
				Sensitivity - 1 m Tailings Volume with 10% Load Factor	Sensitivity - 1.5 m Tailings Volume with 20% Load Factor	
Cobalt	0.021	0.014	0.030	0.034	0.24	<0.000050
Copper	0.060	0.070	0.091	0.18	0.73	0.00088
Iron	0.053	0.29	0.29	0.77	2.4	0.051
Lead	0.0092	0.0019	0.0064	0.0048	0.043	0.000039
Lithium	0.042	0.063	0.058	0.17	0.49	<0.0025
Magnesium	210	260	344	683	2504	4.0
Manganese	1.5	1.7	3.4	4.5	25	0.00060
Mercury	<0.00001	0	0	0	0	0.0000055
Molybdenum	0.28	0.20	0.65	0.51	5.2	0.000053
Nickel	0.033	0.06	0.24	0.15	1.5	0.00026
Potassium	44	252	542	656	3843	0.29
Selenium	0.019	0.032	0.058	0.085	0.44	0.00030
Silicon	3.6	37	76	97	570	2.7
Silver	<0.00002	0.00059	0.00116	0.0016	0.0096	0.0000067
Sodium	21	63	235	148	1895	5.2
Tin	<0.0001	0.010	0.053	0.025	0.33	0.000061
Titanium	0.016	0.0055	0.0116	0.014	0.096	<0.0050
Vanadium	0.00029	0.016	0.028	0.043	0.21	<0.00050
Zinc	0.44	0.18	0.52	0.48	4.3	0.00061

Table 3.4 TSF Closure Pond Water Quality at TSF Pond Filling - Beach Loading Sensitivity Lower Bound

Parameter (mg/L unless indicated)[1]	Year 0	Year 1	Year 2	Year 3[2]
	Sensitivity - Tailings Infiltration Average Bound Water Quality Reporting to TSF Pond from 1 m Deep Tailings Beach Volume and 10% Load Factor			
Pond Volume (m3)	10,000			
pH	7.9	>7	>7	>7
Acidity (as CaCO3)	23	14	13	10
Alkalinity (as CaCO3)	100	612	566	450
Sulphate	1,700	172	128	94
TDS	2,000	91	47	28
Fluoride	0.55	0.033	0.021	0.016
Chloride	5.9	0.47	0.34	0.29
Dissolved				
Aluminum	0.39	0.44	0.40	0.32
Antimony	0.042	0.019	0.017	0.013
Arsenic	0.036	0.014	0.012	0.0097
Barium	0.58	3.6	3.4	2.7
Beryllium	0.000076	0.00038	0.00037	0.00034
Bismuth	0.26	0.012	0.0063	0.0039
Boron	0.13	0.12	0.11	0.086
Cadmium	0.0016	0.00024	0.00019	0.00015
Calcium	260	192	173	137
Chromium	0.00025	0.0031	0.0029	0.0024
Cobalt	0.021	0.0038	0.0031	0.0024
Copper	0.060	0.018	0.016	0.012
Iron	0.053	0.077	0.072	0.060
Lead	0.0092	0.00082	0.00060	0.00044
Lithium	0.0092	0.016	0.015	0.012
Magnesium	210	66	57	45
Manganese	1.5	0.44	0.38	0.29
Mercury	0.0000050	0.0000043	0.0000042	0.0000042
Molybdenum	0.28	0.054	0.045	0.035
Nickel	0.033	0.014	0.012	0.0097
Potassium	44	56	51	40
Selenium	0.019	0.0082	0.0073	0.0058
Silicon	3.6	8.1	7.5	5.9
Silver	0.000010	0.00013	0.00012	0.000099
Sodium	21	14	13	10
Tin	0.000050	0.0021	0.0020	0.0016
Titanium	0.016	0.0059	0.0055	0.0053
Vanadium	0.00029	0.0039	0.0037	0.0030
Zinc	0.44	0.060	0.047	0.036

Notes:

1. Green value: indicates ½ the method detection limit
2. Shaded value: exceeds BCWQG freshwater aquatic guidelines. No water will be discharged from the TSF pond until Year 3after closure.

Table 3.5 TSF Closure Pond Water Quality at TSF Pond Filling – Beach Loading Sensitivity Upper Bound

Parameter (mg/L unless indicated)[1]	Year 0	Year 1	Year 2	Year 3[2]
	Sensitivity - Tailings Infiltration 95th Percentile Water Quality Reporting to TSF Pond from 1.5 m Deep Tailings Beach Volume and 20% Load Factor			
Pond Volume (m3)	10,000			
pH	7.9	>7	>7	>7
Acidity (as CaCO3)	23	30	27	20
Alkalinity (as CaCO3)	100	1,672	1,540	1,131
Sulphate	1,700	422	358	258
TDS	2,000	91	47	28
Fluoride	0.55	0.033	0.021	0.016
Chloride	5.9	0.47	0.34	0.29
Dissolved				
Aluminum	0.39	1.32	1.21	0.89
Antimony	0.042	0.089	0.081	0.059
Arsenic	0.036	0.068	0.062	0.045
Barium	0.58	9.6	8.8	6.5
Beryllium	0.000076	0.00076	0.00072	0.00059
Bismuth	0.26	0.012	0.0065	0.0040
Boron	0.13	1.2	1.1	0.79
Cadmium	0.0016	0.00091	0.00081	0.00059
Calcium	260	537	490	360
Chromium	0.00025	0.0074	0.0068	0.0051
Cobalt	0.021	0.0151	0.0136	0.0099
Copper	0.060	0.046	0.041	0.030
Iron	0.053	0.16	0.15	0.11
Lead	0.0092	0.0029	0.0025	0.0019
Lithium	0.0092	0.031	0.029	0.022
Magnesium	210	156	140	102
Manganese	1.5	1.5	1.4	1.0
Mercury	0.0000050	0.0000043	0.0000042	0.0000042
Molybdenum	0.28	0.32	0.29	0.21
Nickel	0.033	0.088	0.080	0.059
Potassium	44	226	208	153
Selenium	0.019	0.027	0.024	0.018
Silicon	3.6	34	31	23
Silver	0.000010	0.00056	0.00052	0.00038
Sodium	21	112	103	76
Tin	0.000050	0.019	0.018	0.013
Titanium	0.016	0.010	0.0096	0.0082
Vanadium	0.00029	0.013	0.012	0.0088
Zinc	0.44	0.27	0.25	0.18

Notes:

1. Green value: indicates ½ the method detection limit
2. Shaded value: exceeds BCWQG freshwater aquatic guidelines. No water will be discharged from the TSF pond until Year 3.

3.3.3.3 Sensitivity of Cyclone Sand Dam Geochemical Load – Post Closure

On post-closure, runoff from the cyclone sand dams will be collected in the seepage recovery ponds and will be returned to the TSF pond. When the water quality is suitable for discharge the seepage recovery ponds will be decommissioned.

An estimate of the geochemical loading source from the cyclone sand was made based on humidity cell data. Table 3.6 shows the tailings cyclone sand (Coarse fraction > 0.53 µm) kinetic testing results summary. Estimates of sulphide (< 0.1%) depletion based on the last 10 weeks of operation confirms the N-PAG status. Cyclone sand leachate characteristics are not expected to materially change.

Table 3.6 Humidity Cell Tailings Coarse Fraction (Cyclone Sand) Leachate Quality Over 80 Weeks of Operation

Parameters	Units	Average	95th Percentile (5th Percentile)	Maximum (Minimum)
pH		7.8	8.1 (7.4)	8.2 (7.1)
Conductivity	uS/cm	118	141	308
Alkalinity	mg/L as $CaCO_3$	48	58	71
Acidity	mg/L as $CaCO_3$	1.0	1.0	1.0
Sulphate	mg/L	7.6	12	58
Dissolved Metals				
Mercury	mg/L	0.000050	0.000050	0.000050
Silver	mg/L	0.000010	0.000020	0.000030
Aluminum	mg/L	0.034	0.049	0.13
Arsenic	mg/L	0.0010	0.0024	0.0033
Barium	mg/L	0.29	0.35	0.40
Berylium	mg/L	0.000014	0.000020	0.000020
Boron	mg/L	0.0084	0.043	0.092
Bismuth	mg/L	0.0000071	0.000010	0.000020
Calcium	mg/L	14	21	24
Cobalt	mg/L	0.00025	0.00052	0.0024
Cadmium	mg/L	0.000013	0.000030	0.000030
Chromium	mg/L	0.00023	0.00025	0.00050
Copper	mg/L	0.0012	0.0016	0.0022
Iron	mg/L	0.0050	0.0050	0.0050
Lithium	mg/L	0.0011	0.0010	0.0030

Table 3.6 Humidity Cell Tailings Coarse Fraction (Cyclone Sand) Leachate Quality Over 80 Weeks of Operation (cont'd)

Parameters	Units	Average	95th Percentile (5th Percentile)	Maximum (Minimum)
Potasium	mg/L	4.3	9.3	11
Magnesium	mg/L	4.5	5.9	6.6
Manganese	mg/L	0.030	0.058	0.071
Molybdenum	mg/L	0.0035	0.011	0.021
Sodium	mg/L	1.1	4.1	15
Nickel	mg/L	0.00100	0.0041	0.0056
Lead	mg/L	0.000032	0.00011	0.00013
Antimony	mg/L	0.0014	0.0038	0.0041
Selenium	mg/L	0.00056	0.0010	0.0010
Tin	mg/L	0.00018	0.00091	0.0011
Silicon	mg/L	0.64	1.3	1.4
Titanium	mg/L	0.000094	0.00020	0.00040
Vanadium	mg/L	0.00028	0.00048	0.00051
Zinc	mg/L	0.0031	0.0090	0.019

Notes:

1. Green value: indicates ½ the method detection limit
2. Shaded value: exceeds BCWQG freshwater aquatic guidelines. No water will be discharged from the TSF pond until Year 3.

Sensitivity case #3, assuming loading from the 50% to 100% of the dam mass, is overly conservative as it assumes the entire dam mass is contributing loadings. Therefore, the sensitivity runs were modified to use the same approach as previously described in sensitivity scenarios one and two above (i.e., a 1.0 m and 1.5 m upper dam layer contributes loading as run-off/infiltration with 10% and 20% availability factors at average and 95th percentile source term leachate quality as per Table 3.6). Table 3.7 shows the upper and lower sensitivity runs for the TSF Pond water quality on closure, with the cyclone sand load. Note that the alkalinity expected for these two cases will result in pHs greater than pH 7. The upper sensitivity run potentially results in additional parameters of concern that include sulphate, aluminum, arsenic and selenium at exceedances slightly above BCWQO.

Table 3.7 TSF Closure Pond Water Quality at TSF Pond Filling Sensitivity Analyses

Parameter (mg/L unless indicated)[1]	Year 0	Year 1	Year 2	Year 3[2]	Year 3[2] Sensitivity - Average Quality Run-off from 1 m Cycloned Sand Dam Layer with 10% Load Factor	Year 3[2] Sensitivity – 95th Percentile Quality Run-off from 1.5 m Cycloned Sand Dam Layer with 20% Load Factor
pH	7.9	6.12	6.11	6.07	>7	>7
Acidity (as CaCO3)	23	2.9	2.3	1.7	3.0	6.5
Alkalinity (as CaCO3)	100	11	8.4	5.9	82	303
Sulphate	1,700	185	136	92	85	135
TDS	2,000	217	160	108	186	86
Fluoride	0.55	0.069	0.053	0.039	0.032	0.032
Chloride	5.9	0.86	0.70	0.55	0.46	0.46
Dissolved						
Aluminum	0.39	0.043	0.032	0.021	0.071	0.25
Antimony	0.042	0.0046	0.0034	0.0023	0.0040	0.017
Arsenic	0.036	0.0039	0.0029	0.0020	0.0032	0.013
Barium	0.58	0.063	0.046	0.031	0.49	1.7
Beryllium	0.000076	0.00023	0.00024	0.00024	0.00023	0.00031
Bismuth	0.26	0.028	0.021	0.014	0.011	0.011
Boron	0.13	0.019	0.015	0.012	0.024	0.22
Cadmium	0.0016	0.00018	0.00014	0.00010	0.00010	0.00023
Calcium	260	29	22	15	35	106
Chromium	0.00025	0.00025	0.00025	0.00025	0.00059	0.0015
Cobalt	0.021	0.0023	0.0017	0.0012	0.0013	0.0035
Copper	0.060	0.0070	0.0052	0.0037	0.0049	0.011
Iron	0.053	0.019	0.018	0.017	0.023	0.040
Lead	0.0092	0.0010	0.00076	0.00052	0.00047	0.00086
Lithium	0.0092	0.0032	0.0030	0.0029	0.0042	0.0076
Magnesium	210	23	17	12	17	36

Table 3.7 TSF Closure Pond Water Quality at TSF Pond Filling Sensitivity Analyses (cont'd)

Parameter (mg/L unless indicated)[1]	Year 0	Year 1	Year 2	Year 3[2]	Year 3[2] Sensitivity - Average Quality Run-off from 1 m Cycloned Sand Dam Layer with 10% Load Factor	Year 3[2] Sensitivity – 95th Percentile Quality Run-off from 1.5 m Cycloned Sand Dam Layer with 20% Load Factor
Manganese	1.5	0.16	0.12	0.08	0.11	0.33
Mercury	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050
Molybdenum	0.28	0.030	0.022	0.015	0.017	0.066
Nickel	0.033	0.0040	0.0031	0.0023	0.0034	0.017
Potassium	44	4.8	3.5	2.4	8.8	42
Selenium	0.019	0.0025	0.0020	0.0015	0.0021	0.0058
Silicon	3.6	0.41	0.31	0.22	1.2	6.1
Silver	0.000010	0.000010	0.000010	0.000010	0.000021	0.00010
Sodium	21	3.2	2.6	2.1	3.3	22
Tin	0.000050	0.000050	0.000050	0.000050	0.00031	0.0035
Titanium	0.016	0.0062	0.0059	0.0056	0.0050	0.0058
Vanadium	0.00029	0.00048	0.00048	0.00049	0.00088	0.0026
Zinc	0.44	0.049	0.036	0.025	0.025	0.065

Notes:

1. Green value: indicates ½ the method detection limit
2. Shaded value: exceeds BCWQG freshwater aquatic guidelines. No water will be discharged from the TSF pond until Year 3.

3.3.3.4 Summary

Sensitivity analysis of temporal loads from the tailings beach and the cyclone sand for the post closure TSF water pond indicate several parameters that may exceed BCWQGs at Year 3 after closure. At this time the management plan would include components of the following:

- Increase storage in the TSF to allow further dilution with surface water.
- Seasonal discharge during high flow to obtain mixing dilution in the receiving streams.
- Use of site specific water quality guidelines, as described in Section 5 of this report.

3.4 PAG Porewater

High PAG waste rock will be placed in the base of the open pit between elevation 486 m and approximately 600 m in the later years of mining when the LGO is being processed. The revised pore water quality calculation is based upon the following:

1. 100% of the High PAG rock (34 Mt) is assumed to be acidic with pH 3.
2. Mixing inputs include: cleaner tailings water, groundwater and precipitation.
3. To allow for the risk of potential inefficiency of mixing – the Upper Bound water quality is the weighted average of 80% of the recalculated limed treatment of all of the High PAG rock volume (starting at pH=3) and 20% of pH 5.2.

The Low PAG waste rock (119 Mt) will fill the remainder of the pit. The water quality calculation is based upon:

1. 26 Mt of Low PAG is assumed to be acidic (see Table 4.2) with pH=5.2, the remainder will be neutral PAG.
2. Mixing includes: residual (surplus) High PAG porewater, groundwater and precipitation.
3. To allow for the potential inefficiency of mixing – the Upper Bound water quality was recalculated based upon: 70% neutral rock, 20% pH adjusted to pH 8, 10% at pH 5.2.

Table 3.8 shows the sensitivity runs according to the above listed variables. The average porewater quality assumes that all material is mixed together and completely mixed with lime. Sensitivity results indicate similar or better concentrations at year 4.5 as the estimated treatment concentrations for a pH 8 for some parameters (i.e., sulphate, cadmium, thallium, etc). Other modeled parameters are slightly higher (i.e., arsenic, copper, zinc, etc).

Implications of the sensitivity analysis are a requisite control for thorough mixing of PAG porewater (i.e., homogenization of waste rock-lime slurry) during the treatment stage to limit pockets of low porewater pH.

Table 3.8 Estimated PAG Porewater Quality

Parameter YEAR	Average PAG Porewater	High PAG Porewater Year -2 to -1	Low PAG Porewater Year 4.5
pH	8.0	<7	>7
Acidity		159	50
Alkalinity		155	112
Sulphate	6,660	3,686	4,334
Fluoride		0.97	0.54
Chloride		9.7	3.3
Aluminum	0.41	3.5	1.1
Antimony	<0.002	0.0023	0.0012
Arsenic	<0.0004	0.0091	0.0036
Barium	0.045	0.066	0.042
Berylium	<0.0004	0.0020	0.0011
Boron	0.32	0.15	0.21
Cadmium	0.0050	0.0027	0.0031
Calcium	463	443	431
Chromium	<0.004	0.0024	0.0015
Cobalt	1.1	0.54	0.58
Copper	0.032	3.6	0.94
Iron	<0.02	0.54	0.21
Lead	<0.0008	0.0097	0.0060
Lithium		0.052	0.032
Magnesium	2,030	642	1,059
Manganese	13	4.8	7.3
Mercury		0.00015	0.00014
Molybdenum	0.0050	0.072	0.045
Nickel	0.61	0.25	0.33
Phosphorus	<0.04	0.29	0.17
Potasium	2.4	39	25
Selenium	0.0021	0.011	0.0037
Silicon	0.80	7.0	3.8
Silver	<0.00008	0.000029	0.000038
Sodium	3.6	71	55
Strontium	0.20	4.9	3.7
Tellurium		0.00033	0.00029
Thallium	0.0031	0.0013	0.0015
Thorium		0.00016	0.00014
Tin	<0.02	0.0022	0.0046
Titanium	<0.02	0.023	0.015
Tungsten		0.10	0.063
Uranium	0.00050	0.0040	0.0022
Vanadium	<0.02	0.0061	0.0076
Zinc	0.064	0.63	0.30
Net Acidity		4	-62

3.5 Water Treatment Plant

The water treatment plant uses a conventional high density sludge lime treatment plant, with secondary ponds for pH treatment where required. RGC's alternative source terms for key parameters for treated water are summarized in Table 3.9 and suggest that sulphate and magnesium treatment concentrations may not be achievable.

Table 3.9 Summary of Predicted Effluent Treatment Objectives and RGC Alternate Treatment Concentrations

Parameter (mg/L)	Treatment Objective (RRR - REV.2)	RGC Treatment Predictions
Sulphate	2000	5700
Aluminum	0.46	0.464
Cadmium	0.0005	0.00032
Copper	0.007	0.0049
Iron	0.02	0.02
Magnesium	210	1660
Selenium	0.0019	0.0019
Zinc	0.064	0.02

*Shaded parameters are higher than treatment objectives.

The design of the water treatment plant is being carried out by SGS-CEMI and their review of the treatment requirements for sulphate and magnesium are included in SGS-CEMI (2012) letter, which provides a discussion on water treatment (Appendix III). Sulphate and magnesium treatability is summarized below.

Sulphate: Sulphate removal is a function of pH and retention time. At higher pH and 60 minutes retention time, sulphate concentrations could be approximately 2,000 mg/L. The sulphate concentration in the water sample dropped from 11,760 mg/L to 5,700 mg/L which indicates removal efficiency of more than 50%. However, the sulphate concentration was significantly above the discharge target. High Density Sludge (HDS) is one of the best options to reduce the sulphate concentration in water. In a typical HDS plant operated at pH 9.5 to 9.8, with a 60 minute retention time, results in sulphate concentration well below 2,000 mg/L. Although a 40 minute retention time in the bench scale test work was sufficient in removing most of the metals, a higher retention time is recommended to improve the sulphate removal efficiency. Also, the high retention time provides sufficient contingency to manage peak flows without having a significant impact on the effluent quality.

Magnesium: Magnesium (Mg) precipitation improves with sludge recycle and at higher pH, typically less than 0.1 mg/L with an HDS system at pH 9.3. The maximum Mg precipitation takes place at pH 9.8 or higher as experienced at other mining sites. Typically over 90% of Mg will precipitate at pH 9.9 unless the Mg is complexed with sulphate as $MgSO_4$.

Summary

The water treatment plant utilizes conventional technology and the designers believe that it can meet the water treatment objectives. The operation of the system also provides flexibility in temporary storage of water within the open pit in the event of system malfunction or temporary exceedance of water quality objectives.

4. CLOSURE CONSIDERATIONS

4.1 General

Review observations with temporary, early and final closure were identified and primarily relate to the management of low PAG, High PAG and LGO ore during operations and closure. An associated observation raised by the Ministry of Mines was the economic cost of backfilling the open pit as opposed to placing PAG rock into the TSF.

4.2 Life of Mine Plan and Waste Volumes

The open pit will be developed in four phases which progressively expand the depth and aerial extent. A summary of the mine stages, waste rock production and LGO tonnage are summarized in Table 4.1. An annual breakdown of waste rock classifications and LGO is presented in Table 4.2.

The four phases of pit development are shown in plan on Figure 4.1 to Figure 4.3.

Table 4.1 Summary of Waste Rock and Pit Volumes over Life of Mine

Phase	Year	Pit Base Elevation	Mined Tonnage Mt	
			LGO	PAG Waste Rock
II	0-7	576	36	28
II	4-11	576	36	34
III	8-17	480	26	41
IV	12 -18	480	26.6	51

The quantities of acidic PAG rock were determined using the following assumptions:

- High PAG rock is 20% of total waste rock based on screening of the SNPR and %S for the deposit.
- The percentage of low PAG rock is 70% of the total waste rock.

- NAG rock is 10% of the total waste rock.

In addition, the Low PAG rock has been further subdivided to estimate the quantity that may become acidic during the life of the mine. This calculation assumes that 30% of the Low PAG could become acidic within 10 years. High PAG rock is assumed to produce pH=3 water and Low PAG rock is assumed to produce pH=5.2 water.

Table 4.2 Summary of Annual Waste Volumes

Year	Waste Rock		Non PAG		PAG		High PAG		Low PAG		Low PAG Acidic	Low PAG Non-Acidic	LGO Cumulative
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Cumulative	Cumulative	
-1	5.1	5	0.5	1	4.6	5	1.0	1	4	4		4	3
1	9.4	15	0.9	1	8.5	13	1.9	3	7	10		10	7
2	7.5	22	0.8	2	6.8	20	1.5	4	5	15		15	17
3	4.6	27	0.5	3	4.1	24	0.9	5	3	19		19	25
4	11.1	38	1.1	4	10.0	34	2.2	8	8	26		26	26
5	7.9	46	0.8	5	7.1	41	1.6	9	6	32		32	31
6	8.1	54	0.8	5	7.3	48	1.6	11	6	38		38	34
7	8.3	62	0.8	6	7.5	56	1.7	12	6	43		43	37
8	10.3	72	1.0	7	9.3	65	2.1	14	7	51		51	36
9	10.9	83	1.1	8	9.8	75	2.2	17	8	58		58	33
10	10.5	94	1.1	9	9.5	84	2.1	19	7	66	1.1	65	34
11	8.9	103	0.9	10	8.0	93	1.8	21	6	72	3.1	69	36
12	13.2	116	1.3	12	11.9	104	2.6	23	9	81	4.7	76	33
13	12	128	1.2	13	10.8	115	2.4	26	8	89	5.6	84	32
14	13.6	141	1.4	14	12.3	127	2.7	28	10	99	8.0	91	29
15	13.3	155	1.3	15	12.0	139	2.7	31	9	108	9.7	99	27
16	11.1	166	1.1	17	10.0	149	2.2	33	8	116	11.4	105	26
17	3	169	0.3	17	2.7	152	0.6	34	2	118	13.2	105	27
18	0.6	169	0.1	17	0.5	153	0.1	34	0	119	15.3	103	27
19	0.3	170	0.0	17	0.3	153	0.1	34	0	119	17.6	101	17
20						153		34		119	19.9	99	6
21								34		119	21.8	97	0
22								33.9		119	24.6	94	
TOTALS	170		17		153		34		119		26	93	0

* Low PAG Acidic rock assumes 30% of Low PAG rock becomes acidic in 10 years.

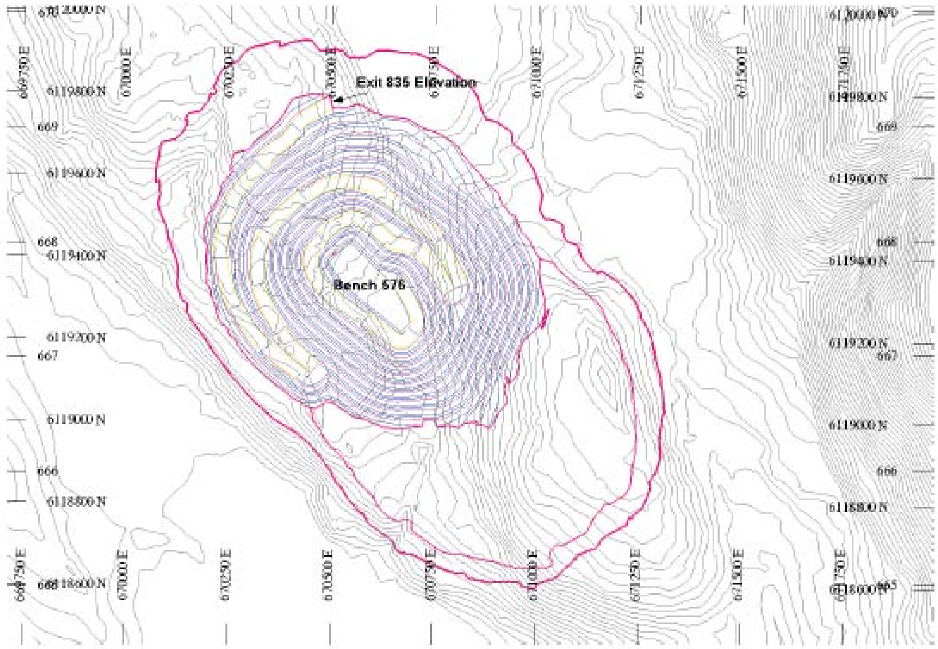


Figure 4.1 Phase I Plan

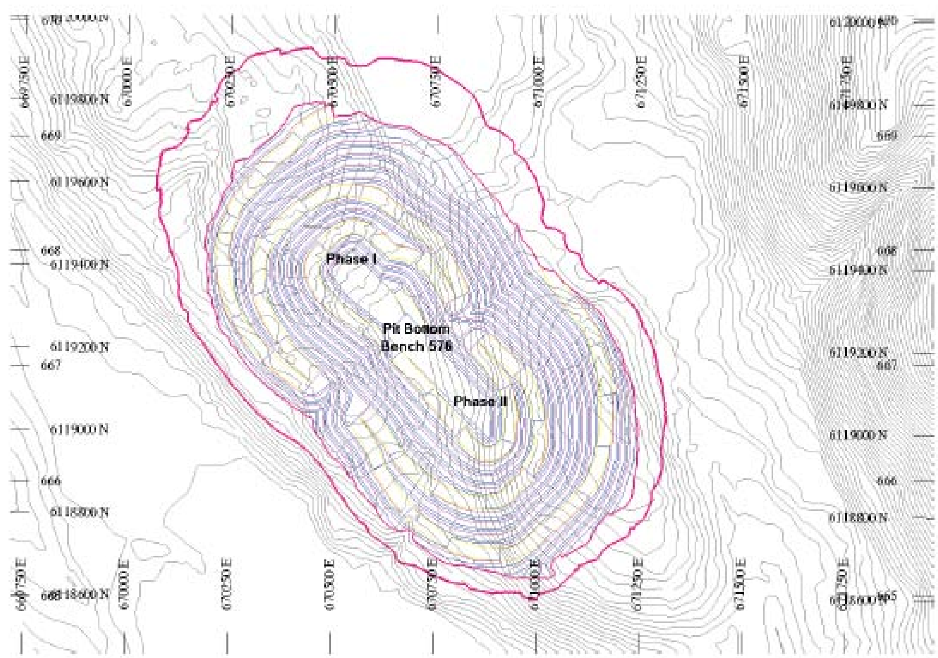


Figure 4.2 Phase II Plan

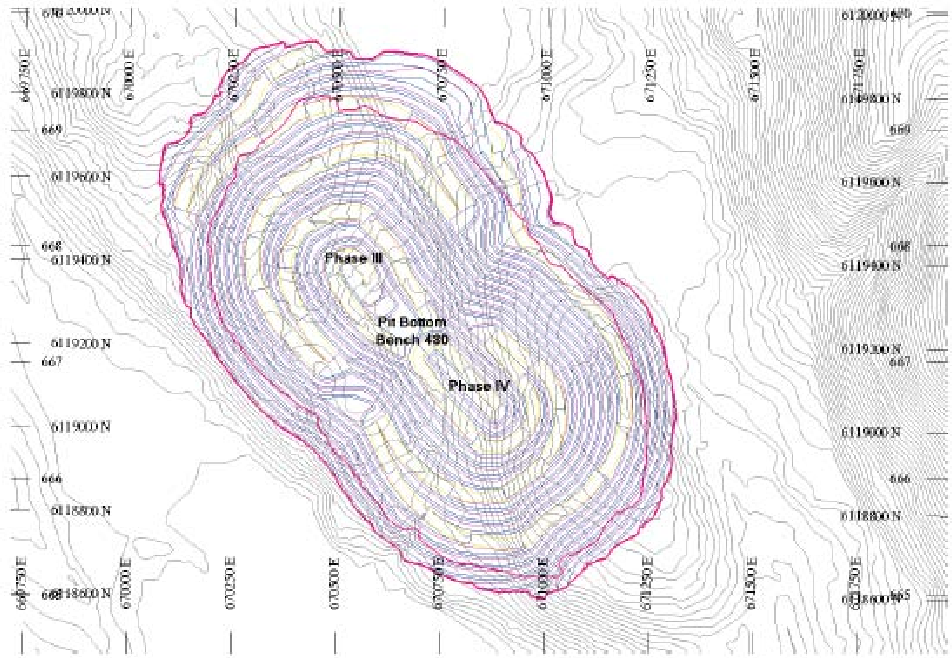


Figure 4.3 Phase III and Phase IV Plan

4.3 Temporary Closure Plan

The plan for temporary closure principally centers on management of water. The site has a net positive water balance with an annual water surplus in the order of 3.5 Mm^3/yr to 5 Mm^3/yr. A large portion of the water is derived from the open pit dewatering flows and the approximate distribution for temporary shutdown in Year 10 and Year 15 is summarized in Table 4.3.

Table 4.3 Surplus Water Summary for Temporary Closure

Year	Expected Case (m^3/hr)		Upper Bound (m^3/hr)	
	Water Treatment	Pit Dewatering	Water Treatment	Pit Dewatering
Year 10	400	50	500	275
Year 15	500	100	500	375

The water management plan for temporary closure will include:

- Maximize segregation of contact water and non-contact water.
- Discharge pit dewatering flows via a diffuser into Morrison Lake.
- Assess potential for “land area discharge” or surface water treatment ponds for groundwater interceptions and low level contaminant surface water.
- Install water treatment plant to treat contaminated water from the TSF, waste dump drainage and pit basin or wall runoff onto pit ramps.
- Store surplus water in the open pit.

An assessment of the water quality, assuming that all of the surplus water is treated and discharged into Morrison Lake, via a diffuser, is presented in Section 7.2.5 of this report. If the water is not treated and discharged into Morrison Lake it will accumulate within the open pit and will need to be treated prior to reopening of the mine. At that time it would be necessary to discharge the treated water into a much larger water body, such as Babine Lake, in order to have the assimilative capacity.

4.4 Early Closure Plan

Early closure of the mine, which assumes permanent closure, would follow the permanent closure framework and requires the following management components:

- Milling of stockpiled LGO, with rougher tailings sent to the TSF and cleaner tailings sent to the open pit. The volumes of the LGO stockpile each year is summarized in Table 4.4.
- Placement of residual Low PAG rock into the TSF. The volumes of surplus PAG rock each year is summarized in Table 4.4.

- Placement of High PAG rock into the base of the open pit, and placement of Low PAG in the remaining available volume.

Table 4.4 Summary of Annual Early Closure and Closure Waste Volume Allocations

Year	Available Open Pit Storage	Cumulative Storage Requirement	Surplus	High PAG to Open Pit	Low PAG to Open Pit	
		PAG	Low PAG potentially to TSF	Acidic pH=3	Acidic pH = 5.2	Non-Acidic
-1	0	5	5	1	0	4
1	0	13	13	3	0	10
2	4	20	16	4	0	15
3	10	24	14	5	0	19
4	20	34	14	8	0	26
5	30	41	11	9	0	32
6	36	48	12	11	0	38
7	48	56	8	12	0	43
8	56	65	9	14	0	51
9	64	75	11	17	0	58
10	72	84	12	19	1	65
11	80	93	13	21	3	69
12	88	104	16	23	5	76
13	96	115	19	26	6	84
14	104	127	23	28	8	91
15	116	139	23	31	10	99
16	124	149	25	33	11	105
17	132	152	20	34	13	105
18	140	153	13	34	15	103
19	148	153	5	34	18	101
20	148	153	5	34	20	94
21	148	153	5			
22						
TOTALS						

4.5 Final Closure - PAG Backfill Plan

The final volumes that require storage in the open pit are summarized as follows:

- High PAG waste rock – 33 Mt.

- Low PAG: 94 Mt of non-acidic PAG and 20 Mt of acidic PAG.

Waste Rock Placement

High PAG rock will be placed between the base of the open pit (elevation 480 m) and approximately elevation 540 m and 600 m. Waste rock would be hauled down the main access ramp as shown on Figure 4.4. The lifts would be extended to the northwest and southeast. While the rock dump is being progressed over the underlying cleaner tailings, remote dozers may be required for dump safety until stability of the pile is improved as the waste rock abuts against the east side of the pit.

The Low PAG rock would be placed in one lift from approximately elevation 725 m. Access would be along the main access haul road ramp as shown in Figure 4.5.

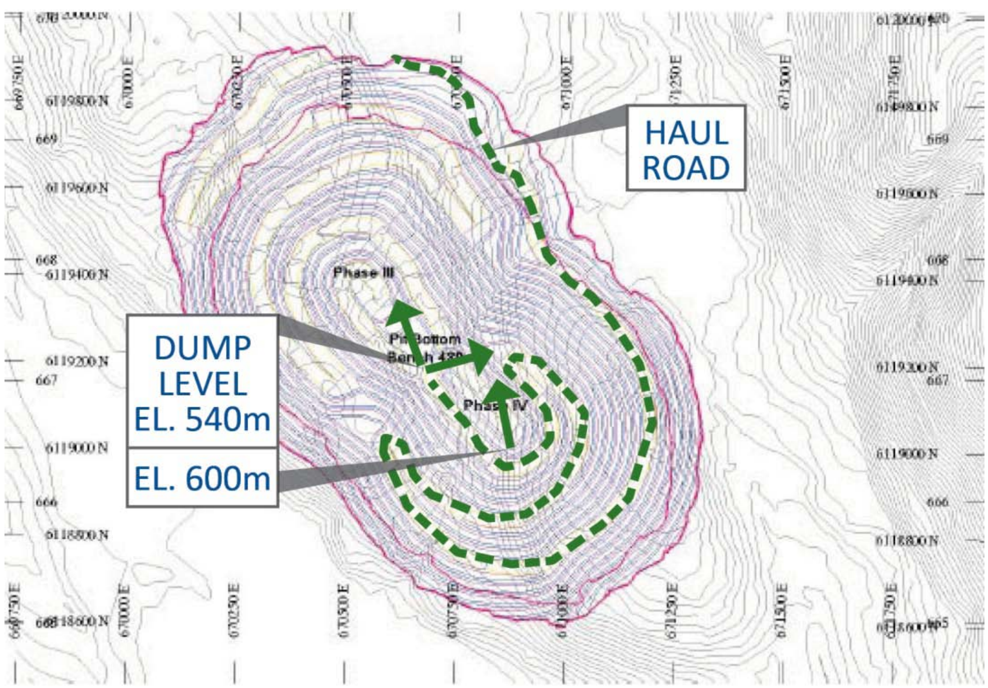


Figure 4.4 High PAG Placement on Closure

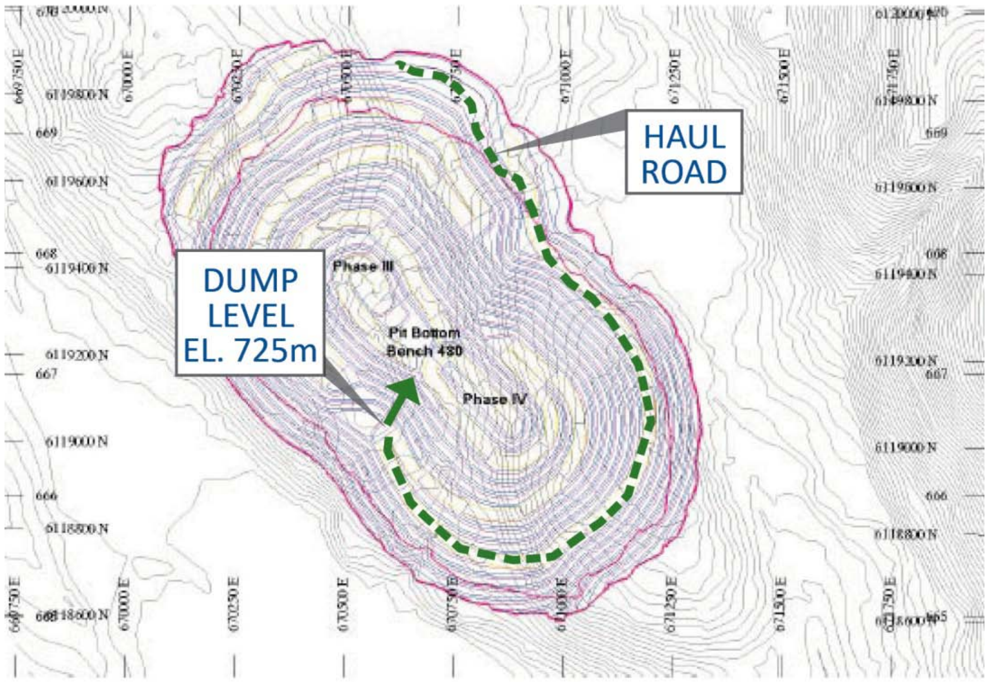


Figure 4.5 Low PAG Placement on Closure

Lime Mixing Procedures

The procedure for lime mixing will be dependent upon and integrated with the water balance and the water pond in the open pit during filling. The pit water balance shown in Table 7.5 of the RRR-Rev.2 predicts a surplus of water volume in the order of 3 Mm^3 to 5 Mm^3 during the filling period. The pond water will be limed with a mixing system which will raise the pH to a level above the predicted requirement. In addition to lime mixing in the ponds, the waste rock will be "dosed" with lime slurry which will be added with an overhead flexible pipe that discharges into the surface of the rock in the haul truck. The dosage will be determined on the basis of the rock type (high PAG versus low PAG).

4.6 Final Closure Cost Estimate

The closure cost estimate has been updated to directly account for the haulage of the High PAG waste rock to the base of the open pit and additional incremental haul distance increase for the Low PAG waste rock, and these are summarized in Table 4.5.

The alternative to store PAG rock in the TSF, as opposed to the open pit, has not been selected due to the additional cost and the disadvantage of not being able to close the open pit as a pond-wetland. The main disadvantages for storage of PAG rock in the TSF include:

- The TSF is an additional haul distance of 6 km uphill (12 km return) over that required to place rock into the open pit. The additional haul will increase greenhouse gas emissions, and result in increased costs due to labour and fuel, road maintenance and safety. The total incremental cost increase is in the order of $144 million. In addition, concurrent disposal with tailings will require additional placement costs.
- Capital cost requirements for roads and extra trucks are in the order of $10 million.
- Tailing dam construction costs required to provide storage for the additional volume of rock over the life of the mine increase cost by approximately $14 million.

Accordingly, the preferred alternative is to place the PAG rock into the open pit on closure.

The cost estimate does not incorporate the likely reduction in total waste rock due to the additional bonding costs for waste rock, which will lower the effective cutoff grade for milling.

Table 4.5 Closure and Reclamation Cost Estimate

Mine Activity Category and Description	Quantity	Unit	Cost	Total Cost
Closure Costs – Area Disturbance				
Load – haul – place High PAG rock in pit ($0.65/t)	34,000,000	tonne	$22,100,000	
Load – haul – place Low PAG rock in pit ($0.45/t)	114,000,000	tonne	$51,300,000	
Load-haul place Low PAG in TSF ($1.00/t)	5,000,000	tonne	5,000,000	
Lime treatment of PAG rock	7.5	years	$6,400,000	
Hauling and placing soil materials	613	ha	$12,800,000	
Hauling and placing non-PAG rock	4,000,000	tonne	$2,000,000	
Hauling and placing overburden materials	80	ha	$7,000,000	
Site road and general re-contouring			$500,000	
Revegetation of site (seeing/planting/mulch)	613	ha	$4,600,000	
Subtotal				**$111,700,000**
Closure Costs – Lump Sum Items				
Mill building and foundation	LS		$500,000	
Structures in plantsite area (13)	LS		$1,750,000	
Structures outside of plantsite area (18)	LS		$300,000	
Landfill decommissioning	LS		$150,000	
Land farming hydrocarbons	LS		$250,000	
Stockpiles and collection ditches	LS		$200,000	
TSF closure spillway and earthworks	LS		$300,000	
Subtotal				**$3,450,000**
Post Closure Costs				
Local power line decommissioning	LS		$50,000	
Hauling and placing soil materials	129	ha	$2,710,000	
Revegetation of site (seeing/planting/mulch) – terrestrial (120 ha) and littoral (40ha)	160	ha	$1,000,000	
Seepage collection system decommissioning TSF	LS		$500,000	
Water treatment plant and diffuser	LS		$13,000,000	
Subtotal				**$16,260,000**
TOTAL				**$131,410,000**

Post-closure monitoring will be required and is estimated to cost $0.62 million per year for the first five years and then decrease with time. In addition, the annual operating cost of the water treatment plant is estimated to be in the order of $260,000 per year, plus sludge disposal costs of $10,000 per year and infrastructure support of $100,000 per year; total costs $370,000 per year.

5. PRELIMINARY PROPOSED WATER QUALITY OBJECTIVES

5.1 General

Preliminary proposed site specific water quality objectives (PPWQOs) have been developed for emergent groundwater and the TSF receiving streams to be protective of the site-specific species present. Procedures for development of site specific guidelines have been developed by BCMOE and CCME, and the main methodology referred to as the "recalculation" procedure has been used for this assessment. In addition, the Biotic Ligand Model and U.S. EPA guidelines have been used to provide further context, particularly where the data set for recalculation is less robust.

PPWQOs have been developed for emergent groundwater effects for: sulphate, aluminum, arsenic, cadmium, cobalt, copper and selenium. For hardness dependent parameters (sulphate, cadmium, copper), PPWQOs have been developed for three generic water hardness that reflect potential loading conditions, that range from 100 mg/L to 528 mg/L.

The potential influences of emergent groundwater on aquatic habitat are summarized as follows:

Receiving Streams

- Base flow: emergent groundwater flow from the TSF is predicted to report to the streams (7, 8, & 10) during low flow conditions. At this time flow in the streams can be ephemeral and during winter the streams have been observed to be completely frozen at times. Hardness predictions are in the order of 338 mg/L to 528 mg/L.

- Average flow: during average flow the emergent groundwater from the TSF mixes with surface runoff with hardness predictions in the order of 100 mg/L.

Morrison Lakebed

The TSF affected emergent groundwater may enter Morrison Lake within a shoreline area downstream of the TSF. The groundwater will mix with the lake water and the predicted effects of this are described under the lake water quality modeling (Section 7 of this report). The emergent groundwater also has some potential to affect the lake water quality in the sand and gravel salmon spawning beds that have been identified near the mouth of Stream MCS-7. The mixing of the groundwater with the lake water could be expected to be less effective within the sand and gravels, which form the habitat for spawning sockeye alevins (egg stage). Consequently, the water quality within the sands and gravels could be assumed to vary from the emergent groundwater at the base of the sands and gravels (say 1 m below lakebed level) to lake water quality at the surface of the sands and gravels. The emergent groundwater could have a hardness in the order of 365 mg/L to 528 mg/L, which would then dilute to the predicted a lake hardness of 30 mg/L to 90 mg/L.

5.2 Copper

5.2.1 Background

BCMOE's water quality guidelines for copper were established in 1987. Both acute and chronic guidelines were established to be hardness-dependent, to account for the observation that freshwater organisms typically become less sensitive to the toxic effects of copper as the hardness of water increases. The chronic guideline is represented by the following equation:

$$Guideline\ (\mu g / L) \quad = \quad 0.04 \quad \bullet \quad hardness$$

Based on the expected water hardness of emergent groundwater downstream of the TSF (338 mg/L $CaCO_3$), the BCMOE recommended water quality guideline is 13.5 ug/L.

A PPWQO has been developed based on a re-calculation procedure that considered site-specific environmental chemistry (multiple variables as required by the Biotic Ligand Model recommended by U.S. EPA).

5.2.2 U.S. EPA Biotic Ligand Model

The U.S. EPA drafted its water quality guidelines for copper in 2003 and finalized them in 2007. Its guidelines incorporate more recent scientific data than the 1987 BCMOE guideline. The U.S. EPA water quality guidelines for copper are dependent, in part, on water hardness, and are thus somewhat similar in concept to the approach used by BCMOE. However, the U.S. EPA guidelines are also dependent on other variables known to affect the bioavailability and toxicity of copper in freshwater organisms.

U.S. EPA (2001) derived its water quality guideline for copper based on acute toxicity data for 38 different species belonging to 27 different genera (all toxicity data normalized to 12 different default water quality parameters; see Table 5.1. Sockeye salmon were included in the dataset, as well as six other species belonging to the genus *Oncorhynchus*. Although *Oncorhynchus* was the most sensitive genus of fish to copper, it was approximately an order of magnitude less sensitive than some aquatic invertebrates. Among the seven *Oncorhynchus* species, sockeye salmon were the least sensitive to copper.

Due to the statistical complexity in integrating and normalizing toxicity values to multiple site-specific independent variables, site-specific water quality guidelines can be calculated using the *Biotic Ligand Model* (BLM) software (version 2.2.3) available from U.S. EPA. The BLM-based water quality criteria are sometimes more stringent and other times less stringent than simple hardness-based water quality criteria. When site-specific water quality parameters for Morrison are utilized (see Table 5.1), a PPWQO of 17.8 ug/L is obtained.

Table 5.1 Water Quality Guidelines for Copper Based on Biotic Ligand Model

Source	Chronic Water Quality Guideline for Dissolved Copper (ug/L) (a)	Chronic Water Quality Guideline for Total Copper (ug/L) (b)	Water Quality Parameters used as Input Biotic Ligand Model (c)											
			Temperature (ºC)	pH	Dissolved Organic Carbon (mg/L)	Humic Acid (%)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Alkalinity (mg/L)	Sulfide (mg/L)
U.S. EPA (2007)	1.45	1.51	20	7.5	0.5	10	14	12.1	26.3	2.1	81.4	1.9	65	0.003
Site-specific PPWQO (Surface Water)	11.4	11.9	20	8	2.5	10	27	8	10	1.6	40	0.57	93	0.003
Site-specific PPWQO (Emergent Groundwater, expected case)	17.1	17.8	20	8	2.5	10	67	42	80	9.4	248	6.9	262	0.003
Site-specific PPWQO (Emergent Groundwater, upper-bound case)	17.8	18.5	20	8	2.5	10	98	70	79	13	523	3	263	0.003
Servizi and Martens (1978)	na	na	7.15	7.63	2.58	10	22.3428	6.313221	10.259	7.5024	25.1	9.994	62.5	0.0003

Notes:

a) Biotic Ligand Model output, based on acute toxicity data from 38 different species belonging to 27 different genera (Table 3a of USEPA 2007), and acute-to-chronic ratios from 6 different species belonging to 4 different genera (Table 2c of USEPA 2007).

b) Dissolved guideline converted to total guideline using ratio of 0.96 from USEPA 2007.

c) Water quality parameters from USEPA as listed in footnotes of Table 1 from USEPA 2007; water quality parameters from Servizi and Martens 1978 as listed in Appendix E from USEPA 2007; site-specific water quality parameters are for expected emergent groundwater.

5.2.3 Recalculation Based on Toxicity Data for Sockeye Salmon

One study was found in which the effects of copper on sockeye salmon were examined (Servizi and Martens 1978). Various life stages of sockeye salmon were exposed to copper in water for 7 days (flow-through conditions; nominal concentrations not analytical verified). Toxicity values were within a factor of two for all life stages. The LC50 value for fry was 150 ug/L. Smolt LC50 values were 170 ug/L, 190 ug/L, 210 ug/L, and 240 ug/L. Alevin LC50 values were 100 ug/L, 110 ug/L, 130 ug/L, 190 ug/L, and 200 ug/L.

Experimental LC50 values were converted to site-specific estimates using the Biotic Ligand Model (see Table 5.2). Given the low variability in toxicity data for sockeye salmon, the geometric mean of all 10 acute toxicity values (i.e., all life stages) was used as a point-of-departure (i.e., geometric mean of site-specific LC50 values is 592 ug/L). An acute-to-chronic ratio for sockeye salmon has not been identified, but can be estimated based on ACR values for two other species belonging to the genus *Oncorhynchus* (see footnotes from Table 5.2). Based on the estimated ACR value of 4.01, a final chronic toxicity value of 148 ug/L is predicted for sockeye salmon. A PPWQO of 17.8 provides a safety factor of 8 to this sockeye salmon final chronic toxic value.

Table 5.2 Species-Specific Toxicity Data for Copper (µg/L)

Scientific Name	Common Name	Life Stage	Acute LC50 (reported) (a)	Normalized Site-Specific LC50 (b)	Acute Toxicity Value (c)	Acute-to-Chronic Ratio (d)	Chronic Toxicity Value (e)
Oncorhynchus nerka	Sockeye salmon	alevin (newly hatched)	190	801	592	4.01	148
		alevin	200	901			
		alevin	100	235			
		alevin	110	270			
		alevin	130	357			
		fry	150	473			
		smolt	210	1009			
		smolt	170	621			
		smolt	190	801			
		smolt	240	1362			

Notes:
All LC50 values in units of ug/L (ug of total copper per L of water).
(a) Reported by Servizi and Martens (1978).
(b) Normalized using Biotic Ligand Model (see Table 1 of this report for reported and site-specific water quality parameters). Normalization performed with dissolved copper data; dissolved copper converted to total copper using ratio of 0.96 from USEPA (2007).
(c) Geometric mean of the 10 normalized LC50 values listed.
(d) Geometric mean of ACR values available for two species belonging to *Oncorhynchus*, as listed in Table 2c of USEPA 2007 (2.88 for rainbow trout; 5.59 for chinook salmon).
(e) Calculated as acute toxicity value divided by acute-to-chronic ratio.

Graphical comparisons of the adjustable BCMOE WQG, the PPWQO, and the chronic toxicity value for sockeye salmon are presented in Figure 5.1.

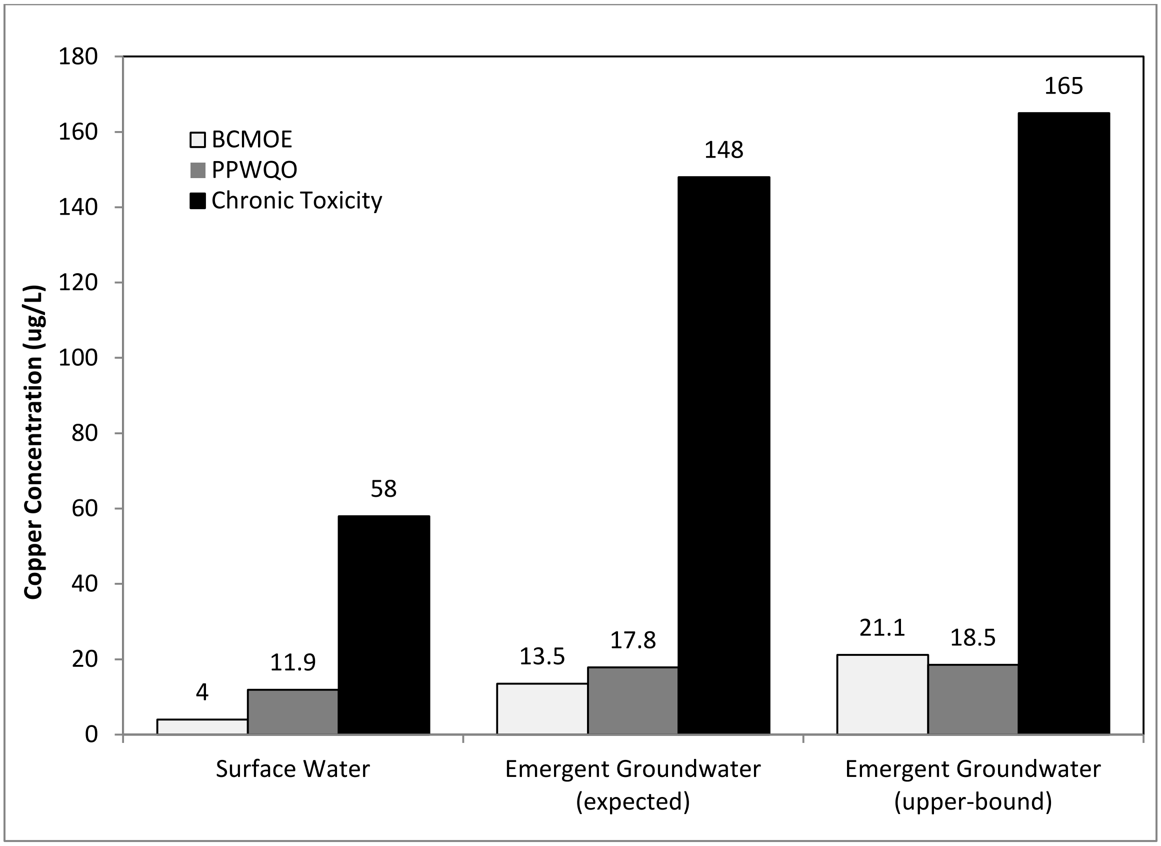


Figure 5.1 Water Quality Guidelines for Copper

5.3 Cadmium

5.3.1 Background

BCMOE's working water quality guideline for cadmium was set equal to the CCME guideline, which was set in 1999 on an interim basis. A guideline of 0.017 ug/L was derived by applying a safety factor of 10 to the lowest estimate of toxicity for the most sensitive organism to cadmium, the freshwater flea (16-day LOEL of 0.17 ug/L for *Daphnia magna*). There appears to be general agreement that vertebrates (e.g., salmon) are less sensitive to the effects of cadmium than are the species that served as the point of departure for the guideline. For example, according to CCME, the lowest estimate of toxicity for the most sensitive fish to cadmium, the Atlantic salmon alevin, was a 46-day LOEL of 0.47 ug/L (hardness not specified).

The interim guideline of 0.017 ug/L was converted to an adjustable hardness-dependent guideline by characterizing the linear relationship between water hardness and acute toxicity at a normalized water hardness of ~50 mg/L. The guideline was established to be hardness-dependent, to account for the observation that freshwater organisms typically become less sensitive to the toxic effects of cadmium as the hardness of water increases. The BCMOE / CCME guideline is represented by the following equation:

$$Guideline\ (\mu g\ /\ L) \quad = \quad 10^{(0.86(\log \bullet hardness) - 3.2)}$$

Based on the expected water hardness of emergent groundwater downstream of the TSF (338 mg/L $CaCO_3$), the BCMOE recommended water quality guideline is 0.094 ug/L.

A PPWQO has been developed based on a re-calculation procedure that considered site-specific environmental chemistry (water hardness-dependent equation recommended by U.S. EPA).

5.3.2 U.S. EPA Hardness-Dependent Guideline

U.S. EPA performed an extensive review of the peer-reviewed scientific literature (including the same studies that served as the basis for the CCME guideline) and in 2001 published hardness-dependent guidelines that are protective of chronic toxicity in aquatic biota. U.S. EPA (2001) derived its water quality guideline for cadmium based on chronic toxicity data for 21 different species belonging to 16 different genera (all toxicity data normalized to water hardness of 50 mg/L). Sockeye salmon were not included in the dataset, but three other species belonging to the genus *Oncorhynchus* were included.

Although *Oncorhynchus* was the most sensitive genus of fish to cadmium, it was approximately an order of magnitude less sensitive than some aquatic invertebrates.

The U.S. EPA guideline is represented by the following equation:

$$Guideline\ (\mu g / L) \quad = \quad e^{(0.7409(\ln \bullet hardness) - 4.719)}$$

At water hardness of 338 mg/L, the U.S. EPA recommended water quality guideline for cadmium is 0.67 ug/L.

5.3.3 Recalculation Based on Toxicity Data for Sockeye Salmon

One study was found in which the effects of cadmium on sockeye salmon were examined (Servizi and Martens 1978). Various life stages of sockeye salmon were exposed to cadmium in water for 7 days (flow-through conditions; water hardness of 83.1 mg/L CaCO3; nominal concentrations not analytical verified). Toxicity was extremely variable, with LC50 values ranging close to 3 orders of magnitude, depending on the life stage. Fry were observed to be the most sensitive life stage, with LC50 values of 8 ug/L and 30 ug/L. Smolt were somewhat less sensitive, with an LC50 value of 360 ug/L. Alevin were the least sensitive life stage, with LC50 values of 500 ug/L, 1,000 ug/L, and 4,500 ug/L. There is some uncertainty in the results of Servizi and Martens (1978), because nominal cadmium concentrations were not analytically verified, but the life stage sensitivity pattern observed for sockeye in this experiment is similar to that observed in other salmonid species (U.S.EPA 2001).

Experimental LC50 values were converted to site-specific estimates using the relationship between hardness and toxicity as described by U.S.EPA (2001) (see Table 5.3). Given the extreme variability in toxicity data for sockeye salmon, the most conservative estimate among the six acute toxicity values was used as a point-of-departure (i.e., normalized site-specific LC50 estimate of 33 ug/L for fry). An acute-to-chronic ratio for sockeye salmon has not been identified, but can be estimated based on ACR values for three other species belonging to the genus *Oncorhynchus* (see Table 5.4). Based on the estimated ACR value of 2.66, a chronic toxicity value of 12.5 ug/L is predicted for sockeye salmon. A PPWQO of 0.67 provides a safety factor of 19 to this sockeye salmon final chronic toxic value.

Table 5.3 Species-Specific Toxicity Data for Cadmium (μg/L)

Scientific Name	Common Name	Life Stage	Acute LC50 (reported) (a)	Normalized Site-Specific LC50 (b)	Acute Toxicity Value (c)	Acute-to-Chronic Ratio (d)	Chronic Toxicity Value (e)
Oncorhynchus nerka	Sockeye salmon	alevin (newly hatched)	4500	18735	33	2.66	12.5
		alevin	1000	4163			
		alevin	500	2082			
		fry	30	125			
		fry	8	33			
		smolt	360	1499			

Notes:
All LC50 values in units of ug/L (ug of total cadmium per L of water)
(a) Reported by Servizi and Martens (1978).
(b) Normalized using hardness-acute toxicity relationship slope of 1.0166, and hardness of the expected emergent groundwater (338 mg/L).
(c) Lowest of the six normalized LC50 values listed.
(d) Geometric mean of ACR values estimated for three species belonging to *Oncorhynchus* (see Table 5.4 of this report).
(e) Calculated as acute toxicity value divided by acute-to-chronic ratio.

Table 5.4 Acute-to-Chronic Ratios for Selected Fish Species Exposed to Cadmium (µg/L)

Scientific Name	Common Name	Species Mean Acute Value		Species Mean Chronic Value		Acute-to-Chronic Ratio	
		Reported (a)	Normalized (b)	Reported (c)	Normalized (d)	Species-Specific (e)	Genus-Specific (f)
Oncorhynchus kisutch	Coho salmon	6.2	43.4	4.3	17.6	2.47	2.66
Oncorhynchus tshawytscha	Chinook salmon	4.3	30.0	2.6	10.8	2.79	
Oncorhynchus mykiss	Rainbow Trout	2.1	14.7	1.3	5.4	2.73	

Notes:
Together the three Oncorhynchus species are considered a surrogate for sockeye salmon
All LC50 values in units of ug/L (ug of total cadmium per L of water).
(a) Reported in Table 3a of USEPA 2001.
(b) Normalized using hardness-acute toxicity relationship slope of 1.0166, and hardness of the expected emergent groundwater (338 mg/L).
(c) Reported in Table 3c of USEPA 2001.
(d) Normalized using hardness-chronic toxicity relationship slope of 0.7409, and hardness of the expected emergent groundwater (338 mg/L).
(e) Ratio of normalized acute value to normalized chronic value.
(f) Geometric mean of three normalized ACR values.

Graphical comparisons of the hardness-dependent BCMOE WQG, the PPWQO, and the chronic toxicity value for sockeye salmon are presented in Figure 5.2 and Figure 5.3.

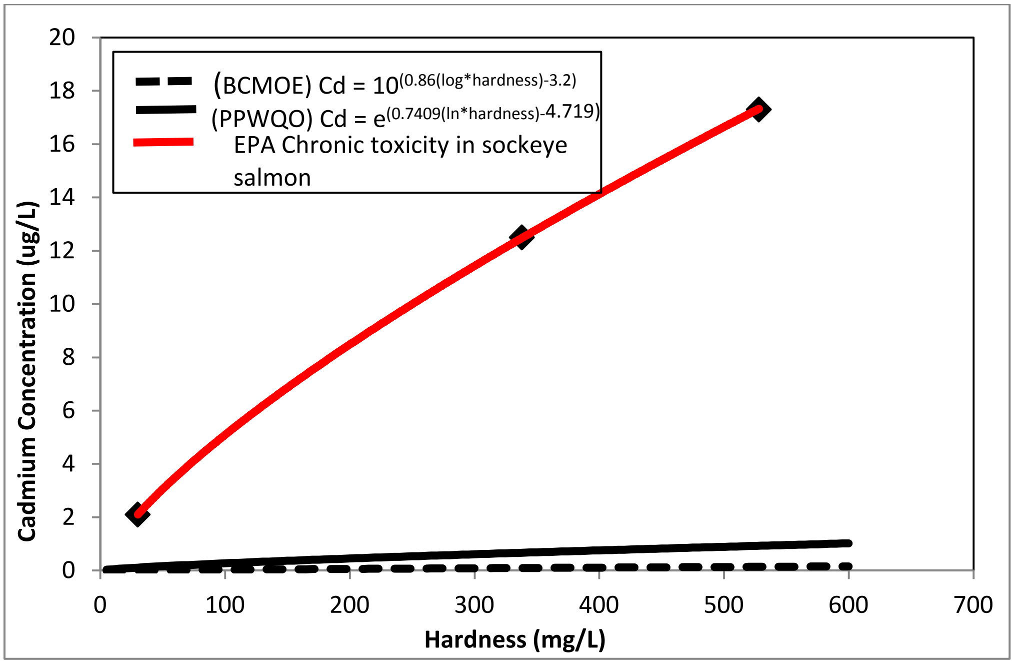


Figure 5.2 Hardness-Toxicity Relationships for Cadmium in Rainbow Trout

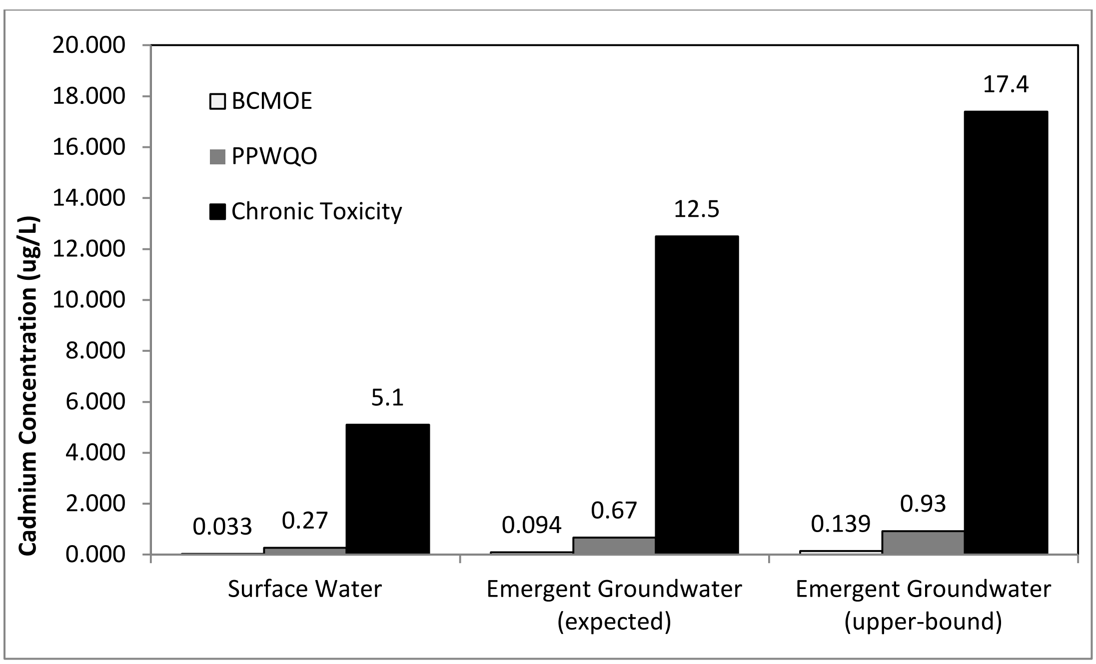


Figure 5.3 Water Guidelines for Cadmium

5.4 Aluminum

5.4.1 Background

BCMOE's water quality guideline for aluminum is 50 ug/L. It was developed in 1988 but was in effect derived based on the U.S. EPA criterion from 1973: a maximum criterion level was set equal to the CCME guideline (100 ug/L; itself set equal to the U.S. EPA criterion), and "the 30-day average criterion level was set *arbitrarily* at 50 percent of the maximum criterion level". U.S. EPA drafted water quality criteria for aluminum in 1986 (acute guideline of 950 ug/L; chronic guideline of 150 ug/L), but these values were not considered appropriate for use in BC for reasons outlined in BCMOE (1988). U.S. EPA finalized its water quality criteria for aluminum in 1988 (acute guideline of 750 ug/L; chronic guideline of 87 ug/L), and so these values were not available to BCMOE which was publishing its WQG in the same year.

5.4.2 Recalculation Based on Toxicity Data for Rainbow Trout

No studies examining the effects of aluminum on sockeye salmon were identified in the peer-reviewed scientific literature. In lieu of species-specific data, toxicity data for *Oncorhynchus*, the genus to which sockeye salmon belong, were compiled. Five studies examining the effects of aluminum on rainbow trout were identified and used as a surrogate for sockeye salmon data.

- Gunderson et al (1994) reported ten acute LC50 values that ranged from 1,940 ug/L to 7,670 ug/L.
- Call (1984) reported four acute LC50 values that ranged from 7,400 ug/L to 24,700 ug/L.
- Hunter et al (1980) reported a single LC50 value of 50,000 ug/L.
- Birge et al (1978) reported a single LC50 value of 560 ug/L.

- Freeman and Everhart (1971) reported five LC50 values that ranged from 513 ug/L to 5,230 ug/L.

The geometric mean of the 6 chronic LC50 values is 2,431 ug/L (compiled in Table 5.5). The geometric mean of the 15 acute LC50 values is 7,283 ug/L (also compiled in Table 5.5). An acute-to-chronic ratio has not been identified for any species belonging to the genus *Oncorhynchus*, but can be estimated based on ACR values available for other genera. Based on the estimated ACR value of 3.26, a chronic toxicity value of 2,234 ug/L is predicted for rainbow trout based on acute data. The geometric mean of the directly-estimated chronic LC50 (2,431 ug/L) and the indirectly-estimated chronic LC50 (2,234 ug/L) is 2,331 ug/L. With an uncertainty factor of 10, the PPWQO would be 233 ug/L.

A graphical comparison of the BCMOE WQG, the PPWQO, and the chronic toxicity value is presented in Figure 5.4.

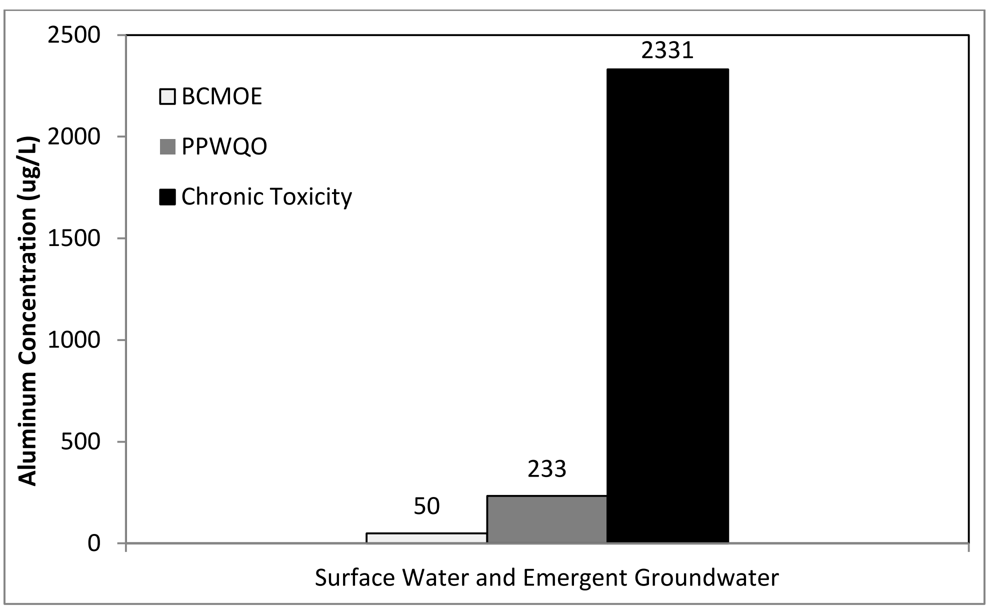


Figure 5.4 Water Quality Guidelines for Aluminum

Table 5.5 Genus-Specific Toxicity Data for Aluminum (μg/L)

<table>
<tr><th>Scientific Name</th><th>Common Name</th><th>Life Stage</th><th>pH</th><th>Chronic LC50 (reported)</th><th>Acute LC50 (reported)</th><th>Acute Toxicity Value</th><th>Acute-to-Chronic Ratio</th><th>Chronic Toxicity Value</th><th>Chronic Toxicity Value</th></tr>
<tr><td rowspan="21">Oncorhynchus mykiss</td><td rowspan="21">Rainbow Trout</td><td>embryo, larva</td><td>7.4</td><td>560 (a)</td><td>na</td><td rowspan="6">na</td><td rowspan="6">na</td><td rowspan="6">2431 (h)</td><td rowspan="21">2331 (j)</td></tr>
<tr><td>fingerling</td><td>8.02</td><td>5230 (b)</td><td>na</td></tr>
<tr><td>fingerling</td><td>8.48</td><td>5140 (b)</td><td>na</td></tr>
<tr><td>fingerling</td><td>8.99</td><td>5200 (b)</td><td>na</td></tr>
<tr><td>fingerling</td><td>6.64</td><td>513 (b)</td><td>na</td></tr>
<tr><td>fingerling</td><td>6.8</td><td>5140 (b)</td><td>na</td></tr>
<tr><td>-</td><td>"slightly alkaline"</td><td>na</td><td>6170 (c)</td><td rowspan="15">7283 (f)</td><td rowspan="15">3.26 (g)</td><td rowspan="15">2234 (i)</td></tr>
<tr><td>-</td><td>"slightly alkaline"</td><td>na</td><td>6170 (c)</td></tr>
<tr><td>-</td><td>"slightly alkaline"</td><td>na</td><td>7670 (c)</td></tr>
<tr><td>-</td><td>"slightly alkaline"</td><td>na</td><td>6930 (c)</td></tr>
<tr><td>-</td><td>"slightly alkaline"</td><td>na</td><td>1940 (c)</td></tr>
<tr><td>-</td><td>"slightly alkaline"</td><td>na</td><td>3910 (c)</td></tr>
<tr><td>-</td><td>"slightly alkaline"</td><td>na</td><td>3750 (c)</td></tr>
<tr><td>-</td><td>"slightly alkaline"</td><td>na</td><td>5430 (c)</td></tr>
<tr><td>-</td><td>"slightly alkaline"</td><td>na</td><td>4600 (c)</td></tr>
<tr><td>-</td><td>"slightly alkaline"</td><td>na</td><td>5220 (c)</td></tr>
<tr><td>juvenile</td><td>7.46</td><td>na</td><td>8600 (d)</td></tr>
<tr><td>juvenile</td><td>6.59</td><td>na</td><td>7400 (d)</td></tr>
<tr><td>juvenile</td><td>7.31</td><td>na</td><td>14600 (d)</td></tr>
<tr><td>juvenile</td><td>8.17</td><td>na</td><td>24700 (d)</td></tr>
<tr><td>juvenile</td><td>8</td><td>na</td><td>50000 (e)</td></tr>
</table>

Notes:
Rainbow trout considered a surrogate for sockeye salmon.
All LC50 values in units of ug/L (ug of total aluminum per L of water).
(a) Reported by Birge et al (1978).
(b) Reported by Freeman and Everhart (1971).
(c) Reported by Gunderson et al (1994).
(d) Reported by Call (1984).
(e) Reported by Hunter et al (1980); LC40 considered an approximation of LC50.
(f) Geometric mean of the 15 acute LC50 values listed.
(g) Geometric mean of ACR values available for two species listed in Table 2 of USEPA 1988 (10.64 for fathead minnow; 0.9958 for *Ceriodaphnia dubia*).
(h) Geometric mean of the 6 chronic LC50 values listed.
(i) Calculated as acute toxicity value divided by acute-to-chronic ratio.
(j) Geometric mean of the directly-estimated chronic toxicity value (2431 ug/L) and the indirectly-estimated chronic toxicity value (2234 ug/L).

5.5 Arsenic

5.5.1 Background

BCMOE's water quality guideline for arsenic of 5 ug/L was set equal to the CCME guideline, which was derived in 1999 and updated in 2001. The guideline was for *total* arsenic, and was derived by applying a safety factor of 10 to the lowest estimate of toxicity for the most sensitive organism to arsenic, the alga (14-day EC50 of 50 ug/L for *Scenedesmus obliquus*). There appears to be general agreement that vertebrates (e.g., salmon) are less sensitive than plants to the effects of arsenic. Freshwater vertebrates are approximately an order of magnitude less sensitive than aquatic plants to the toxic effects of arsenic: lowest estimates of toxicity for fish included 500 μg/L (7-day LOEC for climbing perch), 550 μg/L (28-day LC50 in rainbow trout), and 970 μg/L (7-day LOEC of for catfish).

For comparison purposes, chronic water quality guidelines for arsenic in the U.S. vary depending on the speciation of arsenic in the water. The U.S. EPA chronic guideline for trivalent arsenic is 150 ug/L. A Tier II value of 8.1 ug/L has been developed for pentavalent arsenic. These guidelines are intended to be protective of all species, including sensitive groups.

5.5.2 Recalculation Based on Toxicity Data for Rainbow Trout

No studies examining the effects of arsenic on sockeye salmon were identified in the peer-reviewed scientific literature. In lieu of species-specific data, toxicity data for *Oncorhynchus*, the genus to which sockeye salmon belong, were compiled. Toxicity values were found for trivalent (one chronic LC50; five acute LC50s) and pentavalent (two chronic LC50s; 14 acute LC50s) forms of arsenic in rainbow trout (all compiled in Table 5.6). The four potential final chronic toxicity values based on these data include:

- A directly-estimated chronic LC50 of 550 ug/L for trivalent arsenic.
- An indirectly-estimated chronic LC50 of 3,679 ug/L for trivalent arsenic (geometric mean of five acute LC50 values, divided by an estimated ACR value of 4.47).
- A directly-estimated chronic LC50 of 18,715 ug/L for pentavalent arsenic.
- An indirectly-estimated chronic LC50 of 13,150 ug/L for pentavalent arsenic (geometric mean of 14 acute LC50 values, divided by an estimated ACR value of 4.47).

Table 5.6 Genus-Specific Toxicity Data for Arsenic (µg/L)

Scientific Name	Common Name	Duration, chemical form	LC50 (reported)	Acute Toxicity Value	Acute-to-Chronic Ratio	Chronic Toxicity Value
Oncorhynchus mykiss	Rainbow Trout	chronic, As(III)	550 (a)	na	na	550
		chronic, As(V)	16600 (b)	na	na	18715 (m)
		chronic, As(V)	21100 (b)			
		acute, As(III)	13300 (c)	16445 (j)	4.47 (l)	3679 (n)
		acute, As(III)	13340 (d)			
		acute, As(III)	17700 (e)			
		acute, As(III)	18500 (f)			
		acute, As(III)	20700 (e)			
		acute, As(V)	5100 (i)	58779 (k)	4.47 (l)	13150 (n)
		acute, As(V)	10800 (g)			
		acute, As(V)	28000 (h)			
		acute, As(V)	31700 (i)			
		acute, As(V)	43600 (i)			
		acute, As(V)	47700 (i)			
		acute, As(V)	58000 (e)			
		acute, As(V)	58500 (i)			
		acute, As(V)	67500 (i)			
		acute, As(V)	102000 (i)			
		acute, As(V)	114000 (e)			
		acute, As(V)	197000 (i)			
		acute, As(V)	306000 (i)			
		acute, As(V)	360000 (i)			

Notes:
Rainbow trout considered a surrogate for sockeye salmon.
All LC50 values in units of ug/L (ug of arsenic species listed per L of water).
(a) Reported by Birge et al (1979).
(b) Reported by Erickson et al (2011).
(c) Reported by Dixon and Sprage (1981).
(d) Reported by Johnson and Finley (1980).
(e)) Reported by McGeachy and Dixon (1989).
(f) Reported by Rankin and Dixon (1994).
(g) Reported by Hale (1977).
(h) Reported by Palawski et al (1985).
(i) Reported by Buhl and Hamilton (1990).
(j) Geometric mean of the 5 acute LC50 values for trivalent arsenic listed.
(k) Geometric mean of the 5 acute LC50 values for pentavalent arsenic listed.
(l) Geometric mean of ACR values available for two species listed in Table 2 of USEPA 1995 (4.199 for fathead minnow; 4.748 for *Daphnia magna*).
(m) Geometric mean of the 2 chronic LC50 values for pentavalent arsenic listed.
(n) Calculated as acute toxicity value divided by acute-to-chronic ratio.

The lowest final chronic toxicity value of 550 ug/L for trivalent arsenic was used as the point-of-departure for calculating the PPWQO. With a standard uncertainty factor of 10, the PPWQO would be 55 ug/L.

A graphical comparison of the BCMOE WQG, the PPWQO, and the chronic toxicity value is presented in Figure 5.5.

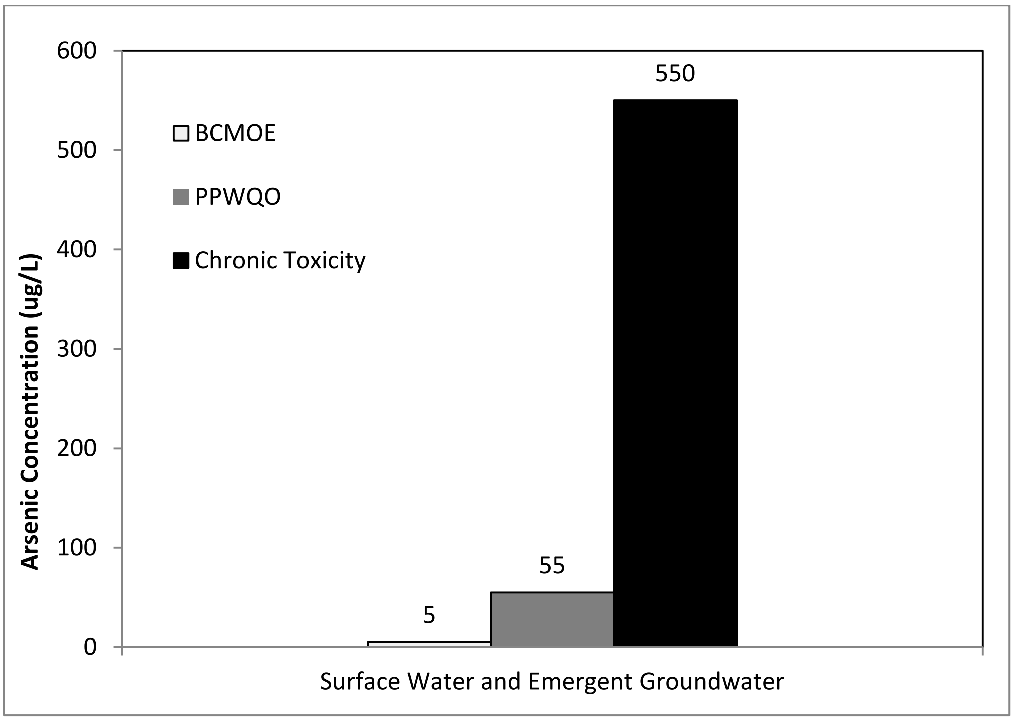


Figure 5.5 Water Quality Guidelines for Arsenic

5.6 Sulfate

5.6.1 Background

BCMOE's water quality guideline for sulfate was developed in 2000. The guideline was set at 100 mg/L (maximum concentration not to be exceeded at any time), based on three studies that investigated the effects of sulfate on: striped bass (lowest-reported NOEC of

100 mg/L, with no safety factor); the amphipod *Hyalella* (lowest-reported LC50 of 205 mg/L, with a safety factor of 2); and aquatic moss (toxicity values in four other species ranged from 100 mg/L to >250 mg/L). BCMOE (2000) has stated that "generally, for most aquatic organisms tested including fish, toxicity decrease[s] with increased water hardness".

5.6.2 Recalculation Based on Toxicity Data for Rainbow Trout

No studies examining the effects of sulfate on sockeye salmon were identified in the peer-reviewed scientific literature. In lieu of species-specific data, toxicity data for *Oncorhynchus*, the genus to which sockeye salmon belong, were compiled. Four studies examining the effects of sulfate on rainbow trout were identified and used as a surrogate for sockeye salmon data (all compiled in Table 5.7).

- PESC (1996) reported acute (4-day) LC50 values of 5,000 mg/L, 9,750 mg/L, and 9,900 mg/L. These toxicity values corresponded to the varying hardness of the water (25 mg/L, 100 mg/L, and 250 mg/L, respectively).

