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ATTACHMENT A
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<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>AEMP</td>
<td>Aquatic Effects Monitoring Program</td>
</tr>
<tr>
<td>De Beers</td>
<td>De Beers Canada Inc.</td>
</tr>
<tr>
<td>DSL</td>
<td>Downstream Lake</td>
</tr>
<tr>
<td>EAR</td>
<td>Environmental Assessment Report</td>
</tr>
<tr>
<td>EQC</td>
<td>effluent quality criteria</td>
</tr>
<tr>
<td>Golder</td>
<td>Golder Associates Ltd.</td>
</tr>
<tr>
<td>HEC-RAS</td>
<td>Hydrologic Engineering Center River Analysis System</td>
</tr>
<tr>
<td>i.e.</td>
<td>that is</td>
</tr>
<tr>
<td>Mine</td>
<td>Snap Lake Mine</td>
</tr>
<tr>
<td>PK</td>
<td>processed kimberlite</td>
</tr>
<tr>
<td>RO</td>
<td>reverse osmosis</td>
</tr>
<tr>
<td>STP</td>
<td>sewage treatment plant</td>
</tr>
<tr>
<td>WECA</td>
<td>western embankment catchment area</td>
</tr>
<tr>
<td>WMP</td>
<td>water management pond</td>
</tr>
<tr>
<td>WTP</td>
<td>water treatment plant</td>
</tr>
</tbody>
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### UNITS OF MEASURE AND SYMBOLS

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>%</td>
<td>percent</td>
</tr>
<tr>
<td>°C</td>
<td>degree Celsius</td>
</tr>
<tr>
<td>km</td>
<td>kilometre</td>
</tr>
<tr>
<td>m³/day</td>
<td>cubic metres per day</td>
</tr>
<tr>
<td>mm</td>
<td>millimetre</td>
</tr>
<tr>
<td>mm/°C</td>
<td>millimetres per degree Celsius</td>
</tr>
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</table>
1.0 INTRODUCTION

De Beers Canada Inc. (De Beers) owns and operates the Snap Lake Mine (Mine) in the Northwest Territories. The Mine is located approximately 220 kilometres (km) northeast of Yellowknife, 30 km south of MacKay Lake, and 100 km south of Lac de Gras where the Diavik Diamond Mine and the Ekati Diamond Mine are located. The Mine officially opened on 25 July 2008.

Following a downturn in diamond prices, operations at the Mine were halted in 2015 and the Mine was put under Extended Care and Maintenance. Extended Care and Maintenance conditions require alterations to operational water management activities, including those related to minewater consumption, underground workings development and maintenance, and processing of kimberlite.

De Beers retained Golder Associates Ltd. (Golder) to develop models of the Mine site and receiving environment (i.e., Snap Lake and the downstream lakes) to account for the Closure and Post-closure activities at the Mine. The hydrological models were developed in GoldSim and are presented in this report. The objective of the hydrological models was to provide a water balance for the Mine site and receiving environment that could be linked to water quality models.

It is noted that this report does not consider the effects of climate change or the thermal state of the North Pile, as these were not part of the objectives of the current study.

The sections that follow provide:

- A summary of the model components including existing and future site conditions (Section 2.0).
- The methods used for the development of the water balance (Section 3.0).
- Model calibration (Section 4.0).
- Results (Section 5.0).
2.0 MODEL COMPONENTS
2.1 Site Model
2.1.1 Existing Conditions

The water balance for the Mine site was developed using GoldSim based on three sources of information:

- Flow from the Mine underground workings (Itasca 2013).
- Meteorological data from the Snap Lake ‘Hill’ and Snap Lake ‘Lake’ meteorological stations.
- Pumping, water level, and surface area records from De Beers.

Existing water storage and conveyance at the Mine and Snap Lake are illustrated in flow diagrams presented in Attachment A and described in Table 2-1. The model was calibrated to monitoring data in 2016 and 2017. During the calibration period, the key components are:

- **Underground Workings** – Inflow to the Mine includes seepage from the lake and natural (connate) groundwater (SE11 and SE10). Flooding of the underground workings occurred from 15 January to 9 February 2017. After 15 January 2017, minewater from underground was no longer pumped to the surface. The underground workings will only accept water from the water management pond (WMP) (PR15) as needed. The same volume of water that is pumped from the WMP to the underground workings is assumed to enter Snap Lake. Modelling of this underground scenario was not conducted by Itasca (Itasca 2013 and De Beers 2016). This assumption is considered conservative since more affected mine water enters Snap Lake; however, it is not conservative if the affected mine water is entering another waterbody.

- **North Pile** – Water quality is influenced by slurry water concentrations (processing), minewater influence, and interactions of the water with solid phase materials in the North Pile. Water migrates through the North Pile towards the perimeter ditches and sumps (Sump 1, Sump 2, Sump 3, Sump 4, Sump 5, western embankment catchment area (WECA), IL6). From the sumps, water is pumped to the WMP (PR11a-e). Pumped volumes were calculated to maintain monitored water levels.

