BACK RIVER PROJECT
Responses to Technical Comments for Water Licence (2AM-BRP1831) Amendment

February 12, 2021

BACK RIVER PROJECT

Responses to Water Licence Amendment TCs

Table of Contents

Table of Contents i

1. Responses to Comments 1-1
   - 1.1 Response to Crown-Indignous Relations and Northern Affairs Canada 1-1
     - CIRNA-WLA-TC-01: Saline Water Pond Balance 1-1
     - CIRNA-WLA-TC-02: Hydrodynamic Model 1-3
     - CIRNA-WLA-TC-03: Arsenic concentration in tailings beach sediments 1-4
     - CIRNA-WLA-TC-04: Criteria for segregating PAG and non-PAG rock 1-5
     - CIRNA-WLA-TC-05: Use of containment ponds as tailings facilities 1-6
     - CIRNA-WLA-TC-06: Temporary PAG stockpiles 1-7
     - CIRNA-WLA-TC-07: Quarry site development plans 1-8
     - CIRNA-WLA-TC-08: Additional approved infrastructure in Tailings Management Plan 1-9
     - CIRNA-WLA-TC-09: Saline Water Management Plan title 1-10
   - 1.2 Response to Environment and Climate Change Canada 1-11
     - ECCC-WLA-TC-01: Tailings Production and Storage 1-11
     - ECCC-WLA-TC-02: Tailings Storage Facility 1-12
     - ECCC-WLA-TC-03: Waste Rock Storage Area Design 1-14
     - ECCC-WLA-TC-04: Changes to Outputs of the Water and Load Balance 1-15
     - ECCC-WLA-TC-05: Establishment of Meromixis in Umwelt Reservoir 1-16
     - ECCC-WLA-TC-06: Hydrodynamic Modelling and Water Quality in Goose Lake 1-19
     - ECCC-WLA-TC-07: Inconsistencies in Water and Load Balance 1-20
     - ECCC-WLA-TC-08: Updated Modelling Predictions and Comparison to Water Quality Guidelines 1-22
     - ECCC-WLA-TC-09: Air Quality 1-23

Attachment TC-A: Hydrodynamic and Water Quality Modelling of Goose Lake

Attachment TC-B: Water Quality Projections With Treatment

1. Responses to Comments

1.1 RESPONSE TO CROWN-INDIGNOUS RELATIONS AND NORTHERN AFFAIRS CANADA

CIRNA-WLA-TC-01: Saline Water Pond Balance

Detailed Review Comment

Managing saline groundwater in the short and long term will be one of the challenges of this project. The present plan involves storing saline groundwater in a saline water pond (SWP) for the first three years of operations and subsequently using the mined out Umwelt pit. The mined out pit will also serve as a permanent storage location as a meromictic pit lake (lake having layers with no intermixing), so understanding the inputs to the Umwelt pit/reservoir are important for confirming how meromictic conditions will develop.

CIRNAC's information request (IR) 14 requested more information on the SWP salinity at the time of filling the pit lake, and a discussion on how the final salinity might vary in the SWP both under the present mine plan and in a situation where operations paused for a period of time.

Sabina's response includes figure CIRNAC 14-2 which raises some questions. The dashed line in this figure shows the volume of water in the SWP over time. In the first three years of operation, Umwelt is an operating pit rather than a reservoir able to accept saline water. There should be no outflow other than evaporation from the SWP. Applying the annual evaporation rate of 324 mm stated in the Water and Load Balance model to an estimated lake area of 480,000 m^2 produces only ~155,000 m^3 of evaporation. The SWP volume drops by 200,000 m^3 after year 1 and 250,000 m^3 after year 2, according to the graph's time axis. The increase in pond volume in the third year is also far greater than prior years – presumably due to deeper works intercepting more groundwater. The reasons for the large annual variability in the pond volumes shown in the figure CIRNAC 14-2 in the response document should be examined and better explained.

Recommendation/Request:

1.1) CIRNAC recommends the applicant:

- Detail the reasons for SWP volume decrease prior to the planned transfer of saline water to pit storage in Year 3; and
- Confirm the reasons for the increased rate of SWP filling in the third year.

1.2) CIRNAC recommends the annual comparison of measured groundwater inflow rates to model predictions described in Section 5.1 of the Saline Water Management Plan be included in the annual reports. The Nunavut Water Board could consider adding this requirement to Appendix B of the water licence.

Sabina Response:

Sabina appreciates CIRNAC's recommendations and provides the following responses.

Part 1.1

Figure CIRNA-1-1 shows the Saline Water Pond (SWP) free-water volume, the volume of water stored in the ice cover, and the cumulative evaporation volume. Variations observed in SWP free-water volumes are due to the ice cycle, where the free-water volume decreases during winter months due to formation of surface ice. During the summer, the ice melts and consequently, the volume in the pond increases.

The increase in water losses over time is because evaporation is modelled as a function of pond surface area. The surface area of the SWP increases as the pond fills and consequently evaporation increases.

CIRNAC is correct in presuming the increased rate of SWP filling observed in Year 3 is due to an increase in Umwelt Underground dewatering rate to the SWP.

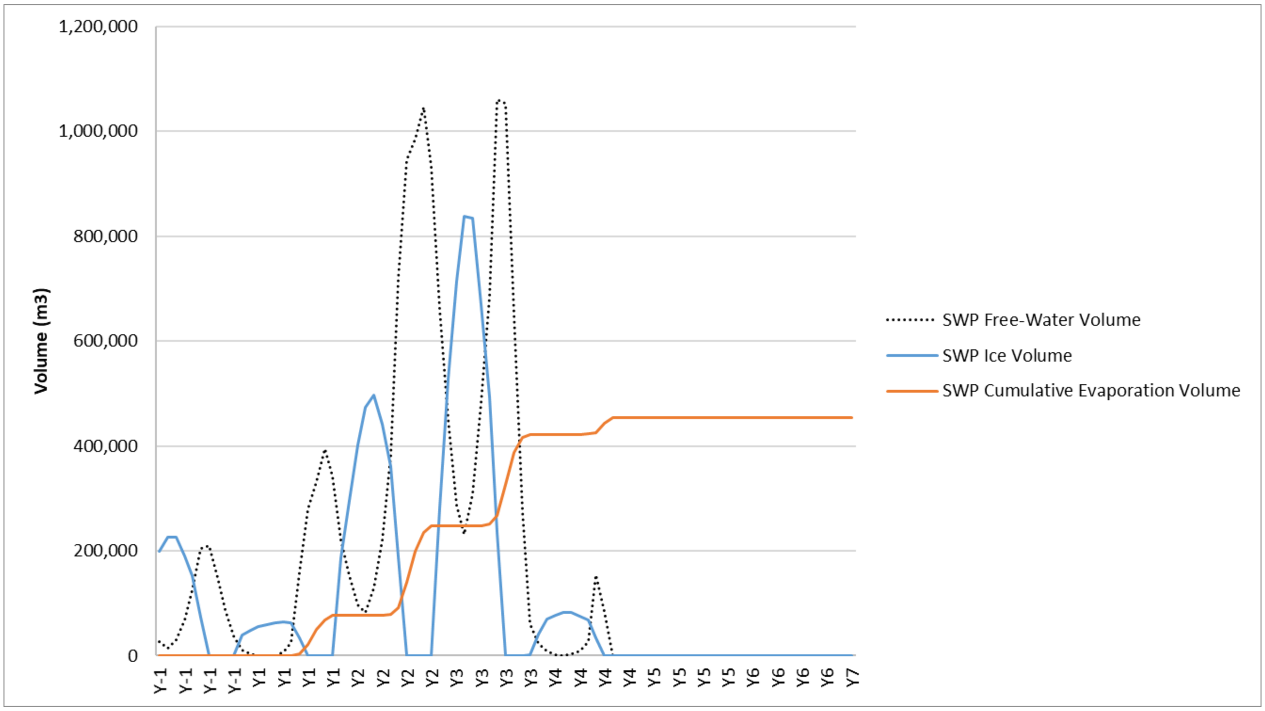


Figure CIRNA-1-1: Saline Water Pond Volumes over time

Part 1.2

Sabina will include an annual comparison of measured groundwater inflow rates to model predictions in the NWB Annual Report, as described in Section 5.1 of the Saline Water Management Plan (2AM-BRP1831, Part B, Item 14p, Appendix C).

CIRNA-WLA-TC-02: Hydrodynamic Model

Detailed Review Comment

Part E, Item 15 b of the current water licence requires Sabina to submit an updated hydrodynamic model. This technical review period is a good opportunity to review the updated model. Additionally, the model results would help validate assumptions used in the Water and Load Balance, such as metal concentrations in Goose Lake.

Recommendation/Request:

CIRNAC recommends the applicant provide an updated hydrodynamic model, which they have committed to do on or before February 15, 2021.

Sabina Response:

Refer to Attachment TC-A, Technical Memorandum Hydrodynamic and Water Quality Modelling of Goose Lake (Golder 2021).

Reference:

Golder (Golder Associates Ltd.). 2021. Technical Memorandum Hydrodynamic and Water Quality Modelling of Goose Lake. Prepared for Sabina Gold & Silver Corp. February 2021. Ref No. 20147072-074-TM-Rev0.

CIRNA-WLA-TC-03: Arsenic concentration in tailings beach sediments

Detailed Review Comment

The Water and Load Balance is used to calculate concentrations of parameters of interest throughout the water system using estimated parameter concentrations for geochemical source terms. The concentration of arsenic in the tailings beach is 5.1 mg/L in Table 4-4 of the 2020 model and 0.54 mg/L in Table 4-4 of the 2017 model. This appears to be a potential typographical error.

Recommendation/Request:

CIRNAC recommends the applicant confirm that the correct value can be found in Appendix C of the report and furthermore that the correct value was used in the modelling.

Sabina Response:

Sabina acknowledges CIRNAC's request and confirms that Table 4-4 Summary of Geochemical Source Terms (2020) did contain some typographical errors. Sabina has included an updated table below, and further confirms that the correct values were used in the Water and Load Balance Model (SRK 2020).

Source Term	Descriptor	Sulphate (mg/L)	Chloride (mg/L)	Arsenic (mg/L)	Copper (mg/L)
Ore Stockpile	Pre-Operation	490	32	0.14	0.012
	Operation	1,900	-	0.27	0.012
	Post-Operation	250	16	0.14	0.012
Waste Rock (unfrozen)	Umwelt	2,100	-	0.22	0.012
	Llama	2,100	-	0.22	0.012
	Goose	2,200	-	0.22	0.012
Waste Rock (frozen)	Umwelt	210	16	0.097	0.012
	Llama	210	16	0.097	0.012
	Goose	250	16	0.096	0.012
Pit Wall	Umwelt	53	6.1	0.23	0.012
	Llama	56	5.9	0.16	0.012
	Goose	40	3.4	0.18	0.012
High Wall	Umwelt	23	1.1	0.054	0.012
	Llama	4	1	0.049	0.0022
	Goose	4	1	0.001	0.0022
Industrial Pads/Roads/Dykes		36	-	0.044	0.0036
Tailings Beach		1,100	5.1	0.081	0.38

Reference:

SRK (SRK Consulting Canada Inc.). 2020. Back River Project Water and Load Balance. Prepared for Sabina Gold & Silver Corp. June 2020. Ref No. 1CS020.018.

CIRNA-WLA-TC-04: Criteria for segregating PAG and non-PAG rock

Detailed Review Comment

The 2020 Mine Waste Rock Management Plan and the 2020 Borrow Pit and Quarry Management Plan describe how potentially acid generating (PAG) and non-PAG rock are to be identified. Though both plans use total sulphur (S) and neutralization potential ratio (NPR – also NP/AP neutralization potential to acid potential) as criteria, the definition of PAG is not consistent between the plans, as presented in the table below.

Management Plan	Section	PAG	Non-PAG
Mine Waste Rock	Table 5.3-1	NPR < 3	NPR > 3 or total S <0.15%
Borrow Pit and Quarry	Figure 8.3-1	NPR < 3 and total S >0.15%	NPR > 3 or total S <0.15%

Recommendation/Request:

CIRNAC recommends the applicant clarify why both NPR and total sulphur are used to define PAG in the Borrow Pit and Quarry Management Plan, and only NPR is used in the Mine Waste Rock Plan.

Sabina Response:

Sabina acknowledges CIRNA's comment and clarifies that the criteria listed in these two management plans should be consistent. This appears to have been a typo and Sabina commits to revise the tables in the next revision of the Mine Waste Rock Management Plan. The 2020 Mine Waste Rock Management Plan should use the following criteria:

Management Plan	Section	PAG	Non-PAG
Mine Waste Rock	Table 5.3-1	NPR < 3 and total S > 0.15%	NPR > 3 or total S < 0.15%
Borrow Pit and Quarry	Figure 8.3-1	NPR < 3 and total S > 0.15%	NPR > 3 or total S < 0.15%

Sabina will address the inconsistency in the next update to the Nunavut Water Board (NWB) in the form of an addendum to be included with the 2020 Annual Report, as required under the Type A Water Licence 2AM-BRP1831 Part B, Item 17, and Part B, Item 2, respectively.

CIRNA-WLA-TC-05: Use of containment ponds as tailings facilities

Detailed Review Comment

The 2020 Modification Package introduces the use of Llama pit to store tailings, which is within the scope the project certificate. The use of mined out pits as tailings storage facilities was considered in general during the initial water licence application. In section 5.2.6 of the 2020 Water Management Plan, Sabina states: *"that all open pits, Umwelt Lake, and other containment ponds may be utilized for mine waste disposal. The licence amendment should be revised to include all four open pits (Umwelt, Llama, Goose Main, and Echo), Umwelt Lake, and other containment ponds as potential tailings facilities."*

Containment pond design criteria as described in sections 6.2 and 6.4 of the Water Management Plan are dependent on the pond's intended use. Broadening potential tailings facilities to all containment ponds could result in storage of tailings in ponds which were not designed and built to an appropriate standard.

Recommendation/Request:

CIRNAC recommends any amended water licence require any ponds converted to tailings facilities be designed for that purpose. CIRNAC notes that additional tailings facilities would need to be captured in the Closure and Reclamation Plan and reclamation cost estimate.

Sabina Response:

Sabina acknowledges CIRNAC's request and confirms that only ponds and facilities which are appropriate for the storage of tailings will be utilized for this purpose. Based on the permitting work competed to date, that includes the Umwelt, Llama, Goose, and Echo open pits, and the Tailings Storage Facility.

Sabina confirms that reclamation costs associated with using the four open pits (Umwelt, Llama, Goose Main, and Echo) for permanent tailings storage is included in the Updated Cost Estimate currently under review with KIA and CIRNAC. Should additional facilities, including other containment ponds be identified in the future for the permanent storage of tailings, Sabina acknowledges that an adjustment to the ICRP and associated Cost Estimate may be required.

Sabina acknowledges CIRNAC's request and notes, as stated in the Tailings Management Plan (TMP; Sabina 2020): "*…Sabina intends to provide the NWB at least 60 days' notice prior to the disposal of waste in any [tailings facilities] and will present the following information: waste disposal quantities, volumes, disposal timing, maximum pit capacity, effects to pit closure, and appropriate mitigation and monitoring plans."*

Reference:

Sabina (Sabina Gold & Silver Corp). November 2020. Back River Project Tailings Management Plan.

CIRNA-WLA-TC-06: Temporary PAG stockpiles

Detailed Review Comment

Updates to the 2020 Borrow Pits and Quarry Management Plan include modifications to section 7.1 "Identification, segregation and placement of quarry rocks", which was section 6.2 in the 2017 version of the plan. Both versions of the plan state PAG will be avoided, but should it be encountered, the new plan proposes: "*PAG quarry rock will be hauled to one of the designated Waste Rock Storage Areas for disposal (per the Waste Rock Management Plan) or temporarily stockpiled until it can be incorporated into these areas.*"

No information was found on how long a temporary stockpile might be kept, or what measures for collecting run-off would be in place. Though tests indicate there should be a lag before acid generation from PAG rock, field results may be different and it would be prudent to monitor the situation

Recommendation/Request:

CIRNAC recommends the applicant provide constraints on the temporary PAG stockpiles they propose, if this is to be an element of their Borrow Pit and Quarry Management Plan. These might include maximum duration of stockpiling or water monitoring measures.

Sabina Response:

Sabina confirms any temporary PAG stockpiles will be located upgradient or within a quarry boundary so that runoff is captured in the quarry footprint. Quarry runoff will be monitored and sampled as required by the Type A Water Licence (2AM-BRP1831 Schedule I, Table 2).

In addition, Sabina highlights that the results from the Geochemical Characterization Report (SRK 2015) that the estimated lag time to the onsite of acidic conditions in the waste rock for the Project are expected to be greater than 10 years in the field (Section 5.2.1 Implications for Waste and Water Management). The temporary PAG stockpiles would be in place for a shorter period of time, and only until it is operationally feasible to relocate the temporary PAG stockpile to the Waste Rock Storage Areas.

Reference:

SRK (SRK Consulting Canada Inc). Geochemical Characterization in Support of the Final Environmental Impact Statement (FEIS) for the Back River Project, Nunavut. Prepared for Sabina Gold & Silver Corp. November 2015. Ref. No. 1CS020.008.

CIRNA-WLA-TC-07: Quarry site development plans

Detailed Review Comment

The 2020 updated Borrow Pit and Quarry Management Plan no longer includes a description and commitment to produce rock quarry development plans before the start of development for each rock quarry. Section 4.5.1 of the 2017 Plan specified a detailed procedure *"will be provided to the NWB 60 days prior to construction"* and listed the information to be included in the site layout and setup.

These quarry specific plans are helpful in understanding specific arrangements for each quarry and used by Water Resources Officers during site inspections.

Recommendation/Request:

CIRNAC recommends the applicant modify the Borrow Pit and Quarry Management to keep their commitment to sharing with the Nunavut Water Board development plans specific for each rock quarry.

Sabina Response:

Sabina acknowledges CIRNAC's request and reconfirms the commitment to provide quarry development plans specific to each rock quarry. This will be included in the next update to the NWB in the form of an addendum to be included with the 2020 Annual Report in accordance with the Type A Water Licence 2AM-BRP1831 Part B, Item 17, and Part B, Item 2, respectively.

Furthermore, to align with the Project Certificate (No. 007), Sabina proposes to provide site-specific quarry operation and management plans thirty (30) days prior to the use of borrow or quarry sites.

CIRNA-WLA-TC-08: Additional approved infrastructure in Tailings Management Plan

Detailed Review Comment

Several updated management plans have been provided with this amendment application. Most updated plans include a section on infrastructure approved under the water licence, but not in the current mine plan. Since those potential infrastructure are not addressed in the current version of the management plans, the section describing them typically includes a statement such as: *"infrastructure that may be reintroduced and reintegrated into the Mine plan*".

The Tailings Management Plan does not include such a section, and it would be helpful for the reader to envisage other tailings infrastructure which have already been considered and approved.

Recommendation/Request:

CIRNAC recommends the applicant include a section on other approved infrastructure in the Tailings Management Plan the next time they update it.

Sabina Response:

Consistent with Sabina's Type A Water Licence (2AM-BRP1831, Part B, Item 17), the Tailings Management Plan (Plan) will next be updated "as required by changes in operation and/or technology and modify the Plan accordingly." Revisions to the Plan will be submitted in the form of an Addendum to be included with the Annual Report as required the Type A Water Licence (2AM-BRP1831 Part B, Item 2) or as otherwise directed by the NWB in determination of the amendment and Sabina will include a section on other approved infrastructure in the Tailings Management Plan.

CIRNA-WLA-TC-09: Saline Water Management Plan title

Detailed Review Comment

The title above the table of the contents of the Saline Water Management Plan is “Mine Waste Rock Management Plan”, which could lead to confusion.

Recommendation/Request:

CIRNAC recommends the applicant use a plan title consistent with the content and how the plan is referred to the next time they update the plan.

Sabina Response:

Sabina acknowledges the inconsistency and will update the title of the Saline Water Management Plan in subsequent versions of the plan. This update will be included as an addendum in the Annual Report in accordance with the Type A Water Licence (2AM-BRP1831 Part B, Item 17).

1.2 RESPONSE TO ENVIRONMENT AND CLIMATE CHANGE CANADA

ECCC-WLA-TC-01: Tailings Production and Storage

Detailed Review Comment

The Proponent states, *"the purpose-built TSF [Tailings Storage Facility] is located on Crown land and in the area of a natural depression about 2 km south of Goose Main Open Pit. Containment will be achieved with construction of a frozen foundation dam with a geosynthetic clay liner (GCL) on the northern end of the facility (TSF Containment Dam),and a small control structure at the south end of the facility (TSF South Dyke). Three small streams and four ponds are located within the footprint of the TSF and will be covered by the facility as shown on 2020 Modification Package Appendix A, Figure 3. A plan view of the TSF Containment Area is shown in Figure A-01."*

It is not clear whether the three streams and four ponds are water bodies frequented by fish that will require listing in Schedule II of the Metal and Diamond Mining Effluent Regulations (MDMER).

Recommendation/Request:

ECCC requests that the Proponent confirm that the three streams and four ponds have been assessed and determined not to be waterbodies frequented by fish.

Sabina Response:

Sabina can confirm that the streams and ponds within the footprint of the Tailings Storage Facility have been appropriately assessed for the presence of fish. This information was considered as part of the Schedule 2 listing process under the Metal and Diamond Mining Effluent Regulations for the Tailings Storage Facility. This information was provided to the Department of Fisheries and Oceans (DFO) and Environment and Climate Change Canada (ECCC) during the Environmental Assessment. The Tailings Storage Facility was published in Gazette 2 on June 10, 2020 and Sabina received notice that this Schedule 2 was completed by Environment & Climate Change Canada in June 2020.

ECCC-WLA-TC-02: Tailings Storage Facility

Detailed Review Comment

The Proponent states, *"During the 2015 drill program, small zones of fractured bedrock (2 to 3 m thick) were found in some of the drill holes near the west abutment of the dam, which may provide a pathway for seepage through the foundation of the dam. However, the thickness of dam bulk fill present in this specific portion of the TSF Dam, as well as along most of the TSF Dam alignment, will far exceed the minimum thermal cover requirement to maintain the underlying overburden materials in a frozen state; therefore seepage is unlikely to occur."*

ECCC notes that the 2-3 m fracture zone is of potential concern, depending on how fractured and altered the zone is. From the above description, it appears that the zone may be highly fractured and could be a major conduit pathway for water. The mitigation of bulk fill will not prevent the flow of water through the zone because the fracture zone connects to a recharge source and may be permeable enough to allow flows. It is also not clear whether the Proponent intends to seal off the fracture zone completely using grout. Bulk fill alone may not be enough to prevent flow through the zone.

ECCC acknowledges the Proponent intends to complete *"Packer testing… in select drillholes to evaluate bedrock hydraulic conductivity."* However, it is unclear whether bedrock hydraulic conductivity test will provide a determination of the hydraulic conductivity of the 2-3 m fracture zone in order to assess the rate of flow through the fracture zone.

Recommendation/Request:

ECCC requests the Proponent:

- Provide clarification on whether the packer testing will provide a determination of the hydraulic conductivity of the 2-3 m fracture zone.
- Provide additional information on how the bulk fill will prevent flow through the 2-3 m fracture zone.

Sabina Response:

Sabina acknowledges ECCC's request and confirms that Sabina is committed to complete an infill geotechnical characterization program at the Tailings Storage Facility (TSF) as outlined in Part D, Item 4 of the Type A Water Licence (2AM-BRP1831). The information from the field characterization will ensure that the design meets the required intent of managing seepage through both the foundation and the body of the TSF Dam.

As outlined in technical comment response, WT-INAC-TRC-16, submitted during the original Type A Water Licence process, Sabina highlights that geotechnical drilling completed to date at the TSF suggests that there are no continuous potential flow pathways. Where fracture zones occur at depth, below overburden, any open void is confined; should water seep into such voids, it will freeze as it has no pathway by which to emerge. If the fractured rock is open (i.e., has no overburden cover), the seepage water entering the void space could well up and emerge as surface seepage. Any such areas will be identified through the proposed further field characterization (noted above and below) in support of final design of the infrastructure, and appropriate engineering mitigation would be adopted into the design.

As noted in technical comment response, WT-INAC-TRC-17, Sabina will conduct percolation testing immediately prior to Tailings Storage Facility (TSF) Dam construction prior to excavating the key trench for the TSF Containment Dam. This is a series of shallow drillholes (approximately 10 m deep) that will be completed using a blast hole drill at close spacing (about 25 m) along both the upstream and downstream extent of the key trench. The drill cuttings from each of the drill holes are collected, logged, sampled. In addition, select samples are tested for salinity and water content (which indicates ice content). Next, a falling head hydraulic conductivity test will be completed on each drill hole, using heated water if conditions require it. This is a standard construction procedure for any frozen dam and the information collected in this fashion confirms foundation excavation depth.