- PESC (1996) reported chronic (7-day) EC50 values of 1,105 mg/L, 1,925 mg/L, and 3,116 mg/L in early-life stage trout. These toxicity values corresponded to the varying hardness of the water (25 mg/L, 100 mg/L, and 250 mg/L, respectively).

- BC Research Inc. (1998) reported chronic (7-day) toxicity values of 1,060 mg/L (NOEC) and 3,500 mg/L (LOEC) in one experiment and 1,280 mg/L (EC25) and 1,477 mg/L (EC50) in a separate experiment. Water hardness was not reported for the experiments but variable water hardness may be responsible for the EC25 and EC50 values being lower than the LOEC.

- Elphick et al (2011) reported chronic (31-day) toxicity values of 205 mg/L (NOEC), 340 mg/L (LOEC), 356 mg/L (EC10), 501 mg/L (EC25), and 734 mg/L (EC50). Each toxicity value corresponded to a water hardness of 15 mg/L.

Table 5.7 Genus-Specific Toxicity Data for Sulfate (µg/L)

Scientific Name	Common Name	Water Hardness (mg/L)	Chronic LC50 (reported)	Acute LC50 (reported)	Normalized Site-Specific Chronic LC50
Oncorhynchus mykiss	Rainbow Trout	25	na	5000 (a)	na
		100	na	9750 (a)	na
		250	na	9900 (a)	na
		25	1105 (a)	na	3599 (d)
		100	1925 (a)	na	
		250	3116 (a)	na	
		--	1477 (b)	na	
		15	734 (c)	na	

Notes:
Rainbow trout considered a surrogate for sockeye salmon.
All LC50 values in units of mg/L (mg of sulfate per L of water).
(a) Reported by PESC (1996).
(b) Reported by BC Research (1998).
(c) Reported by Elphick et al (2011).
(d) Normalized using hardness-chronic toxicity relationship from Figure 5, and hardness of expected emergent groundwater (338 mg/L).

The above studies therefore generally support the observation that sulfate toxicity decreases as water hardness increases. The exact relationship between water hardness and the chronic toxicity of sulfate has not been characterized, but can be roughly estimated for the genus *Oncorhynchus* based on the chronic toxicity experiment conducted by PESC (1996). If the relationship between water hardness and chronic toxicity for sockeye salmon is as described by the trendline equation in Figure 5.5, then the chronic toxicity value would be 3,599 mg/L at a water hardness of 338 mg/L. With an uncertainty factor of 10, the PPWQO would then be 360 mg/L. (This is approximately equal to the LOEC observed by Elphick et al (2011), although the LOEC was observed in very soft water of 15 mg/L.) Graphical comparisons of the adjustable BCMOE WQG, the PPWQO, and the chronic toxicity value are presented in Figure 5.6 and Figure 5.7.

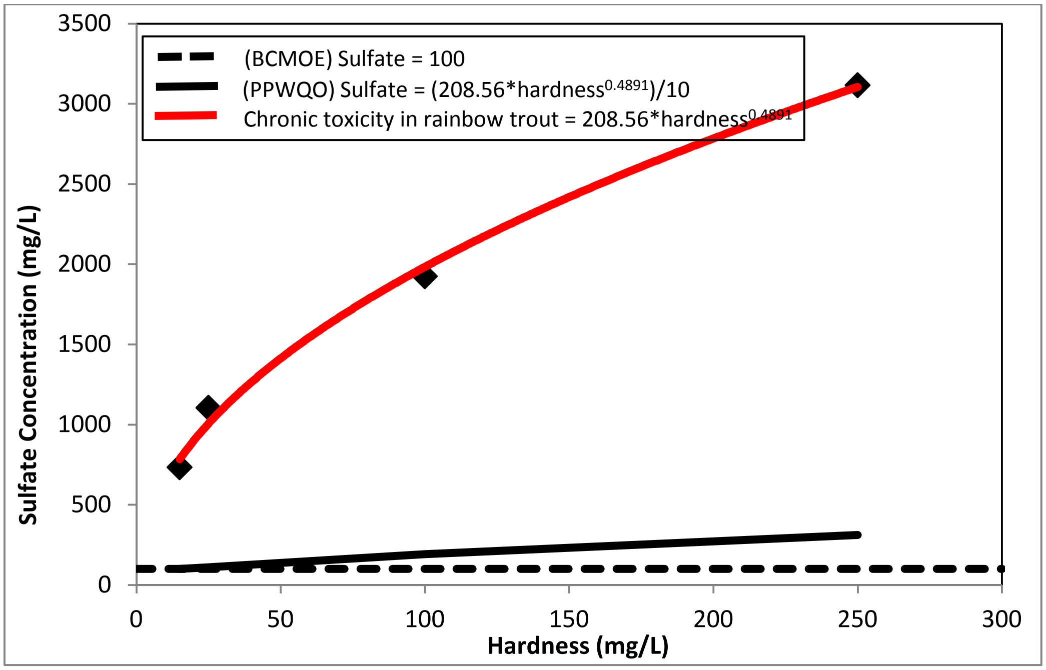


Figure 5.6 Hardness-Toxicity Relationships for Sulfate in Rainbow Trout

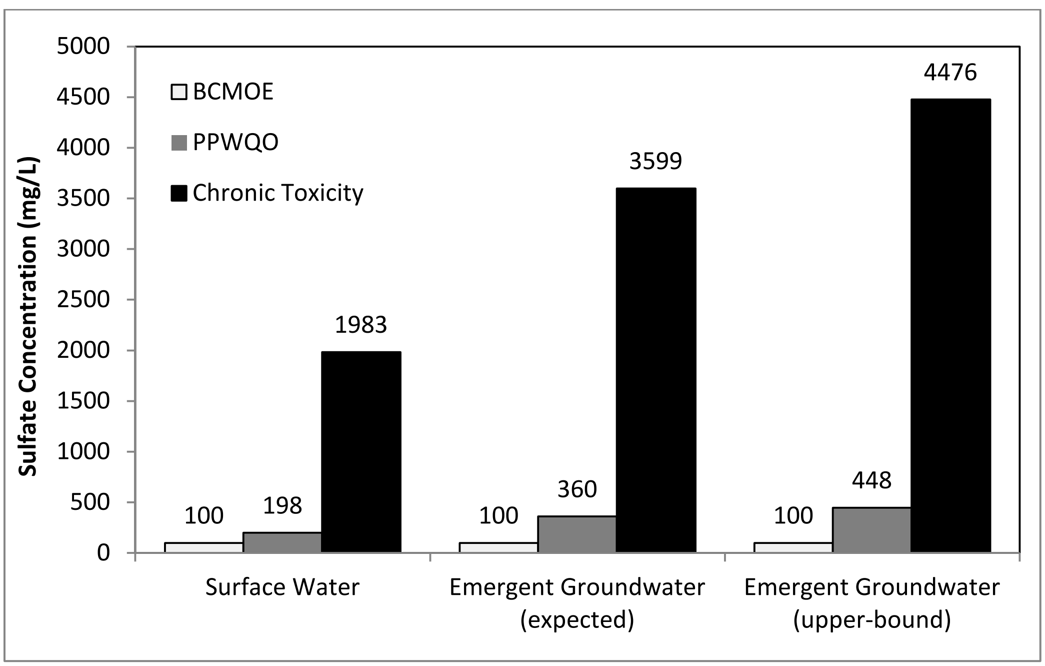


Figure 5.7 Water Quality Guidelines for Sulfate

5.7 Cobalt

5.7.1 Background

BCMOE's water quality guidelines for cobalt were established in 2004. The chronic water quality guideline of 4 ug/L was derived by applying a safety factor of 2 to the geometric mean of four chronic toxicity values in invertebrates: chronic toxicity values of 12 ug/L and 9.3 ug/L from *Daphnia magna*, and chronic toxicity values of 12.5 ug/L and 3.3 ug/L from *Ceriodaphnia dubia*.

There appears to be general agreement that vertebrates (e.g., salmon) are less sensitive than invertebrates to the effects of cobalt. BCMOE (2004) has stated that "based on the literature reviewed, aquatic invertebrates appear to be the most sensitive group of organisms to cobalt exposure, followed by fish and plants".

5.7.2 Recalculation Based on Toxicity Data for Rainbow Trout

No studies examining the effects of cobalt on sockeye salmon were identified in the peer-reviewed scientific literature. In lieu of species-specific data, toxicity data for *Oncorhynchus*, the genus to which sockeye salmon belong, were compiled. Eleven chronic LC50 values were found for effects of cobalt on rainbow trout (compiled in Table 5.8). The geometric mean of these values (451 ug/L) was used as the point-of-departure for the PPWQO. With an uncertainty factor of 10, the PPWQO would then be 45 ug/L. (This is a factor of 3 lower than a chronic NOEC of 132 ug/L reported by Marr et al 1998).

Table 5.8 Genus-Specific Toxicity Data for Cobalt (µg/L)

Scientific Name	Common Name	Chronic LC50 (reported)	Chronic Toxicity Value
Oncorhynchus mykiss	Rainbow Trout	346 (a)	451
		470 (b)	
		490 (b)	
		520 (a)	

Notes:
Rainbow trout considered a surrogate for sockeye salmon.
All LC50 values in units of ug/L (ug of cobalt per L of water).
(a) Reported by Marr et al (1998).
(b) Reported by Birge et al (1978).

A graphical comparison of the BCMOE WQG, the PPWQO, and the chronic toxicity value is presented in Figure 5.8.

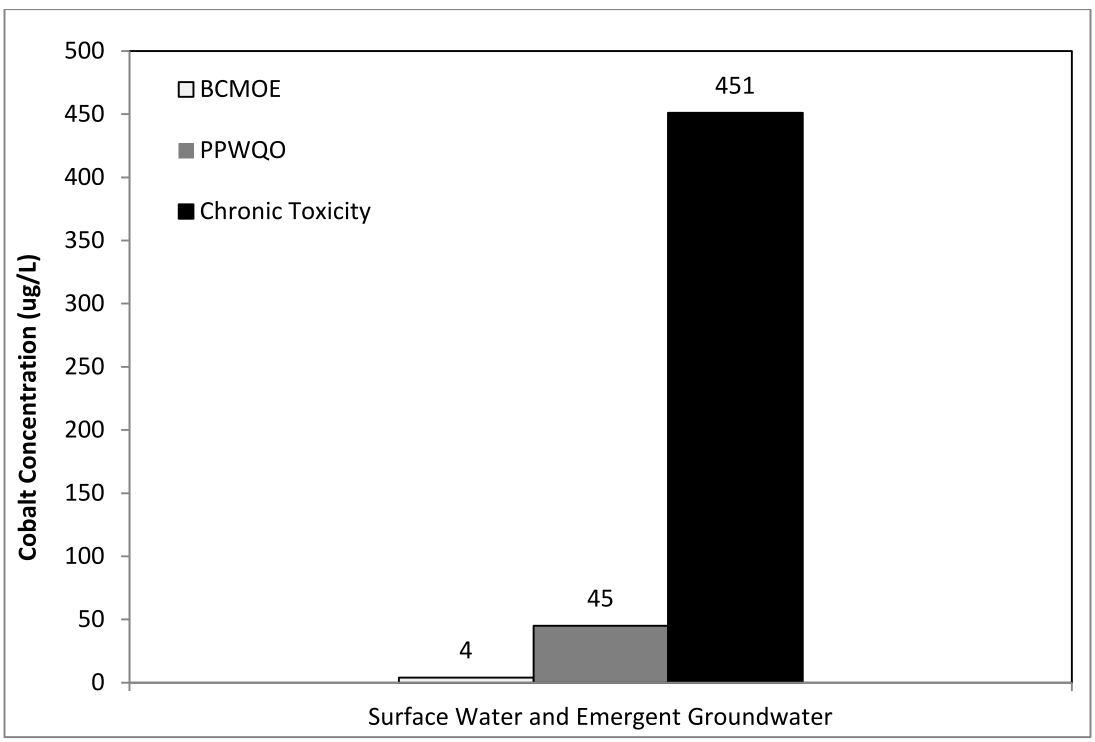


Figure 5.8 Water Quality Guidelines for Cobalt

5.8 Selenium

5.8.1 Background

BCMOE established a water quality guideline for selenium in 2001. A guideline of 2 ug/L was derived by applying a safety factor of 5 to a concentration of 10 ug/L, which was found to be the most sensitive lowest-observed-effects-levels in the following six species:

- *Bluegill Sunfish*: Cumbie and VanHorn (1978) reported that a concentration of 10 ug/L resulted in mortality, deformity, a reduction in standing crop, and complete reproductive failure in a 2-year exposure study. Gillespie and Baumann (1986) reported that a concentration between 9 ug/L and 12 ug/L resulted in reproduction failure and larvae deformity in a 2-year exposure study. Hermanutz et al (1992) reported that a concentration of 10 ug/L resulted in reduced adult growth and reproduction in a 1-year exposure study.

- *Fathead Minnow*: Schultz and Hermanutz (1990) reported that a concentration of 10 ug/L resulted in edema and lordosis in embryos in a 1-year exposure study. Hermanutz (1992) reported that a concentration of 10 ug/L resulted in malformation of late juveniles and early adults in a 1-year exposure study.

- *Green Sunfish*: Cumbie and VanHorn (1978) reported that a concentration of 10 ug/L resulted in mortality, deformity, and a reduction in standing crop in a 2-year exposure study. BCMOE (2001) lists no other studies that examined this species.

- *Largemouth Bass*: Cumbie and VanHorn (1978) reported that a concentration of 10 ug/L resulted in mortality, deformity, a reduction in standing crop, and complete reproductive failure in a 2-year exposure study.

- *Threadfin Shad*: Cumbie and VanHorn (1978) reported that a concentration of 10 ug/L resulted in mortality, deformity, and a reduction in standing crop in a 2-year exposure study.

- *Flat Bullhead*: Cumbie and VanHorn (1978) reported that a concentration of 10 ug/L resulted in mortality, deformity, and a reduction in standing crop in a 2-year exposure study.

BCMOE also established a tissue residue guideline for selenium in 2001. A guideline of 1 ug/g body weight (wet weight) was derived based on the results of Brix et al (2000), who statistically examined various datasets and reported that a concentration of 6 ug/g body weight (dry weight) was the threshold (EC10) associated with toxicity in Chinook salmon (60-day exposure data). The dry weight concentration of 6 ug/g was converted to a wet weight concentration of 1.2 ug/g by assuming a moisture content of 80% in the body of a fish. The concentration of 1.2 ug/g was subsequently rounded down by BCMOE to 1.0 ug/g.

5.8.2 U.S. EPA Selenium Guidelines

U.S. EPA derived a chronic water quality guideline of 5 ug/L for selenium in 1987. Since that time, however, EPA's position has been that a water-based criterion is not appropriate for selenium because the diet is the most important route of exposure for chronic toxicity. In 2004, EPA published its *draft* aquatic life water quality criteria for selenium, with a tissue residue-based chronic guideline that varied between 5.85 ug/g (dry body weight if fish collected during summer months) and 7.91 ug/g (dry body weight if fish collected during winter months). The guideline was set equal to the tissue concentration observed in a single experiment with the most sensitive fish species, the bluegill sunfish.

5.8.3 Recalculation Based on Toxicity Data for Oncorhynchus

No studies examining the effects of selenium on sockeye salmon were identified in the peer-reviewed scientific literature. In lieu of species-specific data, toxicity data for

Oncorhynchus, the genus to which sockeye salmon belong, were compiled. BCMOE (2001) summarizes toxicity data for three species that belong to the genus *Oncorhynchus*. Eleven chronic LC50 values were found for effects of selenium on rainbow trout:

- *Goettl and Davies (1976)*: Reported chronic LOELs of 30 ug/L (rainbow trout egg mortality), 80 ug/L (rainbow trout embryo deformity), 170 ug/L (rainbow trout egg mortality).
- *Hodson et al (1980)*: Reported chronic LOELs of 28 ug/L and 53 ug/L (rainbow trout egg hatching success).
- *Adams (1976)*: Reported chronic LC50s of 250 ug/L and 500 ug/L (rainbow trout).
- *Hunn et al (1987)*: Reported chronic LOELs of 12 ug/L (reduced calcium levels in backbone of rainbow trout sac fry), 47 ug/L (reduced length and mortality in rainbow trout sac fry), and 100 ug/L (reduced length and mortality in rainbow trout sac fry).
- *Davis et al (1988)*: Reported a chronic LOEL of 44 ug/L (mortality in rainbow trout).

These data did not serve as the point-of-departure for the BCMOE guideline. Based on this data, it appears that species belonging to *Oncorhynchus* are somewhat more resistant to the effects of selenium than are the species that served as the point-of-departure for the guideline. The geometric mean of the above values (69.7 ug/L) was used as the point-of-departure for the PPWQO. With an uncertainty factor of 10, the PPWQO would then be 7.0 ug/L.

A graphical comparison of the BCMOE WQG, the PPWQO, and the chronic toxicity value is presented in Figure 5.9.

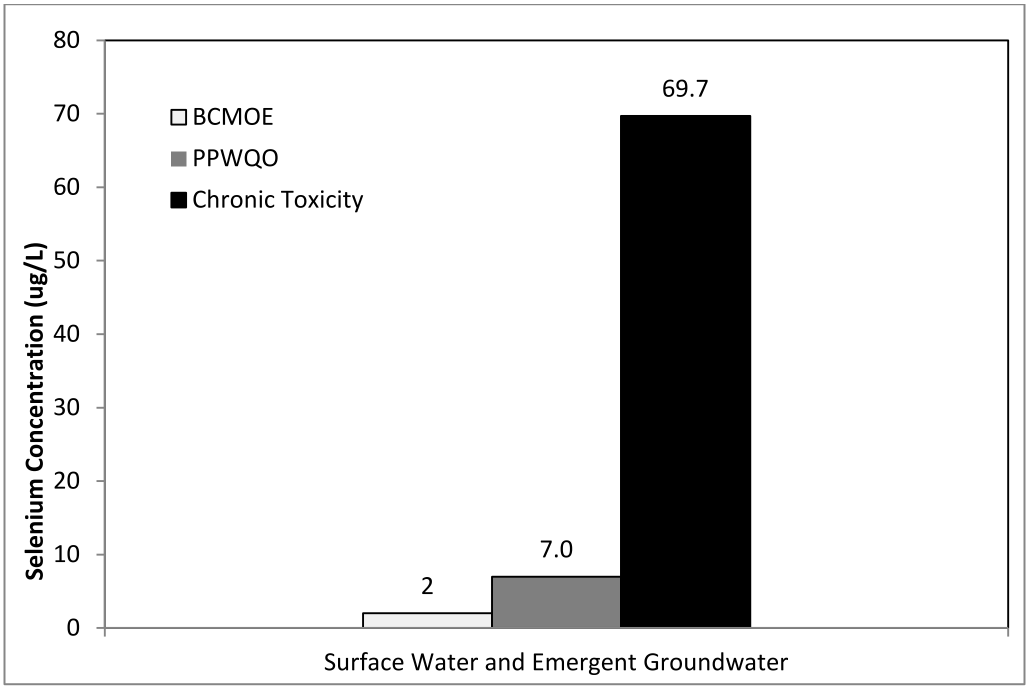


Figure 5.9 Water Quality Guidelines for Selenium

The tissue-residue-based guideline was also adjusted to a site-specific value to reflect the observation that cold-water species appear to be less sensitive to the toxic effects of selenium than warm-water species that served as the basis for the tissue-residue guidelines. U.S. EPA (2004) presents eight chronic toxicity values from three species belonging to *Oncorhynchus* (compiled in Table 5.9). If the guideline had been set based on the geometric mean of *Oncorhynchus* data, the tissue residue guideline would have been approximately 10.66 ug/g (dry body weight).

Table 5.9 Genus-Specific Toxicity Data for Selenium (μg/L)

Scientific Name	Common Name	Concentration in Whole Body	Chronic Toxicity Value	Chronic Toxicity Value
Oncorhynchus tshawytscha	Chinook salmon	15.74	12.8	10.66
		10.47		
Oncorhynchus mykiss	Rainbow Trout	11.65	9.3	
		19.16		
		5.79		
		5.85		
Oncorhynchus clarki	Cutthroat trout	10.92	10.1	
		9.37		

Notes:
All concentration values in units of ug/L (ug of selenium species per L of water).
All data as reported by BCMOE (2001).

5.9 Summary

Each PPWQO has been derived using standard re-calculation procedures that consider one or both of site-specific characteristics (environmental chemistry and/or the organisms of concern). The following re-calculation procedures were used:

Copper: Based on a re-calculation procedure that considered site-specific environmental chemistry (multiple variables in the Biotic Ligand Model).

Cadmium: Based on a re-calculation procedure that considered site-specific environmental chemistry (water hardness-dependent equation from U.S. EPA).

Aluminum, Arsenic, Cobalt and Selenium: Based on a re-calculation procedure that considered site-specific organisms of concern (toxicity data in rainbow trout used as a surrogate for sockeye salmon).

Sulfate PPWQO: Based on a re-calculation procedure that considered both site-specific environmental chemistry (water hardness) and site-specific organisms of concern (toxicity data in rainbow trout used as a surrogate for sockeye salmon).

Preliminary Proposed Water Quality Objectives (PPWQOs) have been derived for sulphate, aluminum, arsenic, cadmium, cobalt, copper and selenium for various hardness values and these are summarized in Table 5.10.

Table 5.10 Summary of Recommended PPWQOs and BCWQGs

Parameter	Hardness (mg/L)	PPWQO	BCWQG
Sulphate (mg/L)	100	198	100
	338	360	100
	528	448	100
Aluminum (µg/L)	NA	233	50
Arsenic (µg/L)	NA	55	5
Cadmium (µg/L)	100	0.27	0.033
	338	0.67	0.094
	528	0.93	0.139
Cobalt (µg/L)	NA	45	4
Copper (µg/L)	100	11.9	4
	338	17.8	13.5
	528	18.5	21.1
Selenium (µg/L)	NA	0.0077	0.0022

The PPWQOs have a typical uncertainty (safety) factor of 10 and should be applied to the expected case conditions. The use of the PPWQOs for Upper Bound conditions should consider the likelihood of combining uncertainty factors for different conditions which are not related. Accordingly, final selection of the PPWQOs for specific Upper Bound conditions will be developed in detail during the Permitting stage of the project and will account for the likelihood of combined uncertainty factors.

6. WATER FLOWS AND WATER BALANCE

6.1 Water Flow Effects

6.1.1 Morrison River Flow Changes

Baseline Flow

The outlet channel of Morrison Lake represents an intermediate channel with a bank-full width of 20 m to 30 m, a mean depth of 0.30 m and an upper gradient limit of ~3%. The site represents a pool-riffle sequence and provides spawning and rearing habitat for sockeye salmon during fall spawning (Photo 6.1).

Photo 6.1 Outlet of Morrison Lake (*i.e.*, Morrison River inlet) at low flow in September (~ 1.2 m^3/s).

A stream flow gauge has been installed in Morrison River near the outlet of Morrison Lake and flow measurements are available over the period of 2007 to 2011, although data during the winter months may not be accurate, likely due to freezing of the pressure gauge. The available data is shown in Figure 6.1. In lieu of measured flows, an estimate of the low flow was carried out for the EA (Rescan Volume VII - Appendix 22) for the 7Q2 and 7Q10 flows, which are 0.576 m^3 and 0.224 m^3/s, respectively.

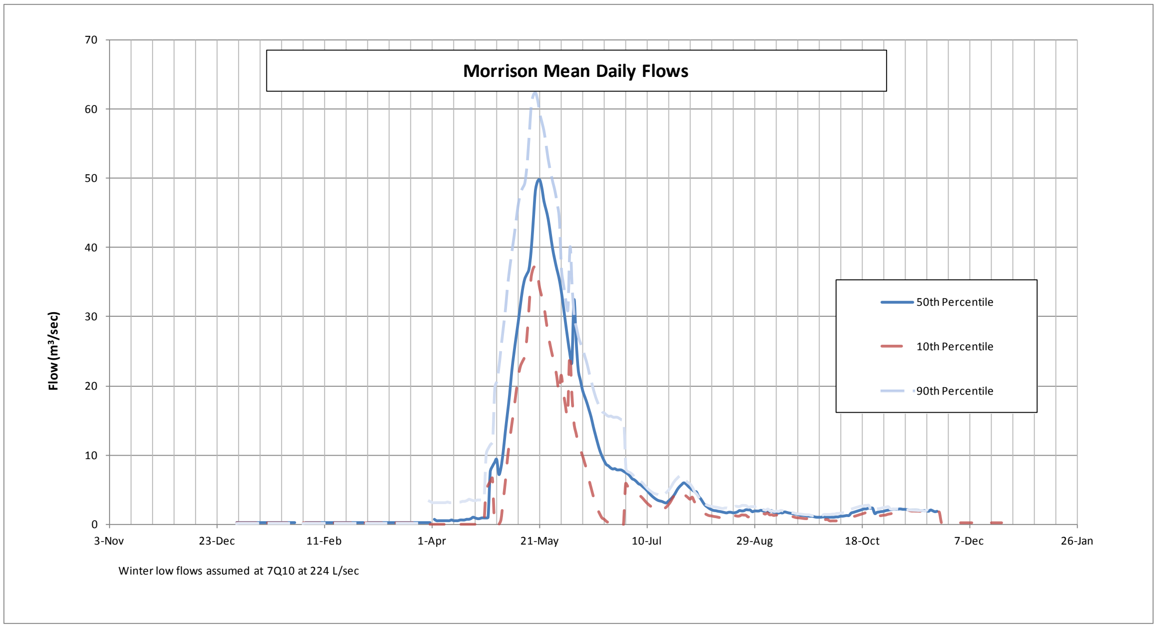


Figure 6.1 Morrison River – Flows

Flow Changes Due to Morrison Mine

The potential changes to flows in Morrison Lake and Morrison River due to the mine derive from the following sources:

- Fresh water pumping from the lake: Fresh water for makeup water will be pumped from Morrison Lake to the process plant. The quantity of water varies in response to the overall water balance and is up to 87 m^3/hr. The makeup water rate decreases with increasing groundwater flow into the open pit as the groundwater flow will then be used as the source of makeup water.
- Groundwater flows from Morrison Lake into the open pit: The flows vary over the life of mine and increase with the increasing depth of the open pit

and the estimated flow ranges from 133 m^3/hr (Expected Case) to 320 m^3/hr (Upper Bound). Groundwater pit inflows greater than the Expected Case will be offset by discharge of surplus pit dewatering water to Morrison Lake.

- Groundwater flows from the mine area and TSF to Morrison Lake will be altered by the mine with flows decreasing in the mine area due to the open pit and flows increasing in the TSF area due to seepage from the TSF. The flows approximately balance each other out.
- Surface water flows during spring freshet and the fall rains would decrease due to interception by the mine area and TSF.

The net effect on the flow changes, therefore, ranges over the year and summarized as follows:

- Flow reduction in the order of up to 150 m^3/hr (0.042 m^3/s) during the winter low flow months.
- Flow reduction of 212 m^3/hr to 307 m^3/hr (0.056 m^3/s to 0.085 m^3/s) during the spring to fall period when flows are highest due to spring melt and higher precipitation.

6.1.2 Biological Effect of Morrison River Flow Changes

During the period of spring freshet to fall rains, the changes to Morrison Lake and Morrison River are within the natural variation in the flow and no measureable effects are predicted.

Fall Spawning Period

The spawning period for Morrison River sockeye salmon occurs in September and October. During this time, average median flow varies between 0.48 m^3/sec and 2.00 m^3/sec, depending on the year of record. The British Columbia In-stream Flow

Guidelines for Fish recommended flow thresholds for fish-bearing streams as a seasonally-adjusted threshold for alterations to natural stream flows. The thresholds are calculated as percentiles of mean natural daily flows for each calendar month. These percentiles vary through the year to ensure higher protection during low flow months than during high flow months.

Due to the variation in the Morrison River hydrograph during the fall spawning period, the minimum flow requirement for Morrison River was conservatively set to the 20th percentile of the mean daily flows in October from 2007-2011. This results in an in-stream flow requirement of 0.9 m^3/sec during the fall sockeye spawning period. Provided this flow threshold is met, no impacts to fish or fish habitat are anticipated during the fall sockeye salmon spawning period. Even with the reduction in Morrison River flow during this time period due to the mine, the river flows are well above the in-stream flow requirement.

Winter Low Flow Period

During the winter low flow period, the potential flow reduction in Morrison River, assuming no attenuation from the Morrison Lake outlet, is approximately 7% of the 7Q2 and 18% of the 7Q10 flows.

Baseflow reductions during winter months have the potential to impact the development rates of incubating sockeye eggs, alevin, and emerging fry in Morrison River by lowering water temperatures and/or the availability of dissolved oxygen concentrations under winter ice. As in most fish, development rate for incubating sockeye eggs is a function of incubation temperature and adequate oxygenation. Survival of developing sockeye eggs is highest at 6°C and lowest at 2°C. Decreases in winter low flows may lower the river temperatures and dissolved oxygen concentrations enough to decrease egg survival or delay fry emergence. Furthermore, flow reductions may expose a small number of redds along the margins of Morrison River channel and in shallow side channels.

The likelihood of a significant effect on the salmon spawning alevins and emerging fry during winter low flow is low given that the potential reduction in stream flows is within the natural variation of the river. A monitoring program to measure stream flow more accurately during the winter months and to survey the extent of the salmon spawning habitat will be carried out prior to construction of the mine.

6.2 Life of Mine Water Balance

The life of mine water balance model has been rerun and the results are included in Appendix IV. Modifications to the water balance have been made in response to the potential for higher groundwater inflows into the open pit during mining, as described in Section 2.3 of this report. The main changes to the water management plant include discharge of surplus pit dewatering water during operations and, for the Upper Bound case, water treatment starting in Year 5. Life of mine TSF water pond volumes are shown in Figure 6.2 and Figure 6.3 for the Expected Case and Upper Bound, respectively.

A summary of the Expected Case and Upper Bound case water balances for the life of mine are shown in Table 6.2 and Table 6.3, respectively, and the annual worksheets are included in Appendix IV.

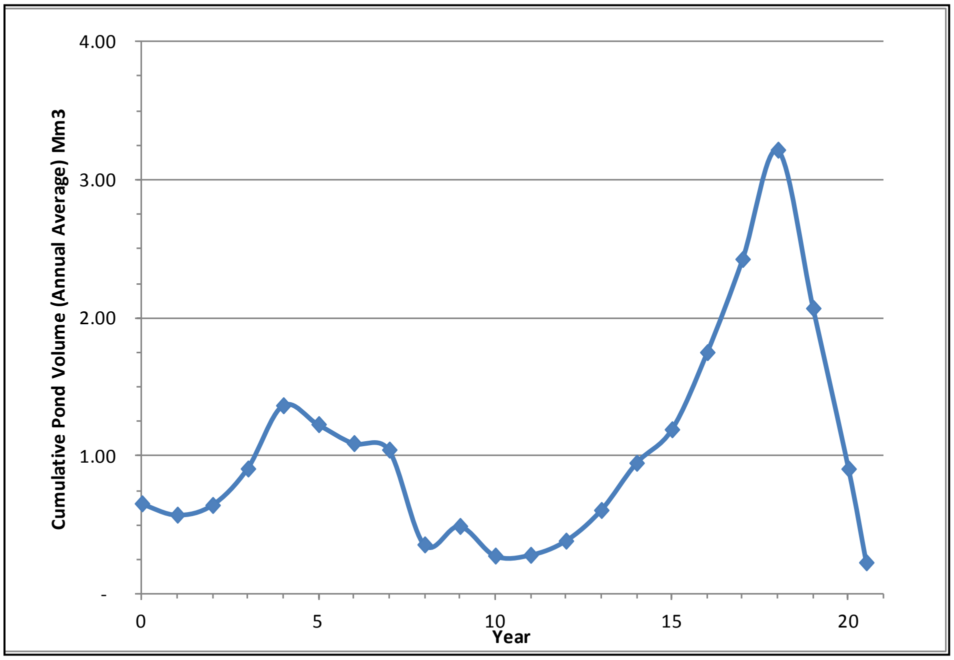


Figure 6.2 TSF Water Pond Volume – Expected Case

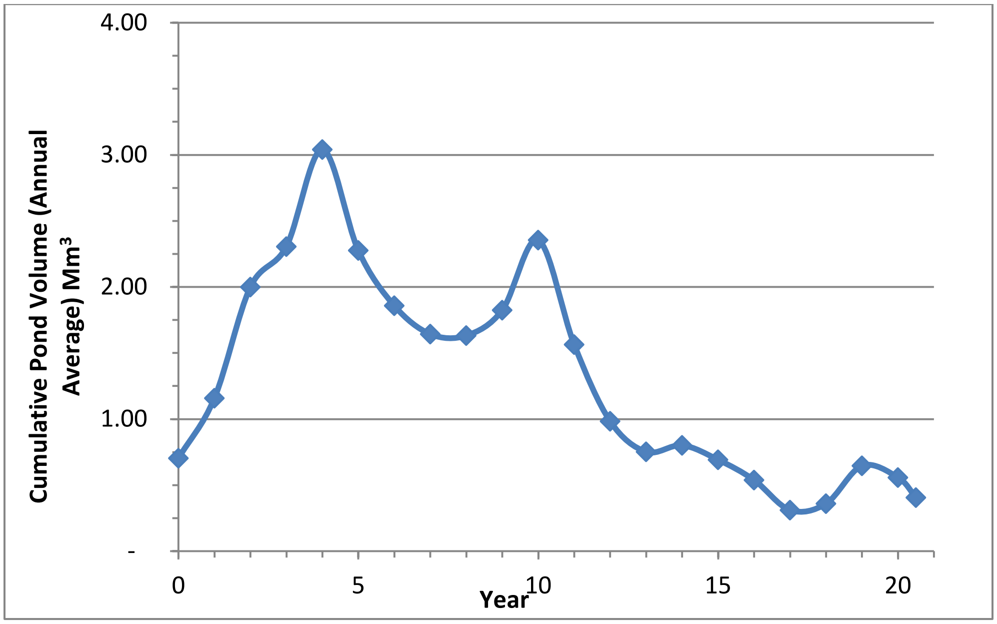


Figure 6.3 TSF Water Pond Volume – Upper Bound

A summary of the pit dewatering flows and the discharge water management volumes for the Expected and Upper Bound cases is presented in Table 6.1. The portion of pit dewatering water available for discharge was assumed to be less than 80% of the total dewatering pit flows.

Table 6.1 Summary of Surplus Water Management Flow Rates

Component	Year 5		Year 10		Year 18	
	EC	UB	EC	UB	EC	UB
Pit Dewatering Flows	152	271	229	409	368	685
Surplus TSF flows	90	330	140	500	165	640
Discharge of Pit Dewatering flows to Lake	90	150	140	330	165	515
Water treatment plant discharge to Lake	0	170	0	170	0	170

Table 6.2 Annual Water Balance – Expected Case

Annual Precipitation (mm)	550
Annual Evaporation (mm)	389
Undisturbed (Diverted) Land Runoff Coefficient	0.5
TSF	
Tailings pond area (sq. km)	varies
Undiverted Catchment runoff area (sq.km.)	varies
Diverted uphill catchment area (sq.km.)	varies
% Diversion ditch seepage	10%
Ultimate Tailings pond area (sq. km)	5.1

Process Plant	
Waste Dump/Plant Site Runoff Coefficient	0.7
Open Pit Runoff Coefficient	1.0
Processes %Availability	92.0%
Undiverted WRD/Plant Site Catchment Area (sq.km)	varies
Diverted WRD/Plant Site Catchment Area (sq.km)	varies
% Diversion ditch seepage	10%
Open Pit Area (sq.km)	1.1

Tailings		tpd	% Solids	
Total Daily Tonnage		29,621	Transport	InSitu
9%	Rougher	27,003	35.61%	72.2%
91%	Cleaner	2,619	22.76%	72.2%
Cyclone Efficiency		85%		
24%	Cyclone U/F	7,157		85.0%
76%	Cyclone O/F	22,465		72.2%

	Parameter	unit		Construction	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 20.5
DATA	Annual precipitation	mm	550																						
	Annual evaporation	mm	389																						
TSF Area	Diverted catchment area (external to TSF)	km²		4.07	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80
	Diverted Within TSF				2.10	2.10	2.10	2.10	2.10	1.25	1.25	1.25	1.25	1.25	0.70	0.70	0.70	0.70	0.70	0.00	0.00	0.00	0.00	0.00	0.00
	Diverted runoff coefficient	%	0.5																						
	Diversion ditch efficiency	%	90%		Yr 5 footprint Diversion					Yr 10 footprint diversion					Yr 15 footprint diversion					UTSF diversion					
	Undiverted catchment area (not including TSF)	km²		6.47	1.80	1.08	0.72	0.36	0.00	0.68	0.51	0.34	0.17	0.00	0.44	0.33	0.22	0.11	0.00	0.56	0.42	0.28	0.14	0.00	0.00
	Undiverted runoff coefficient	%	0.5																						
	TSF impoundment area	km²		1.20	1.20	1.92	2.28	2.64	3.00	3.17	3.34	3.51	3.68	3.85	3.96	4.07	4.18	4.29	4.40	4.54	4.68	4.82	4.96	5.10	5.10
	TSF impoundment runoff coefficient	%	1.0							5.10	5.10	5.10	5.10		5.10										

	Parameter	unit	Transport	In Situ
Mine Area	Rougher Tailings Density	% solids	35.61%	72.2%
	Cleaner Tailings Density		22.76%	72.2%
	Cyclone Underflow	% solids	-	85.0%
	Cyclone Overflow	% solids	-	72.2%

Inflows 0.0% 0.0%
0 Losses 39.47
Balance -3946.8%

	Parameter	unit		Construction	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 20.5
	Diverted LGO/WRD/Plantsite area	km²		0.62	1.7	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	0.00	0.00	0.00
	Diverted runoff coefficient	%	0.5																						
	Diversion ditch efficiency	%	90%																						
	Undiverted LGO/WRD/Plantsite area	km²		2.52	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	0.00	0.00	0.00
	LGO/WRD/Plantsite runoff coefficient	%	0.7																						
	Open pit area	km²	1.1																						
	Open pit runoff coefficient	%	1.0																						
INFLOWS																									
TSF Area	Runoff from undiverted catchment	m³/hr		206	57	34	23	11	0	22	16	11	5	5	14	11	7	4	0	18	13	9	4	0	0
	Leakage from Diversion Ditches			0	50	50	50	50	50	45	45	45	45	45	8	41	41	41	41	37	37	37	37	37	34
	Precipitation on TSF Impoundment			76	76	122	145	168	191	202	213	223	234	245	252	259	266	273	280	289	298	307	316	325	279
	Cleaner Tailings Water (direct discharge)			0	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	0	0	0
	Rougher Tailings Water (direct discharge)			0	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034
	Seepage reclaim			0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	SUBTOTAL - TSF Inflows			**282**	**2593**	**2616**	**2627**	**2639**	**2650**	**2677**	**2682**	**2688**	**2693**	**2699**	**2716**	**2720**	**2723**	**2727**	**2730**	**2752**	**2757**	**2761**	**2396**	**2400**	**2352**
Mine Area	Runoff from LGO/WRD plantsite area	m³/hr		0	133	133	133	133	133	133	133	133	133	133	133	133	133	133	133	133	133	133	0	0	0
	Leakage from diversion ditches			0	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	0	0	0
	Precipitation/Runoff into open pit			0	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	0	0	0
	Open pit dewatering			0	33	63	93	122	152	167	183	198	214	229	245	260	278	296	314	332	350	368	0	0	0
	Fresh water makeup			0	47	47	47	47	47	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Ore rock moisture			0	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39
	SUBTOTAL - Mine Inflows			**0**	331	361	391	421	450	434	449	381	480	496	511	526	544	562	580	598	616	634	54	54	54
OUTFLOWS																									
	Evaporation from TSF impoundment	m³/hr		54	54	86	103	119	135	143	150	158	166	173	178	183	188	193	198	204	210	217	223	229	208
	TSF seepage			5	10	13	16	19	22	24	27	30	33	36	39	42	45	48	51	53	56	59	65	65	65
	Tailings void loss - whole			0	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	433	433	433
	-overflow			0	204	204	204	204	204	204	204	204	204	204	204	204	204	204	204	204	204	204	0	0	0
	-underflow (cyclone sand)			0	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	0	0	0
	Dust Suppression			21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	17
	Concentrate Load Out			0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Potable Water			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Reclaim Water			0	0	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	1834	1834	1834
	Pit Dewatering Discharge to Lake			125	0	0	0	0	90	90	90	90	90	140	140	140	140	140	165	160	160	160	0	0	0
	SUBTOTAL - Outflows			**207**	2933	2969	2988	3007	3116	3127	3137	3148	3158	3219	3227	3234	3242	3250	3283	3287	3296	3305	2580	2587	2561
NET	**Net Flow**			**75**	-9	8	30	52	-16	-16	-5	-78	15	-24	1	12	25	39	28	64	77	90	-131	-133	-155
	Net Annual Volume	m³		655,551	- 82,005	70,311	264,095	457,879	- 136,737	- 137,245	- 47,031	- 686,400	133,397	- 214,388	5,418	102,543	222,195	341,846	242,497	558,632	674,828	791,023	- 1,146,849	- 1,162,976	- 677,785
CUMULATIVE	**Cumulative Volume**			655,551	573,546	643,856	907,951	1,365,830	1,229,093	1,091,848	1,044,817	358,417	491,814	277,426	282,844	385,387	607,582	949,428	1,191,925	1,750,557	2,425,384	3,216,408	2,069,558	906,583	228,797
	Cumulative Volume	Mm³		0.66	0.57	0.64	0.91	1.37	1.23	1.09	1.04	0.36	0.49	0.28	0.28	0.39	0.61	0.95	1.19	1.75	2.43	3.22	2.07	0.91	0.23
MAXIMUM	**LOM Max Pond Volume**	3.22	Mm³																						
END	**End of Mine Pond Volume:**	0.23	Mm³																						

Table 6.3 Annual Water Balance – Upper Bound

Summary - Upper Bound Condition Managed

* Annual Precipitation (mm)	550
Annual Evaporation (mm)	389
Undisturbed (Diverted) Land Runoff Coefficien	0.5
TSF	
Tailings pond area (sq. km)	varies
Undiverted Catchment runoff area (sq.km.)	varies
Diverted uphill catchment area (sq.km.)	varies
% Diversion ditch seepage	20%
Ultimate Tailings pond area (sq. km)	5.1

Process Plant	
Waste Dump/Plant Site Runoff Coefficient	0.7
Open Pit Runoff Coefficient	1.0
Processes %Availability	92.0%
Undiverted WRD/Plant Site Catchment Area (sq.km)	varies
Diverted WRD/Plant Site Catchment Area (sq.km)	varies
% Diversion ditch seepage	20%
Open Pit Area (sq.km)	1.1

Tailings		tpd	% Solids	
			Transport	InSitu
Total Daily Tonnage		29,621		
91%	Rougher	27,003	35.61%	73.7%
9%	Cleaner	2,619	22.76%	73.7%
Cyclone Efficiency		85%		
24%	Cyclone U/F	7,157		85.0%
76%	Cyclone O/F	22,465		73.7%

* *10-yr wet year*

	Parameter	unit		Construction	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 20.5
DATA	Annual precipitation	mm	550											733											
	Annual evaporation	mm	389																						
TSF Area	Diverted catchment area (external to TSF)	km^2		4.07	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80
	Diverted Within TSF	km^2			2.10	2.10	2.10	2.10	2.10	1.25	1.25	1.25	1.25	1.25	0.70	0.70	0.70	0.70	0.70	0.00	0.00	0.00	0.00	0.00	0.00
	Diverted runoff coefficient	%	0.5																						
	Diversion ditch efficiency	%	80%		Yr 5 footprint Diversion					Yr 10 footprint diversion					Yr 15 footprint diversion					UTSF diversion					
	Undiverted catchment area (not including TSF)	km^2		6.47	1.80	1.08	0.72	0.36	0.00	0.68	0.51	0.34	0.17	0.00	0.44	0.33	0.22	0.11	0.00	0.56	0.42	0.28	0.14	0.00	0.00
	Undiverted runoff coefficient	%	0.5																						
	TSF impoundment area	km^2		1.20	1.20	1.92	2.28	2.64	3.00	3.17	3.34	3.51	3.68	3.85	3.96	4.07	4.18	4.29	4.40	4.54	4.68	4.82	4.96	5.10	5.10
	TSF impoundment runoff coefficient	%	1.0																						
			Transport																						
Mine Area	Rougher Tailings Density	% solids	35.61%	73.7%																					
	Cleaner Tailings Density		22.76%	73.7%																					
	Cyclone Underflow		-	85.0%																					
	Cyclone Overflow		-	73.7%																					
	Diverted LGO/WRD/Plantsite area	km^2		0.62	1.7	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	0.00	0.00	0.00
	Diverted runoff coefficient	%	0.5																						
	Diversion ditch efficiency	%	80%																						
	Undiverted LGO/WRD/Plantsite area	km^2		2.52	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	0.00	0.00	0.00
	LGO/WRD/Plantsite runoff coefficient	%	0.7																						
	Open pit area	km^2	1.1																						
	Open pit runoff coefficient	%	1.0																						
INFLOWS																									
TSF Area	Runoff from undiverted catchment	m^3/hr		206	57	34	23	11	0	22	16	11	5	0	14	11	7	4	0	18	13	9	4	0	0
	Leakage from Diversion Ditches			0	101	101	101	101	101	90	90	90	90	120	83	83	83	83	83	74	74	74	74	74	69
	Precipitation on TSF Impoundment			76	76	122	145	168	191	202	213	223	234	327	252	259	266	273	280	289	298	307	316	325	279
	Cleaner Tailings Water (direct discharge)			0	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	0	0	0
	Rougher Tailings Water (direct discharge)			0	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034
	Seepage reclaim			0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	SUBTOTAL - TSF Inflows			282	2643	2666	2677	2689	2700	2722	2727	2733	2738	2855	2758	2761	2765	2768	2772	2789	2794	2798	2432	2437	2386
Mine Area	Runoff from LGO/WRD plantsite area	m^3/hr		0	133	133	133	133	133	133	133	133	133	177	133	133	133	133	133	133	133	133	0	0	0
	Leakage from diversion ditches			0	23	23	23	23	23	23	23	23	23	30	23	23	23	23	23	23	23	23	0	0	0
	Precipitation/Runoff into open pit			0	69	69	69	69	69	69	69	69	69	92	69	69	69	69	69	69	69	69	0	0	0
	Open pit dewatering			0	48	104	160	215	271	299	326	354	381	409	436	464	507	543	578	614	649	685	0	0	0
	Fresh water makeup			0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Ore rock moisture			0	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39
	SUBTOTAL - Mine Inflows			**0**	312	368	424	480	535	563	591	618	646	747	701	728	772	807	843	878	914	949	42	42	42
OUTFLOWS																									
	Evaporation from TSF impoundment	m^3/hr		54	54	86	103	119	135	143	150	158	166	173	178	183	188	193	198	204	210	217	223	229	208
	TSF seepage			5	10	12	14	16	18	21	23	25	27	29	31	33	35	37	39	42	44	46	48	50	50
	Tailings void loss - whole			0	191	191	191	191	191	191	191	191	191	191	191	191	191	191	191	191	191	191	401	440	440
	-overflow			0	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	0	0	0
	-underflow (cyclone sand)			0	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	0	0	0
	Dust Suppression			21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	17
	Concentrate Load Out			0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Potable Water			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Pit Dewatering and/or Treatment Discharge			119	0	0	110	110	330	330	330	330	330	500	500	500	500	500	550	600	640	640	0	0	0
	Reclaim Water			0	2405	2405	2405	2405	330	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	1744	1744	1744
	SUBTOTAL - Outflows			**202**	2903	2938	3066	3085	3323	3333	3342	3352	3362	3542	3549	3556	3563	3570	3627	3685	3734	3742	2442	2489	2463
NET	**Net Flow**			**80**	52	96	35	84	-87	-48	-25	-1	22	61	-90	-66	-26	6	-12	-18	-26	6	33	-10	-35
	Net Annual Volume	m^3		703,001	454,457	841,449	306,308	734,768	- 763,972	- 418,272	- 214,771	- 11,269	192,232	530,660	- 791,043	- 580,630	- 231,130	48,826	- 109,217	- 153,612	- 227,511	48,990	286,660	- 89,024	- 151,824
CUMULATIVE	**Cumulative Volume**			703,001	1,157,458	1,998,906	2,305,215	3,039,983	2,276,011	1,857,739	1,642,968	1,631,699	1,823,931	2,354,591	1,563,548	982,917	751,787	800,614	691,396	537,784	310,273	359,263	645,923	556,899	405,075
	Cumulative Volume	Mm^3		0.70	1.16	2.00	2.31	3.04	2.28	1.86	1.64	1.63	1.82	2.35	1.56	0.98	0.75	0.80	0.69	0.54	0.31	0.36	0.65	0.56	0.41
MAXIMUM	**LOM Max Pond Volume**	3.04	Mm^3																						
END	**End of Mine Pond Volume**	0.41	Mm^3																						
			Year:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	20.5

6.3 Closure Water Balance

6.3.1 TSF Water Balance

The closure water balance for the TSF is the same as presented in RRR-Rev.2 and is summarized in Table 6.4.

Table 6.4 TSF Water Balance on Initial and Full –Closure

	Initial Closure 0 TO 3 Years after Mining			Full Closure 3 Years after Mining		
INPUTS (GAINS)	**Area (km^2)**	**Runoff Coefficient**	**Flow (m^3/hr)**	**Area (km^2)**	**Runoff Coefficient**	**Flow (m^3/hr)**
Runoff - diverted catchment	3.82	0.5	0	3.82	0.5	120
Precipitation - TSF pond	1	1	63	1.7	1	107
Runoff - TSF beaches	4.1	0.7	180	3.4	0.5	107
TSF beach sub-surface flow	4.1	0.1	26			
TSF Total Inputs			269			333
OUTPUTS (LOSSES)						
Evaporation - TSF pond	1	1	45	1.7	1	76
TSF - Seepage			50			50
TSF Total Losses			95			126
Net used for TSF pond building			174			
Net discharged to stream 7			120			207

6.3.2 Mine Area Water Balance – Pit Backfill Stage

The mine area water balance for the pit backfill stage has been updated to incorporate the higher groundwater inflow rates. The higher inflow rates will require that the pit dewatering discharges to Morrison Lake continue during the pit backfill stage to control and manage the volume of water required to fill the voids of the PAG mine rock. The water balance for the Expected Case and Upper Bound are shown in Table 6.5 and Table 6.6, respectively. The water quality effects on Morrison Lake for the pit backfill stage are presented in Section 7.2.4 of this report.

Table 6.5 Water and Mass Balance for Pit Infilling – Expected Case

Year	cleaner tailings solids		cleaner tailings surplus water[1]	reclaim to process plant m3/hr	reclaim to process plant m3	decant of TSF to open pit[1]	ground water inflow rate	ground water volume	cumulative groundwater volume	mine area avg runoff	open pit evaporation	mine area runoff	volume of waste rock @ 2t/m^3	Waste rock void water @5% solidsby weight	cumulative rock tonnage	Total Annual Solids Volume	cumulative solids volume	total water inflow volume	cumulative water volume	Cumulative volume of voids	Pit Dewatering	Water Treatment	Cumulative volume	Net pit suplus water
	tonnes	volume @1.3 t/m3	assume settle from 22.8% solids to 72% solids																					
19	817,752	629,040	2,450,865	200	1,752,000		320	2,803,200	2,803,200	200	0	1,752,000	20,000,000	1,052,632	20,000,000	10,629,040	10,629,040	6,306,696	6,306,696	2,690,909	220	120	2,978,400	
20	963,600	741,231	2,887,982	200	1,752,000		270	2,365,200	5,168,400	200	0	1,752,000	20,000,000	1,052,632	40,000,000	10,741,231	21,370,271	6,305,814	12,612,511	5,381,818	170	120	5,518,800	
21	558,448	429,575	1,673,711	200	864,000		210	1,839,600	7,008,000	200	5	1,708,200	20,000,000	1,052,632	60,000,000	10,429,575	31,799,846	5,410,143	18,022,653	8,072,727	160	120	7,971,600	
22						290,000	170	1,489,200	8,497,200	200	10	1,664,400	20,000,000	1,052,632	80,000,000	10,000,000	41,799,846	4,206,232	22,228,885	10,763,636	110	120	9,986,400	
23							140	1,226,400	9,723,600	200	10	1,664,400	20,000,000	1,052,632	100,000,000	10,000,000	51,799,846	3,943,432	26,172,316	13,454,545	80	120	11,738,400	
24							130	1,138,800	10,862,400	150	10	1,226,400	20,000,000	1,052,632	120,000,000	10,000,000	61,799,846	3,417,832	29,590,148	16,145,455		120	12,789,600	
25							110	963,600	11,826,000	150	10	1,226,400	20,000,000	1,052,632	140,000,000	10,000,000	71,799,846	3,242,632	32,832,780	18,836,364		120	13,840,800	
26							95	832,200	12,658,200	100	10	788,400	8,000,000	421,053	148,000,000	4,000,000	75,799,846	2,041,653	34,874,432	19,912,727		120	14,892,000	69,705

Table 6.6 Water and Mass Balance for Pit Infilling – Upper Bound Case

Year	cleaner tailings solids		cleaner tailings surplus water[1]	reclaim to process plant m3/hr	reclaim to process plant m3	decant of TSF to open pit[1]	ground water inflow rate	ground water volume	cumulative groundwater volume	mine area avg runoff	open pit evaporation	mine area runoff	volume of waste rock @ 2t/m^3	Waste rock void water @5% solidsby weight	cumulative rock tonnage	Total Annual Solids Volume	cumulative solids volume	total water inflow volume	cumulative water volume	Cumulative volume of voids	Pit Dewatering	Water Treatment	Cumulative volume	net pit suplus water
	tonnes	volume @1.3 t/m3	assume settle from 22.8% solids to 72% solids																					
19	817,752	629,040	2,450,865	290	2,540,400		600	5,256,000	5,256,000	200	0	1,752,000	20,000,000	1,052,632	20,000,000	10,629,040	10,629,040	7,971,096	7,971,096	2,690,909	460	170	5,518,800	
20	963,600	741,231	2,887,982	290	2,540,400		500	4,380,000	9,636,000	200	0	1,752,000	20,000,000	1,052,632	40,000,000	10,741,231	21,370,271	7,532,214	15,503,311	5,381,818	380	170	10,336,800	
21	558,448	429,575	1,673,711	290	1,252,800		400	3,504,000	13,140,000	200	5	1,708,200	20,000,000	1,052,632	60,000,000	10,429,575	31,799,846	6,685,743	22,189,053	8,072,727	260	170	14,103,600	
22						290,000	300	2,628,000	15,768,000	200	10	1,664,400	20,000,000	1,052,632	80,000,000	10,000,000	41,799,846	5,345,032	27,534,085	10,763,636		170	15,592,800	
23							200	1,752,000	17,520,000	200	10	1,664,400	20,000,000	1,052,632	100,000,000	10,000,000	51,799,846	4,469,032	32,003,116	13,454,545		170	17,082,000	
24							160	1,401,600	18,921,600	150	10	1,226,400	20,000,000	1,052,632	120,000,000	10,000,000	61,799,846	3,680,632	35,683,748	16,145,455		170	18,571,200	
25							140	1,226,400	20,148,000	150	10	1,226,400	20,000,000	1,052,632	140,000,000	10,000,000	71,799,846	3,505,432	39,189,180	18,836,364		170	20,060,400	
26							127	1,112,520	21,260,520	100	10	788,400	8,000,000	421,053	148,000,000	4,000,000	75,799,846	2,321,973	41,511,152	19,912,727		170	21,549,600	48,825

6.3.3 Mine Area Water Balance – Closure

The mine area water balance for closure has been updated to include the increased groundwater inflows and the Expected Case is summarized in Table 6.7. A water inflow from seepage from the diversion ditch has not been included at this time due to the thick deposits of low hydraulic conductivity glacial till uphill of the open pit.

Table 6.7 Water Balance for Pit Area on Full –Closure – Expected Case

Component	Surface Area (km^2)	Runoff Coefficient	Inflow (m^3/hr)	Outflow (m^3/hr)	Net Flow for Water Treatment (m^3/hr)
Runoff from pit walls	0.29	0.9	16		
Runoff from un-diverted catchment	0.27	0.7	12		
Precipitation on pit pond area	0.12	1.0	7.5		
Precipitation on wetland area	0.7	1.0	44		
Groundwater inflow			95		
Evaporation from pit pond area	0.12			5.3	
Evapotranspiration from wetland area	0.68			30	
Net			**175**	**35**	**140**

The water balance for the Upper Bound case has a groundwater inflow of 127 m^3/hr, resulting in a net flow for water treatment of 170 m^3/hr.

6.3.4 Water Balance Temporary Closure

During temporary closure conditions the open pit could either be allowed to infill with water or pit dewatering and water treatment could be implemented to manage surplus water. An estimate of surplus water flow rates and potential management options is summarized in Table 6.8, using Year 15 as a surrogate. The water quality effects on Morrison Lake for the temporary closure water management plans are presented in Section 7.2.5 of this report.

Table 6.8 Summary of Surplus Water Management Flow Rates – Temporary Closure – Year 15

Component	Flows (m^3/hr)	
	EC	**UB**
Pit Dewatering Flows	409	578
Surplus TSF flows	629	912
Discharge of Pit Dewatering flows to Lake	330	475
Water treatment plant discharge to Lake	300	437

7. WATER QUALITY EFFECTS ASSESSMENT

7.1 TSF Effects on Stream Water Quality

7.1.1 Methodology

The water quality models for streams MCS-7, MCS-8 and MCS-10 have been rerun using the predicted % solutes from the revised groundwater modeling (Section 1.2 of this report). The results of the solute modeling are summarized in Table 7.1 and Table 7.2 for the Expected Case and Upper Bound groundwater models.

Table 7.1 Predicted Relative Concentrations of Seepage in TSF Receiving Streams – Expected Case Groundwater Model

Concentration Relative to TSF Source (%)	MCS-7 Downstream (m)	MCS-7i West Tributary (m)	MCS-7ii East Tributary (m)	MCS-8 (m)	MCS-10 (m)
0 to 20	1029	283	2067	2752	2429
20 to 40	0	183	275	0	0
40 to 60	0	402	25	0	0
60 to 80	0	520	0	0	0
80 to 100	0	0	0	0	0
Total Stream Length (m)	**1029**	**1388**	**2367**	**2752**	**2429**
Average % Solute	10%	47%	13%	10%	10%
Average % Solute in Stream 7	22%				

Table 7.2 Predicted Relative Concentrations of Seepage in TSF Receiving Streams – Upper Bound Groundwater Model

Concentration Relative to TSF Source (%)	MCS-7 Downstream (m)	MCS-7i West Tributary (m)	MCS-7ii East Tributary (m)	MCS-8 (m)	MCS-10 (m)
0 to 20	5	100	2267	2467	1668
20 to 40	248	372	28	2850	318
40 to 60	728	323	72	0	288
60 to 80	48	591	0	0	155
80 to 100	0	2	0	0	0
Total Stream Length (m)	**1029**	**1388**	**2367**	**2752**	**2429**
Average % Solute	46%	50%	11%	12%	21%
Average % Solute in Stream 7	30%				

During winter base flow conditions it is assumed that there is no dilution of seepage water with surface water. During the remainder of the year, the base flow groundwater is diluted with the average surface water flow. The receiving groundwater quality is calculated using the %solute and adding the baseline groundwater load {%solute x TSF water quality + (1-%solute) x baseline groundwater quality}.

7.1.2 Results

The results of the stream effects water quality are presented in Table 7.3, Table 7.4, and Table 7.5 for the Expected Case groundwater model and the Expected Case and Upper Bound TSF porewater quality. The baseline groundwater and surface water data has been updated to include the data up to August 2011.

A sensitivity analysis was made that used the Upper Bound groundwater model with the Expected Case and Upper Bound TSF porewater quality and elevated concentrations of aluminum and arsensic, as suggested by RGC. These results are presented in Table 7.6, Table 7.7 and Table 7.8 for streams MCS-7, MCS-8 and MCS-10, respectively.

Table 7.3 Surface Water Quality in Stream MCS-7 Downstream of the TSF at Low and Average Flow Conditions

Parameter (mg/L, except pH) (Total Concentrations, except Al)	TSF Porewater		Baseline Water Quality		Expected Case Water Quality MCS-7		Upper Bound Water Quality MCS-7		BCWQG's Expected Case		BCWQGs Upper Bound	
	EC	UB	Groundwater	Surface	Low	Average	Low	Average	Low	Average	Low	Average
pH	8.2	7.9	8.3	8.0	8.0	8.0	8.0	8.0	6.5-9	6.5-9	6.5-9	6.5-9
Alkalinity ($CaCO_3$)	96	100	327	65	276	77	277	77	10	10	10	10
Flouride-F	0.47	0.55	1.3	0.064	1.1	0.13	1.1	0.13	30	30	30	30
Chloride-CI	20	5.9	1.8	0.31	5.8	0.63	2.7	0.45	150	150	150	150
Sulphate-SO_4	887	1,700	65	5.9	246	20	425	30	100	100	100	100
Nitrite-NO_2	0.030	0.10	0.0018	0.088	0.0080	0.083	0.0234	0.084	0.058	0.020	0.027	0.020
Nitrate-NO_3	0.33	3.50	0.016	0.51	0.08	0.49	0.782	0.53	13	13	13	13
Ammonia-NH_3	0.096	1.40	0.073	0.0054	0.078	0.0096	0.365	0.0264	1.6	1.6	1.6	1.6
Mercury-Hg	0.000028	0.0000050	0.0000080	0.0000069	0.000012	0.0000072	0.0000073	0.0000069	0.000020	0.000020	0.000020	0.000020
Silver-Ag	0.000023	0.000010	0.000012	0.0000064	0.000015	0.0000069	0.000012	0.0000067	0.0015	0.0015	0.0015	0.0015
Aluminum-Al	0.22	0.39	0.057	0.047	0.09	0.050	0.13	0.052	0.050	0.050	0.050	0.050
Arsenic-As	0.015	0.018	0.0049	0.00030	0.0071	0.00070	0.0078	0.00074	0.0050	0.0050	0.0050	0.0050
Barium-Ba	0.35	0.58	0.10	0.024	0.16	0.032	0.21	0.035	1.0	1.0	1.0	1.0
Beryllium-Be	0.000048	0.000076	0.00037	0.00031	0.00030	0.00031	0.00031	0.00031	No WQG			
Boron-B			0.13	0.026	0.101	0.031	0.101	0.031	1.2	1.2	1.2	1.2
Calcium-Ca	148	260	35	19	60	21	85	23	No direct WQO (part of Hardness)			
Cadmium-Cd	0.00088	0.0016	0.000068	0.00000098	0.00025	0.000015	0.00041	0.000025	0.000085	0.000027	0.00012	0.000029
Cobalt-Co	0.011	0.021	0.0018	0.000077	0.0038	0.00030	0.0060	0.00043	0.0040	0.0040	0.0040	0.0040
Chromium-Cr	0.00035	0.00044	0.00047	0.00032	0.00044	0.00033	0.00046	0.00033	0.0010	0.0010	0.0010	0.0010
Copper-Cu	0.032	0.0600	0.00067	0.00094	0.0076	0.0013	0.0137	0.00169	0.0119	0.0031	0.0179	0.0035
Iron-Fe	0.037	0.053	0.73	0.072	0.58	0.10	0.58	0.10	1.0	1.0	1.0	1.0
Potasium-K	30	44	1.4	0.50	7.7	0.9	11	1.1	No WQG			
Lithium-Li	0.022	0.042	0.069	0.0025	0.059	0.0058	0.063	0.0060	0.087	0.087	0.087	0.087
Magnesium-Mg	110	210	15	3.9	36	5.8	58	7.1	No direct WQO (part of Hardness)			
Manganese-Mn	0.76	1.5	0.73	0.0033	0.73	0.046	0.90	0.055	1.9	0.95	2.6	1.0
Molybdenum-Mo	0.17	0.28	0.0068	0.00017	0.043	0.0027	0.067	0.0041	1.0	1.0	1.0	1.0
Sodium-Na	26	21	101	4.4	85	9.1	84	9.0	No WQG			
Nickel-Ni	0.018	0.033	0.0025	0.00039	0.0059	0.00071	0.009	0.0009	0.15	0.15	0.15	0.15
Lead-Pb	0.0047	0.0092	0.00021	0.00017	0.0012	0.00023	0.0022	0.00029	0.016	0.0056	0.025	0.0060
Antimony-Sb	0.023	0.042	0.00021	0.000041	0.0052	0.00034	0.009	0.00059	0.020	0.020	0.020	0.020
Selenium-Se	0.0098	0.019	0.00024	0.00034	0.0023	0.00046	0.0044	0.00057	0.0020	0.0020	0.0020	0.0020
Silicon-Si	2.9	3.6	5.4	2.7	4.8	2.8	5.0	2.8	No WQO			
Tin-Sn			0.42	0.00011	0.32	0.019	0.32	0.019	No WQO			
Vanadium-V	0.00040	0.00029	0.00070	0.0043	0.00063	0.0041	0.00061	0.0041	No WQO			
Zinc-Zn	0.22	0.44	0.0045	0.0013	0.052	0.0043	0.10	0.0071	0.16	0.0075	0.28	0.0075
Hardness	821	1,500	150	64	298	78	447	86				

BCWQG based on 30 day mean where available.
Shading indicates exceedance of BCWQGs.

Table 7.4 Surface Water Quality in Stream MCS-8 Downstream of the TSF at Low and Average Flow Conditions

Parameter (mg/L, except pH) (Total Concentrations, except Al)	TSF Porewater		Baseline Water Quality		Expected Case Water Quality MCS-8		Upper Bound Water Quality MCS-8		BCWQG's Expected Case		BCWQGs Upper Bound	
	EC	UB	Groundwater	Surface	Low	Average	Low	Average	Low	Average	Low	Average
pH	8.2	7.9	8.3	8.0	8.0	8.0	8.0	8.0	6.5-9	6.5-9	6.5-9	6.5-9
Alkalinity ($CaCO_3$)	96	100	327	93	304	136	304	136	10	10	10	10
Flouride-F	0.47	0.55	1.3	0.081	1.2	0.32	1.2	0.32	30	30	30	30
Chloride-CI	20	5.9	1.8	0.25	3.6	0.95	2.2	0.66	150	150	150	150
Sulphate-SO_4	887	1,700	65	7.7	148	37	229	53	100	100	100	100
Nitrite-NO_2	0.030		0.0018	0.0016	0.0046	0.0022	0.0016	0.0016	0.036	0.020	0.022	0.020
Nitrate-NO_3	0.33		0.016	0.81	0.047	0.66	0.014	0.65	13	13	13	13
Ammonia-NH_3	0.096		0.073	0.0069	0.075	0.021	0.065	0.019	1.6	1.6	1.6	1.6
Mercury-Hg	0.000028	0.0000050	0.0000080	0.0000072	0.000010	0.0000078	0.0000077	0.0000073	0.000020	0.000020	0.000020	0.000020
Silver-Ag	0.000023	0.000010	0.000012	0.0000050	0.000013	0.0000067	0.000012	0.0000064	0.0015	0.0015	0.0015	0.0015
Aluminum-Al	0.22	0.39	0.057	0.017	0.073	0.029	0.090	0.032	0.050	0.050	0.050	0.050
Arsenic-As	0.015	0.018	0.0049	0.00044	0.0059	0.0016	0.0062	0.0016	0.0050	0.0050	0.0050	0.0050
Barium-Ba	0.35	0.58	0.10	0.044	0.13	0.061	0.15	0.066	1.0	1.0	1.0	1.0
Beryllium-Be	0.000048	0.000076	0.00037	0.00022	0.00034	0.00024	0.00034	0.00025	No WQG			
Boron-B			0.13	0.015	0.12	0.036	0.12	0.036	1.2	1.2	1.2	1.2
Calcium-Ca	148	260	35	28	47	32	58	34	No direct WQO (part of Hardness)			
Cadmium-Cd	0.00088	0.0016	0.000068	0.0000089	0.00015	0.000038	0.00022	0.000053	0.000065	0.000037	0.000082	0.000041
Cobalt-Co	0.011	0.021	0.0018	0.000064	0.0027	0.00062	0.0037	0.00082	0.0040	0.0040	0.0040	0.0040
Chromium-Cr	0.00035	0.00044	0.00047	0.00027	0.00046	0.00031	0.00047	0.00031	0.0010	0.0010	0.0010	0.0010
Copper-Cu	0.032	0.0600	0.00067	0.0011	0.0038	0.0017	0.00660	0.0023	0.00870	0.00462	0.01142	0.00518
Iron-Fe	0.037	0.053	0.73	0.095	0.66	0.21	0.67	0.21	1.0	1.0	1.0	1.0
Potasium-K	30	44	1.4	0.39	4.2	1.2	5.6	1.5	No WQG			
Lithium-Li	0.022	0.042	0.069	0.0025	0.064	0.015	0.066	0.016	0.087	0.087	0.087	0.087
Magnesium-Mg	110	210	15	4.9	25	9.0	35	11	No direct WQO (part of Hardness)			
Manganese-Mn	0.76	1.5	0.73	0.023	0.73	0.17	0.80	0.18	1.6	1.1	1.9	1.2
Molybdenum-Mo	0.17	0.28	0.0068	0.00014	0.023	0.0049	0.034	0.0071	1.0	1.0	1.0	1.0
Sodium-Na	26	21	101	4.5	94	23	93	23	No WQG			
Nickel-Ni	0.018	0.033	0.0025	0.00046	0.0040	0.0012	0.0055	0.0015	0.15	0.15	0.15	0.15
Lead-Pb	0.0047	0.0092	0.00021	0.000046	0.00066	0.00017	0.0011	0.00027	0.012	0.0071	0.015	0.0077
Antimony-Sb	0.023	0.042	0.00021	0.000046	0.0025	0.00055	0.0044	0.00094	0.020	0.020	0.020	0.020
Selenium-Se	0.0098	0.019	0.00024	0.00021	0.0012	0.00041	0.0021	0.00060	0.0020	0.0020	0.0020	0.0020
Silicon-Si	2.9	3.6	5.4	4.0	5.1	4.2	5.2	4.2	No WQO			
Tin-Sn			0.42	0.000050	0.37	0.077	0.37	0.077	No WQO			
Vanadium-V	0.00040	0.00029	0.00070	0.00045	0.00067	0.00049	0.00066	0.00049	No WQO			
Zinc-Zn	0.22	0.44	0.0045	0.00094	0.026	0.0061	0.048	0.011	0.10	0.027	0.15	0.037
Hardness	821	1,500	150	89	218	115	285	129				

BCWQG based on 30 day mean where available.
Shading indicates exceedance of BCWQGs.

Table 7.5 Surface Water Quality in Stream MCS-10 Downstream of the TSF at Low and Average Flow Conditions

Parameter (mg/L, except pH) (Total Concentrations, except Al)	TSF Porewater		Baseline Water Quality		Expected Case Water Quality MCS-10		Upper Bound Water Quality MCS-10		BCWQG's Expected Case		BCWQGs Upper Bound	
	EC	UB	Groundwater	Surface	Low	Average	Low	Average	Low	Average	Low	Average
pH	8.2	7.9	8.3	7.6	8.0	8.0	8.0	8.0	6.5-9	6.5-9	6.5-9	6.5-9
Alkalinity ($CaCO_3$)	96	100	327	41	304	63	304	63	10	10	10	10
Flouride-F	0.47	0.55	1.3	0.041	0.61	0.13	0.62	0.14	30	30	30	30
Chloride-CI	20	5.9	1.8	0.25	1.8	0.49	1.1	0.41	150	150	150	150
Sulphate-SO_4	887	1,700	65	3.0	74	14	114	22	100	100	100	100
Nitrite-NO_2	0.030		0.0018	0.0018	0.0023	0.0019	0.00081	0.0018	0.020	0.020	0.020	0.020
Nitrate-NO_3	0.33		0.016	0.052	0.024	0.048	0.0071	0.049	13	13	13	13
Ammonia-NH_3	0.096		0.073	0.014	0.038	0.017	0.033	0.018	1.6	1.6	1.6	1.6
Mercury-Hg	0.000028	0.0000050	0.0000080	0.0000070	0.0000050	0.0000067	0.0000039	0.0000071	0.000020	0.000020	0.000020	0.000020
Silver-Ag	0.000023	0.000010	0.000012	0.000010	0.0000066	0.0000095	0.0000060	0.000010	0.0015	0.0015	0.0015	0.0015
Aluminum-Al	0.22	0.39	0.057	0.13	0.037	0.12	0.045	0.13	0.050	0.050	0.050	0.050
Arsenic-As	0.015	0.018	0.0049	0.00051	0.0030	0.00088	0.0031	0.0010	0.0050	0.0050	0.0050	0.0050
Barium-Ba	0.35	0.58	0.10	0.026	0.063	0.032	0.075	0.036	1.0	1.0	1.0	1.0
Beryllium-Be	0.000048	0.000076	0.00037	0.00019	0.00017	0.00019	0.00017	0.00020	No WQG			
Boron-B			0.13	0.0060	0.058	0.014	0.058	0.015	1.2	1.2	1.2	1.2
Calcium-Ca	148	260	35	11	23	13	29	15	No direct WQO (part of Hardness)			
Cadmium-Cd	0.00088	0.0016	0.000068	0.000053	0.00007	0.000056	0.00011	0.000067	0.000036	0.000017	0.000045	0.000017
Cobalt-Co	0.011	0.021	0.0018	0.00010	0.0014	0.00030	0.0019	0.00041	0.0040	0.0040	0.0040	0.0040
Chromium-Cr	0.00035	0.00044	0.00047	0.00032	0.00023	0.00031	0.00023	0.00033	0.0010	0.0010	0.0010	0.0010
Copper-Cu	0.032	0.0600	0.00067	0.0012	0.0019	0.0013	0.00330	0.0016	0.0044	0.0007	0.0057	0.0009
Iron-Fe	0.037	0.053	0.73	0.61	0.33	0.56	0.33	0.61	1.0	1.0	1.0	1.0
Potasium-K	30	44	1.4	0.27	2.1	0.55	2.8	0.71	No WQG			
Lithium-Li	0.022	0.042	0.069	0.0025	0.032	0.0070	0.033	0.0078	0.087	0.087	0.087	0.087
Magnesium-Mg	110	210	15	2.6	12	4.1	17	5.3	No direct WQO (part of Hardness)			
Manganese-Mn	0.76	1.5	0.73	0.10	0.36	0.14	0.40	0.16	1.1	0.68	1.2	0.71
Molybdenum-Mo	0.17	0.28	0.0068	0.000055	0.012	0.0018	0.017	0.0029	1.0	1.0	1.0	1.0
Sodium-Na	26	21	101	2.4	47	9.2	47	10.0	No WQG			
Nickel-Ni	0.018	0.033	0.0025	0.0012	0.0020	0.0013	0.0028	0.0015	0.15	0.15	0.15	0.15
Lead-Pb	0.0047	0.0092	0.00021	0.000061	0.00033	0.00010	0.00056	0.00015	0.0069	0.0036	0.008	0.0038
Antimony-Sb	0.023	0.042	0.00021	0.000040	0.0012	0.00022	0.0022	0.00040	0.020	0.020	0.020	0.020
Selenium-Se	0.0098	0.019	0.00024	0.00023	0.00060	0.00028	0.0011	0.00038	0.0020	0.0020	0.0020	0.0020
Silicon-Si	2.9	3.6	5.4	2.9	2.6	2.8	2.6	3.1	No WQO			
Tin-Sn			0.42	0.000050	0.19	0.029	0.19	0.031	No WQO			
Vanadium-V	0.00040	0.00029	0.00070	0.00046	0.00033	0.00044	0.00033	0.00048	No WQO			
Zinc-Zn	0.22	0.44	0.0045	0.0016	0.013	0.0034	0.024	0.0055	0.022	0.0075	0.047	0.0075
Hardness	821	1,500	150		109	17	143	24				

BCWQG based on 30 day mean where available.
Shading indicates exceedance of BCWQGs .

Table 7.6 Upper Bound Groundwater Sensitivity Analysis Surface Water Quality in Stream MCS-7 Downstream of the TSF at Low and Average Flow Conditions –

Parameter (mg/L, except pH) (Total Concentrations, except Al)	TSF Porewater		Baseline Water Quality		Expected Case Water Quality MCS-7		Upper Bound Water Quality MCS-7		BCWQG's Expected Case		BCWQGs Upper Bound	
	EC	UB	Groundwater	Surface	Low	Average	Low	Average	Low	Average	Low	Average
pH	8.2	7.9	8.3	8.0	8.0	8.0	8.0	8.0	6.5-9	6.5-9	6.5-9	6.5-9
Alkalinity ($CaCO_3$)	96	100	327	65	258	76	259	76	10	10	10	10
Flouride-F	0.47	0.55	1.3	0.064	1.1	0.12	1.1	0.12	30	30	30	30
Chloride-CI	20	5.9	1.8	0.31	7.3	0.72	3.1	0.47	150	150	150	150
Sulphate-SO_4	887	1,700	65	5.9	312	24	556	38	100	100	100	100
Nitrite-NO_2	0.030	0.10	0.0018	0.088	0.0103	0.083	0.0313	0.084	0.073	0.020	0.031	0.020
Nitrate-NO_3	0.33	3.50	0.016	0.51	0.11	0.49	1.061	0.54	13	13	13	13
Ammonia-NH_3	0.096	1.40	0.073	0.0054	0.080	0.0097	0.471	0.0326	1.6	1.6	1.6	1.6
Mercury-Hg	0.000028	0.0000050	0.0000080	0.0000069	0.000014	0.0000073	0.0000071	0.0000069	0.000020	0.000020	0.000020	0.000020
Silver-Ag	0.000023	0.000010	0.000012	0.0000064	0.000015	0.0000069	0.000012	0.0000067	0.0015	0.0015	0.0015	0.0015
Aluminum-Al	0.22	0.50	0.057	0.047	0.11	0.050	0.19	0.055	0.050	0.050	0.050	0.050
Arsenic-As	0.015	0.036	0.0049	0.00030	0.0079	0.00075	0.0142	0.00111	0.0050	0.0050	0.0050	0.0050
Barium-Ba	0.35	0.58	0.10	0.024	0.18	0.033	0.25	0.037	1.0	1.0	1.0	1.0
Beryllium-Be	0.000048	0.000076	0.00037	0.00031	0.00027	0.00031	0.00028	0.00031	No WQG			
Boron-B			0.13	0.026	0.091	0.030	0.091	0.030	1.2	1.2	1.2	1.2
Calcium-Ca	148	260	35	19	69	22	103	24	No direct WQO (part of Hardness)			
Cadmium-Cd	0.00088	0.0016	0.000068	0.00000098	0.00031	0.000019	0.00053	0.000032	0.000098	0.000028	0.00014	0.000031
Cobalt-Co	0.011	0.021	0.0018	0.000077	0.0046	0.00034	0.0076	0.00052	0.0040	0.0040	0.0040	0.0040
Chromium-Cr	0.00035	0.00044	0.00047	0.00032	0.00043	0.00033	0.00046	0.00033	0.0010	0.0010	0.0010	0.0010
Copper-Cu	0.032	0.0600	0.00067	0.00094	0.0101	0.0015	0.0185	0.00196	0.0141	0.0032	0.0222	0.0037
Iron-Fe	0.037	0.053	0.73	0.072	0.52	0.10	0.53	0.10	1.0	1.0	1.0	1.0
Potasium-K	30	44	1.4	0.50	10.0	1.1	14	1.3	No WQG			
Lithium-Li	0.022	0.042	0.069	0.0025	0.055	0.0056	0.061	0.0059	0.087	0.087	0.087	0.087
Magnesium-Mg	110	210	15	3.9	44	6.2	74	8.0	No direct WQO (part of Hardness)			
Manganese-Mn	0.76	1.5	0.73	0.0033	0.74	0.046	0.96	0.059	2.2	0.96	3.0	1.0
Molybdenum-Mo	0.17	0.28	0.0068	0.00017	0.056	0.0034	0.089	0.0053	1.0	1.0	1.0	1.0
Sodium-Na	26	21	101	4.4	79	8.7	77	8.6	No WQG			
Nickel-Ni	0.018	0.033	0.0025	0.00039	0.0071	0.00078	0.012	0.0010	0.15	0.15	0.15	0.15
Lead-Pb	0.0047	0.0092	0.00021	0.00017	0.0016	0.00025	0.0029	0.00033	0.019	0.0057	0.032	0.0062
Antimony-Sb	0.023	0.042	0.00021	0.000041	0.0070	0.00045	0.013	0.00078	0.020	0.020	0.020	0.020
Selenium-Se	0.0098	0.019	0.00024	0.00034	0.0031	0.00050	0.0059	0.00066	0.0020	0.0020	0.0020	0.0020
Silicon-Si	2.9	3.6	5.4	2.7	4.6	2.8	4.8	2.8	No WQO			
Tin-Sn			0.42	0.00011	0.29	0.017	0.29	0.017	No WQO			
Vanadium-V	0.00040	0.00029	0.00070	0.0043	0.00061	0.0041	0.00058	0.0041	No WQO			
Zinc-Zn	0.22	0.44	0.0045	0.0013	0.069	0.0053	0.14	0.0092	0.20	0.0075	0.36	0.0095
Hardness	821	1,500	150	64	352	81	555	93				

BCWQG based on 30 day mean where available.
Shading indicates exceedance of BCWQGs .