- **Modular Water Treatment Plant/ Water Management Pond** – Flows from the underground workings, WMP, and the North Pile report to the modular water treatment plant (WTP) with treated effluent discharged to Snap Lake. The WMP collects site runoff from developed and undeveloped lands, as well as water pumped from the North Pile sumps, and provides backup and upset storage capacity during Operations.

- **Snap Lake** – Snap Lake consists of two main waterbodies, the northwest arm and main basin, which are connected by a narrow channel. A portion of the main basin provides recharge to the Mine underground workings (SE11), and that water is ultimately recycled to Snap Lake through releases from the modular WTP (PR7) until flooding of the underground starts on 15 January 2017, then considered null thereafter. Other inflows to Snap Lake consist of surface runoff (RO11) from natural areas, the airport and explosives area, roads, and disturbed mine site areas (non-point sources). Seepage from the North Pile (SE8) and seepage from the WMP (SE9) also contribute directly to Snap Lake inflows. A water intake allows collection of water from Snap Lake for potable use at the Mine (PR9).
2.1.2 Future Conditions

Future water storage and conveyance at the Mine and Snap Lake are illustrated in a flow diagram presented in Attachment A and described in Table 2-1. The future site conditions of the Mine are divided into three periods:

- **Extended Care and Maintenance Period (January 2018 to December 2020)** – Starting in May 2018, treated effluent discharge to Snap Lake from the modular WTP (PR7) will be treated by a RO unit before discharging into Snap Lake. The modular WTP and RO unit is understood to only accept water from the WMP during freshet, based on communication with De Beers and 2018 pumping data. The underground workings will accept water and brine reject from the WMP (PR15) or RO unit (PR16) as needed, based on communication with De Beers.

- **Closure Period (January 2021 to December 2025)** – The Closure period includes:
  - Decommissioning of site infrastructure.
  - Covering of the North Pile.
  - Pumping of water from the North Pile (PR11a-e) to the modular WTP and RO unit (PR4).
  - Constructing of east and west free water surface flow wetlands (East Wetland and West Wetland); passive treatment by the East and West wetlands is not represented in the model.

- **Post-closure Period (January 2026 to January 2050)** – In 2026, the WMP, modular WTP and RO unit are decommissioned and surface water from the North Pile is directed to Snap Lake from Sump 3 (PR11c) and Sump 5 (PR11e). Runoff from the Mine site is directed to Snap Lake (RO10).
<table>
<thead>
<tr>
<th>Flow Type</th>
<th>Flow ID</th>
<th>Flow Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Flow</td>
<td>PR4</td>
<td>Water from the WMP pumped to the modular WTP.</td>
</tr>
<tr>
<td></td>
<td>PR5</td>
<td>Overflow water from the modular WTP directed to the WMP.</td>
</tr>
<tr>
<td></td>
<td>PR6</td>
<td>Water from the STP pumped to the modular WTP.</td>
</tr>
<tr>
<td></td>
<td>PR7</td>
<td>Discharge from the modular WTP to Snap Lake or RO unit (through both diffusers).</td>
</tr>
<tr>
<td></td>
<td>PR8</td>
<td>Water pumped from the underground workings to the modular WTP.</td>
</tr>
<tr>
<td></td>
<td>PR9</td>
<td>Water withdrawn from Snap Lake and pumped to the STP.</td>
</tr>
<tr>
<td></td>
<td>PR10</td>
<td>Deep groundwater pumped from the underground workings through the Procon Line to</td>
</tr>
<tr>
<td></td>
<td>PR11(a-e)</td>
<td>the modular WTP.</td>
</tr>
<tr>
<td></td>
<td>PR14</td>
<td>Water for dust control for the site is sourced from the modular WTP and assumed</td>
</tr>
<tr>
<td></td>
<td>PR15</td>
<td>Water from the WMP pumped to the underground workings.</td>
</tr>
<tr>
<td></td>
<td>PR16</td>
<td>Brine reject from the RO unit to the underground workings.</td>
</tr>
<tr>
<td>Seepage Flow</td>
<td>SE1-S7</td>
<td>Water seeping from the North Pile to each of the North Pile sumps.</td>
</tr>
<tr>
<td></td>
<td>SE8</td>
<td>Water seeping from the North Pile to Snap Lake.</td>
</tr>
<tr>
<td></td>
<td>SE9</td>
<td>Water seeping from the WMP through Dam 1 to Snap Lake.</td>
</tr>
<tr>
<td></td>
<td>SE10</td>
<td>Water seeping from deep groundwater sources (connate) to the underground</td>
</tr>
<tr>
<td></td>
<td>SE11</td>
<td>Water seeping from Snap Lake to the underground workings.</td>
</tr>
<tr>
<td></td>
<td>SE12</td>
<td>Water seeping from the flooded underground workings to Snap Lake.</td>
</tr>
<tr>
<td>Overflow</td>
<td>OV11(a-e)</td>
<td>Overflow from the North Pile sumps during Post-closure</td>
</tr>
<tr>
<td>Direct Precipitation</td>
<td>DP1-DP10</td>
<td>Direct precipitation reporting to open water surfaces.</td>
</tr>
<tr>
<td>Runoff</td>
<td>RO1-RO11</td>
<td>Runoff water reporting to site facilities and Snap Lake.</td>
</tr>
<tr>
<td>Evaporation</td>
<td>EV1-EV10</td>
<td>Evaporation water loses from open water surfaces.</td>
</tr>
</tbody>
</table>