Sabina also notes that a diversion berm, called the TSF WSRA Diversion Berm, will be constructed concurrent with TSF Containment Dam construction, that is intended to collect seepage and runoff from the facility. If, based on this additional characterization, Sabina believes that there remain areas where seepage could occur, Sabina will install the necessary monitoring instrumentation to confirm the performance of the TSF Dam and the TSF WRSA Diversion Berm.

The TSF will also be subject an annual geotechnical inspection completed by a Geotechnical Engineer in accordance with the *Canadian Dam Safety Guidelines* (2AM-BRP1831 Part I, Item 10) as well as seepage and runoff monitoring from the TSF (2AM-BRP1831 Schedule B, Item 8). Should these annual inspections or seepage monitoring confirm that addition mitigation is required at the TSF, Sabina will respond accordingly to verify the facility meets all performance and Project water quality guidelines prior to any discharge entering the receiving environment.

ECCC-WLA-TC-03: Waste Rock Storage Area Design

Detailed Review Comment

In section 5.4.1.1 (Umwelt Waste Rock Storage Area), the Proponent indicates, *"One small stream and two ponds are located within the footprint, or immediately upstream, of the Umwelt WRSA and will be covered by the facility (2020 Modification Package Appendix A, Figure 3). The stream and ponds are less than 2 m deep and freeze to the bottom annually during winter."* In section 5.4.1.3 (Tailings Storage Facility Waste Rock Storage Area), the Proponent indicates, *"Three small streams and four ponds are located within the footprint of the TSF WRSA and will be covered by the facility (2020 Modification Package Appendix A, Figure 3). Except for one pond, these streams and ponds are less than 2 m deep and freeze to the bottom annually in winter."*

It is not readily clear whether the streams and ponds referred to above are water bodies that are frequented by fish. If they are water bodies frequented by fish, they will likely require listing in schedule II of the MDMER

Recommendation/Request:

ECCC requests the Proponent confirm they have assessed the streams and ponds in the Umwelt Waste Rock Storage Area and Tailings Storage Facility Waste Rock Storage Area, and determined the streams and ponds are not water bodies frequented by fish.

Sabina Response:

Sabina can confirm that the streams and ponds within the footprint of the Umwelt Waste Rock Storage Area (WRSA) and the Tailings Storage Facility WRSA have been appropriately assessed for the presence of fish. This information was provided to the Department of Fisheries and Oceans (DFO) and Environment and Climate Change Canada (ECCC) during the Environmental Assessment. The Tailings Storage Facility was published in Gazette 2 on June 10, 2020 and Sabina received notice that this Schedule 2 was completed by Environment & Climate Change Canada in June 2020.

ECCC-WLA-TC-04: Changes to Outputs of the Water and Load Balance

Detailed Review Comment

In response to ECCC-4 and CIRNAC-8, the Proponent has provided a table outlining the changes in model assumptions from the 2015 model to the 2020 Modification package. However, the response does not outline how the changes in model assumptions have influenced the outputs of the modelling compared to the 2015 prediction. A comparison of the updated 2020 modification outputs (water quality concentrations) to the 2015 model at key modelling nodes provides a more fulsome understanding of how the changes to the mine plan and corresponding changes to assumptions in the Water and Load Balance have resulted in changes to water quality on site.

Recommendation/Request:

ECCC recommends that the Proponent provide a comparison of changes in outputs from the water and load balance (changes to water quality) as a result of the changes to model assumptions included as part of the 2020 Modification.

Sabina Response:

Sabina acknowledges ECCC's request and has provided Table ECCC-4-1 for consideration. This table includes a comparison of water and load balance modelling outputs for key water quality parameters from the 2015 and 2020 models. Notes have also been included to provide context on the table values.

Table ECCC-4-1: Water and Load Balance Model Outputs for Key Parameters - 2015 and 2020

Parameter	2015 Model Results				2020 Model Results[1]			
	PN04		PN06		PN04		PN05[2]	
	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Sulphate[3]	20	47	21	260	11	690	11	35
Chloride	2	180	0.95	82	1.6	59	0.82	3
Total Ammonia (as N)[4]	DL	0.96	DL	0.24	DL	11	DL	0.26
Total Arsenic	0.0065	0.0096	0.0057	0.023	0.0021	0.021	0.0031	0.0098
Total Copper	0.0019	0.0021	0.0019	0.0041	0.00066	0.0087	0.00077	0.0025

Notes:

1. Differences in projections between the 2015 and 2020 models for arsenic, copper, and chloride are attributed to changes in the mine plan and various model assumptions. The model assumptions are summarized in Table CIRNA-8-1 of IR Response, CIRCA-WLA-IR-08.
2. PN06 in the 2015 model corresponds to PN05 in 2020 model.
3. The 2020 model predicts higher sulphate concentrations because it includes the sulphate load resulting from NaS_2O_5 used in the Process Plant for cyanide destruction.
4. The 2020 model predicts higher ammonia concentrations because it includes the ammonia load resulting from degradation of cyanide reagents added in the Process Plant.

ECCC-WLA-TC-05: Establishment of Meromixis in Umwelt Reservoir

Detailed Review Comment

In response to ECCC-3 the Proponent provided additional rationale for their assumption that meromixis will establish and remain stable within Umwelt reservoir. In the previously approved mine plan, Llama was intended to be used for saline water management, and analysis was completed on the overall stability of the meromixis in this pit. During the previously approved plan, "meromixis in Llama Pit (then called Llama Reservoir) is initiated with a large inflow of freshwater (839,700 m3) and melting ice cover (estimated 1.1 m of ice) from breaching the surrounding Llama management structures in Year 4. The melting ice and freshwater inflow result in a freshwater cap of approximately 7.5 m over the surface of the reservoir." However, while the ice thickness and surface area of Umwelt is similar to Llama, the 2020 modification indicates that Umwelt will require additional inflow of freshwater at surface to develop meromixis. As noted by the Proponent, Umwelt reservoir will receive approximately 350,000 m3 of freshwater from the Primary Pond Breach in Year 3, resulting in a freshwater cap of 3 m.

Due to the reduction in initial freshwater cap (previously 7.5m, now 3m) as well as reductions in annual inputs due to runoff (previously 839,700m3, now 350,000 m3) it is unclear whether the two layers will remain stratified during the filling of the pits due to the lower annual inputs and increased time for mixing/diffusion between the layers. According to the water and load balance (Section 6.4) the 95th percentile volume of saline water that would be deposited into Umwelt Reservoir is 3,486,000 m3. The Proponent does not discuss how this volume may differ from the Approved Project, which describes depositing saline water into Llama Pit (more/less saline water) or how the these changes to the initial conditions and filling over time may impact the potential to develop meromixis.

In the previous analysis of establishment of meromixis in Llama Pit that is referenced, the potential for stratification is examined once the pit has filled, assuming that the energy of deposition was dissipated, and that the freshwater cap is 55 m thick over a lower saline layer 75 m thick. It is not discussed whether the thickness of the freshwater cap over the thickness of saline layer continues to be applicable to the Umwelt Pit.

Recommendation/Request:

ECCC recommends that the Proponent:

- Provide a discussion of how the changes to the initial conditions and reduced annual freshwater inputs may impact the development of meromixis in Umwelt pit as compared to Llama pit.
- Provide information on the final ratio of freshwater to saline water in Umwelt Pit as compared to Llama Pit.

Sabina Response:

The establishment of meromictic conditions is dependent on the density gradient between the freshwater cap and the underlying hypersaline layer. The Wedderburn Number can be used to assess the resistance of Umwelt Lake to wind mixing.

The Wedderburn Number (W) measures the balance between wind forcing and buoyancy force and is used to estimate the amount of upwelling in a lake. A Wedderburn Number equivalent to 1.0 is the minimum value at which stratification can be expected to be maintained. For $W >> 1$, the buoyancy force is much greater than the wind stress and there is strong stratification. For $W << 1$, there is a high probability that the chemocline will tilt at the upwind end of the lake and underlying water will be entrained into the surface layer. Wedderburn number is written as:

$$W = \frac{g' z_e^2}{u_*^2 L_s}$$

where $g' = g\Delta\rho/\rho_h$ is the reduced gravity due to density difference ($\Delta\rho$) between the monimolimnion (ρ_h) and mixolimnion (ρ_e), z_e is the depth of the mixolimnion, L_s is the fetch length (400 m), u_* is the shear velocity at the air-water interface given as:

$$u_* = \sqrt{\frac{\tau_w}{\rho_e}}$$

where $\tau_w = C_D \rho_{air} U^2$ is the wind shear on the water surface calculated using ρ_{air} – the density of air (1.3 kg/m^3), C_D – the drag coefficient (1.5x10^{-3}), and U – the wind speed at 10 m above the water surface. A wind analysis of the Project indicates a 1000-year wind speed up to 38.4 m/s (SRK 2015).

The density (ρ) of each layer can be estimated by a simplified equation of state:

$$\rho = 1000 - 0.008(T-4)^2 + 0.8S$$

where T is the water temperature and S is the salinity (approximated as total dissolved solids [TDS]). A timeseries of the TDS of each layer is shown in Figure ECCC-5-1. For a hypersaline concentration of 26,000 mg/L and a freshwater TDS concentration of 450 mg/L, and assuming an isothermal system at 4°C, the density of the hypersaline and freshwater layers was calculated as 1020.69 kg/m^3 and 1000.37 kg/m^3, respectively.

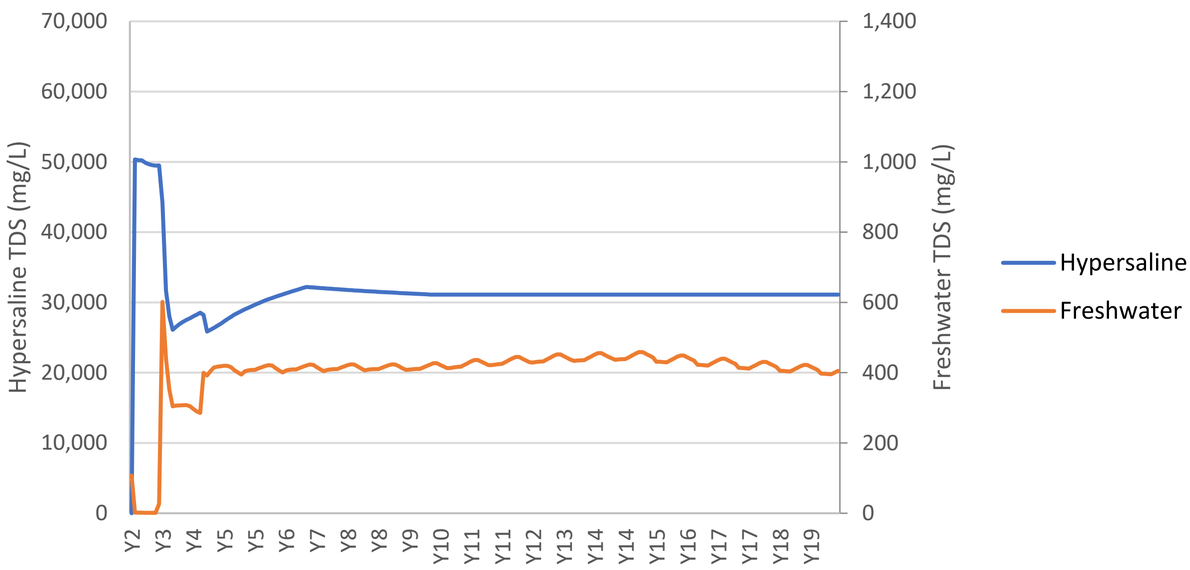


Figure ECCC-5-1: TDS concentrations of Umwelt Reservoir layers

Sabina notes that how projected TDS values are calculated in the water and load balance model has been improved since the original Type A Water License process. TDS was previously modelled in GoldSim assuming conservation of mass. Projections are now calculated as shown in the formula:

TDS Calculated = 1.22[Total Alkalinity]+[Na^+]+[Mg^+]+[K^+]+[Ca^{2+}]+[SO_4^{2-}]+[Cl^-]+4.43*[NO_3_N]+[$Si(OH)_3O^-$].*

Sabina highlights that the 1.22 value in the above formula is the conversion from total alkalinity to bicarb, taking into account the charge balance. The alkalinity source terms remain the same, and as determined by the Project's geochemistry.

For a 3-m freshwater cap, the Wedderburn Number is 2.1, which indicates a relatively strong vertical stratification with limited shear/mixing at the density gradient.

Overtime, the freshwater cap is expected to deepen from the seasonal influx of surface runoff, further enhancing the meromictic stability. Figure ECCC-5-2 shows the ratio of volumes between the freshwater and hypersaline layers in Umwelt Reservoir. Initially, the freshwater layer is thin compared to the hypersaline layer but continues to deepen seasonally, in advance of, and until, Umwelt Reservoir begins to overflow in Year 11.

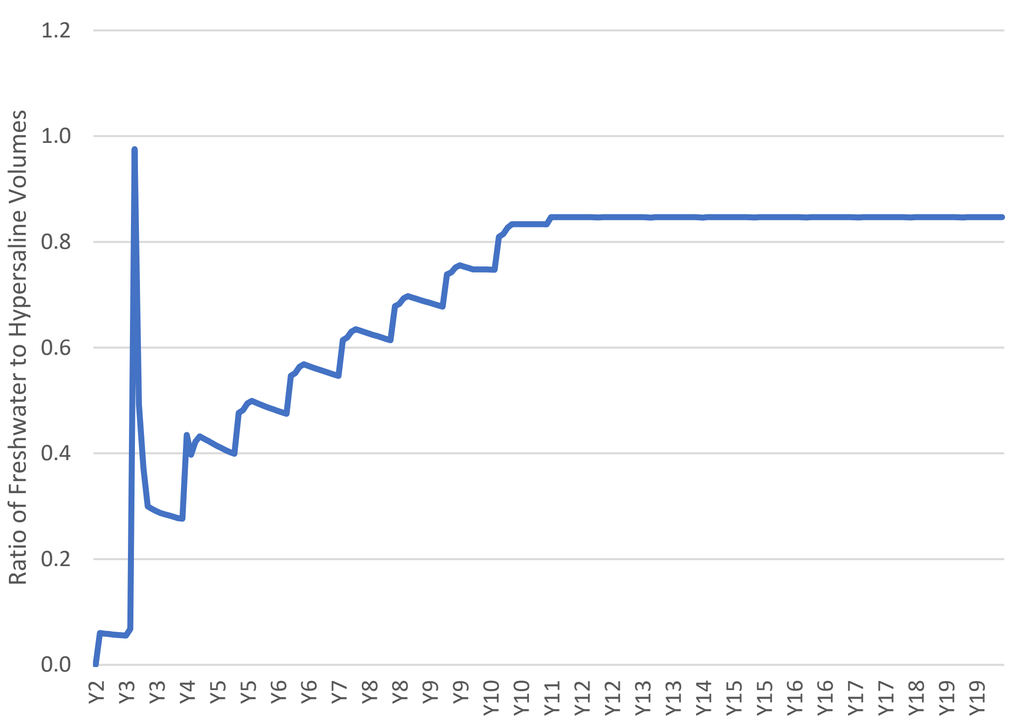


Figure ECCC-5-2: Ratio of Umwelt Reservoir Freshwater and Hypersaline Layer Volumes

To provide a Wedderburn Number equivalent to 1.0, the minimum value in which stratification can be expected to be maintained, the TDS concentration in the hypersaline layer would need to be reduced to approximately 13,000 mg/L. Monitoring of the TDS concentrations in the Saline Water Pond will be included in order to ensure that the minimum TDS concentrations are achieved prior to dewatering to the Umwelt Reservoir. In the event that TDS concentrations are less than the minimum required to facilitate a Wedderburn Number of 1.0, additional mitigation measures, including development of a thicker freshwater cap, may be incorporated to increase stability of the meromictic system.

Sabina will monitor the Umwelt Reservoir during the open water season to ensure the freshwater cap is maintained. Should monitoring indicate additional freshwater is required to maintain the meromixis in Umwelt Reservoir, Sabina may increase the freshwater cap thickness by pumping from other freshwater sources available, if required.

ECCC-WLA-TC-06: Hydrodynamic Modelling and Water Quality in Goose Lake

Detailed Review Comment

In KIA-11, additional information was requested on the extent of elevated water quality concentrations within Goose Lake as water from PN-04 and PN-05 moves through towards PN-03. In addition, this comment requested additional clarity on what "maximum" represents in the tables provided in Appendix D of the Water and Load Balance (maximum concentration vs. maximum average monthly concentrations). In response, the Proponent has identified that the location within Goose Lake where quality will meet water quality guidelines (CCME and site-specific water quality objectives (SSQWO)) has not yet been determined and will be proposed based on results of ongoing hydrodynamic modelling and mixing zone assessment. In addition, maximum values provided in the water and load balance are maximum monthly average concentrations.

CIRNAC-11 also requested additional details regarding upcoming hydrodynamic modelling, and in response, the Proponent stated that the hydrodynamic model will be provided during the review process for this amendment application prior to the technical meeting.

ECCC notes that while the modelling results presented in Attachment IR-C (Water Quality Prediction Results) are consistent with the statement provided by the Proponent that SSWQO are met at PN-03 (maximum average - Arsenic = 0.009219 mg/, copper = 0.004088 mg/L), the predicted concentrations for Goose Lake are above the SSWQO for both arsenic and copper (maximum averages of 0.01875 mg/L and 0.009474 mg/L, respectively). Given that this modelling indicate that exceedances of the SSWQO in Goose Lake are expected, a completed hydrodynamic model would aid reviewers in understanding the extent of water quality above guidelines within Goose Lake.

Recommendation/Request:

ECCC supports the submission of an updated hydrodynamic model in advance of the technical meeting in order to aid in interpretation of modelling results and understanding of the extent of aquatic impacts within the Project Area.

Sabina Response:

Refer to Attachment TC-A, Technical Memorandum Hydrodynamic and Water Quality Modelling of Goose Lake (Golder 2021).

Reference:

Golder (Golder Associates Ltd.). 2021. Technical Memorandum Hydrodynamic and Water Quality Modelling of Goose Lake. Prepared for Sabina Gold & Silver Corp. February 2021. Ref No. 20147072-074-TM-Rev0.

ECCC-WLA-TC-07: Inconsistencies in Water and Load Balance

Detailed Review Comment

In the completeness review and as outlined in ECCC-5, ECCC identified several anomalies in the data presented in Appendix D of the Water and Load Balance including: unrealistically high concentrations, inconsistencies with data presented in the body of the report, and modelling outputs appearing to not incorporate treatment in "with treatment" scenarios. In response, the Proponent has provided an updated Appendix D in Attachment IR-C.

Upon review of the data provided in Attachment IR-C, there still are inconsistencies in the data presented that potentially question that validity of the conclusions made from this modelling. For example:

- Umwelt Reservoir
  - Maximum concentration
    - Nitrite = 10 mg/L
    - Mercury = 0.89 mg/L
  - Maximum concentration (with treatment)
    - Nitrite = 276 mg/L
    - Mercury = 167.4 mg/L

In the example above, it is unclear how the maximum concentrations presented for the same modelling node could be so substantially different between the "with" and "without" treatment scenarios. In addition, although the differences in concentration are large, the 'with-treatment' modelling concentrations are higher than the 'without.' It is unclear whether these potential errors are prevalent throughout the model and therefore impact all model nodes or if potential errors are limited to a small number of inputs or parameters. In addition, it is unclear how potential errors in the modelling have influenced other model outputs and the interpretation of water quality conditions related to the Project.

Recommendation/Request:

ECCC recommends the Proponent review the outputs of the water balance model presented in Attachment IR-C to ensure that information presented is accurate.

Sabina Response:

Sabina reviewed the referenced outputs of the water balance model that were presented in Attachment IR-C of the Water Licence Amendment Information Request Response Package (Sabina 2020).

Sabina confirms the inconsistences observed were typographical errors only. Sabina further confirms that these errors were not carried into, and did not affect, model results; the model were rechecked to confirm this conclusion.

Sabina has provided updated outputs for the water and load balance model in Attachment TC-B.

Sabina notes that how projected TDS values are calculated in the water and load balance model has been improved since the original Type A Water License process. TDS was previously modelled in GoldSim assuming conservation of mass. Projections are now calculated as shown in the formula:

$$TDS\ Calculated = 1.22*[Total\ Alkalinity]+[Na^+]+[Mg^+]+[K^+]+[Ca^{2+}]+[SO_4^{2-}]+[Cl^-]+4.43*[NO_3\_N]+[Si(OH)_3O^-].$$

Sabina highlights that the 1.22 value in the above formula is the conversion from total alkalinity to bicarb, taking into account the charge balance. The alkalinity source terms remain the same, and as determined by the Project's geochemistry.

Reference:

Sabina (Sabina Gold & Silver Corp.). 2020. Back River Project Responses to Information Requests for Water Licence (2AM-BRP1831) Amendment. Submitted to Nunavut Water Board. November 30, 2020.

ECCC-WLA-TC-08: Updated Modelling Predictions and Comparison to Water Quality Guidelines

Detailed Review Comment

The Water and Load Balance indicates that water quality at PN04 and PN05 will meet MDMER criteria and that PN03 will meet SSWQO. However, ECCC notes that SSWQO are only included for arsenic and copper and therefore the Water and Load Balance does not address whether CCME water quality guidelines for the protection of aquatic life will be met at PN03. In addition, there is no discussion provided on expected water quality compared to guidelines, SSWQO, or other criteria for any of the other modelling nodes or modelled water bodies included in the Water and Load Balance.

In response to ECCC-5, the Proponent has provided updated output concentrations from the water and load balance addressing inconsistencies and incorrect assumptions that were identified in the completeness review (Attachment IR-C). Although predicted PN03 (with treatment) water quality does not exceed the SSWQO for copper or arsenic, the predicted maximum average concentrations exceed several CCME water quality guidelines (e.g., aluminum, nitrate, nitrite, iron, mercury). In some cases (nitrite, mercury), these concentrations are considerably above guidelines, in the range where serious effects to aquatic life may be expected and call into question the validity of the model outputs. However, if these exceedance of guidelines are accurate this represents a large deterioration in water quality at PN03 compared to the Approved Project, and the impact of such concentrations to aquatic life have not been discussed or evaluated by the Proponent.

PN03 is specifically used as example for this comment given that the Proponent stated that SSWQO would be achieved at this point. However, ECCC also notes that additional modelling nodes also indicate maximum average concentrations exceeding CCME Water Quality Guidelines. Additional clarity on guideline exceedances should be provided for all nodes where CCME/SSWQO are applicable.

Recommendation/Request:

ECCC recommends the Proponent:

- Clarify which modelling nodes are intending to meet which criteria (eg. CCME, SSWQO, MDMER, etc.) and provide clear comparison of modelled water quality to the relevant guidelines and criteria;
- Provide a discussion of sources of exceedances of CCME Water Quality Guidelines for the Protection of Aquatic life and whether assumptions used in the model have resulted in accurate predictions of water quality;
- Provide a discussion of the modelled exceedances of CCME Water Quality Guidelines for the Protection of aquatic life at PN03 and other relevant nodes, and potential impacts to aquatic life if these concentrations are realized.

Sabina Response:

Refer to Attachment TC-A, Technical Memorandum Hydrodynamic and Water Quality Modelling of Goose Lake (Golder 2021).

Reference:

Golder (Golder Associates Ltd.). 2021. Technical Memorandum Hydrodynamic and Water Quality Modelling of Goose Lake. Prepared for Sabina Gold & Silver Corp. February 2021. Ref No. 20147072-074-TM-Rev0.

ECCC-WLA-TC-09: Air Quality

Detailed Review Comment

The Proponent notes that the upgraded gravel sections of the winter ice road will be negligible contributors of fugitive dust emissions. The Proponent relies on appropriate emissions guidance to reach this conclusion and no further comment is required at this time.

Recommendation/Request:

n/a

Sabina Response:

Sabina thanks ECCC for their comment.

Attachment TC-A: Hydrodynamic and Water Quality Modelling of Goose Lake

TECHNICAL MEMORANDUM

DATE February 12, 2021 **REFERENCE No.** 20147042-074-TM-Rev0

TO Merle Keefe
Sabina Gold & Silver Corp.

