DE BEERS CANADA INC.

SNAP LAKE MINE

EVALUATION OF EFFLUENT QUALITY CRITERIA

December 2013

EXECUTIVE SUMMARY

De Beers Canada Inc. owns and operates the Snap Lake Mine (Mine) in the Northwest Territories. As part of their operational Water Licence to discharge treated effluent to Snap Lake, the Mine is required to maintain parameter concentrations at the point of discharge at levels that are protective of the receiving environment (i.e., effluent quality criteria [EQC]). Water Licence MV2011L2-0004 (Water Licence) for the Mine specifies EQC for total suspended solids (TSS), ammonia, nitrate, nitrite, chloride, fluoride, sulphate, aluminum, arsenic, chromium, copper, lead, nickel, zinc, and extractable petroleum hydrocarbons. Under Schedule 5: Part F, 3b (ii) and 4b (ii) of the Water Licence, recommendations and rationale for revised EQC are specifically required for total dissolved solids (TDS), chloride, fluoride, ammonia, and nitrate. Golder Associates Ltd. was retained to review the existing EQC in the Water Licence, and identify opportunities for refining them or proposing new benchmarks that would allow the Mine to discharge treated effluent to Snap Lake while maintaining constituent concentrations in the lake that are protective in terms of the aquatic environment. This work was conducted in support of the *TDS Response Plan*, *Nitrogen Response Plan,* and the Water Licence Amendment Application.

Variability in the treated effluent is accounted for in the Water Licence through the requirement for two EQC:

1) Maximum daily limit (MDL), which represents the maximum concentration of a parameter measured in a single grab sample of the treated effluent; and,

2) Average monthly limit (AML), which represents the average concentration of a parameter that the Mine may release into Snap Lake, determined by averaging consecutive samples collected at six-day intervals over a thirty-day period.

In addition, long-term accumulation in Snap Lake is represented by an annual loading limit (ALL), which is dependent on both the concentration and volume of treated effluent discharged to Snap Lake.

The AMLs, MDLs, and ALLs (collectively referred to as EQC) were calculated conservatively for key parameters based on recent information from the Mine. The proposed EQC were compared to existing EQC in the Water Licence, treated effluent discharge quality in 2012, and predicted treated effluent discharge quality (i.e., remainder of Mine life). Based on those comparisons, it is recommended that the:

- whole-lake average TDS[1] Water Licence limit of 350 milligrams per litre (mg/L) be removed, and an AML of 684 mg/L and an MDL of 1,003 mg/L for TDS be added to the Water Licence and applied at end-of-pipe: average TDS concentrations from samples collected over a 30-day period in treated effluent should remain below 684 mg/L (the AML) and the maximum concentration in any grab sample should remain below 1,003 mg/L (the MDL);
- AML to come into effect on January 1, 2015, be increased from 4 milligrams as nitrogen per litre (mg-N/L) to 14 mg-N/L for nitrate, from 160 to 378 mg/L for chloride, and from 0.15 to 2.43 mg/L for fluoride;

[1] As per the Water Licence, the whole-lake average is calculated three times per year (i.e., twice during the ice-free period and once during ice-cover) using data collected from nine monitoring stations in the main basin, comprising SNP 02-18.

- MDL to come into effect on January 1, 2015, be increased from 8 to 32 mg-N/L for nitrate, from 320 to 607 mg/L for chloride, and from 0.30 to 3.73 mg/L for fluoride;
- AML and MDL for nitrite (0.5 and 1 mg-N/L) be increased to 1 and 3 mg-N/L, respectively;
- AML and MDL for TSS (i.e., 7 and 14 mg/L) and ammonia (i.e., 10 and 20 mg-N/L) be retained;
- AML and MDL for sulphate be increased from 75 to 427 mg/L and from 150 to 640 mg/L, respectively;
- AML and MDL for aluminum be retained, but EQC for other metals and metalloids, and for extractable petroleum hydrocarbons be eliminated from the Water Licence;
- ALL be reduced for nitrate and total phosphorus, and retained at the limit for ammonia to prevent the accumulation of these parameters in Snap Lake;
- Long-term average total phosphorus concentrations in the treated effluent remain below 0.01 milligrams as phosphorus per litre (mg-P/L) to meet the proposed ALL for total phosphorus.
- The Water Licence continue to specify that the treated effluent discharge be pH-regulated and non-acutely toxic;
- EQC be applied to treated effluent discharge at Surveillance Network Program (SNP) station SNP02-17B, and monitoring requirements at SNP02-17B remain the same with the exception of reducing sampling frequency for metals; and,
- Wording used to describe the EQC Table in Part F, 9a of the Water Licence be changed from “maximum average” to “average monthly limit” to improve clarity.