Table 7.7 Upper Bound Groundwater Sensitivity Analysis -Surface Water Quality in Stream MCS-8 Downstream of the TSF at Low and Average Flow Conditions

Parameter (mg/L, except pH) (Total Concentrations, except Al)	TSF Porewater		Baseline Water Quality		Expected Case Water Quality MCS-8		Upper Bound Water Quality MCS-8		BCWQG's Expected Case		BCWQGs Upper Bound	
	EC	UB	Groundwater	Surface	Low	Average	Low	Average	Low	Average	Low	Average
pH	8.2	7.9	8.3	8.0	8.0	8.0	8.0	8.0	6.5-9	6.5-9	6.5-9	6.5-9
Alkalinity ($CaCO_3$)	96	100	327	93	299	135	300	135	10	10	10	10
Flouride-F	0.47	0.55	1.3	0.081	1.2	0.31	1.2	0.32	30	30	30	30
Chloride-CI	20	5.9	1.8	0.25	4.0	1.02	2.3	0.68	150	150	150	150
Sulphate-SO_4	887	1,700	65	7.7	164	40	262	60	100	100	100	100
Nitrite-NO_2	0.030		0.0018	0.0016	0.0052	0.0023	0.0016	0.0016	0.040	0.020	0.023	0.020
Nitrate-NO_3	0.33		0.016	0.81	0.053	0.66	0.014	0.65	13	13	13	13
Ammonia-NH_3	0.096		0.073	0.0069	0.076	0.021	0.064	0.019	1.6	1.6	1.6	1.6
Mercury-Hg	0.000028	0.0000050	0.0000080	0.0000072	0.000010	0.0000079	0.0000076	0.0000073	0.000020	0.000020	0.000020	0.000020
Silver-Ag	0.000023	0.000010	0.000012	0.0000050	0.000013	0.0000067	0.000012	0.0000064	0.0015	0.0015	0.0015	0.0015
Aluminum-Al	0.22	0.50	0.057	0.017	0.077	0.029	0.110	0.036	0.050	0.050	0.050	0.050
Arsenic-As	0.015	0.036	0.0049	0.00044	0.0061	0.0016	0.0086	0.0021	0.0050	0.0050	0.0050	0.0050
Barium-Ba	0.35	0.58	0.10	0.044	0.13	0.062	0.16	0.068	1.0	1.0	1.0	1.0
Beryllium-Be	0.000048	0.000076	0.00037	0.00022	0.00033	0.00024	0.00034	0.00024	No WQG			
Boron-B			0.13	0.015	0.11	0.035	0.11	0.035	1.2	1.2	1.2	1.2
Calcium-Ca	148	260	35	28	49	32	62	35	No direct WQO (part of Hardness)			
Cadmium-Cd	0.00088	0.0016	0.000068	0.0000089	0.00017	0.000041	0.00025	0.000059	0.000068	0.000038	0.000088	0.000043
Cobalt-Co	0.011	0.021	0.0018	0.000064	0.0029	0.00065	0.0041	0.00090	0.0040	0.0040	0.0040	0.0040
Chromium-Cr	0.00035	0.00044	0.00047	0.00027	0.00045	0.00031	0.00047	0.00031	0.0010	0.0010	0.0010	0.0010
Copper-Cu	0.032	0.0600	0.00067	0.0011	0.0044	0.0018	0.00779	0.0025	0.00924	0.00473	0.01250	0.00540
Iron-Fe	0.037	0.053	0.73	0.095	0.65	0.21	0.65	0.21	1.0	1.0	1.0	1.0
Potasium-K	30	44	1.4	0.39	4.8	1.3	6.5	1.6	No WQG			
Lithium-Li	0.022	0.042	0.069	0.0025	0.063	0.015	0.066	0.016	0.087	0.087	0.087	0.087
Magnesium-Mg	110	210	15	4.9	27	9.4	39	12	No direct WQO (part of Hardness)			
Manganese-Mn	0.76	1.5	0.73	0.023	0.73	0.17	0.82	0.19	1.6	1.1	2.0	1.2
Molybdenum-Mo	0.17	0.28	0.0068	0.00014	0.026	0.0055	0.040	0.0083	1.0	1.0	1.0	1.0
Sodium-Na	26	21	101	4.5	92	23	92	22	No WQG			
Nickel-Ni	0.018	0.033	0.0025	0.00046	0.0043	0.0013	0.0061	0.0016	0.15	0.15	0.15	0.15
Lead-Pb	0.0047	0.0092	0.00021	0.000046	0.00075	0.00019	0.0013	0.00030	0.013	0.0073	0.017	0.0080
Antimony-Sb	0.023	0.042	0.00021	0.000046	0.0029	0.00064	0.0052	0.00111	0.020	0.020	0.020	0.020
Selenium-Se	0.0098	0.019	0.00024	0.00021	0.0014	0.00045	0.0025	0.00068	0.0020	0.0020	0.0020	0.0020
Silicon-Si	2.9	3.6	5.4	4.0	5.1	4.2	5.2	4.2	No WQO			
Tin-Sn			0.42	0.000050	0.37	0.075	0.37	0.075	No WQO			
Vanadium-V	0.00040	0.00029	0.00070	0.00045	0.00066	0.00049	0.00065	0.00049	No WQO			
Zinc-Zn	0.22	0.44	0.0045	0.00094	0.030	0.0070	0.057	0.012	0.11	0.029	0.17	0.041
Hardness	821	1,500	150	89	231	118	312	135				

BCWQG based on 30 day mean where available.
Shading indicates exceedance of BCWQGs .

Table 7.8 Upper Bound Groundwater Sensitivity Analysis Surface Water Quality in Stream MCS-10 Downstream of the TSF at Low and Average Flow Conditions

Parameter (mg/L, except pH) (Total Concentrations, except Al)	TSF Porewater		Baseline Water Quality		Expected Case Water Quality MCS-10		Upper Bound Water Quality MCS-10		BCWQG's Expected Case		BCWQGs Upper Bound	
	EC	UB	Groundwater	Surface	Low	Average	Low	Average	Low	Average	Low	Average
pH	8.2	7.9	8.3	7.6	8.0	8.0	8.0	8.0	6.5-9	6.5-9	6.5-9	6.5-9
Alkalinity ($CaCO_3$)	96	100	327	41	278	60	279	61	10	10	10	10
Flouride-F	0.47	0.55	1.3	0.041	0.57	0.12	0.58	0.13	30	30	30	30
Chloride-CI	20	5.9	1.8	0.25	2.8	0.64	1.3	0.45	150	150	150	150
Sulphate-SO_4	887	1,700	65	3.0	119	21	204	37	100	100	100	100
Nitrite-NO_2	0.030		0.0018	0.0018	0.0039	0.0021	0.00071	0.0018	0.028	0.020	0.020	0.020
Nitrate-NO_3	0.33		0.016	0.052	0.041	0.050	0.0062	0.049	13	13	13	13
Ammonia-NH_3	0.096		0.073	0.014	0.039	0.017	0.029	0.017	1.6	1.6	1.6	1.6
Mercury-Hg	0.000028	0.0000050	0.0000080	0.0000070	0.0000061	0.0000069	0.0000037	0.0000070	0.000020	0.000020	0.000020	0.000020
Silver-Ag	0.000023	0.000010	0.000012	0.000010	0.0000072	0.0000096	0.0000059	0.000010	0.0015	0.0015	0.0015	0.0015
Aluminum-Al	0.22	0.50	0.057	0.13	0.046	0.12	0.075	0.14	0.050	0.050	0.050	0.050
Arsenic-As	0.015	0.036	0.0049	0.00051	0.0035	0.00097	0.0057	0.0014	0.0050	0.0050	0.0050	0.0050
Barium-Ba	0.35	0.58	0.10	0.026	0.077	0.034	0.101	0.041	1.0	1.0	1.0	1.0
Beryllium-Be	0.000048	0.000076	0.00037	0.00019	0.00015	0.00018	0.00015	0.00020	No WQG			
Boron-B			0.13	0.0060	0.051	0.013	0.051	0.014	1.2	1.2	1.2	1.2
Calcium-Ca	148	260	35	11	29	14	41	17	No direct WQO (part of Hardness)			
Cadmium-Cd	0.00088	0.0016	0.000068	0.000053	0.00012	0.000063	0.00019	0.000081	0.000046	0.000017	0.000064	0.000017
Cobalt-Co	0.011	0.021	0.0018	0.00010	0.0019	0.00038	0.0029	0.00058	0.0040	0.0040	0.0040	0.0040
Chromium-Cr	0.00035	0.00044	0.00047	0.00032	0.00022	0.00030	0.00023	0.00033	0.0010	0.0010	0.0010	0.0010
Copper-Cu	0.032	0.0600	0.00067	0.0012	0.0036	0.0016	0.00656	0.0022	0.0058	0.0009	0.0087	0.0014
Iron-Fe	0.037	0.053	0.73	0.61	0.29	0.56	0.30	0.60	1.0	1.0	1.0	1.0
Potasium-K	30	44	1.4	0.27	3.7	0.79	5.2	1.10	No WQG			
Lithium-Li	0.022	0.042	0.069	0.0025	0.030	0.0066	0.032	0.0075	0.087	0.087	0.087	0.087
Magnesium-Mg	110	210	15	2.6	18	4.9	28	7.1	No direct WQO (part of Hardness)			
Manganese-Mn	0.76	1.5	0.73	0.10	0.37	0.14	0.44	0.17	1.2	0.70	1.6	0.76
Molybdenum-Mo	0.17	0.28	0.0068	0.000055	0.021	0.0032	0.032	0.0054	1.0	1.0	1.0	1.0
Sodium-Na	26	21	101	2.4	43	8.6	42	9.2	No WQG			
Nickel-Ni	0.018	0.033	0.0025	0.0012	0.0029	0.0014	0.0044	0.0018	0.15	0.15	0.15	0.15
Lead-Pb	0.0047	0.0092	0.00021	0.000061	0.00058	0.00014	0.00105	0.00023	0.0084	0.0038	0.012	0.0042
Antimony-Sb	0.023	0.042	0.00021	0.000040	0.0025	0.00042	0.0045	0.00078	0.020	0.020	0.020	0.020
Selenium-Se	0.0098	0.019	0.00024	0.00023	0.00112	0.00036	0.0021	0.00055	0.0020	0.0020	0.0020	0.0020
Silicon-Si	2.9	3.6	5.4	2.9	2.4	2.8	2.5	3.1	No WQO			
Tin-Sn			0.42	0.000050	0.16	0.025	0.16	0.027	No WQO			
Vanadium-V	0.00040	0.00029	0.00070	0.00046	0.00032	0.00044	0.00031	0.00047	No WQO			
Zinc-Zn	0.22	0.44	0.0045	0.0016	0.025	0.0052	0.048	0.0095	0.049	0.0075	0.103	0.0075
Hardness	821	1,500	150		146	22	217	36				

BCWQG based on 30 day mean where available.
Shading indicates exceedance of BCWQGs .

7.1.3 Summary of Stream Effects

The predicted stream water quality exceeds BCWQGs for a number of parameters, principally for the low flow condition, and occasionally for the average flow condition. The parameters of potential concern include: sulphate, nitrate, aluminum, arsenic, cadmium, cobalt and selenium. Nitrate concentrations exceed BCWQGs during average flow due to the elevated baseline surface water quality, which exceeds BCWQGs. In the baseline groundwater quality, aluminum and cadmium exceed BCWQGs and arsenic is within 2% of BCWQGs. All parameters, with the exception of sulphate for the Upper Bound groundwater model sensitivity case with the Upper Bound geochemical loading, meet the preliminary proposed water quality objectives (PPWQOs) presented in Section 5.9 of this report. The probability of the Upper Bound groundwater flows and Upper Bound TSF pore water quality, occurring together is low. Additionally, the streams typically freeze in winter and fish use is limited during that period.

7.2 Water Quality Effects on Morrison Lake

7.2.1 General

Water quality effects on the overall Morrison Lake water quality have been made on the basis of lake modeling of the diffuser and groundwater flows. The assessment has been carried out by Dr. Greg Lawrence of the University of British Columbia and the report is included in Appendix V. Baseline water quality data for Morrison Lake and the mine area groundwater are included in Appendix VI.

The potential for TSF seepage flows to impact sockeye salmon spawning beds located near the mouth of Stream MCS-7 has been assessed on the basis of contaminant transport modeling to determine the spatial and temporal effect of seepage.

7.2.2 Morrison Lake Modeling

The model predicts the lake wide concentrations at fall turnover, at the end of winter (Cw) and the end of spring. It also predicts the epilimnetic and hypolimnetc concentrations at the end of summer (Ch). Depending on the relative flows rate and concentrations in the water treatment plant (WTP), PAG porewater from the open pit, and TSF seepage inflows, the maximum concentrations occur at the end of winter. Concentrations in the immediate vicinity of the diffuser will be greater. The diffuser will be engineered to achieve a dilution of greater that 100:1 at the edge of the mixing zone (location where dilution is 100:1). The typical size of the plume, to achieve the 100:1 dilution, will be a vertical ellipse with a width of approximately 5 m and a height of 40 m.

Temporal Effects of Loads on Morrison Lake

The temporal effects of loading on the lake are dependent upon when the water treatment plant is implemented and the lag time for groundwater seepage from the TSF to reach the lake. The temporal distribution of TSF seepage is discussed in Section 7.2.3 of this report and included in Appendix I. The distribution for the Expected Case can be simplified as starting in Year 25, peaking in Year 50 and decreasing to Year 100 as shown in Figure 7.1.

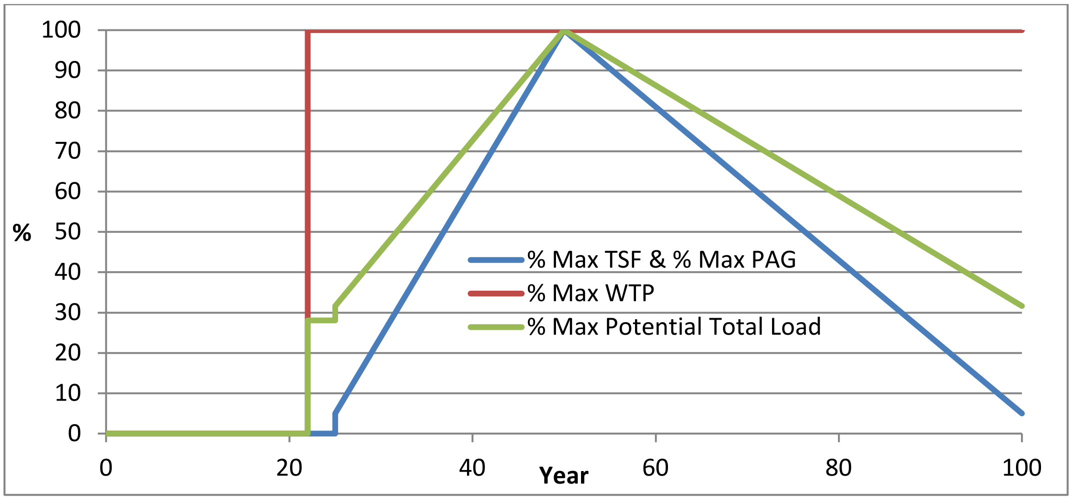


Figure 7.1 Temporal Distribution of Loading Sources to Morrison Lake

The temporal effect on the lake water quality for end of winter (Cw) and end of summer (Ch), for cadmium, is shown in Figure 7.2 for the Expected Case and in Figure 7.3 for the Upper Bound case. Model outputs for other parameters are included in Appendix V.

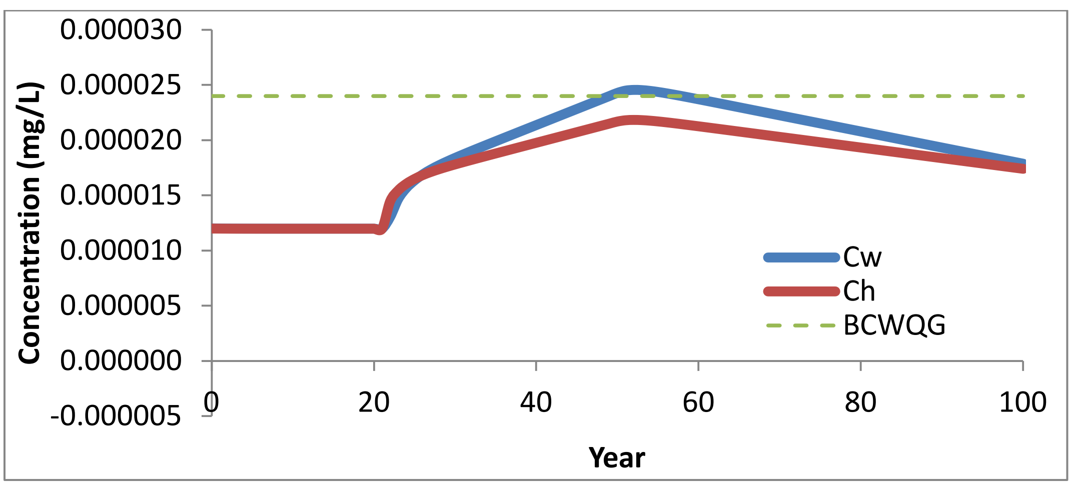


Figure 7.2 Morrison Lake Water Quality with Time – Expected Case – Cadmium

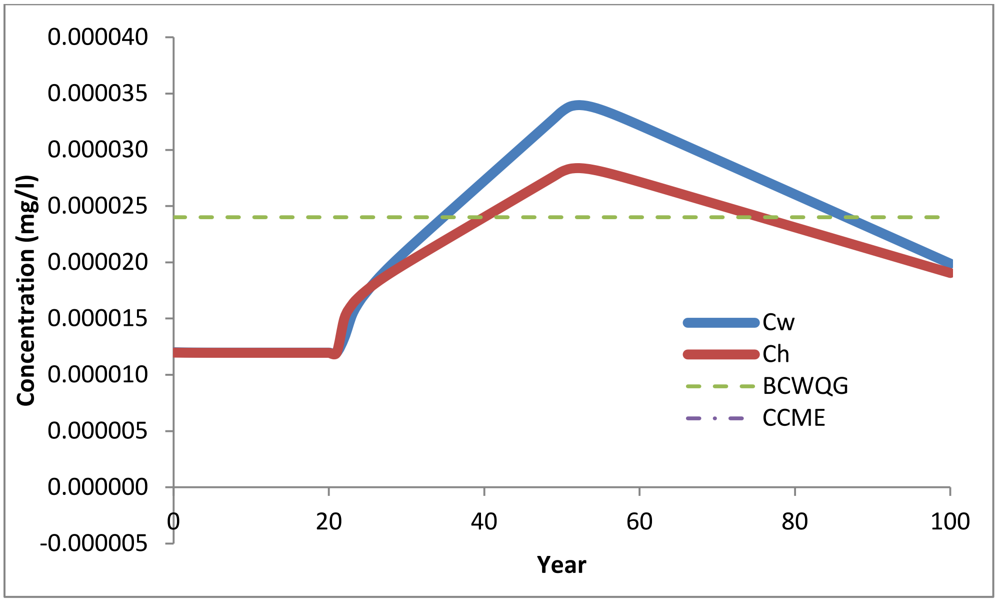


Figure 7.3 Morrison Lake Water Quality with Time – Upper Bound - Cadmium

The predicted Morrison Lake water quality meets all BCWQGs for the Expected Case and slightly exceeds the guideline for the Upper Bound case. The sensitivity run for the Upper Bound includes a combined Upper Bound groundwater modeled flows with Upper Bound TSF seepage water quality, and the results for the Upper Bound are summarized in Table 7.9. The likelihood of the Upper Bound groundwater model combined with the Upper Bound TSF porewater quality occurring together is low. In addition, cadmium will be absorbed on the glacial till clays – further reducing the likelihood of the occurrence.

Table 7.9 Sensitivity Run for Upper Bound Concentrations (mg/L) of Key Parameters in Morrison Lake

Parameter	WTP	PAG	TSF	Baseline	Maximum Background	Maximum Edge of Mixing Zone	BCWQG	CCME
Flow Rate m^3/hr	172	0.4	137					
Nitrate	90	90	1	0.038	1.19	2.08	13.3	13
Sulphate	2000	4000	1700	2.3	44	64	100	
Aluminum	0.46	0.41	0.39	0.033	0.043	0.047	0.05	0.1
Cadmium	0.0005	0.0042	0.0016	0.000012	0.000034	0.000039	0.000024	
Copper	0.007	0.032	0.06	0.011	0.0116	0.0116	0.0036	0.004
Iron	0.02	0.02	0.053	0.17	0.17	0.17	0.15	0.3
Magnesium	210	210	210	1.9	6.6	8.6		
Selenium	0.0019	0.0023	0.019	0.00014	0.00018	0.00020	0.002	0.001
Zinc	0.02	0.064	0.44	0.0016	0.0061	0.0063	0.0075	0.0075

Notes:
1. Shaded boxes indicate exceedance of BCWQGs.
2. Guidelines based on lake hardness 90 mg/L (compared to baseline hardness of 29 mg/L.

Discussion on Conceptual Diffuser Design to Optimize Mixing

Effective dilution of discharge from the proposed water treatment plant into Morrison Lake can be achieved using a multiport diffuser; i.e., a pipe resting on the bottom of the lake with a series of ports through which treated wastewater jets into the lake. For the sake of simplicity one can assume that the jets discharge vertically[1], and that the ports are spaced uniformly with a separation such that they merge into a “line” source. The behavior of the resulting jet is determined by the initial fluxes of momentum and buoyancy (m and b) per unit length of diffuser (the length of pipe containing discharge ports), where:

$$m = \frac{Q^2}{L \sum A_p}$$

and

[1] Other more efficient designs are possible, but the purpose of this discussion is to summarize the basic factors that will influence the design and effectiveness of the diffuser.

$$b = \frac{g_o' Q}{L}$$

where: Q is the total volumetric discharge from the wastewater treatment plant;
L is the length of the diffuser;
$\sum A_p$ is the total cross-section area of the diffuser ports; and
the reduced gravitational acceleration:

$$g_o' = \frac{(\rho_L - \rho_{WTP})}{\rho_L} g$$

where: ρ_L is the density of the lakewater at the depth of the diffuser;
ρ_{WTP} is the density of the treated wasterwater; and
g is the gravitational acceleration.

In the case of the proposed Morrison Lake project it is probable that $\rho_{WTP} > \rho_L$ and the buoyancy flux will be negative. The momentum flux will need to be high enough to prevent the denser treated wastewater from accumulating at the bottom of the lake. This will be achieved by designing the diffuser so that the jet will reach the surface of the lake; i.e.:

$$\frac{m}{b^{2/3}} > H$$

where: H is the depth of the lake.

Substituting from above yields:

$$\left(\frac{Q^2}{g_o'}\right)^{2/3} \left(\frac{1}{\sum A_p \sqrt[3]{L}}\right) > H$$

Choosing a sufficiently low total port area, which increases the momentum flux without altering the buoyancy flux, can most readily satisfy this criterion. There is a potential cost associated with the design in that a low total port area will require a low cross-section area of the delivery pipe, which will increase the head loss in the pipe. The water treatment plant will need to be located high enough above the lake surface to provide the required head, or the treated water will need to be pumped through the outfall.

The above criterion will ensure that the jet reaches the surface of the lake. The dilution that will be achieved is given by:

$$S = 0.5\sqrt{\frac{HL}{\sqrt{A_P}}}$$

Thus, by appropriate choice of L and $\sqrt{A_P}$ the desired dilution can be achieved, in practical terms a dilution of 100:1 should not be difficult to achieve.

In the summer the diluted treated water is assumed to mix throughout the hypolimnion of the lake, and in the winter it is assumed to mix throughout the entire lake. If this is not the case; for example, if the mixed fluid does not reach the small northern and southern basins of the lake, or if a hypolimnion persists in winter, the maximum concentrations will either not increase, or only increase marginally.

The results give above are derived from equations given in “Mixing in Inland and Coastal Waters” with by Fisher et al. and published by Academic Press, Inc in 1979.

7.2.3 Potential TSF Seepage Effects to Salmon Spawning Habitat

The potential seepage effects to the salmon spawning habitat in Morrison Lake, which has been documented to the south of the mouth of Stream 7, has been assessed on the basis of the contaminant transport model for the groundwater modeling of the TSF. The TSF affected emergent groundwater may enter Morrison Lake within an area along the shoreline. The groundwater will mix with the lake water and the predicted effects of this are described under the lake water quality modeling in the previous section of this report. The emergent groundwater also has a potential to affect the water quality in the sand and gravel salmon spawning beds. The mixing of the groundwater with the lake water could be expected to be less effective within the sand and gravels, which form the habitat for spawning sockeye alevins (egg stage). Consequently, the water quality within the sands and gravels could be assumed to vary from the emergent groundwater at the base of the sands and gravels (say 1 m below lakebed level) to lake water quality at the surface of the sands and gravels. A schematic of the lakebed illustrating the spawning areas and water quality influences are shown on Figure 7.4. A plan showing observed and potential salmon spawning beds is shown on Figure 7.5.

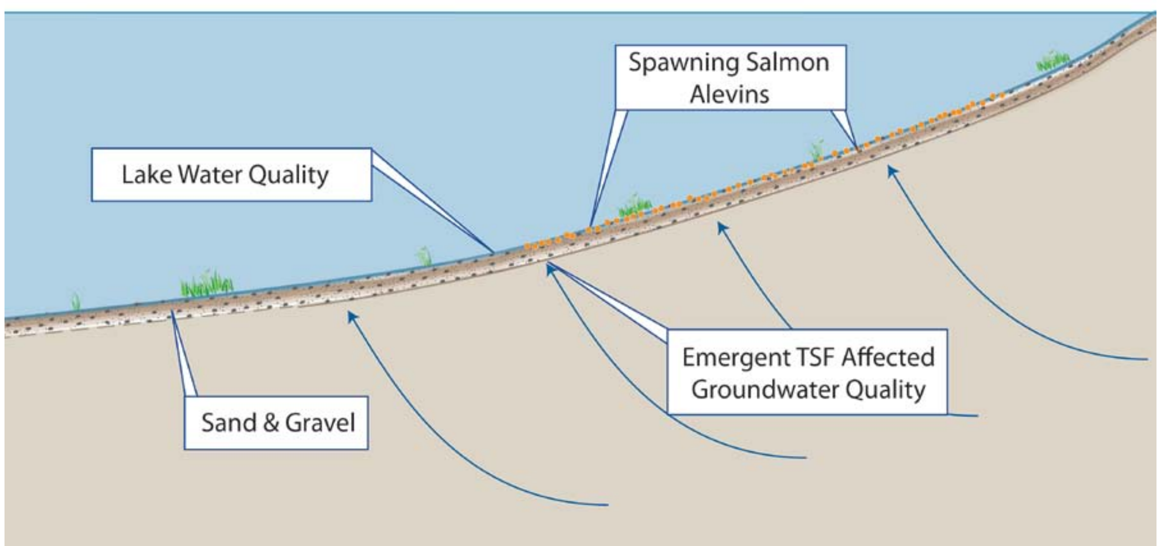


Figure 7.4 Illustration of Morrison Lakebed Spawning Habitat

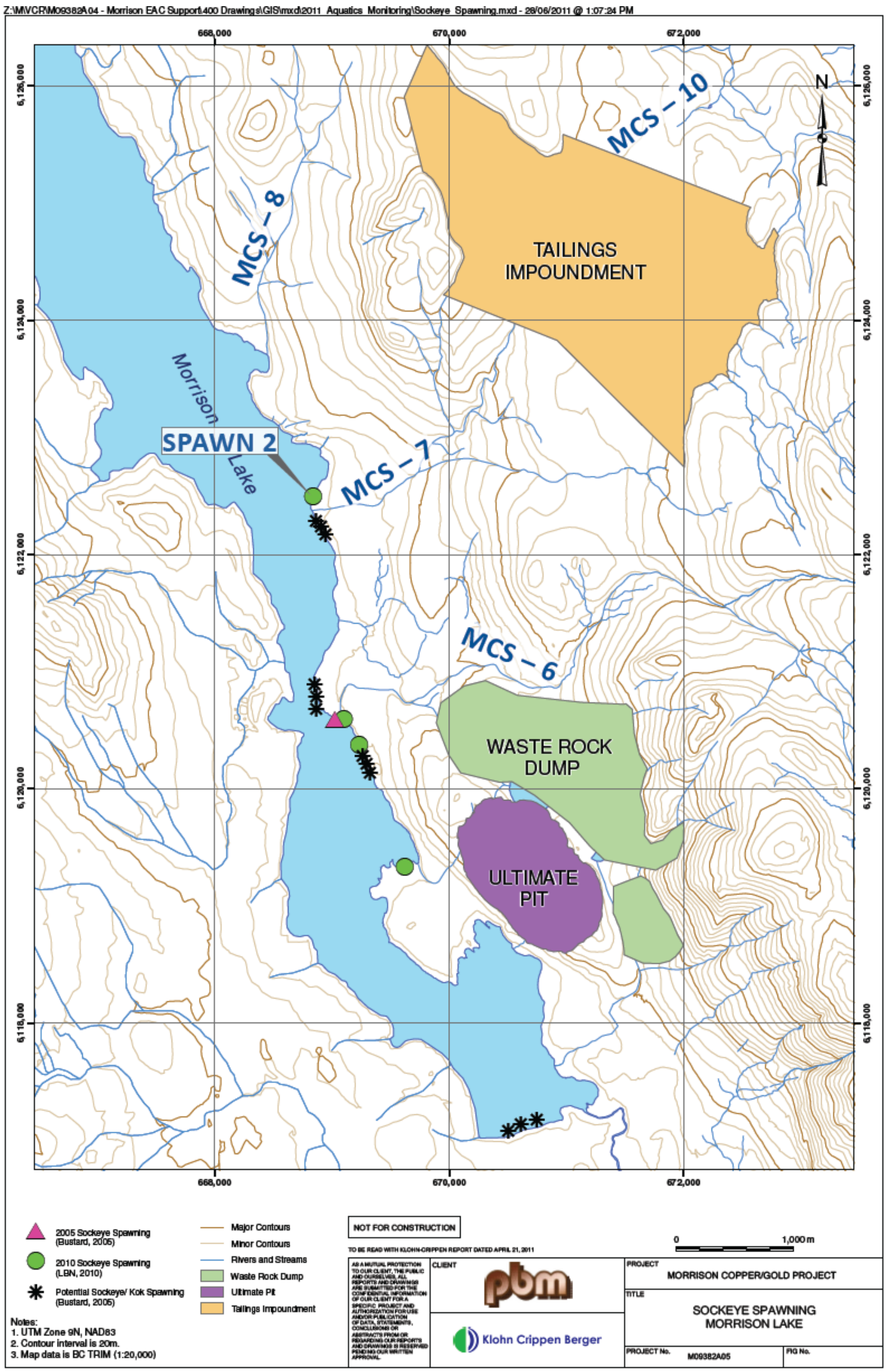


Figure 7.5 Sockeye Spawning Locations – Morrison Lake

Contaminant transport modeling has been carried out to assess the temporal and spatial extent of the groundwater plume from the TSF to Morrison Lake. For contaminant transport modeling, the Expected Case and Upper Bound groundwater models were run for the full TSF model for 25 years with the Expected Case water quality source terms. The groundwater plume concentrations were then input into the closure model run (Year 25 to steady state (approximately Year 100)). The closure model run utilized a sulphate concentration of 50 mg/L in the closure TSF pond. The models were run for the Expected Case and Upper Bound groundwater model conditions and results are included in Appendix I. A printout of the sulphate plume in the groundwater in Year 75, for the Expected Case, is shown in plan view in Figure 7.6.

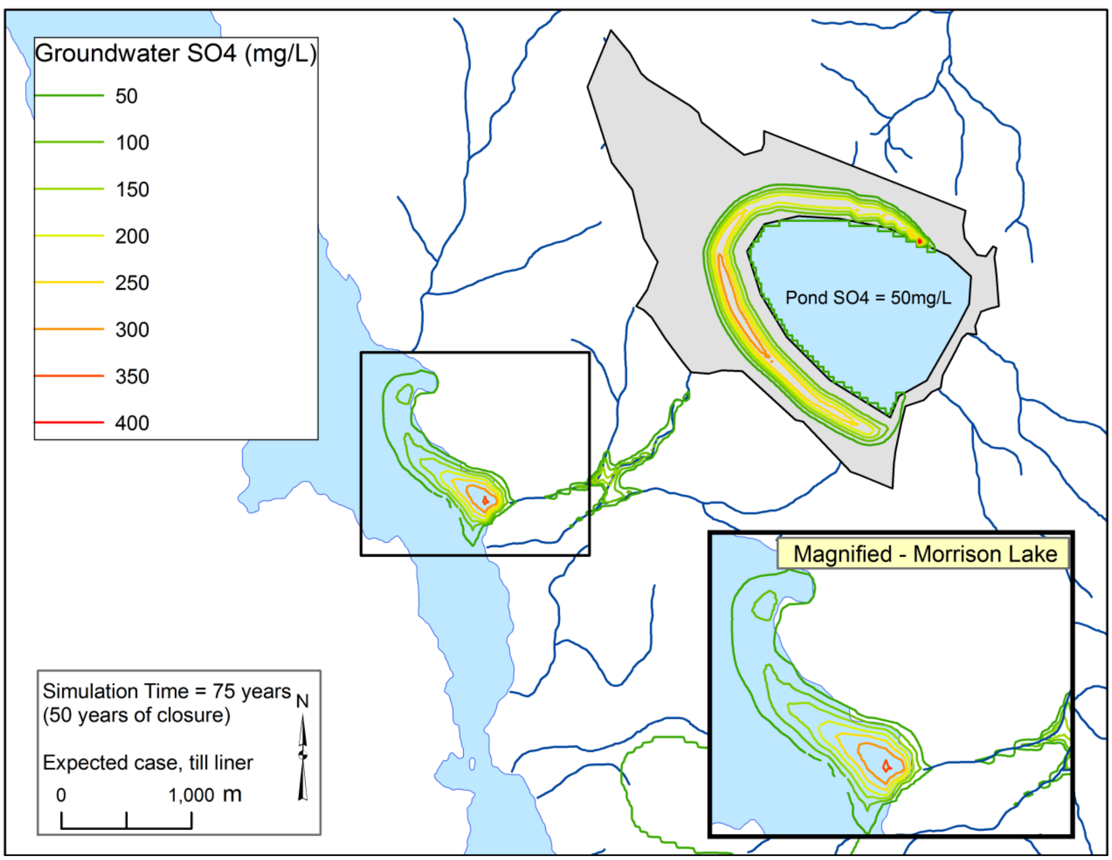


Figure 7.6 Plan of Sulphate Plume at Year 75 – Expected Case

Four locations were selected in Morrison Lake, as shown in Figure 7.7, which are representative of the spatial extent of the potential groundwater plume. Sites: Spawn 1 is located mid-zone in the plume; Spawn 2 is located in an area of potential salmon spawning habitat and Spawn 3 is located in an area of mapped salmon spawning habitat, as shown in Figure 7.5. Spawn 4 is in the center of the highest plume concentration. Spawn 3 is located just south of the area with identified potential salmon spawning habitat.

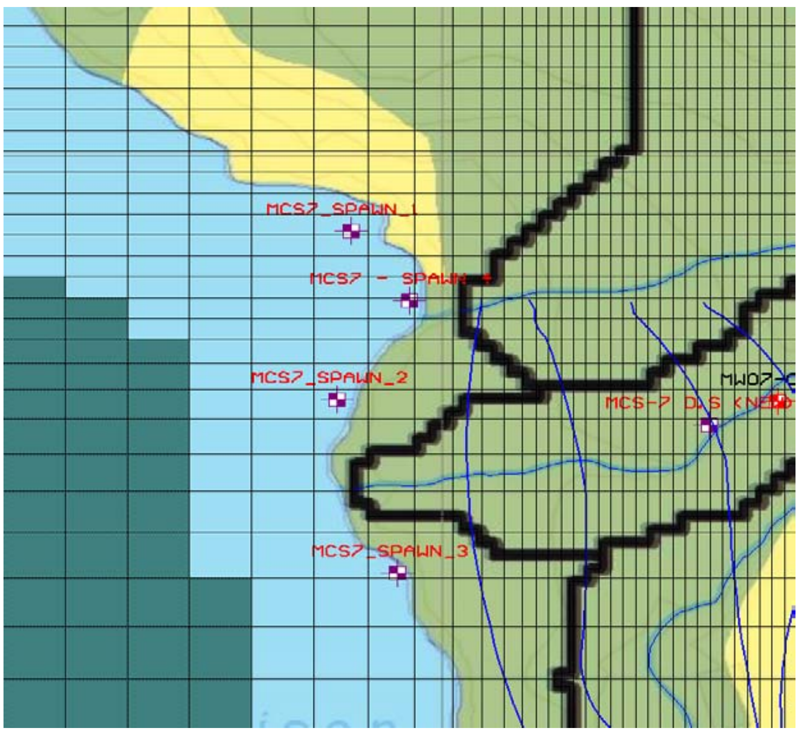


Figure 7.7 Morrison Lake Salmon Spawning Groundwater Observation Locations

Predicted sulphate concentrations at 2 m below lakebed are shown in Figure 7.8, Figure 7.9, Figure 7.10 and Figure 7.11 for the four spawning observation points.

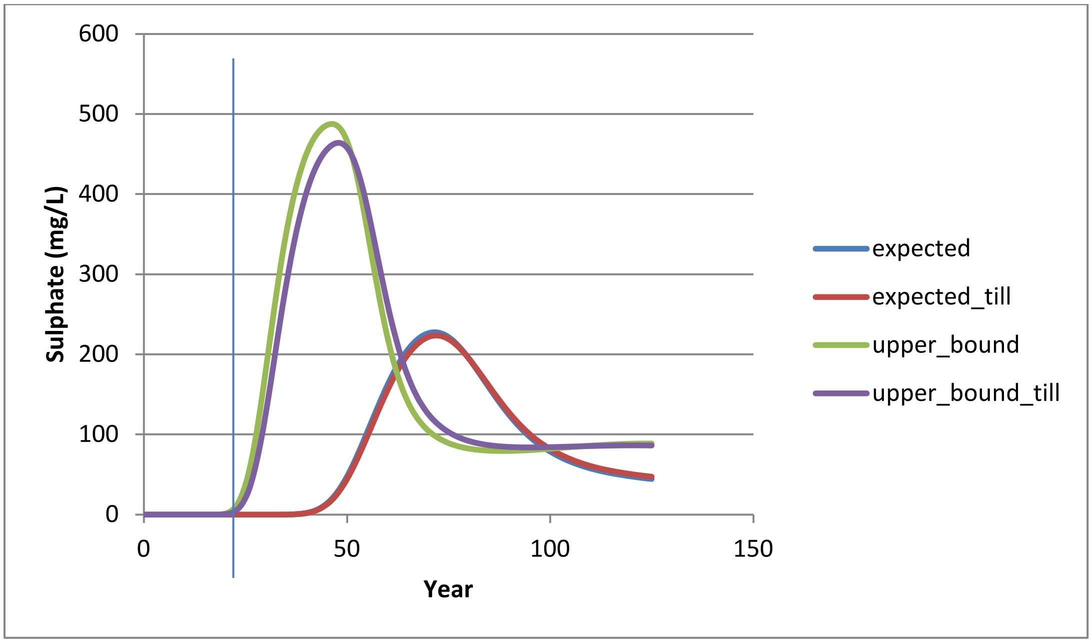


Figure 7.8 Sulphate Concentrations at Morrison Lake – Spawn 1 Location

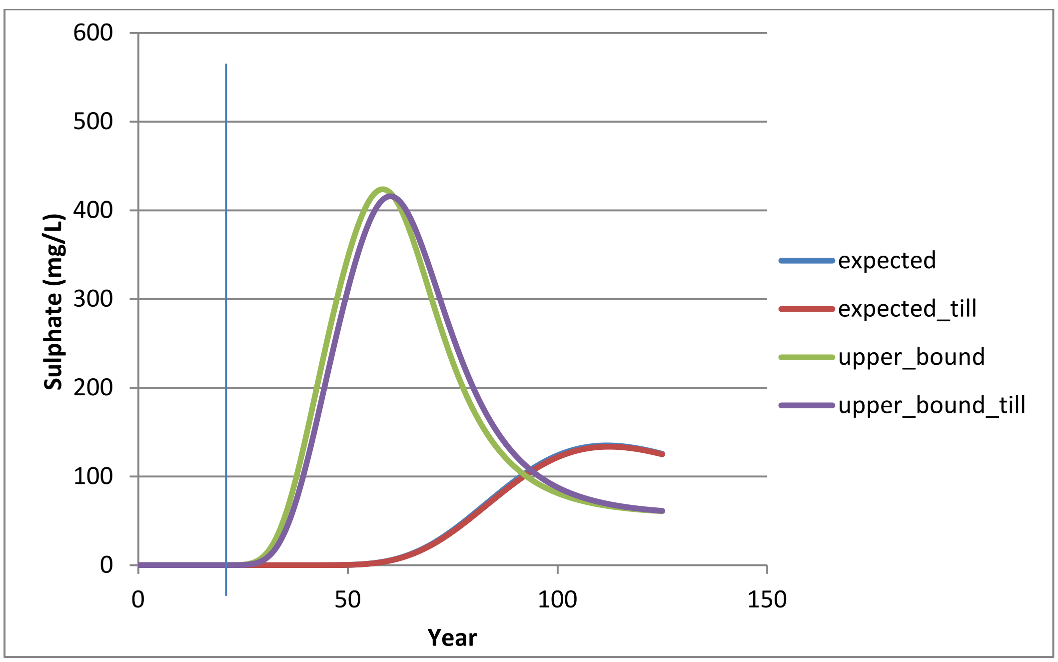


Figure 7.9 Sulphate Concentrations at Morrison Lake – Spawn 2 Location

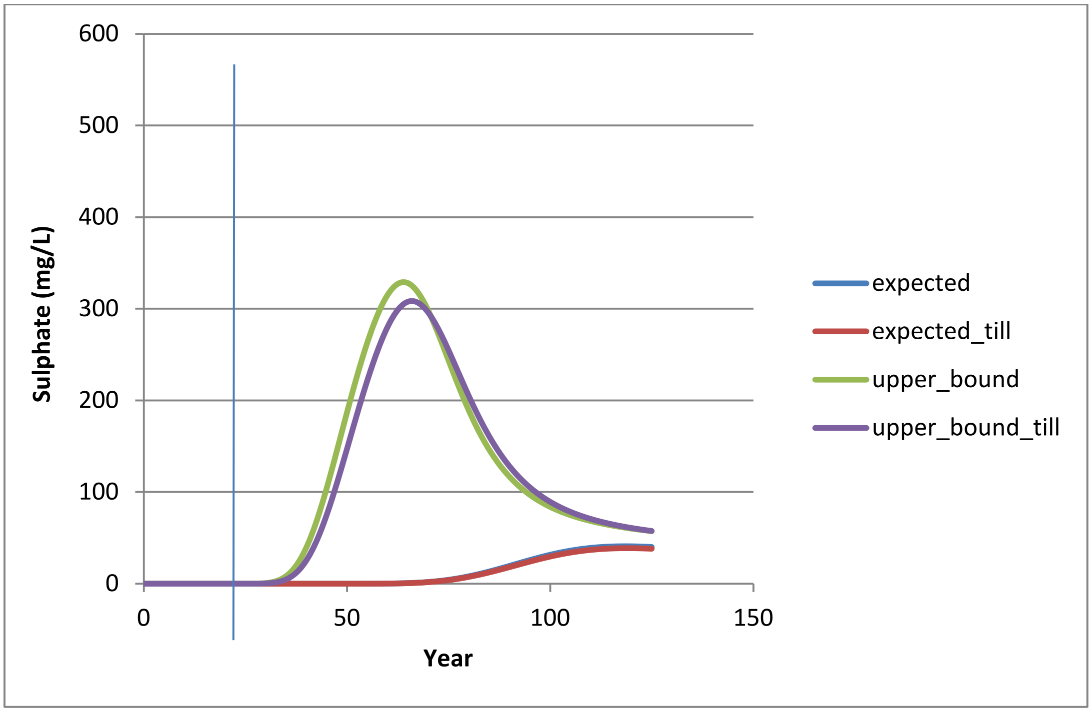


Figure 7.10 Sulphate Concentrations at Morrison Lake – Spawn 3 Location

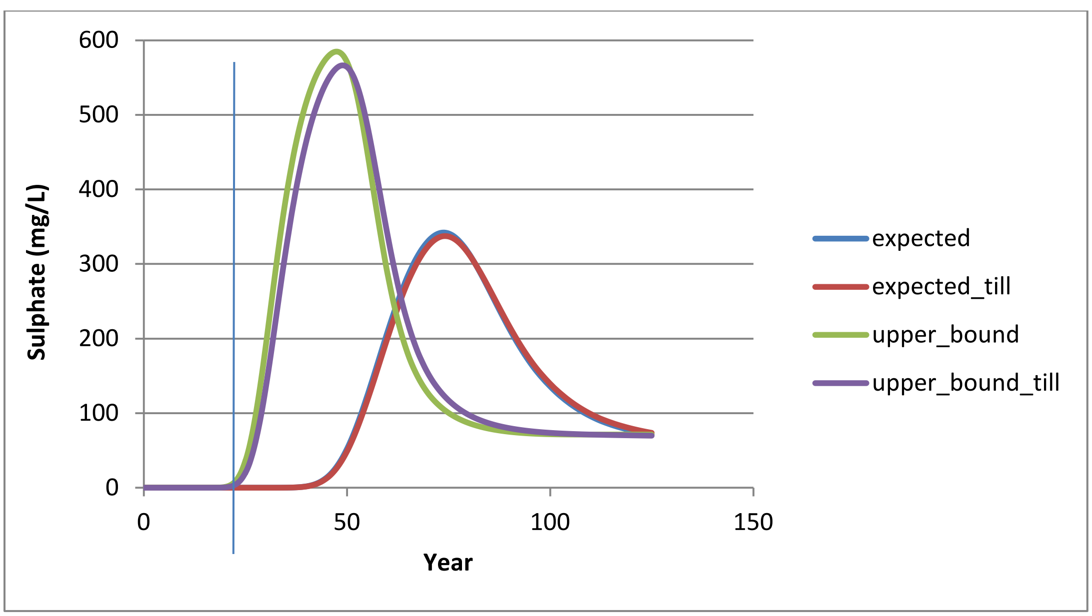


Figure 7.11 Sulphate Concentrations at Morrison Lake – Spawn 4 Location

Prediction of other water quality parameters at the Spawn 2 location, which is the confirmed salmon spawning area, have been carried out using sulphate as the surrogate parameter and varying the % solute in the stream modeling worksheets to simulate the predicted sulphate concentration. Predicted water quality for the Expected Case groundwater conditions are shown in Table 7.10 for both the Expected Case and Upper Bound TSF porewater quality.

Table 7.10 Peak Groundwater Concentrations in Spawn 2 – Expected Groundwater Model Case

Parameter (mg/L, except pH) (Total Concentrations, except Al)	TSF Porewater		Baseline Water Quality	Expected Case Water Quality	Upper Bound Water Quality	BCWQG's Expected Case	BCWQGs Upper Bound	PPWQOs	
	EC	UB	Groundwater					Expected Case	Upper Bound
pH	8.2	7.9	8.3	8.0	8.0	6.5-9	6.5-9		
Alkalinity ($CaCO_3$)	96	100	327	253	254	10	10		
Flouride-F	0.47	0.55	1.3	1.0	1.1	30	30		
Chloride-CI	20	5.9	1.8	7.6	3.1	150	150		
Sulphate-SO_4	887	1,700	65	328	588	100	100	360	460
Nitrite-NO_2	0.030	0.10	0.0018	0.0108	0.0332	0.076	0.031		
Nitrate-NO_3	0.33	3.50	0.016	0.12	1.131	13	13		
Ammonia-NH_3	0.096	1.40	0.073	0.080	0.497	1.6	1.6		
Mercury-Hg	0.000028	0.0000050	0.0000080	0.000014	0.0000070	0.000020	0.000020		
Silver-Ag	0.000023	0.000010	0.000012	0.000016	0.000011	0.0015	0.0015		
Aluminum-Al	0.22	0.39	0.057	0.11	0.16	0.050	0.050	0.233	0.233
Arsenic-As	0.015	0.018	0.0049	0.0081	0.0091	0.0050	0.0050	0.055	0.055
Barium-Ba	0.35	0.58	0.10	0.18	0.26	1.0	1.0		
Beryllium-Be	0.000048	0.000076	0.00037	0.00027	0.00028	No WQG			
Boron-B			0.13	0.088	0.088	1.2	1.2		
Calcium-Ca	148	260	35	71	107	No direct WQO (part of Hardness)			
Cadmium-Cd	0.00088	0.0016	0.000068	0.00033	0.00056	0.000101	0.00015	0.7	0.001
Cobalt-Co	0.011	0.021	0.0018	0.0048	0.0080	0.0040	0.0040	0.045	0.045
Chromium-Cr	0.00035	0.00044	0.00047	0.00043	0.00046	0.0010	0.0010		
Copper-Cu	0.032	0.0600	0.00067	0.0107	0.0197	0.0146	0.0233		
Iron-Fe	0.037	0.053	0.73	0.51	0.52	1.0	1.0		
Potasium-K	30	44	1.4	10.5	15		No WQG		
Lithium-Li	0.022	0.042	0.069	0.054	0.060	0.087	0.087		
Magnesium-Mg	110	210	15	46	78	No direct WQO (part of Hardness)			
Manganese-Mn	0.76	1.5	0.73	0.74	0.97	2.2	3.2		
Molybdenum-Mo	0.17	0.28	0.0068	0.059	0.094	1.0	1.0		
Sodium-Na	26	21	101	77	76	No WQG			
Nickel-Ni	0.018	0.033	0.0025	0.0074	0.012	0.15	0.15		
Lead-Pb	0.0047	0.0092	0.00021	0.0016	0.0031	0.020	0.033		
Antimony-Sb	0.023	0.042	0.00021	0.0075	0.014	0.020	0.020		
Selenium-Se	0.0098	0.019	0.00024	0.0033	0.0062	0.0020	0.0020	0.0077	0.0077
Silicon-Si	2.9	3.6	5.4	4.6	4.8	No WQO			
Tin-Sn			0.42	0.28	0.28	No WQO			
Vanadium-V	0.00040	0.00029	0.00070	0.00060	0.00057	No WQO			
Zinc-Zn	0.22	0.44	0.0045	0.073	0.14	0.21	0.38		
Hardness	821	1,500	150	365	582				

Note: Shaded parameters exceed PPWQOs

An Upper Bound sensitivity case, using the Upper Bound groundwater model and the Upper Bound TSF concentrations was run for the Spawn 4 location, which indicated the highest plume concentration, and the results are presented in Table 7.11.

Table 7.11 Peak Groundwater Concentrations in Spawn 4 – Sensitivity Run with Upper Bound Groundwater Model and Upper Bound TSF Water Quality

Parameter (mg/L, except pH) (Total Concentrations, except Al)	TSF Porewater		Baseline Water Quality	Expected Case Water Quality	Upper Bound Water Quality	BCWQG's Expected Case	BCWQGs Upper Bound	PPWQOs	
	EC	UB	Groundwater					Expected Case	Upper Bound
pH	8.2	7.9	8.3	8.0	8.0	6.5-9	6.5-9		
Alkalinity ($CaCO_3$)	96	100	327	183	185	10	10		
Flouride-F	0.47	0.55	1.3	0.8	0.8	30	30		
Chloride-CI	20	5.9	1.8	13.2	4.4	150	150		
Sulphate-SO_4	887	1,700	65	579	1,087	100	100	460	
Nitrite-NO_2	0.030		0.0018	0.0194	0.0007	0.200	0.044		
Nitrate-NO_3	0.33		0.016	0.212	0.006	13	13		
Ammonia-NH_3	0.096		0.073	0.087	0.027	1.6	1.6		
Mercury-Hg	0.000028	0.0000050	0.0000080	0.000021	0.0000061	0.000020	0.000020		
Silver-Ag	0.000023	0.000010	0.000012	0.000019	0.000011	0.0015	0.0015		
Aluminum-Al	0.22	0.39	0.057	0.159	0.265	0.050	0.050	0.233	0.233
Arsenic-As	0.015	0.018	0.0049	0.0112	0.0131	0.0050	0.0050	0.055	0.055
Barium-Ba	0.35	0.58	0.10	0.26	0.40	1.0	1.0		
Beryllium-Be	0.000048	0.000076	0.00037	0.00017	0.00019	No WQG			
Boron-B			0.13	0.05	0.05	1.2	1.2		
Calcium-Ca	148	260	35	106	176	No direct WQO (part of			
Cadmium-Cd	0.00088	0.0016	0.000068	0.00058	0.00103	0.000148	0.000239	0.001	0.0012
Cobalt-Co	0.011	0.021	0.0018	0.0076	0.0138	0.0040	0.0040	0.045	0.045
Chromium-Cr	0.00035	0.00044	0.00047	0.00039	0.00045	0.0010	0.0010		
Copper-Cu	0.032	0.0600	0.00067	0.0203	0.03775	0.02278	0.03976		
Iron-Fe	0.037	0.053	0.73	0.30	0.31	1.0	1.0		
Potasium-K	30	44	1.4	19.3	28.0	No WQG			
Lithium-Li	0.022	0.042	0.069	0.040	0.052	0.087	0.087		
Magnesium-Mg	110	210	15	74	137	No direct WQO (part of			
Manganese-Mn	0.76	1.5	0.73	0.75	1.21	3.1	5.0		
Molybdenum-Mo	0.17	0.28	0.0068	0.109	0.178	1.0	1.0		
Sodium-Na	26	21	101	54	51	No WQG			
Nickel-Ni	0.018	0.033	0.0025	0.0122	0.0215	0.15	0.15		
Lead-Pb	0.0047	0.0092	0.00021	0.00302	0.0058	0.032	0.063		
Antimony-Sb	0.023	0.042	0.00021	0.0145	0.0263	0.020	0.020		
Selenium-Se	0.0098	0.019	0.00024	0.0062	0.0120	0.0020	0.0020	0.0077	0.0077
Silicon-Si	2.9	3.6	5.4	3.8	4.3	No WQO			
Tin-Sn			0.42	0.16	0.16	No WQO			
Vanadium-V	0.00040	0.00029	0.00070	0.00051	0.00044	No WQO			
Zinc-Zn	0.22	0.44	0.0045	0.139	0.277	0.37	0.69		
Hardness	821	1,500	150	570	994				

Note: Shaded parameters exceed PPWQOs

Summary

The potential emergent groundwater quality for the Expected Case groundwater model exceeds BCWQGs for sulphate, aluminum, arsenic, cadmium, cobalt and selenium for the Expected Case and Upper Bound TSF water quality loading cases at the maximum concentration of the groundwater plume. For the Expected Case, all parameters are near or below the preliminary proposed site specific water quality objectives (PPWQOs) summarized in Section 5.9 of this report. For the Upper Bound case, sulphate is 27% above the PPWQO and nitrite is a few percent over PPWQO. For the Upper Bound sensitivity case, which uses the Upper Bound groundwater model and the Upper Bound TSF water quality, sulphate and selenium are approximately twice the PPWQO and aluminum is 13% over the PPWQO. The likelihood that the Upper Bound conditions will occur is considered to be low. Additionally, the predictions assume zero mixing with lake water along the surface of the spawning beds and no attenuation or adsorption of metals.

7.2.4 Morrison Lake Effects for Operational Discharges

The groundwater model for the open pit has been revised, as described in Section 1.2 of this report, and results in an increase in the pit dewatering flows during operations. The net effect of the increase in water flows is that groundwater may need to be discharged to Morrison Lake during operations to maintain the water balance of the TSF. In addition, water treatment of surplus water will be required for the Upper Bound case.

Potential pit dewatering flows vary from up to 60 m^3/hr for the Expected Case, to 375 m^3/hr for the Upper Bound case. An assessment of the potential effect of discharge of open pit dewatering water has been made on the following basis:

- Pit dewatering water quality will be the same as the baseline mine area groundwater quality.
- TSF loading will not reach Morrison Lake during operations and the water treatment plant will not be operational.

The predicted lake water quality for the Expected Case is summarized in Table 7.12 and for the Upper Bound case in Table 7.13.

Table 7.12 Morrison Lake Water Quality - Expected Case – Operational Discharges – Year 18

Parameter (Total mg/L unless noted)	Treatment Plant Effluent	Pit Dewatering Water	Combined Diffuser Flow	Lake Background Baseline - Avg (Total)	Morrison Lake Water Quality Maximum Steady State-	Morrison Lake Water Quality Maximum (100:1 diffuser)	BCWQG*	CCME
Flows (m^3/hr)	0	165	165					
Nitrate	90	0.052	0	0.038	0.04	0.04	13.3	13
Sulphate	2000	142	142	2.3	4	6	100	n/a
Aluminum (dissolved)	0.46	0.28	0.277	0.033	0.037	0.040	0.05	0.1
Cadmium	0.0005	0.00015	0.00015	0.000012	0.000014	0.000016	0.000014	
Copper	0.007	0.0079	0.00793	0.0113	0.0114	0.0114	0.0026	0.0021
Iron	0.02	3.6	3.58	0.170	0.22	0.25	0.15	0.3
Magnesium	210	31	31	1.9	2.3	2.6	n/a	n/a
Selenium	0.0019	0.00033	0.00033	0.00014	0.00014	0.00015	0.002	0.001
Zinc	0.02	0.015	0.0148	0.0016	0.0018	0.0019	0.0075	0.0075
Hardness	1470	319	319	30	34	37		

Notes: * BCWQGs are based on modified lake hardness
Shaded parameter exceeds BCWQG

Table 7.13 Morrison Lake Water Quality - Upper Bound Case – Operational Discharges – Year 18

Parameter (Total mg/L unless noted)	Treatment Plant Effluent	Pit Dewatering Water	Combined Diffuser Flow	Lake Background Baseline - Avg (Total)	Morrison Lake Water Quality Maximum Steady State-	Morrison Lake Water Quality Maximum (100:1 diffuser)	BCWQG*	CCME
Flows (m^3/hr)	170	515	685					
Nitrate	90	0.052	22	0.038	1.30	1.51	13.3	13
Sulphate	2000	142	603	2.3	36	42	100	n/a
Aluminum (dissolved)	0.46	0.28	0.322	0.033	0.052	0.054	0.05	0.1
Cadmium	0.0005	0.00015	0.00024	0.000012	0.000026	0.000028	0.000023	
Copper	0.007	0.0079	0.00770	0.0113	0.0117	0.0117	0.0026	0.0021
Iron	0.02	3.6	2.69	0.170	0.32	0.35	0.15	0.3
Magnesium	210	31	75	1.9	6.1	6.8	n/a	n/a
Selenium	0.0019	0.00033	0.00072	0.00014	0.00018	0.00019	0.002	0.001
Zinc	0.02	0.015	0.0161	0.0016	0.0025	0.0026	0.0075	0.0075
Hardness	1470	319	605	30	64	69		

Notes: * BCWQGs are based on modified lake hardness
Shaded parameter exceeds BCWQG

Summary

The Morrison Lake water quality during operational discharges meets BCWQGs for all parameters for the Expected Case. In the Upper Bound there are the following exceedances:

- Cadmium is exceeded by 2 ng/L at the edge of the diffuser zone for the Expected Case and up to 5 ng/L over for the Upper Bound.
- Iron concentrations are just over BCWQGs, but below CCME.
- Copper is naturally elevated in Morrison Lake baseline water quality and the predicted increase is approximately 4% over baseline for the Upper Bound.

7.2.5 Morrison Lake Effects for Temporary Closure

In the event of temporary closure of the mine it is desirable to maintain a neutral water balance and not accumulate surplus water. A large accumulation of surplus water in the open pit would be difficult to accommodate if the mine were to re-open. Accordingly, an assessment of water treatment and discharge requirements has been made assuming temporary mine closure in Year 15. The simplified lake modeling spreadsheet utilized for the RRR.-Rev.2 was used for sensitivity assessment of potential temporary closure. The approximate water flows for the Expected Case and Upper Bound are summarized in Table 7.14 and Table 7.15, respectively, along with the water quality estimates for the Year 15 temporary closure case.

Table 7.14 Morrison Lake Water Quality – Temporary Closure – Year 15 – Expected Case

Parameter (Total mg/L unless noted)	Treatment Plant Effluent	Pit Dewatering Water	Combined Diffuser Flow	Lake Background Baseline - Avg (Total)	Morrison Lake Water Quality		BCWQG*	CCME
					Maximum Steady State-	Maximum (100:1 diffuser)		
Flows (m^3/hr)	300	330	630					
Nitrate	90	0.052	43	0.038	2.26	2.67	13.3	13
Sulphate	2000	142	1027	2.3	56	65	100	n/a
Aluminum (dissolved)	0.46	0.28	0.364	0.033	0.052	0.055	0.05	0.1
Cadmium	0.0005	0.00015	0.00032	0.0000120	0.000029	0.000031	0.000033	
Copper	0.007	0.0079	0.00749	0.0113	0.0117	0.0116	0.003	0.0022
Iron	0.02	3.6	1.88	0.170	0.27	0.28	0.15	0.3
Magnesium	210	31	116	1.9	7.9	9.0	n/a	n/a
Selenium	0.0019	0.00033	0.00108	0.00014	0.00020	0.00020	0.002	0.001
Zinc	0.02	0.015	0.0173	0.0016	0.0025	0.0026	0.0075	0.0075
Hardness	1470	319	867	30	75	83		

* Notes: BCWQGs are based on modified lake hardness
Shaded parameter exceeds BCWQG

Table 7.15 Morrison Lake Water Quality – Temporary Closure Year 15 - Upper Bound

Parameter (Total mg/L unless noted)	Treatment Plant Effluent	Pit Dewatering Water	Combined Diffuser Flow	Lake Background Baseline - Avg (Total)	Morrison Lake Water Quality		BCWQG*	CCME
					Maximum Steady State-	Maximum (100:1 diffuser)		
Flows (m^3/hr)	437	475	912					
Nitrate	90	0.052	43	0.038	3.28	3.67	13.3	13
Sulphate	2000	142	1032	2.3	80	89	100	n/a
Aluminum (dissolved)	0.46	0.28	0.365	0.033	0.061	0.064	0.05	0.1
Cadmium	0.0005	0.00015	0.00032	0.000012	0.000036	0.000039	0.000038	
Copper	0.007	0.0079	0.00749	0.0113	0.0119	0.0118	0.003	0.0024
Iron	0.02	3.6	1.87	0.170	0.31	0.33	0.15	0.3
Magnesium	210	31	117	1.9	10.6	11.7	n/a	n/a
Selenium	0.0019	0.00033	0.00108	0.00014	0.00022	0.00023	0.002	0.001
Zinc	0.02	0.015	0.0173	0.0016	0.0029	0.0030	0.0075	0.0075
Hardness	1470	319	871	30	95	103		

*Notes: BCWQGs are based on modified lake hardness
Shaded parameter exceeds BCWQG

Summary

BCWQGs are exceeded for several parameters and discussed as follows:

- Aluminum and iron are slightly over the BCWQGs but below CCME.
- Cadmium is 1 ng/L over BCWQGs for the Upper Bound case.
- Copper is naturally elevated in Morrison Lake baseline water quality and the predicted increase is approximately 5% over baseline.

7.3 Summary of Effects Assessment on Morrison Lake and Receiving Streams

Potential effects on Morrison Lake water quality have been assessed for a range of expected and upper bound conditions as described in the previous section. The likelihood of an effect and the magnitude of the effects are summarized for the overall lake water quality and the potential TSF seepage effects on salmon spawning beds.

Overall Morrison Lake Water Quality

Lake modeling indicates that for all potential upset conditions, Morrison Lake has the assimilative capacity to meet BCWQGs for all parameters, with the exception of cadmium for the Upper Bound conditions.

The likelihood of the elevated cadmium and copper being significant is low due to the following:

- The lake modeling assumes that 100% of the TSF metal loads reports directly to the lake is a very conservative assumption due to the following:
  - cadmium and copper will be adsorbed on the clay tills along the seepage flow path;

- the loading is temporal, peaking in Year 75 for the Expected Case and Year 50 for the Upper Bound case;
- upper bound source water quality assumes that all TSF porewater will be the same water quality as the worst water quality at end of mining, which is an unrealistically conservative assumption; and
- the TSF seepage modeled used a 1.7 km^2 pond area for the full tailings level for 25 years. In reality the TSF will be raised over the 22.5 years of mine life and the water pond is expected to be smaller.

- The BCWQG for cadmium is at least an order of magnitude lower than the US EPA guidelines and development of the Preliminary Site Specific Water Quality Objective confirms that a higher guideline is still protective of aquatic life while still including a safety factor of 10 for uncertainty in the database.
- Groundwater flows to the open pit on closure are expected to be lower than predicted, which will reduce the water treatment flow discharges. Numerical groundwater models typically “over-predict” actual conditions.
- In the long term, geochemical loads from the pit wall rocks will decrease as the sulphides are oxidized and depleted.
- Secondary water treatment can be carried out for select parameters.

The magnitude of the effect is low due to the following:

- The diffuser plume is very small in comparison to the lake area of 13,500,000 m^2.
- The water quality concentrations are either below or near BCWQGs for all cases and well below PPWQOs for key parameters.

TSF Seepage Effects on Salmon Spawning Beds

TSF seepage modeling predicts emergent groundwater quality in the salmon spawning gravels located near the mouth of Stream MCS-7 in Morrison Lake. The modeling predicts that for the Expected Case, all water quality parameters meet the PPWQOs. Upper Bound modeling indicates potential exceedance of sulphate, aluminum and selenium.

The likelihood that the water quality exceedance is significant is low due to the following:

- Cadmium and copper will be adsorbed on the clay tills along the seepage flow path.
- The loading is temporal, peaking in Year 75 for the Expected Case and Year 50 for the Upper Bound case.
- Upper bound source water quality assumes that all TSF pore-water will be the same water quality as the worst water quality at end of mining, which is an unrealistically conservative assumption.
- The TSF seepage modeled used a 1.7 km^2 pond area for the full tailings level for 25 years. In reality the TSF will be raised over the 22.5 years of mine life and the water pond is expected to be smaller.
- The emergent groundwater will be diluted with the lake-water, which will reduce concentrations.

The magnitude of the effect is low due to the following:

- The seepage plume covers a limited aerial extent, with the higher concentrations covering an area of approximately 250 m by 400 m.
- The mapped salmon spawning beds are not located in the area of the highest concentrations. This will be further confirmed prior to construction.
- The effects are temporal and will start in approximately Year 25 and peak in approximately Year 50, and then decrease with time.

8. UPDATED ADAPTIVE MANAGEMENT PLANS AND TABLE OF COMMITMENTS

8.1 General

Adaptive management plans have been described in the RRR-Rev.2 report and are reproduced in the following sections, along with additional detail and modifications to suit any changes as a result of this report. The adaptive management plans will form the basis for development of Environmental Management Plans, which will be developed in detail for permitting.

8.2 Tailings Storage Facility Adaptive Management Plans

8.2.1 Contingency for Raising the TSF Dam to Store Waste Rock or Water

The design basis for cyclone sand production exceeds dam fill requirements and there is sufficient cyclone sand and borrow materials to provide flexibility in raising the TSF dams to store additional volumes of waste rock or water, as/if, required. Based on the available data there is sufficient tailings sand for a 10 m raise in the dam elevation, which provides storage for approximately 50 Mm^3 (30% increase). This additional capacity may be allocated, as required, for surplus waste rock, surplus water or unprocessed low grade ore, and is sufficient for the various contingency plans described in the following sections. The current mine plan has a relatively minor (5 Mt) of surplus mine rock on closure and it is probable that this quantity will be eliminated during the detailed design phase when the volume of waste rock is expected to decrease due to the increase in metal prices and the increase in bonding costs for storage of waste rock. Similarly, as discussed in the next section, surplus water will be managed to reduce the risk of requiring it to be stored in the TSF.

8.2.2 Contingency for Storage of Surplus Water Balance

The TSF capacity increases as the dams are constructed and the completed TSF has a design capacity of approximately 160 Mm^3, (224 million tonnes of tailings). With respect to storage of surface water, the TSF, without raising the dam above the current design elevation, has the capacity to store up to approximately 12 Mm^3 of water below the crest elevation of the dam. The actual available volume of pond water depends on the stage of the TSF and the final beach slopes. For example, beach slopes of 0.5% and 0.75% result in 10 Mm^3 and 15 Mm^3, respectively, for the later stages of the TSF.

Normally the TSF, even for the Upper Bound water balance, would be managed with a water pond in the order of 3 Mm^3 and surplus pit dewater would be discharged to Morrison Lake. Given the time lag to reach the total volume of water for various water management scenarios, as well as the potential for further dam raises, the TSF has sufficient capacity for the Expected Case as well as the Upper Bound case.

8.2.3 Contingency for Disposal of PAG Waste Rock and/or LGO for the Early Closure Case

The management plans for the PAG waste rock and LGO for early closure is described in Section 4.4, and includes the following main components:

- The remaining LGO will be processed and the Cleaner tailings will be placed in the open pit, which is estimated to take approximately 3 years.
- High PAG waste rock will be placed in the base of the open pit. And Low PAG rock will be placed in the remaining pit volume.
- Residual Low PAG waste rock will be placed in the TSF during the first year of early closure to assure that it will be covered with Rougher tailings and kept in a saturated state for closure of the TSF.

Placing surplus PAG waste rock, if required, in the TSF in advance of closure will ensure that the rock is placed below the final tailings elevation such that it remains permanently saturated to mitigate potential ARD. The rock to be placed in the TSF will consist of freshly mined PAG waste rock, of sufficient volume as to offset potential PAG rock. The PAG rock (sand, gravel, cobble, boulder sizes) would be placed near the perimeter of the tailings beach to a maximum elevation to ensure the PAG rock will eventually be flooded and covered with tailings prior to mine closure. The material would be placed with haul trucks and spread with dozers.

8.2.4 Contingency Plan for TSF if LGO is not Processed

PBM will commit to processing the LGO in the event of early closure or closure.

8.2.5 Contingency Plan if Rougher Tailings has ARD Potential

The design includes sulphide separation in the process plant with the Cleaner and Rougher circuits. Bench scale processing tests indicate that the majority of the Rougher tailings will be non PAG. However there is a risk that additional processing could be required to ensure that the sulphides have been sufficiently removed. Consequently, the contingency plan for this case would be to install an additional sulphide separation circuit, either at the dam at the process plant. The additional sulphide separation would ensure that neutral (non-PAG). Rougher tailings can be produced for construction of the dam and for the final beach slopes.

8.3 Mine Rock Adaptive Management Plans

The project design presented in this report has been developed on a base case estimate of waste rock types. Contingency plans are available to manage variations in the actual quantities produced during mining, and potential scenarios and management plans are discussed below.

Surplus PAG Rock

If it is not possible to segregate non-PAG waste rock there could be an additional 17 Mt of PAG rock requiring disposal (assuming no changes to waste rock volumes in detail design). This material would need to be placed in the TSF as the base case condition already has the maximum amount placed in the open pit. The contingency plan would be the same as that described in Section 8.2.3 of this report. Storage of the additional 17 Mt would require raising the TSF by approximately 2 m, which is readily accommodated.

Non-PAG Rock has Neutral Metal Leaching Concerns

If the segregated non-PAG rock develops neutral ML concerns it will be treated as PAG, as discussed above.

Non PAG Rock Volume is Low

The closure plan for the open pit assumes approximately 4 Mt of non-PAG rock will be placed in the "wetland" area of the open pit. If this rock is not available, low PAG rock will be placed instead. The potential consequence of using low PAG rock will be to introduce additional geochemical loading to the water pond. However, the water quality predictions and water flows predictions for the effects assessment on closure conservatively assume all water has a low pH and will be treated.

Higher Quantities of High PAG Rock

The closure design conservatively assumes a lime requirement for treatment of 50% of the PAG rock placed back into the open pit. The consequence of have higher quantities of high PAG, would, therefore, not change the effects assessment. The main effect is the quantity of lime required for closure.

8.4 Seepage and Groundwater Flows Adaptive Management Plans

8.4.1 Contingency for Excessive Seepage Losses from the TSF

The TSF will develop over the life of the mine and hydrogeologic models and results from groundwater monitoring wells will be used to update, confirm, and refine predictions of potential seepage losses. The contingency plan for further mitigating the potential seepage losses from the TSF will include the following components:

- Additional site investigations will include geophysics, test pits, drilling and pump testing to provide broader spatial distribution.
- Sections of the TSF will be lined, as required, with low hydraulic conductivity glacial till, or geomembrane liners. The TSF will have, as a minimum, a soil liner with a hydraulic conductivity of < 10^{-8} m/s.

The project design includes seepage recovery ponds downstream of each of the three main dams which will collect the majority of seepage for return to the TSF. A groundwater monitoring program will be implemented that includes monitoring wells located between the TSF and Morrison Lake and Nakinilerak Lake. Water quality monitoring, particularly of sulphate which is typically not significantly attenuated, will identify potential flow paths and TSF seepage contributions. If measured sulphate concentrations exceed predictions, such that total seepage out of the TSF is indicated to be higher than that used for this report, then the following contingency measures will be implemented:

- The use of the seepage recovery dams and ponds will be continued as long as required.
- Additional seepage collection facilities would be constructed in areas with measureable TSF affected seepage. This could include springs or areas downstream of the seepage recovery facilities.

- The application of seepage mitigation works for the remaining areas of the TSF will be increased with the use geomembranes or clay tills with a lower hydraulic conductivity.
- The tailings deposition plan will be reviewed to assess if there is a benefit to moving the location of the active reclaim pond. Preferential spigotting of cyclone overflow tailings will be carried out in the areas of suspected seepage.
- The potential use of grouting or seepage recovery wells will be assessed, however it is generally recognized that these are not preferred contingency measures due the difficulty and cost of implementation, as well as their effectiveness.

8.4.2 Contingency for Excessive Seepage Inflows from Morrison Lake into the Open Pit

The open pit will be developed over the life of the mine and results from ongoing geological mapping, groundwater models and groundwater well monitoring will be used to update, confirm, and refine predictions of potential seepage flows from Morrison Lake to the Open Pit. In conjunction with the Adaptive Management plans for the Water Balance (see Section 8.5 of this report) the contingency plan for mitigation of the seepage flows will include a grouting program. The grouting, for example, could be carried out with a row of primary grout holes at 6 m centers, up to 100 m deep, or deeper. Depending on the grout take secondary holes would be developed between the primary holes. Similar grouting programs are routinely carried out for large dam projects using standard technology. Similarly, grouting of fault zones could be carried out.

8.4.3 Contingency for Groundwater Flows from PAG Porewater to Morrison Lake – Closure

The revised groundwater model for the open pit on closure indicates a low likelihood of seepage effects from PAG porewater to Morrison Lake for closure. Nonetheless, an improved understanding of the hydraulic connectivity between Morrison Lake and the

Open Pit will be developed during operations. The potential flow path is anticipated to be variable and consist of a component of shallow groundwater flow through the near surface bedrock and soils, as well as deeper flows through bedrock and the lakebed sediments. The groundwater quality will be monitored with groundwater wells and with sampling of the lake water quality. If adverse seepage effects are observed contingency plans will include interception of the groundwater, which would be recycled back to the open pit pond and sent to the water treatment plant.

8.5 Water Balance Adaptive Management Plans

8.5.1 Contingency Plan for Surplus Water Balance

The Upper Bound water balance case results in a surplus of TSF pond water, which will require measures to reduce the volume during the operating mine life. The water balance will be tracked over the mine life with annual reconciliation of all flows and calibration of the life of mine water balance to the actual conditions. If a trend of increasing net water balance flows is observed, the management plan will be implemented to mitigate the accumulation of water. The “trigger” value for what surplus water balance would require additional mitigation works is dependent on a lot of variables that include:

- Assessment of climate related factors, e.g. extreme wet or dry cycles.
- Rate of increases of inputs, such as pit inflows with depth.
- Effectiveness of diversions and management of non-contact water.

Nonetheless, a surplus water balance stored volume in the TSF of 25% over the predicted water balance volume should be used as the first trigger for the need to implement water management mitigation works.

The management plan will include components of the following, as required, and as appropriate:

1. Seepage into the open pit may be reduced with a grouting program.
2. Groundwater dewatering wells inflows to the open pit may be separately collected and discharged via a diffuser to Morrison Lake. This would be feasible if large water volumes are coming from the perimeter pit dewatering wells.
3. Water treatment of TSF water would be initiated earlier in the mine life.
4. Water treatment of TSF water to a higher rate that accounts for the lag time of TSF seepage to Morrison Lake. As discussed in Section 4.3 for the temporary closure plan, it is possible to treat significantly higher volumes of TSF surplus water and still meet Morrison Lake water quality objectives as discussed in Section 7.2.4 of this report.

9. OBSERVATIONS ON THE TABLE OF COMMITMENTS

The following sections provide supporting comments for specific commitments which were commented upon in the 3rd Party Review. In addition, an updated Table of Commitments will be included with the final Project Description for the EA Application.

Commitment No. 7: Zero Discharge Water Balance Objective

Unchanged, refer to Section 6.2 of this report. The objective recognizes that if pit groundwater inflows are high, a management plan for discharge of surplus pit dewatering water will be implemented.

Commitment No. 8: TSF Water Balance Surplus Control

The proposed commitment trigger is “water balance volumes are > 50% over Expected Case. The volume referred to is the cumulative stored water volume in the TSF at the end of each year. The selection of 50% is a guideline and the actual trigger is also dependent on the cause of the increase (e.g. wet year or very large pit inflows) and whether the increase is a single event or an indication of continued accumulation of surplus water. Annual water balance reconciliation will be carried out, along with annual bathymetric surveys, to confirm the actual volumes. The TSF will be enlarged over the life of mine and the accumulated water volumes and storage capacity available increases with dam height and there is resiliency in the system to attenuate larger volumes for a period of time. Nonetheless, an annual water balance volume of > 50% is a clear indication that adaptive management plans need to be implemented. As discussed in the Adaptive Management Plan (Section 8.5.1 of this report), PBM would use a lower trigger of 25% as the first indication that surplus water is accumulating and should be assessed and monitored to determine if actions can be implemented to reduce the increase. Increasing the dam height is an interim measure to ensure dam safety. The preferred mitigation alternatives, assuming all surface water is being optimally managed, are: a) land area discharge of "clean" groundwater intercepted from the pit dewatering wells; b) discharge of groundwater via a diffuser into Morrison Lake; and c) water treatment and discharge via a diffuser into Morrison Lake.

Commitment No. 9: Zero Water Balance cannot be achieved.

As discussed in Commitment No. 8, the TSF has resiliency to store surplus water until either a land area discharge, pit dewatering diffuser, or a water treatment plant can be constructed.

Commitment No. 10: Mine Area Water Balance exceeds predictions.

The trigger values apply to Upper Bound water balance surplus volumes for the project that are exceeded due to large groundwater inflows.

Commitment No. 11 Pit Inflows have a significant adverse effect on Morrison Lake levels and Morrison Creek flows.

The trigger value for significant flow reductions in Morrison River will be determined in conjunction with DFO and MoE and will be based on the biological effects of flow reduction as discussed in Section 6.1.2 of this report.

Commitment No. 1, 20 and 24: Placement of surplus high PAG rock or un-milled LGO.

PBM has made the commitment that LGO will not be placed in the TSF. The relative volume of NAG rock is small and the mine plan has the resiliency to manage this quantity if segregation from PAG is not effective.

Commitment No. 14 and 17: Seepage rates from TSF exceed predictions and have the potential to exceed water quality objectives.

The trigger seepage increase of 25% applies to total seepage out of the TSF. The correlation to total seepage will be measured by the %solute in the monitoring locations (wells, seeps and streams) using sulphate as the tracer element. PBM has seepage recovery systems downstream of the main dams and these will be operated as long as they are shown to be intercepting contaminated seepage. PBM commits to assessment and implementation of feasible seepage mitigation works which include: liners, selective spigotting, grouting and collection of springs. Seepage mitigation works that include pump back wells will be a low priority due to concerns about their effectiveness and sustainability.

Commitment No. 25: Seepage from the low grade ore stockpile may contaminate Morrison Lake.

The LGO is placed upon a low permeability glacial till foundation. PBM commits to testing the foundation material and, if required, placing additional low permeability soil.

Commitment No. 27: Rougher tailings placement in TSF during milling of LGO

If a de-sulphidation circuit is included for modification of rougher tailings, the same commitment will apply to the sulphides extracted in that circuit.

Commitment No. 29: High PAG rock will be placed in the base of the open pit.

The influence of High PAG rock, based on the updated hydrogeology assessment, is minimal. In addition, a detailed PAG backfill plan is presented in Section 4.5 of this report In addition, an updated pore water quality prediction, based on a reduced efficiency of liming, is presented in Section 3.4 of this report.

Commitment No. 32: Water treatment plant.

PBM commits to operating the water treatment plant to meet, as a minimum, to meet the specified treated water quality presented in the Review Response Report. Rev.2. The commitment includes construction and operation of additional stages of treatment, if required. In addition, if water quality monitoring of Morrison Lake indicates that parameters exceed predictions then additional water treatment technologies will be implemented. Testing of site generated water quality will be carried out during operations to confirm final design of the water treatment plant.

Commitments No. 40 to 46

These commitments are standard operating best practice and will be followed. Consequently they are not regarded as Key Commitment.

New Commitments

The following new commitments will be added:

- Working with the Lake Babine Nation and DFO in measuring sockeye escapement numbers on an annual basis and advancing the knowledge of the fish distribution in Morrison Lake with fish population measurements in various areas of the lake. Additional spawning surveys, particularly in the area downstream of the TSF, along the shoreline and at depth to better quantify the spatial extent of salmon spawning will be carried out.

- The physical behaviour of the lake will continue to be monitored with water quality monitoring and temperature and conductivity probes. The design of the diffuser and lake mixing model will be further developed prior to construction.

- Spawning surveys in Morrison River will be carried out to better quantify the potential effect of the reduction in flow due to the mine. This will be combined with more accurate stream gauging stations to ensure that low flow measurements are captured.

10. CLOSING

The 3rd Party Review Response report provides additional information to respond specifically to the main issued raised in the review and to further support the assessment that the Morrison Copper/Gold Project will not have a significant adverse effect on Morrison Lake.

PBM is committed to working through the detailed design and permitting process, with LBN and the Agencies, to ensure the Project design can be constructed, operated and closed to minimize the environmental effects.

KLOHN CRIPPEN BERGER LTD.