CC Matthew Pickard (Sabina); Dionne Filiatrault, Jen Range (Golder)

FROM Shadi Dayyani and Greg Rose **EMAIL Shadi_Dayyani@golder.com; Greg_Rose@golder.com**

HYDRODYNAMIC AND WATER QUALITY MODELLING OF GOOSE LAKE

1.0 INTRODUCTION

Sabina Gold & Silver Corp. (Sabina) owns the Back River Project (the Project), which is located in the West Kitikmeot Region of Nunavut. The Project is a proposed open pit and underground gold mine with an estimated 28-year life from mobilization to post-closure. Water associated with mine-affected discharges to the receiving environment (Goose Lake) are not planned to occur until Year 11 of the operational period.

1.1 Background

Sabina (2015) submitted the Final Environmental Impact Assessment (FEIS) in 2015, which included a three-dimensional (3-D) hydrodynamic model of Goose Lake prepared by Rescan (2015) to predict arsenic concentrations for all Project phases. The Nunavut Water Board (NWB) subsequently issued a Type A Water Licence for the Project, signed by the Minister of Crown-Indigenous Relations in November 2018.

Sabina is in the process of amending the current Type A Water Licence (2AM-BRP1831) and submitted the Modification Package for the Project to the NWB in October 2020 (Sabina 2020a). Per Part E, Item 15 of the Type A Water Licence (2AM-BRP1831), Sabina is to provide an updated three-dimensional (3-D) hydrodynamic and water quality model of Goose Lake. As part of the updated modelling work, Golder Associates Ltd. (Golder) upgraded the previous version of the model developed by Rescan (MIKE3) for the FEIS to MIKE3 Flexible Mesh (FM), which included enhanced spatial resolution. This model update was calibrated using monitoring data collected under the framework of the FEIS (Sabina 2015) and Aquatic Baseline Synthesis Report (Golder 2019) and run to predict concentrations of water quality constituents with water quality benchmark.

1.2 Objective

The main objective of this study was to predict water quality constituent concentrations at the outlet of Goose Lake and identify constituents of potential concern as a result of mine discharges and water withdrawals at key stages of the life of mine. For the purposes of this assessment, constituents of potential concern are being identified as constituents with concentrations that are predicted to approach or exceed water quality benchmarks at the lake outlet.

1.3 Report Structure

This document presents the methods, data inputs, water quality criteria, assumptions, and results of the upgraded 3-D hydrodynamic and water quality model of Goose Lake prepared to support the Type A Water Licence Amendment.

- Section 2.0 of this report describes the approach, inputs, and model assumptions used to develop the Goose Lake hydrodynamic and water quality model.
- Section 3.0 describes the calibration process used to optimise performance of the model.
- Section 4.0 lists model assumptions and uncertainties.
- Section 5.0 present future simulations specifications and model results.
- Section 6.0 presents the key findings of this study.

2.0 METHODS

2.1 Model Platform

Several lake processes are of potential relevance to constituent fate and behaviour in Goose Lake, including lake water balance, lake circulation, and chemical and temperature stratification. Accordingly, a 3-D free-surface finite volume flow model platform was applied for this study that can integrate these processes to enhance our understanding of constituent fate and behaviour.

The 3-D hydrodynamic and water quality model of Goose Lake (here after referred to as "the Goose Lake Model") was developed in MIKE3 FM. MIKE is a hydrodynamic modelling platform, produced by the Danish Hydraulic Institute (DHI), that combines several computational components in either two-dimensional (2-D) or 3-D environments. This modelling platform provides 3-D simulation of hydrodynamics, thermodynamics, and dispersion-advection within lakes. MIKE's built-in capability to couple the hydrodynamic module with a dispersion module enables MIKE3 to provide an accurate and efficient way of tracking plumes and assessing lake circulation and mixing potential.

The hydrodynamic module simulates unsteady three-dimensional flows as a result of meteorology, density variations, bathymetric changes, currents, Coriolis forcing, and other hydrographic conditions (DHI 2017). The governing equations for MIKE3 correspond with the mass conservation equation and 3-D Reynolds-averaged Navier-Stokes equations including a turbulence closure (hydrodynamic equations resolved in the hydrodynamic module) and the salinity and temperature conservation equations (advection-dispersion equations resolved in the transport module) (DHI 2017).

For Goose Lake, MIKE3 FM was configured for increased mesh resolution in the vicinity of the discharge and near-shore areas, while limiting computational intensity in areas of less focus. Water quality predictions were simulated using MIKE's transport module, which simulates the advection-dispersion transport of conservative water quality constituents. Each modelled water quality constituent was represented by a generic conservative constituent for all natural and mine-affected inflows to Goose Lake. Water quality constituents were assumed to behave conservatively in the water column, which means that they would not undergo chemical reactions (e.g., precipitation) or physical processes (e.g., settling).

2.2 Modelling Periods

Two modelling periods were used in the Goose Lake Model:

- **Calibration Period:** 2012 to 2013. The model was initialised in fall 2011 before lake freeze-up to accommodate a warm-up period. The model was subsequently calibrated against monitoring data collected during both ice-cover and open-water seasons for 2012 and 2013. During this period, all inflows to the lake remained natural and there was no discharge from the Project to Goose Lake.
- **Forecast Periods:** Project mining Year 11 to 25 (SRK 2020, Appendix A). This period includes the final two years of operation, eight years of closure, and five years of post-closure (as discharge quality is expected to improve after closure). This specific timeframe was used in the modelling as this is the period that site contact water will be discharged to Goose Lake. The model forecast simulation was initialised in fall of Year 10 of operations prior to lake freeze-up to accommodate a warm-up period.

In both modelling periods, a warm-up period was included to provide sufficient time for the model to reach dynamic equilibrium before simulation results were used for comparison against measured data or for future predictions.

2.3 Screening Criteria

Model predictions for Goose Lake were compared to selected water quality benchmarks for the protection of aquatic life (Table 1) which considered:

- Acute and chronic Canadian Council of Ministers of the Environment Canadian aquatic life guidelines (CCME 1999), with the exception of copper and arsenic.
- Chronic site-specific water quality objectives (SSWQO) for copper (Golder 2016) and arsenic (Appendix E1 of Sabina 2017).

Table 1: Water Quality Benchmarks

Parameter[(a)]	Unit	CCME Aquatic Life Guideline or SSWQO[(b)]		
		Acute	Chronic	SSWQOs
Major Ions				
Chloride	mg/L	640	120	-
Fluoride	mg/L	-	0.12	-
Nutrients				
Nitrate	mg-N/L	124	2.9	-
Nitrite	mg-N/L	-	0.06	-
Ammonia	mg-N/L	-	timeseries (2-9.5)[(c)]	-
Total Metals				
Aluminum	mg/L	-	0.005 or 0.1[(d)]	-
Arsenic	mg/L	-	-	0.01
Boron	mg/L	29	1.5	-
Cadmium	mg/L	timeseries (0.00029 - 0.004) [(e)]	timeseries (0.000036-0.00037)[(e)]	-
Chromium	mg/L	-	0.001[(f)]	-
Copper	mg/L	-	-	0.0042
Iron	mg/L	-	0.3	-
Lead	mg/L	-	timeseries (0.001-0.007)[(e)]	-

Parameter[a]	Unit	CCME Aquatic Life Guideline or SSWQO[b]		
		Acute	Chronic	SSWQOs
Mercury	mg/L	-	0.000026	-
Molybdenum	mg/L	-	0.073	-
Nickel	mg/L	-	timeseries (0.025 - 0.15)[e]	-
Selenium	mg/L	-	0.001	-
Silver	mg/L	-	0.00025	-
Thallium	mg/L	-	0.0008	-
Uranium	mg/L	0.033	0.015	-
Dissolved Metals[g]				
Manganese	mg/L	timeseries (1.2 - 11.7)[e]	timeseries (0.19 - 0.62)[h]	-
Zinc	mg/L	timeseries (0.021 - 0.18)[i]	timeseries (0.0087 - 0.06)[j]	-
Other				
Cyanide	mg/L	-	0.005	-

CCME = Canadian Council of Ministers of the Environment. $CaCO_3$ = calcium carbonate; - = guideline not available; DOC = dissolved organic carbon.

Note:

- Values of pH and DOC used to calculate pH and DOC dependent guidelines were based on data collected in Goose Lake during open-water conditions (2011 to 2018) presented in the Aquatic Baseline Synthesis Report (Golder 2019).
- Values of temperature and hardness used to calculate temperature and hardness dependent guidelines were based on the predicted value of temperature or hardness from the model. The range in the predicted timeseries of guidelines from Year 11 to Year 25 at the lake outlet are shown for guidelines that are temperature or hardness dependent.

(a) Only parameters with water quality guidelines or objectives are included in this table.

(b) CCME (1999), with the exception of two site-specific water quality objectives for copper (Golder 2016) and arsenic (Appendix E1 of Sabina 2017).

(c) Guideline is temperature and pH dependent. The range in the guideline is shown based on the range of predicted temperatures at the lake outlet (0 to 20ºC) from the model and a pH 7.3, which was the maximum pH value in the baseline data during open-water conditions (2011 to 2018).

(d) Guideline is pH dependent. The 5 µg/L guideline corresponds to a pH less than 6.5 and 100 µg/L corresponds to a pH greater than or equal to 6.5. The minimum guideline is shown based on the minimum pH of 5.2 in the baseline data during open-water conditions (2011 to 2018).

(e) Guideline is hardness dependent. The range in the guideline is shown based on a range in predicted hardness (14 to 190 mg/L at the lake outlet, as $CaCO_3$) calculated from predicted calcium and magnesium concentrations in the model.

(f) Guideline is for chromium VI.

(g) Predicted concentrations of total manganese and zinc were conservatively compared to guidelines for the dissolved fractions of these two metals.

(h) The chronic dissolved manganese guideline is pH and hardness dependent. The range in the guideline shown is the lowest chronic guidelines based on a minimum pH of 5.2 or maximum pH of 7.3 in the baseline data during open-water conditions (2011 to 2018) and the range in predicted hardness at the lake outlet (14 to 190 mg/L, as $CaCO_3$) calculated from predicted calcium and magnesium concentrations in the model.

(i) The acute dissolved zinc guideline is hardness and DOC dependent. The range in the guideline shown is the lowest acute guidelines based on a minimum DOC concentration of 3.5 mg/L in the baseline data during open-water conditions (2011 to 2018) and the range in predicted hardness at the lake outlet (14 to 190 mg/L, as $CaCO_3$) calculated from predicted calcium and magnesium concentrations in the model.

(j) The chronic dissolved zinc guideline is pH, hardness and DOC dependent. The range in the guideline shown is the lowest chronic guidelines based on a maximum pH of 7.3 and minimum DOC concentration of 3.5 mg/L in the baseline data during open-water conditions (2011 to 2018), and the range in predicted hardness at the outlet (14 to 190 mg/L, as $CaCO_3$) calculated from predicted calcium and magnesium concentrations in the model.

2.4 Model Inputs

Inputs to the Goose Lake Model and their data sources are described in this subsection. Model inputs are categorized into bathymetric, meteorological, hydrological, and water quality data.

2.4.1 Bathymetric Data

A critical aspect of any hydrodynamic model involves achieving a reasonably accurate representation of the shape, depth, and volume of the modelled waterbody. Model segmentation is the process of discretizing the physical domain of a water body into small cells that can be used by the model to iteratively calculate variables at all locations within the lake, and to propagate momentum and mass among and between cells during each time step of the simulation. This discretized model domain is defined as the mesh. A 3-D mesh of Goose Lake was developed using bathymetric data provided by Sabina (Sabina 2020c), which includes the location of inflows from natural lakes and tributaries, and discharges from the Project. The mesh used to represent lake bathymetry consisted of a combination of unstructured triangular and quadrangular cells ranging in size to provide sufficient resolution around points of interest (e.g., discharge points and the channels located at neck of the lake) by using the MIKE3 FM capability (Figure 1). The cell sizes vary from approximately 20 m, close to mine affected discharges, to approximately 150 m in the middle of the lake. Horizontally, the mesh is represented by 706 cells (on the surface) which covers the footprint of Goose Lake up to the land-water boundary (lake surface area of 3.27 km^2). Vertically, the model domain includes the entire volume of Goose Lake (11 Mm^3). Figure 1 presents the mesh and location of inflows to Goose Lake (used for calibration and forecast periods), and location of the lake outflow. The comparison of hypsographic curves developed for the Goose Lake Model and from the bathymetric map are presented in Figure 2, which demonstrate reasonable representation of the lake surface and volume.

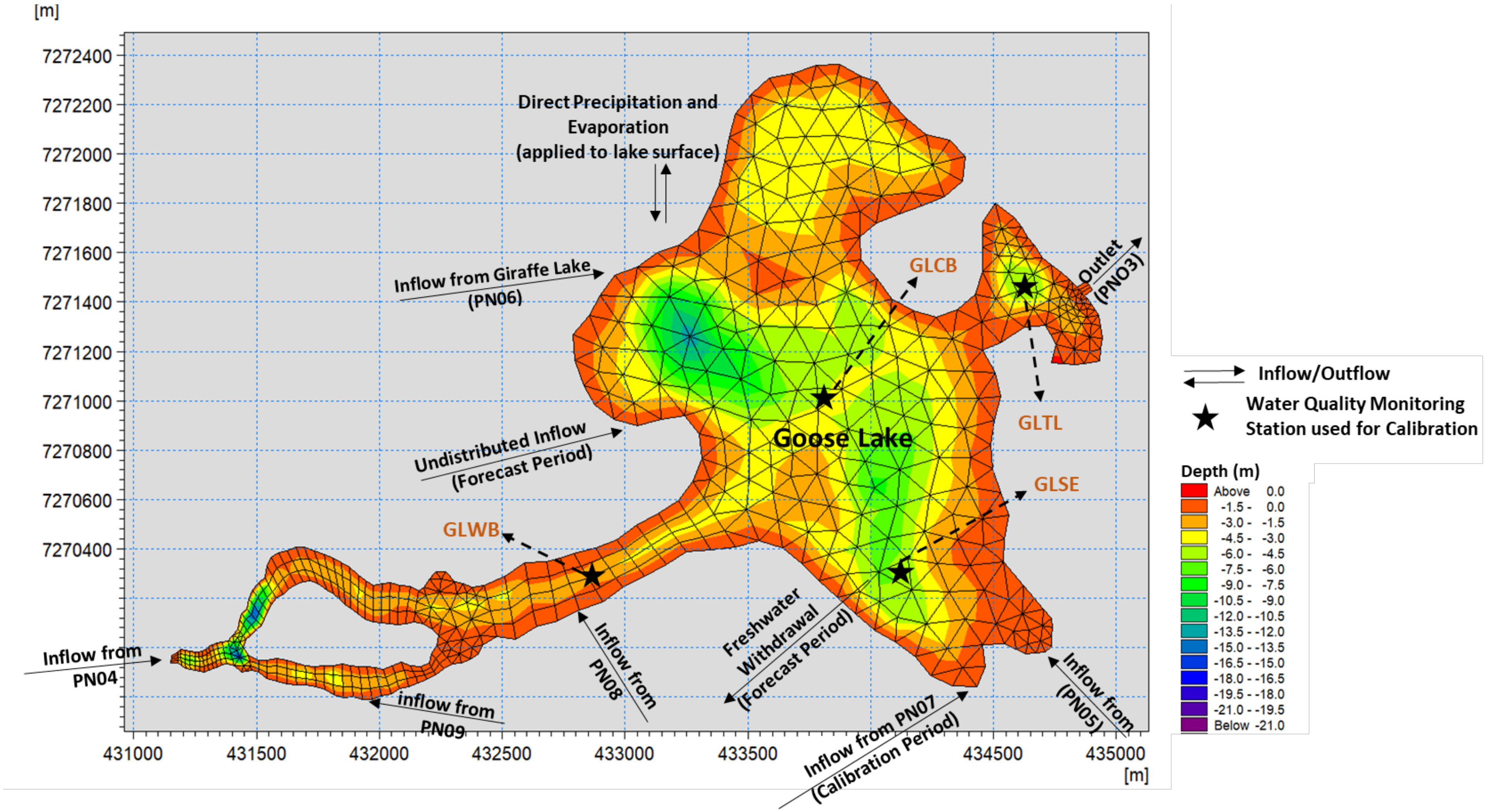
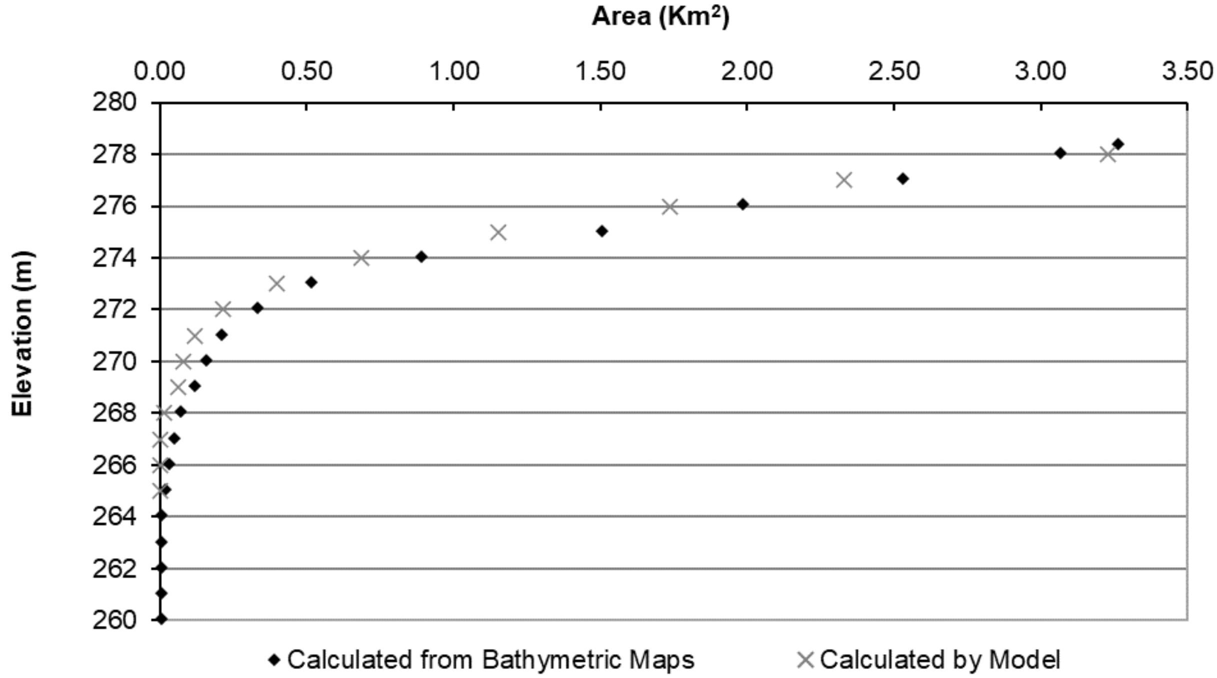


Figure 1: Goose Lake Model Mesh (Plan View) with Inflows and Outflows During Calibration and Forecast Periods and Location of Water Quality Monitoring Stations used for Calibration (GLWB, GLCB, GLSE, and GLTL are monitoring stations used for model calibration)

a) Depth and Area



b) Depth and Volume

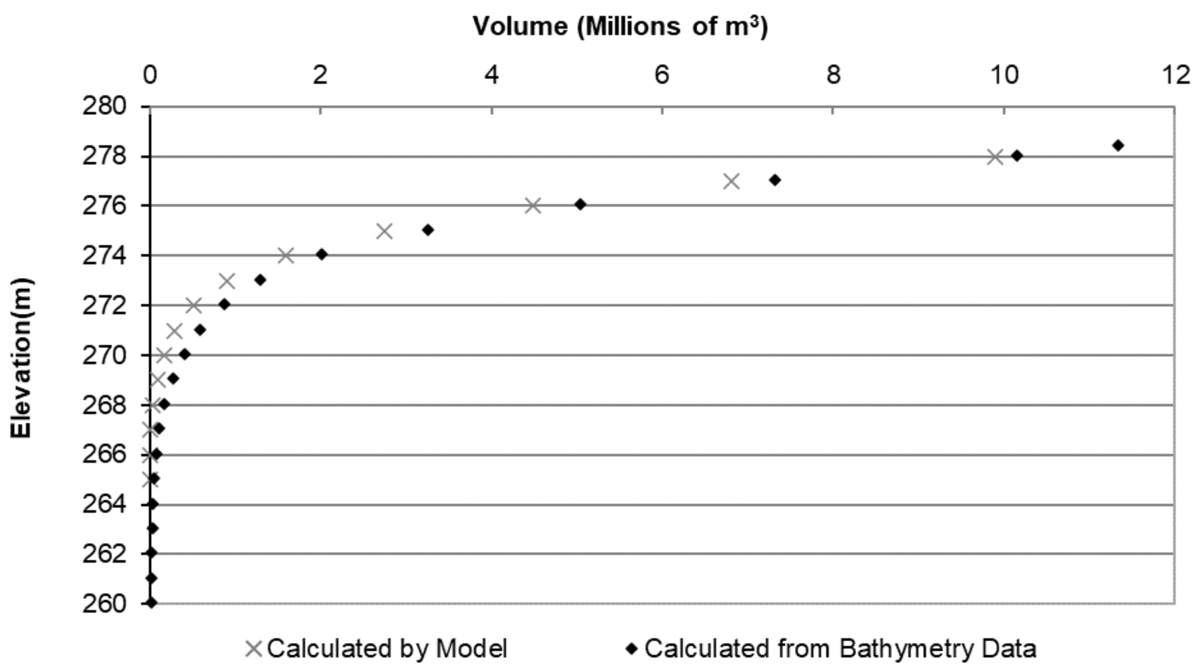


Figure 2: Hypsographic Curves for Goose Lake

2.4.2 Meteorological Data

Meteorological inputs are key drivers of lake circulation and thermal dynamics. The meteorological input data required for the Goose Lake Model were air temperature, wind speed and direction, relative humidity, barometric pressure, short and long-wave radiation, clearness coefficient (cloud cover), and precipitation.

Hourly timeseries were developed for each of the time-dependent variables based on observed data collected from the on-site meteorological station (Goose Lake) from 2004 to 2013 and 2017 to 2018. These timeseries were developed for air temperature, wind speed and direction, relative humidity, barometric pressure, and short-wave radiation. Short data gaps (less than 24 hours) were infilled using measured data at the station at the corresponding time of year from the previous year. Longer gaps were infilled using measured data from a nearby meteorological station also monitored by Sabina (i.e., George Lake Station).

Long-wave radiation was estimated by the model using an empirical formulation. Monthly precipitation data for an average climate year were obtained from the water and load balance model (WLB) report (SRK 2020) to provide consistency between water balance and hydrodynamic study components. Hourly cloud cover data were extracted from the Meteoblue database (Meteoblue 2020) and applied in the model in the form of a clearness coefficient.

Daily timeseries of direct precipitation on the lake was developed using monthly precipitation values obtained from the WLB Report (SRK 2020). Evaporation was calculated by the hydrodynamic model based on modelled water temperature, air temperature, relative humidity, and wind speed inputs.

Observed meteorological data collected on-site during the specific dates under evaluation (i.e., 2012 to 2013) were used for the calibration period. For the forecast period (15 years), observed meteorological data collected on-site from 2004 to 2014 and 2017 to 2018 were used to develop a 12-year timeseries and then repeated to cover the full forecast period (15 years).

2.4.3 Hydrologic Inputs

Hydrological inputs (inflows) for each modelling period are described below.

- Inflows to Goose Lake:
  - Calibration period (2012 to 2013): Inflows from regional watersheds/natural tributaries within Goose Lake basin were obtained from Hydrology Baseline Reports (Rescan 2012a, 2012b, 2014a, 2014b) included as appendices V6-1A, V6-1B, V6-1C, and V6-1D to the FEIS (Sabina 2015). These inflows (daily timeseries) were obtained from measured flows at the monitoring stations presented in Table 2. Data gaps in the dataset at the WR-H1 station in 2011 and 2012 were filled using data measured in 2013.
  - Forecast period (Year 11 to Year 25): Inflows from local watersheds/natural tributaries and mine affected discharges reporting to Goose Lake were obtained (monthly basis) from the WLB Report (SRK 2020).
- Lake outflows: For both modelling periods, the outflow from Goose Lake (through the outlet channel to Propeller Lake) is defined in terms of a stage-discharge relationship. Measured water levels at Goose Lake during the open water season in 2013 and measured flows downstream of Goose Lake during the open water season from 2011 to 2014 were used to estimate a relationship between outflows from Goose Lake and water levels in the lake. The method and available data used to estimate the relationship are described below:

- Water level measurements at Goose Lake were available for the period of June 7 to October 3, 2013 at GC-L1 station (Sabina 2020d).
- Measured flows at the instream inlet to Propeller Lake were available for the period 2011 to 2014 (Rescan 2012a, 2012b, 2014a, 2014b) at gauging station PL-H2. Because PL-H2 is not located at the outlet of Goose Lake, the flow measurements at this station include outflows from Goose Lake and another small catchment. To scale down measured flows at PL-H2 to Goose Lake outlet, a scaling factor of 0.935 was used reflecting the ratio between the catchment area reporting to Goose Lake outlet (approximately 95 km^2) and the total catchment area reporting to PL-H2 (approximately 101.6 km^2).
- During the period of record when water levels at GC-L1 were collected, the measured flows (Rescan, 2014a) at PL-H2 were scaled down to Goose Lake Outlet and used to develop a relationship between lake levels and outflows (levels were expressed in terms of a local datum). This developed relationship was input to the model.