WMP = water management pond; WTP = water treatment plant; RO = reverse osmosis; STP = sewage treatment plant.
2.2 Receiving Environment Model

2.2.1 Existing Conditions

The existing site conditions were modelled prior to 2018 and used as a calibration period. The Receiving Environment model simulates the stream discharges and water surface elevations in waterbodies upstream of the MacKay Lake Inlet in the King River, including Snap Lake. The following waterbodies were modelled:

- Snap Lake
- Downstream Lake (DSL) 1
- DSL 2
- DSL 3 (Lac Capot Blanc)
- DSL 4
- DSL 5
- DSL 6
- DSL 7
- DSL 8
- DSL 9
- DSL 10
- DSL 11 (King Lake)
- Northeast Lake
- North Lake
- Camsell Lake
- MacKay West (MacKay Lake watershed west of Node 22)
- MacKay Lake Embayment Area
- MacKay Lake Direct Watershed area upstream of MacKay Lake Embayment Area
- Node 22 Area

Each modelled waterbody was represented in GoldSim as a closed container with inputs, storage, and outputs. As mentioned in Section 2.1, Snap Lake receives treated effluent discharge from the modular WTP or RO unit (PR7), seepage from the WMP (SE9) and seepage from the North Pile (SE8). In addition, water pumped from the WMP to UG (PR15) after flooding is assumed to enter Snap Lake. PR7, PR15, SE8, and SE9 results from the Site model were used as inflows to Snap Lake in the Receiving Environment model, which then flows into DSL 1.

2.2.2 Future Conditions

Future conditions were modelled from 2018 to 2050. In 2026, the WMP and modular WTP and RO unit are decommissioned and the North Pile overflows to Snap Lake. In addition, runoff from the former WMP area (RO10) will flow to Snap Lake.
2.3 Model Modification

The predicted water balance was primarily based on the water balance models described in Golder 2016b [Site model] and Golder 2016a [downstream model], with the following modifications:

- Closure activities were added to the models as described in Section 2.1.2.
- From 2018 to 2050, climate data (i.e., rainfall, snowfall, evaporation, and temperature data) were based on mean annual conditions, following methods described in Section 3.1.
- Processed flows and seepages were based on monitoring data provided by De Beers as described in Section 3.1.4.
- Rating curves previously derived for waterbodies with similar catchment areas were applied to DSL 4, DSL 6, DSL 7, DSL 8, and DSL 10 as described in Section 3.2.6.
- Snowfall runoff coefficient was updated based on calibration results (see Section 4.0).

The structure of the models was also updated:

- Tributary watershed and lake area runoff from the terminal lake were separated to eliminate evapo-concentration of water quality parameters.
- The North Pile sumps were modelled as five individual containers in GoldSim instead of one container.
- The North Pile area in the model was separated into fine processed kimberlite (PK) and coarse PK.
3.0 METHODS

3.1 Site Model

3.1.1 Climate Data

Climate data have been collected from the Snap Lake ‘Hill’ and Snap Lake ‘Lake’ meteorological stations since 2006 and used as inputs to the model.

For years that Snap Lake meteorological station data were not available, derived data from the Snap Lake 2002 Environmental Assessment Report (EAR; EA01-004) were used to generate the long-term climate record from 1943 to 2001 (De Beers 2002). Data from the EAR for 1943 to 2001 were then entered as model input from 1950 to 2008 to eliminate gaps in the input climate data set. This method was considered appropriate, as a long-term record is used to capture the range of natural variability, but the model is not intended to provide accurate representations of the hydrology in any specific year.

3.1.1.1 Rainfall Data

Rainfall data from the Snap Lake meteorological stations were used as inputs since 2009 and were supplemented with rainfall data from the from Environment Canada Climate Station 2204101 (Yellowknife A) (Government of Canada 2018) as needed. Rainfall data were adjusted for under-catch by a factor of 1.12 as per recommendations by Environment Canada (2013). For model input years prior to 2009, monthly EAR rainfall data were used (De Beers 2002). For model years after 2017, average monthly rainfall data were used to create daily rainfall inputs.

3.1.1.2 Snowfall Data

Snowfall data from the Snap Lake meteorological stations were not used due to low data reliability. Snowpack data from surveys conducted prior to freshet in 2012, 2013, 2014, 2015 and 2017 were used as model inputs. No snowpack surveys were conducted in 2016; therefore, precipitation data from the Snap Lake meteorological station were adjusted with data from the Yellowknife A station and used as model input. For model input years prior to 2012, monthly EAR snowfall data were used (De Beers 2002). For model input years after 2017, average monthly snowfall data based on derived EAR values were used to create a pre-freshet snowpack. An under-catch factor was applied to snowfall data during the derivation conducted in the EAR (De Beers 2002).

3.1.1.3 Temperature Data

Temperature data from the Snap Lake meteorological stations were used as input since 2008. For model input years prior to 2008 and after 2017, average daily temperatures were used.