N. McLEOD

Harvey McLeod, P.Eng., P.Geo.
Project Director

Andrew Hovey, B.Sc.
Senior Hydrogeologist

Claudio Andrade, M.Sc.
Geochemist

Martine Long, R.P.Bio.
Environmental Scientist

COLLEGE OF APPLIED BIOLOGY
Kevin Haines
R.P. Bio
2305
CAB

Kevin Haines, MSc., R.P.Bio.
Senior Toxicologist

APPENDIX I

Groundwater Model Report

TABLE OF CONTENTS

PAGE

I-1. INTRODUCTION 1
I-2. CONCEPTUALIZATION - REVIEW 3
I-2.1 Hydrogeological Parameters 3
I-2.2 Recharge/Discharge 3
I-3. NUMERICAL FLOW MODELLING ASSESSMENT 8
I-3.1 Introduction 8
I-3.2 Software and Model Grid..9
I-3.3 Boundary Conditions 9
I-3.4 Recharge 10
I-3.5 Timing...11
I-3.6 Calibration..11
I-3.7 Parameterization 20
I-3.8 Water Balance...21
I-4. PREDICTIVE SCENARIOS 22
I-4.1 Tailings Storage Facility 22
I-4.2 Contaminant Transport 23
I-4.3 Seepage Mitigation Options..25
I-4.4 Results..28
I-4.5 Sensitivity Analysis 36
I-4.6 Pit Dewatering Assessment...39
I-4.7 Results...40
I-4.8 Pit Infilling 41
I-4.9 Sensitivity 42
I-4.10 Final Pit Lake Assessment 45
I-4.11 Results..46
I-4.12 Sensitivity Trials 47
I-5. LIMITATIONS..49

TABLE OF CONTENTS
(continued)

I-6. CONCLUSIONS AND RECOMMENDATIONS 51

REFERENCES 53

TABLES

Table I-1 Estimated Baseflow Rates and Stream Characteristics.............................. 5

Table I-2 Assigned Model Boundary Conditions (previous and revised) 9

Table I-3 Units Targeted for Adjustment to Achieve the Upper Bound Calibration 13

Table I-4 Statistics for Expected and Upper Bound Calibration 16

Table I-5 Statistics for Expected and Upper Bound Calibration 16

Table I-6 Calibrated TMF Model Hydraulic Parameters 20

Table I-7 Cumulative Model Water Balance (m3/d) 21

Table I-8 Simulated Seepage Mitigation Design Options 26

Table I-9 Contact Seepage Loss from TSF Zone 30

Table I-10 Predicted MCS-7 Maximum Sulphate Concentration and Distribution (t=25 years) 31

Table I-11 Sensitivity Trials completed for TSF. 37

Table I-12 Sensitivity Trials completed for TSF. 38

Table I-13 Simulated Scenarios – Pit Dewatering... 39

Table I-14 Pit Dewatering – Operational Inflows. 41

Table I-15 Sensitivity Trials completed for Pit Dewatering...................................... 42

Table I-16 Sensitivity Trials – Pit Inflow Rates 43

Table I-17 Sensitivity Trials – Inflow from Morrison Lake...................................... 43

Table I-18 Inflow in to the Final Pit Lake and Exchange with Morrison Lake under Differing Operating Levels 46

Table I-19 Sensitivity Trials completed for the Final Pit Lake (El 732 m)................ 47

Table I-20 Sensitivity Trial Results – Pit Lake Inflows 47

Table I-21 Sensitivity Trial Results – Exchange with Morrison Lake 48

TABLE OF CONTENTS
(continued)

FIGURES

Figure I-1 Piper Plot Showing Water Type by Location (Surface Water and Groundwater) 7
Figure I-2 Expected Case Steady State Calibration – Observed vs Predicted Heads 16
Figure I-3 Upper Bound Case Steady State Calibration – Observed vs Predicted Heads..... 17
Figure I-4 Predicted Steady State Head Distribution – Expected Case Calibration (a) Layer 1 and (b) Layer 25 18
Figure I-5 Predicted Steady State Head Distribution – Upper Bound Case Calibration (a) Layer 1 and (b) Layer 25..... 19
Figure I-6 Concentration Observation Well Locations – MCS-7 Potential Spawning Beds..... 25
Figure I-7 Tailings Storage Facility (incl. Dams) Partial Geomembrane Layout #1. 27
Figure I-8 Tailings Storage Facility (incl. Dams) Partial Geomembrane Layout #2. 28
Figure I-9 Sulphate Concentration in Groundwater (2m) MCS-7 SPAWN1 33
Figure I-10 Sulphate Concentration in Groundwater (2 m) MCS-7 SPAWN2 34
Figure I-11 Sulphate Concentration in Groundwater (2 m) MCS-7 SPAWN3 35
Figure I-12 Sulphate Concentration in Groundwater (2 m) MCS-7 SPAWN4 36

APPENDICES

Appendix I Updated Groundwater Level Data
Appendix II Predicted Sulphate Distribution Plots (End of Operations)
Appendix III Predicted Sulphate Distribution Plots (100 years of Operation)
Appendix IV Predicted Head Distribution for Pit Dewatering Scenarios

I-1. INTRODUCTION

This report summarizes the results and findings of a review and update to existing conceptual hydrogeological and numerical groundwater flow/transport models for the Morrison Copper/Gold Project. The assessment was undertaken in response to a review of previous hydrogeological studies for the project by RGC Geoconsultants Inc (2011) and feedback from MOE; interim review comments received by DRT Environmental (2011) were also considered in this assessment.

The primary objective of this assessment was to provide revised estimates of groundwater flow, levels and quality at the Morrison Mine during operations and post-closure in support of an assessment of whether the project might pose a significant adverse effect to the environment. The specific objectives of this assessment were:

- Complete a review the existing hydrogeological conceptualization, with consideration to data and information acquired following completion of the Rescan baseline study (Rescan, 2009).
- Assess the rate and fate of seepage from the Tailings Storage Facility (TSF) and optimize the TSF seepage mitigation design (SMD) strategy. Results from this assessment were incorporated into conjunctive studies to assess the potential impacts to sensitive receptor sites under various SMD options, which in turn guided SMD trade-off and selection.
- Estimate groundwater inflows into the mine pit during operation, and the final pit lake at closure. These results serve as inputs to the site-wide water balance, which in turn guides water management at the site.
- Optimize closure pit lake levels to balance potential water treatment requirements against groundwater through flow to Morrison Lake.
- Assess uncertainty in the data and conceptualization through sensitivity analysis.

Data and information considered in this assessment was acquired during previous studies, specifically Rescan (2009, 2009a), KCB (2010, 2010a, 2011) and Knight Piesold (2006). Numerical modelling was completed using the 3D numerical flow and transport model setup by Rescan (2009a), with revision and update where required. Results from this assessment are intended to supersede those presented in Rescan (2009a) and KCB (2011).

I-2. CONCEPTUALIZATION - REVIEW

The hydrogeological conceptualization presented in Rescan (2009a) is consistent with available data, and regional-scale head and flow patterns which might be expected in relatively steep glaciated terrain with permanent lakes at low elevations. Specific elements of the conceptualization which were reviewed as part of this assessment are summarized in the following sections.

I-2.1 Hydrogeological Parameters

A collective review of hydraulic conductivity data was undertaken to assist with deriving input values for the numerical model; results are discussed in subsequent sections of this report. No pumping tests have been completed at the site to date, and as such, storage parameters have not been defined. Estimates of storativity and specific yield included in the Rescan model are consistent with literature values for the type and condition of overburden and bedrock encountered during drilling and are therefore considered suitable for use in the current assessment. A recommendation to complete a test pumping program is included in Section I-6.

I-2.2 Recharge/Discharge

Rainfall/Snowmelt

Previous groundwater recharge estimates were derived through model calibration and included: 100 mm/yr in low lying areas near Morrison Lake, 110 mm/yr on steep slopes and 75 mm/yr in upland areas. As the calibration and optimized parameters are non-unique, recharge was estimated independently from field data as part of this study using a chloride mass balance approach (Eriksson and Khunakasem, 1969).

The geometric mean chloride concentration in groundwater in the tailings and mine areas was 2.2 mg/L (n=4 sites) and 1.6 mg/L (n=6 sites), respectively[1]. There was negligible change in concentration temporally at locations for which long term monitoring data was available (<0.25 mg/L). Using a 550 mm mean annual precipitation (rainfall and snowmelt; Rescan, 2009a) and assuming a chloride concentration of 0.25 mg/L in meteoric water and a dry deposition concentration of 0.01 mg/L[2], the resultant recharge rates were:

- TSF area (high elevation) = 62.5 mm/yr (11.3% MAR)
- Pit area (low elevation) = 85.9 mm/yr (15.6% MAR)

These values are comparable to the rates derived by Rescan through model calibration. The following should be noted:

- Recharge rates derived using a chloride mass balance account for losses associated with evapotranspiration etc.
- Chloride concentrations in groundwater are very low (relative to most natural waters; Hem, 1985), and potentially suggest short residence times and/or minimal water-rock interaction. Furthermore, the suggestion that recharge values derived for fractured rock settings using a chloride mass balance approach are underestimates due to the contribution of chloride from fracture weathering / clay infill (Cook, 2003) does not appear to be of relevance;
- Rainfall records were available from a single weather station located near the proposed pit. Orographic effects and their potential influence on recharge were therefore not considered directly. Aspect, slope and variability in soil / rock at surface are also likely to be important

[1] Results with high TSS were excluded from statistical analysis, however, the chloride concentration for these sites / monitoring rounds is low, and comparable to the reported geometric mean.
[2] Being inland and mountainous, the site is not expected to be influenced significantly by coastal processes.

considerations for spatial recharge variability, however, were not able to be assessed;

- Updated groundwater level data was reviewed in conjunction with initial baseline data to assist with recharge estimation (Appendix I). Trends which might represent seasonal/short duration recharge were not apparent (i.e. levels remained relatively static), and is likely a consequence of the monitoring frequency. A recommendation to undertake automated intensive monitoring is included in Section I-6; this will assist with verification of current recharge estimates.

Surface Water/Groundwater Interaction

Updated stream hydrographs for existing gauging stations were reviewed for this assessment (post-EIA data). Absolute level data from the sensors and stage-discharge curves produced by Rescan were used to calculate flows from the updated data; manual readings were not available to verify the updated flow records.

Data was analyzed to estimate baseflow rates and seasonal variability, and assess surface water – groundwater interconnectivity. Data gaps, uncertainty in the reliability of the updated data and the overall short recording period complicated this process. Baseflow separation techniques were initially used to assist with estimation of baseflow, however, high flows during freshet limited the suitability of these methods. Winter low flows, together with review and professional judgment on the remaining data set and observations were instead used to derive estimates presented in Table I-1.

Table I-1 Estimated Baseflow Rates and Stream Characteristics

Stream_ID	Estimated Baseflow (L/s)	Notes*
MCS-1	8	Permanent
MCS-4	3	Permanent
MCS-5	3	Permanent
MCS-6	20	Permanent
MCS-7	16	Potentially intermittent
MCS-8	12	Permanent
MCS-10	<1	Potentially ephemeral

* Based primarily upon review of 2007-2008 data.

Groundwater and surface-water quality data was also reviewed to assist with understanding groundwater-surface water interaction. A piper plot for locations which had complete data records is included as Figure I-1. No seasonal change in water quality and type (surface water and groundwater) was apparent from the data. Surface water is consistently of Ca-HCO_3 type, as would be expected given most flow is derived from precipitation. Overburden-hosted groundwater tends to be of Na (±Ca) HCO_3/CO_3 type, particularly in the TSF area. Bedrock-hosted groundwater in both the TSF and mine area and overburden-hosted groundwater in the mine area trends between Na-HCO_3/CO_3 and Ca-HCO_3 type along a linear 'mixing' line and possibly indicates mixing between deeper groundwater and perched groundwater or surface water (noting the line does not end on the surface water cluster).

- Based on visual inspection of variability in streamflow along MCS-7, MCS-8 and MCS-10 under varying flow conditions losing stream reaches do not appear extensive (pers. Comm., KCB field staff).

- At least MCS-7 and MCS-10 are seasonally intermittent, with no flow periods recorded during winter months. This suggests baseflow does not permanently sustain streamflow in all watercourses. This may be due to local variability in the hydrogeological setting of these areas, as groundwater levels and stream conditions generally appear consistent.

- Groundwater hosted in overburden (in both the mine and TSF areas) and in bedrock in the TSF area is generally compositionally distinct to surface water and Morrison Lake, however, there is an apparent mixing trend between general end members. This suggests that interconnectivity between aquifer units and surface water-groundwater is more complex than the single 'continuum' assumed in the previous conceptualization.

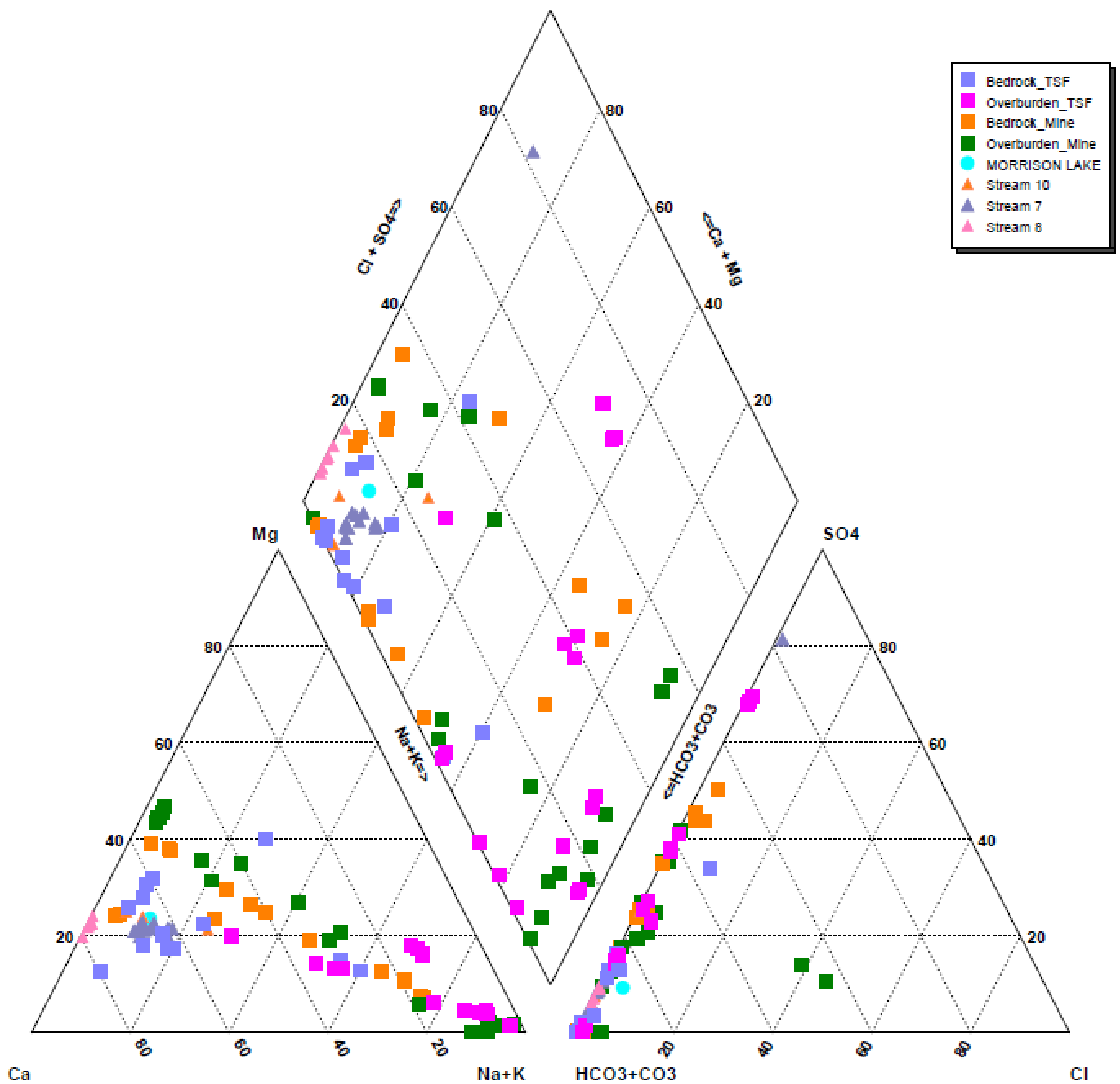
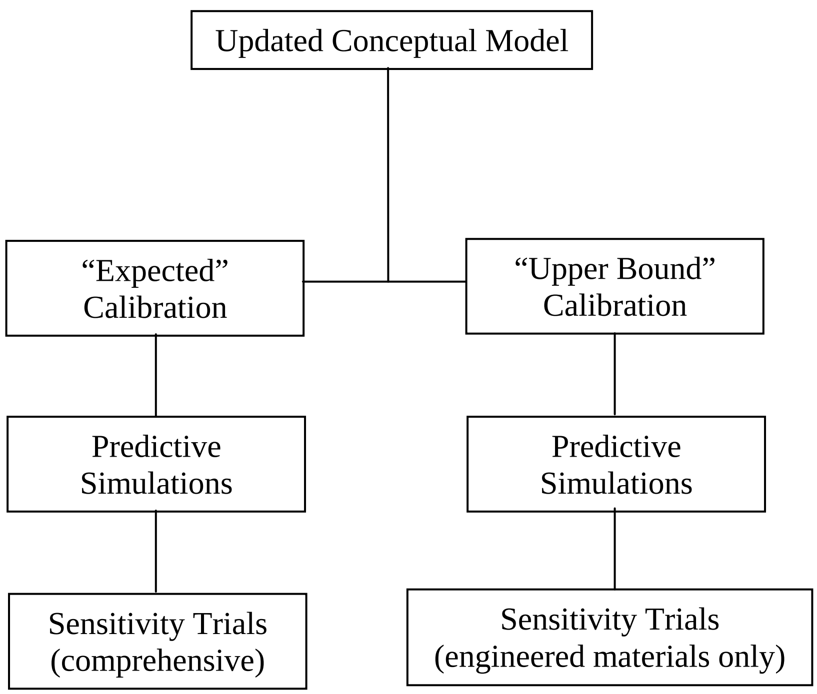


Figure I-1 Piper Plot Showing Water Type by Location (Surface Water and Groundwater)

I-3. NUMERICAL FLOW MODELLING ASSESSMENT

I-3.1 Introduction

The numerical flow model developed by Rescan was updated to account for the revised conceptualization, changes to the project and the understanding of potential environmental effects. Although this assessment relied on the basic framework of the previous model for predicting groundwater impacts, the setup, calibration and simulation approach differed. Key to the current assessment was a more detailed characterization of uncertainty associated with the conceptualization and data to derive a range of estimates for seepage and inflow for consideration in the effects assessment. An overview of the modelling approach is presented below, with further details provided in subsequent sections.



I-3.2 Software and Model Grid

The model software, grid and layer discretization and layer assignment were consistent with that reported by Rescan (2009a). The model was completed used the USGS MODFLOW package (McDonald and Harbaugh, 1988) with the Visual MODFLOW GUI. Electronic model and spatial data files developed by Rescan were provided by Pacific Booker, and verified before use.

I-3.3 Boundary Conditions

Boundary conditions assigned to the model were revised in line with the updated conceptualization. Consistent with the previous model, all boundary conditions were assigned to model layer 1. A summary of the revised boundary conditions included is presented in Table I-2.

Table I-2 Assigned Model Boundary Conditions (previous and revised)

Boundary	Previous Condition	Revised Condition
Morrison Lake	Constant Head El. 732 m	General Head El. 732m, C_d = 3
Major Watercourses	Streams (variable stage, width, roughness, conductance, K and inflow)	Drains Elevation = topo-1 m; C_d = 50
Lakes and Wetlands	Constant/General Head	General Head (Elevation/C_d variable)
Seepage – low lying areas within ~200m of Morrison Lake	N/A	Drains Elevation = topo-0.5 m; C_d=100

- A General Head Boundary (GHB) was assigned to Morrison Lake in preference to the previously used Constant Head Boundary. Consistent with the conceptual model, this allows regional groundwater to be 'imperfectly' connected to lake, and for groundwater levels to fall below the lake level if drawdown influence from pit dewatering extends to this boundary. Morrison Lake still provides recharge to groundwater, however, the rate is no longer unlimited, and is controlled by a conductance term (C_d), which accounts for the limiting effects of lake bed sediments on groundwater / surface water exchange. C_d was assigned a uniform value (to readily allow adjustment during calibration), however, the cell size within the lake was variable (cell dimensions are an input for estimating C_d).

- GHB's were also assigned to lakes and wetlands within the model domain which were previously represented using constant head boundaries. This adjustment was made to allow adjustment of C_d values during calibration if required. The extent of these smaller lake/wetland areas was consistent with the previous model.

- Drain cells were assigned along major watercourses to allow groundwater to leave the model (as surface water). Unlike the stream boundary condition assigned previously, a MODFLOW drain is not able to simulate losing stream conditions; these do not appear to be significant, and were not predicted in the Rescan model. Drain cells were also selected as they are less numerically complex, and unlike do not require multiple assumed inputs (unlike stream cells). The base of watercourse drain cells was set 1 m below topography, and a relatively high conductance term was assigned to allow water to discharge unimpeded (bedrock outcrop or sand/gravel has been observed in most streams).

- Drain cells were also assigned along the foreshore of Morrison Lake (nominally, within 200 m of the lake edge) to allow groundwater to leave the model as seepage; drain in this areas also assisted with relieving elevated heads which tended to develop in low lying elevation areas of the model due to driving gradients from high elevation areas[3]. The base of drains on the foreshore of Morrison Lake were set at topography and assigned a C_d of 100.

I-3.4 Recharge

The recharge zonation assigned by Rescan was maintained for the model update. Initial recharge values for high and low elevation areas were assigned in-line with chloride mass balance derived estimates (86 mm/yr for low elevation areas and 63 mm/yr for high elevation areas, respectively). A comparatively low initial recharge value was assigned to

[3] This phenomena was apparent in the Rescan model where elevated heads were observed even with relatively significant increases in hydraulic conductivity and assignment of a constant head boundary to Morrison Lake.

steep slopes as most precipitation is expected to be lost as runoff. Evapotranspiration was accounted for through recharge, and was not assigned.

I-3.5 Timing

Groundwater flow simulations were run to steady state for calibration and predictive scenarios. This approach was preferred as it eliminated the role of storage in the model; the designated layering would have maintained a confined storage throughout a transient simulation, and would not allow a transition to unconfined storage (specific yield) during pit dewatering. Although this process is important at a conceptual level, it resulted in extensive cell drying using the standard MODFLOW code, and extensive numerically instability.

Contaminant transport simulations were undertaken under transient conditions; however, the underlying flow model remained at steady state. The total simulation time for the contaminant transport simulations was 100 years, divided into 20 equal five year time steps.

I-3.6 Calibration

Approach

Two separate model calibration cases were developed to account for uncertainty in data and the conceptualization, and assist with defining a range of pit inflows and seepage rates for design purposes. These were termed:

- ‘Expected Case’ – parameterization reflects reasonably expected values, or ‘typical’ field-measured values. For design purposes, seepage and inflow predictions from expected case simulations reflect what is anticipated based on current information.

- ‘Upper Bound Case’ – parameterization of inputs which are likely to influence seepage and inflow is skewed toward higher-end estimates and field-measured values (nominally 75th percentile). This adds a factor of safety to seepage and flow predictions, and accounts for uncertainty in the dataset[4].

Throughout development and prior to calibration, model verification was continually undertaken and comprised incremental adjustment and some trial and error representation of various boundary conditions and input parameters until un-calibrated model output was considered to be conceptually correct.

For the expected case, model calibration was undertaken in two stages. The first stage involved applying initial hydraulic inputs assigned by Rescan to the revised model setup and performing automated (regionalized) calibration using PEST. The second stage involved manual adjustment of parameters and boundary condition conductance terms to derive a calibration which satisfied statistical measurements of calibration performance and was conceptually correct in areas where data was not available.

Due to the correlated nature of model input parameters, variations made to the ‘expected case’ calibration to arrive at the ‘upper bound’ calibration focused on increasing both hydraulic conductivity and recharge. The hydraulic conductivity of units which were identified as having the most significant influence on pit inflows and TSF seepage was increased; other units incorporated into the model away from these areas for which no data was available were not adjusted. Targeted units for adjustment in the ‘upper bound’ calibration are detailed in Table I-3.

[4] Considering ‘high end’ values for several inputs collectively is likely also conservative

Table I-3 Units Targeted for Adjustment to Achieve the Upper Bound Calibration

Parameter	Description	Distribution
Hydraulic Conductivity	Ashman Formation	Primary upper bedrock unit in mine area. Approx. ½ to ¾ of total pit depth (layers 1 to 12)
	Eocene Porphyry	Secondary upper bedrock unit in mine area. Approx. ½ to ¾ of total pit depth (layers 1 to 12)
	Till (high elevation)	Surficial unit underlying most of the TSF.
	Till (low elevation)	Surficial unit in the mine area.
	Faults (mine area)	Lineal structural elements within pit shell and pit walls
	Faults (regional)	Regional structural elements outside the pit
	Tailings*	Within TSF
Recharge	Low elevation	Lower elevation areas adjacent to Morrison Lake
	High elevation	Higher elevation areas – east portion of domain

* Predictive scenarios only

Statistical analysis of results from Rescan (2009a), KCB (2010) and Knight Piesold (2006) was completed to assist with selection of input parameters for the expected and upper bound cases. Median to geometric mean values for formations with measured hydraulic conductivity values were targeted / input during the expected case calibration. Seventy fifth percentile values for the formations included in Table I-3 were targeted/input for the upper bound case. The following should be noted:

- All faults in the model were assumed to be ‘open’ and represent zones of relatively high hydraulic conductivity which preferentially convey groundwater. The hydraulic conductivity of apparent fault zones has been measured by KCB (2010) and Knight Piesold (2006), with a hydraulic conductivity range of 1E-07 to 3.8E-06 m/s.

- A decreasing trend in hydraulic conductivity was maintained with depth, with values extrapolated from trends in the overall dataset. Variation in the hydraulic conductivity of the lower bedrock (for which no specific testing data currently is currently available) was assessed independently through sensitivity analysis.

- Variations in storage parameters were not considered, as these do not factor into MODFLOW steady state equations. Variations to drain and GHB conductance were also not considered, however, sensitivity trials for C_d of the Morrison Lake GHB were undertaken.

Upper bound calibration was achieved through trial and error (manual) adjustment of abovementioned inputs (targeting 75^{th} percentile measured values). An acceptable calibration was able to be fairly readily achieved as heads and baseflow remained comparable to observations following adjustment. Final input parameters for the expected and upper bound cases are presented in Table I-6 (Section I-3.7).

The upper bound calibration assumes multiple input parameters which are likely to impart an important influence on seepage; contaminant migration and flow are present simultaneously at the high-end (75^{th} percentile) bound of measured values. The probability of this occurring for all formations and parameters simultaneously is probably slight, however, has been included given the uncertainty which exists in the data and conceptualization.

It should be noted that results from the 'expected' and 'upper bound' cases are considered suitable for deriving seepage and flow estimates for design purposes, as the predictive simulations are based on a model setup which is reasonably calibrated. Sensitivity trials are considered less suitable for design purposes, and are intended primarily to identify the sensitivity of the model to uncertainty in individual inputs, which will be used to guide additional investigation and assessment completed during detailed design.

Calibration Targets

Steady state model calibration targets included the following:

- Groundwater elevations in 27 open drill holes and constructed monitoring wells. Average recorded groundwater elevations at each site were used as calibration targets. Where monitoring data was available values assigned by Rescan were updated.

- Baseflow estimates for streams MCS-4, MCS-7, MCS-8 and MCS-10 (streams within the domain for which gauged data was available).

- Heads and flows in areas of the model where data was not available were consistent with the conceptualization.

All calibration head targets were weighted equally. Lake bathymetry was not considered as a calibration target, as this is a morphological characteristic independent of groundwater elevation.

Results

The accuracy of model calibration is evaluated in absolute terms through statistical methods. Typically, these involve the correlation coefficient (r^2) and the normalized RMFS (root mean fraction squared) as defined by ASTM Standard D 5918-96. A model is commonly considered calibrated when the correlation coefficient is about 0.95 and the normalized RMFS is under 10%.

Calibration statistics for the expected and upper bound cases are presented in Table I-4 and Table I-5, with a plot of observed versus predicted heads shown in Figure I-2 and Figure I-3. Regional steady state head contours are presented as Figure I-4 and Figure I-5.

The resultant correlation coefficient and RMFS error for both cases are within accepted margins with average baseflow rates being comparable to those expected (Section I-2.2). Furthermore, regional gradients and flow directions are consistent with the conceptualization. Given these result, both cases are considered acceptable for use in predictive scenarios. The water balance error for the entire domain was <1% for both scenarios (expected given calibration was undertaken to steady state).

Table I-4 Statistics for Expected and Upper Bound Calibration

Calibration Statistic	Result	
	Expected Case	Upper Bound
Calibration Targets (n)	27	
Minimum residual (m)	-1.4 (MW07-08A/1)	-0.3 (DH07-2A/1)
Maximum residual (m)	-33.6 (DH06-7/1)	-36.2 (DH06-4/1)
Residual Mean (m)	-1.6	-8.8
nRMFS (%)	4.9	4.6
Correlation coeff. (r^2)	0.99	0.99

Table I-5 Statistics for Expected and Upper Bound Calibration

Stream_ID	Target (L/s)	Result	
		Expected Case (L/s)	Upper Bound (L/s)
MCS-4	3	2.9	3.1
MCS-7	16	13.0	7.9*
MCS-8	12	19.3	24.6
MCS-10	<1	6.1	10.5

* The decrease in baseflow to MCS-7 is off-set by an increase in flow to the Morrison Lake zone.

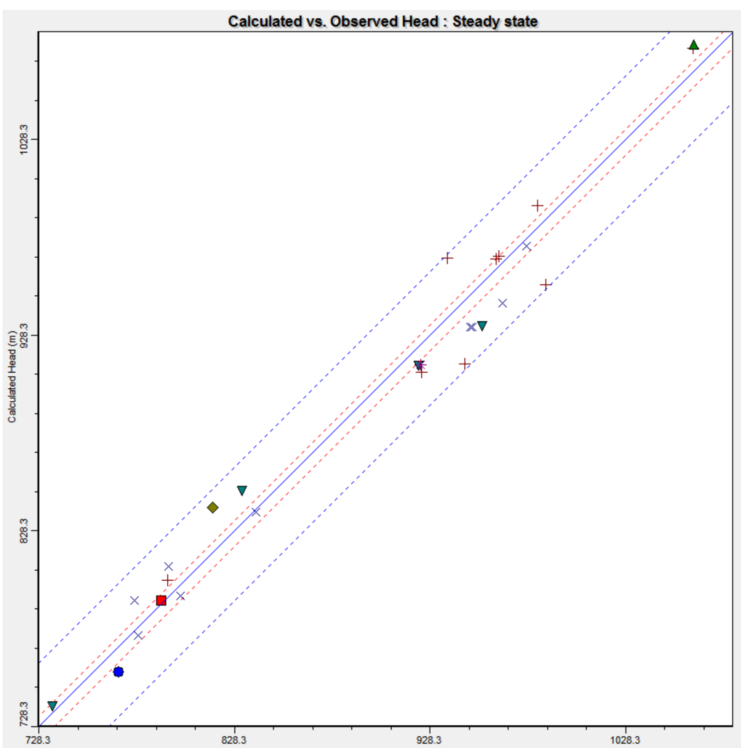


Figure I-2 Expected Case Steady State Calibration – Observed vs Predicted Heads

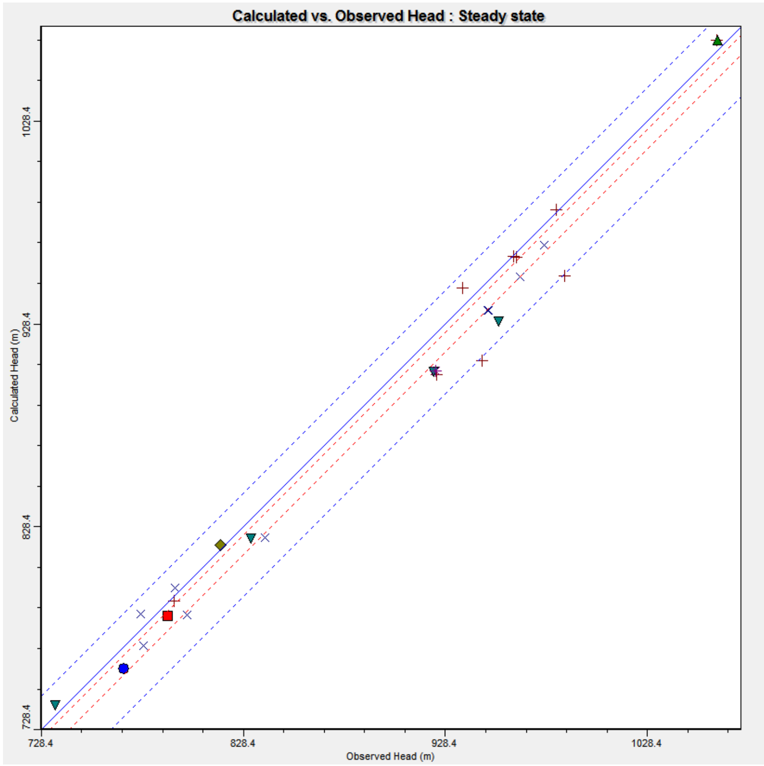


Figure I-3 Upper Bound Case Steady State Calibration – Observed vs Predicted Heads

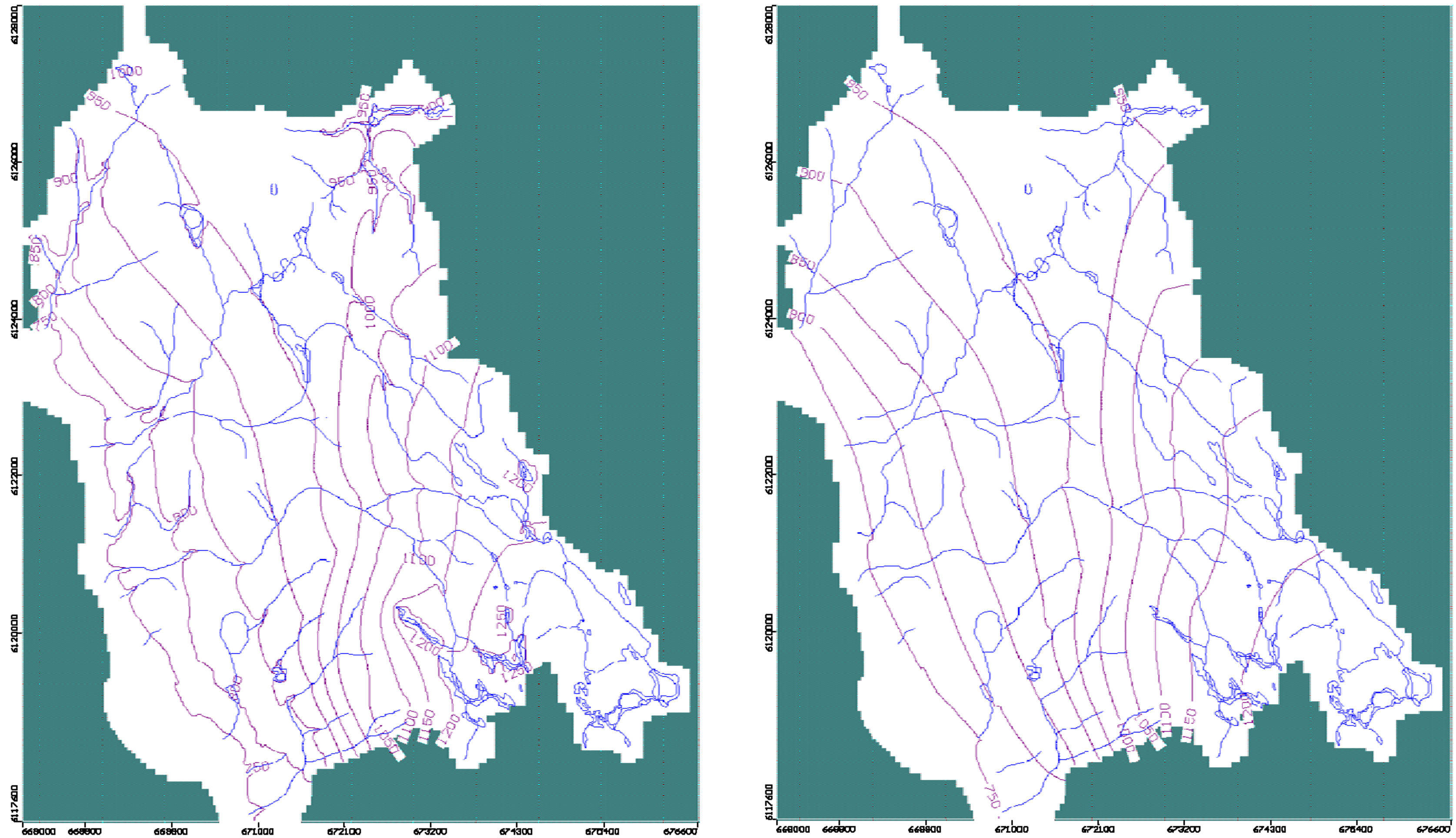


Figure I-4 Predicted Steady State Head Distribution – Expected Case Calibration (a) Layer 1 and (b) Layer 25

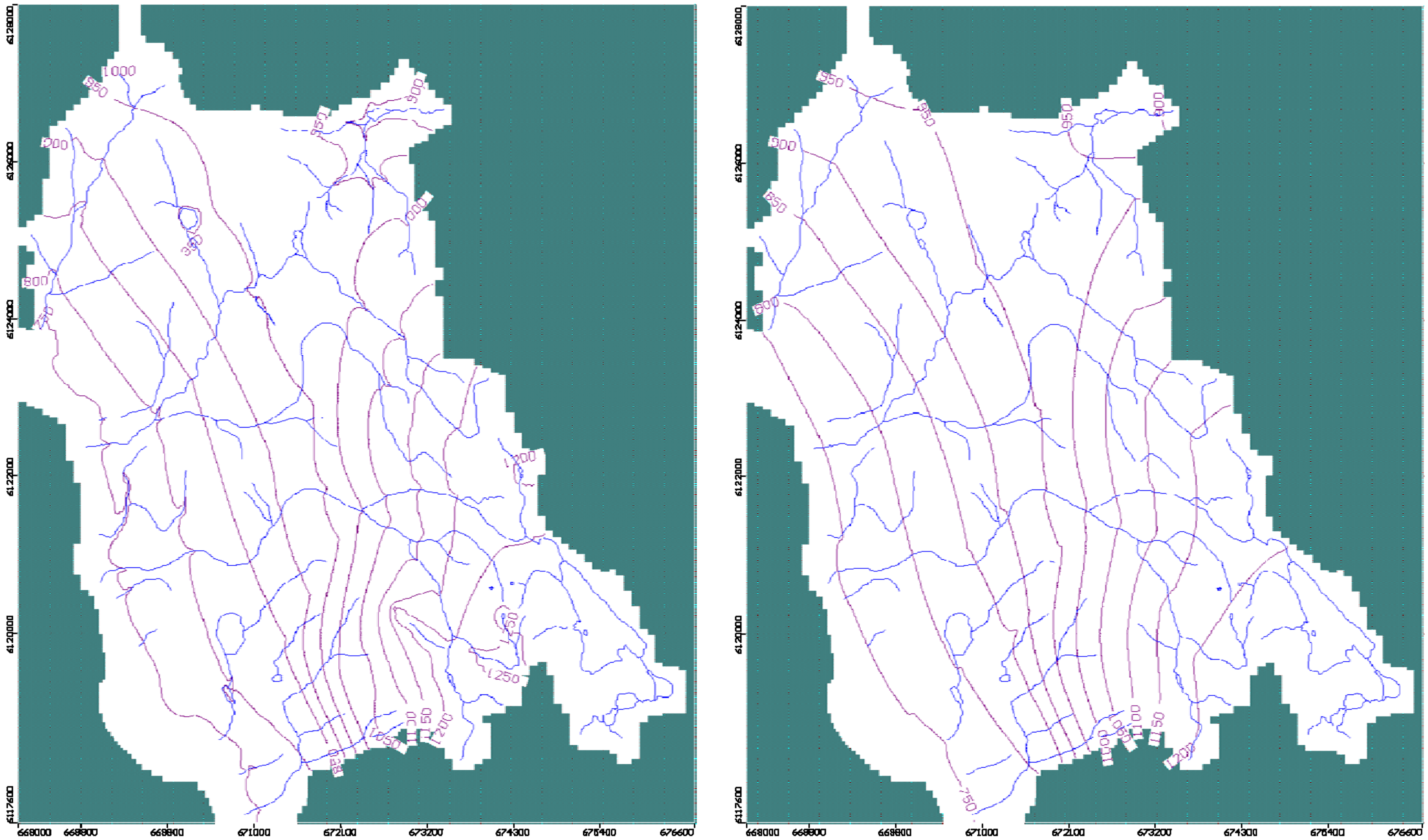


Figure I-5 Predicted Steady State Head Distribution – Upper Bound Case Calibration (a) Layer 1 and (b) Layer 25

I-3.7 Parameterization

Calibrated parameters adopted for the expected and upper bound models are summarized in Table I-6. Storage parameters were consistent with those applied by Rescan and are not reproduced. A decrease in hydraulic conductivity with depth was maintained in the model (regional lower bedrock layers) and accounts the effects of increased stress with depth (Rutqvist and Stephannson, 2003) and extrapolation of the observed decline in hydraulic conductivity observed at shallower depths (for which data was available).

Table I-6 Calibrated TMF Model Hydraulic Parameters

Layer	Unit	Spatial Distribution (Refer Fig. 2.1-3, Rescan, 2009)	Horizontal Hydraulic Conductivity (m/s)		Anisotropy $(K_h:K_v)$
			Expected	Upper Bound	
	Glacial Till (high elevations)	High elevation areas – east portion of domain	2.8E-08	**1.0E-07**	
	Glacial Till (low elevations)	Low elevation areas – west portion of domain	6.0E-08	**2.0E-07**	
	Colluvium (Slopes)	Steeply sloping areas – central portion of domain	3.0E-07		
	Morrison Lakebed	Beneath Morrison Lake	3.0E-08		
	Eocene porphyry (Ebgd)	Secondary upper bedrock unit in mine area	1.0E-08	**2.0E-07**	
	Qtz Diorite (Ebqd)	Mid slopes, east of mine pit	3.0E-07		
	Unnamed Diorite (LKdr)	Upper slopes, east of mine pit	2.4E-07		
	Hanawald Conglomerate (IKSH)	Low elevations, west of TSF	3.5E-07		
	Kitsuns Creek Fm (IKSKC)	West of pit, beneath Morrison Lake	4.1E-07		1:1
	Sedimentary Units (IKS)	Southeast of mine area	2.4E-07		
	Ashman Fm (uJBAmst)	Primary upper bedrock unit in mine/low elevation area	3.3E-07	**1.0E-06**	
	Smithers Fm (mJHSHms)	Upper slopes, north of TSF. Low slopes near Morrison Lake (north of pit)	5E-07		
	Saddle Hill Fm (ImJHSH)	Mid to upper slopes, southern portion of domain	6.0E-08		
	Nikitkwa Fm (IJHNk)	Mid slopes, north of pit, southern portion of TSF	5.0E-07		
	Telkwa Fm (IJHT)	Mid-slopes, SW of TSF	6.5E-07		
	"Middle" bedrock (generic)	Entire Domain	3.2E-08		
	"Lower" bedrock (generic)	Entire Domain	9.1E-09		
	"Bottom" bedrock (generic)	Entire Domain	1.4E-09		

Table I-6 Calibrated TMF Model Hydraulic Parameters (cont'd)

Layer	Unit	Spatial Distribution (Refer Fig. 2.1-3, Rescan, 2009)	Horizontal Hydraulic Conductivity (m/s)		Anisotropy (K_h:K_v)
			Expected	Upper Bound	
	Faults (pit area)		1.5E-06	**3.0E-08**	
	Faults (regional)		8.0E-07	**1.0E-06**	1:1
Engineered Materials					
1	Tailings		1.5E-07	**5.0E-07**	**10:1 (Ex) 5:1 (Up)**
	Pit Void (dewatering)		1.0-04		1:1
	Pit Infill (closure) (Waste Rock)		1.5-06		1:1

* Shaded values increased relative to expected case.

I-3.8 Water Balance

The cumulative water balance for the expected and upper bound calibrated models prior to mine development is presented in Table I-7. As expected, total in and outflow from the model was higher in the upper bound case (+21% compared to the expected case) as a result of higher recharge and increased ability for groundwater to migrate towards discharge boundaries (Morrison Lake, Streams).

Table I-7 Cumulative Model Water Balance (m3/d)

Component	Expected		Upper Bound	
	In	Out	In	Out
Storage	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Constant Head (SE highland Lakes, Nakinilerak Lake)	5.8E+04	1.1E+07	2.9E+05	1.9E+07
Drains (streams and Morrison Lake Foreshore)	0.0E+00	2.6E+08	0.0E+00	3.4E+08
General Head (Morrison Lake, Upland Wetlands)	6.0E+07	1.1E+08	1.4E+08	1.3E+08
Recharge	3.3E+08	0.0E+00	3.5E+08	0.0E+00
TOTAL	3.9E+08	3.9E+08	4.9E+08	4.9E+08
IMBALANCE	+0.3%		+0.2%	

I-4. PREDICTIVE SCENARIOS

Models for estimation of TSF seepage and contaminant migration under differing SMD options were setup and run independently of the pit dewatering and pit lake models due to the inclusion of transient contaminant transport, which increased input requirements and run times. Although direct interaction between the facilities was not recorded (i.e. TSF seepage did not migrate to the pit), the TSF and pond were included in the pit simulations, and the dewatered or filled pit (El. 732 m) was included in the TSF scenarios.

I-4.1 Tailings Storage Facility

The following revisions were made to the calibrated model to calculate contact seepage rates from the TSF, and to assist with assessing the environmental effects:

- The top of model layer 1 was reprofiled to account for impounded tailing at El. 1013 m.
- Tailings (model layer 1 within the TSF) were assigned a horizontal hydraulic conductivity of 1.5E-08 m/s for the ‘expected case’ (Kh:Kv=10:1), and 5E-08 m/s for the ‘upper bound’ case (Kh:Kv=5:1).
- A 1.7 km^2 pond was assigned to the facility with an elevation of El. 1013 m (modeled as a constant head boundary). This is the expected average pond size that will exist within the facility at the end of mining and into closure.

Although this model setup reflects the layout the TSF at the end of operations only (year 25), the modeling approach assumes the facility exists in this form throughout mine life. Contact seepage rates and contaminant loading from the TSF are expected to be less during earlier years of operation. Although this approach leads to potential conservatism, it has been adopted for assessment purposes for contingency.

I-4.2 Contaminant Transport

Two model cases were considered for estimating contaminant loading from the TSF to regional groundwater and sensitive receptors:

- Operational Mining Scenarios – setup to represent the TSF during operations (25 years), when seepage and contaminant concentrations in the TSF pond/pore water are expected to be highest.
- Post-closure Scenarios – although pond water quality improves post-closure, a 'plume' of contact seepage will likely remain in regional groundwater and may migrate toward streams and Morrison Lake. This scenario assesses contaminant migration lag time and long-term concentrations.

For operational mining scenarios a constant concentration of 880 mg/L was assigned to the 1.7 km^2 TSF pond area in model layer 1. This is the average estimated sulphate concentration in TSF pore water predicted over mine life. The background sulphate concentration included in the operational mining scenarios was 0 mg/L. Although actual background concentrations are higher, this approach more readily allows the final concentration of other POC's in groundwater to be assessed, relative to the source concentration in the pond. A longitudinal dispersivity of 10 m was assigned across the entire domain; other contaminant (adsorption and reaction) were not considered (but are likely to occur).

The sulphate concentration in the TSF pond was reduced to 50 mg/L for the subsequent post-closure model runs, consistent with predicted pond water post-closure. For these simulations, the initial concentration of sulphate in regional groundwater was imported from the year 25 result of the corresponding operational mining scenario. The total simulation time for both the operational and closure TSF models was 100 years, comprised of 20 equal five year time steps. A simulation time longer than proposed mine life (25 years) was selected for the operational scenarios so as to allow the sulphate distribution in streams and Morrison Lake to reach an approximate equilibrium, the results of which were incorporated into the water quality model to estimate water quality within the streams.

Sulphate was selected for explicit representation because: (a) it is a predicted to occur at concentrations above BC guideline water quality objectives during operation, (b) it is a common parameter of concern (POC) associated with tailings, and (c) Sulphate is relatively conservative, and is not typically demobilized in groundwater through reaction and sorption to the same extent as metals[5]. In practice, the concentration of any POC's in groundwater could be conservatively estimated from the model using a mass balance approach whereby the observed concentration is divided by the estimated source concentration in the TSF pond.

Four concentration observation wells were assigned to Morrison Lake at the outlet of MCS-7 to monitor groundwater sulphate concentration changes during operation and post-closure (Figure I-6). This area has been identified as a potential salmon spawning area (subject to further assessment), where alevins are potentially reliant on gravels in the hyporheic zone, which conceptually may be influenced by groundwater discharge. In each well observation points were simulated at 2 m, 5 m and 15 m below lake level.

[5] Noting that hydrogeological and geochemical conditions are important site-specific considerations.

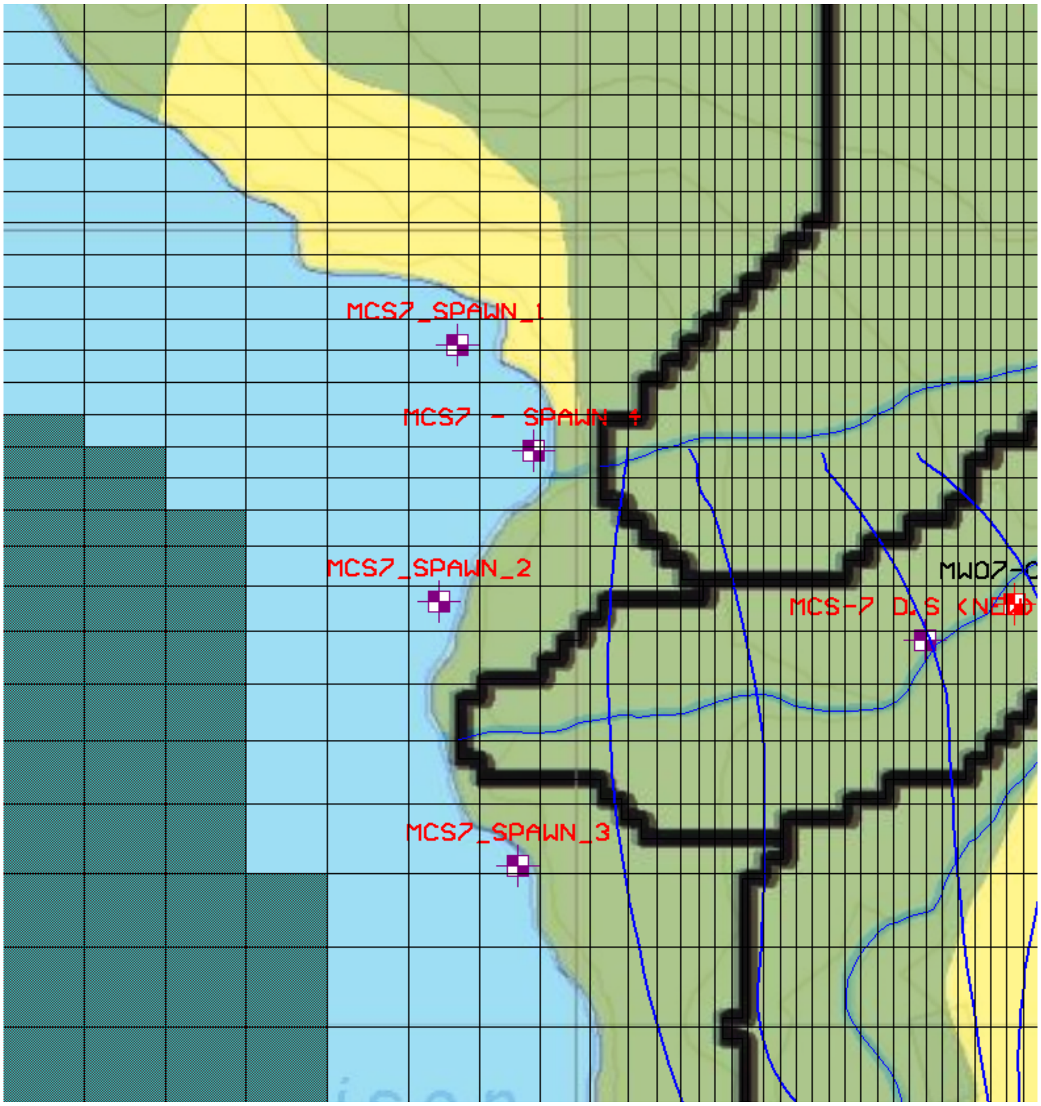


Figure I-6 Concentration Observation Well Locations – MCS-7 Potential Spawning Beds.

I-4.3 Seepage Mitigation Options

The various seepage mitigation design options incorporated into the model are summarized in Table I-8, in approximate order of increasing engineering complexity and cost. These options were selected as they are potentially suitable for site conditions, and will conceptually reduce seepage from the TSF.

Table I-8 Simulated Seepage Mitigation Design Options

Simulation	Seepage Mitigation	Simulation Approach	Area
1	No seepage mitigation	Base setup	--
2	Full Engineered Till Liner	Model layer 2 K revised to $1E^{-8}$ m/s.	Entire TSF footprint (5.2 km^2)
3	Partial Geomembrane Liner (#1)	Model layer 2 K revised to $1E^{-10}$ m/s in lined area.	Mapped areas of till veneer (<2 m thick); (2.5 km^2)
4	Partial Geomembrane Liner (#2)		Mapped areas of till veneer (<2 m thick) – western TSF and colluvium; (2.6 km^2)
5	Full Geomembrane Liner	Model layer 2 K revised to $1E^{-10}$ m/s.	Entire TSF footprint (5.2 km^2)

The ‘full engineered till liner’ is designed to augment/improve the existing surficial till cover by achieving a consistent placed hydraulic conductivity. Although mapping and testing completed to date suggest the existing till is generally of low hydraulic conductivity (and is represented as such in the model), there is potential for relatively thin and/or granular zones to exist which might preferentially convey seepage. The benefits of the engineered till liner relative to the no SMD option will therefore be underestimated by the model, as local scale permeable zones are not represented, but may conceptually be of importance for seepage.

The distribution of the partial liners was selected to cover overburden materials which conceptually have the most potential to transmit contact seepage to regional groundwater; the extent of these materials was based on surficial geological mapping completed by Rescan. The partially lined options avoided mapped areas of swamp and wetland due to the complexity of lining these areas relative to their size.

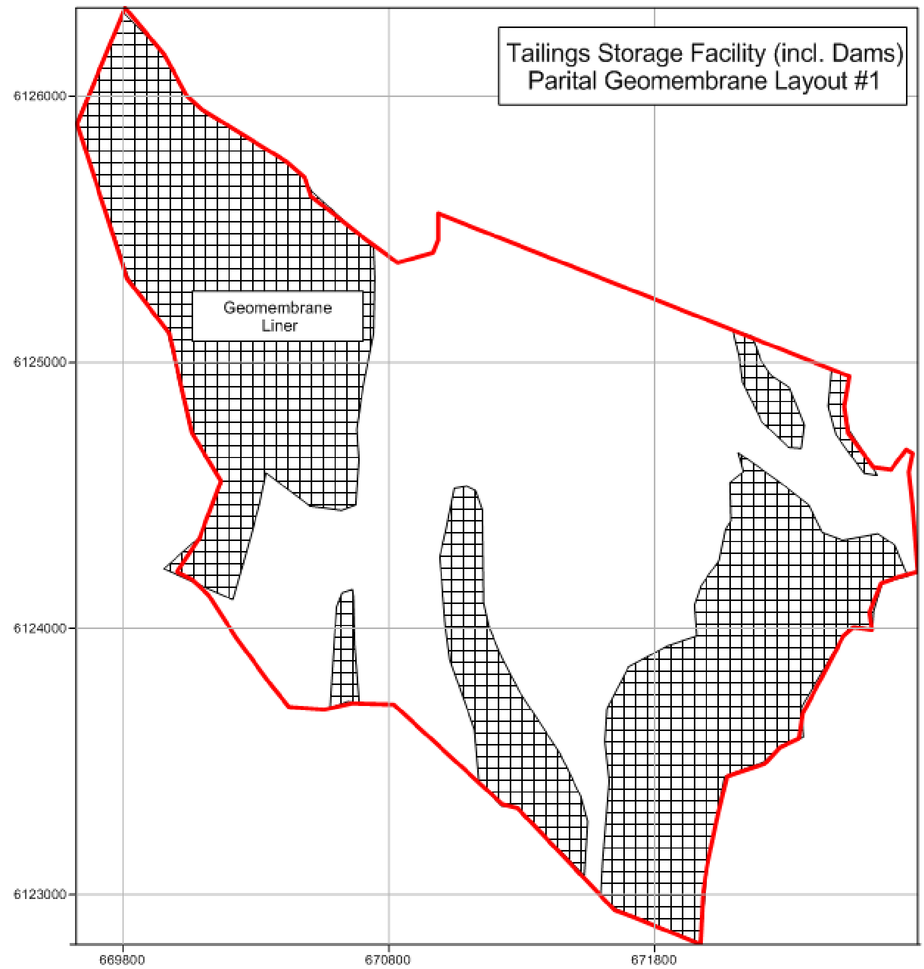


Figure I-7 Tailings Storage Facility (incl. Dams) Partial Geomembrane Layout #1

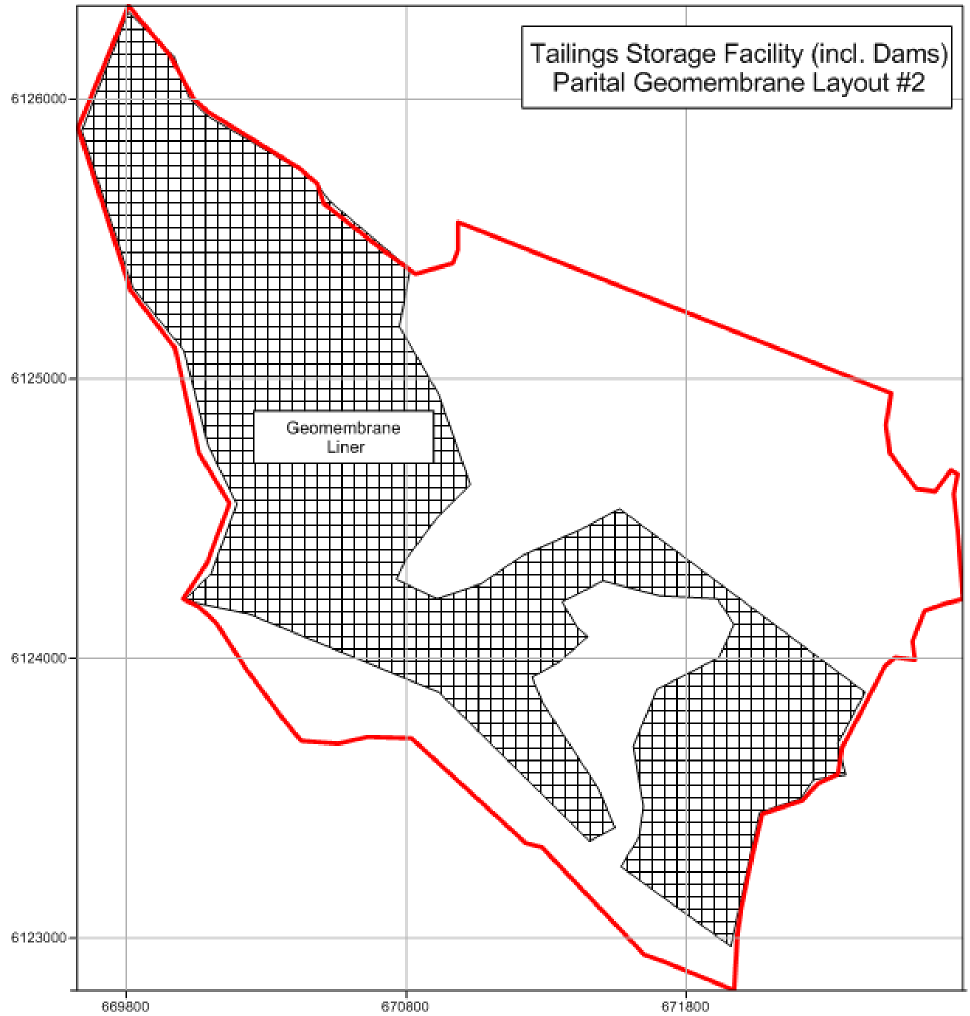


Figure I-8 Tailings Storage Facility (incl. Dams) Partial Geomembrane Layout #2

I-4.4 Results

A total of 34 individual model runs were completed to predict the distribution of sulphate (and indirectly, other contaminants) in groundwater under the various proposed seepage mitigation measures. These simulated each of the SMD options during operation (25 years) under 'expected' and 'upper bound' conditions, and the 'no seepage mitigation' and 'full engineered till liner' SMD options for 100 years post-closure (also under expected and upper bound conditions). Only the full engineered till liner was considered for the post-closure simulation, as results from the water quality model indicated that the predicted seepage rate and water quality at receptor sites were deemed to satisfy environmental objectives.

The effectiveness of each SMD option and impacts was assessed using the following outputs (considered directly and as part of separate studies):

1. Calculation of the total rate of non-recoverable contact seepage loss from the TSF to regional groundwater.
2. Assessment of the spatial sulphate concentration distribution in shallow[6] groundwater and Morrison Lake at year 25 (end of operations).
3. Assessment of the spatial solute concentration distribution in shallow groundwater at 100 years of operation, to derive estimates of maximum contaminant loading to watercourses.
4. For the full engineered till liner and no 'no SMD' option – assessment of concentrations near the potential spawning beds during operation and post-closure.

The purpose of the assessment was not to assess the effectiveness of the SMD options relative to each other or the 'no SMD' case; the fully lined geomembrane option would always be preferred under such a design basis. Instead, the outputs from this assessment have been considered as part of an environmental effects assessment to determine what level of mitigation might be required to minimize potential impacts. By including results of the expected and upper bound scenarios, together with results of the sensitivity analyses, assists with addressing uncertainty in the data, and therefore, the related impacts.

[6] 'Shallow groundwater' was represented by the contaminant concentration distribution in model layer 1.

Contact Seepage from TSF

A summary of the predicted rates of foundation seepage are presented in Table I-9. Seepage rates were measured for the TSF zone using the MODFLOW zone budget. Conceptually, the sulphate concentration of the seepage reflects a combination of average pond and tailings pore water.

Table I-9 Contact Seepage Loss from TSF Zone

Simulation	Seepage Mitigation	Contact Seepage Loss to Foundation (m^3/hr)	
		Expected Case	Upper Bound
1	"no SMD"	65	137
2	Full Engineered Till Liner	64	128
3	Partial Geomembrane Liner (#1)	60	132
4	Partial Geomembrane Liner (#2)	55	127
5	Full Geomembrane Liner	20	46

Contaminant Distribution in Groundwater

End of Operations (25 years)

Contour plots of the predicted sulphate concentration distribution in shallow groundwater after 25 years of operation are presented as Appendix II. Contact seepage from the TSF was not predicted to reach Morrison Lake, MCS-8 or MCS-10 under any of the simulations during operations (expected or upper bound), however, the predicted sulphate concentration and distribution in MCS-7 varied as a function of the simulated seepage mitigation option. A summary of the approximate maximum concentration in MCS-7 under each scenario is presented in Table I-10.

Table I-10 Predicted MCS-7 Maximum Sulphate Concentration and Distribution (t=25 years)

Simulation	Seepage Mitigation	MCS-7 (Expected)		MCS-7 (Upper Bound)	
		Maximum [SO4] (mg/L)*	Total area >100 mg/L** (km^2)	Maximum [SO4] (mg/L)*	Total area >100 mg/L**
1	"no SMD"	300	0.047	400	0.075
2	Full Engineered Till Liner	300	0.043	400	0.049
3	Partial Geomembrane Liner (#1)	300	0.033	400	0.067
4	Partial Geomembrane Liner (#2)	100	0.011	400	0.048
5	Full Geomembrane Liner	0	0	0	0

* Influenced by model cell size

** Rounded down to nearest 100 mg/L.

No sulphate breakthrough was predicted at MCS-7 after 25 years with the full geomembrane liner option; other SMD options were comparable to the 'no SMD' option. The full geomembrane liner option does not prevent contact seepage reaching MCS-7, but as simulated in the model, this approach reduced the seepage rate and increased the lag time for breakthrough at MCS-7.

<u>100 years of Operation</u>

Contour plots of the predicted sulphate concentration distribution in shallow groundwater after 100 years of operation are presented as Appendix III. These results were output to assist with predicting the extent of potential impacts from the TSF, and the likely maximum contaminant loading to streams (assessed as part of the water balance assessment); a condition where the full TSF contains elevated sulphate levels beyond operations is not anticipated, and these results should not be considered as representative of the potential impacts from the TSF.

The results indicate that after 100 years of (theoretical) operation, the sulphate distribution in groundwater under the no SMD, engineered till liner and partial geomembrane liner scenarios was similar, and had reached a steady state distribution.

The same concentration distribution would also be reached under the full geomembrane liner option, however, the time to achieve this is greater than 100 years.

It should be noted that the model is not a coupled surface water-groundwater model, and as such, the reported concentrations for Morrison Lake are predicted in groundwater beneath the lake (ie. not surface water within the lake). Diffusion and mixing with non-contact surface water will reduce final contaminant concentrations within the lake.

Sulphate Concentration – Potential Spawning Grounds

The sulphate concentration at the four concentration observation locations within the shallows of Morrison Lake (corresponding to potential spawning areas) was predicted by plotting time-series sulphate concentrations from the operational (0-25 years) and post-closure (25-125 years) models; results are shown as Figure I-9 to Figure I-12 (groundwater, 2 m below Morrison Lake). Results for the expected and upper bound case are presented, for the 'no SMD' and 'full engineered till liner' scenarios. It should be noted that for each simulation the final SO4 concentration in the pond was 50 mg/L which is higher than the initial background concentration of 0 mg/L assumed for the model.

As would be expected, the peak sulphate concentration at each observation site is greater for the upper bound case, as TSF seepage rates are higher under these conditions. The breakthrough time is also faster, and the peak response faster than for the expected case due to groundwater velocities and the total water budget being higher.

These results have been considered with respect to site specific water quality objectives applicable to salmon alevins (potential sensitive receptors which may be indirectly dependent on groundwater in the lake bed) as part of the water balance and effects assessment.

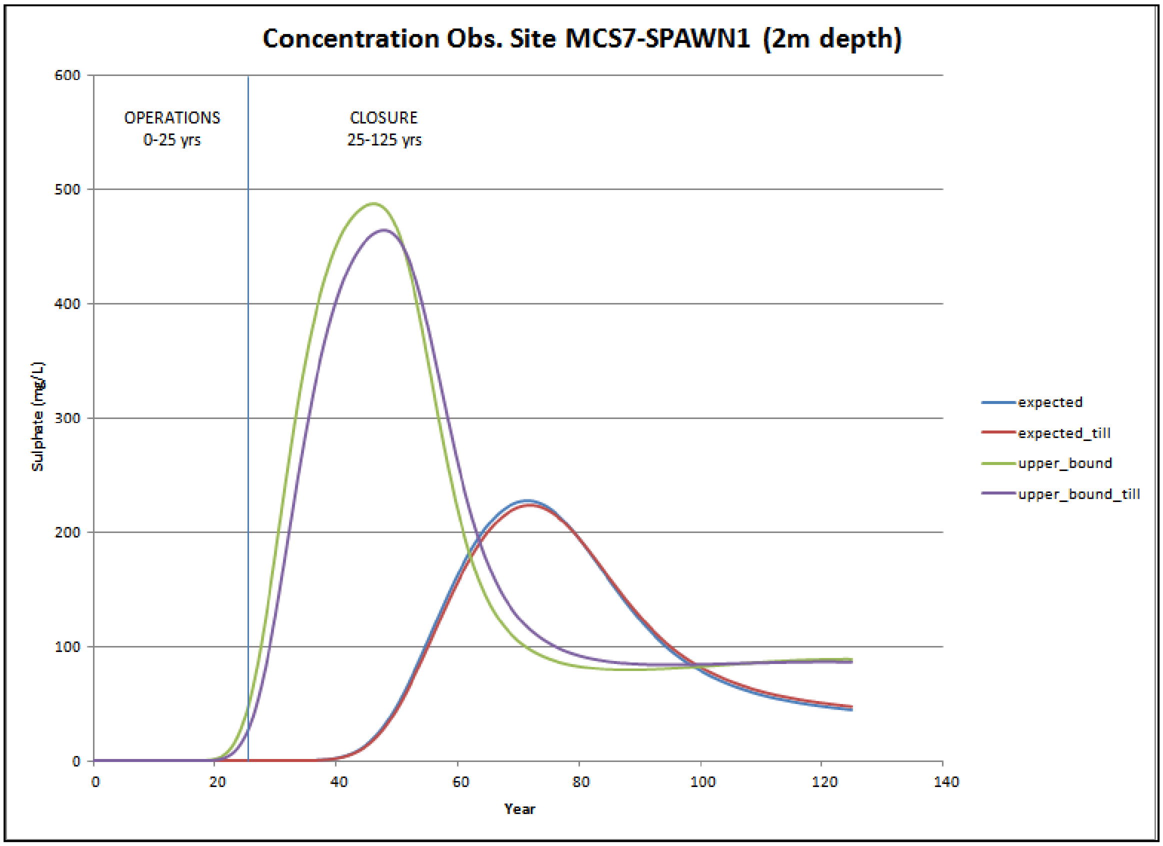


Figure I-9 Sulphate Concentration in Groundwater (2m) MCS-7 SPAWN1

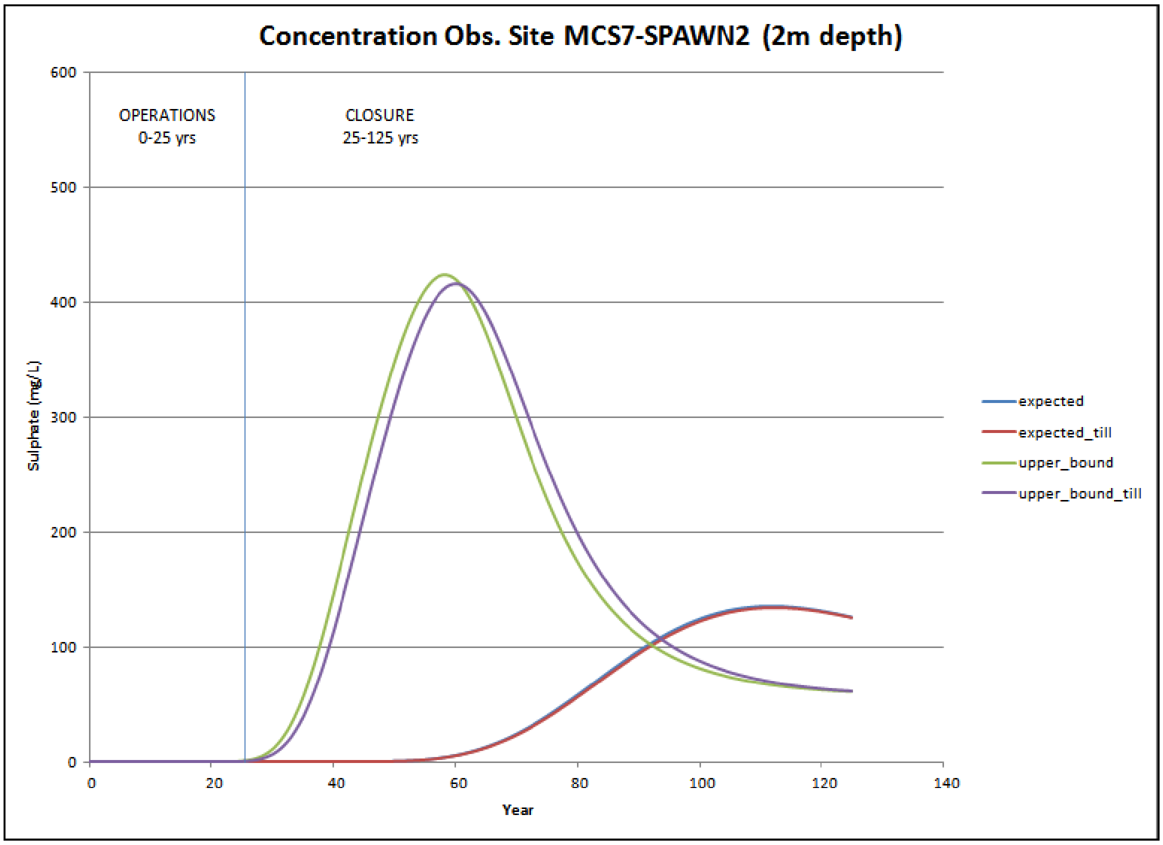


Figure I-10 Sulphate Concentration in Groundwater (2 m) MCS-7 SPAWN2

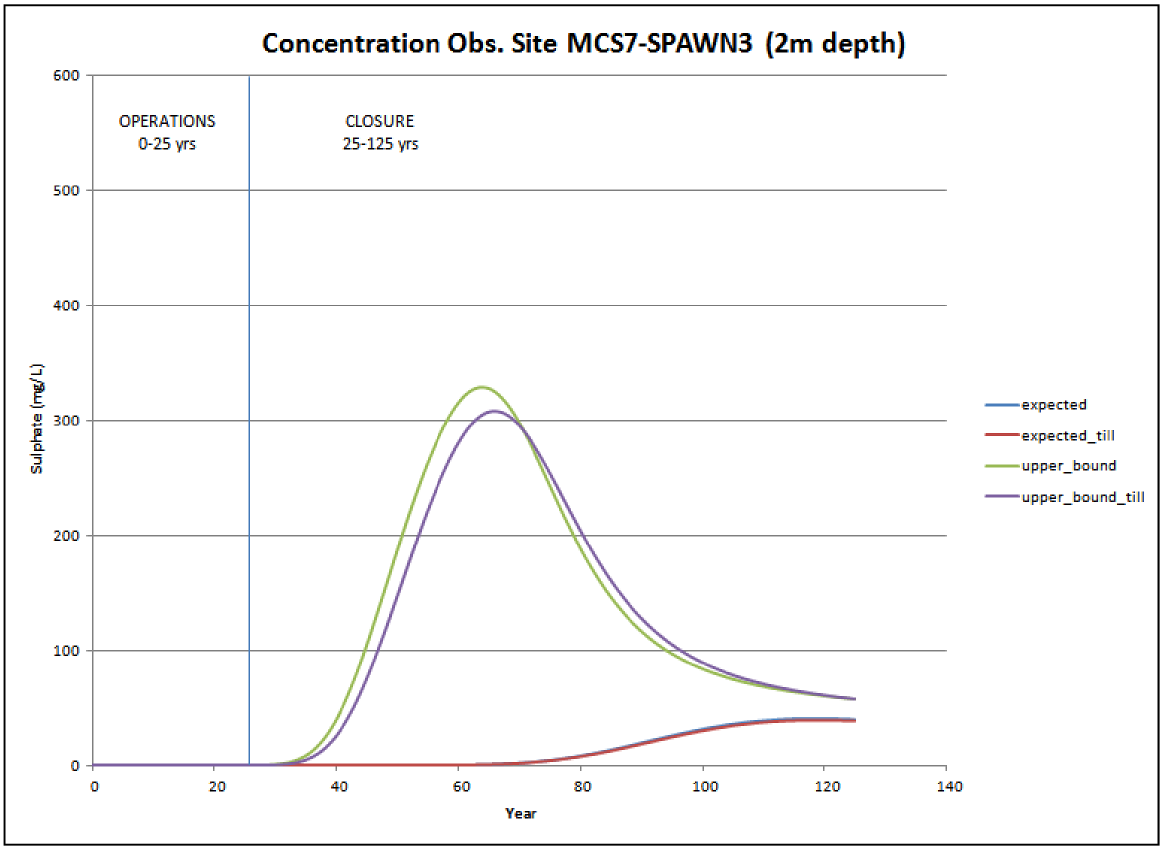


Figure I-11 Sulphate Concentration in Groundwater (2 m) MCS-7 SPAWN3

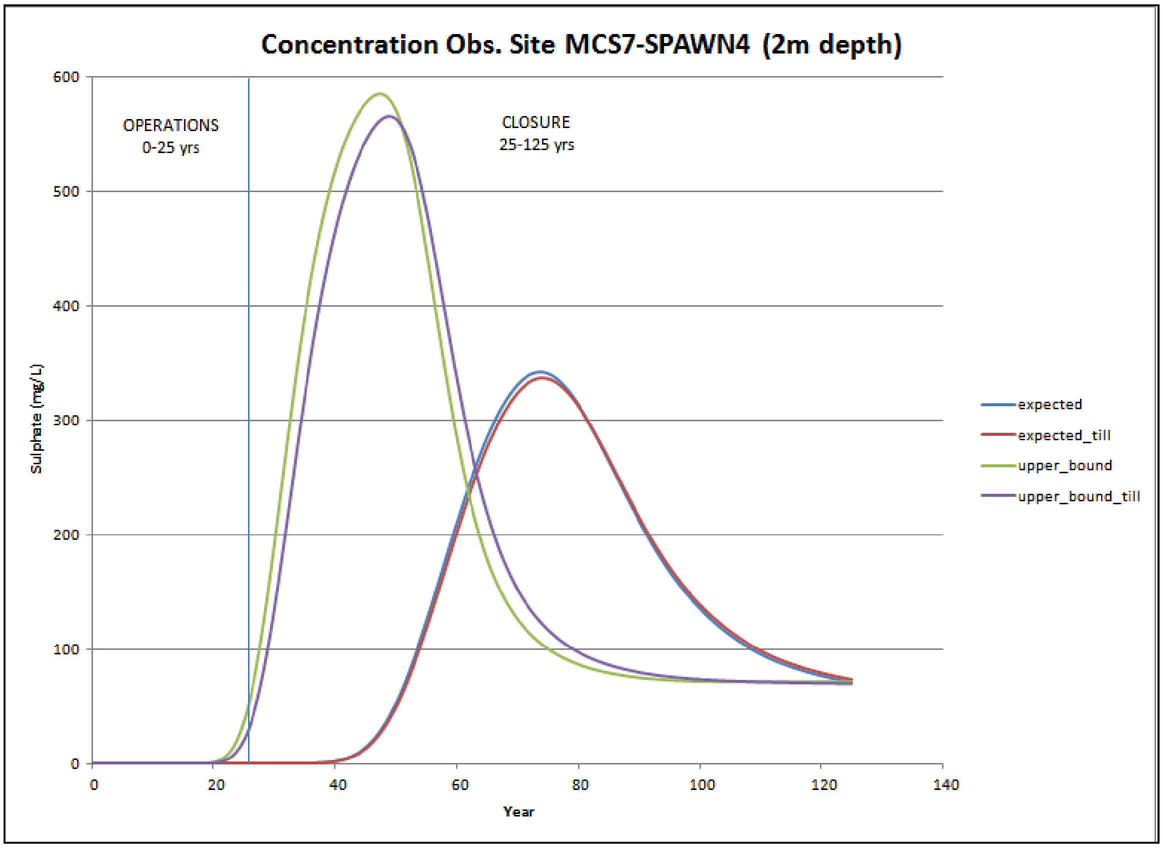


Figure I-12 Sulphate Concentration in Groundwater (2 m) MCS-7 SPAWN4

I-4.5 Sensitivity Analysis

Sensitivity analyses were undertaken to assess variability in the TSF seepage rate that may arise from uncertainty in data/parameterization and operational conditions. Details of the trials completed for the TSF are summarized in Table I-11.

Table I-11 Sensitivity Trials completed for TSF.

Trial #	Trial	Expected Case	Upper Bound	Comments
1 2	Tailings Hydraulic Conductivity (no SMD)	K × 10 K ÷ 10	--	Anisotropy ratio of each case maintained (1:10 expected, 1:5 upper bound).
3 4	Tailings Hydraulic Conductivity (till liner)	K × 10 K ÷ 10	K x 10 K ÷ 10	
5 6	Pond Size (no SMD)	0.5 km^2 2.5 km^2	--	Potential pond size which might exist during flood (2.5 km^2) and variations in tailings/water management (0.5 km^2).
7 8	Pond Size (till liner)	0.5 km^2 2.5 km^2	0.5 km^2 2.5 km^2	
9 10	Fault Hydraulic Conductivity (no SMD)	K × 10 K ÷ 10	--	Not considered for upper bound as fault K already increased.
11 12	Fault Hydraulic Conductivity (till liner)	K × 10 K ÷ 10	--	
13 14	Till Liner	K × 10 K ÷ 10	K × 10 K ÷ 10	Varied from initial input of K=10-08 m/s (isotropic).

Sensitivity trials for the ‘expected case’ were more comprehensive than the ‘upper bound’ case, as the latter already includes higher hydraulic conductivity values for tailings, faults and surficial till. Furthermore, sensitivity trials were only completed for the ‘engineered till liner’ SMD option as results from the primary modeling scenarios indicated this SMD option achieved environmental objectives when considered in the water balance assessment.

The sensitivity trials for faults are considered to be of relatively low reliability for predicting TSF seepage rates as the inputs deviate from those included in the expected and upper bound calibrated models. As the tailings, pond size and till liner were not included in the calibration, results from these sensitivity trials are considered more representative.

Results of the sensitivity trials are summarized in Table I-12.

Table I-12 Sensitivity Trials completed for TSF.

Trial #	Trial	Variation	Expected Case* (m^3/hr)	Upper Bound* (m^3/hr)
Original Result		--	65 (no SMD) 64 (till liner)	128 (till liner)
1 2	Tailings Hydraulic Conductivity (no SMD)	K × 10 K ÷ 10	109 (167%)* 23 (35%)	--
3 4	Tailings Hydraulic Conductivity (till liner)	K × 10 K ÷ 10	104 (161%) 26 (40%)	192 (150%)** 81 (63%)
5 6	Pond Size (no SMD)	2.5km^2 0.5km^2	89 (136%) 26 (40%)	--
7 8	Pond Size (till liner)	2.5km^2 0.5km^2	88 (136%) 26 (40%)	167 (131%) 61 (48%)
9 10	Fault Hydraulic Conductivity (no SMD)	K × 10 K ÷ 10	87 (133%) 58 (88%)	--
11 12	Fault Hydraulic Conductivity (till liner)	K × 10 K ÷ 10	85 (131%) 57 (88%)	--
13 14	Till Liner	K × 10 K ÷ 10	67 (104%) 49 (77%)	136 (106%) 93 (73%)

* Percentage values indicate the predicted sensitivity seepage estimate relative to the original result
** The upper bound tailings hydraulic conductivity was already higher than the expected case, this value is therefore considered an extreme upper bound (Kh=5E-06 m/s)

For the expected case the change in the rate of seepage was comparable for the scenarios with and without the till liner. This outcome is expected result given the hydraulic conductivity of the till is similar to the overlying tailings and underlying surficial till included in the model. The results of the sensitivity trials for scenarios, which included the till liner, indicate:

- All high-end predicted seepage rates for 'expected case' sensitivity scenarios were less than the predicted seepage rate for the upper bound case. This suggests that collectively considering upper bound inputs collectively has a greater effect on the results than uncertainty in any single parameter.

- The seepage rate from the TSF was most sensitive to the hydraulic conductivity of the tailings. The rate increased by 50% (upper bound) to 61% (expected) for a one order of magnitude increase in tailings K, and decreased to 40% (expected) to 63% (upper bound) of the initial rate with a one order of magnitude decrease.

- Varying the hydraulic conductivity of the faults had a reasonable effect on seepage rates, increasing by 31% when the hydraulic conductivity of TSF area faults was increased to 8E-06 m/s, and decreasing to 88% of the initial rate when the hydraulic conductivity was decreased to 8E-08 m/s. These results suggest that relatively permeable faults beneath the TSF may be important controls on seepage, even when overlain by a till liner.