Table 2 presents the streamflow monitoring stations used to extract historical inflow rates (for the calibration period; Rescan 2012a, 2012b, 2014a, 2014b) for each inflow to the lake (inflow nodes/locations presented on Figure 1). Annual average flows for all hydrological inputs during calibration and forecast periods are summarized in Table 3.

Table 2: Goose Lake Inflow Nodes/Locations and Historical Streamflow Monitoring Stations

Hydrometric Station (Historical Inflows – Calibration Period)[a]	Goose Lake Inflow/Outflow Nodes/Locations
PL-H2	PN-03 (lake outflow)
GL-H1	PN04
WR-H1	PN05
GI-H1	PN06
WL-H1	PN07
GL-H3	PN08
EL-H1	PN09

(a): Sabina (2015).

Table 3: Annual Average Inflows (Mm^3/yr)

Inflow Name	Inflow Rates (Mm^3/yr)			
	Calibration Period[a]	Forecast Period[b]		
		Operational	Closure	Post-closure
PN04	1.5	2.8	3.1	3.1
PN05	0.85	0.41	4.5	5.1
PN06	3.6	4.1	3.7	3.7
PN07	3.1	0	0	0
PN08	0.85	1.1	1.1	1.1
PN09	0.16	0.23	0.22	0.22
Precipitation	1.3	1.3	1.3	1.3
Treated Sewage Effluent	0	0.012	0.004	0
Undisturbed Runoff	0	1.1	1.1	1.1
Total	**11**	**11**	**15**	**15.6**

(a): Sabina (2015).
(b): SRK (2020).

Ice Formation and Melting

Ice thickness, and the time of ice formation and thawing was manually defined in the model based on monitoring data collected as part of the baseline programs (Golder 2019, Appendix 2D). A daily timeseries of ice thickness was developed using the dates and measured ice thicknesses presented below. Modelling the processes of ice formation and thawing was based on the following assumptions:

- Ice thickness was assumed to be constant across the entire lake.
- Maximum ice thickness is 1.6 m.
- Ice formation developed from 15 October and reached maximum thickness at the end of February.
- Ice remained at the maximum thickness from 1 March to the end of April.
- Ice thawing occurred from 1 May to 30 June on a linear basis.
- Water is drawn from the lake to form ice and the corresponding water volume is gradually removed from the lake during the ice formation period to simulate this process.
- Water volume is removed from, and returned to, the lake according to the depths and dates listed above (i.e., ice thickness: 1.6 m; ice formation: 15 October to end of February; ice melting: 1 May to 30 June).
- The volume of water removed to form ice and returned to the lake during melting was adjusted by a factor of 0.92 to account for the density difference between ice and freshwater.
- Salts are rejected from the water during ice formation, and pure water is added back to the lake as the ice melts.

2.4.4 Modelled Constituents

Calibration Period

The purpose of model calibration was to optimise model performance to reasonably match measured and predicted hydrodynamic and transport behaviour in Goose Lake. Total dissolved solids (TDS) and temperature were included in the Goose Lake Model during the calibration period for the purposes of comparing model results to field measurements and iteratively improving model performance.

Forecast Period

The constituents included in the Goose Lake Model (Table 2) for future predictions (Table 4) were generally limited to those with water quality benchmarks identified in Table 1 of Section 2.4. Calcium and magnesium were added to the suite of constituents to provide information required for the calculation of hardness-dependent benchmarks, and TDS was included to provide a generalised estimate of mixing throughout the lake.

Table 4: Goose Lake Modelled Constituants

Group	Constituent	Group	Constituent
Conventional Constituents	Water temperature	**Metals**	Copper
	Total dissolved solids		Iron
Major Ions	Calcium		Lead
	Chloride		Manganese
	Fluoride		Mercury
	Magnesium		Molybdenum
Nutrients	Nitrate		Nickel
	Nitrite		Selenium
	Total ammonia		Silver
Metals	Aluminum		Thallium
	Arsenic		Uranium
	Boron		Zinc
	Cadmium	**Other**	Free Cyanide
	Chromium		

2.4.5 Water Quality Inputs

Water quality data required for the Goose Lake Model included chemistry and temperature data for inflows to the lake:

- For the calibration period: TDS and water temperature
- For the forecast period: modelled constituents (Table 4) and water temperature

These inputs are summarized below:

- During the calibration period TDS concentrations of inflows from local watersheds (natural tributaries of Goose Lake basin) were represented by the median TDS concentrations (values reported as “calculated TDS”, calculated from major ions as per APHA 2012) reported in the Aquatic Baseline Synthesis Report (Golder 2019), except for PN-04 where average monthly concentrations were used (given the variability observed in the measured data) (Table 5). Continuous measurements of stream water temperature were not available for inflows from natural tributaries, thus, temperature timeseries were developed using data collected at streams draining into Snap Lake dated from 2009 and 2016 (De Beers 2017).
- During the forecast period, the water quality of inflows (Table 6) was based on outputs from the WLB model (SRK 2020). The water temperature of these inflows was assumed to be the same as for the calibration period. Modelled concentrations of fluoride, mercury, and free cyanide were not available (as part of the WLB model), thus the following assumptions were made for inflow to the lake:

- Fluoride: a concentration of 0.05 mg/L was applied to inflows affected by mining (i.e., PN04 and PN05) and an average background concentration (0.02 mg/L; Golder 2019) was applied to natural inflows to Goose Lake. The mine affected values were based on the waste rock humidity cell test (HCT) program completed as part of the metal leaching and acid rock drainage characterization for the FEIS (SRK 2015, with an update in Golder 2020). Fluoride concentrations in the HCTs were at or near the 0.05 mg/L method detection limit (MDL).
- Mercury: concentrations of mercury in HCT samples were generally non-detectable, thus the MDL value (0.00001 mg/L) was applied to the inflows affected by mining (i.e., PN04 and PN05).
- Free cyanide: Concentrations were assumed to be 1/10 of total cyanide concentration (Sabina 2020e).

- Concentrations for boron, manganese, selenium, silver, and thallium in treated sewage effluent were assumed to be the same as those reported for PN06 inflows.
- Initial conditions on the first day of the calibration period (7 August 2011) within Goose Lake were defined using the monitored data (temperature and TDS) obtained from the Golder 2019. TDS was assumed to be spatially variable and defined based on the locations of monitoring stations.
- Initial conditions on the first day of forecast period (September 15, Year 10; before lake freeze-up) within Goose Lake were defined using the median value reported in Golder 2019 (Appendix 2D, Table 2D-16). Temperature and chemistry were assumed constant throughout the domain for initialization purposes.
- Salinity was estimated based on TDS concentration (mg/L) and expressed in Practical Salinity Units (PSU). The applied conversion ratio assumed that 1 mg/L (TDS) equaled 0.001 PSU (salinity).
- Constituent concentrations in rainfall, snowfall, and evaporation were assumed as zero. Accordingly, these variables affect the water balance and lake concentrations but not the mass balance.
- Concentrations of constituents that were below detection limits were assumed to be equal to half the MDL, with the exception of those specified above (i.e., fluoride and mercury).

Table 5: Average Input TDS Concentration of Inflows – Calibration Period

Inflow	TDS Concentration (mg/L)
PN-04	170 (Monthly ranging from 39 to 299)
PN-05	34
PN-06	21
PN-07	21
PN-08	35
PN-09	63

Table 6: Average Input Chemistry of Inflows – Forecast Period (SRK 2020)

Constituent	Unit	PN04			PN05			PN06			PN08			PN09			Treated Sewage Effluent		Undisturbed Runoff		
		Average			Average			Average			Average			Average			Average		Average		
		Operational	Closure	Post-Closure	Operational	Closure	Post-Closure	Operational	Closure	Post-Closure	Operational	Closure	Post-Closure	Operational	Closure	Post-Closure	Operational	Closure	Operational	Closure	Post-Closure
Total dissolved solids	mg/l	54	664	485	19	49	62	17	17	17	17	17	17	17	17	17	17	17	29	29	29
Major Ions																					
Chloride	mg/l	6.5	29	20	2.5	2.6	2.5	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.8	2.8	2.8
Fluoride	mg/l	0.05	0.05	0.05	0.05	0.05	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Nutrients																					
Nitrate	Mg-N/l	2.0	6.7	3.0	0.041	0.17	0.081	0.0073	0.0055	0.005	0.008	0.0057	0.0051	0.027	0.0094	0.0053	22	22	0.005	0.005	0.005
Nitrite	Mg-N/l	0.1	0.44	0.22	0.0027	0.011	0.0048	0.0011	0.001	0.001	0.0012	0.001	0.001	0.002	0.0012	0.001	0.5	0.5	0.001	0.001	0.001
Ammonia (total)	Mg-N/l	0.91	5.7	3.1	0.027	0.12	0.052	0.0066	0.0053	0.005	0.0051	0.0051	0.0051	0.018	0.0077	0.0052	8	8	0.005	0.005	0.005
Total Metals																					
Aluminum	mg/l	0.12	0.25	0.22	0.077	0.13	0.21	0.016	0.016	0.016	0.028	0.028	0.028	0.027	0.027	0.027	0.021	0.021	0.018	0.018	0.018
Arsenic	mg/l	0.0033	0.011	0.009	0.0012	0.0047	0.0066	0.00024	0.00024	0.00024	0.00042	0.00042	0.00042	0.00041	0.00041	0.00041	0.0001	0.0001	0.00021	0.00021	0.00021
Boron	mg/l	-	0.036	0.042	0.00089	0.0014	0.0011	0.00091	0.00091	0.00091	0.00091	0.00091	0.00091	0.00091	0.00091	0.00091	0.00091	0.00091	0.0013	0.0013	0.0013
Cadmium	mg/l	0.000014	0.000011	0.00001	0.0000075	0.0000078	0.0000072	0.0000077	0.0000077	0.0000077	0.0000076	0.0000076	0.0000076	0.0000076	0.0000076	0.0000076	0.0001	0.0001	0.00001	0.000010	0.00001
Chromium	mg/l	0.00026	0.00093	0.00076	0.00021	0.0003	0.00039	0.00013	0.00013	0.00013	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.0001	0.0001	0.00014	0.00014	0.00014
Copper	mg/l	0.0014	0.0059	0.0044	0.0014	0.0018	0.0021	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0024	0.0024	0.0014	0.0014	0.0014
Iron	mg/l	0.16	0.46	0.36	0.12	0.16	0.18	0.057	0.057	0.057	0.065	0.065	0.065	0.069	0.069	0.069	0.014	0.014	0.059	0.059	0.059
Lead	mg/l	0.000053	0.0004	0.00032	0.000052	0.000055	0.000056	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.000051	0.000051	0.000051	0.0001	0.0001	0.00005	0.00005	0.00005
Manganese	mg/l	0.013	0.033	0.029	0.0082	0.021	0.035	0.005	0.005	0.005	0.0056	0.0056	0.0056	0.0057	0.0057	0.0057	0.005	0.005	0.0074	0.0074	0.0074
Mercury	mg/l	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00000052	0.00000055	0.00000055	0.0000031	0.0000031	0.0000031	0.0000043	0.0000043	0.0000043	0.00000055	0.00000055	0.000001	0.000001	0.000001
Molybdenum	mg/l	0.000076	0.011	0.0066	0.000069	0.00023	0.00043	0.000051	0.000051	0.000051	0.000054	0.000054	0.000054	0.000056	0.000056	0.000056	0.0001	0.0001	0.00005	0.00005	0.00005
Nickel	mg/l	0.0045	0.0048	0.0053	0.0039	0.0053	0.0068	0.0026	0.0026	0.0026	0.0028	0.0028	0.0028	0.0029	0.0029	0.0029	0.0004	0.0004	0.0037	0.0037	0.0037
Selenium	mg/l	0.00012	0.00074	0.00053	0.00011	0.00017	0.00024	0.0001	0.00010	0.0001	0.0001	0.00010	0.0001	0.0001	0.00010	0.0001	0.00010	0.0001	0.0001	0.00010	0.0001
Silver	mg/l	0.00001	0.000018	0.000015	0.00001	0.000011	0.000012	0.0000077	0.0000077	0.0000077	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.0000077	0.0000077	0.00001	0.000010	0.00001
Thallium	mg/l	0.000031	0.000037	0.000038	0.000037	0.000037	0.000036	0.000038	0.000038	0.000038	0.000038	0.000038	0.000038	0.000038	0.000038	0.000038	0.000038	0.000038	0.00005	0.00005	0.00005
Uranium	mg/l	0.000012	0.00027	0.00047	0.00001	0.000016	0.000012	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.0001	0.0001	0.00001	0.000010	0.00001
Zinc	mg/l	0.0027	0.0019	0.0017	0.0011	0.0015	0.0019	0.00075	0.00075	0.00075	0.0008	0.0008	0.0008	0.00082	0.00082	0.00082	0.002	0.002	0.001	0.001	0.001
Other																					
Total Cyanide	mg/l	0.0037	0.0029	0.0027	0.0043	0.0047	0.0045	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0026	0.0026	0.0026

3.0 MODEL CALIBRATION

The calibration process involves selecting the appropriate mesh (grid) sizing, time step, vertical resolution, wind effects and other driving forces, and adjusting model parameters (calibration parameters) that most closely approximate the behaviour of the system under study. Adjustment of parameters is standard practice during calibration (Cole and Wells 2008).

The hydrodynamic and transport modules of MIKE3 FM were calibrated to match measured and predicted thermal and transport behaviour in Goose Lake. The Goose Lake Model was calibrated to measured temperature and TDS concentrations (values reported as "measured TDS") in 2012 and 2013 (Golder 2019) by comparing measured and predicted values.

Calibration parameters were selected based on model developers' recommendations, experience, and previously cited literature and adjusted to allow adequate representation of temperature, TDS, and lake water levels. Calibration parameters used for the Goose Lake Model included eddy viscosity parameters, dispersion coefficients and wind friction. The bathymetry (mesh) was refined through the calibration process to add more resolution in several areas of the lake to avoid model instabilities. During the model calibration, the sensitivity of model predictions to selected parameters in the hydrodynamic, temperature, and transport modules were tested for the parameters included in Table 7.

Table 7: Hydrodynamic Parameters Tested During the Calibration

Parameter	Range Tested	Selected Values
Hydrodynamic Module		
Vertical Eddy Viscosity	k – ε formulation with maximum eddy viscosity in the range 0.001–180 m^2/s	180 m^2/s
Roughness Height	0.05 to 0.1 m	0.05 m
Drying Depth and Wetting Depth	0.05 to 0.25 m and 0.3 to 0.5 m	0.25 m / 0.5 m
Wind Friction Coefficient	Constant (0.00001255-0.0001255) or variable with wind speed (0.001255–0.002425)	Constant (0.001255)
Temperature Module		
Horizontal Dispersion	Scaled eddy viscosity formulation with constant in the range 0.0001–1	1
Vertical Dispersion	Scaled eddy viscosity formulation with constant in the range 0.0001–1	1
Beta in Beer's Law	0.3 to 0.7	0.3
Light Extinction Coefficient	0.05 to 1	1
Transport Module		
Horizontal Dispersion	Scaled eddy viscosity formulation with constant in the range 0.1–1	1
Vertical Dispersion	Scaled eddy viscosity formulation with constant in the range 0.001–1	1

During calibration, default model parameters were used for all the variables except for those specified in Table 7. In addition, the following considerations were included within the model framework to better replicate observed conditions in Goose Lake:

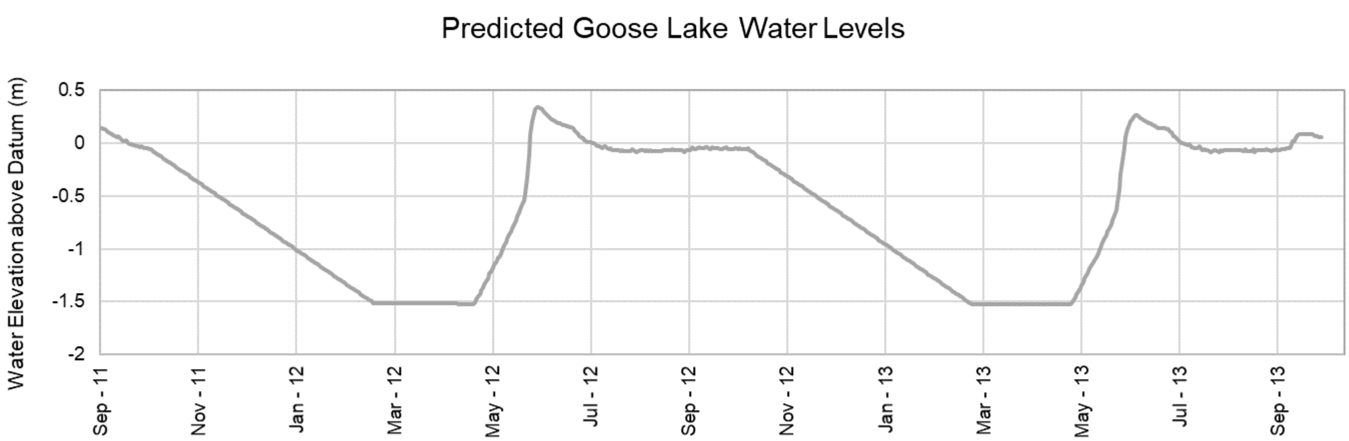
- Within the temperature formulation, the minimum temperature was set to 0°C instead of the default value of -2.1°C to prevent freshwater temperatures dropping below 0°C.
- Water density was set to be a function of temperature and salinity.

Calibration of the hydrodynamic and transport modules considered the horizontal (spatial) and vertical distribution of temperature and TDS in Goose Lake. For the horizontal transport calibration, timeseries plots of predicted surface and bottom temperature and TDS concentrations were compared against measured data. For the vertical calibration, vertical temperature and TDS plots were developed for each calibration station with available data.

3.1 Hydrodynamic Calibration

The hydrodynamic calibration was evaluated using a graphical approach. A qualitative evaluation of model performance was performed by a comparison of predicted and measured water levels.

The first step in the calibration process was to achieve a water balance within the model. For this purpose, predicted water levels in the lake (Table 3) were plotted to confirm the volume of the lake was seasonally balanced and lake water levels were within the observed historical range (~278 masl during the open water season). Overall, predicted water levels did not exhibit increasing or decreasing trends (Figure 3) over multiple years and reproduced the expected seasonal cycle.



Local datum (zero level) corresponds with 278.4 masl

Figure 3: Predicted Goose Lake Water Surface Elevation Over Calibration Period

Time series and profile plots of temperature were created to compare model results to measured data at several locations (calibration stations, Figure 1) across the lake. A total of four locations were selected from the water quality monitoring stations, based on available data, including: GLWB, GLCB, GLTL, and GLSE (Figure 1). Graphical comparisons of modelled to measured water temperatures are presented in Figure 4. Surface and bottom temperature measurements were available at GLTL (timeseries and profile plots presented for this station; Figures 4 and 5), but only surface temperature measurements were available for GLWB, GLCB, and GLSE.

The results show that the model matches the surface and bottom water temperatures during the open-water season reasonably well.

Water column temperature profile plots at GLTL for the dates with measured data are presented in Figure 5. During the open-water season, the predicted thermal profile fits the measured profile reasonably well. During the ice-cover season, the model does not predict winter stratification as suggested by the measured temperature collected on April 14, 2013 (Figure 5).

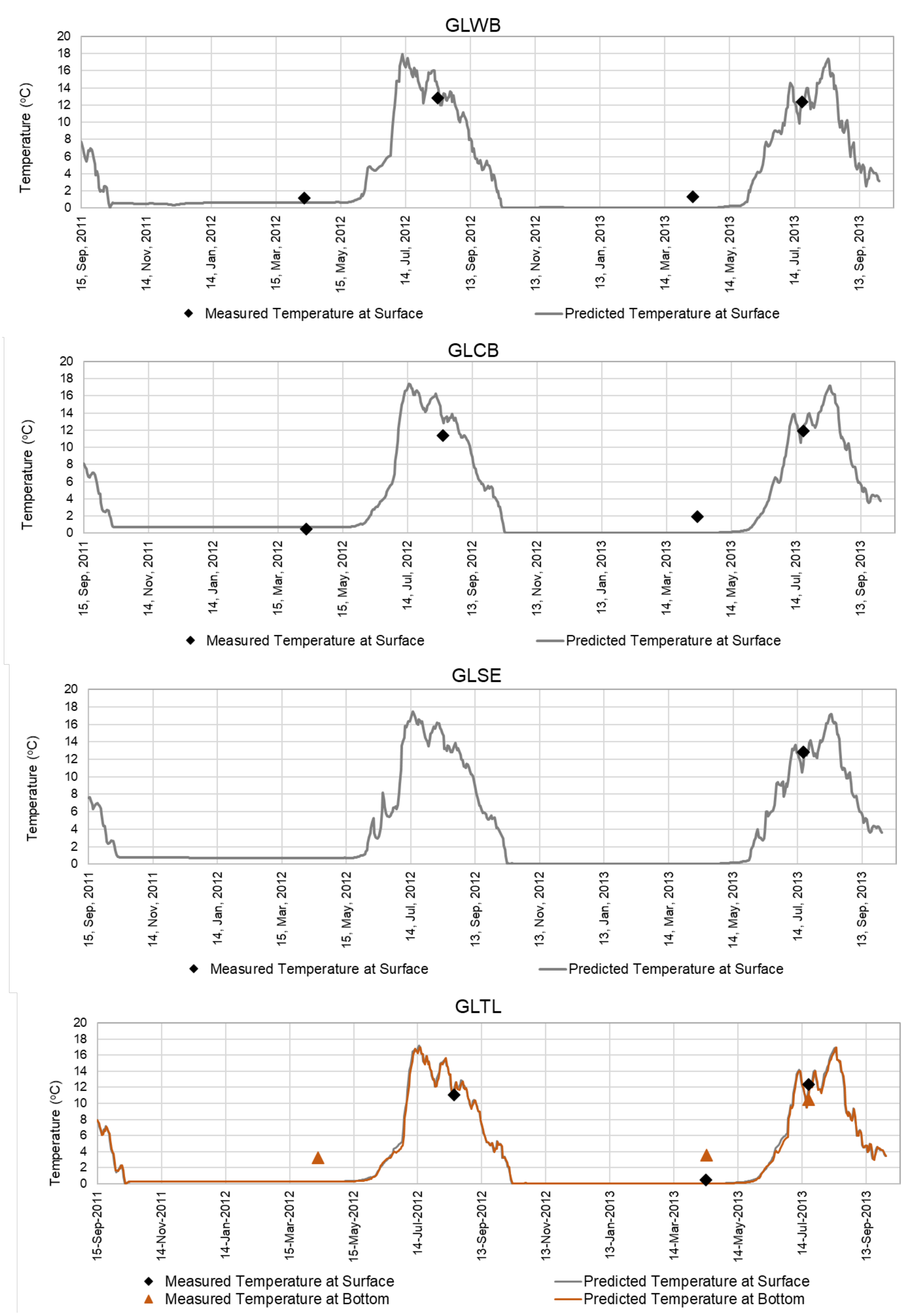


Figure 4: Predicted and Measured Goose Lake Water Temperature Timeseries Over Calibration Period

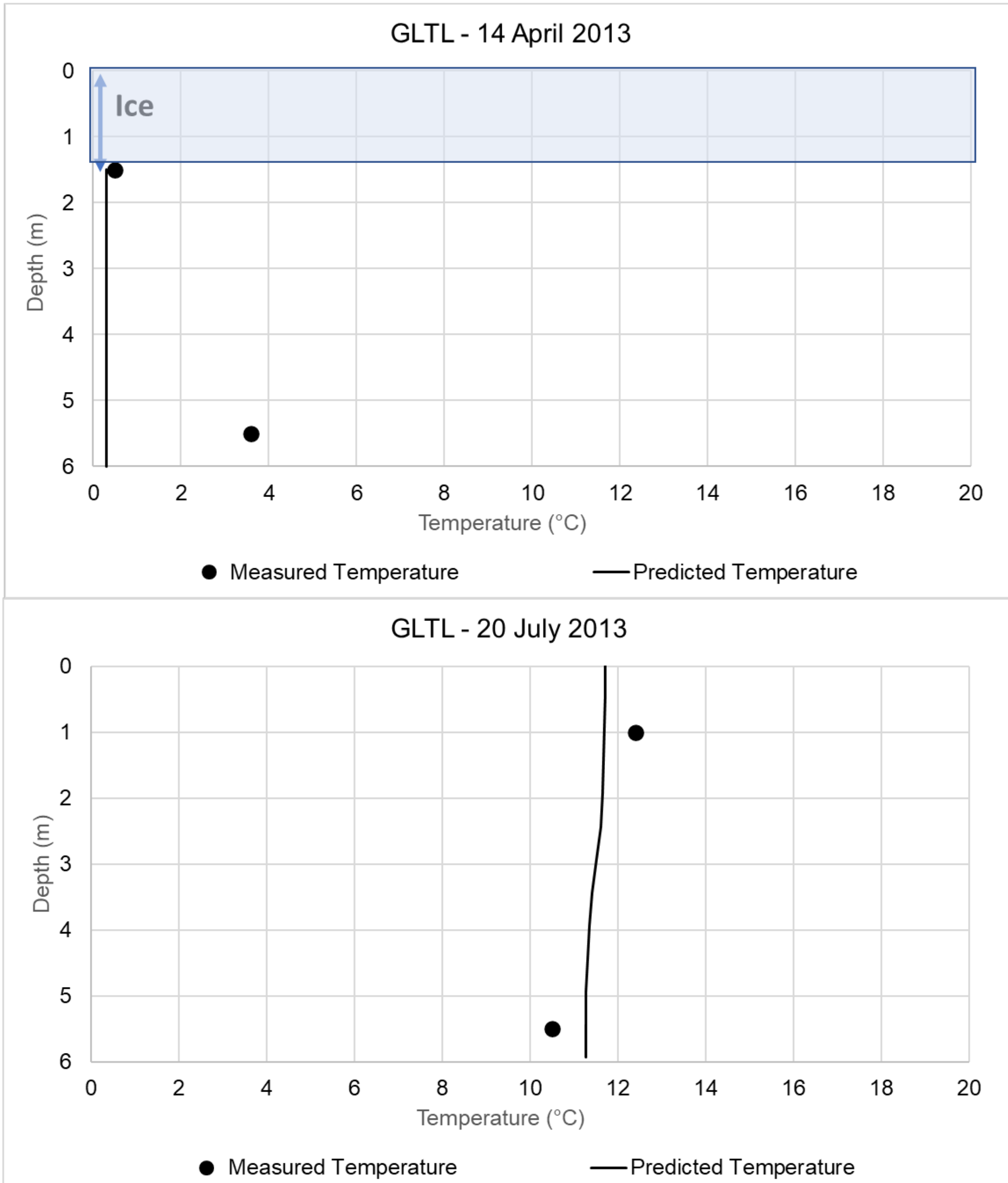


Figure 5: Predicted and Measured Water Temperature Profiles in Goose Lake at GLTL Calibration Station (2013)

3.2 Transport Calibration

The transport module of the Goose Lake Model was calibrated to match measured and predicted TDS behaviour in Goose Lake.