3.1.1.4 Evaporation Data

Evaporation data were calculated from Snap Lake meteorological station data from 2006 to 2015 using the Penman method (Penman 1948). Meteorological data used to calculate evaporation were no longer collected after 2015. For model input years prior to 2006 and after 2015, average monthly evaporation data based on derived EAR values were used to generate daily evaporation values.
3.1.2 Runoff Coefficients, Sublimation, Evapotranspiration and Infiltration

Sublimation, evapotranspiration, and infiltration were all considered in accounting for losses to surface water in the hydrologic system.

In the model, rainfall and snowmelt runoff coefficients were set to incorporate evapotranspiration and infiltration losses. The rainfall runoff coefficient was set to 0.30 and the snowmelt runoff coefficient was set to 0.75 based on experience modelling watersheds in the Northwest Territories and a literature review (Golder 2015).

Sublimation was applied directly as a 30% snowpack reduction based on experience modelling watersheds in the Northwest Territories, and a literature review (Golder 2015).

These runoff coefficients and sublimation losses resulted in annual water yields consistent with measured annual water yields, as discussed in the model calibration section (Section 4.0) and considered appropriate for this model.

Table 3-1 presents the disturbed land and North Pile runoff coefficients for the Site model. The thermal state of the North Pile is not considered in this report. After covering of the North Pile (i.e., end of 2023), the North Pile is assumed to be frozen. A high runoff coefficient for the remediated North Pile was used to represent the cover and frozen state. Natural land and ponds within the Site model used runoff coefficients as noted in Section 3.1.2.

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
<th>Source</th>
<th>Comment/Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disturbed Lands</td>
<td>0.8</td>
<td>Assumed (Golder 2013)</td>
<td>Average annual runoff coefficient applied to roads, airport, and other disturbed areas</td>
</tr>
<tr>
<td>North Pile</td>
<td>0.5 to 0.99</td>
<td>Assumed (Golder 2013, except for remediated pile)</td>
<td>A runoff coefficient of 0.8 was applied to the North Pile during freshet (May) and 0.5 for the remainder of the year. Once the North Pile was covered, the runoff coefficient was increased to 0.99 and the runoff coefficient during remediation was interpolated between the uncovered and covered pile.</td>
</tr>
</tbody>
</table>
3.1.3 Snowmelt

Snowmelt is generated predominantly by the melting of the accumulated snowpack during the period of spring freshet. The spring freshet generally occurs over a period of several weeks and is a major contributor of overall annual runoff and lake inflows in northern environments.

In the model, snowfall from the derived climate data accumulates as snowpack during fall and winter when temperatures were below freezing. Snowmelt begins when the daily average temperature rises above the base temperature \((T_b)\). The snowmelt rate is determined by Equation 3-1.

\[
\text{Daily Snowmelt Runoff} = R_{cs} \times M_f \times (T - T_b)
\]

\textit{Equation 3-1}

Where:

- \(R_{cs}\) = Snowmelt runoff coefficient (dimensionless)
- \(M_f\) = Melt factor (millimetres per degree Celsius [mm/°C])
- \(T\) = Mean daily air temperature (°C)
- \(T_b\) = Base temperature (°C)

The melt factor was set to 1.5 mm/°C, and the base temperature was set to -0.5°C. These were applied based on previous local studies and adjusted to match local hydrographs. The snowmelt runoff coefficient was discussed in Section 3.1.2.

3.1.4 On-Site Monitoring Data

Process flows and seepages for the Site model for 2017 to 2050 were based on assumptions, or monitoring data provided by De Beers:

- **PR4** (i.e., water from the WMP pumped to the modular WTP) was updated based on monitoring data available for 2017. Pumping rates, from 2018 until decommissioning of the WMP and modular WTP in 2026, were based on a constant pump rate of 3,000 cubic metres per day (m³/day). PR4 was also assumed to be zero from July to May of the next calendar year. No flow exists after decommissioning of infrastructure.

- **PR5** (i.e., overflow water from the modular WTP directed to the WMP) was based on monitoring data available for 2017, and then null thereafter.

- **PR6** (i.e., water from the Sewage Treatment Plant [STP] pumped to the WMP) was assumed to be equal to PR9 (i.e., water withdrawn from Snap Lake and pumped to the STP), from 2017 until decommissioning of the STP and WMP in 2026. No flow exists after decommissioning of infrastructure.

- **PR7** (i.e., discharge from the modular WTP and RO unit [operational in 2018] to Snap Lake) represents the balance from other inflows (i.e., PR4, PR6, PR8, and PR10) and outflows (i.e., PR5), from 2017 to decommissioning of the modular WTP and RO unit in 2026.

- **PR8** (i.e., water pumped from the underground workings to the modular WTP) was based on SE11 (i.e., water seeping from Snap Lake to the underground workings). Inflow at SE11 (thus pumping at PR8) was assumed to be zero after flooding of the underground workings occurs in 2017.
- PR9 (i.e., water withdrawn from Snap Lake and pumped to the STP) was based on 2017 monitoring data, assumed to be representative of 2018 until decommissioning of the STP in 2026. No flow exists after decommissioning of infrastructure.