- As would be expected, the seepage rate is sensitive to the size of the pond within the TSF, with the rate being slightly better regulated in the upper bound case compared to the expected case (due to the relative hydraulic conductivity contrast of the liner). A large pond size would be expected to be a short term phenomena corresponding to flood events; comparatively, a smaller pond might be expected during startup and closure.

- Increasing the hydraulic conductivity of the till liner in isolation had only a slight effect on seepage, as the tailings and surficial till materials primarily control the seepage rate. Decreasing the hydraulic conductivity of the till liner by one order of magnitude has a more pronounced effect, and reduces seepage by approximately one-quarter for both the expected and upper bound cases. The reduction in seepage is slightly greater for the latter as the liner is of lower hydraulic conductivity than the underlying till and overlying tailings.

I-4.6 Pit Dewatering Assessment

Dewatering rates for the mine pit were calculated at four stages of operation summarized in Table I-13. For all cases inflows for the expected and upper bound calibrated models were considered, and simulations run to steady state conditions.

Table I-13 Simulated Scenarios – Pit Dewatering.

Mine Year	Floor Elevation	Boundary Condition
1	780 m	Drain Cells
5	648 m	Constant Heads
12	576 m	
19	480/490m	

Constant head and drain boundary conditions were used in preference to dewatering wells, as these enabled dewatering/depressurization of the pit to be fully achieved under the simulated confined conditions. No specific depressurization targets for the pit walls and floor were considered for this study, as none was provided in the design basis (Knight Piesold, 2006). For all floor elevations considered, the (unidentified) depressurization target of 25 m behind the pit walls considered by Rescan (2009a) was achieved.

A drain cell array with an elevation of 780 m was used to represent the dewatered pit at year 1 of mining. This was required as the floor elevation is above Morrison Lake, and using a constant head condition at this elevation would have allowed recharge from the pit to the model domain (ie. the pit floor is above Morrison Lake). A high conductance (C_d =1,000) was assigned to the drains to allow groundwater to flow into the pit unimpeded. For all other simulated years of operation, constant head cells were assigned to the pit floor with an equivalent elevation.

Cells above the pit floor (corresponding to the excavated pit shell) were assigned relatively high hydraulic conductivity (1E-04m/s) and storage parameters (Ss=0.01m^{-1}, Sy=0.75) to simulate 'atmospheric' conditions and allow the pit to be internally depressurized (noting that storage is not considered during steady state simulations).

I-4.7 Results

The estimated inflow rates to the mine pit for the different stages of operation considered are presented in Table I-14.

Table I-14 Pit Dewatering – Operational Inflows.

Mine Year	Floor Elevation	Expected Case		Upper Bound Case	
		Total Inflow (m^3/hr)	From Morrison Lake (m^3/hr)	Total Inflow (m^3/hr)	From Morrison Lake (m^3/hr)
1	780 m	33	0	48	0
5	648 m	152	0	271	0
12	576 m	260	0	464	0
19	480/490m	368	133	685	320

For both the expected and upper bound case, the rate of groundwater inflow into the mine pit increased at a near linear rate over the life of mine for the scenarios considered. Groundwater inflow from Morrison Lake to the mine pit was not recorded until after year 19. Although the steady state drawdown influence from the pit just extends to Morrison Lake at year 12, this does not result in inflow from Morrison Lake, with most inflow being derived from dewatering of the relatively permeable Ashman Formation and elevated gradients to the east.

Plots of regional potentiometry for each year of operation under ‘expected’ and ‘upper bound’ scenarios are presented as Appendix IV. The predicted magnitude and extent of drawdown increases with progressive deepening of the pit, and tends to extend preferentially northwest-southeast along the strike of low elevation faults and the relatively permeable Ashman Formation. Drawdown influence extends to the southern (no flow) extent of the model domain, and likely contributes to some reflection, which likely exacerbates the predicted drawdown influence in this area.

I-4.8 Pit Infilling

Simulations to replicate transient pit refilling were attempted, however, the MODFLOW layer designation assigned to the model resulted was responsible for unrealistic results unless very low (and conceptually incorrect) storage characteristics were assigned to the in-pit waste rock (which represented the primary control on inflow rates). Specifically, the layer properties did not allow a change from elastic (Ss) to gravity (Sy) storage as the head in upper model layers fell below the cell top, and did not reduce transmissivity in-line with the reduction in saturated thickness. This could not be readily overcome by revising the layer type and model setup, as extensive drying of upper model layers led to numerical instability, which was exacerbated by the steep terrain and presence of the pit next to Morrison Lake.

An analytical approach which extrapolated between the inflow rate at the final pit floor level (480 m / 490 m) and the final selected pit lake level was instead adopted to calculate pit refill rates. In practice, if a periphery well field was used during operational dewatering (and inflows were as high as predicted) the rate of recovery could be managed through pumping. Alternatively, if additional make-up water were required, surface water from the lake could be used to supplement any shortfall needed to maintain a water cover over the in-pit waste rock during backfilling.

I-4.9 Sensitivity

Sensitivity trials were completed for both the expected and upper bound pit dewatering cases for the final year of mine life (year 19, pit floor 480m/490m). The scenarios which were undertaken are presented in Table I-15.

Table I-15 Sensitivity Trials completed for Pit Dewatering

Trial #	Trial	Expected Case	Upper Bound	Comments
1 2	Lower Bedrock Hydraulic Conductivity	K × 5 K ÷ 5 (Layers		Lower variation range selected to remain within general data bounds
3 4	Fault Hydraulic Conductivity	K × 10 K ÷ 10		Assess sensitivity of faults independently of other inputs.
5 6	General Head Boundary Conductance	C_d × 100 C_d ÷ 100	--	To assess whether assigned C_d might be resulting in artificial restriction of exchange between Morrison Lake and the pit.
7 8	Grouting of Faults	K faults near pit = 1E-09m/s (Layers 1-20)		To simulate potential grouting of fault zones intersected by pit wall – potential management strategy rather than sensitivity.

As the sensitivity analyses completed for the pit required changes to the calibrate model setup, the results should be considered indicative for water management purposes. Results of the sensitivity trials are summarized in Table I-16 and Table I-17. Furthermore, the hydraulic conductivity of mine area/regional faults incorporated into the upper bound scenario had already been increased relative to the expected case; the high end results for the fault sensitivity scenario therefore represent an extreme upper bound.

Table I-16 Sensitivity Trials – Pit Inflow Rates

Trial #	Trial	Variation	Expected Case (m^3/hr)	Upper Bound (m^3/hr)
Original Result			368	685
1 2	Lower Bedrock Hydraulic Conductivity	K × 5 K ÷ 5	546 (148%) 323 (88%)	872 (127%) 640 (93%)
3 4	Fault Hydraulic Conductivity	K × 10 K ÷ 10	733 (199%) 268 (73%)	1154 (168%) 513 (75%)
5 6	General Head Boundary Conductance	C_d × 100 C_d ÷ 100	370 (101%) 306 (83%)	--
7 8	Grouting of Faults	K faults near pit = 1E-09 m/s (Layers 1-20)	320 (87%)	638 (93%)

Table I-17 Sensitivity Trials – Inflow from Morrison Lake

Trial #	Trial	Variation	Expected Case (m^3/hr)	Upper Bound (m^3/hr)
Original Result			133	320
1 2	Lower Bedrock Hydraulic Conductivity	K × 5 K ÷ 5	205 (154%) 114 (86%)	379 (118%) 307 (96%)
3 4	Fault Hydraulic Conductivity	K × 10 K ÷ 10	300 (226%) 79 (60%)	536 (167%) 213 (66%)
5 6	General Head Boundary Conductance	C_d × 100 C_d ÷ 100	134 (101%) 98 (74%)	--
7 8	Grouting of Faults	K faults near pit = 1E-09 m/s (Layers 1-20)	103 (77%)	299 (93%)

With the exception of the fault hydraulic conductivity increased by one order of magnitude, all estimated for the expected case were less than the upper bound case. The results of the pit inflow sensitivity trial indicate:

- Increasing the hydraulic conductivity of the lower bedrock units increased inflow into the pit by 27% for the upper bound case and 148% for the expected case. Decreasing the hydraulic conductivity reduced inflow by 7% for the upper bound case and 12% for the expected case. The upper bound case is likely less sensitive to changes in lower bedrock hydraulic conductivity due to flow occurring primarily in the more permeable upper bedrock, and the higher hydraulic conductivity of the faults.

- Varying the hydraulic conductivity of the mine area and regional faults had a marked effect on pit inflows, and suggests is an important factor in controlling pit inflow rates.

- Varying the conductance of the GHB assigned to Morrison Lake had a slight effect on pit inflows, and indicates the model is relatively insensitive to moderate variations in this parameter.

- Grouting of faults decreased pit inflows, however, the overall influence was small (7-13% reduction). The simulation approach likely underestimates the effectiveness of this strategy in controlling inflow to the pit, as the model is not capable of truly replicating fracture flow (Section I-5, Limitations).

- For each sensitivity trial, the change in inflow from Morrison Lake to the pit is approximately proportional to the change in total inflow. Fault grouting appears to preferentially reduce flow into the pit from Morrison Lake in preference to regional groundwater.

Discussion

The predicted pit inflow rates are relatively high compared to estimates provided in KCB (2011) and nearby operational sites in comparable fractured rock settings near lakes (Granisle and Bell Mines). However, these rates are not unexpected for a fractured rock setting adjoining a permanent water body with steep gradients in adjoining ridgelines, and could be readily managed through in-pit pumping coupled with periphery wells in relatively permeable zones outside the pit. This dewatering strategy is largely consistent with that proposed by Knight Piesold (2006), noting that the periphery well field was previously considered to be needed only if required, with pit depressurization achieved primarily using horizontal drainage in pit walls (a pit dewatering design element typically used in low permeability formations).

It should be noted that pit inflow rates form this assessment are likely at the higher end of what might be expected due to the modeling approach. As the pit is dewatered, the saturated thickness in the upper model layers decreases, however, the assigned layer properties did not allow recalculation of transmissivity to reflect this change, and values remained at their assigned upper limit. However, this added conservatism is considered appropriate, as inflow rates would be expected to be relatively high leading up to the simulated steady state condition, as groundwater must initially be removed from storage to achieve final conditions.

I-4.10 Final Pit Lake Assessment

An assessment of inflows into the final post-closure pit lake was completed to assist with quantifying potential long-term water treatment requirements and to assess potential exchange of pore water within the backfilled PAG rock with Morrison Lake through groundwater. Conceptually, as the pit lake level increases, inflows from regional groundwater decrease, however, the gradient to Morrison Lake is increased. This reduces water handling requirements but may result in a higher throughput of contact groundwater to Morrison Lake. Conversely, maintaining a pit lake level at or near the average level in Morrison Lake (El. 732 m) increases water handling requirements, but likely maintains the pit as a constant groundwater sink.

A constant head boundary condition with an elevation and area equivalent to differing pit lake levels was assigned to the model to represent the final pit lake. The hydraulic conductivity assigned to the waste rock in the pit was comparable to the faults in the mine area (1.5E-6 m/s for the expected case, 3.0E-06 m/s for the upper bound); although not considered in a steady state solution, the

The range of pit lake elevations simulated was selected following an initial model run which excluded the constant head boundary condition for the pit lake. This represents the level at which the potentiometric level in the pit area would stabilize at post-closure; without an assigned head condition this surface is not flat (as would occur with the final lake). Groundwater levels in the pit without a head condition ranged from approximately El. 750 m to El. 800 m; most of the simulated lake levels (732 m to 763 m) will therefore required some pump-down. Higher pit lake levels were not simulated as being able to undertake water treatment is preferred to flow through of contact seepage to Morrison Lake.

I-4.11 Results

Estimated groundwater inflow into the final pit lake and exchange with Morrison Lake under differing operating levels are summarized in Table I-18. These results are intended to assist with optimization of the closure lake level by achieving a balance between contact groundwater seepage to Morrison Lake and water treatment requirements.

Table I-18 Inflow in to the Final Pit Lake and Exchange with Morrison Lake under Differing Operating Levels

Simulation #	Pit Lake Elevation	Expected Case		Upper Bound	
		Pit Lake Inflow (m^3/hr)	Flow to Morrison Lake (m^3/hr)	Pit Lake Inflow (m^3/hr)	Flow to Morrison Lake (m^3/hr)
1	732 m	95.3	0.1	126.7	0.4
2	735 m	92.0	0.2	121.0	1
3	737 m	90.7	0.4	117.8	1.8
4	745 m	80.5	2.8	97.5	8.1
5	763 m	69.6	6.8	73.8	21.9

At an elevation of 732 m, there is negligible exchange between Morrison Lake and the pit lake, however, inflows form regional groundwater are higher than predicted for higher lake levels. This is expected given the level in the pit lake is the same as in Morrison

Lake. At higher pit lake levels inflows into the pit lake (and hence, water treatment requirements) are less, however, the rate of contact seepage migration to the Lake increases.

I-4.12 Sensitivity Trials

Sensitivity trials were completed for the scenario which considered the final pit lake level at 732 m. The scenarios which were undertaken are presented in Table I-19. Variance of the conductance of Morrison Lake GHB conductance was not undertaken as sensitivity trials completed for the pit dewatering assessment indicate the model results are relatively insensitive to this parameter.

Table I-19 Sensitivity Trials completed for the Final Pit Lake (El 732 m)

Trial #	Trial	Expected Case	Upper Bound	Comments
1 2	Lower Bedrock Hydraulic Conductivity	K × 5 K ÷ 5 (Layers		Lower variation range selected to remain within general data bounds
3 4	Fault Hydraulic Conductivity	K × 10 K ÷ 10		Assess sensitivity of faults independently of other inputs.

Results of the sensitivity trials on pit lake inflows are summarized in Table I-20. Results for groundwater exchange between the final pit lake and Morrison Lake are presented in Table I-21.

Table I-20 Sensitivity Trial Results – Pit Lake Inflows

Trial #	Trial	Variation	Expected Case (m^3/hr)	Upper Bound (m^3/hr)
Original Result			95.3	126.7
1 2	Lower Bedrock Hydraulic Conductivity	K × 5 K ÷ 5	138.5 (145%) 94.0 (99%)	178.0 (140%) 113.6 (90%)
3 4	Fault Hydraulic Conductivity	K × 10 K ÷ 10	155.0 (163%) 92.2 (97%)	222.5 (176%) 110.1 (87%)

Table I-21 Sensitivity Trial Results – Exchange with Morrison Lake

Trial #	Trial	Variation	Expected Case (m^3/hr)	Upper Bound (m^3/hr)
Original Result			0.1	0.4
1	Lower Bedrock Hydraulic Conductivity	K × 5	0.1 (100%)	1.0 (250%)
2		K ÷ 5	0.1 (100%)	0.3 (75%)
3	Fault Hydraulic Conductivity	K × 10	0.4 (400%)	0.9 (23%)
4		K ÷ 10	0.1 (100%)	0.4 (100%)

For both the expected and upper bound cases, inflows into the pit lake were relatively insensitive to a decrease in the hydraulic conductivity of the faults and the lower bedrock. However, an increase in the hydraulic conductivity of these units had a marked effect on pit lake inflows. Unlike the TSF and the pit dewatering sensitivity assessments, the high-end results for the expected case for the final pit lake exceeded the upper bound case for both sensitivity trials.

Despite the percentage change in flow from the pit lake to Morrison Lake being relatively large for most upper bound sensitivity trials, the total flow rate is relatively small when compared to the results for higher lake levels. Outflows from the pit lake to Morrison Lake were relatively insensitive to changes in fault and lower bedrock hydraulic conductivity for the expected case simulations.

I-5. LIMITATIONS

The numerical modelling assessment was undertaken to assess whether the project might pose a significant adverse risk to the environment, and to assist with 'higher level' site-wide planning and water management. The results of this assessment are not considered suitable for design purposes, and should be reviewed as and when new data and information becomes available.

As with any modelling assessment, there are inherent assumptions and limitations which could impact the reliability of the resultant predictions. For this assessment, the following are considered to be of particular relevance:

- The conceptual model for the site suggests groundwater occurrence and is primary associated with zones of fracture and structural deformation in a largely coherent rock mass. These settings are difficult to accurately characterize and reliably model. To approximate groundwater behaviour at the regional scale, an equivalent porous media approach (incorporating relatively permeable faults) was adopted. Actual groundwater behaviour will in practice be variable and scale dependent.

- Uncertainty in the conceptualization and input data required many of the model inputs to be assumed, based on professional judgment. Primary assumptions have been detailed, and where appropriate, have been conservative.

- Pit dewatering, TSF development and the final pit lake scenarios were all simulated under steady-state conditions only and assume site conditions are in equilibrium. The time required to achieve these conditions and the intermediate effects were not assessed.

- Interaction between surface water and groundwater is a relatively important component of site wide water management and assessment of project environmental effects; where appropriate, effects have been assessed using results from this assessment in conjunctive studies. However, the model is not capable of simulating coupled surface water / groundwater interaction, and results should therefore be considered estimates. A fully coupled model would require extensive input data, and is considered beyond the scope of the current project requirements.

I-6. CONCLUSIONS AND RECOMMENDATIONS

The effects of the TSF, dewatered mine pit and final pit lake on regional groundwater were simulated to assist with assessing the potential environmental impacts of the project. From a groundwater management perspective, the rate of seepage from the TSF and inflow into the dewatered mine pit and closure pit lake are considered manageable, and within the range that would be expected for similar sized mines in comparable fractured rock hydrogeological settings.

To advance the project into a detailed design phase, and allow an improved understanding of the potential environmental effects of the project, the following recommendations are made. These target uncertainty in the conceptualization and data, with a particular focus on factors which were shown to be of importance during sensitivity trials and calibration:

- Geologic mapping of bedrock which may be exposed between Morrison Lake and the open pit, to confirm regional mapping and geological structural characteristics (at surface).
- Complete additional drilling and testing in the vicinity of the open pit to confirm assumed hydraulic data for the deeper bedrock units. The drilling program should also assess the condition and hydraulic conductivity of faults in both the mine area and TSF.
- Complete a geophysical survey of the Morrison Lake bed, to provide an indication of the thickness and heterogeneity of lake bed sediments, which may limit connectivity between surface water in the lake and regional groundwater. Lakebed sampling and monitoring should be undertaken to verify the geophysical survey and facilitate pore water / hyporheic zone sampling.
- Implement automated monitoring of groundwater levels to assist with confirmation of groundwater recharge mechanisms and rates. Reliable annual stream gauging records should also be obtained to assist with confirmation of baseflow rates and mechanisms.

- Characterize variability in the hydraulic conductivity of the tailings through laboratory testing.
- Implement a structured and routine baseline groundwater sampling and analysis program. This should include the collection of results near sensitive receptor sites, with the monitoring locations able to remain functional through operations and closure.

Complete a pumping test program to assess aquifer characteristics (transmissivity, storage), boundary effects due to lakes and structural elements and to evaluate aquifer yields. This program will assist with improving the conceptual hydrogeological model and confirming potential dewatering requirements and rates. At least two pumping tests (including step testing, constant rate testing and recovery) each with a separate array of observation wells should be completed.

REFERENCES

Cook, P. (2003). A guide to Regional Groundwater Flow in Fractured Rock Aquifers. CSIRO.

Eriksson, E. and Khunakasem, V. (1969). Chloride Concentration in Groundwater, Recharge Rate and Rate of Deposition of Chloride on the Israel Coastal Plain. J. Hydrogeology, v7, 178-197.

Hem, J. (1985). Study and Interpretation of the Chemical Characteristics of Natural Waters. USGS Water Supply Paper 2254.

McDonald, M.G., and Harbaugh, A.W. (1988). A modular three-dimensional finite-difference ground-water flow model. USGS Techniques of Water-Resources Investigations, Book 6.

Rescan (2009). Morrison Copper/Gold Project Groundwater Baseline 2008.

Rescan (2009a). Morrison Copper/Gold Project Hydrogeological Modelling Report (Appendix 25).

APPENDIX I

Updated Groundwater Level Data

Water levels for drill holes

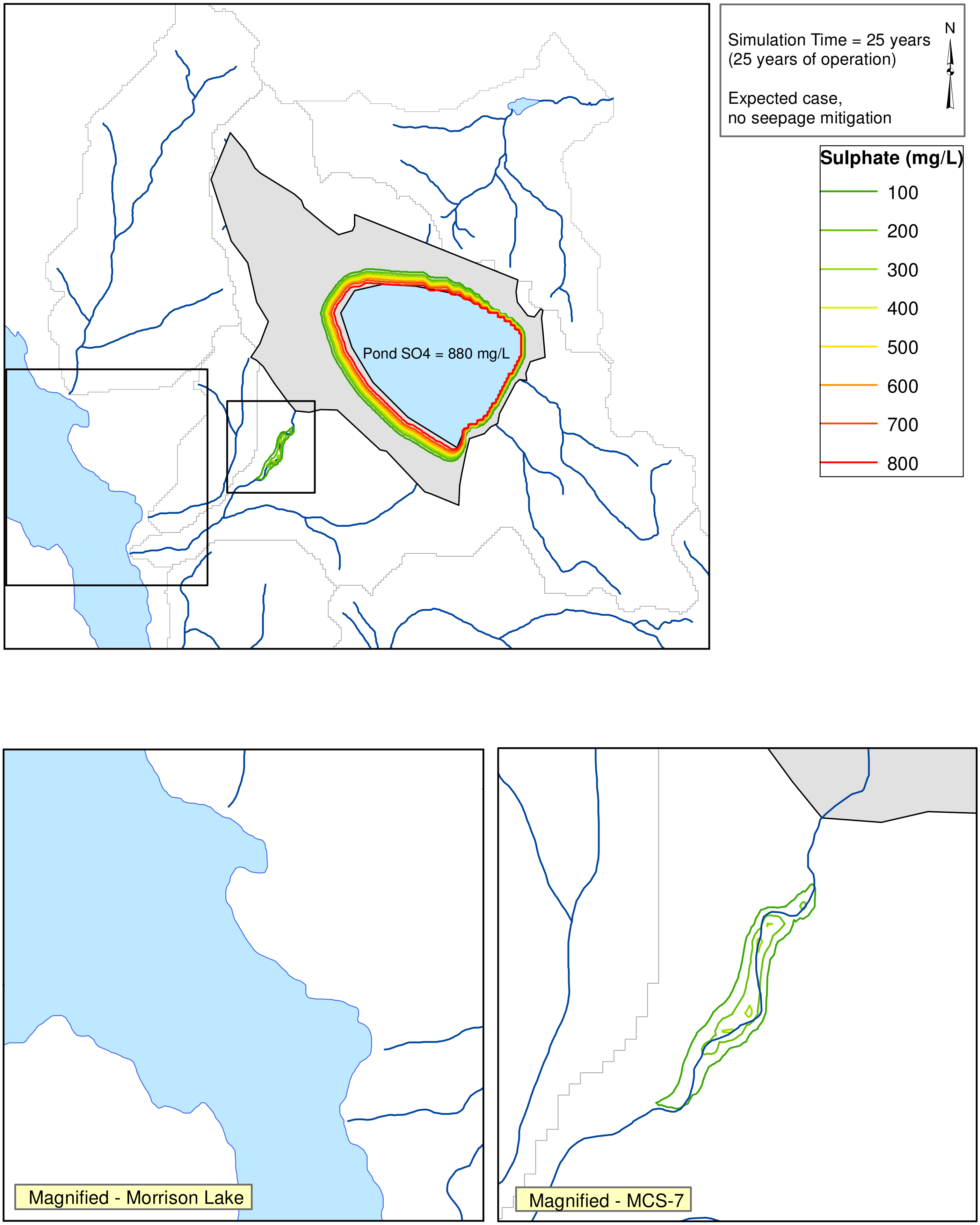
Note: (mbgs) is meters below ground surface

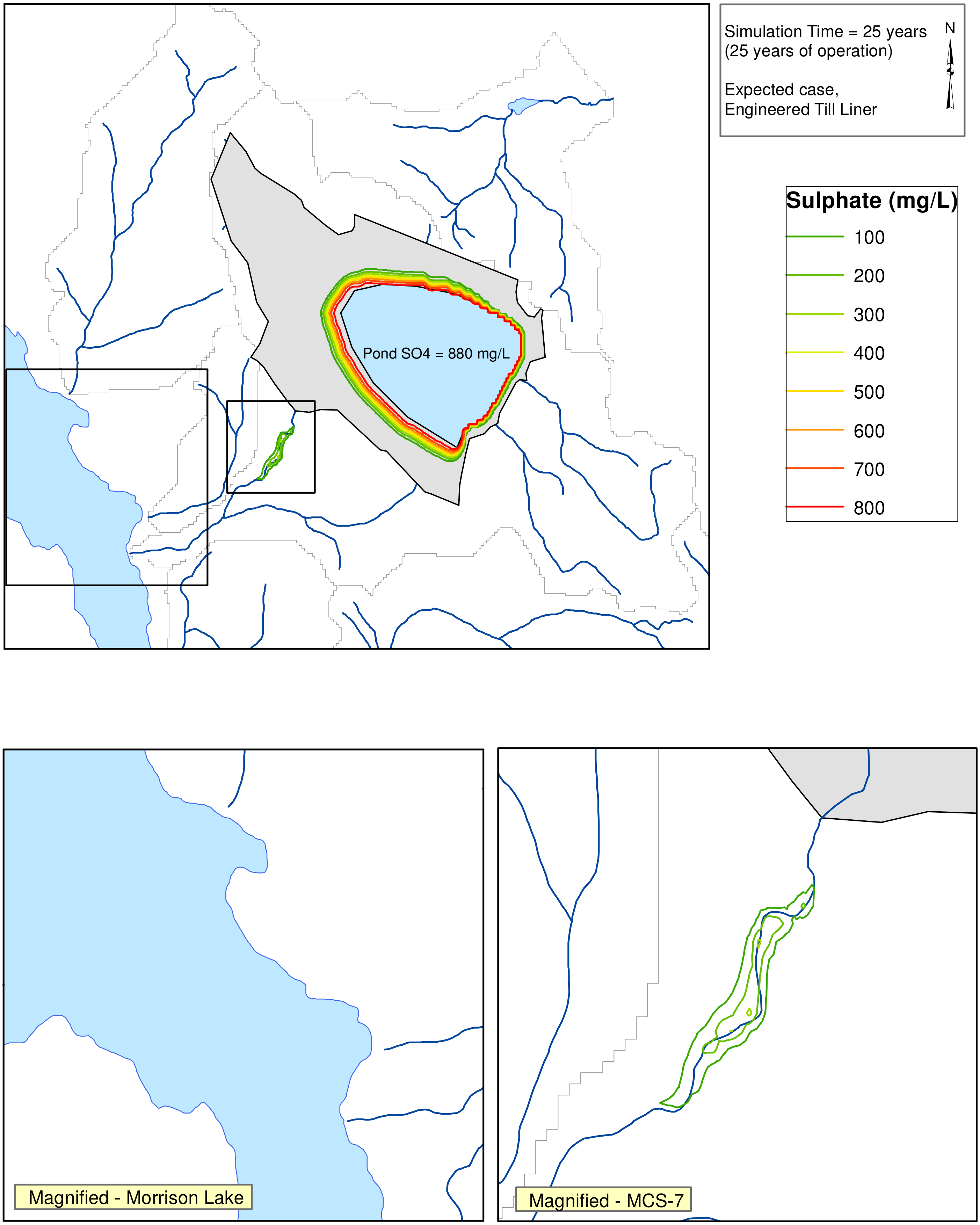
Identification		2006	2007	2008			2010	2011
DH06-2	Date	6-Mar-06		9-Oct-08				
	Water Level (masl)	950		950				
	Water Level (mbgs)	artesian		artesian				
DH06-3	Date	4-Mar-06		9-Oct-08				
	Water Level (masl)	945.5		947.25				
	Water Level (mbgs)	4.5		2.75				
DH06-4	Date	9-Mar-06		9-Oct-08				
	Water Level (masl)	970.8		972.87				
	Water Level (mbgs)	12.2		10.13				
DH06-6	Date	11-Mar-06		9-Oct-08				
	Water Level (masl)	960		960				
	Water Level (mbgs)	artesian		artesian				
DH06-7	Date	1-Mar-06		9-Oct-08			23-Oct-10	10-Jan-11
	Water Level (masl)	993		993			993	993
	Water Level (mbgs)	artesian		artesian			artesian	artesian
DH06-8	Date	20-Mar-06		15-Jul-08	6-Oct-08			
	Water Level (masl)	838		838	838			
	Water Level (mbgs)	artesian		artesian	artesian			
DH06-9	Date	20-Mar-06		15-Jul-08	6-Oct-08			
	Water Level (masl)	814		827.7	827.58			
	Water Level (mbgs)	21		7.3	7.42			
DH06-10	Date	20-Feb-06		18-Jul-08	8-Oct-08			
	Water Level (masl)	971.4		970.72	970.68			
	Water Level (mbgs)	29.6		30.28	30.32			
DH06-11	Date	22-Feb-06		18-Jul-08	8-Oct-08			
	Water Level (masl)	963.8		963	963.21			
	Water Level (mbgs)	1.2		2	1.79			
DH06-12	Date	26-Feb-06		18-Jul-08	8-Oct-08		24-Oct-10	10-Jan-11
	Water Level (masl)	992.2		992.05	991.66		990.71	989.45
	Water Level (mbgs)	3.8		3.95	4.34		5.29	6.55
DH06-13	Date	23-Mar-06						
	Water Level (masl)	799.2						
	Water Level (mbgs)	8.8						
DH06-14	Date	Nov 05 - Apr 06		15-Jul-08	6-Oct-08			
	Water Level (masl)	829.6		833.24	836.46			
	Water Level (mbgs)	10.4		6.76	3.54			
DH06-15a	Date	16-Mar-06		9-Oct-08				
	Water Level (masl)	817		817				
	Water Level (mbgs)	Artesian		artesian				
DH06-15b	Date	17-Mar-06						
	Water Level (masl)	814						
	Water Level (mbgs)	3						
DH06-16	Date	2-Apr-06						
	Water Level (masl)	759						
	Water Level (mbgs)	3						
DH06-17	Date	Nov 05 - Apr 06						
	Water Level (masl)	unknown						
	Water Level (mbgs)	Dry						
GW1	Date	4-Apr-06						
	Water Level (masl)	792.4						
	Water Level (mbgs)	2.6						
9000-1	Date	4-Feb-06						
	Water Level (masl)	795.62						
	Water Level (mbgs)	22.48						
9240-1	Date	24-Jan-06						
	Water Level (masl)	797.06						
	Water Level (mbgs)	51.84						
9240-3	Date	11-Feb-06						
	Water Level (masl)	798.63						
	Water Level (mbgs)	6.37						
DH07-1A	Date		Nov-07	6-Apr-08	18-Jul-08	8-Oct-08		
	Water Level (masl)		977.5	973	973	973		
	Water Level (mbgs)		-4.5 (artesian)	artesian	artesian	artesian		
DH07-1B	Date			6-Apr-08	18-Jul-08	8-Oct-08		
	Water Level (masl)			frozen	973.83	973.83		
	Water Level (mbgs)			frozen	-0.83	-0.83		
DH07-2A	Date		Nov-07	6-Apr-08	18-Jul-08	8-Oct-08		
	Water Level (masl)		962.3	961.29	962.13	962.02		
	Water Level (mbgs)		27.7	27.74	27.87	27.98		
DH07-2B	Date		18-Nov-07	6-Apr-08	18-Jul-08	8-Oct-08		
	Water Level (masl)		979	982.75	983.58	983.68		
	Water Level (mbgs)		11	6.32	6.42	6.32		
DH07-3A	Date		Nov-07	6-Apr-08	9-Oct-08			
	Water Level (masl)		963.27	964.49	965.22			
	Water Level (mbgs)		10.73	8.59	8.78			
DH07-3B	Date		22-Nov-07	6-Apr-08	9-Oct-08			
	Water Level (masl)		963.3	962.42	963.2			
	Water Level (mbgs)		10.7	10.72	10.8			
DH07-4A (S1)	Date		7-Nov-12	6-Apr-08	9-Oct-08			
	Water Level (masl)		950.3	948.9	950.06			
	Water Level (mbgs)		9.7	10.28	9.94			
DH07-4A (S2)	Date		Nov-07	6-Apr-08	9-Oct-08			
	Water Level (masl)		949.5	948.22	949.22			
	Water Level (mbgs)		10.5	10.94	10.78			
DH07-4B (S1)	Date			6-Apr-08	9-Oct-08			
	Water Level (masl)			948.33	949.43			
	Water Level (mbgs)			10.77	10.57			
DH07-4B (S2)	Date			6-Apr-08	9-Oct-08			
	Water Level (masl)			955.04	958.56			
	Water Level (mbgs)			4.05	1.44			
DH07-5A (S1)	Date		Nov-07	6-Apr-08				
	Water Level (masl)		925.7	922.68				
	Water Level (mbgs)		9.3	11.47				
DH07-5A (S2)	Date		Nov-07	6-Apr-08				
	Water Level (masl)		925	923.51				
	Water Level (mbgs)		10	10.62				
DH07-5B	Date		1-Dec-07	6-Apr-08				
	Water Level (masl)		924.55	922.62				
	Water Level (mbgs)		10.45	11.5				
DH07-6	Date			15-Jul-08	21-Sep-08			
	Water Level (masl)			863	836.93			
	Water Level (mbgs)			artesian	-0.93			
DH07-7	Date			15-Jul-08	21-Sep-08			
	Water Level (masl)			842.62	842.86			
	Water Level (mbgs)			8.38	8.14			
DH07-9	Date			15-Jul-08	21-Sep-08			
	Water Level (masl)			839.55	839.53			
	Water Level (mbgs)			1.45	1.47			
DH08-01A	Date			10-Oct-08				
	Water Level (masl)			812.32				
	Water Level (mbgs)			6.68				
DH08-01B	Date			10-Oct-08				
	Water Level (masl)			817.48				
	Water Level (mbgs)			1.52				
DH08-02	Date			10-Oct-08				
	Water Level (masl)			791.29				
	Water Level (mbgs)			4.71				
DH08-03	Date			10-Oct-08				
	Water Level (masl)			824.4				
	Water Level (mbgs)			8.6				
DH-10-01	Date							
	Water Level (masl)							
	Water Level (mbgs)							
DH-10-02	Date						24-Jan-10	
	Water Level (masl)						814.16	
	Water Level (mbgs)						14.84	
DH-10-03	Date							
	Water Level (masl)							
	Water Level (mbgs)							
DH-10-04	Date						16-Jan-10	
	Water Level (masl)						802.1	
	Water Level (mbgs)						17.9	
DH-10-05	Date							
	Water Level (masl)							
	Water Level (mbgs)							
DH-10-06	Date						16-Apr-10	18-Apr-10
	Water Level (masl)						830	835
	Water Level (mbgs)						40	35
DH-10-07	Date							
	Water Level (masl)							
	Water Level (mbgs)							
DH-10-08	Date						5-Apr-10	
	Water Level (masl)						822	
	Water Level (mbgs)						40	
DH-10-09	Date						13-Apr-10	
	Water Level (masl)						789.5	
	Water Level (mbgs)						0.5	
DH-10-10	Date						12-Apr-10	12-Apr-10
	Water Level (masl)						789.5	789.76
	Water Level (mbgs)						0.5	0.24
DH-10-11	Date							
	Water Level (masl)							
	Water Level (mbgs)							
DH-10-12	Date						29-Jan-10	
	Water Level (masl)						774.95	
	Water Level (mbgs)						23.05	

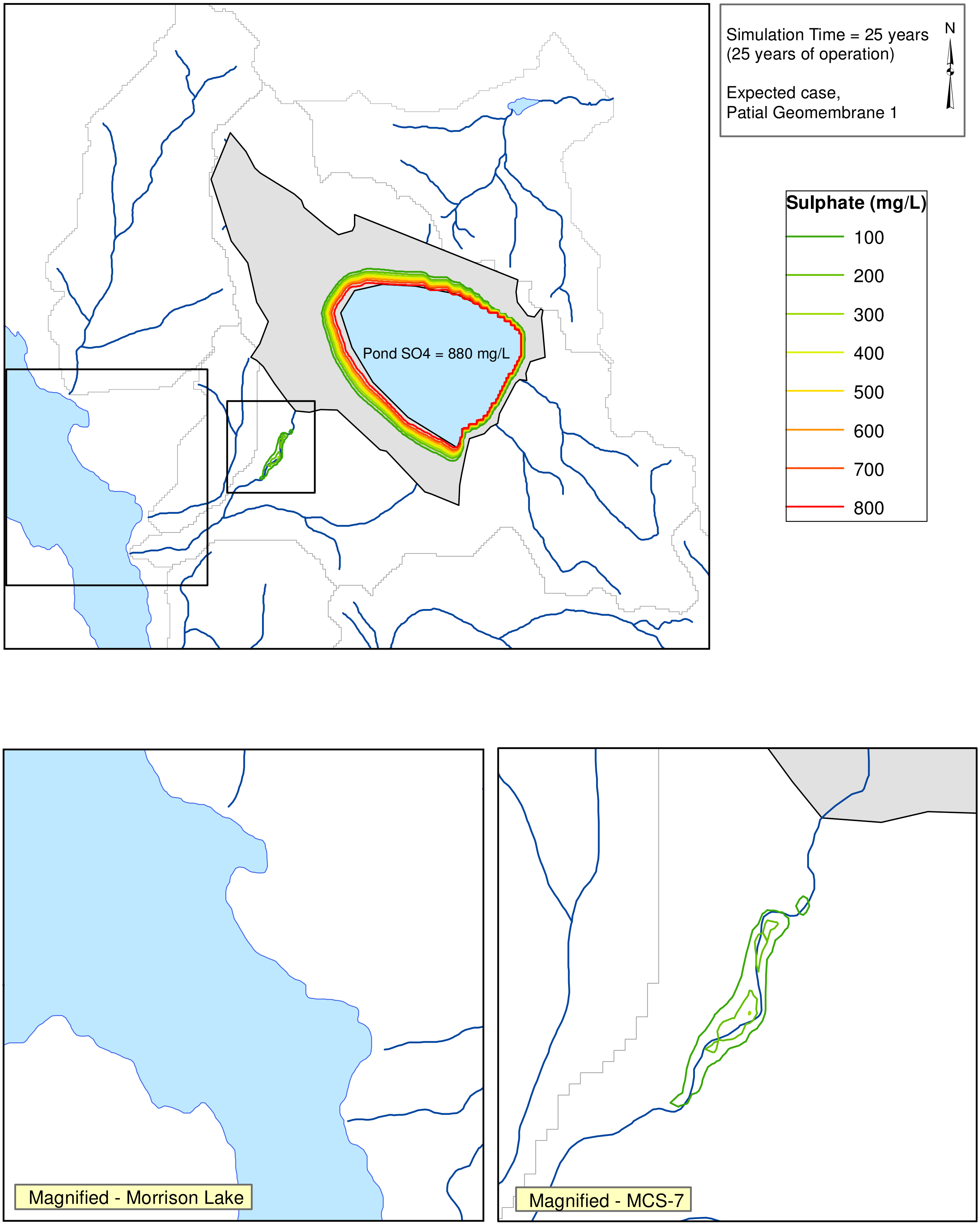
Identification		2007	2008				2010	2011		
MW07-01A	Date	1-Nov-07	1-Jan-08	7-Apr-08	18-Jul-08	8-Oct-08	24-Oct-10	Jan-11	Jun-11	Sep-11
	Water Level (masl)	970	970	970	970	970	970	970	961.1	961.1
	Water Level (mbgs)	artesian	artesian	artesian	artesian	artesian	artesian	artesian	8.9	8.9
MW07-01B	Date	16-Nov-07	23-Jan-08	7-Apr-08	18-Jul-08	8-Oct-08	24-Oct-10	Jan-11	Jun-11	Sep-11
	Water Level (masl)	unknown	unknown	unknown	970.94	964.82	970.55	968.27	970	970
	Water Level (mbgs)	dry	frozen	frozen	-0.94	5.18	-0.55	1.73	artesian	artesian
MW07-02A	Date	2-Nov-07	2-Jan-08	8-Apr-08	18-Jul-08	8-Oct-08	24-Oct-10	Jan-11		
	Water Level (masl)	1088.81	1087.62	1087.66	1089.15	1087.45	1088.03	1088.79		
	Water Level (mbgs)	2.19	3.38	3.34	1.85	3.55	2.97	2.21		
MW07-02B	Date	3-Nov-07	3-Jan-08	9-Apr-08	18-Jul-08	8-Oct-08	24-Oct-10	Jan-11		
	Water Level (masl)	1089.49	1088.48	1088.155	1088.63	1089.07	1088.86	1087.99		
	Water Level (mbgs)	1.51	2.52	2.845	2.37	1.93	2.14	3.01		
MW07-03A	Date	4-Nov-07	4-Jan-08	10-Apr-08	16-Jul-08	5-Oct-08	22-Oct-10		Jun-11	Sep-11
	Water Level (masl)	782	782	782	782.83	781.29	782		782	779.29
	Water Level (mbgs)	artesian	artesian	artesian	-0.83	0.71	0		artesian	2.71
MW07-03B	Date	5-Nov-07	5-Jan-08	11-Apr-08	16-Jul-08	5-Oct-08	22-Oct-10			
	Water Level (masl)	780.49	780.37	780.24	780.415	780.27	780.14			
	Water Level (mbgs)	1.51	1.63	1.76	1.585	1.73	1.86			
MW07-04A	Date	6-Nov-07	6-Jan-08	12-Apr-08	16-Jul-08	5-Oct-08	22-Oct-10	Jan-11		
	Water Level (masl)	798.62	796.63	796.66	796.55	796.62	796.65	796.71		
	Water Level (mbgs)	23.38	25.37	25.34	25.45	25.38	25.35	25.29		
MW07-04B	Date	7-Nov-07	7-Jan-08	13-Apr-08	16-Jul-08	5-Oct-08	22-Oct-10	Jan-11		
	Water Level (masl)	816.58	821.13	821.26	820.26	821.33	821.32	821.09		
	Water Level (mbgs)	5.42	0.87	0.74	1.74	0.67	0.68	0.91		
MW07-05A	Date	8-Nov-07	8-Jan-08	14-Apr-08	18-Jul-08	4-Oct-08	21-Oct-10	Jan-11	Jun-11	Sep-11
	Water Level (masl)	790.41	789.35	789.44	789.81	786.36	783.36	783.05	785.32	785.32
	Water Level (mbgs)	16.59	17.65	17.56	17.19	20.64	23.64	23.95	21.68	21.68
MW07-05B	Date	9-Nov-07	9-Jan-08	15-Apr-08	17-Jul-08	4-Oct-08	21-Oct-10	Jan-11		
	Water Level (masl)	789.66	790.09	789.44	790.865	789.22	790.31	790.94		
	Water Level (mbgs)	17.34	16.91	17.56	16.135	17.78	16.69	16.06		
MW07-06A	Date	10-Nov-07	10-Jan-08	16-Apr-08	28-Jul-08	5-Oct-08	21-Oct-10	Jan-11		
	Water Level (masl)	744.3	742.35	741.515	740.72	741.64	742.06	741.72		
	Water Level (mbgs)	1.7	3.65	4.485	5.28	4.36	3.94	4.28		
MW07-06B	Date	11-Nov-07	11-Jan-08	17-Apr-08	28-Jul-08	5-Oct-08	21-Oct-10	Jan-11		
	Water Level (masl)	743.75	743.78	742.95	742.73	743.31	743.7	743.67		
	Water Level (mbgs)	2.25	2.22	3.05	3.27	2.69	2.3	2.33		
MW07-07A	Date	12-Nov-07	12-Jan-08	18-Apr-08	17-Jul-08	9-Oct-08		Jan-11		
	Water Level (masl)	798.01	797.34	796.88	797.53	794.3		793.15		
	Water Level (mbgs)	38.99	39.66	40.12	39.47	42.7		43.85		
MW07-07B	Date	13-Nov-07	13-Jan-08	19-Apr-08	17-Jul-08	9-Oct-08	21-Oct-10	Jan-11	Jun-11	
	Water Level (masl)	806.37	806.21	806.18	806.83	807.35	< 807	774.91	777.27	
	Water Level (mbgs)	30.63	30.79	30.82	30.17	29.65	>30	32.09	29.73	
MW07-08A	Date	14-Nov-07	14-Jan-08	20-Apr-08	17-Jul-08	4-Oct-08	22-Oct-10	Jan-11		
	Water Level (masl)	839.98	839.28	838.355	838.39	839.51	839.24	838.08		
	Water Level (mbgs)	0.02	0.72	1.645	1.61	0.49	0.76	1.92		
MW07-08B	Date	15-Nov-07	15-Jan-08	21-Apr-08	17-Jul-08	4-Oct-08	22-Oct-10	Jan-11		
	Water Level (masl)	829.69	836.64	832.91	835.13	836.96	839.4	838.07		
	Water Level (mbgs)	10.31	3.36	7.09	4.87	3.04	0.6	1.93		
MW08-01A	Date		10-Oct-08				20-Oct-10	Jan-11	Jun-11	
	Water Level (masl)		807.07				808.34	815.5	807.3	
	Water Level (mbgs)		24.93				23.66	16.5	24.7	
MW08-01B	Date		10-Oct-08				20-Oct-10	Jan-11	Jun-11	
	Water Level (masl)		803.36				814.7	808.26	811.95	
	Water Level (mbgs)		28.64				17.3	23.74	20.05	
MW08-02A	Date		9-Oct-08				21-Oct-10	Jan-11	Jun-11	
	Water Level (masl)		748.17				752	752	747.91	
	Water Level (mbgs)		3.83				artesian	artesian	4.09	
MW08-02B	Date		9-Oct-08				21-Oct-10	Jan-11	Jun-11	
	Water Level (masl)		752				745.05	746.07	752	
	Water Level (mbgs)		0				6.95	5.93	artesian	
MW08-03A	Date		10-Oct-08				22-Oct-10	Jan-11	Jun-11	
	Water Level (masl)		787.34				786.9	790.93	788.09	
	Water Level (mbgs)		12.66				13.1	9.07	11.91	
MW08-03B	Date		10-Oct-08				22-Oct-10	Jan-11		
	Water Level (masl)		786.46				791.84	783.9		
	Water Level (mbgs)		13.54				8.16	13.1		

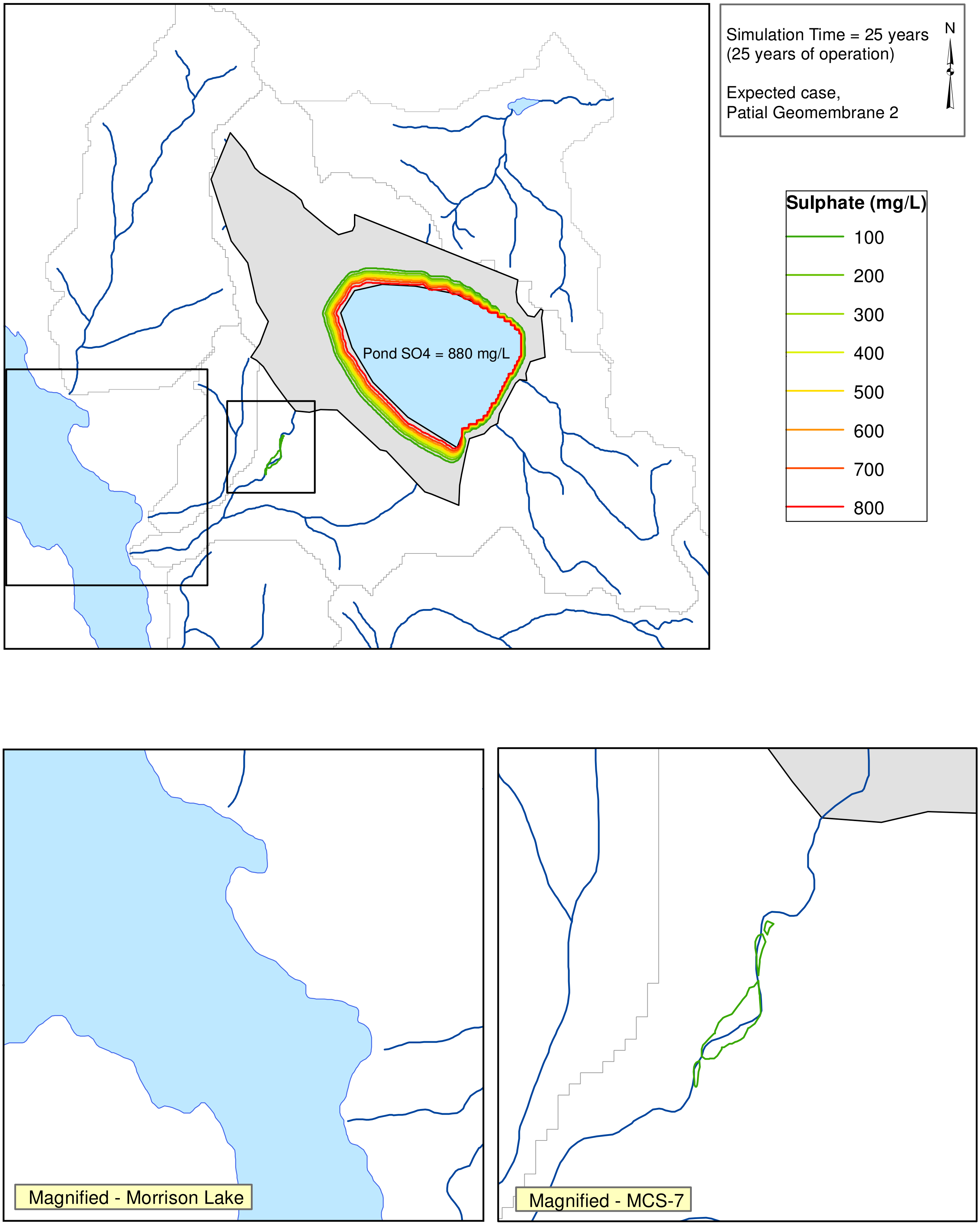
APPENDIX II

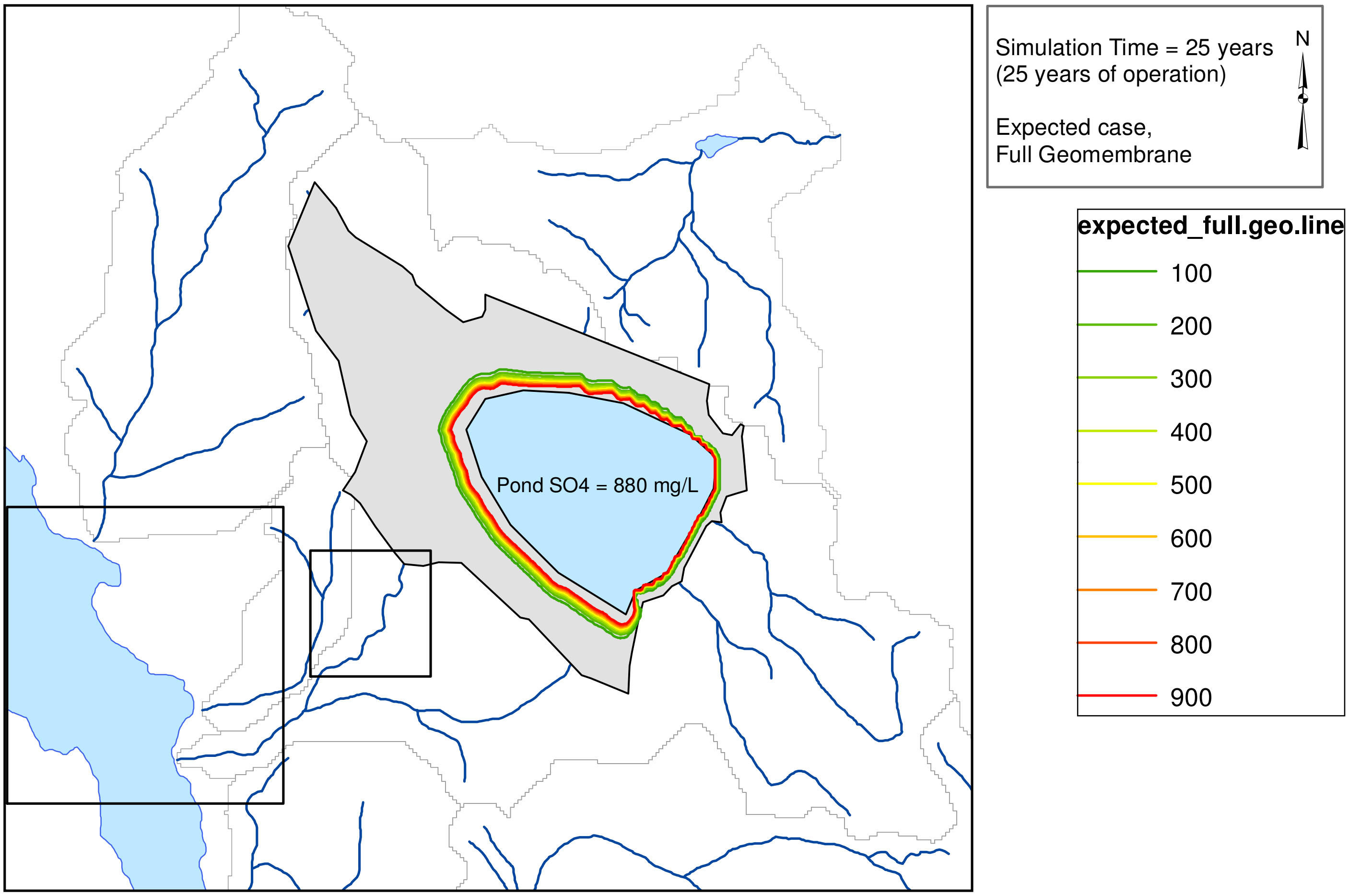
Predicted Sulphate Distribution Plots (End of Operations)

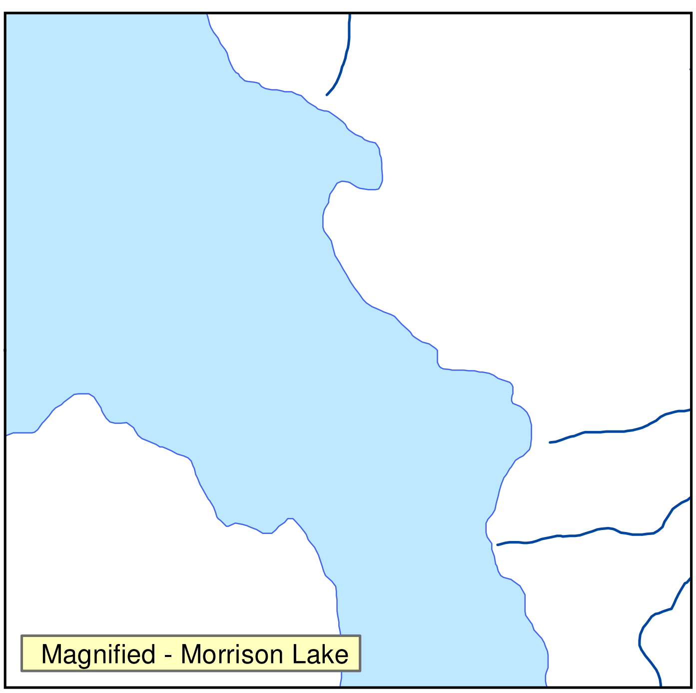

Simulation Time = 25 years
(25 years of operation)
Expected case,
no seepage mitigation
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L
Magnified - Morrison Lake
Magnified - MCS-7

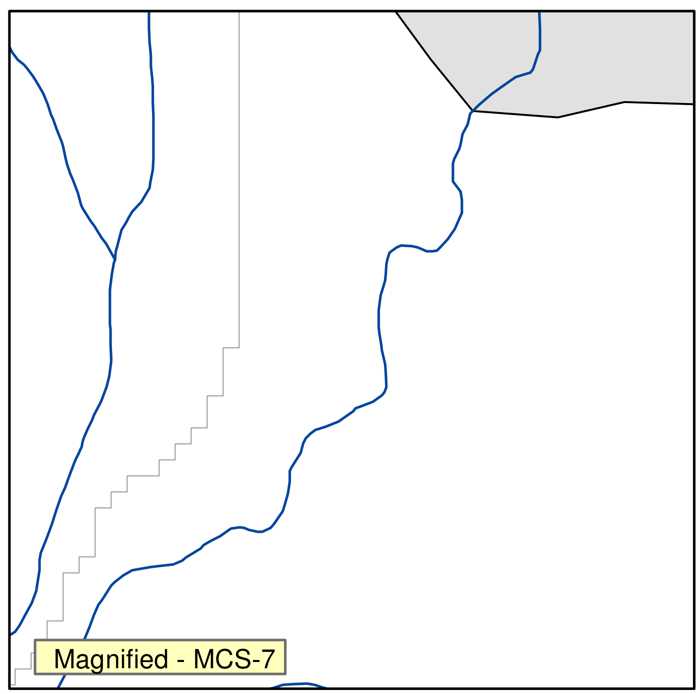

Simulation Time = 25 years
(25 years of operation)
Expected case,
Engineered Till Liner
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L
Magnified - Morrison Lake
Magnified - MCS-7

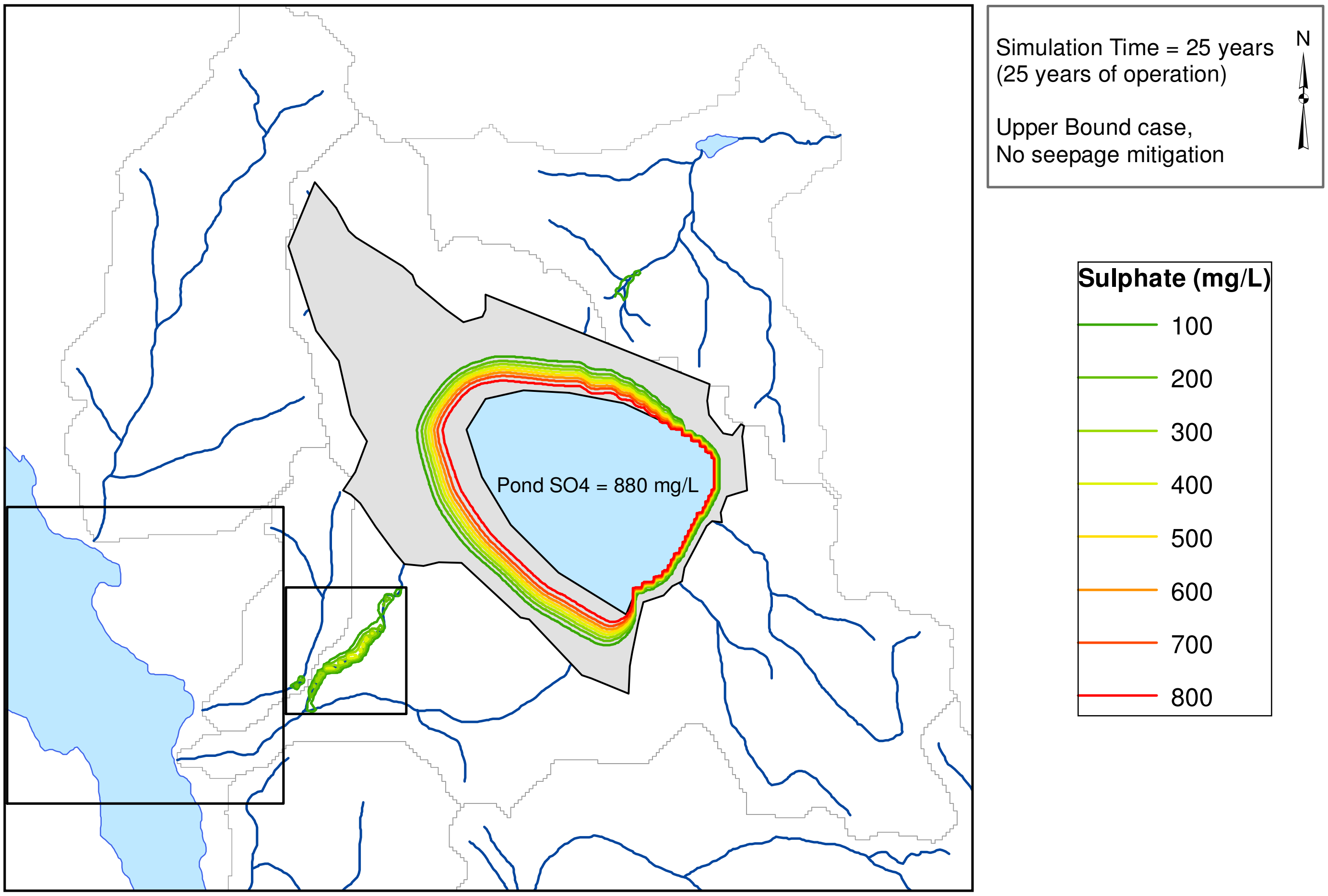

Simulation Time = 25 years
(25 years of operation)
Expected case,
Patial Geomembrane 1
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L
Magnified - Morrison Lake
Magnified - MCS-7

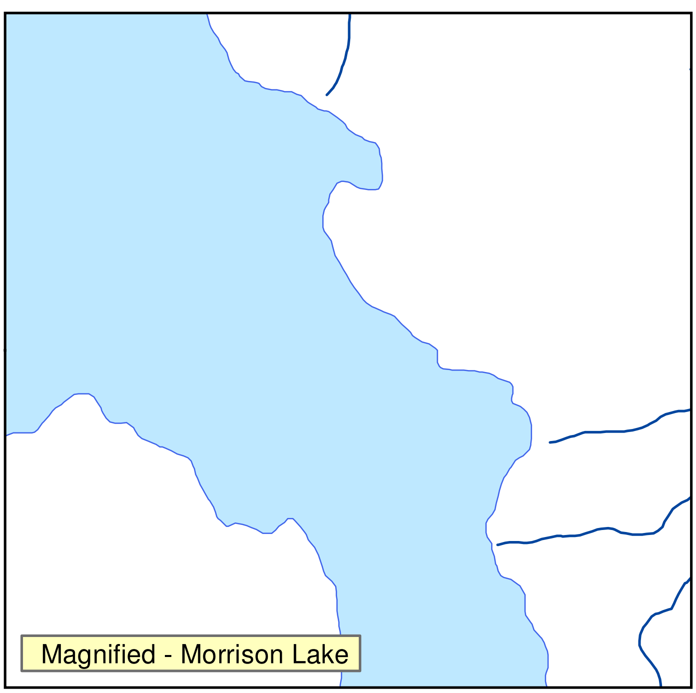

Simulation Time = 25 years
(25 years of operation)
Expected case,
Patial Geomembrane 2
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L
Magnified - Morrison Lake
Magnified - MCS-7

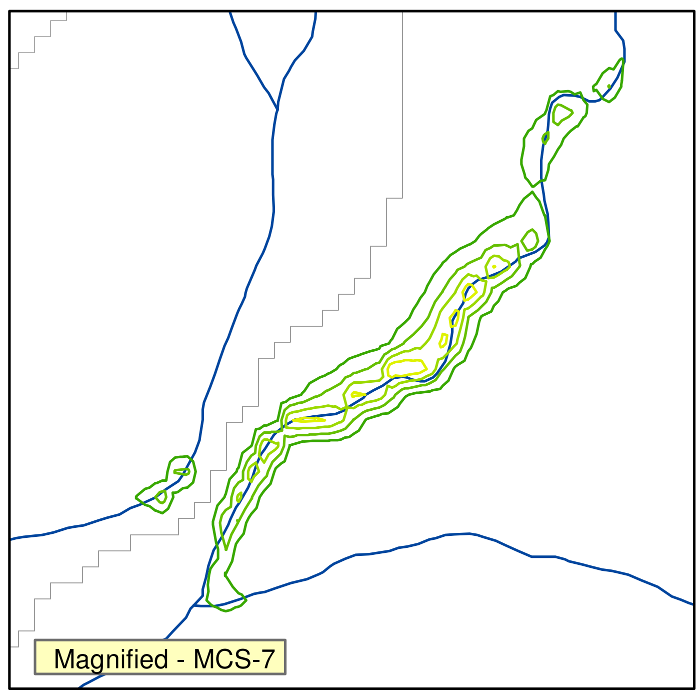

Simulation Time = 25 years
(25 years of operation)
Expected case,
Full Geomembrane
N
expected_full.geo.line
100
200
300
400
500
600
700
800
900
Pond SO4 = 880 mg/L

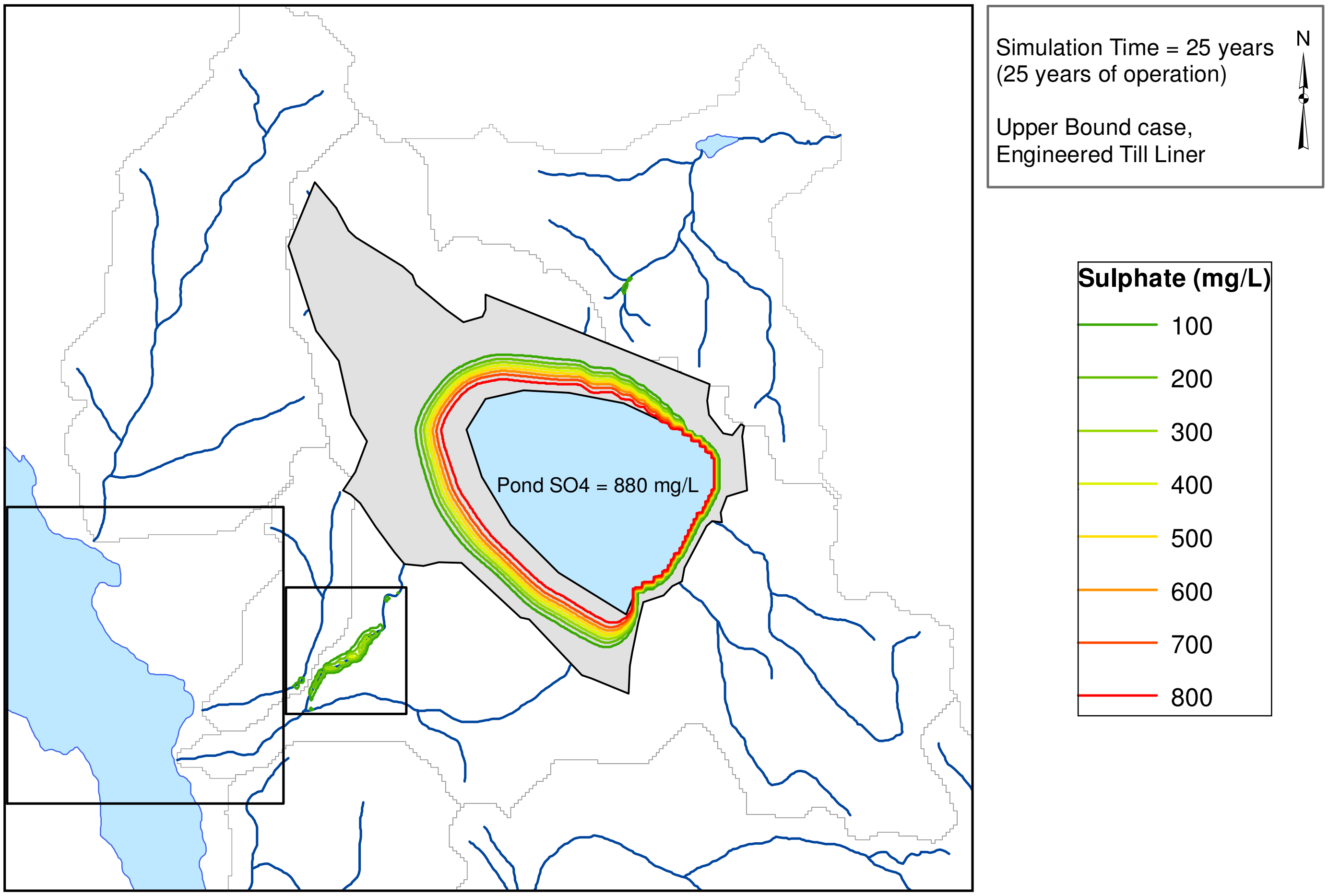

Magnified - Morrison Lake


Magnified - MCS-7

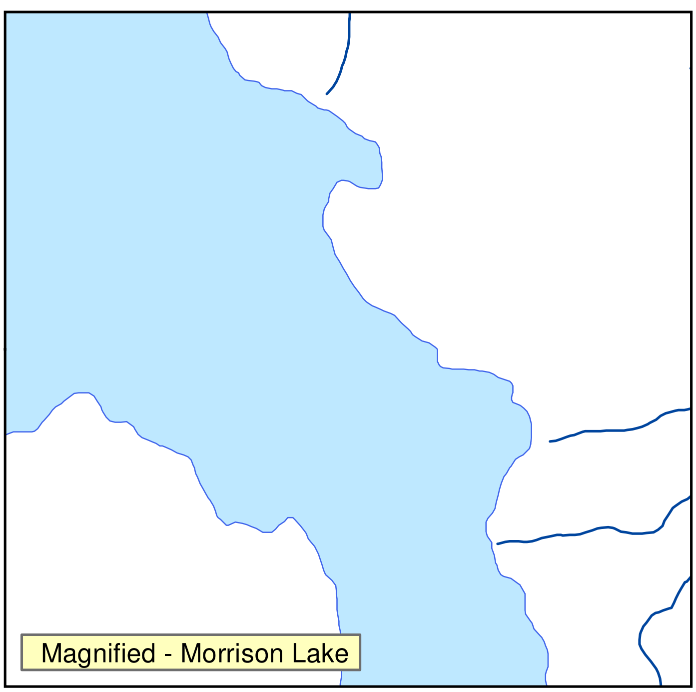

Simulation Time = 25 years
(25 years of operation)
Upper Bound case,
No seepage mitigation
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L


Magnified - Morrison Lake

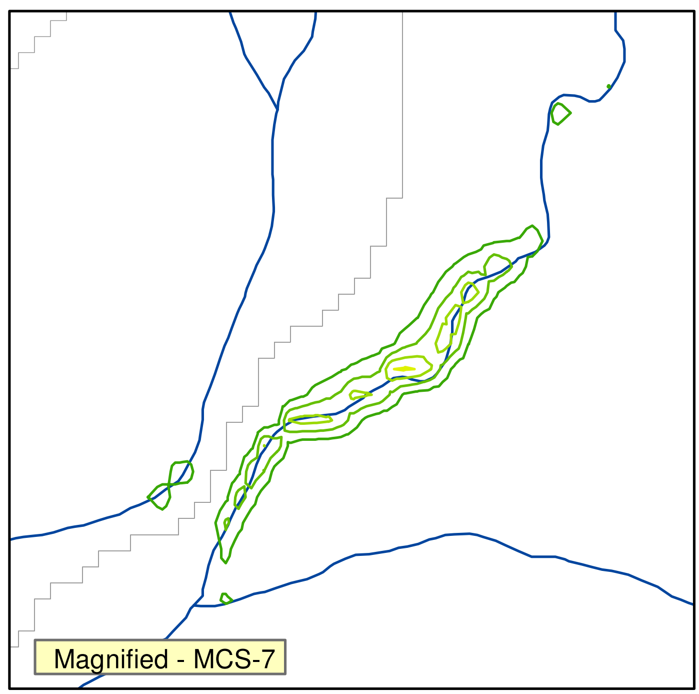

Magnified - MCS-7



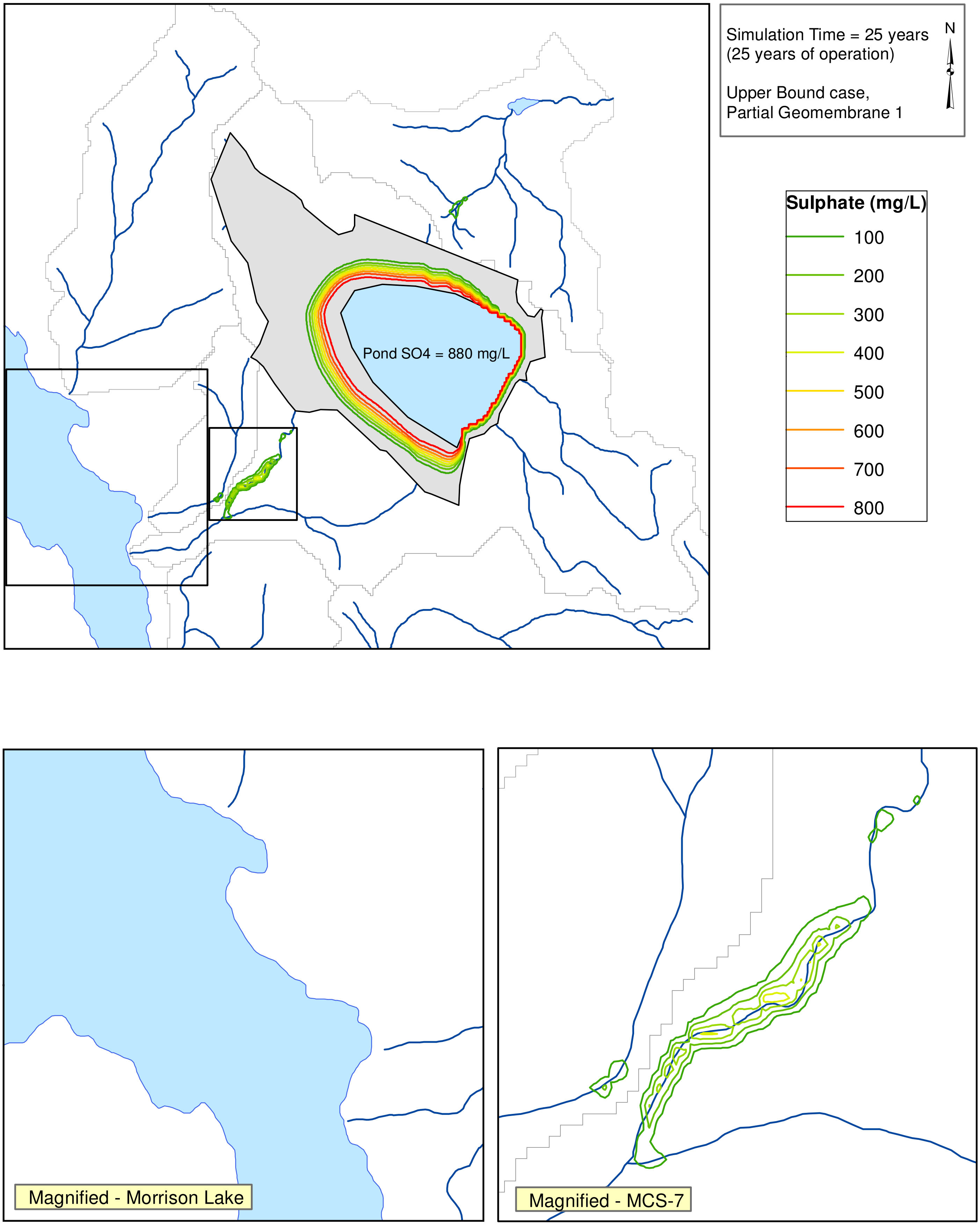
Simulation Time = 25 years
(25 years of operation)
Upper Bound case,
Engineered Till Liner
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L

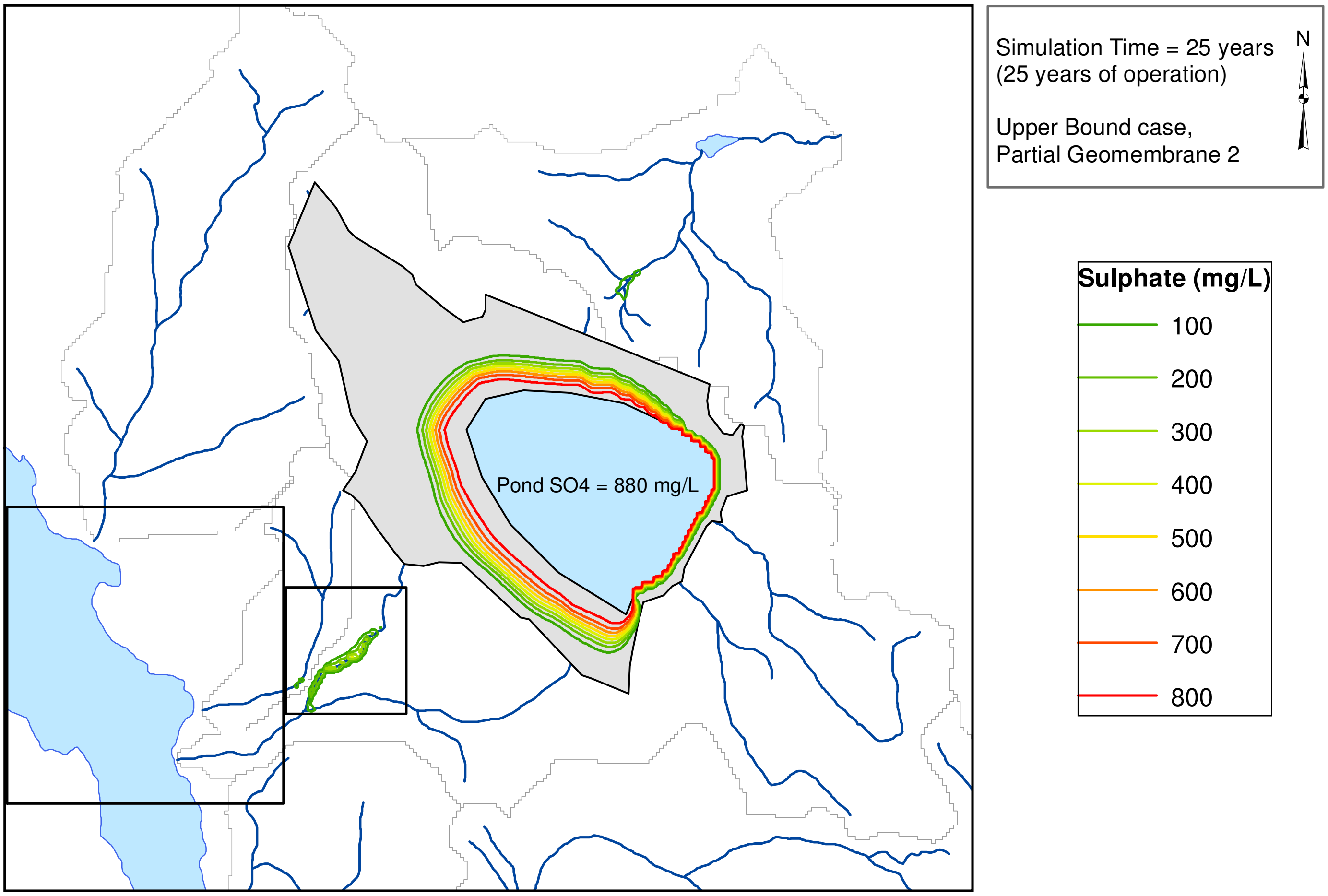


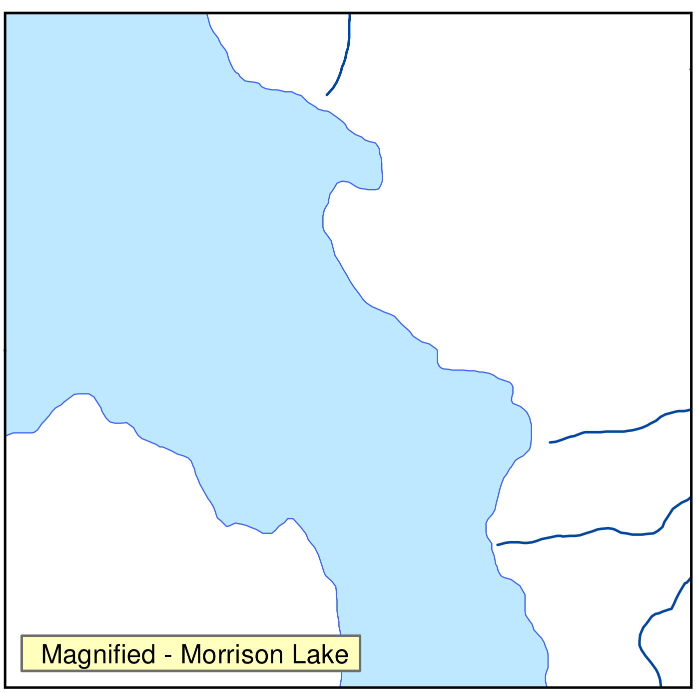
Magnified - Morrison Lake

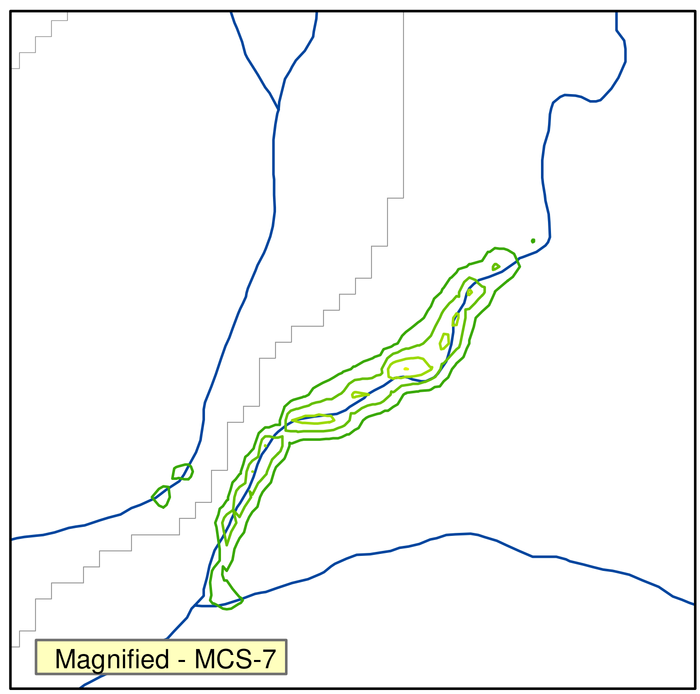


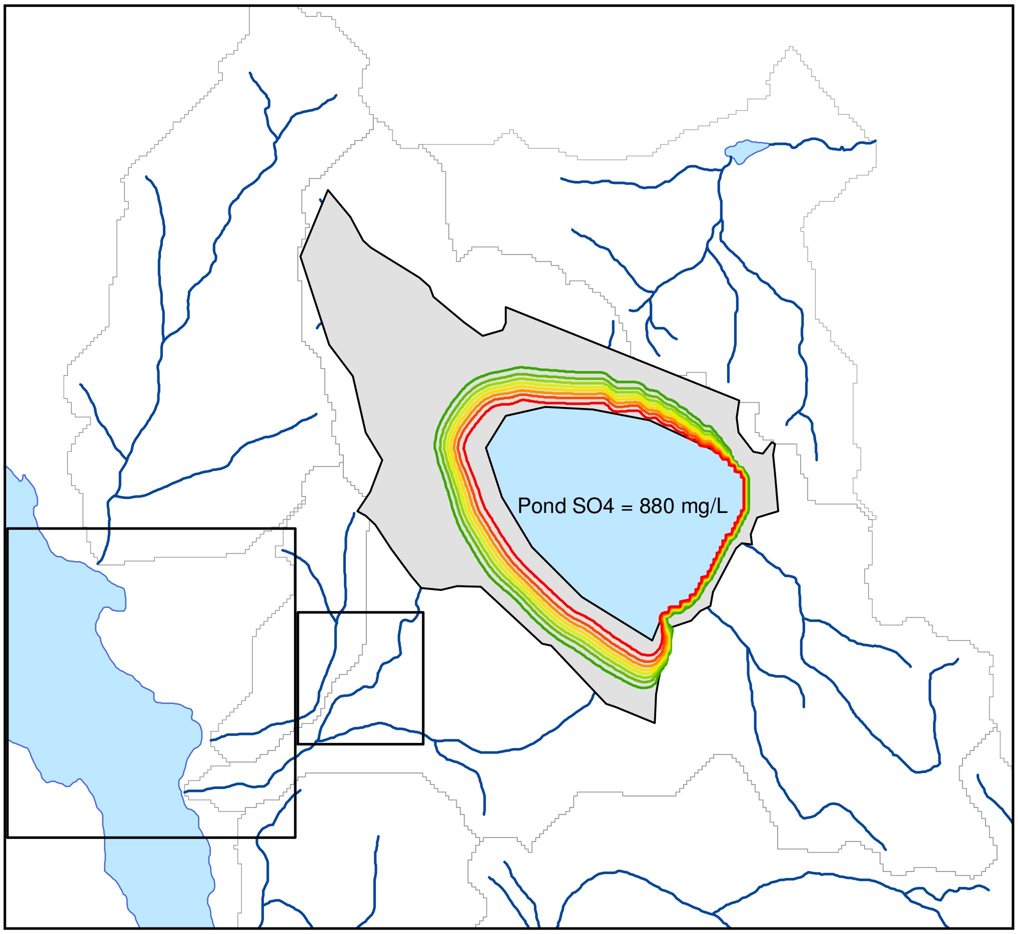
Magnified - MCS-7


Simulation Time = 25 years
(25 years of operation)
Upper Bound case,
Partial Geomembrane 1
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L
Magnified - Morrison Lake
Magnified - MCS-7