Predicted and measured TDS concentrations are presented on Figure 6 (timeseries plots) and Figure 7 (profile plots). Cyclical annual patterns and vertical variability of TDS were captured reasonably well by the model. The predicted TDS concentration timeseries (Figure 6) shows increasing TDS concentrations as ice forms on the lake (due to salt rejection) and then decreasing concentrations as the ice starts melting and during the freshet.

Predicted TDS profiles at GLTL are compared with the measured data on Figure 7. During both open-water and ice-cover seasons, the predicted TDS profile follows the measured profile pattern. As discussed in Section 2.5.4, TDS concentrations of inflows to the lake were based on “lab calculated” values, while the in-lake concentrations (used to compare to predicted results) were based on “field measured” values. The difference between the two TDS values could cause a minor difference in the reported values. Thus, calibration was considered adequate if the observed and predicted TDS followed the same pattern, while recognizing that the absolute values would not be expected to match.

Overall, the transport calibration indicates that the model was tracking the movement of water and dissolved constituents (represented by TDS) reasonably well throughout the vertical and lateral extents of the lake.

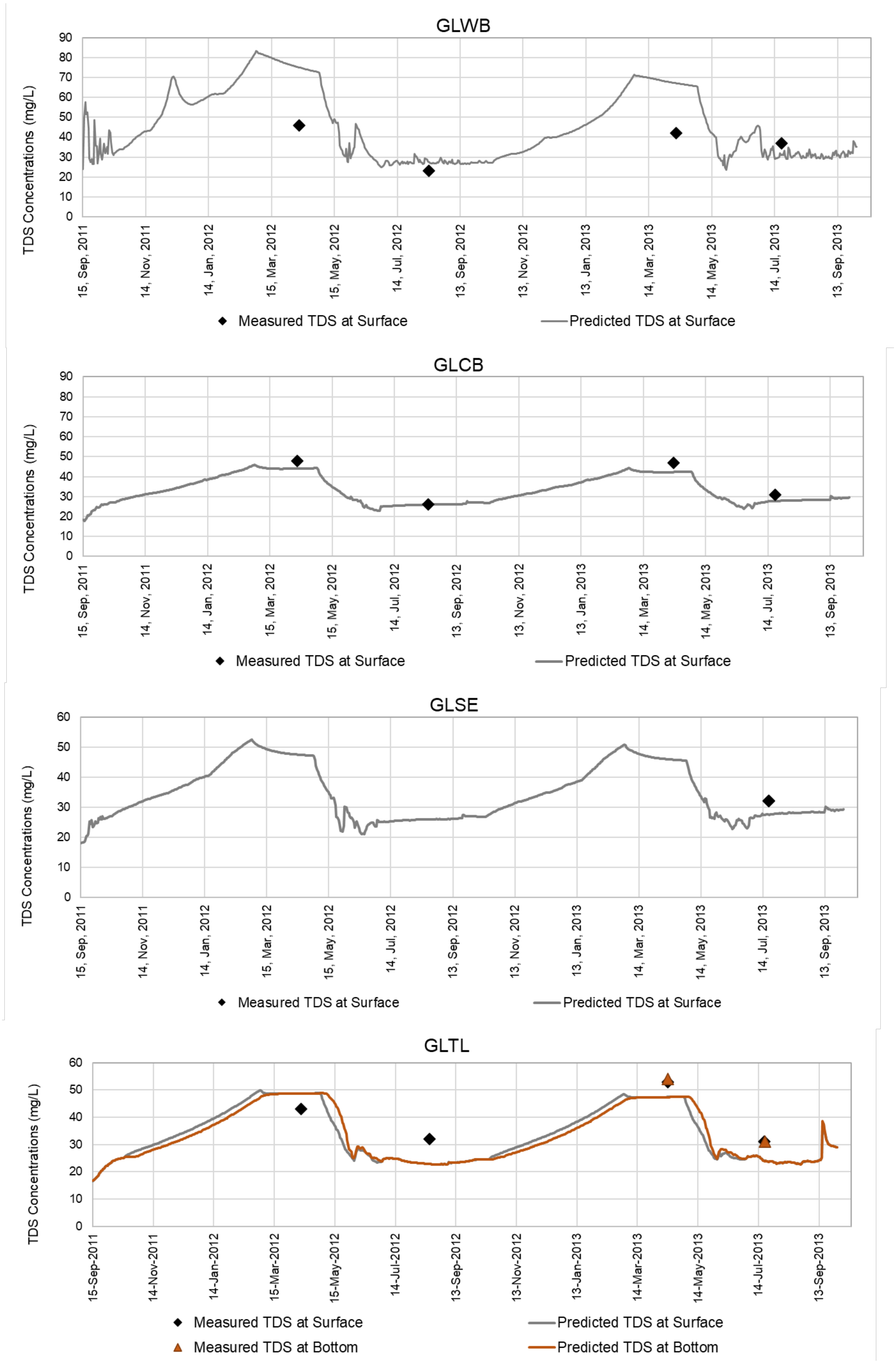


Figure 6: **Predicted and Measured Goose Lake TDS Concentration Timeseries Over Calibration Period**

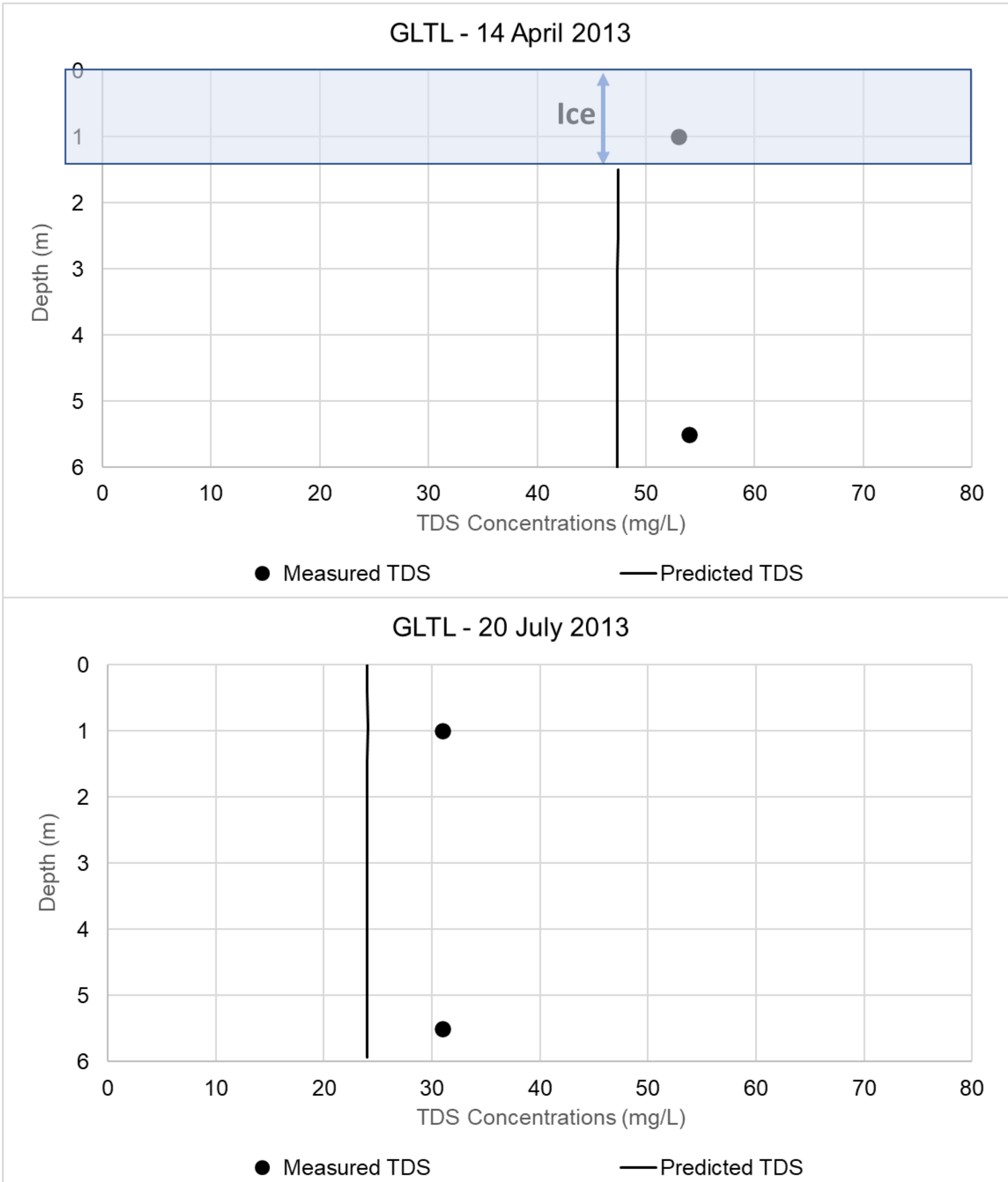


Figure 7: Predicted and Measured TDS Concentration Profiles in Goose Lake at GLTL

3.3 Calibration Results Summary

Overall, the model calibration demonstrates adequate model performance as a predictive tool for water quality forecasts in Goose Lake. The model captures the range in temperature and TDS concentrations from monitoring data sufficiently, and is able to reasonably match the seasonal patterns observed in the monitoring data and spatial distributions of TDS concentrations across Goose Lake.

4.0 MODEL UNCERTAINTIES AND LIMITATIONS

Modelling requires the use of simplifying assumptions related to the physical and chemical characteristics of a system. Predictions are based on several inputs, all of which have inherent uncertainty. Given the inherent uncertainties, the results of a model should be used as a tool in project planning, and to outline potential risks, rather than to produce a set of absolute concentrations. Used conservatively, models can be developed with simplifying assumptions that tend to over-estimate concentrations, and thereby avoid under-estimating the overall risk.

Key limitations and sources of model uncertainty are discussed below:

- It is assumed that inflow rates and chemistry inputs to the Goose Lake Model are representative of their respective sources and will continue to be so in the future.
- For the forecast simulation period, the Goose Lake Model relies on predicted water quantity and quality from the WLB model (SRK 2020).
- Water quality constituents are modelled as conservative constituents in the water column, meaning that they do not undergo chemical or biological reactions or physical processes that would remove mass from the system, besides advective outflow. This adds conservatism to the modelling and could lead to an over-estimation of some in lake constituent concentrations. An example of a constituents that could be overestimated in the model are nitrite and ammonia, which are known to be oxidized in aerobic environments (Bowie et al. 1985, Snow and Vandenberg 2016).
- The Goose Lake Model does not contain a sediment compartment. The model does not account for a source of constituent loading from the lakebed sediment to the water column or a sink for constituent loading from the water column to the sediment.
- MIKE3 does not include a comprehensive ice module. A representation of ice thickness and timing was manually input into the model based on available monitoring data. The model assumes that ice forms on the lake at the same rate and at the same thickness each year during the simulation period.
- The modules used in this study do not account for the sediment-water and ice-water heat exchange.
- Free cyanide was assumed to be 10% of the total cyanide concentration (Sabina 2020e).
- The water balance model is based on average climate conditions (SRK 2020) as such no climate variations are included in the hydrodynamic model, (i.e., wet or dry years).

5.0 GOOSE LAKE MODEL SIMULATIONS (FORECAST PERIOD)

Once the model calibration was complete, the Goose Lake Model was run for three forecast periods to generate water quality predictions. These periods include key mine phases of interest based on the mine project schedule provided in Appendix A of SRK 2020, including:

- Operational period (Year 11 to 12): represents the last two years of the operational period with active mine affected discharges to Goose Lake (at PN04 and PN05). The current water management plan (Sabina 2020f) does not result in mine-related discharges to Goose Lake before Year 11.

- Closure (Year 13 to 20): represents conditions from the end of the operational period to the beginning of post-closure. The majority of the mine workings, tailings structures, and water management structures will be decommissioned throughout Closure, including:
  - Active site closure, removal of site infrastructure, and passive pit flooding and continued water treatment (seasonal), if required.
  - Passive pit flooding and continued water treatment (seasonal), if required.
- Post-Closure (Year 21 to 25): post-closure (Year 21 onward) represents the final configuration of Goose Lake following mine closure. The five years of the post-closure period are considered in the hydrodynamic model, as discharge quality is expected to improve after closure.

5.1 MODEL RESULTS

In this section, model predictions based on maximum monthly depth-averaged constituent concentrations at the outlet of Goose Lake for operational, closure, and post-closure periods are presented and compared to applicable water quality benchmarks (Table 1). Daily timeseries concentrations of modelled water quality constituents over the forecast period (Year 11 to 25; operational, closure, and post-closure periods) are presented in Attachment 1. Predicted constituent concentrations with single benchmark value (i.e., not dependent on modelled hardness or temperature; Table 1) are screened against the corresponding benchmark in Table 8; other constituents are screened against benchmark timeseries in plots presented in Attachment 1. Daily timeseries of TDS concentrations and water temperature at the outlet of Goose Lake for the three modelling periods are presented in Figures 8 and 9.

It is noted that because mine-affected discharges to Goose Lake are not planned to occur until Year 11, there is substantial time to better understand the system and potential effects on water quality as a result of these discharges.

Daily concentrations of modelled constituents at the outlet of Goose Lake are predicted to remain below chronic water quality benchmarks over the forecast period, except for nitrate, nitrite, aluminum, arsenic, chromium, copper, and iron. Concentrations of nitrate, nitrite, arsenic, chromium, copper and iron are predicted to peak during closure or early post-closure and subsequently decrease into the post-closure period (Attachment 1). Aluminum concentrations are predicted to stabilize toward the end of simulated period (5 years into the post-closure) (Attachment 1).

Overall predicted seasonal trends show that concentrations in the lake:

- increase as the ice forms (due to salt rejection) until they reach a peak at the end of ice formation period
- decrease when ice starts melting which also corresponds to start of freshet
- slightly increase as the mine-affected runoff discharges to the lake

Time periods when maximum monthly concentrations for water quality constituents are predicted to be above chronic water quality benchmarks (Table 1) at the outlet of Goose Lake are:

- The modelled operational, closure, and post-closure periods: aluminum and copper
- The modelled closure and the post-closure periods: nitrate, nitrite, arsenic, chromium, and iron

Table 8: Predicted Maximum Monthly Depth-Averaged Concentrations at Outlet of Goose Lake Over Forecast Simulation Periods

Parameter	Unit	CCME Aquatic Life Guideline or SSWQO[(a)]		Monthly Average Constituent Concentrations for Mine Period[(b)]			Maximum Monthly Average Constituent Concentrations for Mine Period[(b)]		
				Lake Outflow			Lake Outflow		
		Acute	Chronic	Operational	Closure	Post-closure	Operational	Closure	Post-closure
Conventional Parameters									
Total dissolved solids	mg/L	-	-	38	236	225	76	572	452
Major Ions									
Chloride	mg/L	640	120	4.6	14	11	8	28	21
Fluoride	mg/L	-	0.12	0.031	0.044	0.051	0.05	0.082	0.085
Nutrients									
Nitrate	mg-N/L	124	2.9	0.35	2.9	1.5	0.7	**6.1**	**3.3**
Nitrite	mg-N/L	-	0.06	0.018	**0.18**	**0.11**	0.038	**0.39**	**0.24**
Total ammonia	mg-N/L	-	timeseries (2-9.5)	0.16	2.3[(c)]	1.6[(c)]	0.35	4.6 [(c)]	3.4 [(c)]
Total Metals									
Aluminum	mg/L	-	0.005 or 0.1	0.05	**0.16**	**0.23**	0.1	**0.33**	**0.38**
Arsenic	mg/L	-	0.01	0.001	0.0062	0.0079	0.002	**0.013**	**0.014**
Boron	mg/L	29	1.5	0.0015	0.011	0.016	0.0032	0.026	0.026
Cadmium	mg/L	timeseries (0.00029 - 0.004)	timeseries (0.000036-0.00037)	0.00001	0.000014	0.000014	0.000017	0.000023	0.000024
Chromium	mg/L	-	0.001	0.00017	0.00046	0.00054	0.00029	0.0009	0.0009
Copper	mg/L	-	0.0042	0.0018	0.0031	0.0034	0.0035	**0.0064**	**0.006**
Iron	mg/L	-	0.3	0.077	0.26	0.3	0.14	**0.54**	**0.52**
Lead	mg/L	-	timeseries (0.001-0.007)	0.000037	0.00015	0.00016	0.000066	0.00034	0.0003
Manganese	mg/L	timeseries (1.2 - 11.7)[d)]	timeseries (0.19 - 0.62)[(d)]	0.009	0.026	0.038	0.016	0.055	0.063
Mercury	mg/L	-	0.000026	0.0000031	0.0000074	0.0000087	0.0000061	0.000014	0.000015
Molybdenum	mg/L	-	0.073	0.000066	0.0036	0.0034	0.00011	0.009	0.0071
Nickel	mg/L	-	timeseries (0.025 - 0.15)	0.0051	0.0067	0.0085	0.008	0.013	0.014
Selenium	mg/L	-	0.001	0.00007	0.00032	0.00035	0.00013	0.00071	0.00063
Silver	mg/L	-	0.00025	0.0000056	0.000014	0.000016	0.00001	0.000026	0.000026
Thallium	mg/L	-	0.0008	0.000029	0.000058	0.000064	0.000058	0.0001	0.00011

Parameter	Unit	CCME Aquatic Life Guideline or SSWQO[a]		Monthly Average Constituent Concentrations for Mine Period[b]			Maximum Monthly Average Constituent Concentrations for Mine Period[b]		
				Lake Outflow			Lake Outflow		
		Acute	Chronic	Operational	Closure	Post-closure	Operational	Closure	Post-closure
Uranium	mg/L	0.033	0.015	0.000009	0.0001	0.00019	0.000015	0.00025	0.00033
Zinc	mg/L	timeseries (0.021 - 0.18)[d]	timeseries (0.0087 - 0.06)[d]	0.0016	0.0021	0.0025	0.0025	0.0038	0.0041
Other									
Cyanide (free)	mg/L	-	0.005	0.00043	0.00054	0.00058	0.00071	0.0009	0.001

Note:

Bold indicates concentration is above a chronic water quality benchmark. Predicted maximum monthly average concentrations at Goose Lake outlet were below acute water quality benchmarks.

a) See Table 1 for list of water quality benchmarks.

b) Peak concentrations during these mine phases are associated with ice-cover season.

c) Concentrations of total ammonia are not predicted to be above the benchmark, see daily timeseries plots presented in Attachment 1.

d) Benchmark values for dissolved fraction are presented.

- = no guideline.

Timeseries of modelled TDS concentrations at the Goose Lake outlet (Figure 8) show increasing trends during the closure period until Year 16 after which a gradual decrease in concentrations is noted during the remaining closure years and the post-closure period. The predicted trend in concentrations exhibits onset and subsequent reduction of mine-affected discharges to the lake (at PN04 and PN05). Predicted annual cycles of water temperatures during the forecast period (Figure 9) remain consistent with those projected during the calibration period (Figure 4).