- PR10 (i.e., deep groundwater pumped from the underground working to the modular WTP) was based on SE10 (i.e., water seeping from deep groundwater sources [connate] to the underground workings). Inflow at SE10 (thus pumping at PR10) was assumed to be zero after flooding of the underground workings occurs in 2017.

- PR11 (i.e., sum of water volume pumped from the North Pile sumps to the WMP for storage) was based on sump volume monitoring data available from 2012, applied from 2017 to decommissioning of the WMP in 2026. This results in dry sumps during the winter to accommodate freshet volumes. Water from the North Pile is directed towards Snap Lake (OV11) starting in 2026.

- PR13 (i.e., deep groundwater pumped from the underground working through the Procon Line to the modular WTP) was updated with monitoring data from the beginning of 2017. Flows were null after flooding of the underground workings.

- PR14 (i.e., water pumped to the modular WTP for dust control) was based on a constant 300 m$^3$/day. PR14 was also assumed to be zero from November to June of the next calendar year. No flow exists after decommissioning of modular WTP.

- PR15 (i.e., discharge from the WMP to underground) started in 2017 based on monitoring data. Pumping rates after 2017 were based on a constant pump rate of 2,000 m$^3$/day, with exception of the winter season where pumping was null. No pumping exists after decommissioning of the WMP in 2026.

- PR16 (i.e., brine reject from the RO unit to underground workings, as needed) based on 25 percent of the total flows to the RO unit. No pumping exists after decommissioning of the RO unit in 2026.

- SE8 (i.e., water seeping from the North Pile to Snap Lake) was based on the Environmental Assessment Report (De Beers 2002) and assumed to remain constant until 2050.

- SE9 (i.e., water seeping from the WMP through Dam 1 to Snap Lake) was based on 2016 monitoring data until decommissioning of the WMP in 2026. For 2026, SE9 was based on half of the 2016 monitoring data (WMP draining).

- SE10 (i.e., water seeping from deep groundwater sources [connate] to the underground workings), and SE11 (i.e., water seeping from Snap Lake to the underground workings) were based on 2015 predictions (Itasca 2013) for 2017 until flooding of the underground workings occurred and were assumed to be null thereafter.

- SE12 (i.e., water seeping to Snap Lake from underground workings) was based on PR15 (i.e., discharge from the WMP to underground).

### 3.1.5 Spatial Data

Spatial data provided by De Beers (De Beers 2013) were used to generate the watershed areas within the Mine site.
3.2 Receiving Environment Model

3.2.1 Climate Data
Climate data were used as described in Section 3.1.1.

3.2.2 Runoff Coefficients, Sublimation, Evapotranspiration and Infiltration
Sublimation, evapotranspiration, and infiltration were all considered in accounting for losses to surface water in the hydrologic system as described in Section 3.1.2.

3.2.3 Ice Effects on Lake Outlets
Except for Snap Lake, North Lake, and Northeast Lake, all lake outlets were assumed to flow continuously over the winter.

For upper-watershed lake outlets of Snap Lake, North Lake, and Northeast Lake, a degree-day method was used to control lake outlets closing due to ice formation in the autumn and opening due to ice degradation in the spring. Lake outlets gradually opened based on the cumulative sum of daily positive temperatures (degrees Celsius [°C]) and closed based on the cumulative sum of daily negative temperatures. Lake outlets were set to completely open at 40-degree days, and close at -76.5-degree days. These values have been shown to be appropriately chosen to result in outlet melt duration and freeze-up of up to two weeks, depending on daily temperatures of each year during the spring melt and freeze-up periods, consistent with durations observed and expected by Golder in the north.

Lower-watershed lake outlets for all other lakes were modelled to discharge throughout the winter. This is supported by winter observations at KING01 made during the Aquatic Effects Monitoring Program from 2005 to 2015 (De Beers 2015).

Melt and freeze-up of lake outlets control the quantity of water stored in each watershed over the winter, and the timing of peaks. The assumptions above resulted in annual water yields shown in Section 4.0 and were deemed suitable for this model. There is a degree of uncertainty related to the timing of the peaks; however, the timing of the peaks is not a significant aspect of the model, which primarily requires accurate quantities on a coarser time scale.

3.2.4 Snowmelt
Snowmelt was calculated using the methods described in Section 3.1.3.

3.2.5 Spatial Data
As mentioned in Golder (2015), spatial data for the downstream model were generated by processing Water Survey of Canada Geogratis database and the Geobase 250K Digital Elevation Model data using Geographical Information System software. Nine watersheds upstream of the MacKay Lake Inlet in the King River were delineated; terminal lake surface area, total lake surface area, and total land surface area were calculated for each watershed.

The MacKay Lake watershed upstream of Node 22 and the MacKay Lake Embayment Area were delineated, and total land and lake surface areas were calculated. The Node 22 mixing area was delineated, and the surface area was calculated.
3.2.6 Rating Curves including HEC-RAS, Stage-discharge, and Overflow

Rating curves for lake outlets were derived using a combination of long-term monitoring data, 2015 field discharge and water level data, and Real-Time Kinematic-GPS surveyed location and elevation data, processed using Hydrologic Engineering Center River Analysis System (HEC-RAS) 1-dimensional hydraulic modelling software.