Simulation Time = 25 years
(25 years of operation)
Upper Bound case,
Partial Geomembrane 2
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L

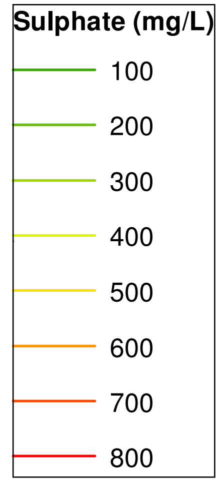

Magnified - Morrison Lake

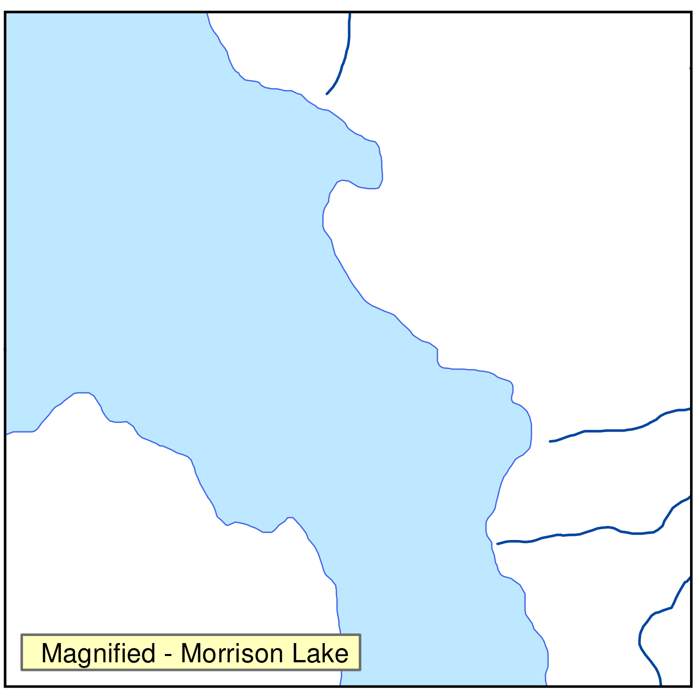

Magnified - MCS-7

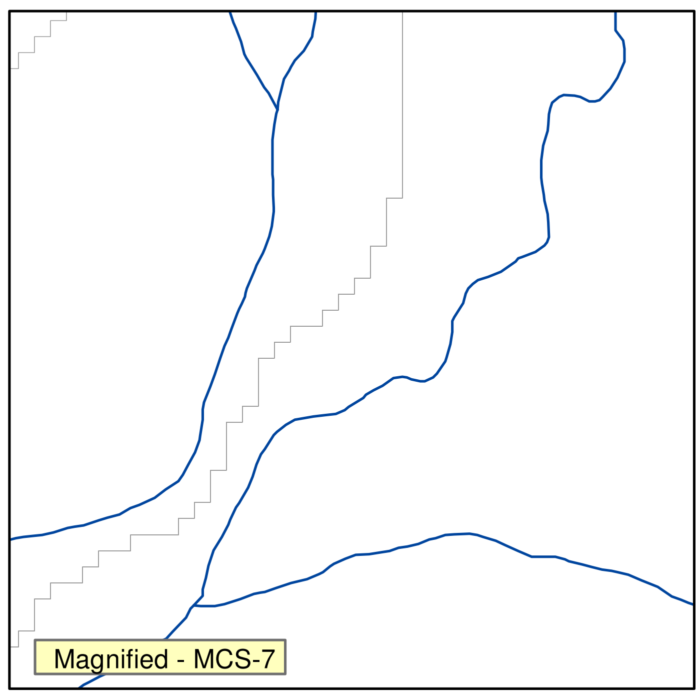


Simulation Time = 25 years
(25 years of operation)

Upper Bound case,
Full Geomembrane Liner

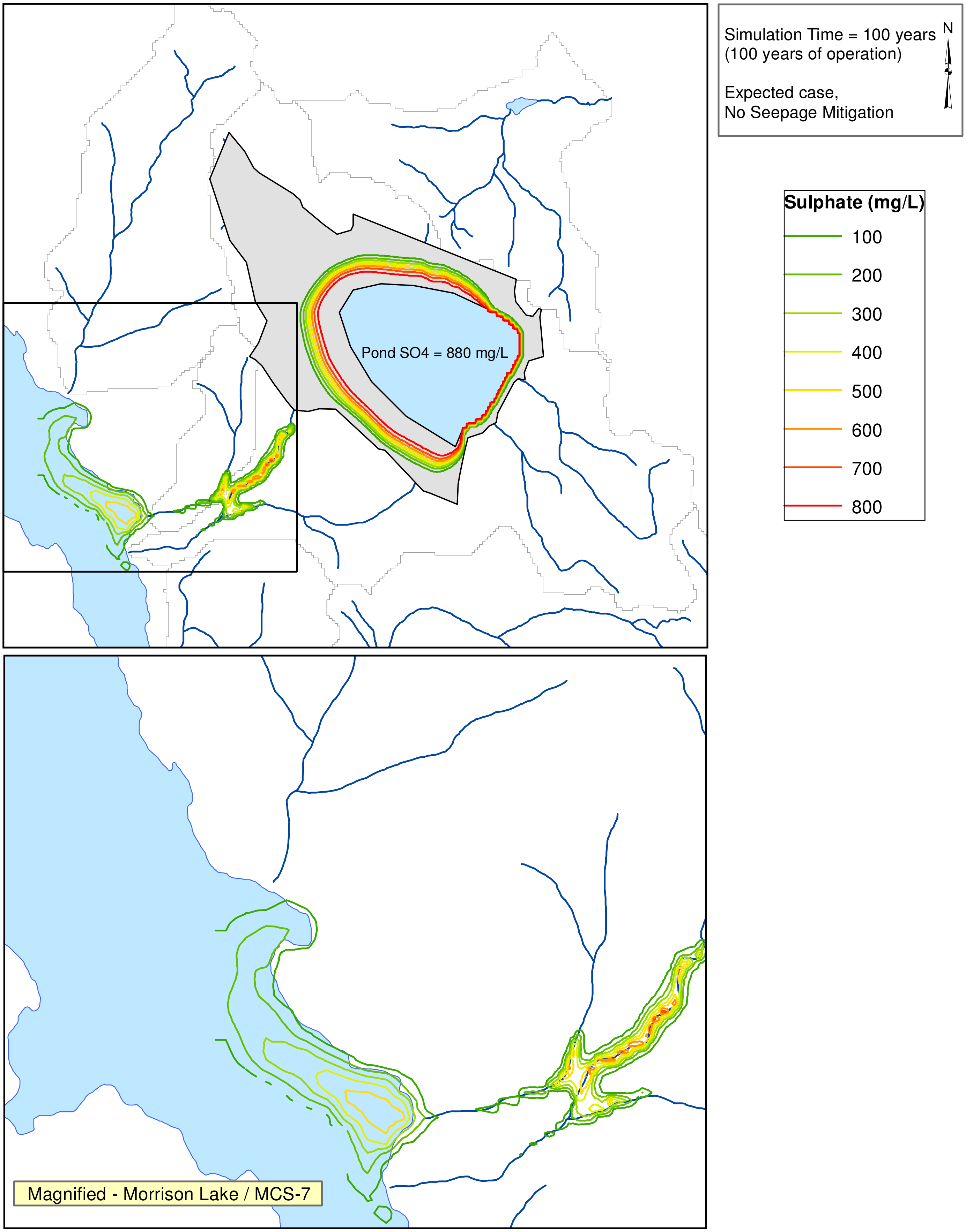




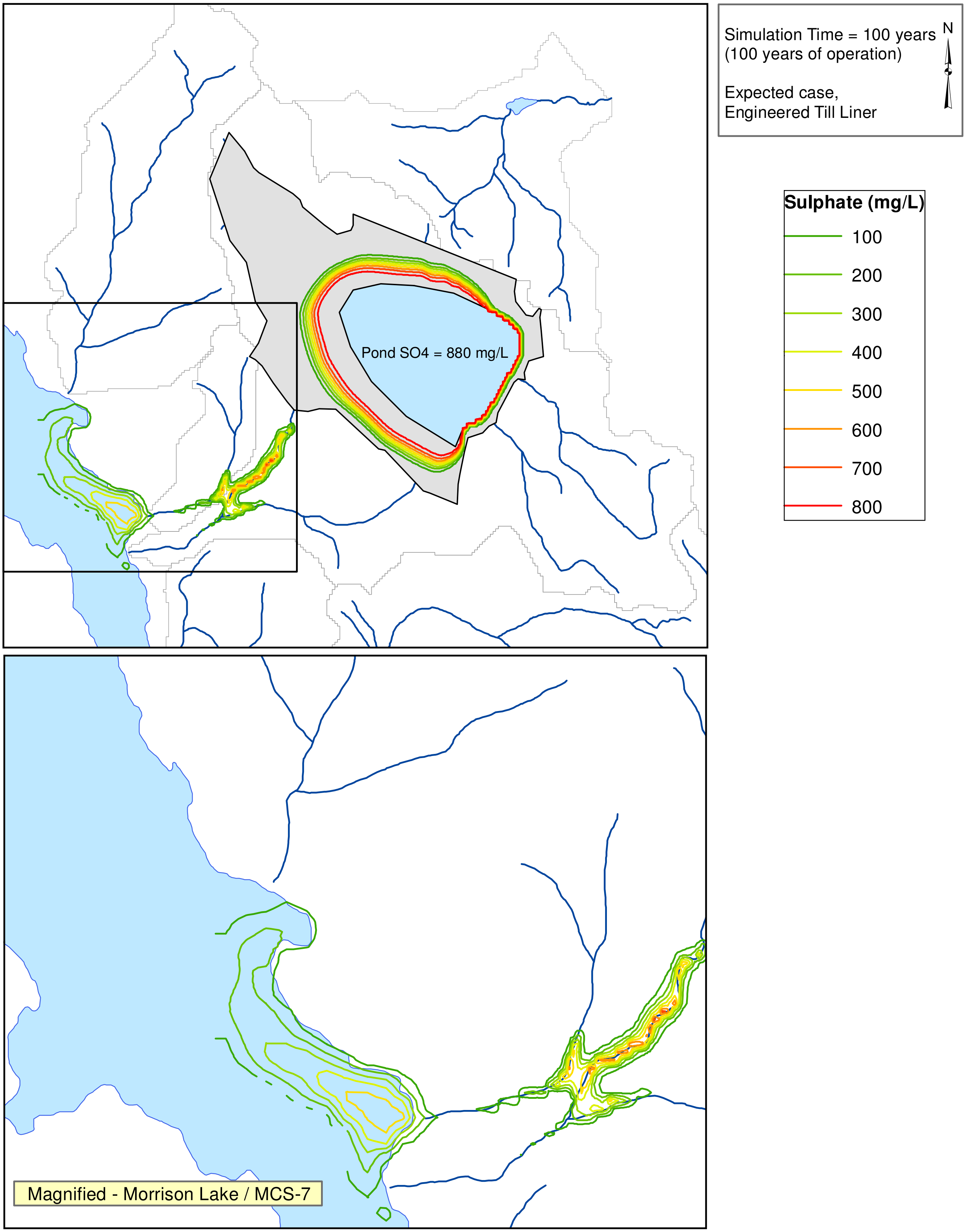


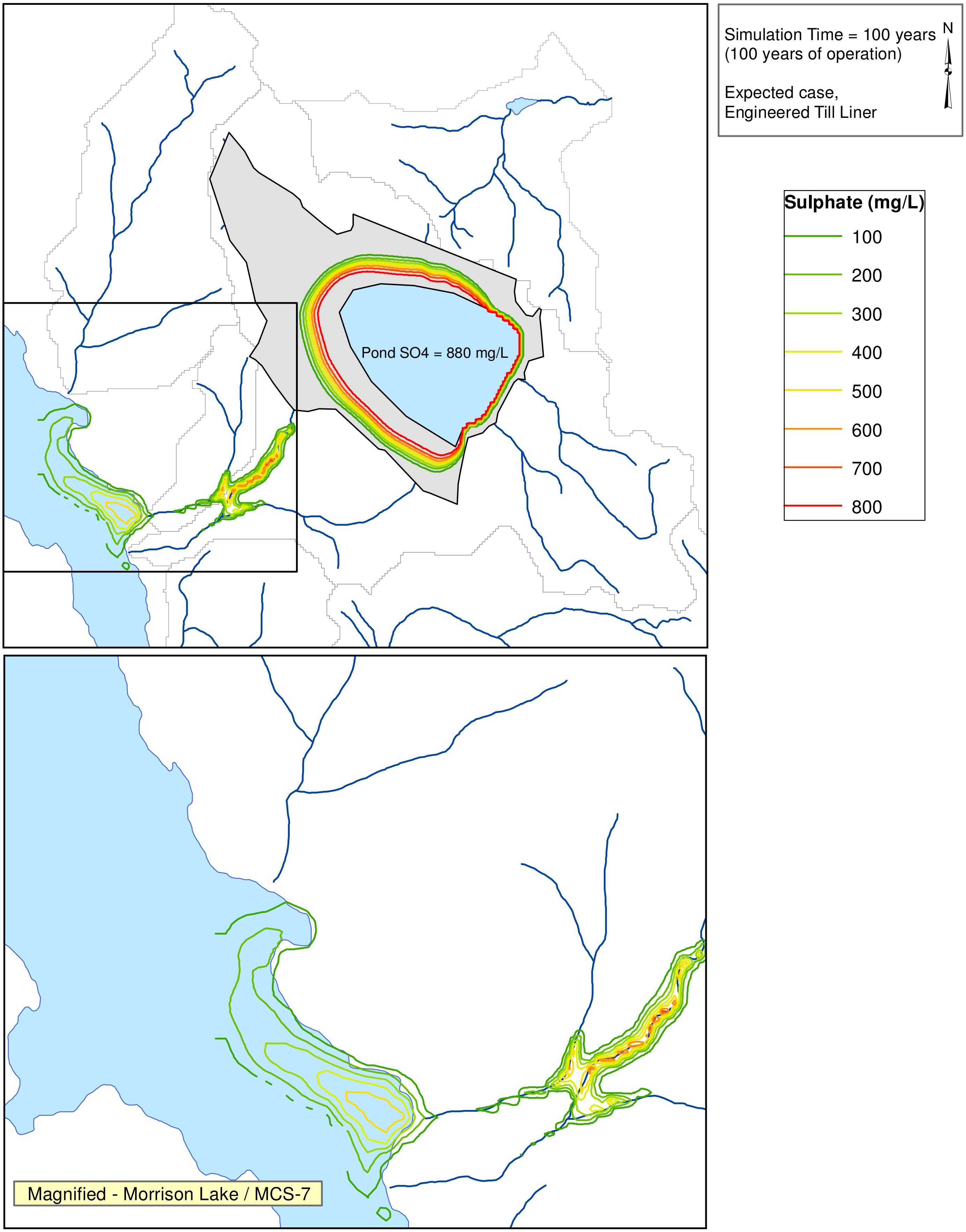
APPENDIX III

Predicted Sulphate Distribution Plots (100 years of Operation)

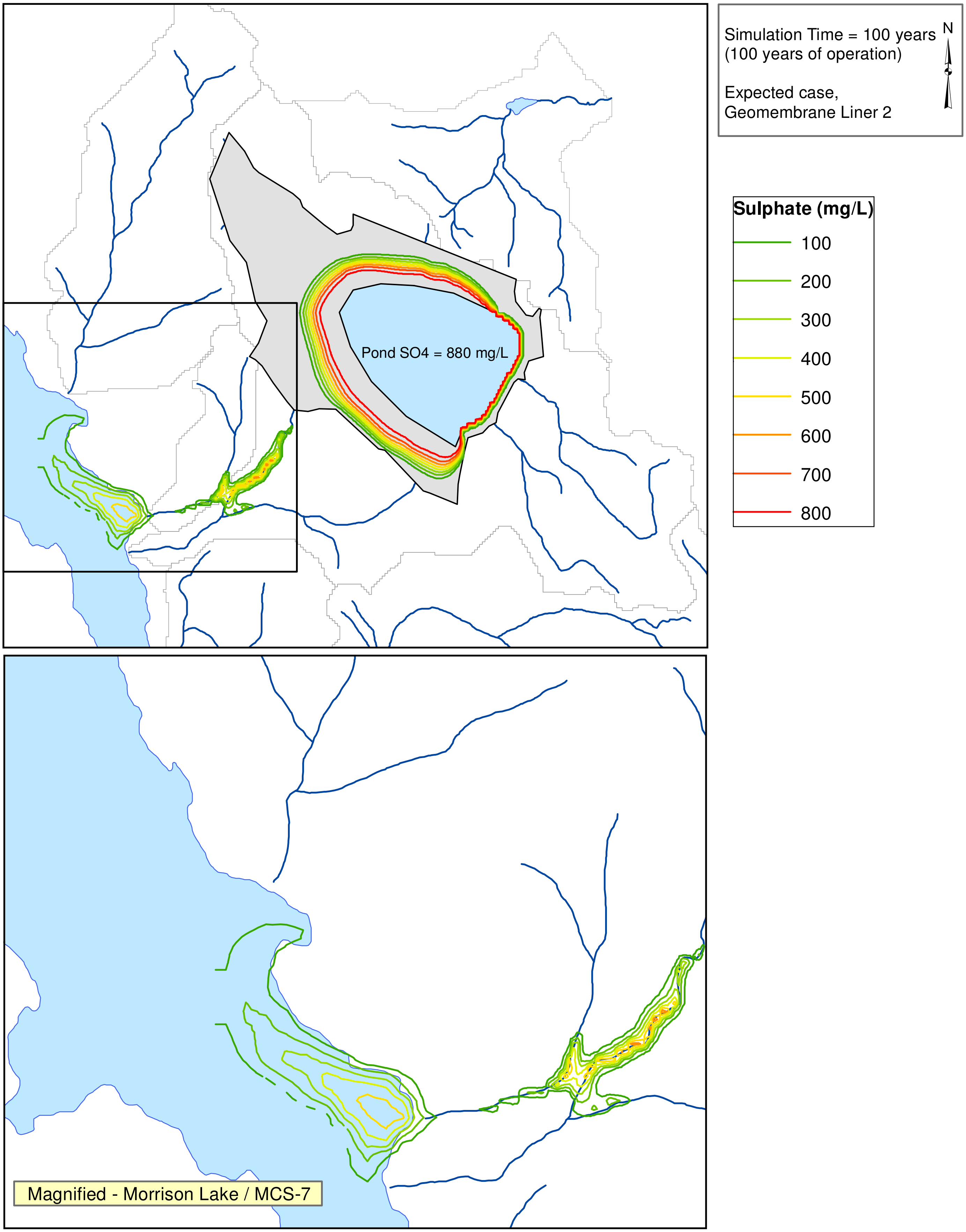


Simulation Time = 100 years
(100 years of operation)
Expected case,
No Seepage Mitigation
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L
Magnified - Morrison Lake / MCS-7

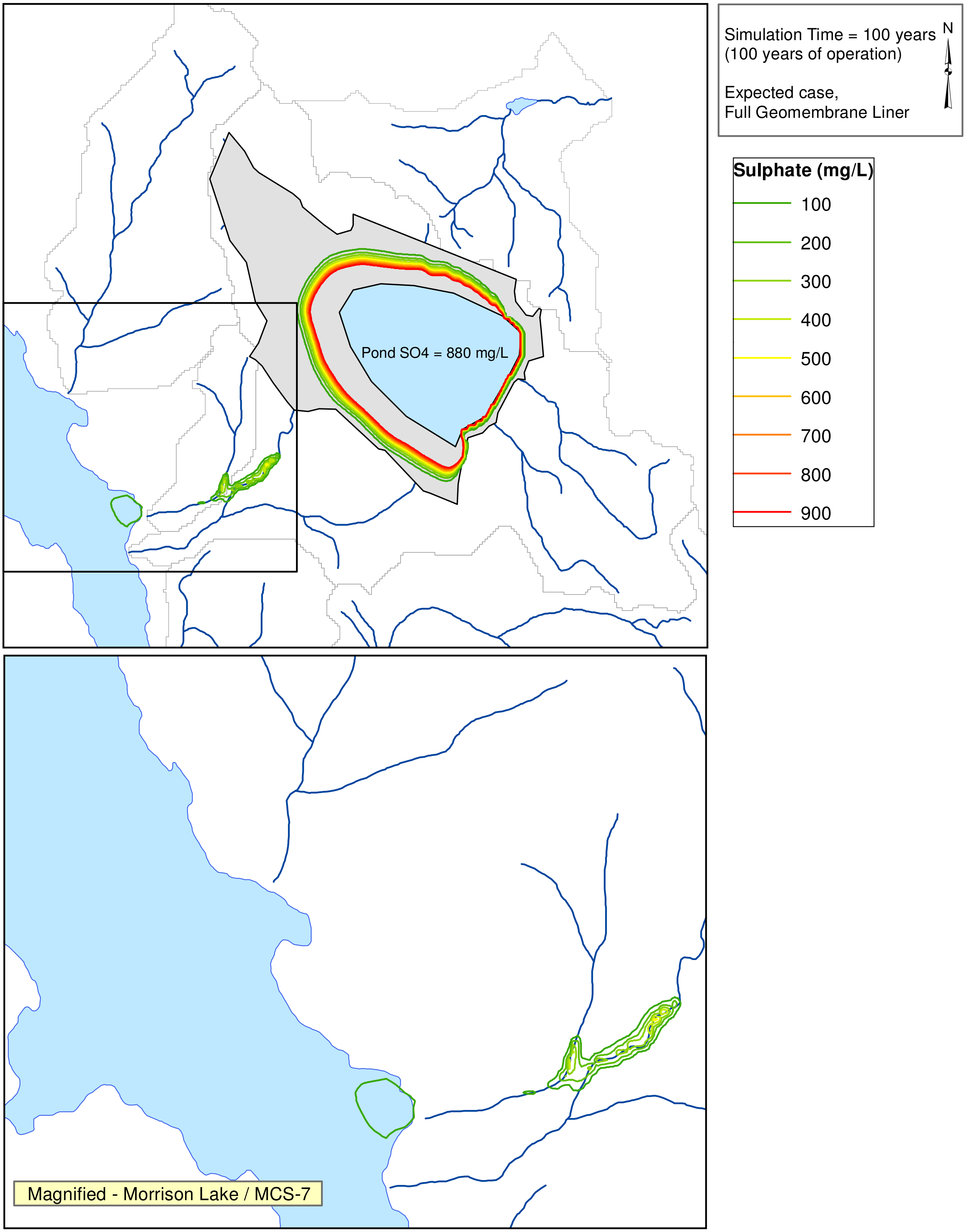

Simulation Time = 100 years
(100 years of operation)
Expected case,
Engineered Till Liner
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L
Magnified - Morrison Lake / MCS-7

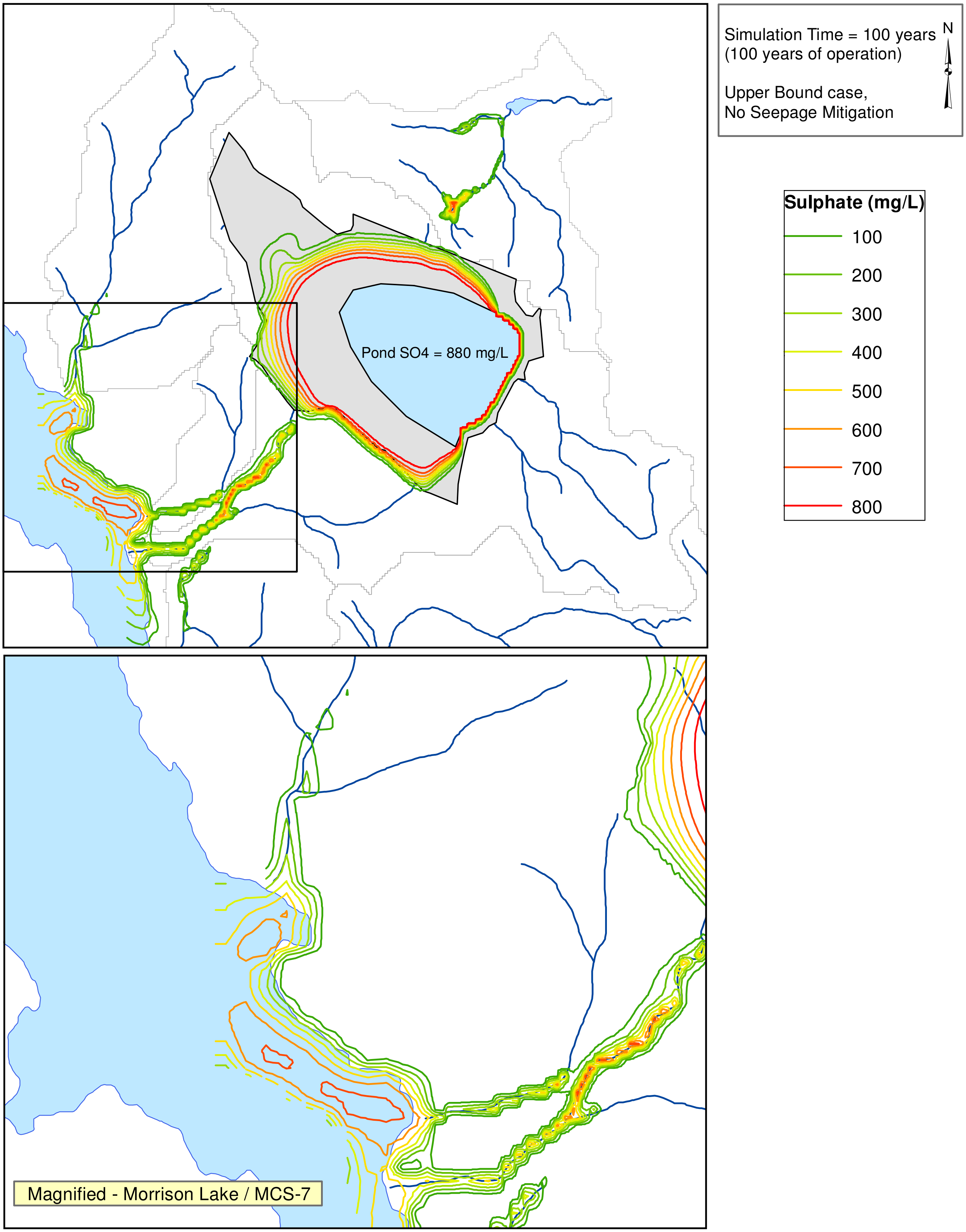


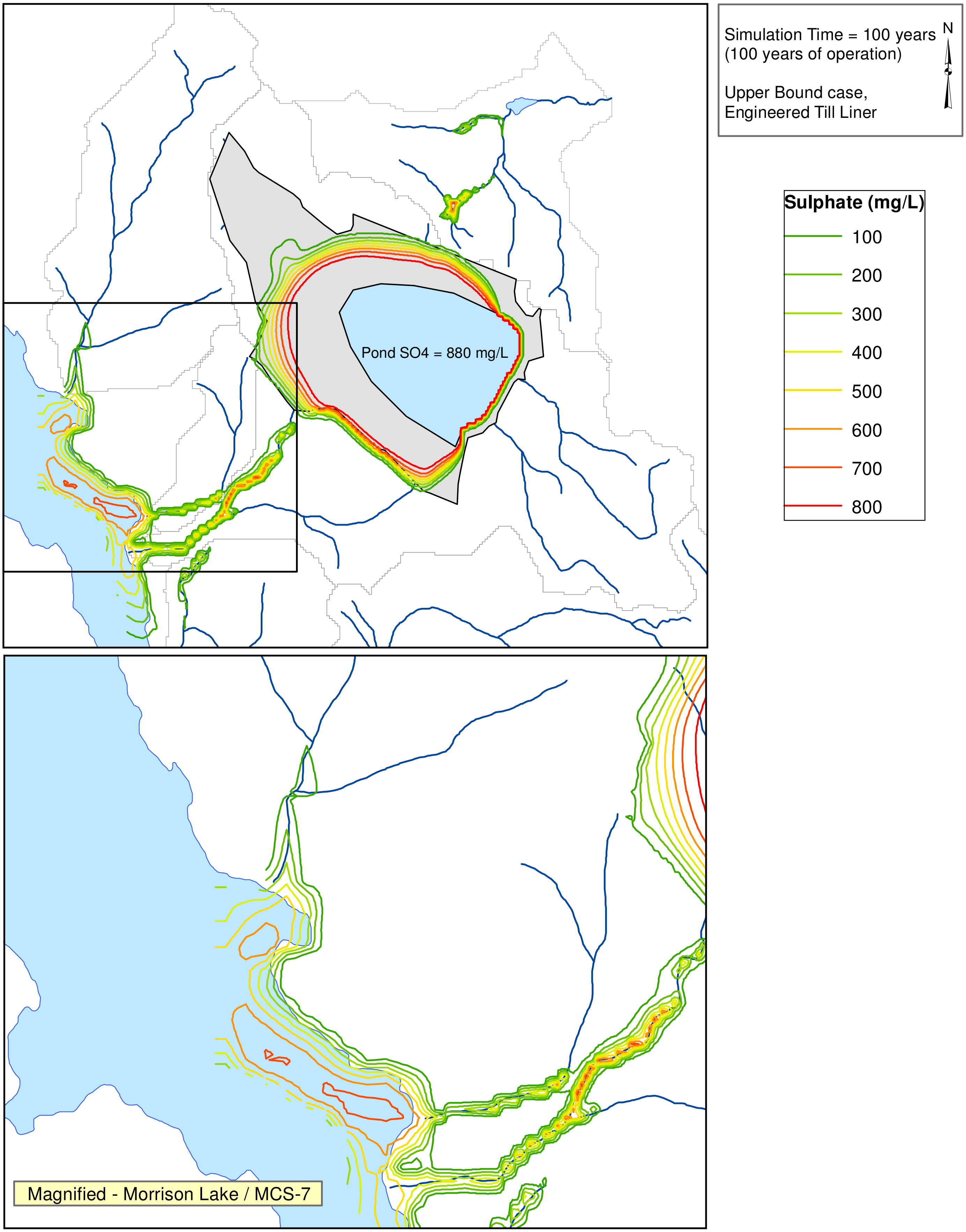
Simulation Time = 100 years
(100 years of operation)
Expected case,
Engineered Till Liner
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L
Magnified - Morrison Lake / MCS-7



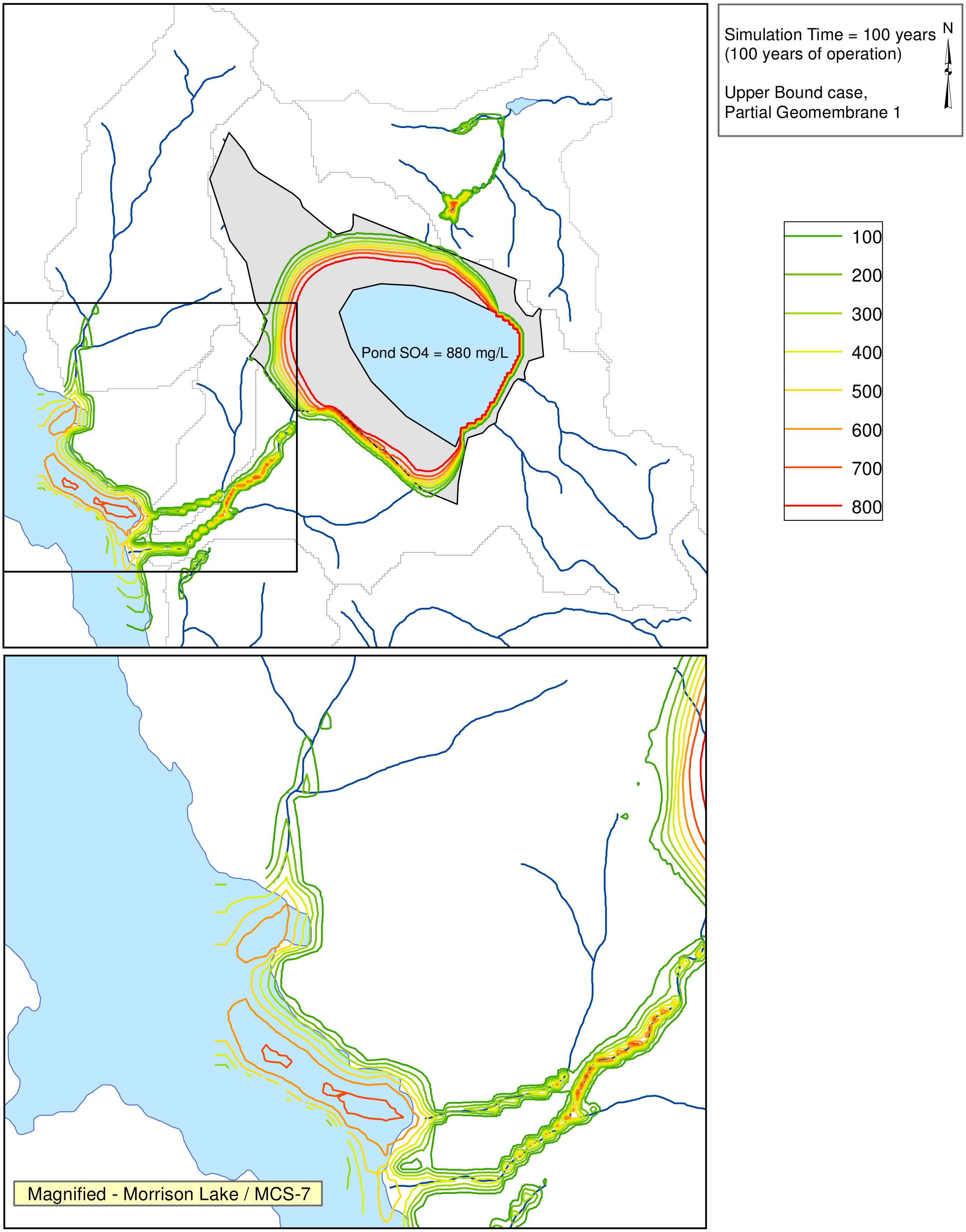
Simulation Time = 100 years
(100 years of operation)
Expected case,
Geomembrane Liner 2
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L
Magnified - Morrison Lake / MCS-7


Simulation Time = 100 years
(100 years of operation)
Expected case,
Full Geomembrane Liner
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
900
Pond SO4 = 880 mg/L
Magnified - Morrison Lake / MCS-7

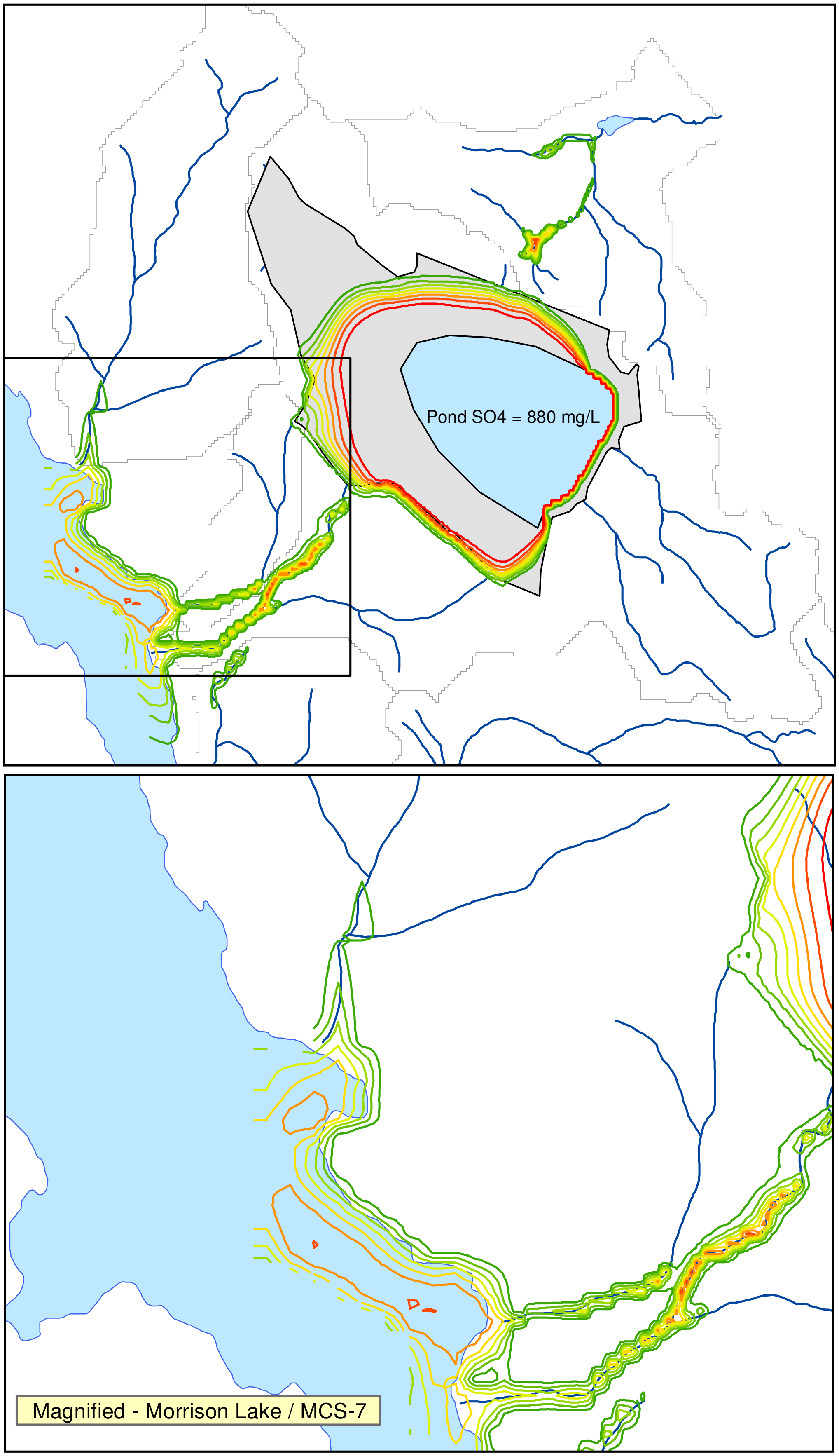

Simulation Time = 100 years
(100 years of operation)
Upper Bound case,
No Seepage Mitigation
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L
Magnified - Morrison Lake / MCS-7



Simulation Time = 100 years
(100 years of operation)
Upper Bound case,
Engineered Till Liner
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L
Magnified - Morrison Lake / MCS-7

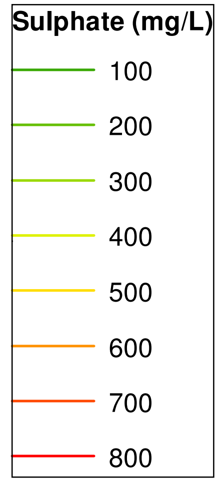


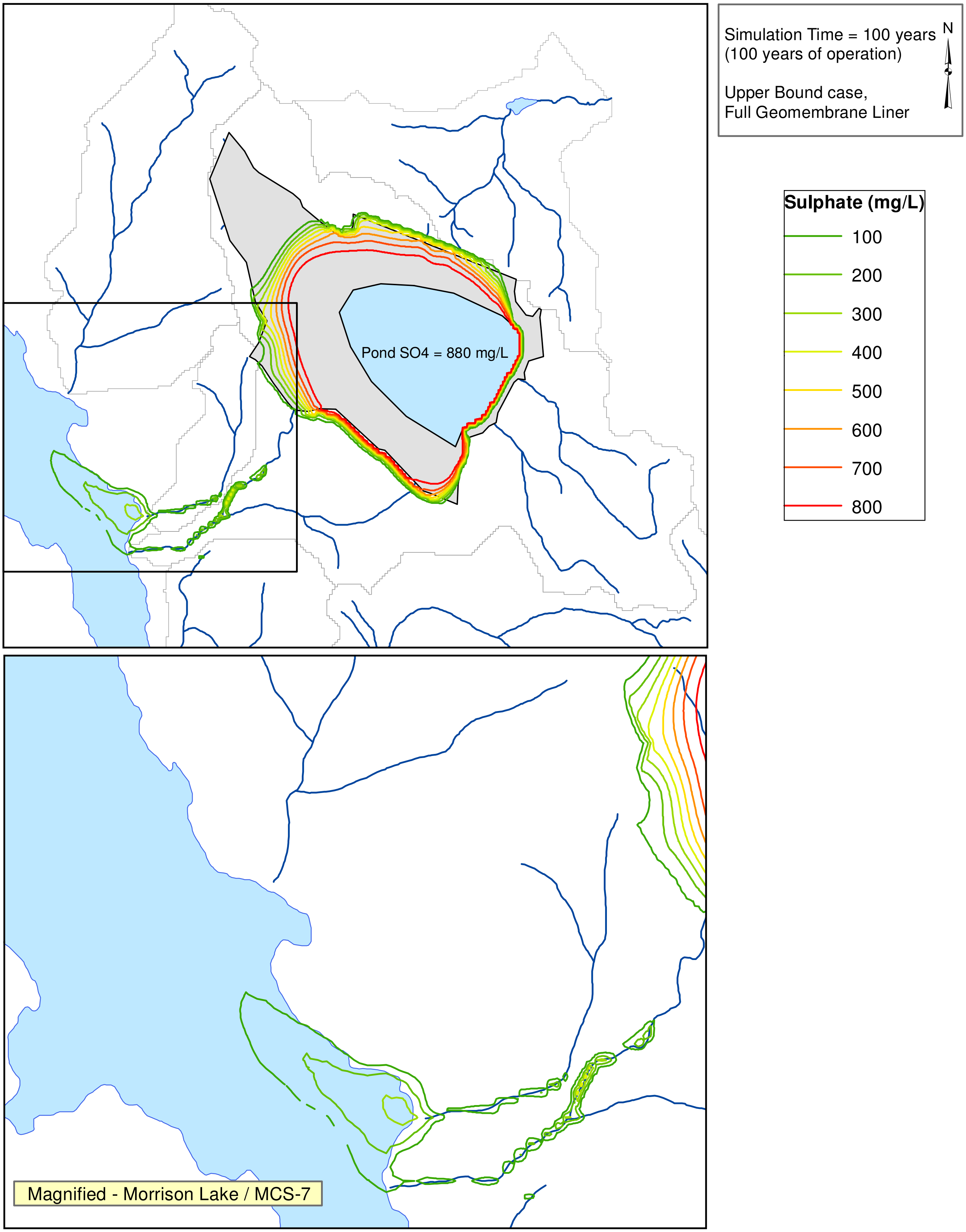
Simulation Time = 100 years
(100 years of operation)
Upper Bound case,
Partial Geomembrane 1
N
Pond SO4 = 880 mg/L
100
200
300
400
500
600
700
800
Magnified - Morrison Lake / MCS-7



Simulation Time = 100 years
(100 years of operation)

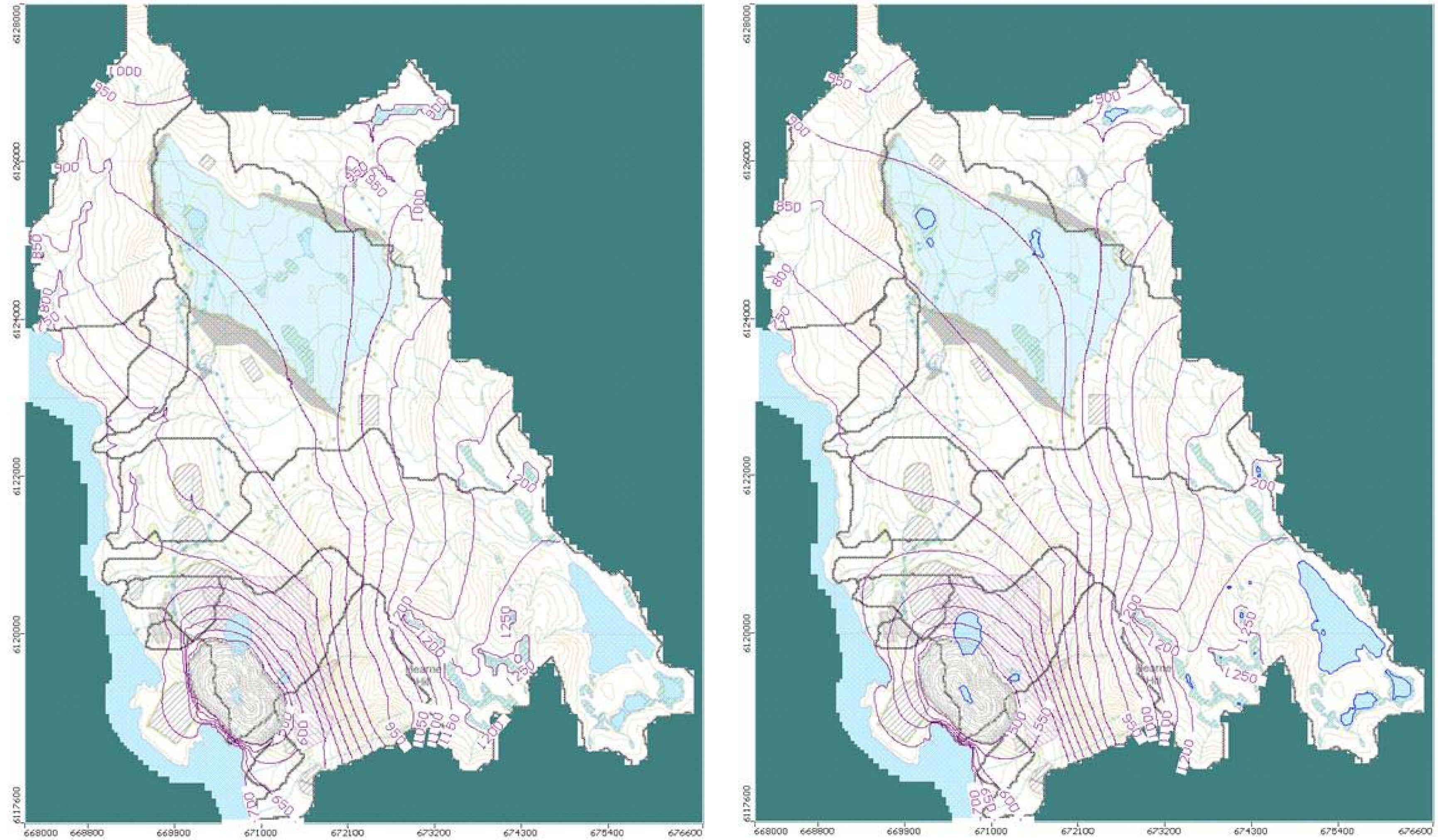
Upper Bound case,
Partial Geomembrane 2



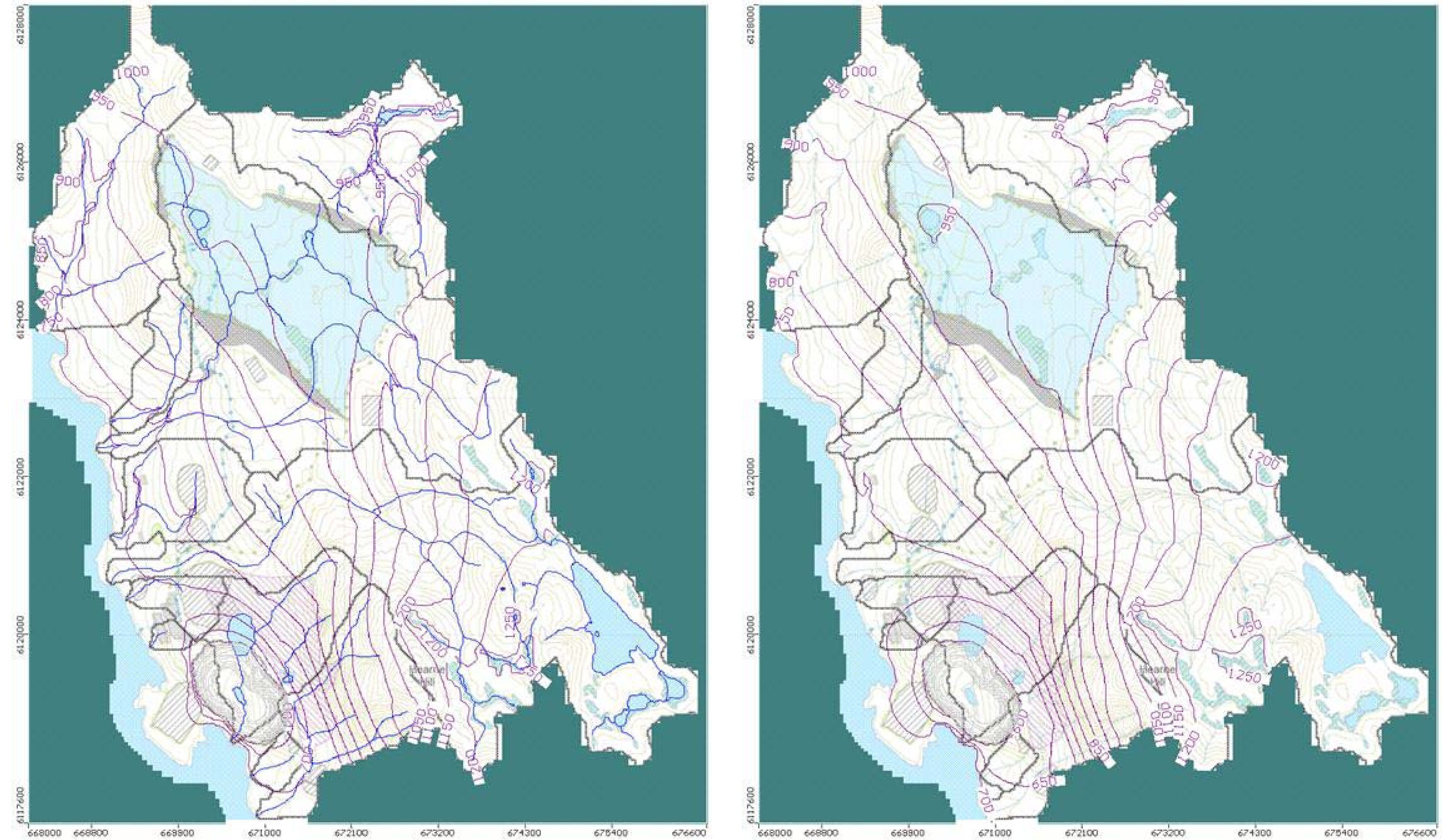

Simulation Time = 100 years
(100 years of operation)
Upper Bound case,
Full Geomembrane Liner
N
Sulphate (mg/L)
100
200
300
400
500
600
700
800
Pond SO4 = 880 mg/L
Magnified - Morrison Lake / MCS-7

APPENDIX IV

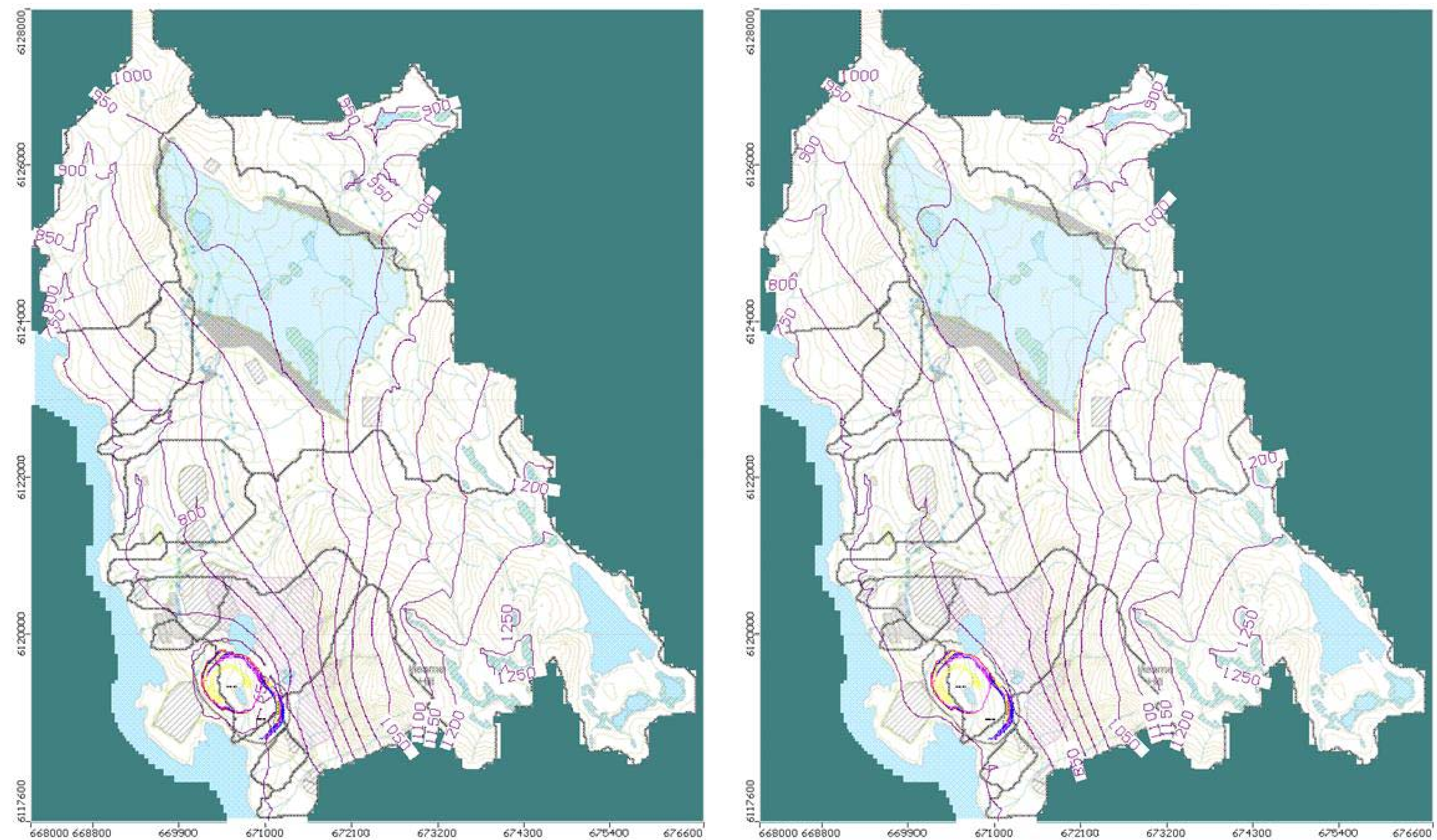
Predicted Head Distribution for Pit Dewatering Scenarios



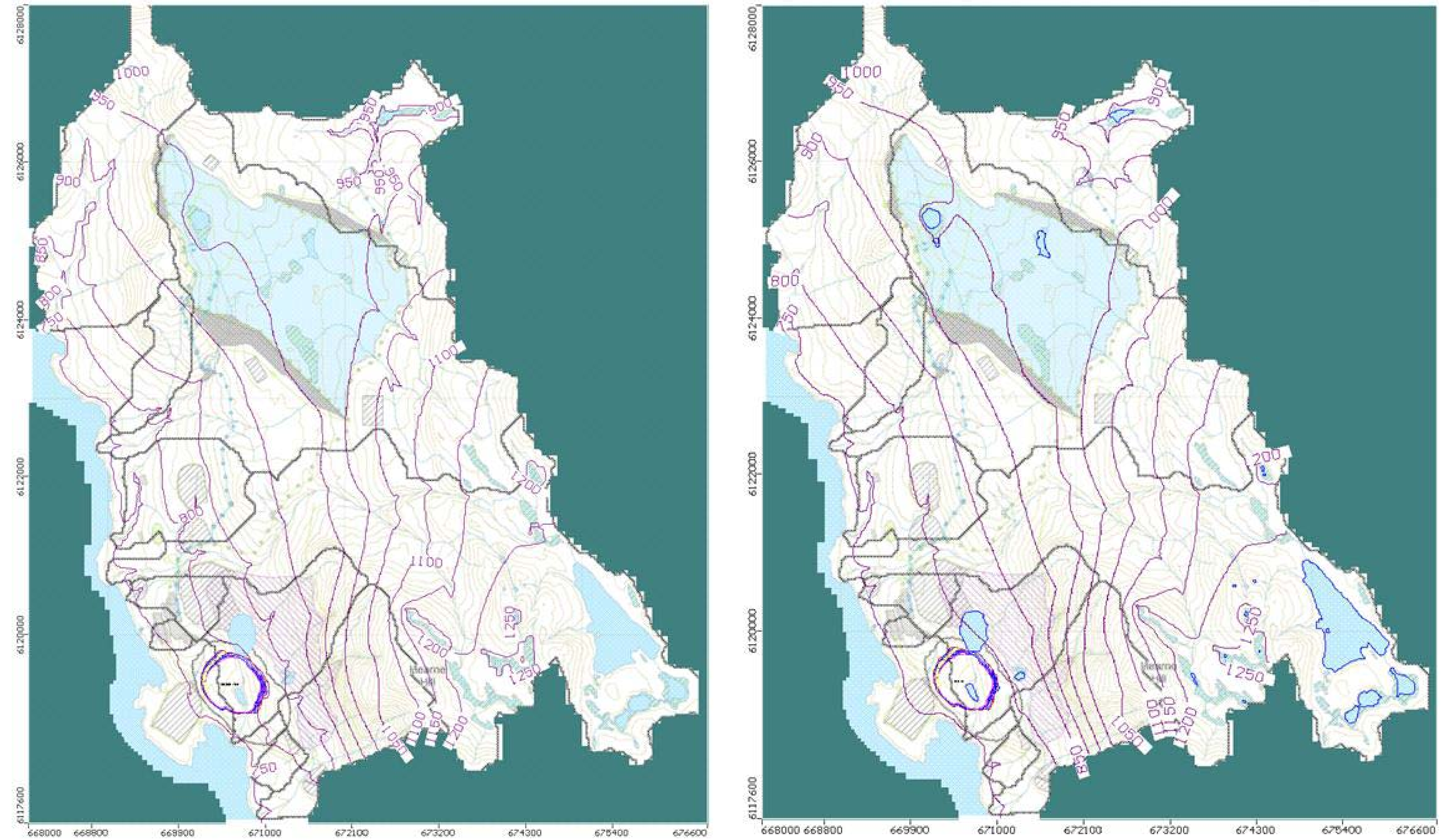
Pit Dewatering – Year 19 (floor Level 480 m/490 m). (a) Expected and (b) Upper Bound Cases. Model Layer 1.



Pit Dewatering – Year 19 (floor Level 576 m). (a) Expected and (b) Upper Bound Cases. Model Layer 1.



Pit dewatering – Year 5 (floor Level 648 m). (a) Expected and (b) Upper Bound Cases. Model Layer 1.



Pit Dewatering – Year 1 (floor Level 780 m). (a) Expected and (b) Upper Bound Cases. Model Layer 1.

APPENDIX II

Hydrogeology Work Plan for Detailed Design

APPENDIX II

Hyrdogeology Work Plan for Detailed Design

II-1. INTRODUCTION

This Appendix outlines the scope of work for hydrogeology studies for the Detail Design Phase of the Morrison Copper/Gold Project. The scope of work is based on our assessment of the site conditions and the observations made by the EA Working Group during the course of the EAC Application process.

Open-pit work will focus on upgrading the existing dewatering concept to a design level suitable for implementation. TSF work will focus on assessment of the impoundment area and the potential requirements for seepage mitigation works. The hydrogeological work will also be used to support any updated effects assessments and design details required for permitting. Additionally the hydrogeological work will improve the knowledge base for development of the Environmental Management System particularly with respect to defining mitigation measures that will be included in the Environmental Management plans and identifying contingency and/or adaptive management opportunities.

Objectives of the hydrogeological studies are outlined below:

- Review existing data, information and reporting in light of feedback from regulators and independent reviewers to identify data gaps which need to be addressed for permitting and dewatering design.
- Augment the existing database of hydrogeological data through additional site investigation, and address data gaps. This will focus on:
    - the hydraulic connectivity between Morrison Lake and regional groundwater;
    - effects of geological structure on groundwater levels and flow;
    - the density of hydrogeological data in areas where there is uncertainty regarding sub-surface characteristics; and
    - ongoing monitoring of groundwater levels and quality.
- Advance the dewatering strategy for the open pit to detailed design.

- Update the regional hydrogeological model for the project site with new data and information acquired through desktop review and site investigation.

- Create new detailed models for the open pit and TSF areas to refine assessments of:

  - groundwater inflow into the pit during operation and closure, and the associated magnitude and extent of drawdown;

  - the rate of seepage from the mine facilities (e.g. roads, waste rock dump and low grade ore stockpile) and its fate;

  - the rate of seepage from the tailings storage facility (TSF) and its fate;

  - hydraulic exchange between Morrison Lake, regional groundwater and mine facilities; and

  - solute loading to streams and lakes.

II-2. SCOPE OF WORK

II-2.1 Task 1 Data Review and Gaps Analysis

A comprehensive review of existing data and information will be undertaken to confirm/identify data gaps which need to be addressed to advance the pit dewatering design, seepage mitigation works and the hydrogeological component of permitting. KCB already have a sound understanding of the project site and the assessment history; the review will therefore focus on information which needs to be assessed in detail as part of the hydrogeological studies or requires re-assessment in-light of EA Working Group response comments. The data review will include:

- Geological data from exploration drilling completed by PBM plus geological models for the resource.

- Deep hydraulic conductivity testing and groundwater measurements by PBM in 2003.

- Groundwater investigations by Knight & Piesold in 2006 for the pit slope design.

- Groundwater investigations by Rescan in 2006-2008 for the EIA.
- Geotechnical site investigations by KCB (2007).
- Groundwater investigations by KCB in 2010 for fault hydraulic conductivity.
- Groundwater level and surface water data for different seasons, if available.
- Sequential pit shells from start to finish of operation.
- Latest comments from regulators and third party reviewers.

Findings from the review and gap analysis will be used as the basis for confirming the site investigation program, which will also aim to address (or refute) recommendations from regulators. A preliminary site investigation program is outlined in subsequent sections of this proposal.

Upon completion of the review, a letter report will be prepared which outlines the review findings and finalizes the proposed site investigation scope. A hold point will follow the review, during which time we will discuss the proposed field program with PBM and regulators to get buy-in and reduce the need for potential rework.

II-2.2 Task 2 Open Pit Hydrogeology Assessment

Task 2.1 - Desktop Assessment

The structural geology of the open pit and wall rocks will be assessed to support the structural characterization of the pit area. Previous work on structural geology has been carried out by Knight & Piesold (2006). The main work items for this task include:

- Assemble all drill hole data in the open pit area. Compilation of structural logs for each drill hole. Where logs are not available, data, including core photos, will be used to synthesize structural logs.
- Assemble all geology information including: PBM regional and local geologic maps and cross-sections; technical papers on the Morrison Deposit; technical paper on geophysical data interpretation; and block model cross sections.

- Compile groundwater-related data and observations recorded during geotechnical and exploration drilling and testing.
- Plot of potentiometric surface and assessment of hydraulic gradients.
- Plot stereonets of structural data and other data.
- Confirm structural domains.

A factual data report will be prepared as an Appendix for the final report. Updated database of geology and groundwater data.

Task 2.2 - Site Investigations

Site investigations will be carried out to provide additional hydrogeology data to support dewatering design and characterization of hydrogeological factors which may be impacted or be significant during pit dewatering. The work will also include the low grade ore (LGO) and operation phase waste rock dumps. The site investigation program will be finalized after Task 1, but is envisaged to include at least the following:

- Geologic mapping of bedrock which may be exposed between Morrison Lake and the open pit, to confirm regional mapping and geological structural characteristics (at surface). Outcrop mapping will include measurement of structures (line mapping) and assessment of rock and alteration types. This information may already have been recorded by PBM.
- Geophysical survey: This will be undertaken to provide an indication of the thickness and heterogeneity of lake bed sediments, which may limit connectivity between surface water in the lake and regional groundwater. A lake bottom survey will be run along two lines perpendicular to the open pit into Morrison Lake. The lines will be approximately 200 m long.
- Lakebed sampling: Samples of lakebed sediments, as identified with the geophysical survey, will be collected with a portable grab sampler or barge mounted vibrocore drill. This sampling is proposed to physically characterize the lakebed sediments, and further assess their ability to hydraulically isolate Morrison Lake from regional groundwater. Approximately 6 locations will be sampled and if possible, stilling wells installed to allow sampling of pore water and measurement of groundwater levels / gradients across the basal sediments.

- Drilling and packer testing in existing and new holes:
  - existing drill holes that may be re-entered to collect additional data include: a) drill hole MO-99-04 in the center of the open pit; b) drill hole MW-11 located in the area adjacent to Morrison Lake – this hole could be extended to potentially cross the West Fault and to collect data at depth; and
  - drill two new inclined drill holes to collect data to 150 m below lake level and to potentially cross the West Fault.
- Complete drilling in the vicinity of the open pit and the lake to establish at least two pumping wells for proposed pumping tests. In addition to the existing monitoring network, additional observation wells may be required nearby the pumping wells.
- Complete a pumping test program in newly installed wells to assess aquifer characteristics (transmissivity, storage), boundary effects due to lakes and structural elements and to evaluate aquifer yields to assist with well design and pump selection. At least two pumping tests (including step testing, constant rate testing and recovery) each with a separate array of observation wells are proposed.
- Ongoing monitoring of groundwater levels and quality in existing and newly installed wells.

A factual data report will be prepared as an Appendix for the final report. Updated database of geology and groundwater data.

<u>Task 2.3 - Groundwater Model</u>

A detailed FEFLOW groundwater model for the open pit area will be developed that will honor the parameterization and boundary conditions of the regional MODFLOW model that. The focused pit model is proposed specifically to assist with evaluation of dewatering design requirements and performance, and to assess interaction between the lake and the open pit. This model will be able to incorporate smaller-scale geological features of importance to dewatering design which are not able to be resolved in the regional model due to scaling.

Results from the focused pit model will be incorporated into the regional model to account for the effects of pit dewatering on groundwater levels and flow. Analytical modeling will also be completed to verify the numerical modeling results.

The work will include:

- Assess all data from Tasks 2.1 and 2.2 and derive appropriate parameterization and boundary conditions.
- Construct and calibrate the model to existing conditions.
- Run the model for progressive time steps in-line with mine development, and trial various dewatering designs to trade-off performance against potential costs.
- Sensitivity studies to assess potential variability and develop Expected Case and Upper Bound cases.

A report will be prepared that describes the model development, baseline conditions and modeling results for various stages of operations and closure. An appendix will include model inputs and outputs and results.

Task 2.4 - Pit Dewatering Design

The approach to the detailed design is to present a clear description of the dewatering approach, and an inventory of material and consumable requirements. The dewatering design will consider both groundwater and surface water (in-pit) management, and will be developed to meet pit wall depressurization requirements identified in the pit slope stability assessment.

Based on previous studies, it is assumed some form of periphery well field will be required to maintain the pit in a dry, workable condition and to meet pit wall depressurization requirements. The design of the dewatering system for groundwater control will include:

- Selection of well, locations based on dewatering needs, accessibility and scheduling (lower bench wells for later commissioning for example). This will also include location and completion recommendations for monitoring wells to collect spatial and temporal data for performance and impact monitoring.

- Presentation of common well construction design. This will take into consideration well construction materials, depth, diameter, pump setting, expected yield, expected operational life, drilling and installation difficulty, and other operational considerations.

- Selection and inventory of consumables and materials for dewatering well and monitoring well construction (to be based on the above design) presented in a format to enable up-front procurement of sufficient materials to commission the starting well-field and take the operation through the first (say) 5 years. Beyond this, additional facilities and materials will be dependent on dewatering performance.

- Recommendations for drilling and well installation techniques so that completed facilities are capable of performing at their design intent.

- Selection of pumps focusing on readily achievable specifications to provide flexibility in operations and in procurement and maintenance.

- Selection of pipe work and flow monitoring requirements consistent with surface water handling requirements discussed in subsequent sections.

- Details of additional methods needed to achieve depressurization (drainage holes, bench well points, sumps etc).

This task will be integrated with Task 2.4 (Modeling) to assist with optimization of the dewatering design and to determine pit inflows during operations, in conjunction with potential inflows from Morrison Lake. The requirements for some form of barrier between the pit and Morrison Lake to minimize inflows to the pit during operation will be assessed. At this time it is envisaged that it is possible that such works could require grouting of selected zones between the lake and the open pit, at some stage of the mining operations.

A report will be prepared that describes the pit dewatering design and seepage mitigation works, if required, will be prepared.

<u>Task 2.5 - Morrison Lake and Water Balance Effects Assessment</u>

The groundwater model will be used to support updated estimates of potential effects on Morrison Lake, which include:

- Water flow effects during operations.

- Potential for seepage effects and mitigation works for the LGO and operational waste rock dumps.

- Seepage effects on closure of potential PAG porewater flow into Morrison Lake.

- Seepage inflows into the closure pit lake (for varying pond levels) for confirmation of water treatment requirements.

The lake effects water quality model will be updated to include the potential effects of PAG porewater seepage and the TSF (as described in Task 3.4).

The site wide water balance model will be updated to include any changes to water flows during operations and on closure.

A groundwater monitoring plan will be developed, along with "trigger" levels to monitor the potential effects. The monitoring plan will also specifically address the potential for seepage effects on salmon spawning areas in Morrison Lake.

A report will be prepared that describes the updated effects assessment and tables with updated water quality predictions and a groundwater monitoring plan.

Task 2.6 - Open Pit Hydrogeology Assessment Report

A report will be prepared that documents all of the work and provides recommendations for ongoing development of the project and future groundwater investigations and modeling requirements.

Design report, with drawings, figures and appendices.

II-2.3 Task 3 TSF Hydrogeology Assessment

Task 3.1 - Desktop Assessment

All available data with respect to hydrogeology will be compiled, which includes:

- Geotechnical site investigations by Knight & Piesold (2006) – drilling, hydraulic conductivity testing and laboratory testing.

- Geotechnical site investigations by KCB (2007) – geophysical resistivity surveys, drilling, hydraulic conductivity testing and laboratory testing.

- Groundwater monitoring wells (Rescan 2007) – drilling, hydraulic conductivity testing and well installations.
- Geology data, air photos (stereo-pair) and satellite imagery.
- Groundwater level and quality data.

A factual data report will be prepared as an Appendix for the final report.

<u>Task 3.2 - Site Investigations</u>

The site investigations for the TSF area will include the following:

- Air photo interpretation and geology assessment: A detailed terrain interpretation, calibrated with site drilling, test pits and geophysical surveys will be carried out to complement the site investigations and delineate areas of different soil and bedrock units. Lineaments and areas of rock outcrop near inferred faults will be field checked for lithology, structure and other evidence of faulting. Exposed rock outcrops will be mapped for lithology and structures (line mapping).
- Geophysical Surveys: Resistivity surveys will be carried out on a grid of approximately 500 m for a total length of approximately 10 km. The resistivity lines will be used to characterize the overburden and identify areas of potential thin soil cover or pervious materials which may represents zones of higher seepage potential.
- Test Pits: Approximately twenty to forty test pits or portable boreholes will be carried out to calibrate the resistivity data and to conduct in situ constant head hydraulic conductivity tests. This information is required to assess the effectiveness of the surficial tills in limiting seepage.
- Groundwater Well Development: Some of the existing groundwater monitoring wells contain high concentrations of suspended sediment and these wells will be re-developed, purged and re-sampled to verify baseline results.
- A spring survey to define locations and mechanisms for groundwater discharge at the existing site.
- Drilling and hydraulic conductivity testing in existing and new holes:

  - Re-testing of DH06-10: The drill hole will be re-entered and hydraulic conductivity tests performed in the previously identify higher permeability zones.

  - Hydraulic testing in potential fault zones: An inclined drill hole across the identified north-south fault to assess the hydraulic conductivity of the fault, to assist with determining whether this represents a zone of potential preferential flow.

  - Impoundment Area: Approximately four drill holes will be completed within the TSF area to facilitate hydraulic conductivity testing of the overburden and bedrock. Exact collar locations and hole orientations will depend on results of the air photo interpretations, test pitting and resistivity investigations. The estimated depths of the holes are approximately 70 m each.

  - Groundwater monitoring wells: Additional groundwater monitoring well(s) will be installed between the TSF and Stream 8 to assess the potential for seepage migration in this area. The location will be chosen based on site access and geology assessment. The installation will include one shallow (10 m) and one deep well (70 m).

- Collection of water level and quality data.

A factual data report will be prepared as an Appendix for the final report including summaries of hydraulic conductivity values, plots of seasonal potentiometric surfaces, etc.

Task 3.3 - Groundwater Model

A detailed TSF MODFLOW groundwater model will be developed as a “telescoping” of the overall regional MODFLOW model, which also includes effects from the focused open pit model. The model will be setup and calibrated to data acquired during the site investigation and to provide a basis for more detailed assessment of seepage mitigation works and site conditions.

The modeling assessment will include sensitivity analyses to assist with defining parameter uncertainty. Contaminant transport modeling will also be undertaken to assess the fate of contaminants, and loading rates to streams and lakes

Report sections that describe the model development, baseline conditions and modeling results for various stages of operations and closure. Appendix with model inputs / outputs and plots of flow vectors, % solute, etc.

Task 3.4 - Updated Seepage Effects on Streams and Lakes

The groundwater model results will be input in into the stream and lake effects assessment to update the potential effects assessment. The baseline groundwater quality and surface water databases will be updated with any new data. The assessment will be carried out for the Expected and Upper Bound cases, with and without various levels of seepage mitigation.

The assessment will be utilized to determine the requirements for seepage mitigation.

A groundwater monitoring plan will be developed, along with "trigger" levels to monitor the potential effects. The monitoring plan will also specifically address the potential for seepage effects on salmon spawning areas in Morrison Lake.

Water quality effects predictions for the receiving streams and Morrison Lake will be updated. A groundwater monitoring plan will be developed, along with "trigger" levels to monitor the potential effects.

Task 3.5 - Seepage Mitigation Design

The scope of the seepage mitigation works will be determined as part of Task 2.4. The design of the works could include:

- Determination of specifications for foundation preparation for the dam foundations.
- Determination of areas of the impoundment that may require placement of liners. Design of liner systems (either soil liners or geosynthetic membranes).
- Determination of grouting specifications, if required.

Report sections that describe seepage mitigation design works.

Task 3.6 - TSF Hydrogeology Report

A report will be prepared that documents all of the work and provides recommendations for ongoing development of the project and future groundwater investigations and modeling requirements.

APPENDIX III

SGS Letter on Water Treatment

Memorandum

Phone: (604) 267-2364
Fax: (604) 264-5535
E-mail:**Sohan.Basra@sgs.com**

Date: January 11, 2012

To: Claudio F. Andrade

Re: PBM-Morrison Project #1115

Background

A 500 ml sample of mine water was spiked on March 10, 2011 to review the effect of lime neutralization on water quality of Morrison project. A 60ml sample of the feed was taken for metal analysis, the water sample was neutralized to pH 7.0, 8.0 and 9.3 using hydrated lime, with the lime being added as 10% slurry. The pH was raised to the target value and agitated for 40 minutes, while maintaining the selected pH with lime addition when necessary. For each pH, 80 mL sample was collected and filtered through a 0.45 micron membrane filter for metal analysis.

Result and Discussion

Based on the test data summarized in the attached table, it was determined that neutralization at pH 9.3 or higher would be required to precipitate most of the metals of concern as well as sulphate and magnesium to low concentrations.

Although the magnesium (Mg) concentration in water was reduced by increasing pH, the maximum precipitation was not anticipated at pH 9.3. The maximum Mg precipitation takes place at pH 9.8 or higher as experienced at other mining sites. Typically over 90% of Mg will precipitate at pH 9.9 unless the Mg is complexed with sulphate and $MgSO_4$.

The sulphate concentration in the water sample dropped from 11,760 to 5,700 mg/l which indicates removal efficiency of more than 50%. However, the sulphate concentration was significantly above the discharge target. High Density Sludge (HDS) is one of the best options to reduce the sulphate concentration in water. In a typical HDS plant operated at pH 9.5 to 9.8 with a 60 minute retention results in sulphate concentration well below 2000 mg/L.

The other factor which could be adjusted to increase sulphate removal efficiency is the retention time. Although a 40 minute retention time in the bench scale teswork was sufficient in removing most of the metals, a higher retention time is recommended to improve the sulphate removal efficiency. Also, the high retention time provides sufficient contingency to manage peak flows without having a significant impact on the effluent quality.

Conducting pilot study is highly recommended to determine precise lime consumption, effluent quality after continuous operation and establish design parameters for design engineering.