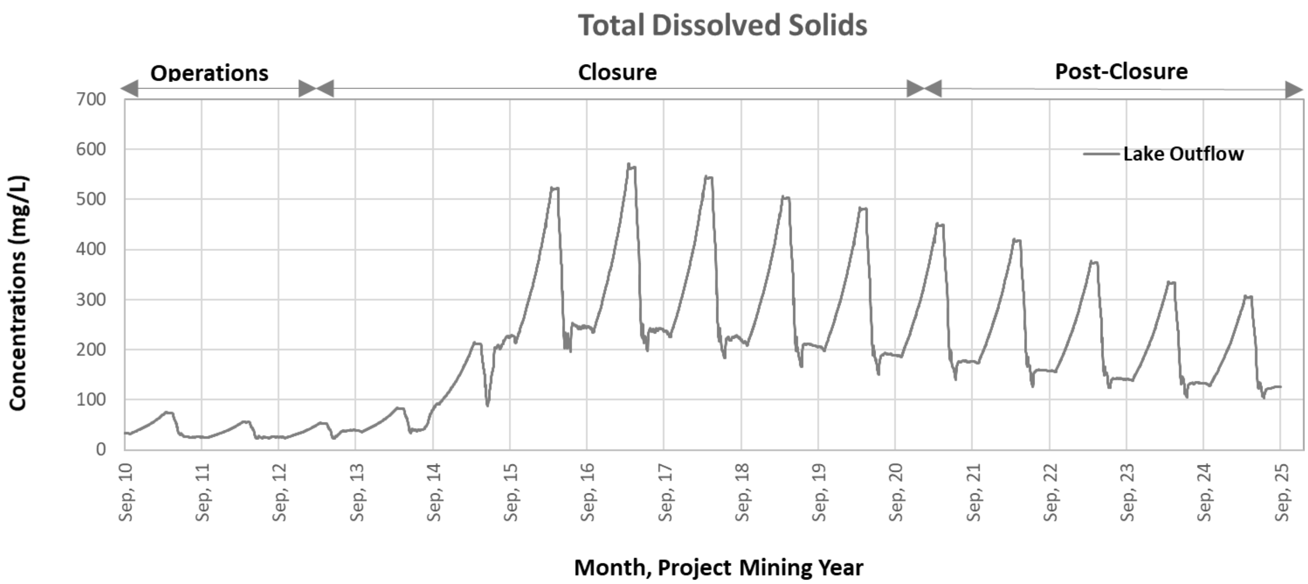


Figure 8: Predicted Goose Lake TDS Concentration Timeseries at the Goose Lak Outlet Over Forecast Period

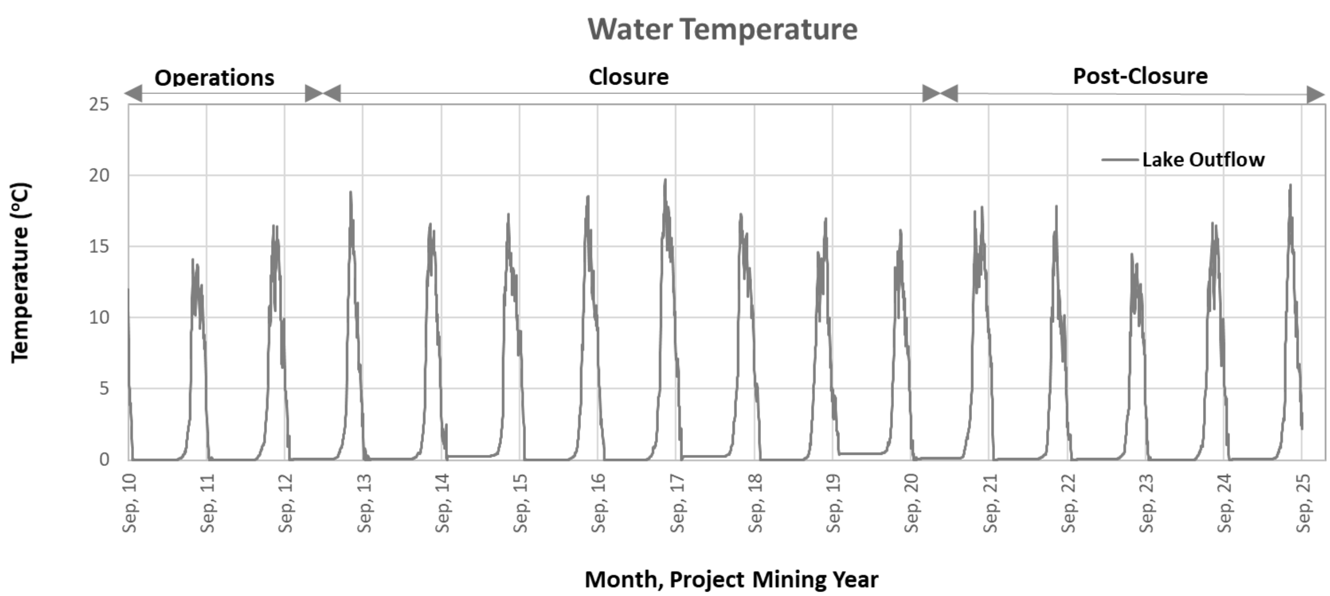


Figure 9: Predicted Goose Lake Water Temperature Timeseries Over Forecast Simulation Period

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The Goose Lake Model was developed using MIKE3 FM to predict water quality concentrations at the outlet of Goose Lake during the period when active mine-affected discharge to the lake occurs.

The model was calibrated using existing field and laboratory data (i.e., measured water temperature and TDS concentrations) and reproduces seasonal fluctuations in water temperatures and TDS concentrations across the lake. Overall, the model calibration indicates that the model is tracking the movement of water and dissolved constituents reasonably well throughout the lake. Thus, the Goose Lake Model is considered a reasonable representation of the system.

The Goose Lake Model projects that two constituents of potential concern during operations (i.e., aluminum and copper) and seven constituents of potential concern during closure and post-closure (i.e., nitrate, nitrite, aluminum, arsenic, chromium, copper, and iron) are expected to be above chronic water quality benchmarks for the protection of aquatic life at the outlet of Goose Lake. Concentrations of these constituents are predicted to decrease, or stabilize for aluminum, over the post-closure period. Concentrations of all other water quality constituents at the outlet of Goose Lake are predicted to remain below applicable chronic water quality benchmarks throughout the forecast period.

6.2 Recommendations

<u>Mine-affected discharges to Goose Lake are not planned to occur until Year 11</u>, which provides substantial time to better understand the system and potential effects on water quality as a result of these discharges. During this time, based on site water quality measurements, Sabina can improve the assumptions and approaches used in WLB and Goose Lake models, such as incorporating updates to water management, as necessary, and potential mitigations (treatment options), in advance of initiating discharges to Goose Lake. It is recommended that future consideration focus on addressing water quality constituents with predicted concentrations that are shown to be above water quality benchmarks, such as:

- Incorporating additional mitigation options to minimise mine-related loading contributions associated with identified constituents of potential concern.
- Evaluating the applicability of using water quality guidelines that incorporate exposure and toxicity modifying factors, thereby accounting for site-specific conditions.
- Developing or updating site-specific water quality objectives based on values from the literature or by performing site-specific toxicity testing.
- Modifying the location (particularly with respect to defining mixing zones), timing, or volumes of discharges to Goose Lake.
- Reviewing and refining level of conservatism in the Goose Lake Model assumptions.
- Reviewing and refining assumptions made in the WLB model (SRK 2020), which is the model that provides mass and volume inputs to the hydrodynamic model.

7.0 CLOSURE

The reader is referred to the Study Limitations section, which follows the text and forms an integral part of this memorandum.

We trust that the content of this technical memorandum meets your expectations. Please do not hesitate to contact the undersigned should you have any questions or comments.

Golder Associates Ltd.

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Water Quality Modeller

Greg Rose, M.A.Sc.
Associate, Senior Water Resources Specialist

SD/GR/jr

Attachments: Study Limitations
Attachment 1: Water Quality Results

https://golderassociates.sharepoint.com/sites/130261/project files/5 technical work/2400_hydrodynamic_model/report/rev0/20147042-074-tm-gooselake_wq_modelling_rev0.docx

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STUDY LIMITATIONS

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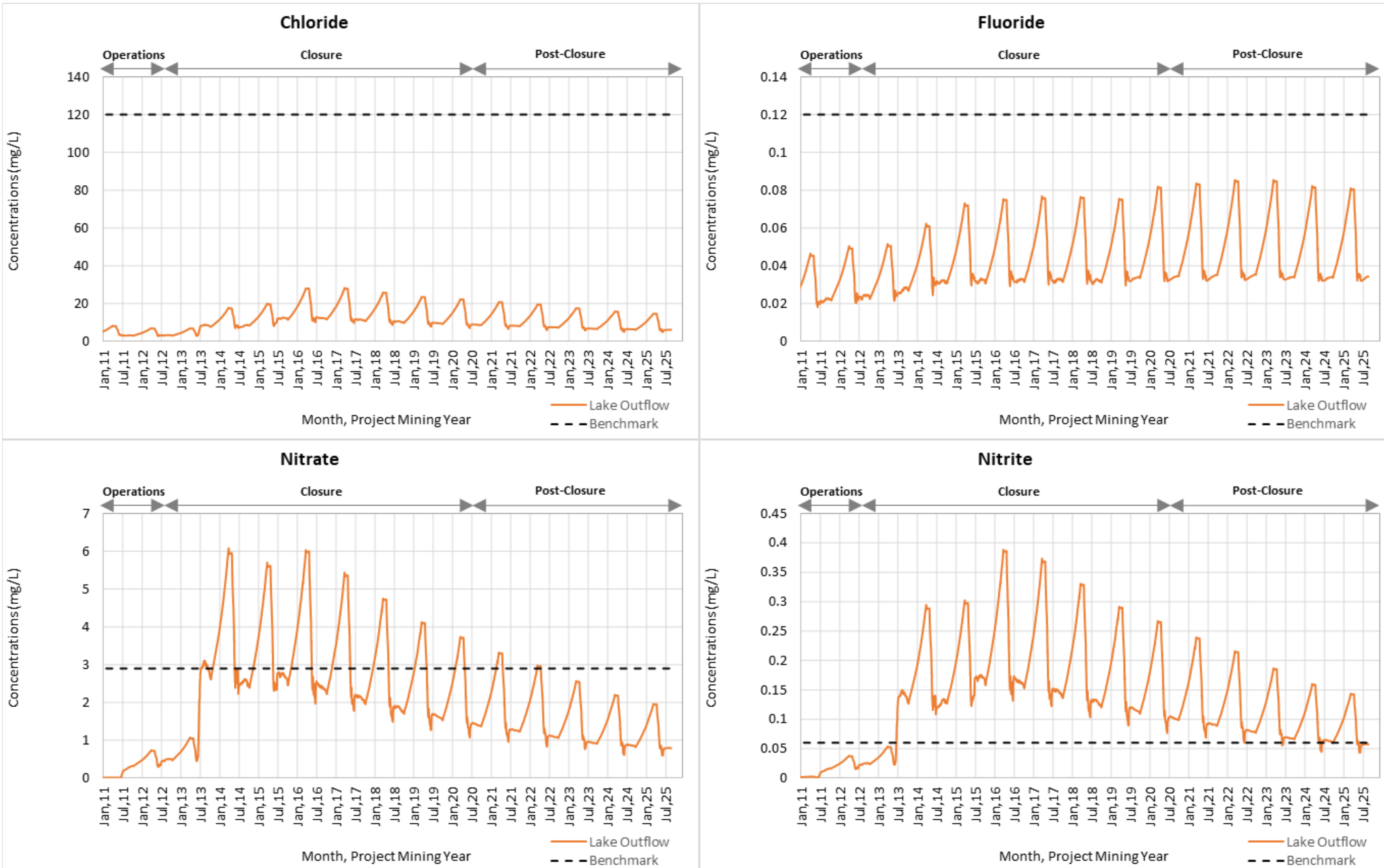
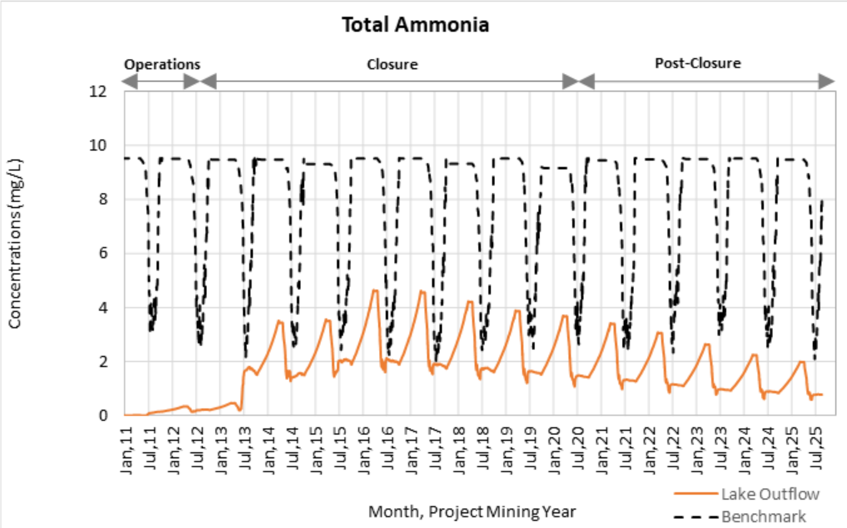
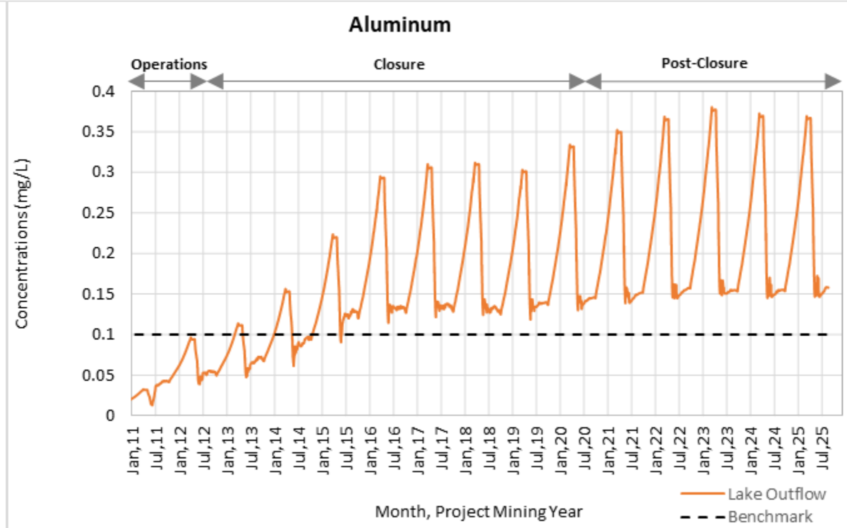
ATTACHMENT 1

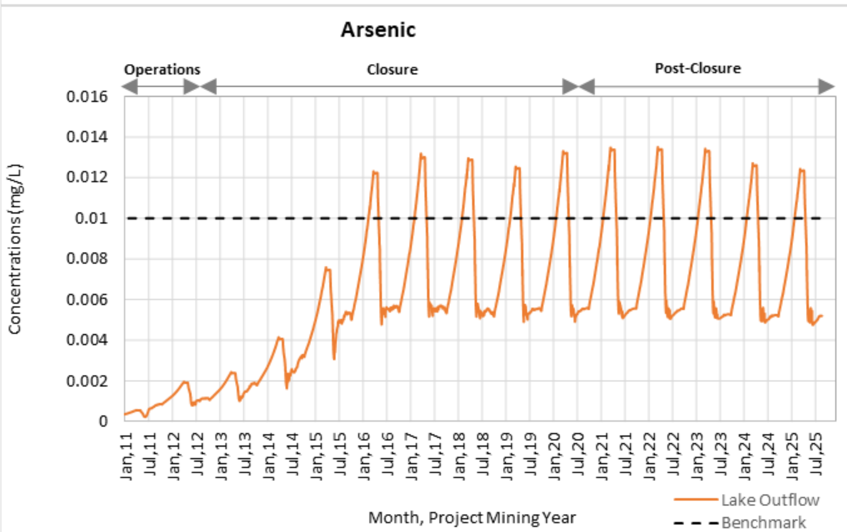
Water Quality Results

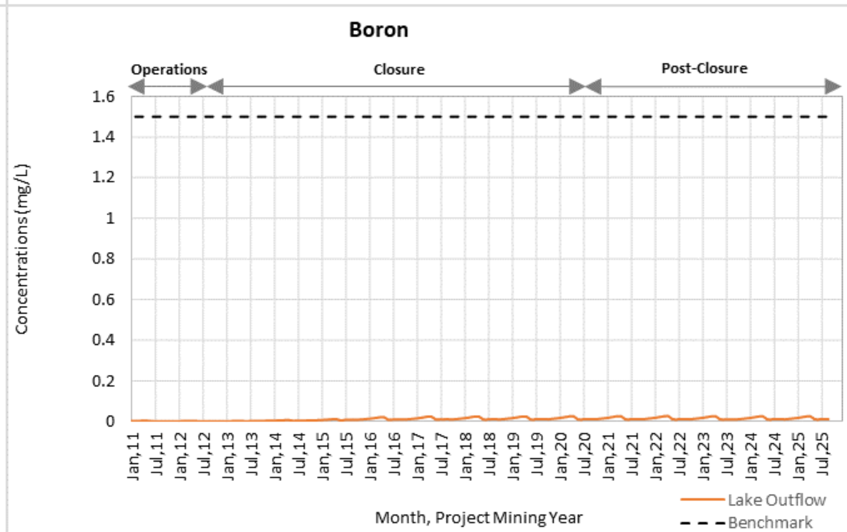
Figure 1: Predicted Time Series Concentrations of Modelled Water Quality Constituents in Goose Lake at the outlet over the Forecast Period

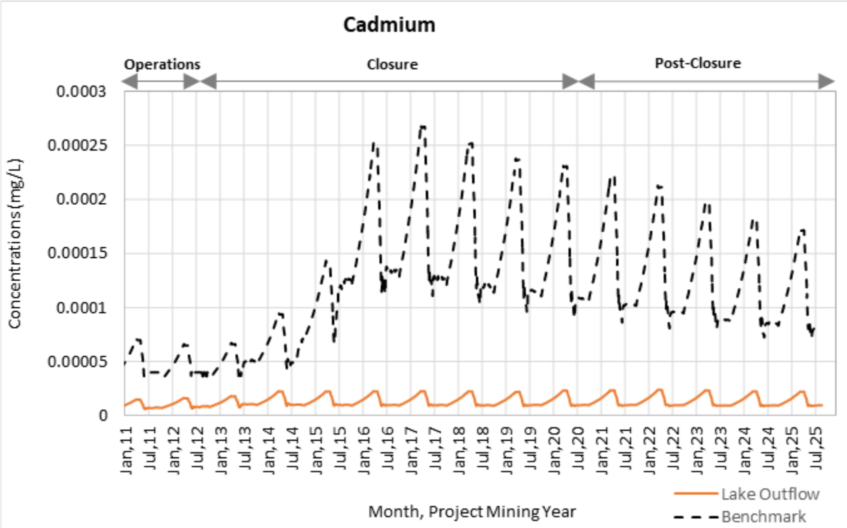


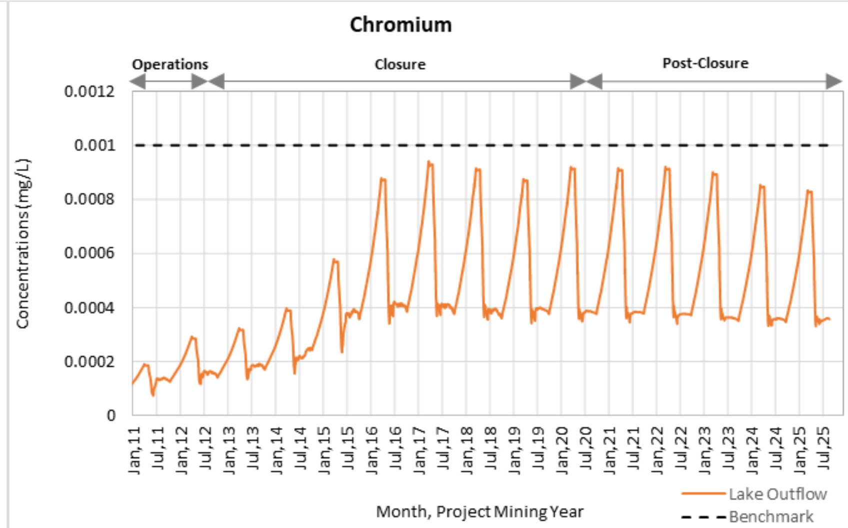

Total Ammonia
Operations
Closure
Post-Closure
Concentrations (mg/L)
0
2
4
6
8
10
12
Jan,11 Jul,11 Jan,12 Jul,12 Jan,13 Jul,13 Jan,14 Jul,14 Jan,15 Jul,15 Jan,16 Jul,16 Jan,17 Jul,17 Jan,18 Jul,18 Jan,19 Jul,19 Jan,20 Jul,20 Jan,21 Jul,21 Jan,22 Jul,22 Jan,23 Jul,23 Jan,24 Jul,24 Jan,25 Jul,25
Month, Project Mining Year
Lake Outflow
Benchmark

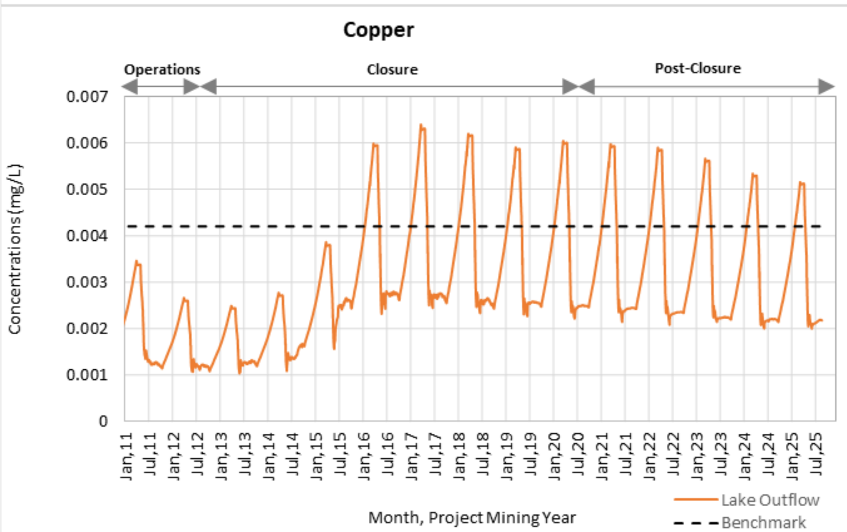

Aluminum
Operations
Closure
Post-Closure
Concentrations (mg/L)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Jan,11 Jul,11 Jan,12 Jul,12 Jan,13 Jul,13 Jan,14 Jul,14 Jan,15 Jul,15 Jan,16 Jul,16 Jan,17 Jul,17 Jan,18 Jul,18 Jan,19 Jul,19 Jan,20 Jul,20 Jan,21 Jul,21 Jan,22 Jul,22 Jan,23 Jul,23 Jan,24 Jul,24 Jan,25 Jul,25
Month, Project Mining Year
Lake Outflow
Benchmark

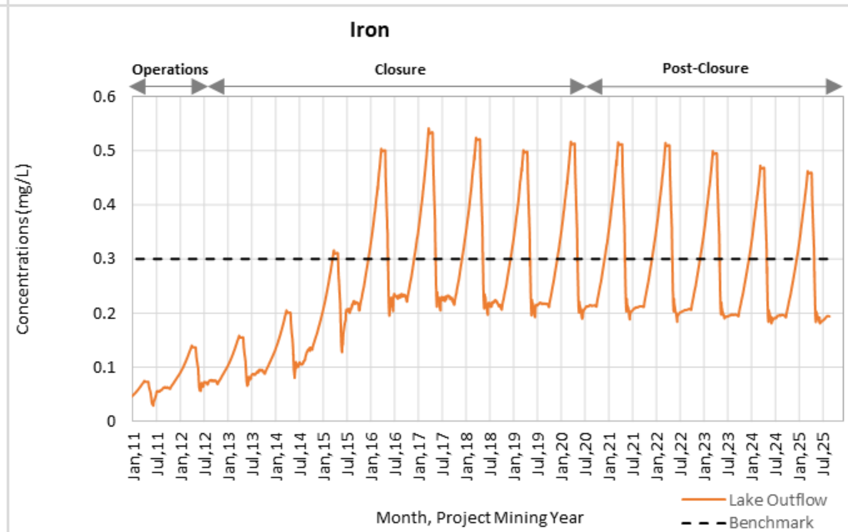

Arsenic
Operations
Closure
Post-Closure
Concentrations (mg/L)
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
Jan,11 Jul,11 Jan,12 Jul,12 Jan,13 Jul,13 Jan,14 Jul,14 Jan,15 Jul,15 Jan,16 Jul,16 Jan,17 Jul,17 Jan,18 Jul,18 Jan,19 Jul,19 Jan,20 Jul,20 Jan,21 Jul,21 Jan,22 Jul,22 Jan,23 Jul,23 Jan,24 Jul,24 Jan,25 Jul,25
Month, Project Mining Year
Lake Outflow
Benchmark

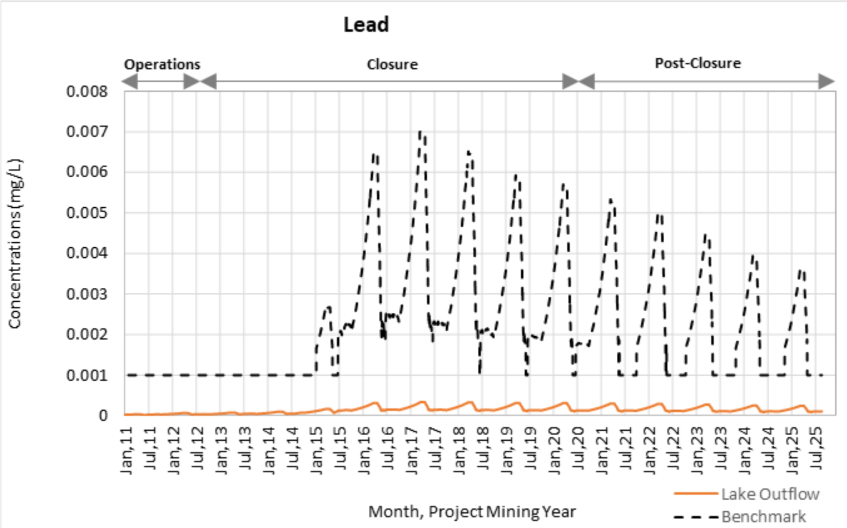

Boron
Operations
Closure
Post-Closure
Concentrations (mg/L)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Jan,11 Jul,11 Jan,12 Jul,12 Jan,13 Jul,13 Jan,14 Jul,14 Jan,15 Jul,15 Jan,16 Jul,16 Jan,17 Jul,17 Jan,18 Jul,18 Jan,19 Jul,19 Jan,20 Jul,20 Jan,21 Jul,21 Jan,22 Jul,22 Jan,23 Jul,23 Jan,24 Jul,24 Jan,25 Jul,25
Month, Project Mining Year
Lake Outflow
Benchmark