The Snap Lake outlet and the Northeast Lake outlet had long-term discharge and water level data collected under the Snap Lake EAR (De Beers 2002) and the De Beers Environmental Agreement (De Beers 2004) from 2002 to 2015. These data were used to develop the stage-discharge rating curves for these outlets.

Rating curves for the DSL 2, Lac Capot Blanc, KING01, Camsell Lake, and MacKay Lake outlets in the King River stations were derived using 2015 water level and discharge data and HEC-RAS outlet models.

Rating curves that were derived previously for lakes with similar catchment areas were applied to DSL 4, DSL 6, DSL 7, DSL 8, and DSL 10.

Lake outlets DSL 5, North Lake, MacKay West, MacKay Lake Embayment Area, and MacKay Lake Direct Watershed area upstream of MacKay Lake Embayment Area were all modelled as reservoirs with overflow elements because no data existed for these locations.
4.0 MODEL CALIBRATION

4.1 Site Model

The Site model was calibrated by trying to match volumes of water pumped from the North Pile sumps to the WMP in 2016. As presented in Table 4-1, the total modelled volume of water pumped from the North Pile sumps to the WMP accounted for 77 percent of the monitoring data. The water volumes pumped from the individual sumps matched the monitoring data within ±10 percent (%), except for the volume of water pumped from Sump 5, which was lower than the monitoring volume by 44%. The variance of Sump 5 is addressed in the Snap Lake Water Quality Model Report.

Calibrated results were achieved by refining the runoff coefficients applied to the North Pile until the modelled volumes of water pumped from the sumps were within an acceptable range of the monitoring data. As mentioned in Section 3.1.2, a runoff coefficient of 0.8 was applied to the North Pile during freshet (May) and 0.5 for the remainder of the year, until reclamation of the North Pile begins.

There were insufficient data to perform model validation; however, calibration parameters appear consistent with other parameters in the Northwest Territories.

Table 4-1: Volume of Water Pumped from North Pile Sumps to the Water Management Pond in 2016

<table>
<thead>
<tr>
<th>Sump 1</th>
<th>Sump 2</th>
<th>Sump 3</th>
<th>Sump 4</th>
<th>Sump 5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modelled (m$^3$)</td>
<td>20,117</td>
<td>45,493</td>
<td>89,088</td>
<td>43,734</td>
<td>124,077</td>
</tr>
<tr>
<td>Measured (m$^3$)</td>
<td>18,676</td>
<td>44,910</td>
<td>86,267</td>
<td>46,680</td>
<td>223,178</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>8%</td>
<td>1%</td>
<td>3%</td>
<td>-6%</td>
<td>-44%</td>
</tr>
</tbody>
</table>

(a) It is recognized that Sump 5 is an outlier, this variance is addressed in the Snap Lake Water Quality Model Report (Section 4.1)

4.2 Receiving Environment Model

The Receiving Environment model was calibrated at the outlets of the following locations where 2015 and 2016 monitoring data were available:

- DSL 2
- DSL 3 (Lac Capot Blanc)
- DSL 9 (KING01)
- MacKay Lake Inlet on the King River
- Northeast Lake
- Camsell Lake

Calibration of the Receiving Environment model was last conducted by Golder (2016b) based on 2015 and 2016 monitoring data. The following calibration parameters were used:

- The base melt temperature was set to -0.5°C to attenuate the peak discharge, and to shift it earlier in the year.
- The early melt factor was changed from 2 mm/°C to 1.5 mm/°C to attenuate the peak discharge.
- The rainfall coefficient was reduced to 0.3 to fit small rainfall events. It is acknowledged that the large event in 2015 could not be matched, and it is assumed that the event was not captured entirely by the rain gauge.
- The snowfall runoff coefficient was reduced from 1 to 0.75 to better fit freshet peaks.
4.3 Calibration Results

The model matched the measured data reasonably well, in consideration of the uncertainties of snowpack in 2016, storage of tributaries, stage-outlet rating curves at higher stages, and local precipitation events which are not necessarily captured by the Snap Lake meteorological stations. For instance, the rainfall event of 2015 could not be modelled accurately, and could lead to the conclusion that the rainfall coefficient is too low; however, the model seems to overestimate a late rainfall event in 2016, and the rainfall coefficient was calibrated to balance the two years. This could be the result of the rain gauge data not representing the mean precipitation depth due to areal variability.

A comparison of the modelled to measured data is presented in Figures 4-1 through 4-12.
Figure 4-1: Modelled versus Measured Water Yields for DSL 2

- Modelled
- Measured

Date

Figure 4-2: Modelled versus Measured Discharge for DSL 2

Date

Figure 4-3: Modelled versus Measured Water Yields for DSL 3 (Lac Capot Blanc)

Date

Figure 4-4: Modelled versus Measured Discharge for DSL 3 (Lac Capot Blanc)

Date
Figure 4-5: Modelled versus Measured Water Yields for DSL 9 (KING01)

- Modelled
- Measured

Figure 4-6: Modelled versus Measured Discharge for DSL 9 (KING01)

- Modelled
- Measured

Figure 4-7: Modelled versus Measured Water Yields for MacKay Lake Inlet on the King River

- Modelled
- Measured

Figure 4-8: Modelled versus Measured Discharge for MacKay Lake Inlet on the King River

- Modelled
- Measured
Figure 4-9: Modelled versus Measured Water Yields for Northeast Lake

- Modelled
- Measured

![Graph showing modelled and measured water yields for Northeast Lake with dates from May 2013 to Mar 2017.]