Table 1. Analysis Results Summary

		Predicted	Feed (Spiked)	pH 7.0	pH 8.0	pH 9.3
Reaction Time (min)				**40**	**40**	**40**
Aluminum (Al)	mg/L	410	239	0.093	0.41	0.464
Antimony (Sb)	mg/L	0.001	<0.002	<0.002	<0.002	<0.002
Arsenic (As)	mg/L	0.072	0.263	<0.0004	<0.0004	<0.0004
Barium (Ba)	mg/L	0.01	0.055	0.058	0.045	0.031
Beryllium (Be)	mg/L	0.03	<0.0004	<0.0004	<0.0004	<0.0004
Bismuth (Bi)	mg/L		<0.004	<0.004	<0.004	<0.004
Boron (B)	mg/L	0.0042	0.22	0.353	0.319	0.309
Cadmium (Cd)	mg/L	0.028	0.063	0.017	0.00498	0.00032
Calcium (Ca)	mg/L	380	7.2	483	463	535
Chromium (Cr)	mg/L	0.18	0.036	<0.004	<0.004	<0.004
Cobalt (Co)	mg/L	7	5.34	2.67	1.05	0.007
Copper (Cu)	mg/L	110	77.4	0.164	0.0321	0.0049
Iron (Fe)	mg/L	110	107	<0.02	<0.02	<0.02
Lead (Pb)	mg/L	0.34	1.4	<0.0008	<0.0008	<0.0008
Manganese (Mn)	mg/L	27	18.1	15	12.7	0.243
Molybdenum (Mo)	mg/L	0.067	0.006	0.008	0.005	<0.004
Nickel (Ni)	mg/L	2.5	3.85	1.79	0.605	0.018
Phosphorus (P)	mg/L	21	0.078	<0.04	<0.04	<0.04
Potassium (K)	mg/L	1.9	0.6	2.2	2.4	2.8
Selenium (Se)	mg/L	0.015	0.0023	0.0021	0.0021	0.0019
Silicon (Si)	mg/L	21	2.61	2.18	0.802	1.12
Silver (Ag)	mg/L	0.00001	<0.00008	<0.00008	<0.00008	<0.00008
Sodium (Na)	mg/L	14	1.7	3.4	3.6	4
Strontium (Sr)	mg/L	4.1	0.015	0.203	0.202	0.226
Thallium (Tl)	mg/L	0.0001	0.0059	0.0032	0.0031	0.0019
Tin (Sn)	mg/L	0.0001	<0.02	<0.02	<0.02	<0.02
Titanium (Ti)	mg/L	0.047	<0.02	<0.02	<0.02	<0.02
Uranium (U)	mg/L	0.048	0.0014	<0.0004	0.0005	<0.0004
Vanadium (V)	mg/L	0.056	<0.02	<0.02	<0.02	<0.02
Zinc (Zn)	mg/L	7.4	10.1	0.557	0.064	<0.02
Zirconium (Zr)	mg/L		<0.002	<0.002	<0.002	<0.002
Sulphate	mg/L	10500	11760	6380	6660	5700

1. Co, Mn, Ni and Zn removal improves with pH
2. Sulphate removal is a function of pH and retention time.
   At higher pH and 60 minute retention time, sulphate concentration could be approximately 2000 mg/L
3. Manganese precipitation improves with sludge recycle and at higher pH, so can be less than 0.1 with an HDS system at pH 9.3
4. pH after treatment can be reduced to discharge requirements by either adding CO_2, air infusion or H_2SO_4

APPENDIX IV

Water Balance Tables

Summary - Expected Condition

Annual Precipitation (mm)	550
Annual Evaporation (mm)	389
Undisturbed (Diverted) Land Runoff Coefficient	0.5
TSF	
Tailings pond area (sq. km)	varies
Undiverted Catchment runoff area (sq.km.)	varies
Diverted uphill catchment area (sq.km.)	varies
% Diversion ditch seepage	10%
Ultimate Tailings pond area (sq. km)	5.1

Process Plant	
Waste Dump/Plant Site Runoff Coefficient	0.7
Open Pit Runoff Coefficient	1.0
Processes %Availability	92.0%
Undiverted WRD/Plant Site Catchment Area (sq.km)	varies
Diverted WRD/Plant Site Catchment Area (sq.km)	varies
% Diversion ditch seepage	10%
Open Pit Area (sq.km)	1.1

Tailings		tpd	% Solids	
Total Daily Tonnage		29,621	Transport	InSitu
9%	Rougher	27,003	35.61%	72.2%
91%	Cleaner	2,619	22.76%	72.2%
Cyclone Efficiency		85%		
24%	Cyclone U/F	7,157		85.0%
76%	Cyclone O/F	22,465		72.2%

DATA	**Parameter**	**unit**		**Construction**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 20.5**
	Annual precipitation	mm	550																						
	Annual evaporation	mm	389																						
TSF Area	Diverted catchment area (external to TSF)	km^2		4.07	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80
	Diverted Within TSF				2.10	2.10	2.10	2.10	2.10	1.25	1.25	1.25	1.25	1.25	0.70	0.70	0.70	0.70	0.70	0.00	0.00	0.00	0.00	0.00	0.00
	Diverted runoff coefficient	%	0.5																						
	Diversion ditch efficiency	%	90%		Yr 5 footprint Diversion					Yr 10 footprint diversion					Yr 15 footprint diversion					UTSF diversion					
	Undiverted catchment area (not including TSF)	km^2		6.47	1.80	1.08	0.72	0.36	0.00	0.68	0.51	0.34	0.17	0.00	0.44	0.33	0.22	0.11	0.00	0.56	0.42	0.28	0.14	0.00	0.00
	Undiverted runoff coefficient	%	0.5																						
	TSF impoundment area	km^2		1.20	1.20	1.92	2.28	2.64	3.00	3.17	3.34	3.51	3.68	3.85	3.96	4.07	4.18	4.29	4.40	4.54	4.68	4.82	4.96	5.10	5.10
	TSF impoundment runoff coefficient	%	1.0							5.10	5.10	5.10	5.10		5.10										
			Transport	In Situ																					
Mine Area	Rougher Tailings Density	% solids	35.61%	72.2%																					
	Cleaner Tailings Density		22.76%	72.2%																					
	Cyclone Underflow	% solids	-	85.0%																					
	Cyclone Overflow	% solids	-	72.2%														Inflows	0.0%	0.0%						
															0		Losses	39.47							
																	Balance	-3946.8%							
	Diverted LGO/WRD/Plantsite area	km^2		0.62	1.7	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	0.00	0.00	0.00
	Diverted runoff coefficient	%	0.5																						
	Diversion ditch efficiency	%	90%																						
	Undiverted LGO/WRD/Plantsite area	km^2		2.52	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	0.00	0.00	0.00
	LGO/WRD/Plantsite runoff coefficient	%	0.7																						
	Open pit area	km^2	1.1																						
	Open pit runoff coefficient	%	1.0																						
INFLOWS																									
TSF Area	Runoff from undiverted catchment			206	57	34	23	11	0	22	16	11	5	5	14	11	7	4	0	18	13	9	4	0	0
	Leakage from Diversion Ditches			0	50	50	50	50	50	45	45	45	45	45	8	41	41	41	41	37	37	37	37	37	34
	Precipitation on TSF Impoundment			76	76	122	145	168	191	202	213	223	234	245	252	259	266	273	280	289	298	307	316	325	279
	Cleaner Tailings Water (direct discharge)	m^3/hr		0	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	0	0	0
	Rougher Tailings Water (direct discharge)			0	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034
	Seepage reclaim			0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	SUBTOTAL - TSF Inflows			**282**	**2593**	**2616**	**2627**	**2639**	**2650**	**2677**	**2682**	**2688**	**2693**	**2699**	**2716**	**2720**	**2723**	**2727**	**2730**	**2752**	**2757**	**2761**	**2396**	**2400**	**2352**
Mine Area	Runoff from LGO/WRD plantsite area			0	133	133	133	133	133	133	133	133	133	133	133	133	133	133	133	133	133	133	0	0	0
	Leakage from diversion ditches			0	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	0	0	0
	Precipitation/Runoff into open pit			0	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	0	0	0
	Open pit dewatering	m^3/hr		0	33	63	93	122	152	167	183	198	214	229	245	260	278	296	314	332	350	368	0	0	0
	Fresh water makeup			0	47	47	47	47	47	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Ore rock moisture			0	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39
	SUBTOTAL - Mine Inflows			**0**	331	361	391	421	450	434	449	381	480	496	511	526	544	562	580	598	616	634	54	54	54
OUTFLOWS																									
	Evaporation from TSF impoundment			54	54	86	103	119	135	143	150	158	166	173	178	183	188	193	198	204	210	217	223	229	208
	TSF seepage			5	10	13	16	19	22	24	27	30	33	36	39	42	45	48	51	53	56	59	65	65	65
	Tailings void loss - whole			0	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	433	433	433
	-overflow			0	204	204	204	204	204	204	204	204	204	204	204	204	204	204	204	204	204	204	0	0	0
	-underflow (cyclone sand)			0	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	0	0	0
	Dust Suppression			21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	17
	Concentrate Load Out	m^3/hr		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Potable Water			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Reclaim Water			0	0	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	1834	1834	1834
	Pit Dewatering Discharge to Lake			125	0	0	0	0	90	90	90	90	90	140	140	140	140	140	165	160	160	160	0	0	0
	SUBTOTAL - Outflows			**207**	2933	2969	2988	3007	3116	3127	3137	3148	3158	3219	3227	3234	3242	3250	3283	3287	3296	3305	2580	2587	2561
NET	**Net Flow**			**75**	-9	8	30	52	-16	-16	-5	-78	15	-24	1	12	25	39	28	64	77	90	-131	-133	-155
	Net Annual Volume	m^3		655,551	- 82,005	70,311	264,095	457,879	- 136,737	- 137,245	- 47,031	- 686,400	133,397	- 214,388	5,418	102,543	222,195	341,846	242,497	558,632	674,828	791,023	- 1,146,849	- 1,162,976	- 677,785
CUMULATIVE	**Cumulative Volume**			655,551	573,546	643,856	907,951	1,365,830	1,229,093	1,091,848	1,044,817	358,417	491,814	277,426	282,844	385,387	607,582	949,428	1,191,925	1,750,557	2,425,384	3,216,408	2,069,558	906,583	228,797
	Cumulative Volume	Mm^3		0.66	0.57	0.64	0.91	1.37	1.23	1.09	1.04	0.36	0.49	0.28	0.28	0.39	0.61	0.95	1.19	1.75	2.43	3.22	2.07	0.91	0.23
MAXIMUM	**LOM Max Pond Volume**	3.22	Mm^3																						
END	**End of Mine Pond Volume:**	0.23	Mm^3																						

Construction
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	No	No	No	No	No	No	No	No	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	128	108	91	76	250	498	405	287	198	152	136	142	**206**
Leakage from Diversion Ditches	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Precipitation on TSF Impoundment	94	64	50	39	62	86	81	78	81	92	94	98	**76**
Cleaner Tailings Water (direct discharge)	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Rougher Tailings Water (direct discharge)	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Seepage reclaim	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	221	172	141	115	312	584	486	365	278	243	230	240	**282**
Plant Area = Process Plant & Site, Open Pit, Waste Dump, Ore Stockpile													
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Leakage from Diversion Ditches	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Precipitation Over Open Pit	0.00	0	0	0	0	0	0	0	0	0	0	0	**0**
Open Pit Groundwater Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Fresh Water Make-up	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Ore Void Water (3% MC)	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Subtotal	0	0	0	0	0	0	0	0	0	0	0	0	**0**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	129	164	163	131	60	0	0	0	**54**
Seepage	5	5	5	5	5	5	5	5	5	5	5	5	**5**
Tailing voids	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Cyclone Overflow Voids	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Cycloned Sand Voids	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Discharge to Environment	0	0	0	0	0	0	140	365	278	243	230	240	**125**
Subtotal	8	8	8	8	187	222	361	554	397	251	238	248	**207**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**213**	**164**	**133**	**107**	**125**	**362**	**125**	**(189)**	**(118)**	**(8)**	**(8)**	**(8)**	**75**
Net Water Surplus (Deficit) (m^3)	**155582**	**120048**	**96976**	**78110**	**91217**	**264392**	**91045**	**(137943)**	**(86355)**	**(5840)**	**(5840)**	**(5840)**	**655,551**
Pond Size (m^3)	**155582**	**275630**	**372606**	**450716**	**541933**	**806325**	**897370**	**759426**	**673071**	**667231**	**661391**	**655551**	

Year 1
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	36	30	25	21	69	139	113	80	55	42	38	39	**57**
Leakage from Diversion Ditches	31	26	22	19	61	122	99	70	48	37	33	35	**50**
Precipitation on TSF Impoundment	94	64	50	39	62	86	81	78	81	92	94	98	**76**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2569	2529	2506	2487	2601	2755	2701	2636	2593	2580	2574	2581	**2,593**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	33	33	33	33	33	33	33	33	33	33	33	33	**33**
Fresh Water Make-up	47	47	47	47	47	47	47	47	47	47	47	47	**47**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	251	231	213	198	376	633	537	415	323	275	260	265	**331**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	129	164	163	131	60	0	0	0	**54**
Seepage	10	10	10	10	10	10	10	10	10	10	10	10	**10**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	2894	2894	2841	2841	3020	3055	3054	3022	2951	2841	2894	2894	**2,933**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**(74)**	**(134)**	**(122)**	**(156)**	**(42)**	**333**	**184**	**29**	**(36)**	**14**	**(61)**	**(48)**	**(9)**
Net Water Surplus (Deficit) (m^3)	**(54271)**	**(97623)**	**(88950)**	**(113816)**	**(30733)**	**242834**	**134258**	**21310**	**(26235)**	**10352**	**(44287)**	**(34845)**	- **82,005**
Pond Size (m^3)	**601280**	**503657**	**414707**	**300892**	**270158**	**512992**	**647250**	**668560**	**642325**	**652678**	**608391**	**573546**	

Year 2
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	21	18	15	13	42	83	68	48	33	25	23	24	**34**
Leakage from Diversion Ditches	31	26	22	19	61	122	99	70	48	37	33	35	**50**
Precipitation on TSF Impoundment	150	103	79	62	100	138	129	125	129	147	150	157	**122**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2611	2556	2525	2502	2611	2751	2704	2651	2619	2618	2614	2624	**2,616**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	63	63	63	63	63	63	63	63	63	63	63	63	**63**
Fresh Water Make-up	47	47	47	47	47	47	47	47	47	47	47	47	**47**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	280	260	243	228	406	662	567	444	352	305	289	295	**361**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	206	262	261	210	96	0	0	0	**86**
Seepage	13	13	13	13	13	13	13	13	13	13	13	13	**13**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	2897	2897	2844	2844	3100	3156	3155	3103	2990	2844	2897	2897	**2,969**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**(6)**	**(80)**	**(75)**	**(114)**	**(83)**	**257**	**116**	**(8)**	**(19)**	**79**	**7**	**22**	**8**
Net Water Surplus (Deficit) (m^3)	**(4082)**	**(58710)**	**(55085)**	**(83563)**	**(60617)**	**187876**	**84698**	**(5615)**	**(13758)**	**57778**	**5187**	**16200**	**70,311**
Pond Size (m^3)	**569464**	**510754**	**455669**	**372106**	**311489**	**499365**	**584063**	**578449**	**564691**	**622469**	**627656**	**643856**	

Year 3

Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	14	12	10	9	28	55	45	32	22	17	15	16	**23**
Leakage from Diversion Ditches	31	26	22	19	61	122	99	70	48	37	33	35	**50**
Precipitation on TSF Impoundment	178	122	94	73	118	164	153	148	153	174	178	186	**145**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2632	2569	2535	2509	2616	2750	2706	2659	2632	2637	2635	2646	**2,627**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	93	93	93	93	93	93	93	93	93	93	93	93	**93**
Fresh Water Make-up	47	47	47	47	47	47	47	47	47	47	47	47	**47**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	310	290	273	257	436	692	597	474	382	335	319	325	**391**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	245	312	310	249	115	0	0	0	**103**
Seepage	16	16	16	16	16	16	16	16	16	16	16	16	**16**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	2900	2900	2847	2847	3142	3208	3207	3146	3011	2847	2900	2900	**2,988**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**42**	**(40)**	**(39)**	**(80)**	**(90)**	**233**	**96**	**(13)**	**3**	**125**	**54**	**71**	**30**
Net Water Surplus (Deficit) (m^3)	**30815**	**(29451)**	**(28350)**	**(58634)**	**(65757)**	**170199**	**69721**	**(9275)**	**2283**	**91293**	**39727**	**51525**	**264,095**
Pond Size (m^3)	**674671**	**645220**	**616870**	**558236**	**492479**	**662678**	**732398**	**723124**	**725406**	**816700**	**856426**	**907951**	

Year 4
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	7	6	5	4	14	28	23	16	11	8	8	8	**11**
Leakage from Diversion Ditches	31	26	22	19	61	122	99	70	48	37	33	35	**50**
Precipitation on TSF Impoundment	206	141	109	85	137	190	177	171	177	202	206	216	**168**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2653	2582	2545	2516	2621	2748	2708	2666	2645	2656	2655	2667	**2,639**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	122	122	122	122	122	122	122	122	122	122	122	122	**122**
Fresh Water Make-up	47	47	47	47	47	47	47	47	47	47	47	47	**47**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	340	320	302	287	466	722	626	504	412	365	349	354	**421**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	284	361	359	288	133	0	0	0	**119**
Seepage	19	19	19	19	19	19	19	19	19	19	19	19	**19**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	2903	2903	2850	2850	3184	3261	3259	3188	3032	2850	2903	2903	**3,007**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**90**	**(0)**	**(2)**	**(46)**	**(97)**	**209**	**75**	**(18)**	**25**	**171**	**102**	**119**	**52**
Net Water Surplus (Deficit) (m^3)	**65712**	**(193)**	**(1616)**	**(33706)**	**(70896)**	**152522**	**54743**	**(12935)**	**18324**	**124808**	**74266**	**86850**	**457,879**
Pond Size (m^3)	**973663**	**973470**	**971855**	**938149**	**867253**	**1019775**	**1074517**	**1061583**	**1079906**	**1204715**	**1278980**	**1365830**	

Year 5
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	-
Leakage from Diversion Ditches	31	26	22	19	61	122	99	70	48	37	33	35	**50**
Precipitation on TSF Impoundment	234	160	124	96	156	215	202	195	202	229	234	245	**191**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2674	2596	2555	2524	2626	2746	2709	2674	2659	2675	2676	2689	**2,650**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	152	152	152	152	152	152	152	152	152	152	152	152	**152**
Fresh Water Make-up	47	47	47	47	47	47	47	47	47	47	47	47	**47**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	370	350	332	317	495	752	656	534	442	394	379	384	**450**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	323	410	408	327	151	0	0	0	**135**
Seepage	22	22	22	22	22	22	22	22	22	22	22	22	**22**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	90	90	90	90	90	90	90	90	90	90	90	90	90
Subtotal	2995	2995	2943	2943	3315	3403	3401	3320	3143	2943	2995	2995	**3,116**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**48**	**(50)**	**(56)**	**(102)**	**(194)**	**95**	**(36)**	**(113)**	**(43)**	**127**	**59**	**77**	**(16)**
Net Water Surplus (Deficit) (m^3)	**34909**	**(36634)**	**(40581)**	**(74477)**	**(141736)**	**69145**	**(25935)**	**(82295)**	**(31336)**	**92624**	**43105**	**56474**	**- 136,737**
Pond Size (m^3)	**1400739**	**1364105**	**1323524**	**1249047**	**1107311**	**1176456**	**1150521**	**1068226**	**1036890**	**1129514**	**1172619**	**1229093**	

Year 6
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	13	11	10	8	26	52	43	30	21	16	14	15	**22**
Leakage from Diversion Ditches	28	24	20	17	54	109	88	62	43	33	30	31	**45**
Precipitation on TSF Impoundment	247	170	131	102	165	228	213	206	213	242	247	259	**202**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2697	2613	2569	2535	2654	2797	2753	2707	2686	2700	2700	2714	**2,677**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	167	167	167	167	167	167	167	167	167	167	167	167	**167**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	353	333	316	300	479	735	640	517	425	378	362	368	**434**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	341	433	432	346	159	0	0	0	**143**
Seepage	24	24	24	24	24	24	24	24	24	24	24	24	**24**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	90	90	90	90	90	90	90	90	90	90	90	90	90
Subtotal	2998	2998	2945	2945	3336	3429	3427	3341	3155	2945	2998	2998	**3,127**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**52**	**(52)**	**(61)**	**(110)**	**(203)**	**103**	**(35)**	**(117)**	**(44)**	**132**	**64**	**83**	**(16)**
Net Water Surplus (Deficit) (m^3)	**37712**	**(37978)**	**(44416)**	**(80304)**	**(148478)**	**75541**	**(25370)**	**(85491)**	**(32070)**	**96626**	**46415**	**60567**	- **137,245**
Pond Size (m^3)	**1266805**	**1228827**	**1184411**	**1104108**	**955630**	**1031171**	**1005801**	**920310**	**888240**	**984865**	**1031280**	**1091848**	

Year 7
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	10	9	7	6	20	39	32	23	16	12	11	11	**16**
Leakage from Diversion Ditches	28	24	20	17	54	109	88	62	43	33	30	31	**45**
Precipitation on TSF Impoundment	260	179	138	107	173	240	225	217	225	255	260	273	**213**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2707	2619	2574	2539	2656	2796	2754	2711	2692	2709	2709	2724	**2,682**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	183	183	183	183	183	183	183	183	183	183	183	183	**183**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	368	349	331	316	494	750	655	533	441	393	378	383	**449**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	359	457	455	365	168	0	0	0	**150**
Seepage	27	27	27	27	27	27	27	27	27	27	27	27	**27**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	90	90	90	90	90	90	90	90	90	90	90	90	90
Subtotal	3001	3001	2948	2948	3357	3455	3453	3363	3166	2948	3001	3001	**3,137**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**74**	**(33)**	**(44)**	**(94)**	**(207)**	**92**	**(45)**	**(120)**	**(34)**	**154**	**86**	**106**	**(5)**
Net Water Surplus (Deficit) (m^3)	**54083**	**(24269)**	**(31899)**	**(68640)**	**(151012)**	**67085**	**(32551)**	**(87327)**	**(24604)**	**112344**	**62617**	**77141**	- **47,031**
Pond Size (m^3)	**1145931**	**1121662**	**1089763**	**1021123**	**870110**	**937196**	**904645**	**817318**	**792714**	**905059**	**967676**	**1044817**	

Year 8
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Leakage from Diversion Ditches	28	24	20	17	54	109	88	62	43	33	30	31	**45**
Precipitation on TSF Impoundment	273	188	145	113	182	252	236	228	236	268	273	287	**223**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2717	2626	2578	2542	2659	2795	2754	2714	2698	2718	2719	2734	**2,688**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	65	65	65	65	65	65	65	65	65	65	65	65	**65**
Fresh Water Make-up	65	65	65	65	65	65	65	65	65	65	65	65	**65**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	301	281	263	248	426	683	587	465	373	325	310	315	**381**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	377	480	478	383	176	0	0	0	**158**
Seepage	30	30	30	30	30	30	30	30	30	30	30	30	**30**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	90	90	90	90	90	90	90	90	90	90	90	90	90
Subtotal	3004	3004	2951	2951	3379	3481	3479	3384	3178	2951	3004	3004	**3,148**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**13**	**(98)**	**(110)**	**(161)**	**(294)**	**(3)**	**(138)**	**(205)**	**(107)**	**92**	**25**	**45**	**(78)**
Net Water Surplus (Deficit) (m^3)	**9656**	**(71359)**	**(80181)**	**(117775)**	**(214346)**	**(2168)**	**(100530)**	**(149962)**	**(77935)**	**67265**	**18021**	**32915**	**- 686,400**
Pond Size (m^3)	**1054472**	**983113**	**902932**	**785158**	**570812**	**568643**	**468113**	**318151**	**240216**	**307481**	**325501**	**358417**	

Year 9
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	3	3	2	2	7	13	11	8	5	4	4	4	**5**
Leakage from Diversion Ditches	28	24	20	17	54	109	88	62	43	33	30	31	**45**
Precipitation on TSF Impoundment	287	197	152	118	191	264	247	239	247	281	287	301	**234**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2727	2632	2583	2545	2661	2795	2755	2718	2704	2727	2729	2744	**2,693**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	214	214	214	214	214	214	214	214	214	214	214	214	**214**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	399	379	362	347	525	781	686	563	471	424	408	414	**480**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	396	503	501	402	185	0	0	0	**166**
Seepage	33	33	33	33	33	33	33	33	33	33	33	33	**33**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	90	90	90	90	90	90	90	90	90	90	90	90	90
Subtotal	3007	3007	2954	2954	3400	3507	3505	3406	3189	2954	3007	3007	**3,158**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**119**	**4**	**(9)**	**(62)**	**(214)**	**69**	**(64)**	**(125)**	**(13)**	**197**	**130**	**151**	**15**
Net Water Surplus (Deficit) (m^3)	**86825**	**3148**	**(6866)**	**(45312)**	**(156082)**	**50175**	**(46912)**	**(91000)**	**(9670)**	**143782**	**95022**	**110287**	**133,397**
Pond Size (m^3)	**445242**	**448390**	**441525**	**396213**	**240130**	**290305**	**243393**	**152393**	**142723**	**286505**	**381527**	**491814**	

Year 10
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	-
Leakage from Diversion Ditches	28	24	20	17	54	109	88	62	43	33	30	31	**45**
Precipitation on TSF Impoundment	300	206	159	124	200	276	259	250	259	294	300	315	**245**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2737	2638	2587	2549	2663	2794	2756	2721	2711	2736	2738	2754	**2,699**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	229	229	229	229	229	229	229	229	229	229	229	229	**229**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	415	395	377	362	541	797	701	579	487	440	424	429	**496**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	414	526	524	420	193	0	0	0	**173**
Seepage	36	36	36	36	36	36	36	36	36	36	36	36	**36**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	140	140	140	140	140	140	140	140	140	140	140	140	140
Subtotal	3060	3060	3007	3007	3471	3583	3581	3477	3250	3007	3060	3060	**3,219**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**91**	**(27)**	**(42)**	**(96)**	**(267)**	**7**	**(124)**	**(177)**	**(53)**	**168**	**102**	**124**	**(24)**
Net Water Surplus (Deficit) (m^3)	**66697**	**(19643)**	**(30849)**	**(70148)**	**(195117)**	**5219**	**(90593)**	**(129336)**	**(38703)**	**123000**	**74724**	**90360**	**- 214,388**
Pond Size (m^3)	**558511**	**538868**	**508019**	**437870**	**242753**	**247973**	**157380**	**28044**	**(10659)**	**112341**	**187065**	**277426**	

Year 11
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	9	7	6	5	17	34	28	20	13	10	9	10	**14**
Leakage from Diversion Ditches	26	22	18	15	50	100	81	58	40	30	27	28	**41**
Precipitation on TSF Impoundment	309	212	163	127	206	284	266	257	266	303	309	324	**252**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2752	2650	2597	2556	2682	2827	2784	2743	2728	2752	2754	2771	**2,716**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	245	245	245	245	245	245	245	245	245	245	245	245	**245**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	430	410	393	377	556	812	717	594	502	455	439	445	**511**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	426	541	539	432	199	0	0	0	**178**
Seepage	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	140	140	140	140	140	140	140	140	140	140	140	140	140
Subtotal	3063	3063	3010	3010	3486	3601	3599	3492	3259	3010	3063	3063	**3,227**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**119**	**(3)**	**(21)**	**(76)**	**(248)**	**38**	**(98)**	**(155)**	**(29)**	**197**	**130**	**153**	**1**
Net Water Surplus (Deficit) (m^3)	**86855**	**(2168)**	**(14986)**	**(55574)**	**(181135)**	**27703**	**(71882)**	**(113059)**	**(20834)**	**143935**	**95210**	**111353**	**5,418**
Pond Size (m^3)	**364281**	**362113**	**347127**	**291553**	**110418**	**138121**	**66238**	**(46821)**	**(67655)**	**76280**	**171490**	**282844**	

Year 12
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	7	6	5	4	13	25	21	15	10	8	7	7	**11**
Leakage from Diversion Ditches	26	22	18	15	50	100	81	58	40	30	27	28	**41**
Precipitation on TSF Impoundment	317	218	168	131	211	292	274	264	274	311	317	333	**259**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2758	2654	2600	2559	2683	2826	2784	2745	2732	2758	2760	2777	**2,720**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	260	260	260	260	260	260	260	260	260	260	260	260	**260**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	446	426	408	393	571	828	732	610	518	470	455	460	**526**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	438	556	554	444	205	0	0	0	**183**
Seepage	42	42	42	42	42	42	42	42	42	42	42	42	**42**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	140	140	140	140	140	140	140	140	140	140	140	140	140
Subtotal	3066	3066	3013	3013	3500	3619	3617	3507	3267	3013	3066	3066	**3,234**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**138**	**14**	**(5)**	**(61)**	**(246)**	**35**	**(100)**	**(152)**	**(17)**	**216**	**149**	**172**	**12**
Net Water Surplus (Deficit) (m^3)	**100677**	**9932**	**(3657)**	**(44797)**	**(179546)**	**25461**	**(73300)**	**(111018)**	**(12773)**	**157335**	**108923**	**125306**	**102,543**
Pond Size (m^3)	**383521**	**393453**	**389795**	**344998**	**165452**	**190913**	**117613**	**6595**	**(6178)**	**151157**	**260080**	**385387**	

Year 13
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	4	4	3	3	8	17	14	10	7	5	5	5	**7**
Leakage from Diversion Ditches	26	22	18	15	50	100	81	58	40	30	27	28	**41**
Precipitation on TSF Impoundment	326	224	172	134	217	300	281	271	281	319	326	342	**266**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2764	2658	2603	2561	2685	2826	2785	2748	2736	2764	2766	2784	**2,723**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	278	278	278	278	278	278	278	278	278	278	278	278	**278**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	464	444	426	411	589	846	750	628	536	488	473	478	**544**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	449	571	569	456	210	0	0	0	**188**
Seepage	45	45	45	45	45	45	45	45	45	45	45	45	**45**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	140	140	140	140	140	140	140	140	140	140	140	140	140
Subtotal	3069	3069	3016	3016	3515	3637	3635	3522	3276	3016	3069	3069	**3,242**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**159**	**33**	**13**	**(44)**	**(241)**	**34**	**(100)**	**(147)**	**(4)**	**236**	**171**	**193**	**25**
Net Water Surplus (Deficit) (m^3)	**116377**	**23909**	**9548**	**(32144)**	**(176080)**	**25096**	**(72839)**	**(107100)**	**(2835)**	**172612**	**124514**	**141137**	**222,195**
Pond Size (m^3)	**501764**	**525672**	**535221**	**503077**	**326997**	**352093**	**279254**	**172154**	**169319**	**341931**	**466445**	**607582**	

Year 14
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	2	2	2	1	4	8	7	5	3	3	2	2	**4**
Leakage from Diversion Ditches	26	22	18	15	50	100	81	58	40	30	27	28	**41**
Precipitation on TSF Impoundment	334	229	177	138	223	308	288	279	288	328	334	351	**273**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2771	2662	2606	2563	2686	2825	2785	2750	2740	2770	2773	2790	**2,727**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	296	296	296	296	296	296	296	296	296	296	296	296	**296**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	482	462	444	429	607	864	768	646	554	506	491	496	**562**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	461	586	584	468	216	0	0	0	**193**
Seepage	48	48	48	48	48	48	48	48	48	48	48	48	**48**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	140	140	140	140	140	140	140	140	140	140	140	140	140
Subtotal	3071	3071	3019	3019	3530	3655	3653	3537	3284	3019	3071	3071	**3,250**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**181**	**52**	**31**	**(27)**	**(236)**	**34**	**(99)**	**(141)**	**10**	**257**	**192**	**215**	**39**
Net Water Surplus (Deficit) (m^3)	**132076**	**37885**	**22754**	**(19490)**	**(172614)**	**24731**	**(72379)**	**(103182)**	**7103**	**187890**	**140104**	**156967**	**341,846**
Pond Size (m^3)	**739658**	**777543**	**800297**	**780807**	**608194**	**632925**	**560546**	**457364**	**464467**	**652357**	**792461**	**949428**	

Year 15
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	-
Leakage from Diversion Ditches	26	22	18	15	50	100	81	58	40	30	27	28	**41**
Precipitation on TSF Impoundment	343	235	182	141	229	316	296	286	296	336	343	360	**280**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2777	2666	2609	2565	2687	2825	2786	2752	2744	2775	2779	2797	**2,730**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	314	314	314	314	314	314	314	314	314	314	314	314	**314**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	500	480	462	447	625	882	786	664	572	524	509	514	**580**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	473	601	599	480	221	0	0	0	**198**
Seepage	51	51	51	51	51	51	51	51	51	51	51	51	**51**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	165	165	165	165	165	165	165	165	165	165	165	165	165
Subtotal	3099	3099	3047	3047	3570	3698	3696	3577	3318	3047	3099	3099	**3,283**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**177**	**46**	**24**	**(34)**	**(257)**	**8**	**(124)**	**(161)**	**(2)**	**253**	**188**	**212**	**28**
Net Water Surplus (Deficit) (m^3)	**129526**	**33612**	**17709**	**(25086)**	**(187397)**	**6117**	**(90169)**	**(117514)**	**(1209)**	**184917**	**137444**	**154547**	**242,497**
Pond Size (m^3)	**1078954**	**1112566**	**1130275**	**1105189**	**917791**	**923908**	**833739**	**716225**	**715016**	**899933**	**1037378**	**1191925**	

Year 16
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	11	9	8	7	22	43	35	25	17	13	12	12	**18**
Leakage from Diversion Ditches	23	19	16	14	45	89	73	51	35	27	24	25	**37**
Precipitation on TSF Impoundment	354	243	187	146	236	326	305	295	305	347	354	371	**289**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2796	2680	2620	2575	2711	2867	2822	2780	2766	2796	2799	2818	**2,752**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	332	332	332	332	332	332	332	332	332	332	332	332	**332**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	518	498	480	465	643	900	804	682	590	542	527	532	**598**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	488	621	618	495	228	0	0	0	**204**
Seepage	53	53	53	53	53	53	53	53	53	53	53	53	**53**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	160	160	160	160	160	160	160	160	160	160	160	160	160
Subtotal	3097	3097	3044	3044	3583	3715	3713	3590	3323	3044	3097	3097	**3,287**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**217**	**81**	**56**	**(5)**	**(228)**	**52**	**(87)**	**(128)**	**34**	**294**	**228**	**252**	**64**
Net Water Surplus (Deficit) (m^3)	**158214**	**58885**	**40930**	**(3505)**	**(166570)**	**37764**	**(63324)**	**(93766)**	**24565**	**214592**	**166549**	**184297**	**558,632**
Pond Size (m^3)	**1350139**	**1409024**	**1449954**	**1446449**	**1279879**	**1317643**	**1254318**	**1160552**	**1185118**	**1399710**	**1566260**	**1750557**	

Year 17
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	8	7	6	5	16	32	26	19	13	10	9	9	**13**
Leakage from Diversion Ditches	23	19	16	14	45	89	73	51	35	27	24	25	**37**
Precipitation on TSF Impoundment	365	250	193	150	243	336	315	304	315	358	365	383	**298**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2805	2685	2624	2578	2713	2866	2822	2783	2772	2803	2807	2826	**2,757**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	350	350	350	350	350	350	350	350	350	350	350	350	**350**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	536	516	498	483	661	918	822	700	608	560	545	550	**616**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	503	640	637	511	235	0	0	0	**210**
Seepage	56	56	56	56	56	56	56	56	56	56	56	56	**56**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	160	160	160	160	160	160	160	160	160	160	160	160	160
Subtotal	3100	3100	3047	3047	3600	3737	3734	3608	3332	3047	3100	3100	**3,296**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**240**	**101**	**75**	**13**	**(226)**	**47**	**(90)**	**(126)**	**47**	**316**	**251**	**276**	**77**
Net Water Surplus (Deficit) (m^3)	**175188**	**73666**	**54730**	**9592**	**(165166)**	**34292**	**(65746)**	**(91787)**	**34206**	**231029**	**183384**	**201438**	**674,828**
Pond Size (m^3)	**1925745**	**1999411**	**2054141**	**2063733**	**1898568**	**1932860**	**1867114**	**1775327**	**1809533**	**2040562**	**2223947**	**2425384**	

Year 18
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	6	5	4	3	11	22	18	12	9	7	6	6	**9**
Leakage from Diversion Ditches	23	19	16	14	45	89	73	51	35	27	24	25	**37**
Precipitation on TSF Impoundment	376	258	199	155	250	346	324	313	324	368	376	394	**307**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2813	2691	2628	2580	2715	2866	2823	2786	2777	2811	2815	2834	**2,761**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Precipitation Over Open Pit	42.61	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	368	368	368	368	368	368	368	368	368	368	368	368	**368**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	554	534	516	501	679	936	840	718	626	578	563	568	**634**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	518	659	656	526	242	0	0	0	**217**
Seepage	59	59	59	59	59	59	59	59	59	59	59	59	**59**
Whole Tailing voids	475	475	71	71	71	71	71	71	71	71	475	475	**206**
Cyclone Overflow Voids	0	0	306	306	306	306	306	306	306	306	0	0	**204**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405
Water Treatment Discharge	160	160	160	160	160	160	160	160	160	160	160	160	160
Subtotal	3103	3103	3050	3050	3618	3759	3756	3626	3342	3050	3103	3103	**3,305**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**263**	**121**	**94**	**31**	**(224)**	**42**	**(93)**	**(123)**	**60**	**339**	**274**	**299**	**90**
Net Water Surplus (Deficit) (m^3)	**192162**	**88448**	**68530**	**22689**	**(163762)**	**30821**	**(68168)**	**(89807)**	**43847**	**247466**	**200219**	**218578**	**791,023**
Pond Size (m^3)	**2617546**	**2705994**	**2774524**	**2797213**	**2633452**	**2664272**	**2596105**	**2506298**	**2550145**	**2797610**	**2997830**	**3,216,408**	

Year 19
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	No	No	No	No	No	No	No	No	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	3	2	2	2	5	11	9	6	4	3	3	3	**4**
Leakage from Diversion Ditches	23	19	16	14	45	89	73	51	35	27	24	25	**37**
Precipitation on TSF Impoundment	386	265	205	159	258	356	333	322	333	379	386	405	**316**
Cleaner Tailings Water (direct discharge)	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2451	2325	2261	2213	2346	2495	2453	2418	2412	2448	2452	2472	**2,396**
Plant Area													
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Leakage from Diversion Ditches	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Precipitation Over Open Pit	0.00	0	0	0	0	0	0	0	0	0	0	0	**0**
Open Pit Groundwater Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	54	54	54	54	54	54	54	54	54	54	54	54	**54**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	533	678	675	541	249	0	0	0	**223**
Seepage	65	65	65	65	65	65	65	65	65	65	65	65	**65**
Rougher (Whole) Tailing voids	433	433	433	433	433	433	433	433	433	433	433	433	**433**
Cyclone Overflow Voids	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Cycloned Sand Voids	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	1834	1834	1834	1834	1834	1834	1834	1834	1834	1834	1834	1834	1834
Water Treatment Discharge	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	2337	2337	2337	2337	2920	3065	3062	2928	2636	2337	2337	2337	**2,580**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**168**	**43**	**(21)**	**(70)**	**(520)**	**(516)**	**(555)**	**(456)**	**(170)**	**165**	**170**	**190**	**(131)**
Net Water Surplus (Deficit) (m^3)	**122639**	**31293**	**(15446)**	**(50814)**	**(379296)**	**(376585)**	**(404808)**	**(332702)**	**(124254)**	**120647**	**123930**	**138548**	**- 1,146,849**
Pond Size (m^3)	**3339046**	**3370339**	**3354894**	**3304080**	**2924783**	**2548198**	**2143390**	**1810689**	**1686434**	**1807081**	**1931011**	**2,069,558**	

Year 20
Expected Condition

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	No	No	No	No	No	No	No	No	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Leakage from Diversion Ditches	23	19	16	14	45	89	73	51	35	27	24	25	**37**
Precipitation on TSF Impoundment	397	273	210	164	265	366	343	331	343	390	397	417	**325**
Cleaner Tailings Water (direct discharge)	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2459	2331	2265	2216	2348	2494	2454	2421	2417	2455	2460	2481	**2,400**
Plant Area													
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Leakage from Diversion Ditches	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Precipitation Over Open Pit	0.00	0	0	0	0	0	0	0	0	0	0	0	**0**
Open Pit Groundwater Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Fresh Water Make-up	15	15	15	15	15	15	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	54	54	54	54	54	54	54	54	54	54	54	54	**54**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	548	697	694	557	256	0	0	0	**229**
Seepage	65	65	65	65	65	65	65	65	65	65	65	65	**65**
Rougher (Whole) Tailing voids	433	433	433	433	433	433	433	433	433	433	433	433	**433**
Cyclone Overflow Voids	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Cycloned Sand Voids	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Reclaim Water	1834	1834	1834	1834	1834	1834	1834	1834	1834	1834	1834	1834	1834
Water Treatment Discharge	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	2337	2337	2337	2337	2935	3084	3081	2943	2643	2337	2337	2337	**2,587**
Plant Transport Water Shortage (m^3/hr)													**Net**
Net Water Surplus (Deficit) (m^3/hr)	**176**	**48**	**(17)**	**(67)**	**(533)**	**(536)**	**(573)**	**(468)**	**(172)**	**173**	**178**	**198**	**(133)**
Net Water Surplus (Deficit) (m^3)	**128586**	**35047**	**(12673)**	**(48743)**	**(388919)**	**(391083)**	**(418257)**	**(341749)**	**(125640)**	**126056**	**129738**	**144661**	**- 1,162,976**
Pond Size (m^3)	**2198144**	**2233192**	**2220519**	**2171775**	**1782856**	**1391773**	**973516**	**631767**	**506127**	**632183**	**761921**	**906583**	

Year 21
Expected Condition

Month	Jan.	Feb	March	April	May	June	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	
Cyclone Sand Operating?	No	No	No	No	No	No	
INFLOWS (m^3/hr)							
TSF Area							**Averages**
Runoff from undiverted catchment	0	0	0	0	0	0	-
Leakage from Diversion Ditches	23	19	16	14	45	89	**34**
Precipitation on TSF Impoundment	397	273	210	164	265	366	**279**
Cleaner Tailings Water (direct discharge)	0	0	0	0	0	0	-
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4
Subtotal	2459	2331	2265	2216	2348	2494	**2,352**
Plant Area							
Runoff from undiverted catchment	0	0	0	0	0	0	**0**
Leakage from Diversion Ditches	0	0	0	0	0	0	**0**
Precipitation Over Open Pit	0.00	0	0	0	0	0	**0**
Open Pit Groundwater Dewatering	0	0	0	0	0	0	**0**
Fresh Water Make-up	15	15	15	15	15	15	**15**
Ore Void Water (3% MC)	39	39	39	39	39	39	**39**
Subtotal	54	54	54	54	54	54	**54**
OUTFLOWS (m^3/hr)							
TSF Area Pond Evaporation	0	0	0	0	548	697	**208**
Seepage	65	65	65	65	65	65	**65**
Rougher (Whole) Tailing voids	433	433	433	433	433	433	**433**
Cyclone Overflow Voids	0	0	0	0	0	0	-
Cycloned Sand Voids	0	0	0	0	0	0	-
Plant Area Dust Suppression	0	0	0	0	50	50	**17**
Concentrate Load Out	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	**3**
Reclaim Water	1834	1834	1834	1834	1834	1834	**1,834**
Water Treatment Discharge	0	0	0	0	0	0	0
Subtotal	2337	2337	2337	2337	2935	3084	**2,561**
Plant Transport Water Shortage (m^3/hr)							**Net**
Net Water Surplus (Deficit) (m^3/hr)	**176**	**48**	**(17)**	**(67)**	**(533)**	**(536)**	**(155)**
Net Water Surplus (Deficit) (m^3)	**128586**	**35047**	**(12673)**	**(48743)**	**(388919)**	**(391083)**	**- 677,785**
Pond Size (m^3)	**1035168**	**1070216**	**1057543**	**1008800**	**619881**	**228,797**	

Summary - Upper Bound Condition Managed

*	Annual Precipitation (mm)	550
	Annual Evaporation (mm)	389
	Undisturbed (Diverted) Land Runoff Coefficient	0.5
	TSF	
	Tailings pond area (sq. km)	varies
	Undiverted Catchment runoff area (sq.km.)	varies
	Diverted uphill catchment area (sq.km.)	varies
	% Diversion ditch seepage	20%
	Ultimate Tailings pond area (sq. km)	5.1

Process Plant	
Waste Dump/Plant Site Runoff Coefficient	0.7
Open Pit Runoff Coefficient	1.0
Processes %Availability	92.0%
Undiverted WRD/Plant Site Catchment Area (sq.km)	varies
Diverted WRD/Plant Site Catchment Area (sq.km)	varies
% Diversion ditch seepage	20%
Open Pit Area (sq.km)	1.1

Tailings		tpd	% Solids	
Total Daily Tonnage		29,621	Transport	InSitu
91%	Rougher	27,003	35.61%	73.7%
9%	Cleaner	2,619	22.76%	73.7%
Cyclone Efficiency		85%		
24%	Cyclone U/F	7,157		85.0%
76%	Cyclone O/F	22,465		73.7%

* 10-yr wet year

	Parameter	unit		Construction	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 20.5
DATA	Annual precipitation	mm	550											733											
	Annual evaporation	mm	389																						
TSF Area	Diverted catchment area (external to TSF)	km^2		4.07	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80
	Diverted Within TSF	km^2			2.10	2.10	2.10	2.10	2.10	1.25	1.25	1.25	1.25	1.25	0.70	0.70	0.70	0.70	0.70	0.00	0.00	0.00	0.00	0.00	0.00
	Diverted runoff coefficient	%	0.5																						
	Diversion ditch efficiency	%	80%		Yr 5 footprint Diversion					Yr 10 footprint diversion					Yr 15 footprint diversion					UTSF diversion					
	Undiverted catchment area (not including TSF)	km^2		6.47	1.80	1.08	0.72	0.36	0.00	0.68	0.51	0.34	0.17	0.00	0.44	0.33	0.22	0.11	0.00	0.56	0.42	0.28	0.14	0.00	0.00
	Undiverted runoff coefficient	%	0.5																						
	TSF impoundment area	km^2		1.20	1.20	1.92	2.28	2.64	3.00	3.17	3.34	3.51	3.68	3.85	3.96	4.07	4.18	4.29	4.40	4.54	4.68	4.82	4.96	5.10	5.10
	TSF impoundment runoff coefficient	%	1.0																						
			Transport																						
Mine Area	Rougher Tailings Density	% solids	35.61%	73.7%																					
	Cleaner Tailings Density	% solids	22.76%	73.7%																					
	Cyclone Underflow	% solids	-	85.0%																					
	Cyclone Overflow	% solids	-	73.7%																					
	Diverted LGO/WRD/Plantsite area	km^2		0.62	1.7	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	0.00	0.00	0.00
	Diverted runoff coefficient	%	0.5																						
	Diversion ditch efficiency	%	80%																						
	Undiverted LGO/WRD/Plantsite area	km^2		2.52	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	0.00	0.00	0.00
	LGO/WRD/Plantsite runoff coefficient	%	0.7																						
	Open pit area	km^2	1.1																						
	Open pit runoff coefficient	%	1.0																						
INFLOWS																									
TSF Area	Runoff from undiverted catchment	m^3/hr		206	57	34	23	11	0	22	16	11	5	0	14	11	7	4	0	18	13	9	4	0	0
	Leakage from Diversion Ditches	m^3/hr		0	101	101	101	101	101	90	90	90	90	120	83	83	83	83	83	74	74	74	74	74	69
	Precipitation on TSF Impoundment	m^3/hr		76	76	122	145	168	191	202	213	223	234	327	252	259	266	273	280	289	298	307	316	325	279
	Cleaner Tailings Water (direct discharge)	m^3/hr		0	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	0	0	0
	Rougher Tailings Water (direct discharge)	m^3/hr		0	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034
	Seepage reclaim	m^3/hr		0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	SUBTOTAL - TSF Inflows			282	2643	2666	2677	2689	2700	2722	2727	2733	2738	2855	2758	2761	2765	2768	2772	2789	2794	2798	2432	2437	2386
Mine Area	Runoff from LGO/WRD plantsite area	m^3/hr		0	133	133	133	133	133	133	133	133	133	177	133	133	133	133	133	133	133	133	0	0	0
	Leakage from diversion ditches	m^3/hr		0	23	23	23	23	23	23	23	23	23	30	23	23	23	23	23	23	23	23	0	0	0
	Precipitation/Runoff into open pit	m^3/hr		0	69	69	69	69	69	69	69	69	69	92	69	69	69	69	69	69	69	69	0	0	0
	Open pit dewatering	m^3/hr		0	48	104	160	215	271	299	326	354	381	409	436	464	507	543	578	614	649	685	0	0	0
	Fresh water makeup	m^3/hr		0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Ore rock moisture	m^3/hr		0	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39
	SUBTOTAL - Mine Inflows			**0**	312	368	424	480	535	563	591	618	646	747	701	728	772	807	843	878	914	949	42	42	42
OUTFLOWS																									
	Evaporation from TSF impoundment	m^3/hr		54	54	86	103	119	135	143	150	158	166	173	178	183	188	193	198	204	210	217	223	229	208
	TSF seepage	m^3/hr		5	10	12	14	16	18	21	23	25	27	29	31	33	35	37	39	42	44	46	48	50	50
	Tailings void loss - whole	m^3/hr		0	191	191	191	191	191	191	191	191	191	191	191	191	191	191	191	191	191	191	401	440	440
	-overflow	m^3/hr		0	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	0	0	0
	-underflow (cyclone sand)	m^3/hr		0	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	0	0	0
	Dust Suppression	m^3/hr		21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	17
	Concentrate Load Out	m^3/hr		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Potable Water	m^3/hr		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Pit Dewatering and/or Treatment Discharge	m^3/hr		119	0	0	110	110	330	330	330	330	330	500	500	500	500	500	550	600	640	640	0	0	0
	Reclaim Water	m^3/hr		0	2405	2405	2405	2405	330	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	1744	1744	1744
	SUBTOTAL - Outflows			**202**	2903	2938	3066	3085	3323	3333	3342	3352	3362	3542	3549	3556	3563	3570	3627	3685	3734	3742	2442	2489	2463
NET	**Net Flow**			**80**	52	96	35	84	-87	-48	-25	-1	22	61	-90	-66	-26	6	-12	-18	-26	6	33	-10	-35
	Net Annual Volume	m^3		703,001	454,457	841,449	306,308	734,768	- 763,972	- 418,272	- 214,771	- 11,269	192,232	530,660	- 791,043	- 580,630	- 231,130	48,826	- 109,217	- 153,612	- 227,511	48,990	286,660	- 89,024	- 151,824
CUMULATIVE	**Cumulative Volume**	m^3		703,001	1,157,458	1,998,906	2,305,215	3,039,983	2,276,011	1,857,739	1,642,968	1,631,699	1,823,931	2,354,591	1,563,548	982,917	751,787	800,614	691,396	537,784	310,273	359,263	645,923	556,899	405,075
	Cumulative Volume	Mm^3		0.70	1.16	2.00	2.31	3.04	2.28	1.86	1.64	1.63	1.82	2.35	1.56	0.98	0.75	0.80	0.69	0.54	0.31	0.36	0.65	0.56	0.41
MAXIMUM	**LOM Max Pond Volume**	3.04	Mm^3																						
END	**End of Mine Pond Volume**	0.41	Mm^3																						

Construction

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	No	No	No	No	No	No	No	No	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	128	108	91	76	250	498	405	287	198	152	136	142	**206**
Leakage from Diversion Ditches	0	0	0	0	0	0	0	0	0	0	0	0	-
Precipitation on TSF Impoundment	94	64	50	39	62	86	81	78	81	92	94	98	**76**
Cleaner Tailings Water (direct discharge)	0	0	0	0	0	0	0	0	0	0	0	0	-
Rougher Tailings Water (direct discharge)	0	0	0	0	0	0	0	0	0	0	0	0	-
Seepage reclaim	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	221	172	141	115	312	584	486	365	278	243	230	240	**282**
Plant Area = Process Plant & Site, Open Pit, Waste Dump, Ore Stockpile													
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Leakage from Diversion Ditches	0	0		0	0	0	0	0	0	0	0	0	**0**
Precipitation Over Open Pit	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Open Pit Groundwater Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Fresh Water Make-up	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Ore Void Water (3% MC)	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Subtotal	0	0	0	0	0	0	0	0	0	0	0	0	**0**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	129	164	163	131	60	0	0	0	**54**
Seepage	5	5	5	5	5	5	5	5	5	5	5	5	**5**
Tailing voids	0	0	0	0	0	0	0	0	0	0	0	0	-
Cyclone Overflow Voids	0	0	0	0	0	0	0	0	0	0	0	0	-
Cycloned Sand Voids	0	0	0	0	0	0	0	0	0	0	0	0	-
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	0	0	0	0	0	0	0	0	0	0	0	0	-
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Discharge to Environment	0	0	0	0	0	0	75	365	278	243	230	240	**119**
Reclaim Water	0	0	0	0	0	0	0	0	0	0	0	0	-
Subtotal	8	8	8	8	187	222	296	554	397	251	238	248	**202**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**213**	**164**	**133**	**107**	**125**	**362**	**190**	**(189)**	**(118)**	**(8)**	**(8)**	**(8)**	**80**
Net Water Surplus (Deficit) (m^3)	**155582**	**120048**	**96976**	**78110**	**91217**	**264392**	**138495**	**(137943)**	**(86355)**	**(5840)**	**(5840)**	**(5840)**	**703,001**
Pond Size (m^3)	**155,582**	**275630**	**372606**	**450716**	**541933**	**806325**	**944820**	**806876**	**720521**	**714681**	**708841**	**703001**	

Year 1

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	36	30	25	21	69	139	113	80	55	42	38	39	**57**
Leakage from Diversion Ditches	62	53	45	37	122	243	198	140	96	74	67	69	**101**
Precipitation on TSF Impoundment	94	64	50	39	62	86	81	78	81	92	94	98	**76**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2600	2556	2528	2506	2662	2877	2800	2706	2641	2617	2607	2616	**2,643**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	48	48	48	48	48	48	48	48	48	48	48	48	**48**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	228	207	179	173	361	630	529	401	304	254	238	244	**312**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	129	164	163	131	60	0	0	0	**54**
Seepage	10	10	10	10	10	10	10	10	10	10	10	10	**10**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	2859	2859	2813	2813	2992	3027	3027	2994	2924	2813	2859	2859	**2,903**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**(31)**	**(96)**	**(106)**	**(135)**	**31**	**479**	**303**	**113**	**21**	**58**	**(14)**	**0**	**52**
Net Water Surplus (Deficit) (m^3)	**(22468)**	**(70010)**	**(77231)**	**(98304)**	**22286**	**349665**	**221027**	**82368**	**15505**	**42167**	**(10577)**	**30**	**454,457**
Pond Size (m^3)	**680533**	**610523**	**533292**	**434988**	**457274**	**806938**	**1027965**	**1110333**	**1125838**	**1168005**	**1157428**	**1157458**	**1,157,458**

Year 2

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	21	18	15	13	42	83	68	48	33	25	23	24	**34**
Leakage from Diversion Ditches	62	53	45	37	122	243	198	140	96	74	67	69	**101**
Precipitation on TSF Impoundment	150	103	79	62	100	138	129	125	129	147	150	157	**122**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2642	2582	2548	2520	2672	2873	2803	2721	2667	2655	2648	2659	**2,666**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	104	104	104	104	104	104	104	104	104	104	104	104	**104**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	284	263	235	229	416	686	585	457	360	310	294	299	**368**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	206	262	261	210	96	0	0	0	**86**
Seepage	12	12	12	12	12	12	12	12	12	12	12	12	**12**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	2861	2861	2816	2816	3072	3128	3127	3075	2962	2816	2861	2861	**2,938**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**65**	**(16)**	**(33)**	**(66)**	**16**	**430**	**262**	**103**	**65**	**150**	**80**	**97**	**96**
Net Water Surplus (Deficit) (m^3)	**47277**	**(11541)**	**(23809)**	**(48495)**	**11958**	**314263**	**191023**	**75000**	**47538**	**109150**	**58454**	**70631**	**841,449**
Pond Size (m^3)	**1204735**	**1193194**	**1169385**	**1120890**	**1132848**	**1447111**	**1638134**	**1713134**	**1760672**	**1869822**	**1928275**	**1998906**	**1,998,906**

Year 3

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	14	12	10	9	28	55	45	32	22	17	15	16	**23**
Leakage from Diversion Ditches	62	53	45	37	122	243	198	140	96	74	67	69	**101**
Precipitation on TSF Impoundment	178	122	94	73	118	164	153	148	153	174	178	186	**145**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2663	2596	2558	2528	2677	2871	2805	2729	2680	2674	2668	2680	**2,677**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	160	160	160	160	160	160	160	160	160	160	160	160	**160**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	340	319	291	284	472	741	641	512	416	366	349	355	**424**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	245	312	310	249	115	0	0	0	**103**
Seepage	14	14	14	14	14	14	14	14	14	14	14	14	**14**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	110	110	110	110	110	110	110	110	110	110	110	110	**110**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	2973	2973	2928	2928	3223	3289	3288	3226	3092	2928	2973	2973	**3,066**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**29**	**(59)**	**(79)**	**(115)**	**(74)**	**323**	**158**	**15**	**4**	**112**	**44**	**62**	**35**
Net Water Surplus (Deficit) (m^3)	**21431**	**(43026)**	**(57818)**	**(84310)**	**(53925)**	**235842**	**115302**	**10596**	**2835**	**81921**	**32249**	**45212**	**306,308**
Pond Size (m^3)	**2020337**	**1977311**	**1919493**	**1835182**	**1781258**	**2017100**	**2132401**	**2142997**	**2145832**	**2227753**	**2260003**	**2305215**	

Year 4

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	7	6	5	4	14	28	23	16	11	8	8	8	**11**
Leakage from Diversion Ditches	62	53	45	37	122	243	198	140	96	74	67	69	**101**
Precipitation on TSF Impoundment	206	141	109	85	137	190	177	171	177	202	206	216	**168**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2684	2609	2567	2535	2682	2869	2807	2736	2694	2693	2689	2702	**2,689**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	215	215	215	215	215	215	215	215	215	215	215	215	**215**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	396	375	347	340	528	797	697	568	471	422	405	411	**480**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	284	361	359	288	133	0	0	0	**119**
Seepage	16	16	16	16	16	16	16	16	16	16	16	16	**16**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	110	110	110	110	110	110	110	110	110	110	110	110	**110**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	2975	2975	2930	2930	3264	3341	3339	3268	3112	2930	2975	2975	**3,085**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**104**	**8**	**(16)**	**(55)**	**(54)**	**326**	**164**	**36**	**53**	**185**	**118**	**137**	**84**
Net Water Surplus (Deficit) (m^3)	**75884**	**5789**	**(11527)**	**(39825)**	**(39508)**	**237721**	**119880**	**26492**	**38432**	**134993**	**86345**	**100093**	**734,768**
Pond Size (m^3)	**2381099**	**2386887**	**2375360**	**2335535**	**2296027**	**2533748**	**2653628**	**2680120**	**2718553**	**2853545**	**2939890**	**3039983**	

Year 5

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	-
Leakage from Diversion Ditches	62	53	45	37	122	243	198	140	96	74	67	69	**101**
Precipitation on TSF Impoundment	234	160	124	96	156	215	202	195	202	229	234	245	**191**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2705	2622	2577	2542	2686	2867	2808	2744	2707	2712	2709	2723	**2,700**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	271	271	271	271	271	271	271	271	271	271	271	271	**271**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	451	430	402	396	584	853	752	624	527	477	461	467	**535**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	323	410	408	327	151	0	0	0	**135**
Seepage	18	18	18	18	18	18	18	18	18	18	18	18	**18**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	330	330	330	330	330	330	330	330	330	330	330	330	**330**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3198	3198	3152	3152	3524	3612	3610	3529	3353	3152	3198	3198	**3,323**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**(41)**	**(145)**	**(172)**	**(214)**	**(254)**	**108**	**(50)**	**(162)**	**(119)**	**38**	**(28)**	**(8)**	**(87)**
Net Water Surplus (Deficit) (m^3)	**(30263)**	**(105996)**	**(125837)**	**(155940)**	**(185691)**	**79001**	**(36141)**	**(118212)**	**(86571)**	**27464**	**(20159)**	**(5626)**	**- 763,972**
Pond Size (m^3)	**3009720**	**2903724**	**2777887**	**2621947**	**2436256**	**2515256**	**2479115**	**2360903**	**2274333**	**2301797**	**2281637**	**2276011**	

Year 6

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	13	11	10	8	26	52	43	30	21	16	14	15	**22**
Leakage from Diversion Ditches	56	47	40	33	109	217	177	125	86	66	59	62	**90**
Precipitation on TSF Impoundment	247	170	131	102	165	228	213	206	213	242	247	259	**202**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2725	2637	2589	2552	2708	2906	2841	2770	2729	2733	2730	2745	**2,722**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	299	299	299	299	299	299	299	299	299	299	299	299	**299**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	479	458	430	423	611	880	780	651	555	505	488	494	**563**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	341	433	432	346	159	0	0	0	**143**
Seepage	21	21	21	21	21	21	21	21	21	21	21	21	**21**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	330	330	330	330	330	330	330	330	330	330	330	330	**330**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3200	3200	3154	3154	3545	3637	3636	3550	3363	3154	3200	3200	**3,333**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**4**	**(105)**	**(135)**	**(179)**	**(225)**	**149**	**(14)**	**(129)**	**(80)**	**84**	**18**	**39**	**(48)**
Net Water Surplus (Deficit) (m^3)	**2893**	**(76616)**	**(98623)**	**(130434)**	**(164421)**	**108645**	**(10552)**	**(94107)**	**(58295)**	**61356**	**13334**	**28548**	- **418,272**
Pond Size (m^3)	**2278904**	**2202288**	**2103665**	**1973231**	**1808810**	**1917455**	**1906903**	**1812796**	**1754501**	**1815857**	**1829191**	**1857739**	

Year 7

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	10	9	7	6	20	39	32	23	16	12	11	11	**16**
Leakage from Diversion Ditches	56	47	40	33	109	217	177	125	86	66	59	62	**90**
Precipitation on TSF Impoundment	260	179	138	107	173	240	225	217	225	255	260	273	**213**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2735	2643	2594	2555	2711	2905	2842	2773	2735	2742	2739	2755	**2,727**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	326	326	326	326	326	326	326	326	326	326	326	326	**326**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	506	485	458	451	639	908	808	679	582	533	516	522	**591**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	359	457	455	365	168	0	0	0	**150**
Seepage	23	23	23	23	23	23	23	23	23	23	23	23	**23**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	330	330	330	330	330	330	330	330	330	330	330	330	**330**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3202	3202	3156	3156	3565	3663	3661	3571	3374	3156	3202	3202	**3,342**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**39**	**(73)**	**(105)**	**(150)**	**(216)**	**150**	**(11)**	**(118)**	**(57)**	**119**	**53**	**75**	**(25)**
Net Water Surplus (Deficit) (m^3)	**28704**	**(53467)**	**(76666)**	**(109329)**	**(157515)**	**109630**	**(8292)**	**(86503)**	**(41387)**	**86515**	**38977**	**54562**	**- 214,771**
Pond Size (m^3)	**1886443**	**1832977**	**1756311**	**1646982**	**1489467**	**1599096**	**1590804**	**1504301**	**1462914**	**1549430**	**1588406**	**1642968**	

Year 8

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	7	6	5	4	13	26	21	15	10	8	7	7	**11**
Leakage from Diversion Ditches	56	47	40	33	109	217	177	125	86	66	59	62	**90**
Precipitation on TSF Impoundment	273	188	145	113	182	252	236	228	236	268	273	287	**223**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2745	2649	2598	2559	2713	2904	2843	2777	2741	2751	2749	2765	**2,733**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	354	354	354	354	354	354	354	354	354	354	354	354	**354**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	534	513	485	479	666	935	835	706	610	560	544	549	**618**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	377	480	478	383	176	0	0	0	**158**
Seepage	25	25	25	25	25	25	25	25	25	25	25	25	**25**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	330	330	330	330	330	330	330	330	330	330	330	330	**330**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3204	3204	3158	3158	3586	3688	3686	3591	3385	3158	3204	3204	**3,352**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**75**	**(42)**	**(75)**	**(121)**	**(206)**	**152**	**(8)**	**(108)**	**(34)**	**153**	**89**	**110**	**(1)**
Net Water Surplus (Deficit) (m^3)	**54516**	**(30318)**	**(54708)**	**(88225)**	**(150610)**	**110615**	**(6032)**	**(78898)**	**(24480)**	**111674**	**64620**	**80575**	- **11,269**
Pond Size (m^3)	**1697484**	**1667167**	**1612459**	**1524234**	**1373624**	**1484239**	**1478207**	**1399309**	**1374829**	**1486503**	**1551123**	**1631699**	

Year 9

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	3	3	2	2	7	13	11	8	5	4	4	4	**5**
Leakage from Diversion Ditches	56	47	40	33	109	217	177	125	86	66	59	62	**90**
Precipitation on TSF Impoundment	287	197	152	118	191	264	247	239	247	281	287	301	**234**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2754	2656	2603	2562	2715	2903	2843	2780	2747	2760	2759	2775	**2,738**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	381	381	381	381	381	381	381	381	381	381	381	381	**381**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	562	541	513	506	694	963	863	734	637	588	571	577	**646**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	396	503	501	402	185	0	0	0	**166**
Seepage	27	27	27	27	27	27	27	27	27	27	27	27	**27**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	330	330	330	330	330	330	330	330	330	330	330	330	**330**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3206	3206	3160	3160	3606	3713	3711	3612	3395	3160	3206	3206	**3,362**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**110**	**(10)**	**(45)**	**(92)**	**(197)**	**153**	**(5)**	**(98)**	**(10)**	**187**	**124**	**146**	**22**
Net Water Surplus (Deficit) (m^3)	**80328**	**(7168)**	**(32751)**	**(67120)**	**(143704)**	**111600**	**(3772)**	**(71294)**	**(7572)**	**136834**	**90263**	**106589**	**192,232**
Pond Size (m^3)	**1712027**	**1704859**	**1672108**	**1604987**	**1461283**	**1572884**	**1569111**	**1497817**	**1490245**	**1627079**	**1717342**	**1823931**	

Year 10

10-year wet year applied this year.

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	74.8	51.3	39.6	30.8	49.8	68.9	64.5	62.3	64.5	73.3	74.8	78.4	**733**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	-
Leakage from Diversion Ditches	74	63	53	44	145	289	236	167	115	88	79	82	**120**
Precipitation on TSF Impoundment	400	274	212	165	267	368	345	333	345	392	400	419	**327**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2883	2746	2673	2618	2820	3066	2989	2908	2868	2889	2888	2910	**2,855**
Plant Area													
Runoff from undiverted catchment	110	93	78	66	215	428	348	246	170	130	117	122	**177**
Leakage from Diversion Ditches	18	15		11	35	70	57	40	28	21	19	20	**30**
Precipitation Over Open Pit	57	48	41	34	111	222	180	128	88	68	61	63	**92**
Open Pit Groundwater Dewatering	409	409	409	409	409	409	409	409	409	409	409	409	**409**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	635	607	570	561	811	1170	1036	865	736	670	648	656	**747**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	414	526	524	420	193	0	0	0	**173**
Seepage	29	29	29	29	29	29	29	29	29	29	29	29	**29**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	500	500	500	500	500	500	500	500	500	500	500	500	**500**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3378	3378	3332	3332	3796	3909	3907	3803	3576	3332	3378	3378	**3,542**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**140**	**(25)**	**(89)**	**(153)**	**(165)**	**328**	**119**	**(29)**	**29**	**226**	**158**	**188**	**61**
Net Water Surplus (Deficit) (m^3)	**102009**	**(18148)**	**(64936)**	**(111877)**	**(120180)**	**239462**	**86896**	**(21231)**	**21021**	**165342**	**115025**	**137278**	**530,660**
Pond Size (m^3)	**1925940**	**1907792**	**1842857**	**1730979**	**1610799**	**1850261**	**1937157**	**1915926**	**1936947**	**2102289**	**2217313**	**2354591**	

Year 11

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	9	7	6	5	17	34	28	20	13	10	9	10	**14**
Leakage from Diversion Ditches	51	44	37	31	100	200	163	115	79	61	55	57	**83**
Precipitation on TSF Impoundment	309	212	163	127	206	284	266	257	266	303	309	324	**252**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2777	2671	2615	2572	2732	2927	2865	2801	2768	2783	2781	2799	**2,758**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	436	436	436	436	436	436	436	436	436	436	436	436	**436**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	617	596	568	561	749	1018	918	789	693	643	626	632	**701**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	426	541	539	432	199	0	0	0	**178**
Seepage	31	31	31	31	31	31	31	31	31	31	31	31	**31**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	500	500	500	500	500	500	500	500	500	500	500	500	**500**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3380	3380	3335	3335	3810	3926	3924	3817	3583	3335	3380	3380	**3,549**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**14**	**(113)**	**(152)**	**(201)**	**(330)**	**19**	**(140)**	**(227)**	**(123)**	**91**	**27**	**51**	**(90)**
Net Water Surplus (Deficit) (m^3)	**10055**	**(82547)**	**(110723)**	**(147050)**	**(240574)**	**14228**	**(102493)**	**(165631)**	**(89907)**	**66384**	**20039**	**37177**	- **791,043**
Pond Size (m^3)	**2364646**	**2282099**	**2171375**	**2024325**	**1783751**	**1797979**	**1695486**	**1529854**	**1439947**	**1506332**	**1526371**	**1563548**	

Year 12

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	7	6	5	4	13	25	21	15	10	8	7	7	**11**
Leakage from Diversion Ditches	51	44	37	31	100	200	163	115	79	61	55	57	**83**
Precipitation on TSF Impoundment	317	218	168	131	211	292	274	264	274	311	317	333	**259**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2784	2675	2618	2574	2733	2927	2866	2803	2772	2788	2788	2806	**2,761**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	464	464	464	464	464	464	464	464	464	464	464	464	**464**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	644	623	595	589	777	1046	945	817	720	670	654	660	**728**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	438	556	554	444	205	0	0	0	**183**
Seepage	33	33	33	33	33	33	33	33	33	33	33	33	**33**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	500	500	500	500	500	500	500	500	500	500	500	500	**500**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3382	3382	3337	3337	3824	3943	3941	3831	3591	3337	3382	3382	**3,556**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**46**	**(84)**	**(123)**	**(174)**	**(314)**	**29**	**(129)**	**(211)**	**(99)**	**122**	**59**	**83**	**(66)**
Net Water Surplus (Deficit) (m^3)	**33318**	**(61007)**	**(89954)**	**(126833)**	**(229544)**	**21427**	**(94470)**	**(154150)**	**(72406)**	**89225**	**43193**	**60570**	**- 580,630**
Pond Size (m^3)	**1596866**	**1535859**	**1445904**	**1319071**	**1089527**	**1110954**	**1016484**	**862334**	**789929**	**879154**	**922347**	**982917**	

Year 13

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	4	4	3	3	8	17	14	10	7	5	5	5	**7**
Leakage from Diversion Ditches	51	44	37	31	100	200	163	115	79	61	55	57	**83**
Precipitation on TSF Impoundment	326	224	172	134	217	300	281	271	281	319	326	342	**266**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2790	2679	2621	2576	2735	2926	2866	2805	2776	2794	2794	2812	**2,765**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	507	507	507	507	507	507	507	507	507	507	507	507	**507**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	688	667	639	632	820	1089	989	860	764	714	697	703	**772**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	449	571	569	456	210	0	0	0	**188**
Seepage	35	35	35	35	35	35	35	35	35	35	35	35	**35**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	500	500	500	500	500	500	500	500	500	500	500	500	**500**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3384	3384	3339	3339	3838	3960	3958	3845	3599	3339	3384	3384	**3,563**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**93**	**(38)**	**(79)**	**(130)**	**(283)**	**55**	**(103)**	**(180)**	**(59)**	**169**	**107**	**131**	**(26)**
Net Water Surplus (Deficit) (m^3)	**68171**	**(27876)**	**(57595)**	**(95025)**	**(206924)**	**40216**	**(74856)**	**(131077)**	**(43314)**	**123657**	**77937**	**95555**	**- 231,130**
Pond Size (m^3)	**1051089**	**1023213**	**965618**	**870593**	**663669**	**703885**	**629029**	**497952**	**454638**	**578295**	**656232**	**751787**	

Year 14

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	2	2	2	1	4	8	7	5	3	3	2	2	**4**
Leakage from Diversion Ditches	51	44	37	31	100	200	163	115	79	61	55	57	**83**
Precipitation on TSF Impoundment	334	229	177	138	223	308	288	279	288	328	334	351	**273**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2796	2683	2624	2578	2736	2925	2867	2807	2780	2800	2800	2819	**2,768**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	543	543	543	543	543	543	543	543	543	543	543	543	**543**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	723	702	674	668	856	1125	1024	896	799	749	733	739	**807**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	461	586	584	468	216	0	0	0	**193**
Seepage	37	37	37	37	37	37	37	37	37	37	37	37	**37**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	500	500	500	500	500	500	500	500	500	500	500	500	**500**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3387	3387	3341	3341	3852	3977	3975	3859	3606	3341	3387	3387	**3,570**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**133**	**(1)**	**(43)**	**(95)**	**(260)**	**73**	**(84)**	**(156)**	**(27)**	**209**	**146**	**171**	**6**
Net Water Surplus (Deficit) (m^3)	**97230**	**(541)**	**(31031)**	**(69013)**	**(190099)**	**53210**	**(61037)**	**(113800)**	**(20017)**	**152293**	**106886**	**124744**	**48,826**
Pond Size (m^3)	**849017**	**848477**	**817446**	**748433**	**558334**	**611545**	**550508**	**436707**	**416691**	**568983**	**675870**	**800614**	

Year 15

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	-
Leakage from Diversion Ditches	51	44	37	31	100	200	163	115	79	61	55	57	**83**
Precipitation on TSF Impoundment	343	235	182	141	229	316	296	286	296	336	343	360	**280**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2803	2688	2627	2581	2738	2925	2867	2810	2784	2806	2806	2825	**2,772**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	578	578	578	578	578	578	578	578	578	578	578	578	**578**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	759	738	710	703	891	1160	1060	931	835	785	768	774	**843**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	473	601	599	480	221	0	0	0	**198**
Seepage	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	550	550	550	550	550	550	550	550	550	550	550	550	**550**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3439	3439	3393	3393	3916	4044	4042	3923	3664	3393	3439	3439	**3,627**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**123**	**(13)**	**(56)**	**(109)**	**(287)**	**41**	**(115)**	**(182)**	**(46)**	**198**	**136**	**161**	**(12)**
Net Water Surplus (Deficit) (m^3)	**89788**	**(9705)**	**(40966)**	**(79500)**	**(209774)**	**29704**	**(83718)**	**(133023)**	**(33220)**	**144429**	**99335**	**117433**	**- 109,217**
Pond Size (m^3)	**890402**	**880697**	**839730**	**760230**	**550456**	**580161**	**496443**	**363419**	**330199**	**474628**	**573963**	**691396**	

Year 16

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	11	9	8	7	22	43	35	25	17	13	12	12	**18**
Leakage from Diversion Ditches	46	39	33	27	90	179	145	103	71	54	49	51	**74**
Precipitation on TSF Impoundment	354	243	187	146	236	326	305	295	305	347	354	371	**289**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2819	2700	2637	2588	2756	2956	2894	2831	2802	2823	2823	2843	**2,789**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	614	614	614	614	614	614	614	614	614	614	614	614	**614**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	794	773	745	739	927	1196	1095	967	870	820	804	810	**878**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	488	621	618	495	228	0	0	0	**204**
Seepage	42	42	42	42	42	42	42	42	42	42	42	42	**42**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	600	600	600	600	600	600	600	600	600	600	600	600	**600**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3491	3491	3445	3445	3983	4116	4113	3991	3723	3445	3491	3491	**3,685**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**123**	**(18)**	**(63)**	**(118)**	**(301)**	**37**	**(123)**	**(193)**	**(51)**	**199**	**136**	**162**	**(18)**
Net Water Surplus (Deficit) (m^3)	**89669**	**(12934)**	**(45979)**	**(85919)**	**(219681)**	**26693**	**(90069)**	**(140597)**	**(37358)**	**144916**	**99494**	**118152**	**- 153,612**
Pond Size (m^3)	**781065**	**768132**	**722152**	**636233**	**416552**	**443245**	**353177**	**212580**	**175222**	**320138**	**419632**	**537784**	

Year 17

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	8	7	6	5	16	32	26	19	13	10	9	9	**13**
Leakage from Diversion Ditches	46	39	33	27	90	179	145	103	71	54	49	51	**74**
Precipitation on TSF Impoundment	365	250	193	150	243	336	315	304	315	358	365	383	**298**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2827	2705	2640	2591	2758	2956	2895	2834	2807	2831	2831	2851	**2,794**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	649	649	649	649	649	649	649	649	649	649	649	649	**649**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	830	809	781	774	962	1231	1131	1002	906	856	839	845	**914**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	503	640	637	511	235	0	0	0	**210**
Seepage	44	44	44	44	44	44	44	44	44	44	44	44	**44**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	640	640	640	640	640	640	640	640	640	640	640	640	**640**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3533	3533	3487	3487	4040	4177	4174	4048	3772	3487	3533	3533	**3,734**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**124**	**(19)**	**(66)**	**(121)**	**(321)**	**10**	**(148)**	**(212)**	**(60)**	**199**	**138**	**164**	**(26)**
Net Water Surplus (Deficit) (m^3)	**90801**	**(13994)**	**(48021)**	**(88663)**	**(234118)**	**7380**	**(108332)**	**(154458)**	**(43558)**	**145511**	**100488**	**119451**	**- 227,511**
Pond Size (m^3)	**628586**	**614592**	**566571**	**477908**	**243790**	**251171**	**142839**	**(11619)**	**(55177)**	**90334**	**190822**	**310273**	

Year 18

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	6	5	4	3	11	22	18	12	9	7	6	6	**9**
Leakage from Diversion Ditches	46	39	33	27	90	179	145	103	71	54	49	51	**74**
Precipitation on TSF Impoundment	376	258	199	155	250	346	324	313	324	368	376	394	**307**
Cleaner Tailings Water (direct discharge)	370	370	370	370	370	370	370	370	370	370	370	370	**370**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2836	2710	2644	2594	2759	2955	2896	2837	2812	2838	2839	2860	**2,798**
Plant Area													
Runoff from undiverted catchment	82	70	59	49	161	321	261	185	127	98	88	91	**133**
Leakage from Diversion Ditches	13	11		8	26	52	43	30	21	16	14	15	**23**
Precipitation Over Open Pit	43	36	30	26	83	166	135	96	66	51	46	47	**69**
Open Pit Groundwater Dewatering	685	685	685	685	685	685	685	685	685	685	685	685	**685**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	865	844	816	810	998	1267	1166	1038	941	891	875	881	**949**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	518	659	656	526	242	0	0	0	**217**
Seepage	46	46	46	46	46	46	46	46	46	46	46	46	**46**
Whole Tailing voids	440	440	66	66	66	66	66	66	66	66	440	440	**191**
Cyclone Overflow Voids	0	0	284	284	284	284	284	284	284	284	0	0	**189**
Cycloned Sand Voids	0	0	45	45	45	45	45	45	45	45	0	0	**30**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	640	640	640	640	640	640	640	640	640	640	640	640	**640**
Reclaim Water	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	2405	**2,405**
Subtotal	3535	3535	3489	3489	4057	4198	4195	4065	3781	3489	3535	3535	**3,742**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**166**	**19**	**(29)**	**(85)**	**(300)**	**24**	**(133)**	**(191)**	**(28)**	**240**	**179**	**205**	**6**
Net Water Surplus (Deficit) (m^3)	**121134**	**14146**	**(20862)**	**(62207)**	**(219355)**	**17268**	**(97395)**	**(139120)**	**(20558)**	**175307**	**130682**	**149950**	**48,990**
Pond Size (m^3)	**431407**	**445554**	**424691**	**362485**	**143130**	**160397**	**63003**	**(76117)**	**(96676)**	**78631**	**209312**	**359263**	

Year 19

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	No	No	No	No	No	No	No	No	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	3	2	2	2	5	11	9	6	4	3	3	3	**4**
Leakage from Diversion Ditches	46	39	33	27	90	179	145	103	71	54	49	51	**74**
Precipitation on TSF Impoundment	386	265	205	159	258	356	333	322	333	379	386	405	**316**
Cleaner Tailings Water (direct discharge)	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2473	2345	2278	2227	2391	2584	2526	2469	2447	2475	2477	2498	**2,432**
Plant Area													
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Leakage from Diversion Ditches	0	0		0	0	0	0	0	0	0	0	0	**0**
Precipitation Over Open Pit	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Open Pit Groundwater Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	42	42	42	42	42	42	42	42	42	42	42	42	**42**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	533	678	675	541	249	0	0	0	**223**
Seepage	48	48	48	48	48	48	48	48	48	48	48	48	**48**
Rougher (Whole) Tailing voids	401	401	401	401	401	401	401	401	401	401	401	401	**401**
Cyclone Overflow Voids	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Cycloned Sand Voids	0	0	0	0	0	0	0	0	0	0	0	0	-
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Reclaim Water	1744	1744	1744	1744	1744	1744	1744	1744	1744	1744	1744	1744	**1,744**
Subtotal	2198	2198	2198	2198	2781	2926	2923	2789	2497	2198	2198	2198	**2,442**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**318**	**189**	**122**	**71**	**(348)**	**(300)**	**(355)**	**(278)**	**(8)**	**319**	**321**	**342**	**33**
Net Water Surplus (Deficit) (m^3)	**231849**	**137972**	**89016**	**51705**	**(254117)**	**(218894)**	**(259238)**	**(202665)**	**(5890)**	**233016**	**234292**	**249614**	**286,660**
Pond Size (m^3)	**591112**	**729083**	**818099**	**869804**	**615688**	**396794**	**137556**	**(65110)**	**(70999)**	**162016**	**396309**	**645923**	

Year 20

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	14.1	13.4	9.4	3.8	-2.9	-8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	9%	9%	9%	10%	10%	11%	**100%**
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	48.4	46.8	48.4	55.0	56.1	58.9	**550**
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	16%	12%	8%	6%	6%	6%	**100%**
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	25%	20%	9%	0%	0%	0%	**100%**
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	98.0	78.6	36.2	0	0	0	**389**
Cyclone Sand Operating?	No	No	No	No	No	No	No	No	No	No	No	No	
INFLOWS (m^3/hr)													
TSF Area													**Averages**
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Leakage from Diversion Ditches	46	39	33	27	90	179	145	103	71	54	49	51	**74**
Precipitation on TSF Impoundment	397	273	210	164	265	366	343	331	343	390	397	417	**325**
Cleaner Tailings Water (direct discharge)	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4	4	4	4	4	4	4
Subtotal	2482	2350	2282	2229	2393	2583	2527	2472	2452	2482	2485	2506	**2,437**
Plant Area													
Runoff from undiverted catchment	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Leakage from Diversion Ditches	0	0		0	0	0	0	0	0	0	0	0	**0**
Precipitation Over Open Pit	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Open Pit Groundwater Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Fresh Water Make-up	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	39	39	39	39	39	39	**39**
Subtotal	42	42	42	42	42	42	42	42	42	42	42	42	**42**
OUTFLOWS (m^3/hr)													
TSF Area Pond Evaporation	0	0	0	0	548	697	694	557	256	0	0	0	**229**
Seepage	50	50	50	50	50	50	50	50	50	50	50	50	**50**
Whole Tailing voids	440	440	440	440	440	440	440	440	440	440	440	440	**440**
Cyclone Overflow Voids	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Cycloned Sand Voids	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Plant Area Dust Suppression	0	0	0	0	50	50	50	50	50	0	0	0	**21**
Concentrate Load Out	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	3	3	3	3	3	3	**3**
Mitigation	0	0	0	0	0	0	0	0	0	0	0	0	**-**
Reclaim Water	1744	1744	1744	1744	1744	1744	1744	1744	1744	1744	1744	1744	**1,744**
Subtotal	2239	2239	2239	2239	2837	2986	2983	2845	2545	2239	2239	2239	**2,489**
													Net
Net Water Surplus (Deficit) (m^3/hr)	**285**	**153**	**85**	**33**	**(402)**	**(361)**	**(415)**	**(331)**	**(51)**	**286**	**288**	**309**	**(10)**
Net Water Surplus (Deficit) (m^3)	**207833**	**111763**	**61826**	**23812**	**(293702)**	**(263356)**	**(302650)**	**(241676)**	**(37239)**	**208462**	**210137**	**225764**	**- 89,024**
Pond Size (m^3)	**853756**	**965519**	**1027345**	**1051157**	**757455**	**494099**	**191449**	**(50227)**	**(87465)**	**120997**	**331135**	**556899**	

Year 21

Upper Bound Condition - Managed

Month	Jan.	Feb	March	April	May	June	Annual
Mean Monthly Temperature	-12.3	-7.1	-3	2.5	7.7	11.8	
Monthly percent of annual precip.	10%	7%	5%	4%	7%	9%	
Average Monthly Precipitation (mm)	56.1	38.5	29.7	23.1	37.4	51.7	
Average monthly runoff (% of annual)	5%	4%	4%	3%	10%	20%	
Monthly percent of annual evap.	0%	0%	0%	0%	20%	25%	
Monthly Pond Evaporation (mm)	0	0	0	0	77.4	98.4	
Cyclone Sand Operating?	No	No	No	No	No	No	
INFLOWS (m^3/hr)							
TSF Area							**Averages**
Runoff from undiverted catchment	0	0	0	0	0	0	**-**
Leakage from Diversion Ditches	46	39	33	27	90	179	**69**
Precipitation on TSF Impoundment	397	273	210	164	265	366	**279**
Cleaner Tailings Water (direct discharge)	0	0	0	0	0	0	**-**
Rougher Tailings Water (direct discharge)	2034	2034	2034	2034	2034	2034	**2,034**
Seepage reclaim	4	4	4	4	4	4	4
Subtotal	2482	2350	2282	2229	2393	2583	**2,386**
Plant Area							
Runoff from undiverted catchment	0	0	0	0	0	0	**0**
Leakage from Diversion Ditches	0	0		0	0	0	**0**
Precipitation Over Open Pit	0	0	0	0	0	0	**0**
Open Pit Groundwater Dewatering	0	0	0	0	0	0	**0**
Fresh Water Make-up	3	3	3	3	3	3	**3**
Ore Void Water (3% MC)	39	39	39	39	39	39	**39**
Subtotal	42	42	42	42	42	42	**42**
OUTFLOWS (m^3/hr)							
TSF Area Pond Evaporation	0	0	0	0	548	697	**208**
Seepage	50	50	50	50	50	50	**50**
Whole Tailing voids	440	440	440	440	440	440	**440**
Cyclone Overflow Voids	0	0	0	0	0	0	**-**
Cycloned Sand Voids	0	0	0	0	0	0	**-**
Plant Area Dust Suppression	0	0	0	0	50	50	**17**
Concentrate Load Out	1	1	1	1	1	1	**1**
Freshwater to Potable Water	3	3	3	3	3	3	**3**
Mitigation	0	0	0	0	0	0	**-**
Reclaim Water	1744	1744	1744	1744	1744	1744	**1,744**
Subtotal	2239	2239	2239	2239	2837	2986	**2,463**
							Net
Net Water Surplus (Deficit) (m^3/hr)	**285**	**153**	**85**	**33**	**(402)**	**(361)**	**(35)**
Net Water Surplus (Deficit) (m^3)	**207833**	**111763**	**61826**	**23812**	**(293702)**	**(263356)**	**- 151,824**
Pond Size (m^3)	**764732**	**876495**	**938321**	**962133**	**668431**	**405075**	

APPENDIX V

Morrison Lake Water Quality Model
Dr. Greg Lawrence

Model of Water Quality in Morrison Lake

by

Gregory A. Lawrence, PhD, PEng

30 January 2012

Model of Water Quality in Morrison Lake

A model has been developed to examine the combined impact of four inflows into Morrison Lake: the natural runoff (RUN); the discharge from wastewater treatment plant through a diffuser located at the deepest point of Morrison Lake (WTP); the subsurface flow of water from the tailings storage facility (TSF); and the flow from potentially acid generating material into the lake (PAG).