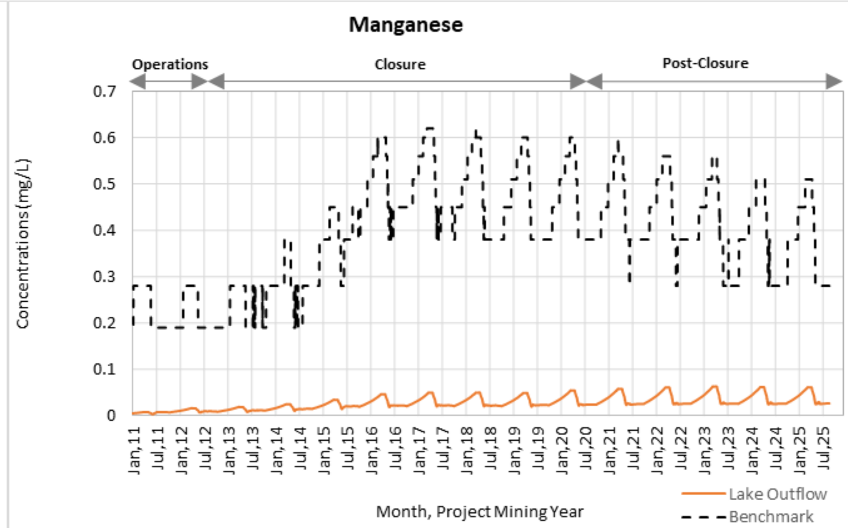

Cadmium
Operations
Closure
Post-Closure
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
Concentrations (mg/L)
Jan,11 Jul,11 Jan,12 Jul,12 Jan,13 Jul,13 Jan,14 Jul,14 Jan,15 Jul,15 Jan,16 Jul,16 Jan,17 Jul,17 Jan,18 Jul,18 Jan,19 Jul,19 Jan,20 Jul,20 Jan,21 Jul,21 Jan,22 Jul,22 Jan,23 Jul,23 Jan,24 Jul,24 Jan,25 Jul,25
Month, Project Mining Year
Lake Outflow
Benchmark

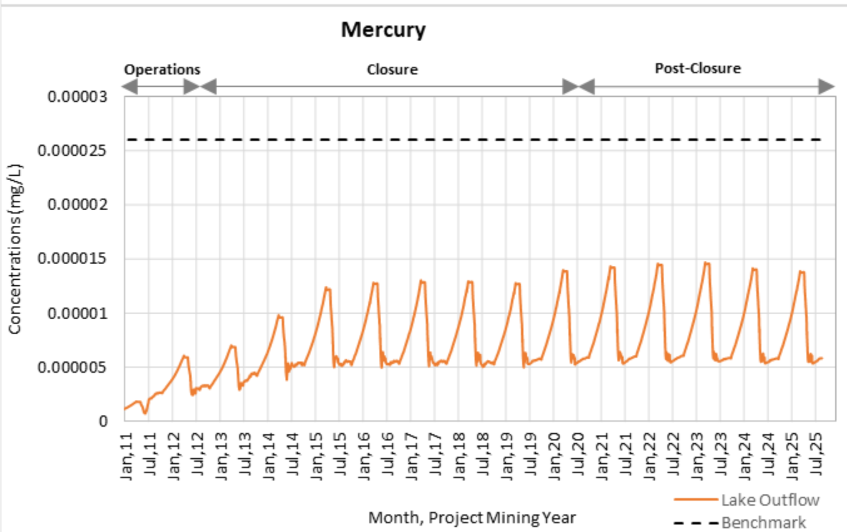

Chromium
Operations
Closure
Post-Closure
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
Concentrations (mg/L)
Jan,11 Jul,11 Jan,12 Jul,12 Jan,13 Jul,13 Jan,14 Jul,14 Jan,15 Jul,15 Jan,16 Jul,16 Jan,17 Jul,17 Jan,18 Jul,18 Jan,19 Jul,19 Jan,20 Jul,20 Jan,21 Jul,21 Jan,22 Jul,22 Jan,23 Jul,23 Jan,24 Jul,24 Jan,25 Jul,25
Month, Project Mining Year
Lake Outflow
Benchmark

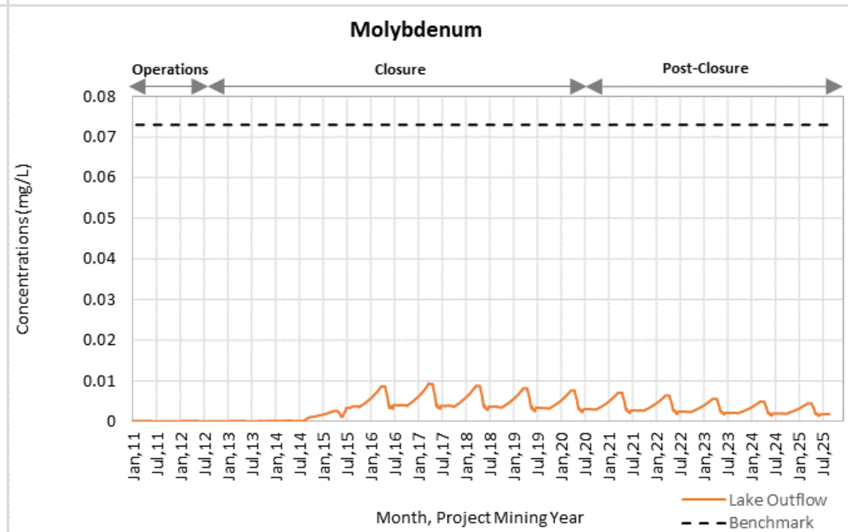

Copper
Operations
Closure
Post-Closure
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Concentrations (mg/L)
Jan,11 Jul,11 Jan,12 Jul,12 Jan,13 Jul,13 Jan,14 Jul,14 Jan,15 Jul,15 Jan,16 Jul,16 Jan,17 Jul,17 Jan,18 Jul,18 Jan,19 Jul,19 Jan,20 Jul,20 Jan,21 Jul,21 Jan,22 Jul,22 Jan,23 Jul,23 Jan,24 Jul,24 Jan,25 Jul,25
Month, Project Mining Year
Lake Outflow
Benchmark

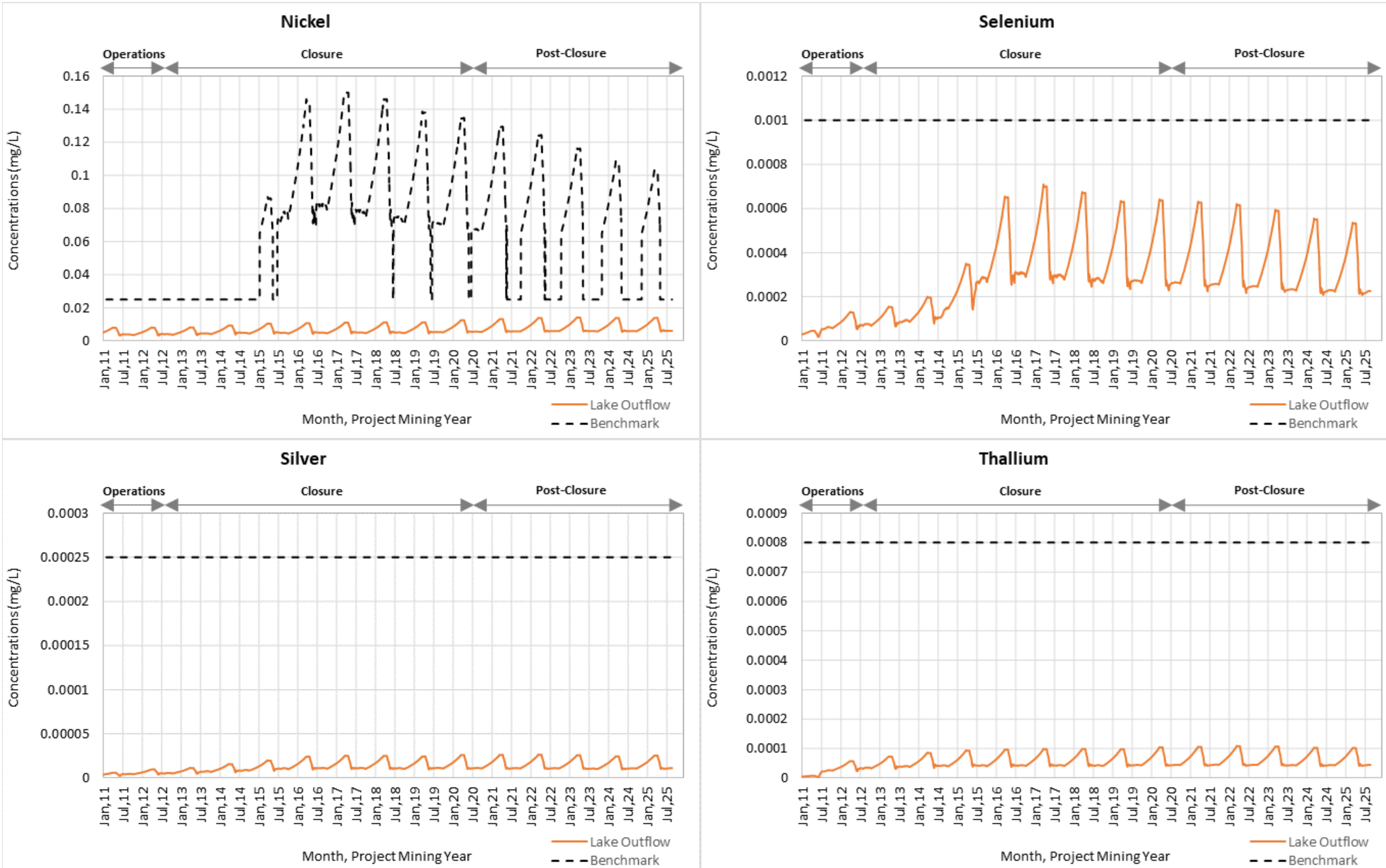

Iron
Operations
Closure
Post-Closure
0.6
0.5
0.4
0.3
0.2
0.1
0
Concentrations (mg/L)
Jan,11 Jul,11 Jan,12 Jul,12 Jan,13 Jul,13 Jan,14 Jul,14 Jan,15 Jul,15 Jan,16 Jul,16 Jan,17 Jul,17 Jan,18 Jul,18 Jan,19 Jul,19 Jan,20 Jul,20 Jan,21 Jul,21 Jan,22 Jul,22 Jan,23 Jul,23 Jan,24 Jul,24 Jan,25 Jul,25
Month, Project Mining Year
Lake Outflow
Benchmark

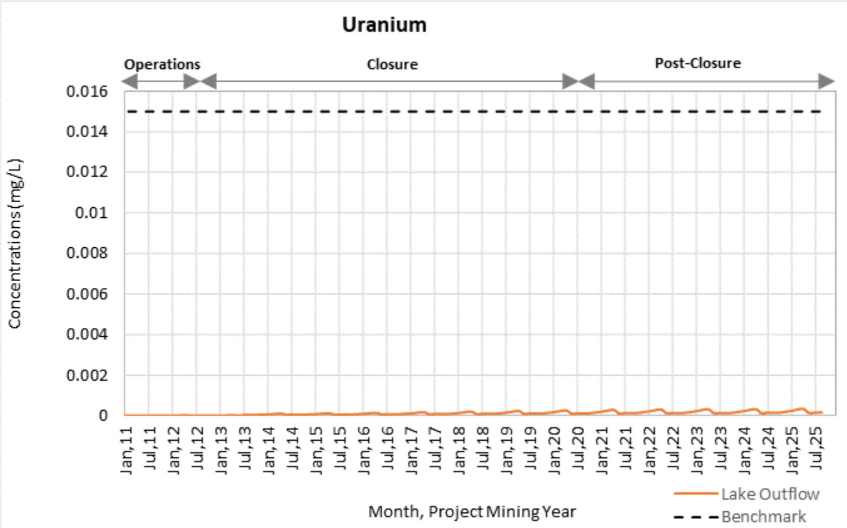

Lead
Operations
Closure
Post-Closure
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Concentrations (mg/L)
Jan,11 Jul,11 Jan,12 Jul,12 Jan,13 Jul,13 Jan,14 Jul,14 Jan,15 Jul,15 Jan,16 Jul,16 Jan,17 Jul,17 Jan,18 Jul,18 Jan,19 Jul,19 Jan,20 Jul,20 Jan,21 Jul,21 Jan,22 Jul,22 Jan,23 Jul,23 Jan,24 Jul,24 Jan,25 Jul,25
Month, Project Mining Year
Lake Outflow
Benchmark


Manganese
Operations
Closure
Post-Closure
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Concentrations (mg/L)
Jan,11 Jul,11 Jan,12 Jul,12 Jan,13 Jul,13 Jan,14 Jul,14 Jan,15 Jul,15 Jan,16 Jul,16 Jan,17 Jul,17 Jan,18 Jul,18 Jan,19 Jul,19 Jan,20 Jul,20 Jan,21 Jul,21 Jan,22 Jul,22 Jan,23 Jul,23 Jan,24 Jul,24 Jan,25 Jul,25
Month, Project Mining Year
Lake Outflow
Benchmark


Mercury
Operations
Closure
Post-Closure
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
Concentrations (mg/L)
Jan,11 Jul,11 Jan,12 Jul,12 Jan,13 Jul,13 Jan,14 Jul,14 Jan,15 Jul,15 Jan,16 Jul,16 Jan,17 Jul,17 Jan,18 Jul,18 Jan,19 Jul,19 Jan,20 Jul,20 Jan,21 Jul,21 Jan,22 Jul,22 Jan,23 Jul,23 Jan,24 Jul,24 Jan,25 Jul,25
Month, Project Mining Year
Lake Outflow
Benchmark


Molybdenum
Operations
Closure
Post-Closure
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Concentrations (mg/L)
Jan,11 Jul,11 Jan,12 Jul,12 Jan,13 Jul,13 Jan,14 Jul,14 Jan,15 Jul,15 Jan,16 Jul,16 Jan,17 Jul,17 Jan,18 Jul,18 Jan,19 Jul,19 Jan,20 Jul,20 Jan,21 Jul,21 Jan,22 Jul,22 Jan,23 Jul,23 Jan,24 Jul,24 Jan,25 Jul,25
Month, Project Mining Year
Lake Outflow
Benchmark


Nickel
Operations
Closure
Post-Closure
Concentrations (mg/L)
Month, Project Mining Year
Lake Outflow
Benchmark
Selenium
Operations
Closure
Post-Closure
Concentrations (mg/L)
Month, Project Mining Year
Lake Outflow
Benchmark
Silver
Operations
Closure
Post-Closure
Concentrations (mg/L)
Month, Project Mining Year
Lake Outflow
Benchmark
Thallium
Operations
Closure
Post-Closure
Concentrations (mg/L)
Month, Project Mining Year
Lake Outflow
Benchmark


Uranium
Operations
Closure
Post-Closure
Concentrations (mg/L)
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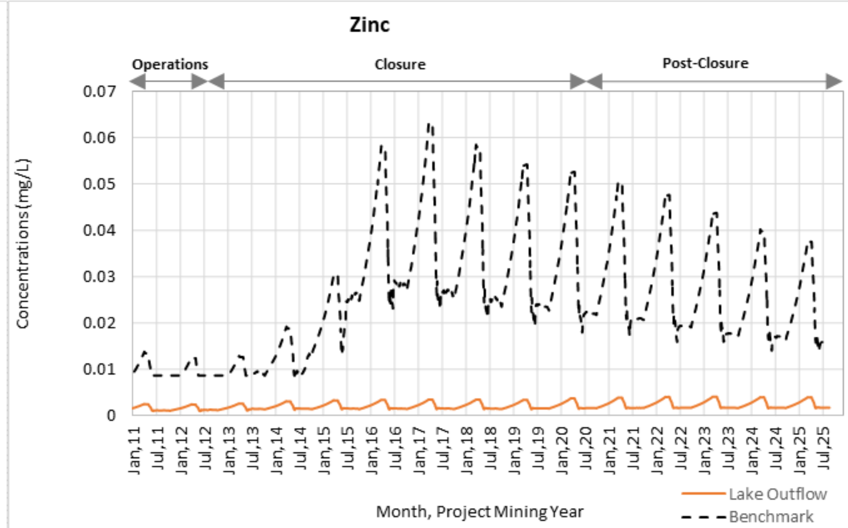
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Month, Project Mining Year
Lake Outflow
Benchmark


Zinc
Operations
Closure
Post-Closure
Concentrations (mg/L)
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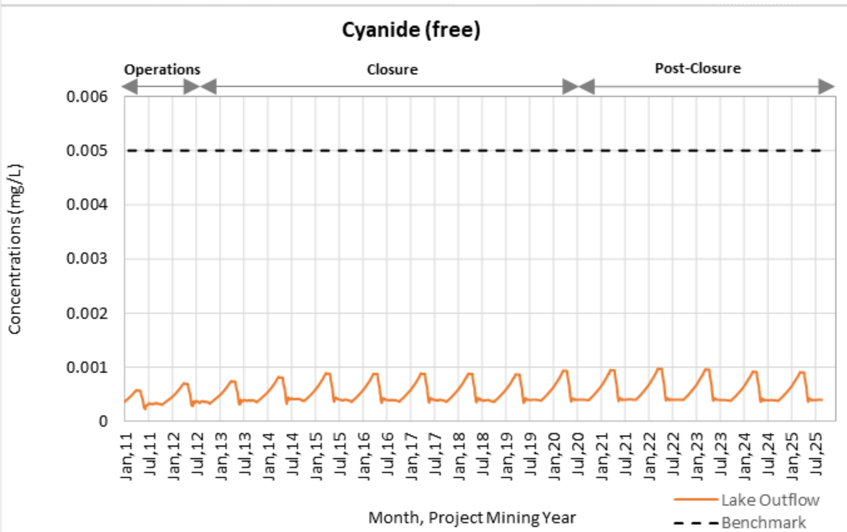
0.06
0.05
0.04
0.03
0.02
0.01
0
Month, Project Mining Year
Lake Outflow
Benchmark


Cyanide (free)
Operations
Closure
Post-Closure
Concentrations (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
Month, Project Mining Year
Lake Outflow
Benchmark

Attachment TC-B: Water Quality Projections With Treatment

Appendix D

Water Quality Projections With Treatment

Water Quality Projections With Treatment

Parameter	Goose Lake		Goose Pit		Llama TF		Primary Pond		TSF Reservoir		Saline Water Pond		Umwelt Reservoir		PN01		PN02	
(mg/L)	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max
TDS	73	590	74	75	170	31000	-	4500	1600	8600	-	23000	280	1100	16	330	21	330
Total_CN	0.0013	0.0019	0.0025	0.003	-	1.1	-	0.0028	-	1.4	-	0.0015	-	0.0021	-	0.0031	-	0.0026
Sulphate	31	310	36	39	80	7100	-	610	960	6200	-	29	110	220	6.2	170	8.5	170
Chloride	4.6	27	2.6	3.5	7.8	3800	-	2800	46	240	-	11000	15	91	1.5	15	1.6	15
Total_Ammonia	-	0.92	-	0.2	-	170	-	190	0.29	83	-	0.089	-	81	-	0.034	-	0.48
Nitrate_N	0.21	5.1	-	0.32	0.82	48	-	300	22	44	-	0.48	4.7	250	0.033	2.8	0.051	2.8
Nitrite_N	0.019	0.4	-	0.041	0.076	3.6	-	15	1.4	2.8	-	0.082	0.3	13	0.0028	0.2	0.0042	0.2
Alkalinity	13	21	17	17	11	41	-	67	40	500	-	9.4	42	44	3.2	12	4	12
Ortho_P	-	0.015	-	-	-	0.069	-	0.0058	0.006	0.026	-	0.033	-	-	-	0.0048	-	0.0048
Phosphate_P	-	0.013	-	-	-	0.24	-	-	0.0059	0.026	-	0.12	-	0.0011	-	0.0038	-	0.0038
TOC	5.5	8.7	3.9	4.6	4.1	4.3	-	25	-	6.9	-	2.9	2.1	3.2	2	5	2	5
Total Aluminum	0.26	0.4	0.35	2.2	0.2	2.3	-	1.3	1.5	56	-	0.24	1.2	2.1	0.043	0.22	0.066	0.22
Total Antimony	0.00024	0.00048	0.00031	0.0013	0.00024	0.0069	-	0.0012	0.0015	0.012	-	0.0024	0.00087	0.0017	0.000052	0.00027	0.000068	0.00027
Total Arsenic	0.0073	0.014	0.011	0.098	0.0067	0.24	-	0.099	0.07	0.49	-	0.012	0.036	0.15	0.0012	0.0077	0.0018	0.0077
Total Barium	0.0097	0.025	0.0067	0.012	0.012	6.8	-	0.038	0.019	0.25	-	3.2	0.021	0.026	0.0032	0.014	0.0034	0.014
Total Beryllium	0.00027	0.00042	-	0.00024	0.00021	0.0012	-	0.0012	-	0.0043	-	0.00066	-	0.00023	-	0.00025	-	0.00025
Total Bismuth	0.00066	0.0011	-	0.0006	0.00051	0.049	-	0.0029	-	0.001	-	0.023	-	0.0016	-	0.00065	-	0.00065
Total Boron	0.019	0.029	-	0.049	0.068	4.3	-	0.24	0.042	2.2	-	2	0.36	0.39	-	0.016	-	0.016
Total Cadmium	0.000015	0.000025	-	0.000057	0.000015	0.00099	-	0.000058	0.000014	0.0012	-	0.00047	0.000036	0.000071	-	0.000014	-	0.000014
Total Calcium	10	60	10	11	18	18000	-	1600	110	1200	-	8400	42	97	2.4	33	3	33
Total Chromium	0.00049	0.00098	0.00048	0.0026	0.00057	0.013	-	0.0018	0.0025	0.049	-	0.0034	0.0021	0.0024	0.00011	0.00056	0.00014	0.00056
Total Cobalt	0.0021	0.0064	0.0024	0.0077	0.0025	0.1	-	0.0096	0.02	0.36	-	0.0056	0.0074	0.017	0.00039	0.0036	0.00055	0.0036
Total Copper	0.0027	0.0064	0.0026	0.0069	0.0027	0.1	-	0.0087	0.026	2.3	-	0.0051	0.0047	0.0097	0.00082	0.0036	0.0009	0.0036
Total Iron	0.25	0.56	0.29	1.7	0.24	6.7	-	1.7	2.1	140	-	2.1	0.87	3.2	0.056	0.31	0.072	0.31
Total Lead	0.00012	0.00035	0.000058	0.00025	0.00025	0.0055	-	0.0012	0.00068	0.0044	-	0.0023	0.00089	0.001	-	0.0002	-	0.0002
Total Lithium	-	0.011	-	0.008	0.0061	7.9	-	0.021	-	0.14	-	3.7	0.019	0.029	-	0.0059	-	0.0059
Total Magnesium	2.7	8.8	2.4	2.9	3	1100	-	54	14	280	-	530	8.3	19	0.83	5	0.9	5
Total Manganese	0.043	0.066	0.06	0.061	0.032	3.2	-	0.18	0.19	5	-	1.5	0.14	0.15	0.0083	0.037	0.012	0.037
Total Mercury	0.001	0.073	0.0012	0.084	0.00057	0.041	-	0.000022	0.0033	0.24	-	-	0.0042	0.31	-	-	-	-
Total Molybdenu	0.00061	0.0093	0.00059	0.00061	0.0025	0.25	-	0.00099	0.029	0.49	-	0.022	0.0017	0.0058	0.00011	0.0052	0.00016	0.0052
Total Nickel	0.01	0.015	0.01	0.023	0.0072	0.034	-	0.032	0.02	0.34	-	0.01	0.025	0.053	0.0025	0.0088	0.003	0.0088
Total Phosphorus	-	-	-	-	-	3.7	-	-	-	-	-	1.7	-	-	-	-	-	-
Total Potassium	1.5	9.6	0.39	2.7	5.4	270	-	12	23	92	-	130	17	22	0.34	5.4	0.44	5.4
Total Selenium	0.00027	0.00072	0.0003	0.0011	0.0003	0.012	-	0.00095	0.0018	0.022	-	0.0047	0.00069	0.0013	-	0.0004	-	0.0004
Total Silicon	1.3	2	0.87	5.8	2.5	23	-	9.9	4.7	95	-	0.88	12	13	0.26	1.1	0.35	1.1
Total Silver	0.000016	0.000028	0.000013	0.000026	0.000013	0.00099	-	0.00006	0.000029	0.0004	-	0.00047	0.000019	0.000034	-	0.000016	-	0.000016
Total Sodium	4.2	140	0.57	2.9	35	7500	-	6.4	360	1400	-	3600	7.5	68	0.83	77	1.1	77
Total Strontium	0.033	0.41	0.014	0.061	0.12	370	-	0.18	0.17	3.2	-	170	0.1	0.29	0.0097	0.23	0.011	0.23
Total Tellerium	0.000027	0.000042	-	0.0016	0.0001	0.0013	-	0.00066	0.000074	0.00095	-	0.00012	0.00057	0.0014	-	0.000023	-	0.000023
Total Thallium	0.000068	0.00011	-	0.000061	0.000056	0.0049	-	0.00029	-	0.00037	-	0.0023	0.00007	0.000075	-	0.000063	-	0.000063
Total Thorium	-	0.000021	0.000011	0.000085	0.000016	0.00036	-	0.000061	0.000076	0.0013	-	-	0.00008	0.000089	-	0.000012	-	0.000012
Total Tin	0.00021	0.00033	-	0.00025	0.0004	0.0099	-	0.0012	0.00027	0.01	-	0.0047	0.0017	0.0018	-	0.00019	-	0.00019
Total Titanium	-	-	-	0.048	-	0.12	-	0.023	0.023	0.32	-	0.06	0.025	0.041	-	-	-	-
Total Uranium	0.00033	0.00053	0.000012	0.00069	0.0012	0.0013	-	0.0047	0.00011	0.0043	-	0.0005	0.007	0.0074	0.000053	0.00029	0.000083	0.00029
Total Vanadium	0.00053	0.00084	0.00014	0.0022	0.0016	0.037	-	0.0087	0.00041	0.016	-	0.018	0.0084	0.0089	0.000097	0.00047	0.00014	0.00047
Total Zinc	-	0.0043	-	0.0055	-	0.33	-	0.0091	0.0068	0.17	-	0.16	0.007	0.013	-	-	-	-
Total Zirconium	0.00011	0.00017	0.000054	0.00033	0.00018	0.00026	-	0.00061	0.000034	0.0045	-	0.000047	0.00074	0.00078	0.000035	0.000099	0.000037	0.000099