Figure 4-10: Modelled versus Measured Discharge for Northeast Lake

- Modelled
- Measured

![Graph showing modelled and measured discharge for Northeast Lake with dates from May 2013 to Mar 2017.]

Figure 4-11: Modelled versus Measured Water Yields for Camsell Lake

- Modelled
- Measured

![Graph showing modelled and measured water yields for Camsell Lake with dates from May 2013 to Mar 2017.]

Figure 4-12: Modelled versus Measured Discharge for Camsell Lake

- Modelled
- Measured

![Graph showing modelled and measured discharge for Camsell Lake with dates from May 2013 to Mar 2017.]

Note: The graphs display the comparison of modelled and measured data for water yields and discharge over the specified dates.
5.0 SIMULATION RESULTS

Model results are presented at key nodes for a representative year of the future to provide context to other linked modules, including the water quality models, and to the overall EQC modelling study. The results shown assume an average precipitation year for future conditions. Sensitivities to climate change were not considered in this report. Results are presented on an annual basis for clarity. Additional results may be obtained at a finer time scale from the model.

5.1 Site Model

For the Site model, results are presented for the following key nodes:

- Water pumped from the WMP to Snap Lake through the modular WTP and RO unit in 2020 (Section 5.1.1).
- Seepage to Snap Lake in 2020 (Section 5.1.2).
- Overflow to Snap Lake in 2028 (Section 5.1.3).

Table 5-1 provides a summary of the annual volume of water discharged, and Table 5-2 provides a summary of the volume of water discharged during freshet (May and June) for the representative year at the key nodes.

<table>
<thead>
<tr>
<th>Flow</th>
<th>Annual Volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMP and North Pile to Snap Lake and Underground Workings in 2020</td>
<td>178,281</td>
</tr>
<tr>
<td>WMP to Snap Lake (through the modular WTP and RO Unit) in 2020</td>
<td>52,257</td>
</tr>
<tr>
<td>WMP to Underground Workings (which seeps to Snap Lake) in 2020</td>
<td>133,766</td>
</tr>
<tr>
<td>Seepage from WMP to Snap Lake in 2020</td>
<td>5,047</td>
</tr>
<tr>
<td>Seepage from North Pile to Snap Lake in 2020</td>
<td>2,877</td>
</tr>
<tr>
<td>North Pile to Snap Lake in 2028</td>
<td>177,604</td>
</tr>
<tr>
<td>North Pile via Sump 3 to Snap Lake in 2028</td>
<td>92,851</td>
</tr>
<tr>
<td>North Pile via Sump 5 to Snap Lake in 2028</td>
<td>84,753</td>
</tr>
</tbody>
</table>

m³ = cubic metres.

<table>
<thead>
<tr>
<th>Flow</th>
<th>Annual Volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMP and North Pile to Snap Lake and Underground Workings in 2020</td>
<td>139,626</td>
</tr>
<tr>
<td>WMP to Snap Lake (through the modular WTP and RO Unit) in 2020</td>
<td>52,257</td>
</tr>
<tr>
<td>WMP to Underground Workings (which seeps to Snap Lake) in 2020</td>
<td>101,287</td>
</tr>
<tr>
<td>Seepage from WMP to Snap Lake in 2020</td>
<td>1,267</td>
</tr>
<tr>
<td>Seepage from North Pile to Snap Lake in 2020</td>
<td>480</td>
</tr>
<tr>
<td>North Pile to Snap Lake in 2028</td>
<td>147,089</td>
</tr>
<tr>
<td>North Pile via Sump 3 to Snap Lake in 2028</td>
<td>76,089</td>
</tr>
<tr>
<td>North Pile via Sump 5 to Snap Lake in 2028</td>
<td>71,281</td>
</tr>
</tbody>
</table>

m³ = cubic metres.
5.1.1 Water Pumped from the WMP to Snap Lake through the RO unit

The flows from WMP, modular WTP and RO unit are presented in Figures 5-1 to 5-9 and illustrated in the flow diagrams presented in Attachment A. A summary of the flow activities from 2018 to 2026 are as follows:

- Underground workings are flooded and only accept water and brine from the WMP and RO as needed.
- The modular WTP receives discharge from the WMP (PR4) and treated domestic wastewater from the STP (PR6).
- A small component of the treated effluent is used for Mine site dust suppression (PR14).
- Treated effluent is discharged to Snap Lake via twin diffusers located offshore (underwater) from the modular WTP and RO unit.

After 2026, WMP, modular WTP and RO unit are decommissioned. Discharge from the North Pile is directed to Snap Lake through Sump 3 and Sump 5 (OV11). Runoff from the Mine site (RO10) flows to Snap Lake. Flows during the Post-closure period represent the flows for the entire period (2026 to 2050).