Morrison Lake is a dimictic lake, exhibiting four distinct "seasons". The lake is strongly temperature stratified in "summer", followed by "fall turnover" a period of intense mixing induced by wind and penetrative convection. The lake exhibits weak reverse temperature stratification in "winter". During "spring freshet" the lakes turns over again until solar heating establishes summer stratification again. Most of the natural runoff into, and outflow from, the lake is during spring freshet.

This seasonal cycle forms the basis of the model. The adage that: "A model should be as simple as possible, but no simpler, has been followed". The objective of the model is not to make accurate predictions of possible future conditions, but to place bounds on possible future conditions. Conservative assumptions regarding the behavior of the lake will allow such bounds to be calculated. The behavior of the lake is modeled in the following manner.

In winter (November – April) the discharge from the WTP is assumed to have sufficient momentum and buoyancy to overcome the weak reverse stratification in the lake, and to be mixed thoroughly throughout the lake. The near surface additions of TSF and PAG will also be mixed throughout the lake.

During spring freshet (May - June) the lake will continue to turnover, but eventually solar heating leads to a warm, less dense, epilimnion overlying a cooler, denser hypolimnion. During summer (July – October) the discharge from the WTP will continue to mix the hypolimnion, but will not be able to penetrate into the epilimnion. Wind generated currents will disperse the TSF and PAG throughout the epilmnion.

For a given set of inflow conditions the maximum build-up of any substance in the lake will be primarily determined by the amount of that substance that is discharged from the lake. If our model provides a conservatively low estimate of the discharge then the build-up within the lake will be overestimated.

There are two conservative assumptions in the model. The first is that while the WTP, PAG and TSF are assumed to flow into the lake all year round, all natural runoff and outflow is assumed to occur during spring freshet. The result of this assumption is that the flushing of WTP, PAG and TSF that does occur during the rest of the year is ignored. The second assumption is that spring freshet is assumed to mix instantaneously throughout the lake, resulting in an underestimate of the amount of contaminated material flushed from the lake.

The four categories of input to the model: flow rates, limnological volumes, "season" durations, and concentrations. The values adopted for the first three categories are given in Table 1.

Table 1. Basic Inputs to the Morrison Lake Water Quality Model

Annual Flow Rate (Mm^3)		Limnological volumes (Mm^3)			Season duration (months)		
V_{RUN}	145	Lake	V_L	289	Winter	T_W	6
V_{PAG}	0.0035 (0.0009)*	Epilimnion	V_E	159	Freshet	T_F	2
V_{TSF}	1.2 (0.6)*	Hypolimnion	V_H	131	Summer	T_S	4
V_{WTP}	1.5 (1.2)						

* The first values are upper bound flow rates; the second are expected flow rates.

The upper bound estimates of the concentrations of each of the substances of concern in the WTP, PAG and TSF are listed in Table 2 together with the baseline concentrations (present values). The concentrations in the natural runoff are assumed to be equal to these baseline concentrations. The WTP, PAG and TSF concentrations vary with time as shown in Figure 1.

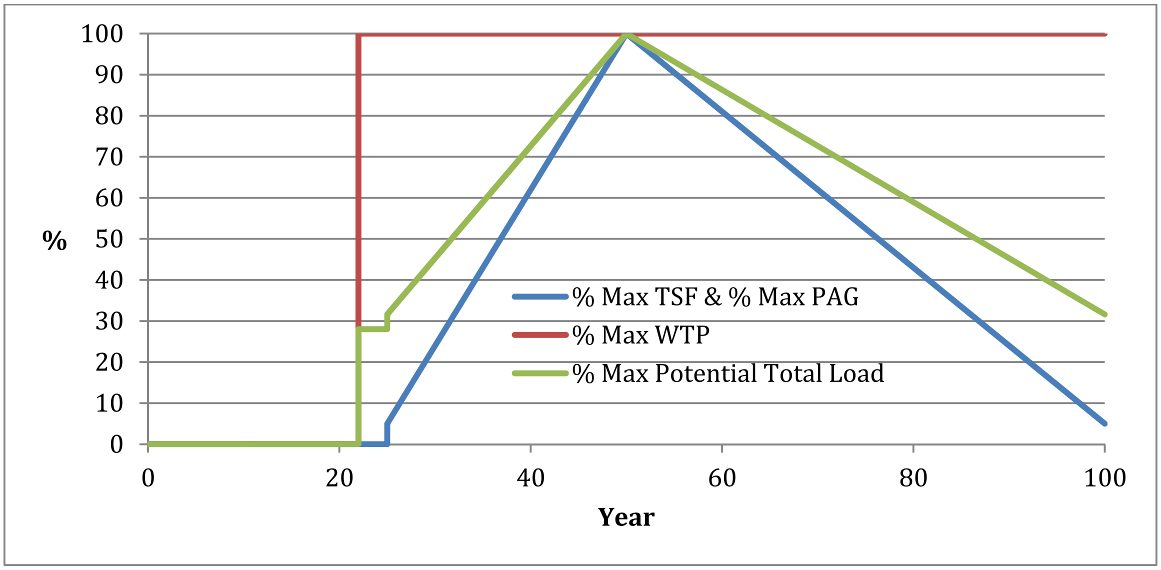
The model predicts the lakewide concentrations at fall turnover, at the end of winter and the end of spring. It also predicts the epilimnetic and hypolimnetc concentrations at the end of summer. Depending on the relative flows rates and concentrations in the WTP, PAG and TSF inflows the maximum concentrations can occur either at the end of winter, or the end of summer. For the values listed in Table 2 the maximum concentrations occur at the end of winter. Concentrations in the immediate vicinity of the diffuser will be greater. Assuming that the diffuser can be engineered to achieve a dilution of greater that 100:1 (not a difficult task) the concentrations at the edge of the mixing zone (location where dilution is 100:1) are listed in Table 2.

Table 2. Concentrations (mg/L) of Key Parameters in Morrison Lake – Upper Bound

Parameter	WTP	PAG	TSF	Baseline	Maximum Background	Maximum Edge of mixing zone	BCWQG	CCME
Flow Rate m^3/hr	172	0.4	137					
Nitrate	90	90	1	0.038	1.19	2.08	13.3	13
Sulphate	2000	4000	1700	2.3	44	64	100	
Aluminum	0.46	0.41	0.39	0.033	0.043	0.047	0.05	0.1
Cadmium	0.0005	0.0042	0.0016	0.000012	0.000034	0.000039	0.000024	
Copper	0.007	0.032	0.06	0.011	0.0116	0.0116	0.036	0.004
Iron	0.02	0.02	0.053	0.17	0.17	0.17	0.15	0.3
Magnesium	210	210	210	1.9	6.6	8.6		
Selenium	0.0019	0.0023	0.019	0.00014	0.00018	0.00020	0.002	0.001
Zinc	0.02	0.064	0.44	0.0016	0.0061	0.0063	0.0075	0.0075

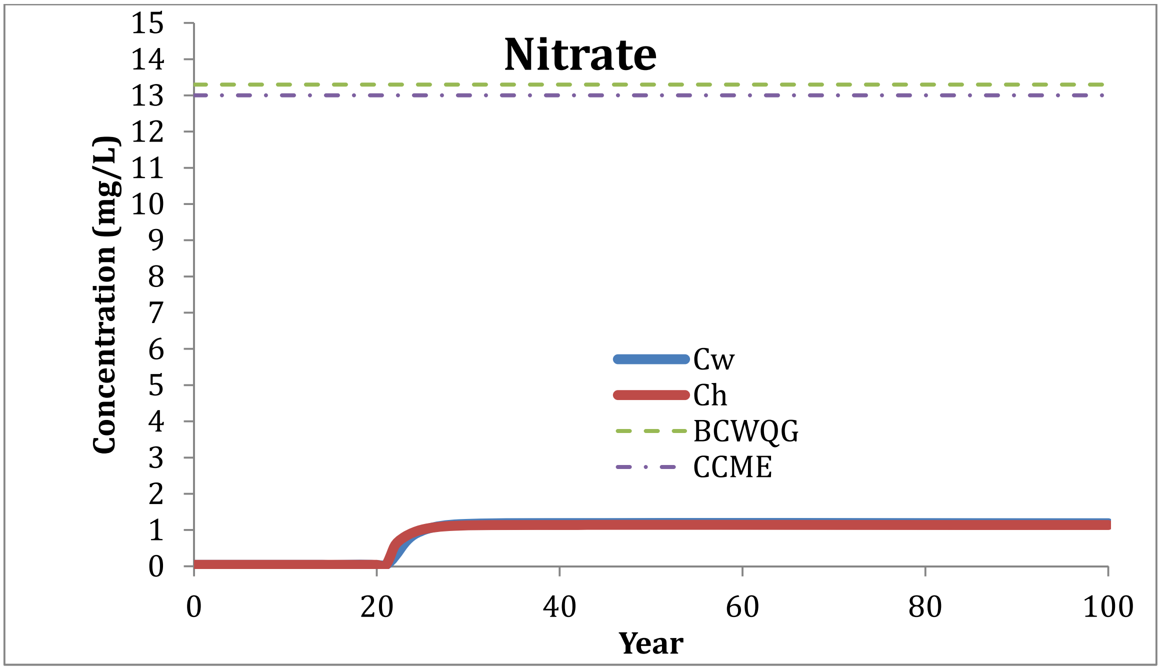
Shaded boxes indicate exceedance of guidelines

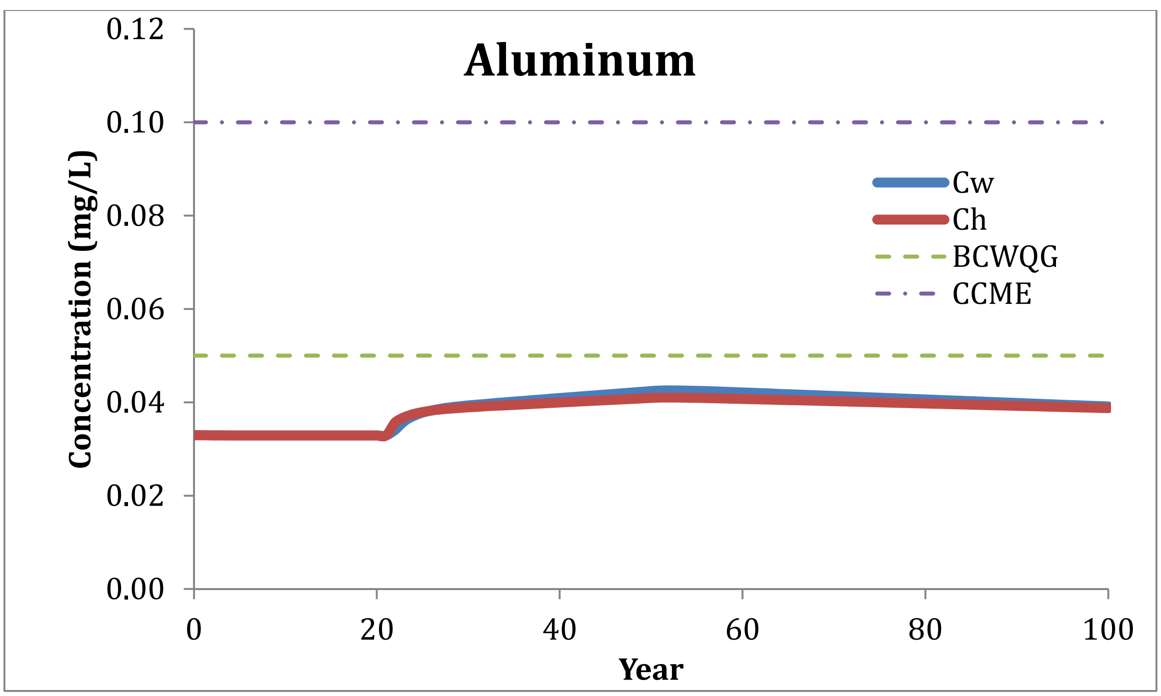
Figure 1. Assumed variation of loadings into Morrison Lake

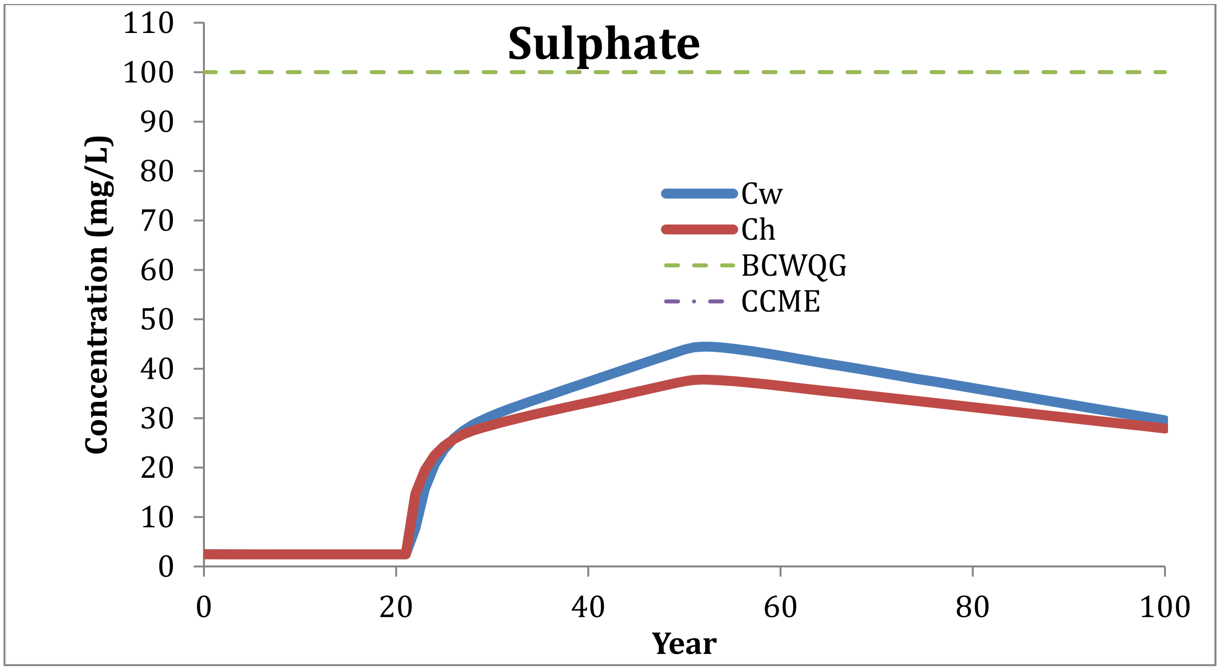


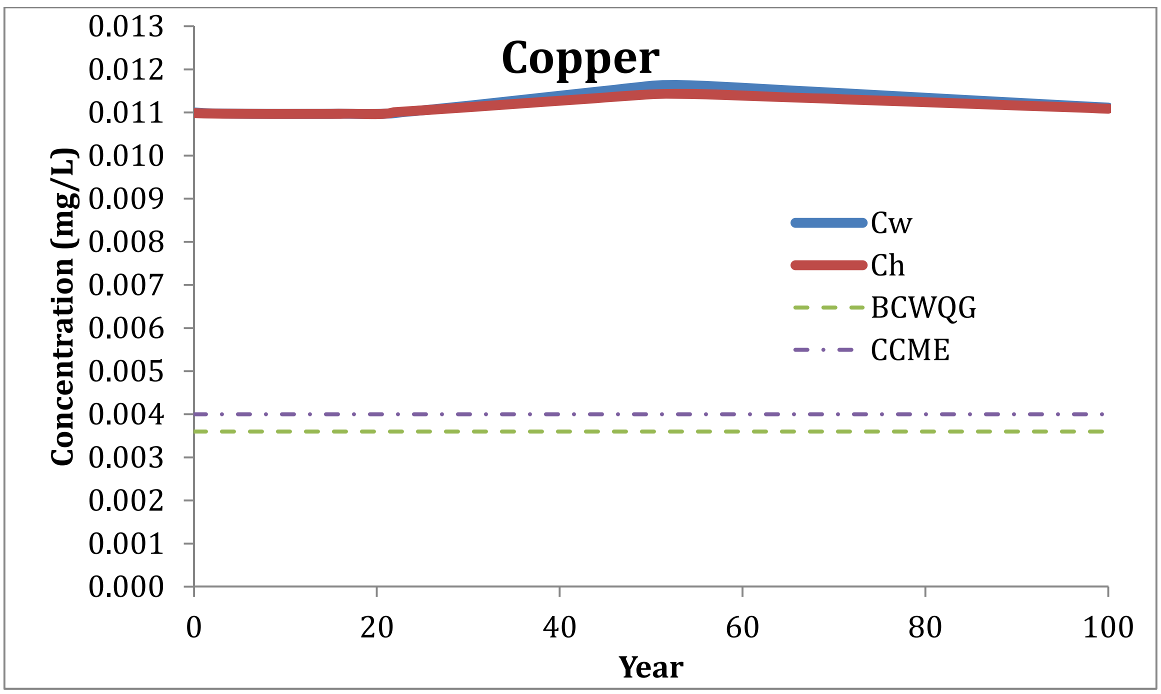
The model predictions of the maximum background concentrations lakewide at the end of winter, C_w, and in the hypolimnion at the end of summer, C_h, are plotted as a function of time, together with the BCWQG and CCME guidelines, in Appendix A. In all cases, except for copper, iron and cadmium the concentrations are comfortably less than the guidelines. Iron exceeds the BCWQG requirement (but not the CCME requirement), solely because of the baseline concentration, the project will not increase the iron concentrations. The concentrations of cadmium are predicted to exceed the BCWQG at the end of winter from about 35 to 85 years after the start of the project. The concentrations in the hypolimnion at the end of summer are predicted to exceed the guideline from about 45 – 75 years after the start of the project. The above comments are all based on the upper bound scenario. The expected concentrations are substantially less than the upper bound values.

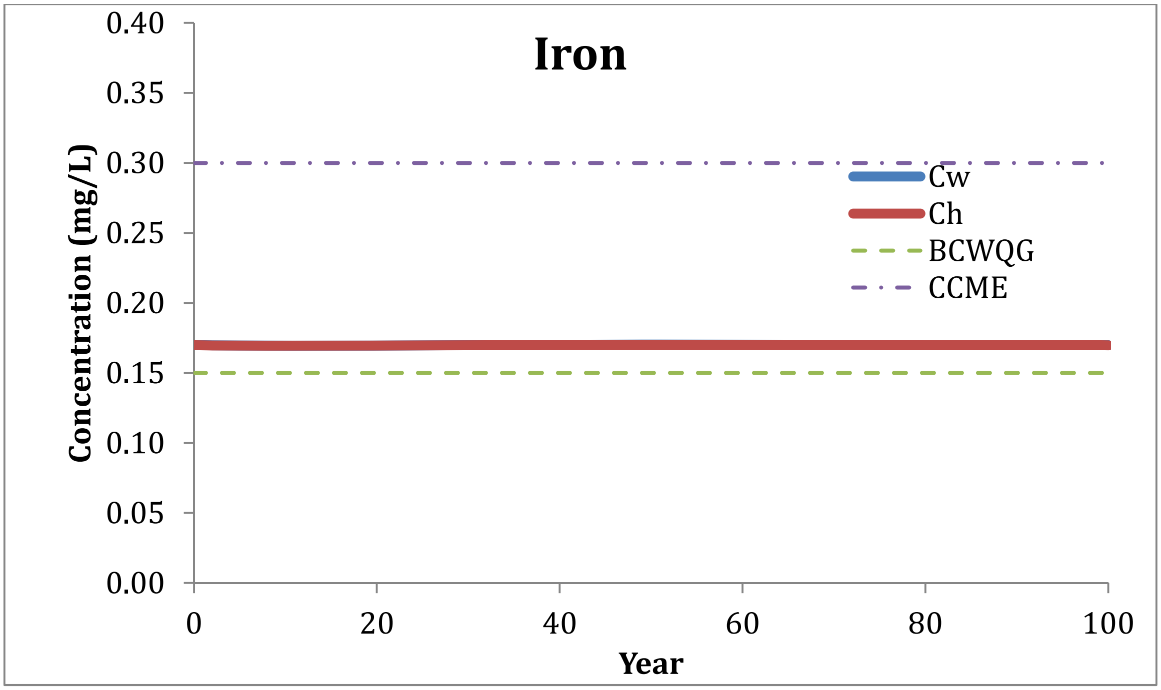
Appendix A: Model predictions made using the upper bound loadings.

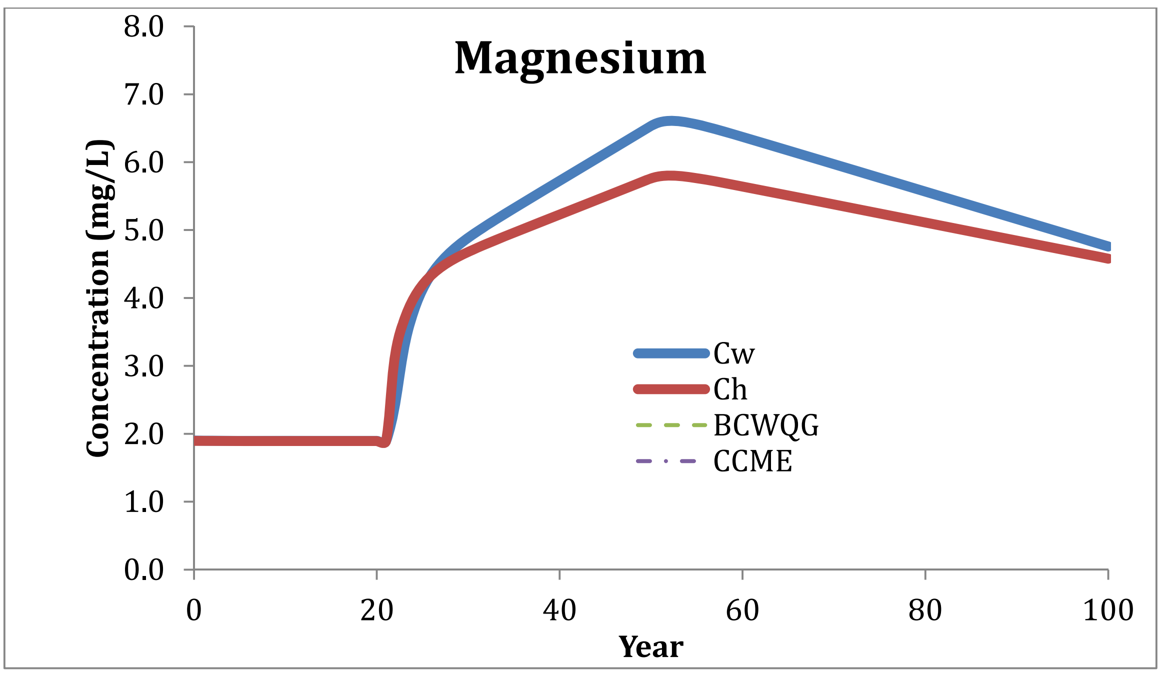


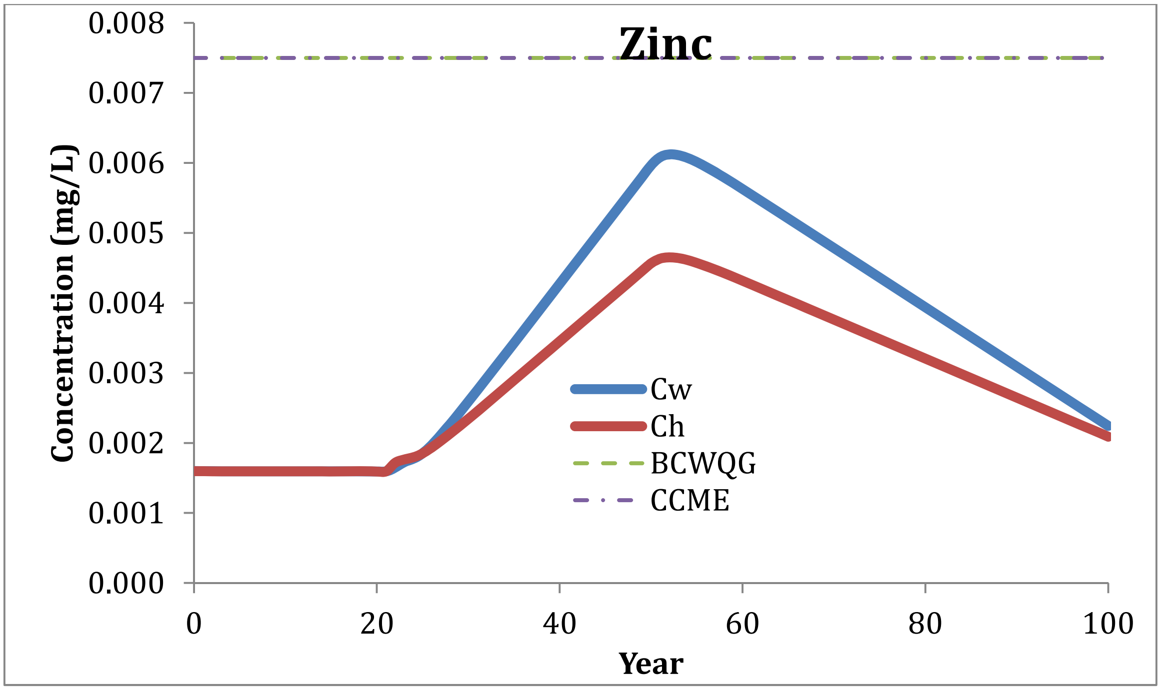


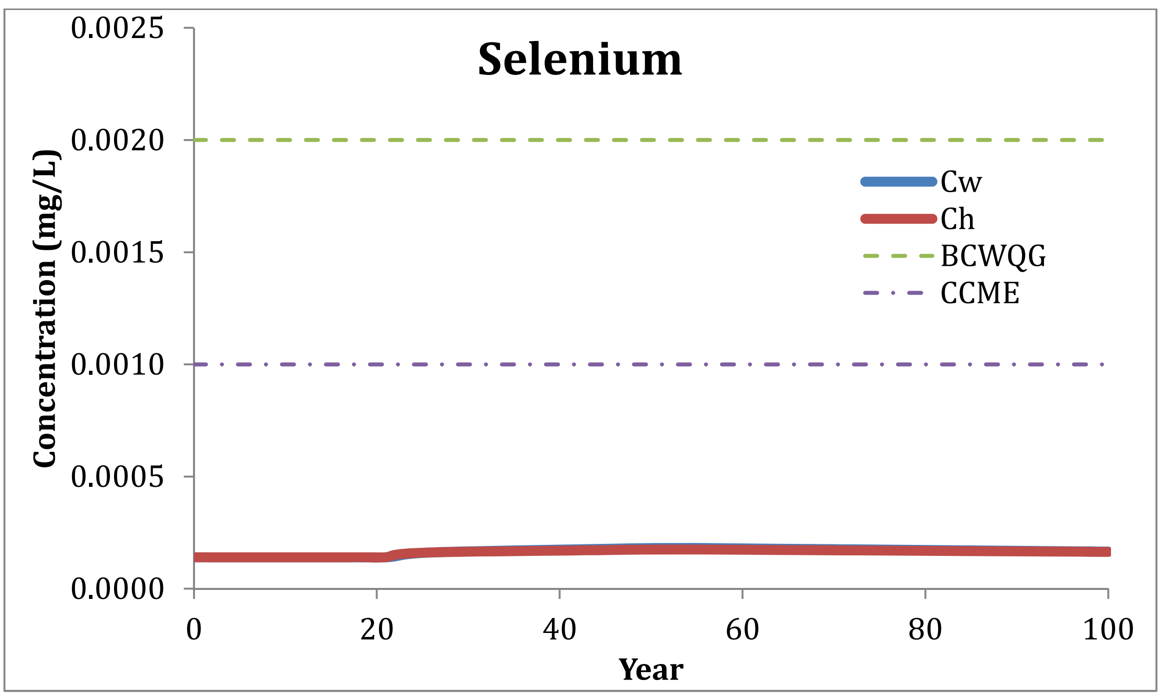

Sulphate
Concentration (mg/L)
110
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
Year
Cw
Ch
BCWQG
CCME

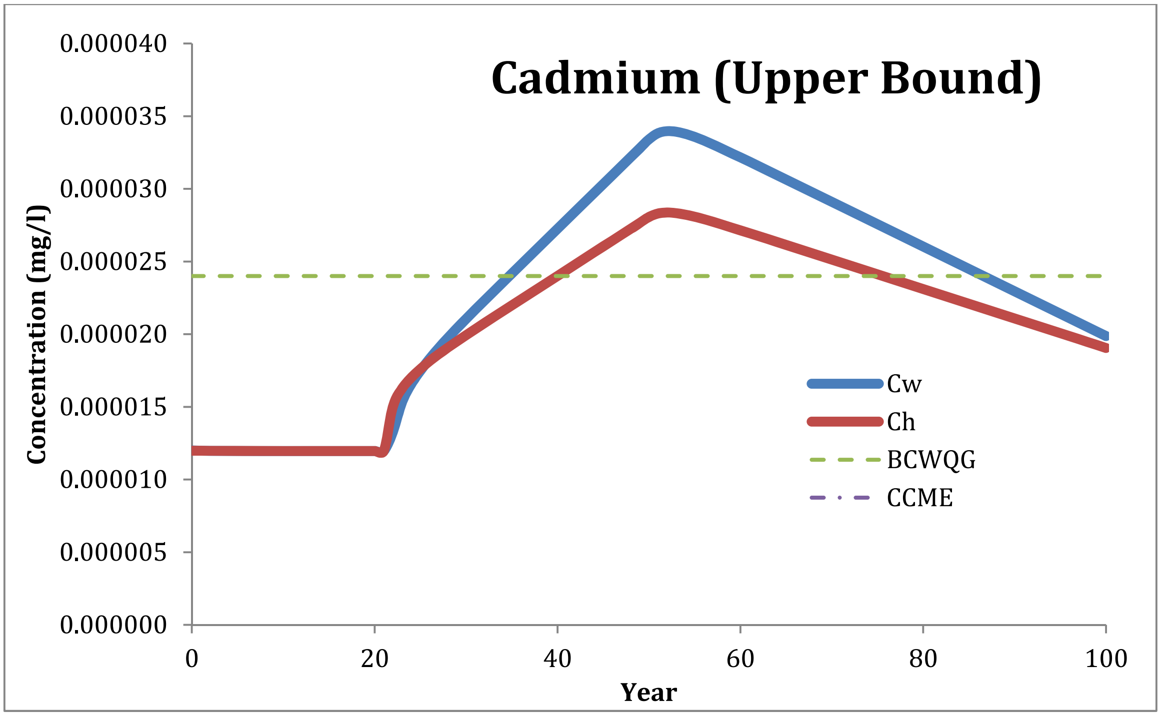

Copper
Concentration (mg/L)
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
0
20
40
60
80
100
Year
Cw
Ch
BCWQG
CCME

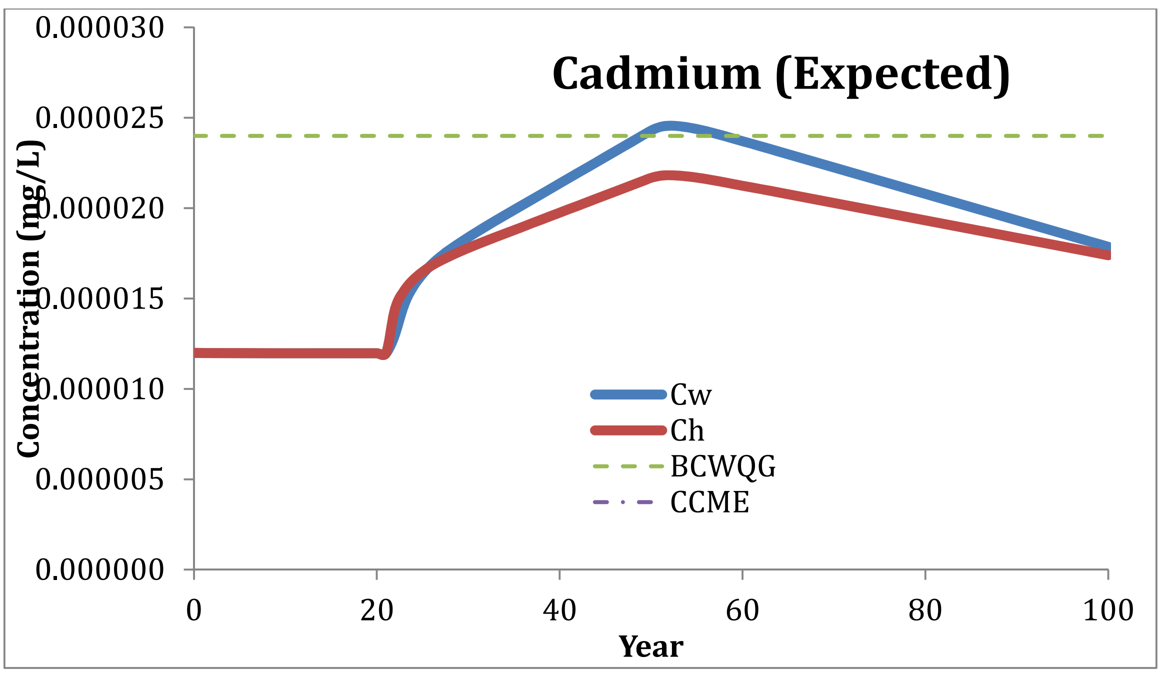

Iron
Concentration (mg/L)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
20
40
60
80
100
Year
Cw
Ch
BCWQG
CCME


Magnesium
Concentration (mg/L)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
20
40
60
80
100
Year
Cw
Ch
BCWQG
CCME


Zinc
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
Concentration (mg/L)
0
20
40
60
80
100
Year
Cw
Ch
BCWQG
CCME


Selenium
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
Concentration (mg/L)
0
20
40
60
80
100
Year
Cw
Ch
BCWQG
CCME


Cadmium (Upper Bound)
0.000040
0.000035
0.000030
0.000025
0.000020
0.000015
0.000010
0.000005
0.000000
Concentration (mg/l)
0
20
40
60
80
100
Year
Cw
Ch
BCWQG
CCME


Cadmium (Expected)
0.000030
0.000025
0.000020
0.000015
0.000010
0.000005
0.000000
Concentration (mg/L)
0
20
40
60
80
100
Year
Cw
Ch
BCWQG
CCME

APPENDIX VI

Baseline Water Quality
Morrison Lake
Mine Area Groundwater

Morrison Lake Baseline

Sample ID	Morrison L A	Morrison L B	Morrison L D	Morrison L E	Morrison L C	Morrison L C - Duplicate	Morrison L A - Surface	Morrison L A - Surface	Morrison L B - Deep	Morrison L B - Surface	Morrison L C - Deep	Morrison L C - Surface	Morrison L D - Surface	Morrison L E - Deep	Morrison Lake D - Deep	Morrison L E - Surface
Date Sampled	24-Aug-06	24-Aug-06	24-Aug-06	24-Aug-06	25-Aug-06	25-Aug-06	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08
Time Sampled																
ALS Sample ID																
Matrix																
Physical Tests																
Colour, True	36	36	36	36	36	38	38	39	37	39	37	39	39	38	37	39
Conductivity	65	64	63	63	64	63	58	59	65	59	62	58	58	61	61	58
Hardness (as CaCO3)	28	30	29	28	29	28	30	30	31	29	30	29	29	28	29	28
pH	7.9	7.8	7.8	7.8	7.8	7.8	7.6	7.7	7.2	7.6	7.4	7.5	7.5	7.4	7.5	7.6
[H+]	0.000000013	0.000000014	0.000000015	0.000000015	0.000000015	0.000000016	0.000000023	0.000000022	0.000000059	0.000000024	0.000000038	0.000000029	0.000000030	0.000000038	0.000000034	0.000000026
Total Suspended Solids	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Total Dissolved Solids	48	48	47	46	48	46	59	57	57	54	57	58	55	58	54	54
Turbidity	0.59	0.38	0.52	0.73	0.56	0.42	0.43	0.45	0.51	0.55	0.45	0.52	0.56	0.54	0.55	0.85
Anions and Nutrients																
Acidity (as CaCO3)	2.9	2.8	3.0	2.8	2.6	2.7	2.1	2.1	3.4	1.7	2.5	2.0	2.5	2.4	2.3	1.8
Alkalinity, Bicarbonate (as CaCO3)							27	26	28	26	28	26	26	27	28	26
Alkalinity, Carbonate (as CaCO3)							1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Alkalinity, Hydroxide (as CaCO3)							1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Alkalinity, Total (as CaCO3)	32	32	32	31	32	32	27	26	28	26	28	26	26	27	28	26
Ammonia as N	0.0025	0.0060	0.0053	0.0073	0.0053	0.0053	0.010	0.010	0.11	0.012	0.0025	0.018	0.021	0.0074	0.0025	0.014
Bromide (Br)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Chloride (Cl)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Fluoride (F)	0.040	0.038	0.036	0.036	0.038	0.036	0.035	0.035	0.035	0.035	0.035	0.035	0.036	0.035	0.022	0.036
Nitrate (as N)	0.010	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0099	0.064	0.0053	0.064	0.0025	0.0066	0.048	0.059	0.0080
Nitrite (as N)	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050
Total Kjeldahl Nitrogen	0.30	0.28	0.38	0.31	0.25	0.26	0.085	0.13	0.12	0.14	0.14	0.14	0.15	0.12	0.16	0.11
Total Nitrogen	0.31	0.28	0.38	0.31	0.25	0.26	0.090	0.14	0.18	0.14	0.20	0.14	0.16	0.17	0.22	0.12
Total Phosphate as P	0.0079	0.0057	0.0071	0.0077	0.0060	0.0059	0.0061	0.0068	0.0058	0.012	0.0063	0.0076	0.0083	0.0070	0.0066	0.012
Sulfate (SO4)	2.5	2.4	2.3	2.3	2.4	2.3	2.4	2.4	2.5	2.4	2.5	2.3	2.4	2.4	2.6	2.6
Cyanides																
Cyanide, Weak Acid Diss																
Cyanide, Total	0.0051	0.0049	0.0051	0.0045	0.0046	0.0048	0.0081	0.0071	0.0063	0.0077	0.0070	0.0080	0.0086	0.0078	0.0076	0.0076
Organic / Inorganic Carbon																
Total Organic Carbon	11	10	11	10	11	10	5.6	10	9.6	9.8	10	9.8	10	10	10.0	10.0
Total Metals																
Aluminum (Al)-Total	0.022	0.032	0.021	0.021	0.025	0.021	0.041	0.041	0.044	0.040	0.043	0.039	0.043	0.048	0.043	0.041
Antimony (Sb)-Total	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050
Arsenic (As)-Total	0.00033	0.00034	0.00031	0.00032	0.00033	0.00030	0.00027	0.00029	0.00029	0.00028	0.00026	0.00028	0.00027	0.00027	0.00029	0.00028
Barium (Ba)-Total	0.018	0.018	0.017	0.017	0.018	0.018	0.015	0.017	0.017	0.016	0.016	0.016	0.016	0.025	0.016	0.016
Beryllium (Be)-Total	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025
Bismuth (Bi)-Total	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025
Boron (B)-Total	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Cadmium (Cd)-Total	0.000010	0.000010	0.000010	0.000010	0.000010	0.000010	0.000031	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085
Calcium (Ca)-Total	8.7	8.6	8.5	8.5	9.8	8.6	7.8	8.4	9.1	8.3	8.2	7.8	8.5	8.3	8.7	8.2
Chromium (Cr)-Total	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.0025	0.00025	0.00025
Cobalt (Co)-Total	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00011	0.000050	0.000050
Copper (Cu)-Total	0.00087	0.00085	0.00079	0.00076	0.00099	0.00082	0.0015	0.0010	0.0011	0.00093	0.00090	0.00083	0.00099	0.0018	0.00091	0.00089
Iron (Fe)-Total	0.12	0.12	0.12	0.12	0.14	0.12	0.11	0.12	0.14	0.13	0.14	0.13	0.12	0.15	0.13	0.12
Lead (Pb)-Total	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000084	0.00015	0.000059	0.000025	0.000054	0.000025	0.000025	0.00015	0.000025	0.000025
Lithium (Li)-Total	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Magnesium (Mg)-Total	1.7	1.7	1.7	1.7	1.9	1.7	1.9	2.0	2.1	1.9	2.0	1.9	2.0	1.9	2.0	1.8
Manganese (Mn)-Total	0.0028	0.0025	0.0021	0.0021	0.0022	0.0019	0.0026	0.0027	0.0035	0.0026	0.0032	0.0025	0.0030	0.0049	0.0034	0.0028

Sample ID	MORRISON LAKE	MORRISON LAKE	MORRISON LAKE A DEEP	MORRISON LAKE B DEEP	MORRISON LAKE A SURFACE	MORRISON LAKE B SURFACE	MORRISON LAKE D DEEP WATER	MORRISON LAKE D SURFACE	MORRISON LAKE C SURFACE	MORRISON LAKE C DEEP	MORRISON LAKE E DEEP
Date Sampled	9-Mar-10	16-Sep-10	20-Oct-10	20-Oct-10	20-Oct-10	20-Oct-10	20-Oct-10	20-Oct-10	20-Oct-10	20-Oct-10	20-Oct-10
Time Sampled	00:00	17:00	13:21	12:50	13:21	12:50	11:25	11:25	10:47	10:47	12:11
ALS Sample ID	L868643-4	L933296-6	L947757-1	L947757-2	L947757-3	L947757-4	L947772-1	L947772-2	L947772-3	L947772-4	L947772-5
Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Physical Tests											
Colour, True	34.9										
Conductivity	61.6	63.5	62.8	62.8	62.4	62.2	62.3	62.1	62.4	63.0	62.7
Hardness (as CaCO3)	29.9	30.3	29.3	29.4	30.2	30.0	29.1	28.0	27.1	26.7	28.5
pH	7.84	7.82	7.86	7.80	7.81	7.79	7.71	7.78	7.76	7.75	7.69
[H+]											
Total Suspended Solids	1.5		1.5	5.0	5.0	1.5	1.5	1.5	1.5	33.0	1.5
Total Dissolved Solids	52		51	50	55	58	57	55	52	52	57
Turbidity	0.37										
Anions and Nutrients											
Acidity (as CaCO3)	5.7		2.2	2.2	2.1	2.1	2.2	2.1	2.1	2.1	2.1
Alkalinity, Bicarbonate (as CaCO3)	28.5										
Alkalinity, Carbonate (as CaCO3)	1										
Alkalinity, Hydroxide (as CaCO3)	1										
Alkalinity, Total (as CaCO3)	28.5	29.1	28.3	28.2	28.0	28.1	28.1	28.2	28.1	28.1	27.6
Ammonia as N	0.01		0.0025	0.0025	0.0025	0.0025	0.0025	0.0058	0.0052	0.0025	0.0025
Bromide (Br)		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Chloride (Cl)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Fluoride (F)	0.036	0.033	0.034	0.034	0.034	0.035	0.021	0.021	0.021	0.020	0.020
Nitrate (as N)			0.0338	0.0390	0.0364	0.0396	0.0679	0.0330	0.0339	0.0429	0.0651
Nitrite (as N)			0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Total Kjeldahl Nitrogen	0.275										
Total Nitrogen											
Total Phosphate as P											
Sulfate (SO4)	2.30	2.44	2.41	2.40	2.42	2.40	2.36	2.40	2.40	2.40	2.36
Cyanides											
Cyanide, Weak Acid Diss											
Cyanide, Total											
Organic / Inorganic Carbon											
Total Organic Carbon	8.58		7.62	9.61	8.07	9.67	9.85	9.91	9.50	9.37	9.83
Total Metals											
Aluminum (Al)-Total	0.0294	0.0332	0.0355	0.0442	0.0540	0.0332	0.0380	0.0413	0.0296	0.109	0.0329
Antimony (Sb)-Total	0.00005	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025
Arsenic (As)-Total	0.00026	0.000355	0.000336	0.000378	0.000346	0.000313	0.000273	0.000291	0.000284	0.000642	0.000305
Barium (Ba)-Total	0.0164	0.0182	0.0165	0.0164	0.0179	0.0166	0.0163	0.0170	0.0162	0.0183	0.0160
Beryllium (Be)-Total	0.00025	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Bismuth (Bi)-Total	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025
Boron (B)-Total	0.005	0.0073	0.0083	0.0085	0.0087	0.0084	0.0098	0.0100	0.0101	0.0105	0.0098
Cadmium (Cd)-Total	0.000025	0.000030	0.0000085	0.0000085	0.000022	0.0000085	0.0000085	0.0000085	0.0000085	0.000063	0.0000085
Calcium (Ca)-Total	8.40	9.77	8.47	8.65	8.90	8.74	8.63	7.82	8.33	7.94	7.97
Chromium (Cr)-Total	0.00025	0.00025	0.00048	0.00036	0.00050	0.00038	0.00050	0.00047	0.00050	0.00076	0.00046
Cobalt (Co)-Total	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Copper (Cu)-Total	0.00093	0.00181	0.00119	0.00151	0.00234	0.00092	0.00113	0.00109	0.00090	0.00219	0.00143
Iron (Fe)-Total	0.088	0.094	0.104	0.137	0.139	0.096	0.104	0.108	0.098	0.342	0.103
Lead (Pb)-Total	0.000025	0.000083	0.000025	0.000025	0.000229	0.000025	0.000025	0.000065	0.000025	0.000251	0.000025
Lithium (Li)-Total	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Magnesium (Mg)-Total	1.95	2.08	1.97	1.94	1.99	1.98	1.81	1.79	1.75	1.71	1.79
Manganese (Mn)-Total	0.00184	0.00313	0.00493	0.00578	0.0150	0.00371	0.00313	0.00358	0.00266	0.0241	0.00276

Blue text denotes measured value at limit of method detection and listed as one half method detection limit

Green cells indicate upper outlier

Morrison Lake Baseline

Sample ID	Morrison L A	Morrison L B	Morrison L D	Morrison L E	Morrison L C	Morrison L C - Duplicate	Morrison L A - Surface	Morrison L A - Surface	Morrison L B - Deep	Morrison L B - Surface	Morrison L C - Deep	Morrison L C - Surface	Morrison L D - Surface	Morrison L E - Deep	Morrison Lake D - Deep	Morrison L E - Surface	MORRISON LAKE	MORRISON LAKE	MORRISON LAKE A DEEP	MORRISON LAKE B DEEP	MORRISON LAKE A SURFACE	MORRISON LAKE B SURFACE	MORRISON LAKE D DEEP WATER	MORRISON LAKE D SURFACE	MORRISON LAKE C SURFACE	MORRISON LAKE C DEEP	MORRISON LAKE E DEEP
Date Sampled	24-Aug-06	24-Aug-06	24-Aug-06	24-Aug-06	25-Aug-06	25-Aug-06	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08	23-Jul-08	9-Mar-10	16-Sep-10	20-Oct-10	20-Oct-10	20-Oct-10	20-Oct-10	20-Oct-10	20-Oct-10	20-Oct-10	20-Oct-10	20-Oct-10
Time Sampled																	00:00	17:00	13:21	12:50	13:21	12:50	11:25	11:25	10:47	10:47	12:11
ALS Sample ID																	L868643-4	L933296-6	L947757-1	L947757-2	L947757-3	L947757-4	L947772-1	L947772-2	L947772-3	L947772-4	L947772-5
Matrix																	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Mercury (Hg)-Total	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.000013	0.0000050	0.0000050	0.0000050	0.000025	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005
Molybdenum (Mo)-Total	0.00016	0.00013	0.00013	0.00014	0.00016	0.00013	0.00012	0.00012	0.00011	0.00012	0.00011	0.00011	0.00013	0.00012	0.000094	0.00011	0.000116	0.000152	0.000127	0.000127	0.000142	0.000122	0.000132	0.000142	0.000130	0.000136	0.000122
Nickel (Ni)-Total	0.00025	0.00025	0.00025	0.00025	0.00060	0.00025	0.00076	0.0020	0.00085	0.00068	0.00094	0.00062	0.00077	0.055	0.00086	0.00074	0.0005	0.00064	0.00049	0.00049	0.00062	0.00053	0.00056	0.00086	0.00072	0.00084	0.00048
Phosphorus (P)-Total	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Potassium (K)-Total	0.35	0.35	0.34	0.34	0.40	0.35	0.34	0.33	0.36	0.34	0.33	0.33	0.36	0.34	0.35	0.33	1	0.437	0.316	0.312	0.330	0.323	0.332	0.324	0.321	0.329	0.318
Selenium (Se)-Total	0.00058	0.00025	0.00025	0.00025	0.00025	0.00025	0.00034	0.00036	0.00036	0.00028	0.00019	0.00011	0.00045	0.00019	0.00022	0.00032	0.0005	0.0001	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Silicon (Si)-Total	2.0	2.1	2.0	2.0	2.0	2.0	2.4	2.5	2.8	2.6	2.8	2.6	2.4	2.7	2.8	2.5	2.48	2.26	2.42	2.40	2.49	2.41	2.62	2.28	2.28	2.39	2.51
Silver (Ag)-Total	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005
Sodium (Na)-Total	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1	2.05	1.99	1.95	2.00	2.00	1.78	1.76	1.72	1.69	1.74
Strontium (Sr)-Total	0.048	0.047	0.047	0.046	0.051	0.047	0.040	0.042	0.047	0.041	0.042	0.040	0.044	0.042	0.042	0.041	0.0471	0.0524	0.0489	0.0478	0.0498	0.0481	0.0486	0.0476	0.0477	0.0468	0.0480
Thallium (Tl)-Total	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00005	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025
Tin (Sn)-Total	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00011	0.000050	0.000050	0.00026	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Titanium (Ti)-Total	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Uranium (U)-Total	0.0000050	0.0000050	0.0000050	0.0000050	0.000010	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005
Vanadium (V)-Total	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.0005	0.00025	0.000104	0.000124	0.000152	0.000089	0.000085	0.000118	0.000085	0.000329	0.000096
Zinc (Zn)-Total	0.00050	0.0010	0.00050	0.00050	0.0025	0.0014	0.0042	0.00050	0.00050	0.00050	0.0011	0.00050	0.0010	0.0015	0.00050	0.00050	0.0005	0.0022	0.0015	0.0015	0.0036	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Dissolved Metals																											
Aluminum (Al)-Dissolved	0.016	0.016	0.016	0.016	0.016	0.018	0.036	0.034	0.034	0.035	0.035	0.035	0.035	0.037	0.034	0.035	0.0258	0.0310	0.0239	0.0256	0.0256	0.0264	0.0289	0.0244	0.0251	0.0245	0.003
Antimony (Sb)-Dissolved	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00005	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025
Arsenic (As)-Dissolved	0.00031	0.00031	0.00030	0.00029	0.00031	0.00030	0.00027	0.00027	0.00026	0.00026	0.00034	0.00027	0.00027	0.00024	0.00026	0.00028	0.00026	0.000321	0.000308	0.000286	0.000332	0.000315	0.000273	0.000303	0.000285	0.000254	0.000194
Barium (Ba)-Dissolved	0.017	0.017	0.017	0.017	0.017	0.017	0.016	0.016	0.016	0.016	0.017	0.016	0.016	0.025	0.016	0.016	0.0157	0.0173	0.0160	0.0160	0.0162	0.0160	0.0158	0.0161	0.0161	0.0175	0.0123
Beryllium (Be)-Dissolved	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Bismuth (Bi)-Dissolved	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025
Boron (B)-Dissolved	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	<0.010	0.005	0.0084	0.0074	0.0078	0.0078	0.0073	0.0102	0.0101	0.0071	0.0033
Cadmium (Cd)-Dissolved	0.000010	0.000010	0.000010	0.000010	0.000010	0.000010	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085	0.000025	0.000021	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085	0.0000085	0.000031	0.0000085
Calcium (Ca)-Dissolved	8.6	8.9	8.7	8.3	8.6	8.4	8.7	8.6	8.9	8.2	8.6	8.2	8.3	8.2	8.6	8.3	8.66	8.97	8.57	8.59	8.91	8.86	8.69	8.36	8.01	7.87	8.68
Chromium (Cr)-Dissolved	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.0017	0.00025	0.00025	0.0005	0.00025	0.00021	0.00045	0.00022	0.00022	0.00019	0.00028	0.00030	0.00022	0.0001
Cobalt (Co)-Dissolved	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Copper (Cu)-Dissolved	0.00087	0.00079	0.00079	0.00078	0.00073	0.00077	0.0010	0.0010	0.0011	0.00097	0.00095	0.00099	0.00091	0.0015	0.00097	0.00087	0.00073	0.00140	0.00098	0.00121	0.00088	0.00079	0.00132	0.00097	0.00078	0.00125	0.00076
Iron (Fe)-Dissolved	0.093	0.092	0.089	0.089	0.087	0.088	0.10	0.10	0.11	0.10	0.11	0.10	0.11	0.12	0.11	0.10	0.089	0.104	0.066	0.069	0.067	0.069	0.077	0.071	0.071	0.071	0.112
Lead (Pb)-Dissolved	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000070	0.000025	0.000025	0.000025	0.000025	0.000025	0.000070	0.000025	0.000025	0.000025	0.000105	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025
Lithium (Li)-Dissolved	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Magnesium (Mg)-Dissolved	1.7	1.8	1.7	1.7	1.7	1.7	2.1	2.0	2.1	2.0	2.1	1.9	2.0	1.9	1.9	1.9	2.01	1.92	1.93	1.92	1.93	1.92	1.80	1.74	1.72	1.72	1.66
Manganese (Mn)-Dissolved	0.00027	0.00027	0.00026	0.00021	0.00022	0.00022	0.00062	0.00061	0.00081	0.00051	0.00073	0.00059	0.00070	0.0015	0.00067	0.00059	0.00146	0.00435	0.000255	0.000371	0.000275	0.000298	0.000363	0.000280	0.000273	0.000260	0.000319
Mercury (Hg)-Dissolved	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.000011	0.0000050	0.0000050	0.0000050	0.000025	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005
Molybdenum (Mo)-Dissolved	0.00014	0.00014	0.00013	0.00013	0.00013	0.00012	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.000102	0.000114	0.000111	0.000113	0.000119	0.000111	0.000107	0.000121	0.000118	0.000126	0.000098
Nickel (Ni)-Dissolved	0.00025	0.00025	0.00025	0.00025	0.00050	0.00057	0.00075	0.0013	0.0011	0.00080	0.0010	0.00066	0.00078	0.053	0.00086	0.00067	0.00025	0.00047	0.00045	0.00053	0.00060	0.00050	0.00055	0.00071	0.00071	0.00058	0.00020
Phosphorus (P)-Dissolved	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Potassium (K)-Dissolved	0.35	0.36	0.36	0.33	0.35	0.33	0.36	0.34	0.37	0.34	0.35	0.34	0.35	0.33	0.34	0.34	1.0	0.401	0.304	0.319	0.377	0.318	0.335	0.328	0.324	0.321	0.282
Selenium (Se)-Dissolved	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00038	0.00044	0.00047	0.00028	0.00026	0.00014	0.00038	0.00012	0.00019	0.00022	0.0005	0.0001	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Silicon (Si)-Dissolved	1.9	2.0	2.0	1.9	1.9	2.0	2.5	2.5	2.8	2.5	2.8	2.5	2.5	2.7	2.7	2.5	2.57	2.18	2.34	2.36	2.34	2.34	2.63	2.27	2.27	2.34	2.48
Silver (Ag)-Dissolved	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005
Sodium (Na)-Dissolved	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2	1.90	1.93	1.96	2.05	1.97	1.76	1.75	1.70	1.72	1.68
Strontium (Sr)-Dissolved	0.047	0.048	0.047	0.045	0.047	0.045	0.043	0.043	0.044	0.041	0.045	0.042	0.044	0.041	0.042	0.041	0.0450	0.0468	0.0468	0.0470	0.0470	0.0466	0.0471	0.0465	0.0465	0.0466	0.0494
Thallium (Tl)-Dissolved	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00005	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025
Tin (Sn)-Dissolved	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00012	0.000050	0.000050	0.00015	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Titanium (Ti)-Dissolved	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Uranium (U)-Dissolved	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005
Vanadium (V)-Dissolved	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.0005	0.00025	0.000078	0.000077	0.000080	0.000082	0.000066	0.000088	0.000100	0.000087	0.000092
Zinc (Zn)-Dissolved	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.0014	0.00050	0.0014	0.00050	0.0013	0.0019	0.0015	0.00050	0.0005	0.0012	0.0015	0.0015	0.0091	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015

Blue text denotes measured value at limit of method detection and listed as one half method detection limit

Green cells indicate upper outlier

Morrison Lake Baseline

Sample ID	MORRISON LAKE E SURFACE	MORRISON C-SURFACE	MORRISON C-DEEP	MORRISON E-SURFACE	MORRISON E-DEEP	MORRISON A - SURFACE	MORRISON B-SURFACE	MORRISON B-DEEP	MORRISON D-SURFACE	MORRISON D-15M	MORRISON D-DEEP	MORRISON A - DEEP	MORRISON A -SHALLOW	MORRISON A - DEEP	MORRISON B - SHALLOW	MORRISON B - SHALLOW (Duplicate)	MORRISON B - DEEP	MORRISON C - SHALLOW	MORRISON C - DEEP	MORRISON D - SHALLOW	MORRISON D - THERMOCLINE	MORRISON D - DEEP	MORRISON E - SHALLOW	MORRISON E - DEEP	Min	Max	Revised Baseline without Upper Outliers
Date Sampled	20-Oct-10	11-Jan-11	11-Jan-11	11-Jan-11	11-Jan-11	11-Jan-11	12-Jan-11	12-Jan-11	12-Jan-11	12-Jan-11	12-Jan-11	12-Jan-11	1-Jun-11	1-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11			(Mean)
Time Sampled	12:11	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	14:30	14:30	14:24	14:30	14:15	13:30	13:25	12:44	12:40	12:15	11:21	11:06			
ALS Sample ID	L947772-6	L971339-3	L971339-4	L971339-8	L971339-9	L973964-1	L971339-1	L971339-2	L971339-5	L971339-6	L971339-7	L973964-2	L1014720-7	L1014720-6	L1014719-1	L1014719-2	L1014719-4	L1014719-3	L1014719-6	L1014720-4	L1014720-5	L1014720-1	L1014720-3	L1014720-2			
Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water			
Physical Tests																											
Colour, True																									35	39	37
Conductivity	62.3	67.9	63.1	73.3	71.3	64.2	61.4	66.0	68.8	62.5	63.1	63.9	60.0	65.6	55.2	56.2	58.7	51.4	62.2	52.0	58.2	57.0	54.4	62	51	73	62
Hardness (as CaCO3)	25.5	33.0	30.0	30.6	28.2	28.1	30.0	31.4	31.7	29.1	27.6	27.8	28.3	30.9	26.3	26.1	28.5	24.5	29.1	24.7	27.6	29.3	27.0	29	25	33	29
pH	7.40	7.83	7.84	7.86	7.86	7.56	7.40	7.79	7.85	7.90	7.86	7.59	7.94	7.92	8.08	7.98	7.61	7.93	7.97	7.90	7.92	7.95	7.92	7.9	7.2	8.1	7.8
[H+]																									0.000000013	0.000000059	0.000000026
Total Suspended Solids	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	14.7	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	33	2.6
Total Dissolved Solids	54	35	44	54	51	45	50	54	51	39	52	47	62	63	60	64	52	62	62	60	62	59	65	61	35	65	54
Turbidity																									0.37	0.85	0.53
Anions and Nutrients																											
Acidity (as CaCO3)	2.8	3.9	3.8	3.5	3.5	1.9	4.4	3.9	3.7	3.5	3.6	1.9	3.8	2.7	3.4	4.0	5.3	2.4	3.6	2.7	4.0	3.9	4.1	2.7	1.7	5.7	3.0
Alkalinity, Bicarbonate (as CaCO3)																									26	29	27
Alkalinity, Carbonate (as CaCO3)																									1.0	1.0	1.0
Alkalinity, Hydroxide (as CaCO3)																									1.0	1.0	1.0
Alkalinity, Total (as CaCO3)	28.0	31.5	28.6	29.2	27.9	30.1	28.3	29.1	31.3	29.7	26.6	29.1	26.2	28.2	23.6	24.1	26.4	21.7	27.1	22.1	25.8	24.9	23.2	28	22	32	28
Ammonia as N	0.0025	0.0129	0.0072	0.0207	0.0127	0.0025	0.0025	0.0071	0.0078	0.0100	0.0115	0.0055	0.0092	0.0175	0.0116	0.0076	0.0137	0.0096	0.0085	0.0118	0.0119	0.0204	0.0086	0.0075	0.0025	0.11	0.0105
Bromide (Br)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.13	0.025	0.13	0.049
Chloride (Cl)	0.25	0.25	0.25	2.41	2.30	0.25	0.25	0.25	0.25	0.25	0.25	0.51	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.3	0.25	2.4	0.57
Fluoride (F)	0.021	0.026	0.026	0.026	0.028	0.026	0.029	0.028	0.028	0.026	0.027	0.026	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.050	0.020	0.050	0.035
Nitrate (as N)	0.0359	0.0650	0.0640	0.0629	0.0643	0.0572	0.0605	0.0630	0.0679	0.0629	0.0663	0.0545	0.025	0.061	0.025	0.025	0.042	0.0125	0.053	0.025	0.048	0.036	0.028	0.062	0.0025	0.068	0.038
Nitrite (as N)	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.00050	0.0025	0.00099
Total Kjeldahl Nitrogen		0.277	0.335	0.275	0.247	0.314	0.244	0.298	0.297	0.260	0.244	0.283	0.524	0.433	0.412	0.473	0.379	0.541	0.314	0.548	0.310	0.305	0.522	0.62	0.085	0.62	0.29
Total Nitrogen		0.230	0.210	0.230	0.230	0.230	0.210	0.250	0.250	0.220	0.210	0.240	0.524	0.493	0.438	0.498	0.421	0.541	0.367	0.548	0.358	0.341	0.550	0.68	0.090	0.68	0.30
Total Phosphate as P		0.0051	0.0050	0.0052	0.0056	0.0049	0.0056	0.0052	0.0053	0.0054	0.0062	0.0065	0.0155	0.0286	0.0125	0.0093	0.0103	0.0111	0.0077	0.0122	0.0098	0.0096	0.0109	0.0069	0.0049	0.029	0.0083
Sulfate (SO4)	2.40	2.64	2.42	2.73	2.68	2.46	2.36	2.54	2.65	2.40	2.40	2.46	2.6	3.0	1.25	1.25	2.7	1.25	2.7	1.25	1.25	1.25	1.25	2.6	1.3	3.0	2.3
Cyanides																											
Cyanide, Weak Acid Diss		0.0025				0.0025		0.0025	0.0025		0.0025	0.0025	0.0025	0.0025		0.0025	0.0025	0.0025		0.0025		0.0025					0.0025
Cyanide, Total		0.0025				0.0065		0.0025	0.0066		0.0071	0.0066	0.0080	0.0080		0.0076	0.0061	0.0074		0.0086		0.0054			0.0025	0.0086	0.0065
Organic / Inorganic Carbon																									0	0	
Total Organic Carbon	9.30	9.86	9.73	10.1	10.5	10.2	9.49	10.5	11.1	10.0	9.98	9.87	10.1	9.17	9.61	17.30	11.3	13.8	10.1	10.2	10.3	8.75	13.3	8.0	5.6	17	10.1
Total Metals																											
Aluminum (Al)-Total	0.0328	0.0309	0.0278	0.0275	0.0281	0.0289	0.0277	0.0338	0.0349	0.0278	0.0372	0.126	0.129	0.373	0.157	0.169	0.113	0.157	0.0766	0.167	0.131	0.0563	0.151	0.083	0.021	0.37	0.065
Antimony (Sb)-Total	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000105	0.000025	0.000025	0.000025	0.000025	0.000025	0.000081	0.000025	0.000084	0.000025	0.000132	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.00013	0.000039
Arsenic (As)-Total	0.000281	0.000306	0.000290	0.000281	0.000285	0.000273	0.000274	0.000308	0.000296	0.000294	0.000288	0.000705	0.000380	0.00145	0.000336	0.000346	0.000324	0.000320	0.000301	0.000324	0.000340	0.000289	0.000316	0.00089	0.00026	0.0015	0.00035
Barium (Ba)-Total	0.0162	0.0172	0.0158	0.0165	0.0160	0.0170	0.0160	0.0172	0.0177	0.0162	0.0163	0.0186	0.0183	0.0233	0.0175	0.0181	0.0174	0.0171	0.0176	0.0175	0.0181	0.0186	0.0177	0.019	0.015	0.025	0.017
Beryllium (Be)-Total	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.00010	0.00010	0.00025	0.00015
Bismuth (Bi)-Total	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025
Boron (B)-Total	0.0097	0.0096	0.0094	0.0102	0.0096	0.009	0.0110	0.0094	0.0099	0.0100	0.0091	0.009	0.0089	0.0091	0.0091	0.0092	0.0094	0.0082	0.0092	0.0091	0.0085	0.0093	0.0090	0.0096	0.0050	0.011	0.0079
Cadmium (Cd)-Total	0.0000085	0.0000348	0.0000074	0.0000103	0.000005	.0000161	0.0000054	0.0000155	0.0000175	0.0000074	0.0000214	0.000033	0.000005	0.000015	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000013	0.000005	0.000005	0.0000050	0.0000050	0.000063	0.000012
Calcium (Ca)-Total	7.50	9.19	8.18	8.46	7.69	8.43	8.43	9.08	9.31	8.56	8.07	8.01	8.52	9.15	7.71	7.78	8.53	7.09	8.92	7.31	8.33	8.89	7.65	8.7	7.1	9.8	8.4
Chromium (Cr)-Total	0.00053	0.00081	0.00025	0.00022	0.00020	0.00025	0.00020	0.00033	0.00027	0.00042	0.00027	0.0004	0.00035	0.00061	0.00042	0.00044	0.00027	0.00035	0.00028	0.00036	0.00035	0.00029	0.00037	0.00027	0.00020	0.0025	0.00039
Cobalt (Co)-Total	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00018	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.000050	0.000050	0.00018	0.000054
Copper (Cu)-Total	0.00100	0.00965	0.0459	0.0112	0.4260	0.00089	0.00084	0.00281	0.00494	0.00319	0.00219	0.00248	0.00146	0.00225	0.00107	0.00131	0.00117	0.00150	0.00112	0.00118	0.00115	0.00155	0.00114	0.00099	0.00076	0.43	0.0113
Iron (Fe)-Total	0.101	0.107	0.080	0.091	0.095	0.077	0.083	0.091	0.087	0.087	0.099	0.387	0.265	0.931	0.310	0.322	0.224	0.317	0.169	0.343	0.262	0.148	0.322	0.33	0.077	0.93	0.17
Lead (Pb)-Total	0.000025	0.000127	0.000025	0.000174	0.000025	0.000025	0.000025	0.0314	0.000081	0.000185	0.000152	0.000067	0.000052	0.000244	0.000053	0.000077	0.000025	0.000079	0.000025	0.000063	0.000025	0.000025	0.000025	0.000025	0.000025	0.031	0.00068
Lithium (Li)-Total	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Magnesium (Mg)-Total	1.77	2.04	1.90	2.12	1.98	2.03	1.87	2.02	2.15	1.97	1.92	2.09	1.87	2.06	1.72	1.75	1.83	1.65	1.89	1.68	1.87	2.04	1.75	1.9	1.7	2.2	1.9
Manganese (Mn)-Total	0.00254	0.00304	0.00220	0.00180	0.00273	0.00108	0.00227	0.00168	0.00151	0.00212	0.00286	0.0301	0.0111	0.0388	0.0115	0.0113	0.00994	0.0112	0.0100	0.0117	0.00978	0.00522	0.0115	0.040	0.0011	0.040	0.0069

Blue text denotes measured value at limit of method detection and listed as one half method detection limit

Green cells indicate upper outlier

Morrison Lake Baseline

Sample ID	MORRISON LAKE E SURFACE	MORRISON C-SURFACE	MORRISON C-DEEP	MORRISON E-SURFACE	MORRISON E-DEEP	MORRISON A - SURFACE	MORRISON B-SURFACE	MORRISON B-DEEP	MORRISON D-SURFACE	MORRISON D-15M	MORRISON D-DEEP	MORRISON A - DEEP	MORRISON A -SHALLOW	MORRISON A - DEEP	MORRISON B - SHALLOW	MORRISON B - SHALLOW (Duplicate)	MORRISON B - DEEP	MORRISON C - SHALLOW	MORRISON C - DEEP	MORRISON D - SHALLOW	MORRISON D - THERMOCLINE	MORRISON D - DEEP	MORRISON E - SHALLOW	MORRISON E - DEEP	Min	Max	Revised Baseline without Upper Outliers
Date Sampled	20-Oct-10	11-Jan-11	11-Jan-11	11-Jan-11	11-Jan-11	11-Jan-11	12-Jan-11	12-Jan-11	12-Jan-11	12-Jan-11	12-Jan-11	12-Jan-11	1-Jun-11	1-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11	2-Jun-11			(Mean)
Time Sampled	12:11	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	14:30	14:30	14:24	14:30	14:15	13:30	13:25	12:44	12:40	12:15	11:21	11:06			
ALS Sample ID	L947772-6	L971339-3	L971339-4	L971339-8	L971339-9	L973964-1	L971339-1	L971339-2	L971339-5	L971339-6	L971339-7	L973964-2	L1014720-7	L1014720-6	L1014719-1	L1014719-2	L1014719-4	L1014719-3	L1014719-6	L1014720-4	L1014720-5	L1014720-1	L1014720-3	L1014720-2			
Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water			
Mercury (Hg)-Total	0.000005	0.000005	0.000031	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.0000050	0.0000050	0.000031	**0.0000061**
Molybdenum (Mo)-Total	0.000127	0.000134	0.000116	0.000120	0.000117	0.000143	0.000109	0.000127	0.000131	0.000120	0.000119	0.000152	0.000118	0.000155	0.000118	0.000116	0.000118	0.000098	0.000120	0.000102	0.000124	0.000126	0.000112	0.00012	0.000094	0.00016	**0.00013**
Nickel (Ni)-Total	0.00043	0.00054	0.00046	0.00048	0.00046	0.00040	0.00045	0.00060	0.00056	0.00049	0.00061	0.00063	0.00061	0.00094	0.00089	0.00081	0.00065	0.00078	0.00072	0.00071	0.00071	0.00063	0.00071	0.00058	0.00025	0.055	**0.00175**
Phosphorus (P)-Total	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	**0.15**
Potassium (K)-Total	0.322	0.338	0.319	0.377	0.332	0.340	0.321	0.343	0.371	0.317	0.316	0.360	0.374	0.407	0.376	0.376	0.346	0.369	0.354	0.373	0.371	0.364	0.383	0.34	0.31	1.0	**0.36**
Selenium (Se)-Total	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.000050	0.000050	0.00058	**0.00014**
Silicon (Si)-Total	2.30	2.44	2.41	2.51	2.47	2.48	2.43	2.56	2.67	2.46	2.50	2.59	2.61	3.20	2.71	2.72	2.64	2.71	2.59	2.71	2.71	2.49	2.67	2.5	2.0	3.2	**2.5**
Silver (Ag)-Total	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.0000050	0.0000050	0.0000050	**0.0000050**
Sodium (Na)-Total	1.72	1.99	1.87	3.11	2.35	1.85	1.84	1.97	2.07	1.87	1.89	2.26	1.84	2.09	1.79	1.80	1.82	1.75	1.85	1.74	1.90	2.06	1.81	1.9	1.0	3.1	**1.6**
Strontium (Sr)-Total	0.0485	0.0492	0.0467	0.0470	0.0462	0.0496	0.0456	0.0491	0.0506	0.0499	0.0468	0.0504	0.0457	0.0481	0.0415	0.0425	0.0443	0.0398	0.0469	0.0406	0.0447	0.0487	0.0416	0.048	0.040	0.052	**0.046**
Thallium (Tl)-Total	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000050	**0.000033**
Tin (Sn)-Total	0.00005	0.00048	0.00111	0.00511	0.00212	0.00005	0.00099	0.00189	0.00017	0.00032	0.00254	0.00005	0.00017	0.00062	0.00005	0.00005	0.00030	0.00005	0.00050	0.00005	0.00145	0.00071	0.00005	0.00048	0.000050	0.0051	**0.00042**
Titanium (Ti)-Total	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.013	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0050	0.0050	0.013	**0.0052**
Uranium (U)-Total	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000019	0.000011	0.000012	0.000005	0.000011	0.000005	0.000011	0.000005	0.000005	0.000005	0.0000050	0.0000050	0.000019	**0.0000059**
Vanadium (V)-Total	0.000111	0.000085	0.000087	0.000091	0.000083	0.000085	0.000077	0.000084	0.000078	0.000077	0.000091	0.000313	0.000291	0.000891	0.000369	0.000402	0.000253	0.000354	0.000180	0.000399	0.000330	0.000134	0.000338	0.00023	0.000077	0.00089	**0.00030**
Zinc (Zn)-Total	0.0015	0.0038	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0038	0.0015	0.0015	0.0031	0.0015	0.0037	0.0015	0.0046	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.00050	0.0046	**0.0016**
Dissolved Metals																											
Aluminum (Al)-Dissolved	0.0228	0.0318	0.0284	0.0278	0.0265	0.0283	0.0284	0.0288	0.0297	0.0294	0.0305	0.0493	0.0490	0.0371	0.0666	0.0625	0.0457	0.0750	0.0394	0.0731	0.0546	0.0299	0.0664	0.031	0.0030	0.075	**0.033**
Antimony (Sb)-Dissolved	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000050	**0.000033**
Arsenic (As)-Dissolved	0.000261	0.000280	0.000319	0.000289	0.000288	0.000302	0.000312	0.000291	0.000315	0.000285	0.000281	0.000489	0.000293	0.000361	0.000274	0.000275	0.000275	0.000270	0.000270	0.000287	0.000276	0.000268	0.000295	0.00034	0.00019	0.00049	**0.00029**
Barium (Ba)-Dissolved	0.0159	0.0179	0.0166	0.0168	0.0163	0.0169	0.0166	0.0170	0.0179	0.0161	0.0160	0.0173	0.0168	0.0191	0.0163	0.0164	0.0166	0.0160	0.0165	0.0159	0.0165	0.0167	0.0167	0.017	0.012	0.025	**0.017**
Beryllium (Be)-Dissolved	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.00010	0.00010	0.00025	**0.00015**
Bismuth (Bi)-Dissolved	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	**0.00025**
Boron (B)-Dissolved	0.0089	0.0059	0.0058	0.0062	0.0054	0.006	0.0061	0.0057	0.0059	0.0053	0.0062	0.006	0.0088	0.0083	0.0081	0.0081	0.0078	0.0079	0.0083	0.0078	0.0078	0.0091	0.0084	0.0080	0.0033	0.010	**0.0065**
Cadmium (Cd)-Dissolved	0.0000085	0.0000267	0.0000094	0.0000123	0.0000063	0.0000025	0.0000114	0.0000064	0.0000114	0.0000025	0.0000194	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.0000050	0.0000025	0.000031	**0.0000093**
Calcium (Ca)-Dissolved	7.33	9.74	8.73	8.58	8.00	7.92	8.80	9.24	9.23	8.43	7.89	7.85	8.35	8.94	7.75	7.72	8.49	7.16	8.66	7.21	8.13	8.69	8.03	8.6	7.2	9.7	**8.4**
Chromium (Cr)-Dissolved	0.00039	0.00051	0.00025	0.00012	0.00012	0.00013	0.00014	0.00017	0.00015	0.00020	0.00016	0.00014	0.00019	0.00018	0.00023	0.00017	0.00019	0.00022	0.00017	0.00022	0.00017	0.00018	0.00019	0.00016	0.00010	0.0017	**0.00026**
Cobalt (Co)-Dissolved	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.000050	0.000050	0.000050	**0.000050**
Copper (Cu)-Dissolved	0.00077	0.00577	0.0473	0.0109	0.0418	0.00120	0.00137	0.00134	0.0107	0.00311	0.00182	0.00090	0.00126	0.00149	0.00100	0.00109	0.00101	0.00114	0.00098	0.00104	0.00096	0.00125	0.00096	0.00086	0.00073	0.047	**0.0034**
Iron (Fe)-Dissolved	0.074	0.110	0.084	0.090	0.096	0.076	0.086	0.086	0.087	0.083	0.092	0.182	0.114	0.106	0.139	0.140	0.106	0.153	0.089	0.162	0.120	0.080	0.149	0.088	0.066	0.18	**0.099**
Lead (Pb)-Dissolved	0.000025	0.000125	0.000110	0.000081	0.000025	0.000025	0.000195	0.000072	0.000063	0.000025	0.000108	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.00020	**0.000040**
Lithium (Li)-Dissolved	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	**0.0025**
Magnesium (Mg)-Dissolved	1.74	2.10	2.00	2.23	2.00	2.03	1.94	2.01	2.10	1.96	1.91	1.98	1.82	2.08	1.69	1.66	1.78	1.60	1.82	1.62	1.77	1.85	1.68	1.8	1.6	2.2	**1.9**
Manganese (Mn)-Dissolved	0.000249	0.00320	0.00240	0.00191	0.00282	0.00122	0.00238	0.00140	0.00143	0.00213	0.00263	0.0192	0.0011	0.0027	0.0018	0.0018	0.0012	0.0023	0.0013	0.0023	0.0018	0.0008	0.0020	0.0024	0.00021	0.019	**0.0016**
Mercury (Hg)-Dissolved	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.0000050	0.0000050	0.000025	**0.0000055**
Molybdenum (Mo)-Dissolved	0.000117	0.000113	0.000104	0.000112	0.000102	0.000120	0.000118	0.000113	0.000115	0.000110	0.000107	0.000092	0.000112	0.000119	0.000104	0.000101	0.000108	0.000106	0.000111	0.000098	0.000108	0.000117	0.000101	0.00011	0.000092	0.00014	**0.00011**
Nickel (Ni)-Dissolved	0.00049	0.00058	0.00049	0.00050	0.00044	0.00047	0.00051	0.00056	0.00053	0.00048	0.00048	0.00051	0.00061	0.00053	0.00069	0.00058	0.00059	0.00074	0.00057	0.00059	0.00060	0.00049	0.00057	0.00052	0.00020	0.053	**0.00163**
Phosphorus (P)-Dissolved	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	**0.15**
Potassium (K)-Dissolved	0.319	0.340	0.329	0.405	0.335	0.344	0.325	0.341	0.358	0.327	0.314	0.322	0.396	0.383	0.359	0.358	0.339	0.361	0.343	0.346	0.347	0.351	0.358	0.33	0.28	1.0	**0.36**
Selenium (Se)-Dissolved	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.000050	0.000050	0.00050	**0.00013**
Silicon (Si)-Dissolved	2.26	2.51	2.47	2.53	2.49	2.50	2.44	2.59	2.70	2.47	2.49	2.45	2.39	2.44	2.48	2.48	2.45	2.50	2.48	2.48	2.44	2.41	2.44	2.4	1.9	2.8	**2.4**
Silver (Ag)-Dissolved	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.0000050	0.0000050	0.0000050	**0.0000050**
Sodium (Na)-Dissolved	1.72	2.02	1.94	3.55	2.30	1.83	1.89	1.96	2.03	1.87	1.82	1.81	1.82	2.17	1.77	1.71	1.77	1.74	1.81	1.73	1.80	1.87	1.75	1.9	1.0	3.6	**1.6**
Strontium (Sr)-Dissolved	0.0466	0.0493	0.0473	0.0492	0.0456	0.0478	0.0487	0.0497	0.0510	0.0464	0.0452	0.0466	0.0443	0.0470	0.0420	0.0415	0.0438	0.0395	0.0450	0.0398	0.0438	0.0469	0.0432	0.047	0.040	0.051	**0.045**
Thallium (Tl)-Dissolved	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000050	**0.000033**
Tin (Sn)-Dissolved	0.00005	0.00026	0.00213	0.00342	0.00173	0.00005	0.00346	0.00176	0.00043	0.00029	0.00215	0.00005	0.00016	0.00054	0.00005	0.00005	0.00027	0.00005	0.00046	0.00005	0.00130	0.00063	0.00005	0.00041	0.000050	0.0035	**0.00042**
Titanium (Ti)-Dissolved	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0050	0.0050	0.0050	**0.0050**
Uranium (U)-Dissolved	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.0000050	0.0000050	0.0000050	**0.0000050**
Vanadium (V)-Dissolved	0.000064	0.000093	0.000068	0.000098	0.000098	0.000082	0.000070	0.000101	0.000088	0.000078	0.000096	0.000142	0.000132	0.000171	0.000154	0.000128	0.000121	0.000160	0.000106	0.000160	0.000123	0.000089	0.000136	0.000094	0.000064	0.00050	**0.00024**
Zinc (Zn)-Dissolved	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.00050	0.0091	**0.0014**

Blue text denotes measured value at limit of method detection and listed as one half method detection limit

Green cells indicate upper outlier