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Model\Results\Final_Back_River_PN_WQ_Results_2021-02-03_IR_LMP.xlsxFinal_Back_River_PN_WQ_Results_2021-02-03_IR_LMP.xlsx

Water Quality Projections With Treatment

Parameter	PN03		PN04		PN05		PN06		PN07		PN08		PN09		PN10	
(mg/L)	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max
TDS	27	350	27	1300	22	69	-	20	-	-	-	21	-	30	-	19
Total_CN	-	0.0017	-	0.003	-	0.0031	-	0.0031	-	-	-	0.0031	-	0.0031	-	0.0031
Sulphate	11	180	11	690	11	35	1.5	4.8	-	-	1.5	5	1.5	5	1.5	4.8
Chloride	1.7	16	1.6	59	0.82	3	0.88	3	-	-	0.87	3	0.87	3	0.88	3
Total_Ammonia	-	0.92	-	11	-	0.26	-	0.18	-	-	-	0.025	-	1.6	-	0.088
Nitrate_N	0.076	3	0.18	18	-	0.41	-	0.28	-	-	-	0.41	-	2.7	-	0.14
Nitrite_N	0.0061	0.21	0.014	0.92	-	0.021	-	0.015	-	-	-	0.021	-	0.13	-	0.0077
Alkalinity	4.9	12	3.1	13	4.9	15	-	4.5	-	-	-	4.6	-	4.6	-	4.5
Ortho_P	-	0.0058	-	0.0053	-	-	-	-	-	-	-	-	-	-	-	-
Phosphate_P	-	0.0049	-	0.005	-	-	-	-	-	-	-	-	-	-	-	-
TOC	2	5	1.1	4.6	1.2	4.8	1.2	4.8	-	-	1.2	4.8	1.2	4.8	1.2	4.8
Total Aluminum	0.095	0.23	0.075	0.41	0.1	0.33	0.0056	0.035	-	-	0.0093	0.046	0.011	0.052	0.0047	0.032
Total Antimony	0.000089	0.00028	0.000064	0.00077	0.000092	0.00029	-	0.000051	-	-	-	0.000055	-	0.000057	-	0.00005
Total Arsenic	0.0027	0.0082	0.0021	0.021	0.0031	0.0098	0.000079	0.00025	-	-	0.00014	0.00044	0.00017	0.00053	0.000066	0.00021
Total Barium	0.0036	0.014	0.0028	0.033	0.0021	0.007	0.0018	0.0069	-	-	0.0018	0.0069	0.0018	0.0069	0.0018	0.0069
Total Beryllium	-	0.00025	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0002
Total Bismuth	-	0.00065	-	0.00062	-	-	-	-	-	-	-	-	-	-	-	0.0005
Total Boron	0.0069	0.017	0.017	0.057	-	-	-	-	-	-	-	-	-	-	-	-
Total Cadmium	-	0.000015	-	0.000017	-	0.000011	-	-	-	-	-	-	-	-	-	0.00001
Total Calcium	3.7	35	3.4	130	3.1	9.8	0.87	3.1	-	-	0.89	3.2	0.89	3.2	0.86	3.1
Total Chromium	0.00018	0.00058	0.00016	0.0014	0.00014	0.00046	-	0.0002	-	-	-	0.00022	-	0.00022	-	0.0002
Total Cobalt	0.00076	0.0038	0.00063	0.012	0.00071	0.0023	-	0.00067	-	-	0.00012	0.00074	0.00013	0.00078	-	0.00065
Total Copper	0.00099	0.0037	0.00066	0.0087	0.00077	0.0025	-	0.0015	-	-	-	0.0015	-	0.0015	-	0.0015
Total Iron	0.093	0.33	0.078	0.88	0.086	0.27	0.019	0.068	-	-	0.022	0.077	0.023	0.081	0.018	0.066
Total Lead	-	0.00021	0.000063	0.00063	-	0.000057	-	0.00005	-	-	-	0.00005	-	0.000051	-	0.00005
Total Lithium	-	0.0063	-	0.023	-	-	-	-	-	-	-	-	-	-	-	-
Total Magnesium	1	5.2	0.78	15	0.72	2.3	0.43	1.4	-	-	0.44	1.4	0.44	1.4	0.43	1.4
Total Manganese	0.016	0.039	0.0094	0.059	0.017	0.056	0.0021	0.012	-	-	0.0023	0.013	0.0024	0.013	0.002	0.012
Total Mercury	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Molybdenu	0.00022	0.0055	0.00028	0.023	0.00017	0.00055	-	0.000051	-	-	-	0.000054	-	0.000056	-	0.00005
Total Nickel	0.0037	0.009	0.0025	0.0092	0.0031	0.01	0.0011	0.0054	-	-	0.0011	0.0056	0.0012	0.0057	0.0011	0.0053
Total Phosphoru	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Potassium	0.55	5.7	1.1	22	0.12	0.44	0.12	0.4	-	-	0.12	0.4	0.12	0.4	0.12	0.4
Total Selenium	-	0.00042	-	0.0012	-	0.00028	-	0.0001	-	-	-	0.0001	-	0.0001	-	0.0001
Total Silicon	0.46	1.2	0.66	2.9	0.26	0.83	0.073	0.37	-	-	0.08	0.39	0.083	0.4	0.071	0.36
Total Silver	-	0.000016	-	0.000024	-	0.000013	-	0.00001	-	-	-	0.00001	-	0.00001	-	0.00001
Total Sodium	1.5	81	3.4	340	0.18	0.65	0.19	0.63	-	-	0.19	0.63	0.19	0.63	0.19	0.63
Total Strontium	0.012	0.24	0.017	0.96	0.0044	0.016	0.0048	0.016	-	-	0.0048	0.016	0.0048	0.016	0.0048	0.016
Total Tellerium	-	0.000025	0.000026	0.000088	-	0.000039	-	-	-	-	-	-	-	-	-	-
Total Thallium	-	0.000063	-	0.000052	-	-	-	-	-	-	-	-	-	-	-	0.00005
Total Thorium	-	0.000012	-	0.00004	-	-	-	-	-	-	-	-	-	-	-	-
Total Tin	-	0.00019	0.0001	0.00035	-	0.0001	-	-	-	-	-	-	-	-	-	0.0001
Total Titanium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Uranium	0.00012	0.00031	0.00031	0.0011	-	0.000023	-	0.00001	-	-	-	0.00001	-	0.00001	-	0.00001
Total Vanadium	0.0002	0.00049	0.00043	0.0014	-	0.00014	-	0.000058	-	-	-	0.000061	-	0.000063	-	0.000057
Total Zinc	-	-	-	0.0033	-	-	-	-	-	-	-	-	-	-	-	-
Total Zirconium	0.000041	0.0001	0.000049	0.00016	0.000017	0.000066	0.000019	0.00006	-	-	0.000019	0.00006	0.000019	0.00006	0.000019	0.00006

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Model\Results\Final_Back_River_PN_WQ_Results_2021-02-03_IR_LMP.xlsxFinal_Back_River_PN_WQ_Results_2021-02-03_IR_LMP.xlsx

Appendix D

Water Quality Projections Without Treatment

Water Quality Projections Without Treatment

Parameter	Goose Lake		Goose Pit		Llama TF		Primary Pond		TSF Reservoir		Saline Water Pond		Umwelt Reservoir		PN01		PN02	
(mg/L)	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max
TDS	73	590	74	75	170	31000	-	4500	1600	8600	-	23000	280	1100	16	330	21	330
Total_CN	0.0013	0.0019	0.0025	0.003	-	1.1	-	0.0028	-	1.4	-	0.0015	-	0.0021	-	0.0031	-	0.0026
Sulphate	31	310	36	39	80	7100	-	610	960	6200	-	29	110	220	6.2	170	8.5	170
Chloride	4.6	27	2.6	3.5	7.8	3800	-	2800	46	240	-	11000	15	91	1.5	15	1.6	15
Total_Ammonia	-	2.4	-	0.2	-	170	-	190	0.29	83	-	0.089	-	81	-	0.052	-	1
Nitrate_N	0.21	5.1	-	0.32	0.82	47	-	300	22	44	-	0.48	4.7	250	0.033	2.8	0.051	2.8
Nitrite_N	0.021	0.4	-	0.041	0.076	3.6	-	15	1.4	2.8	-	0.082	0.3	13	0.0028	0.2	0.0042	0.2
Alkalinity	13	21	17	17	11	41	-	67	40	500	-	9.4	42	44	3.2	12	4	12
Ortho_P	-	0.015	-	-	-	0.069	-	0.0058	0.006	0.026	-	0.033	-	-	-	0.0048	-	0.0048
Phosphate_P	-	0.013	-	-	-	0.24	-	-	0.0059	0.026	-	0.12	-	0.0011	-	0.0038	-	0.0038
TOC	5.5	8.7	3.9	4.6	4.1	4.3	-	25	-	6.9	-	2.9	2.1	3.2	2	5	2	5
Total Aluminum	0.26	0.4	0.35	2.2	0.2	2.3	-	1.3	1.5	56	-	0.24	1.2	2.1	0.043	0.22	0.066	0.22
Total Antimony	0.00024	0.00048	0.00031	0.0013	0.00024	0.0069	-	0.0012	0.0015	0.012	-	0.0024	0.00087	0.0017	0.000052	0.00027	0.000068	0.00027
Total Arsenic	0.0074	0.018	0.011	0.098	0.0077	0.24	-	0.099	0.07	0.49	-	0.012	0.037	0.15	0.0012	0.0099	0.0018	0.0099
Total Barium	0.0097	0.025	0.0067	0.012	0.012	6.8	-	0.038	0.019	0.25	-	3.2	0.021	0.026	0.0032	0.014	0.0034	0.014
Total Beryllium	0.00027	0.00042	-	0.00024	0.00021	0.0012	-	0.0012	-	0.0043	-	0.00066	-	0.00023	-	0.00025	-	0.00025
Total Bismuth	0.00066	0.0011	-	0.0006	0.00051	0.049	-	0.0029	-	0.001	-	0.023	-	0.0016	-	0.00065	-	0.00065
Total Boron	0.019	0.029	-	0.049	0.068	4.3	-	0.24	0.042	2.2	-	2	0.36	0.39	-	0.016	-	0.016
Total Cadmium	0.000015	0.000025	-	0.000057	0.000015	0.00099	-	0.000058	0.000014	0.0012	-	0.00047	0.000036	0.000071	-	0.000014	-	0.000014
Total Calcium	10	60	10	11	18	18000	-	1600	110	1200	-	8400	42	97	2.4	33	3	33
Total Chromium	0.00049	0.00098	0.00048	0.0026	0.00057	0.013	-	0.0018	0.0025	0.049	-	0.0034	0.0021	0.0024	0.00011	0.00056	0.00014	0.00056
Total Cobalt	0.0021	0.0064	0.0024	0.0077	0.0025	0.1	-	0.0096	0.02	0.36	-	0.0056	0.0074	0.017	0.00039	0.0036	0.00055	0.0036
Total Copper	0.0027	0.0078	0.0026	0.0069	0.003	0.1	-	0.0087	0.026	2.3	-	0.0051	0.0047	0.0097	0.00083	0.0044	0.00091	0.0044
Total Iron	0.25	0.56	0.29	1.7	0.24	6.7	-	1.7	2.1	140	-	2.1	0.87	3.2	0.056	0.31	0.072	0.31
Total Lead	0.00012	0.00035	0.000058	0.00025	0.00025	0.0055	-	0.0012	0.00068	0.0044	-	0.0023	0.00089	0.001	-	0.0002	-	0.0002
Total Lithium	-	0.011	-	0.008	0.0061	7.9	-	0.021	-	0.14	-	3.7	0.019	0.029	-	0.0059	-	0.0059
Total Magnesium	2.7	8.8	2.4	2.9	3	1100	-	54	14	280	-	530	8.3	19	0.83	5	0.9	5
Total Manganese	0.043	0.066	0.06	0.061	0.032	3.2	-	0.18	0.19	5	-	1.5	0.14	0.15	0.0083	0.037	0.012	0.037
Total Mercury	0.002	0.073	0.0023	0.084	0.0011	0.041	-	0.000022	0.0065	0.24	-	-	0.0084	0.31	-	-	-	-
Total Molybdenu	0.00061	0.0094	0.00059	0.00061	0.0025	0.25	-	0.00099	0.029	0.49	-	0.022	0.0017	0.0058	0.00011	0.0052	0.00016	0.0052
Total Nickel	0.01	0.015	0.01	0.023	0.0072	0.034	-	0.032	0.02	0.34	-	0.01	0.025	0.053	0.0025	0.0088	0.003	0.0088
Total Phosphorus	-	-	-	-	-	3.7	-	-	-	-	-	1.7	-	-	-	-	-	-
Total Potassium	1.5	9.6	0.39	2.7	5.4	270	-	12	23	92	-	130	17	22	0.34	5.4	0.44	5.4
Total Selenium	0.00027	0.00072	0.0003	0.0011	0.0003	0.012	-	0.00095	0.0018	0.022	-	0.0047	0.00069	0.0013	-	0.0004	-	0.0004
Total Silicon	1.3	2	0.87	5.8	2.5	23	-	9.9	4.7	95	-	0.88	12	13	0.26	1.1	0.35	1.1
Total Silver	0.000016	0.000028	0.000013	0.000026	0.000013	0.00099	-	0.00006	0.000029	0.0004	-	0.00047	0.000019	0.000034	-	0.000016	-	0.000016
Total Sodium	4.2	140	0.57	2.9	35	7500	-	6.4	360	1400	-	3600	7.5	69	0.83	77	1.1	77
Total Strontium	0.033	0.41	0.014	0.061	0.12	370	-	0.18	0.17	3.2	-	170	0.1	0.29	0.0097	0.23	0.011	0.23
Total Tellerium	0.000027	0.000042	-	0.0016	0.0001	0.0013	-	0.00066	0.000074	0.00095	-	0.00012	0.00057	0.0014	-	0.000023	-	0.000023
Total Thallium	0.000068	0.00011	-	0.000061	0.000056	0.0049	-	0.00029	-	0.00037	-	0.0023	0.00007	0.000075	-	0.000063	-	0.000063
Total Thorium	-	0.000021	0.000011	0.000085	0.000016	0.00036	-	0.000061	0.000076	0.0013	-	-	0.00008	0.000089	-	0.000012	-	0.000012
Total Tin	0.00021	0.00033	-	0.00025	0.0004	0.0099	-	0.0012	0.00027	0.01	-	0.0047	0.0017	0.0018	-	0.00019	-	0.00019
Total Titanium	-	-	-	0.048	-	0.12	-	0.023	0.023	0.32	-	0.06	0.025	0.041	-	-	-	-
Total Uranium	0.00033	0.00053	0.000012	0.00069	0.0012	0.0013	-	0.0047	0.00011	0.0043	-	0.0005	0.007	0.0074	0.000053	0.00029	0.000083	0.00029
Total Vanadium	0.00053	0.00084	0.00014	0.0022	0.0016	0.037	-	0.0087	0.00041	0.016	-	0.018	0.0084	0.0089	0.000097	0.00047	0.00014	0.00047
Total Zinc	-	0.0043	-	0.0055	-	0.33	-	0.0091	0.0068	0.17	-	0.16	0.007	0.013	-	-	-	-
Total Zirconium	0.00011	0.00017	0.000054	0.00033	0.00018	0.00026	-	0.00061	0.000034	0.0045	-	0.000047	0.00074	0.00078	0.000035	0.000099	0.000037	0.000099

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Model\Results\Final_Back_River_PN_WQ_Results_2021-02-03_IR_LMP.xlsxFinal_Back_River_PN_WQ_Results_2021-02-03_IR_LMP.xlsx

Water Quality Projections Without Treatment

Parameter	PN03		PN04		PN05		PN06		PN07		PN08		PN09		PN10	
(mg/L)	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max	Long-Term	Max
TDS	27	350	27	1300	22	69	-	20	-	-	-	21	-	30	-	19
Total_CN	-	0.0017	-	0.003	-	0.0031	-	0.0031	-	-	-	0.0031	-	0.0031	-	0.0031
Sulphate	11	180	11	690	11	35	1.5	4.8	-	-	1.5	5	1.5	5	1.5	4.8
Chloride	1.7	16	1.6	59	0.82	3	0.88	3	-	-	0.87	3	0.87	3	0.88	3
Total_Ammonia	-	2.4	-	21	-	0.26	-	0.18	-	-	-	0.025	-	1.6	-	0.088
Nitrate_N	0.076	3	0.18	18	-	0.41	-	0.28	-	-	-	0.41	-	2.7	-	0.14
Nitrite_N	0.0061	0.21	0.014	0.92	-	0.021	-	0.015	-	-	-	0.021	-	0.13	-	0.0077
Alkalinity	4.9	12	3.1	13	4.9	15	-	4.5	-	-	-	4.6	-	4.6	-	4.5
Ortho_P	-	0.0058	-	0.0053	-	-	-	-	-	-	-	-	-	-	-	-
Phosphate_P	-	0.0049	-	0.005	-	-	-	-	-	-	-	-	-	-	-	-
TOC	2	5	1.1	4.6	1.2	4.8	1.2	4.8	-	-	1.2	4.8	1.2	4.8	1.2	4.8
Total Aluminum	0.095	0.23	0.075	0.41	0.1	0.33	0.0056	0.035	-	-	0.0093	0.046	0.011	0.052	0.0047	0.032
Total Antimony	0.000089	0.00028	0.000064	0.00077	0.000092	0.00029	-	0.000051	-	-	-	0.000055	-	0.000057	-	0.00005
Total Arsenic	0.0027	0.01	0.0022	0.031	0.0031	0.0098	0.000079	0.00025	-	-	0.00014	0.00044	0.00017	0.00053	0.000066	0.00021
Total Barium	0.0036	0.014	0.0028	0.033	0.0021	0.007	0.0018	0.0069	-	-	0.0018	0.0069	0.0018	0.0069	0.0018	0.0069
Total Beryllium	-	0.00025	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0002
Total Bismuth	-	0.00065	-	0.00062	-	-	-	-	-	-	-	-	-	-	-	0.0005
Total Boron	0.0069	0.017	0.017	0.057	-	-	-	-	-	-	-	-	-	-	-	-
Total Cadmium	-	0.000015	-	0.000017	-	0.000011	-	-	-	-	-	-	-	-	-	0.00001
Total Calcium	3.7	35	3.4	130	3.1	9.8	0.87	3.1	-	-	0.89	3.2	0.89	3.2	0.86	3.1
Total Chromium	0.00018	0.00058	0.00016	0.0014	0.00014	0.00046	-	0.0002	-	-	-	0.00022	-	0.00022	-	0.0002
Total Cobalt	0.00076	0.0038	0.00063	0.012	0.00071	0.0023	-	0.00067	-	-	0.00012	0.00074	0.00013	0.00078	-	0.00065
Total Copper	0.001	0.0046	0.00069	0.012	0.00077	0.0025	-	0.0015	-	-	-	0.0015	-	0.0015	-	0.0015
Total Iron	0.093	0.33	0.078	0.88	0.086	0.27	0.019	0.068	-	-	0.022	0.077	0.023	0.081	0.018	0.066
Total Lead	-	0.00021	0.000063	0.00063	-	0.000057	-	0.00005	-	-	-	0.00005	-	0.000051	-	0.00005
Total Lithium	-	0.0062	-	0.023	-	-	-	-	-	-	-	-	-	-	-	-
Total Magnesium	1	5.2	0.78	15	0.72	2.3	0.43	1.4	-	-	0.44	1.4	0.44	1.4	0.43	1.4
Total Manganese	0.016	0.039	0.0094	0.059	0.017	0.056	0.0021	0.012	-	-	0.0023	0.013	0.0024	0.013	0.002	0.012
Total Mercury	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Molybdenu	0.00022	0.0055	0.00028	0.023	0.00017	0.00055	-	0.000051	-	-	-	0.000054	-	0.000056	-	0.00005
Total Nickel	0.0037	0.009	0.0025	0.0092	0.0031	0.01	0.0011	0.0054	-	-	0.0011	0.0056	0.0012	0.0057	0.0011	0.0053
Total Phosphorus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Potassium	0.55	5.7	1.1	22	0.12	0.44	0.12	0.4	-	-	0.12	0.4	0.12	0.4	0.12	0.4
Total Selenium	-	0.00042	-	0.0012	-	0.00028	-	0.0001	-	-	-	0.0001	-	0.0001	-	0.0001
Total Silicon	0.46	1.2	0.66	2.9	0.26	0.83	0.073	0.37	-	-	0.08	0.39	0.083	0.4	0.071	0.36
Total Silver	-	0.000016	-	0.000024	-	0.000013	-	0.00001	-	-	-	0.00001	-	0.00001	-	0.00001
Total Sodium	1.5	81	3.4	340	0.18	0.65	0.19	0.63	-	-	0.19	0.63	0.19	0.63	0.19	0.63
Total Strontium	0.012	0.24	0.017	0.95	0.0044	0.016	0.0048	0.016	-	-	0.0048	0.016	0.0048	0.016	0.0048	0.016
Total Tellerium	-	0.000025	0.000026	0.000088	-	0.000039	-	-	-	-	-	-	-	-	-	-
Total Thallium	-	0.000063	-	0.000052	-	-	-	-	-	-	-	-	-	-	-	0.00005
Total Thorium	-	0.000012	-	0.00004	-	-	-	-	-	-	-	-	-	-	-	-
Total Tin	-	0.00019	0.0001	0.00035	-	0.0001	-	-	-	-	-	-	-	-	-	0.0001
Total Titanium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Uranium	0.00012	0.00031	0.00031	0.0011	-	0.000023	-	0.00001	-	-	-	0.00001	-	0.00001	-	0.00001
Total Vanadium	0.0002	0.00049	0.00043	0.0014	-	0.00014	-	0.000058	-	-	-	0.000061	-	0.000063	-	0.000057
Total Zinc	-	-	-	0.0033	-	-	-	-	-	-	-	-	-	-	-	-
Total Zirconium	0.000041	0.0001	0.000049	0.00016	0.000017	0.000066	0.000019	0.00006	-	-	0.000019	0.00006	0.000019	0.00006	0.000019	0.00006

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Model\Results\Final_Back_River_PN_WQ_Results_2021-02-03_IR_LMP.xlsxFinal_Back_River_PN_WQ_Results_2021-02-03_IR_LMP.xlsx