5.1.2 Seepage to Snap Lake

Starting in 2017, the flooded underground workings receive discharge from the WMP (PR15), which is assumed to seep to Snap Lake (SE12) until decommissioning of the WMP in 2026, as presented in Figure 5-5.

Seepage to Snap Lake also occurs from the North Pile (SE8) and the WMP (SE9), as presented in Figure 5-6. Seepage from the North Pile remains constant until 2050. For 2026, half of the seepage from the WMP to Snap Lake is assumed while the WMP is draining, then null when WMP is empty.

5.1.3 Overflow to Snap Lake

In 2026, the water collected from the North Pile sumps and the Mine site runoff is no longer directed to the WMP. Mine site runoff is directed to Snap Lake (Figure 5-7) and the North Pile sumps overflow to Snap Lake as follows:

- Sump 1 overflows to Sump 2, Sump 2 overflows to Sump 3, and Sump 3 overflows to Snap Lake.
- Sump 4 overflows to Sump 5, and Sump 5 discharges to Snap Lake.

Figure 5-8 shows the overflow from the Sump 3 and Sump 5 to Snap Lake.

5.2 Receiving Environment Model

The Snap Lake outlet to DSL 1 is the key node for the Receiving Environment model at which discharges are predicted. Discharge results for Snap Lake are exported from the Site model and used as input to DSL 1 in the Receiving Environment model. Results for this discharge are presented in Figure 5-9.
Figure 5-1: Water Management Pond Input

<table>
<thead>
<tr>
<th>Year</th>
<th>Flow (m³/day)</th>
<th>PR11</th>
<th>R10</th>
<th>DP9</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>5,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>10,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>15,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2022</td>
<td>20,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2023</td>
<td>25,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td>30,000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5-2: Modular Water Treatment Plant Input

<table>
<thead>
<tr>
<th>Year</th>
<th>Flow (m³/day)</th>
<th>PR4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>1,500</td>
<td></td>
</tr>
<tr>
<td>2022</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>2023</td>
<td>2,500</td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>2026</td>
<td>3,500</td>
<td></td>
</tr>
<tr>
<td>2027</td>
<td>4,000</td>
<td></td>
</tr>
<tr>
<td>2028</td>
<td>4,500</td>
<td></td>
</tr>
</tbody>
</table>
Figure 5-3: Modular Water Treatment Plant Output

Figure 5-4: Reverse Osmosis Unit Output
Figure 5-5: Input to the Underground Workings/Snap Lake from the Water Management Pond

Figure 5-6: Seepage to Snap Lake from North Pile and WMP
Figure 5-7: Mine Site Runoff after Closure

![Mine Site Runoff after Closure](image)

Figure 5-8: North Pile Overflow from Sump 3 and Sump 5 to Snap Lake

![North Pile Overflow from Sump 3 and Sump 5 to Snap Lake](image)
Figure 5-9: Discharge to DSL 1 from Snap Lake

[Graph showing discharge to DSL 1 from Snap Lake over years]

- ECM
- Closure
- Post Closure

Discharge (m$^3$/day)

Year

6.0 CLOSURE

We trust this report provides you with the information you require at this time. Should you have any questions regarding the contents of this report, or require any further information, please contact the undersigned.

Golder Associates Ltd.

Original signed

Adelle Roberge, B.Sc.
Water Resources Specialist

Original signed

Nathan Schmidt, Ph.D., P.Eng.
Principal, Senior Water Resources Engineer

AR/NS

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REFERENCES


ATTACHMENT A

Flow Diagrams
Calibration Period (2016 to February 2017)
Calibration Period (February 2017 to December 2017)

Diagram showing the water flow processes including Sumps 1 to 5, WMP, Modular WTP, and Snap Lake. The legend indicates different flow types: Process Flow (PR), Seepage Flow (SE), Runoff (RO), Direct Precipitation (DP), and Evaporation (EV). The diagram includes nodes such as SE1, SE2, SE3, SE4, SE5, SE6, SE7, SE8, SE9, SE10, SE11, SE12, RO1, RO2, RO3, RO4, RO5, RO6, RO7, RO8, DP1, DP2, DP3, DP4, DP5, DP6, DP7, EV1, EV2, EV3, EV4, EV5, EV6, EV7.
Post-closure Period (2026 to 2050)

- North Pile
  - Sump 1
    - RO4b
    - SE1
  - Sump 2
    - OV11a
    - RO3
    - SE2
    - SE5
  - Sump 3
    - RO2
    - DP3
    - EV3
    - SE3
  - Sump 4
    - RO5, RO6, RO7, RO8
    - DP5, DP6, DP7
    - OV11d
    - SE4
  - Sump 5 (WECA + IL6)
    - RO11
    - DP9, DP10
    - SE6
    - SE7
    - EV5, EV6, EV7
    - EV9, EV10
    - OV11c
    - OV11e

- Snap Lake
  - RO10
  - RO11

Legend:
- Overflow (OV)
- Seepage Flow (SE)
- Runoff (RO)
- Direct Precipitation (DP)
- Evaporation (EV)