In regards to the achievability of the EQC listed above, it is recommended that:

- mitigation be implemented prior to 2015 to meet the proposed EQC for TDS, prior to 2017 to meet the proposed AML for chloride, and prior to 2025 to meet the proposed AML for nitrate.

Uncertainty regarding near-field mixing and the size of the mixing zone will be investigated as part of the plume characterization study to be completed post-construction in summer 2014. As part of that study, the mixing zone in Snap Lake will be modelled based on the updated diffuser configuration and predicted maximum treated effluent discharge rates. Data from the diffuser stations will continue to be collected and summarized as part of the SNP program, and will be used to calculate dilution factors. Where uncertainties exist, conservative and appropriate assumptions were made when developing the EQC presented herein.

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LIST OF ACRONYMS

Term	Definition
AB	Alberta
AEMP	Aquatic Effects Monitoring Program
AEP	Alberta Environmental Protection
ALL	annual loading limit
AML	average monthly limit
APHA	American Public Health Association
BCMOE	British Columbia Ministry of the Environment
CA	California
CCME	Canadian Council of Ministers of the Environment
De Beers	De Beers Canada Inc.
DC	District of Columbia
DF	dilution factor
EAR	Environmental Assessment Report
EQC	effluent quality criteria
Golder	Golder Associates Ltd.
Itasca	Itasca Denver Inc.
LTA	long-term average
MB	Manitoba
MDL	maximum daily limit
Mine	Snap Lake Mine
MVEIRB	Mackenzie Valley Environmental Impact Review Board
MVLWB	Mackenzie Valley Land and Water Board
NWT	Northwest Territories
ON	Ontario
Policy	Mackenzie Valley Land and Water Board's Effluent Quality Management Policy
SNP	Surveillance Network Program
SSWQO	site-specific water quality objective
TDS	total dissolved solids
TSS	total suspended solids
USA	United States of America
USEPA	United States Environmental Protection Agency
Water Licence	Water Licence MV2011L2-0004
WLA	waste load allocation
WQG	water quality guideline
WLWB	Wek'èezhìi Land and Water Board
WTP	water treatment plant

LIST OF SYMBOLS

Term	Definition
ap	averaging period for AEMP benchmark
CF	unit conversion factor
C_{IN}	average baseline concentration of parameter “x” in natural inflows to Snap Lake
C_{MZ}	concentration of parameter “x” at the mixing zone boundary in Snap Lake
C_{SL}	concentration of parameter “x” in Snap Lake
C_{TE}	concentration of parameter “x” in treated effluent discharge to Snap Lake
CV	coefficient of variation
C_{WQG}	selected AEMP benchmark
n	number of samples collected per month
Q_{IN}	natural inflows to Snap Lake
Q_{TE}	flow of treated effluent to Snap Lake
z	z score for the normal distribution
σ_n	the standard deviation of the treated effluent discharge quality

UNITS OF MEASURE

Term	Definition
^oC	degrees Celsius
%	percent
m	metres
mg/L	milligrams per litre
mg-N/L	milligrams as nitrogen per litre
mg-P/L	milligrams as phosphorus per litre
m^3/d	cubic metres per day
kg/yr	kilograms per year
km	kilometres

1 INTRODUCTION

1.1 Background

De Beers Canada Inc. (De Beers) owns and operates the Snap Lake Mine (Mine) in the Northwest Territories (NWT). 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. Final regulatory approvals for construction and operation of the Mine were granted in May 2004, and construction began in April 2005. The Mine officially opened on July 25, 2008.

The Environmental Assessment Report (EAR; De Beers 2002) predicted that concentrations of total dissolved solids (TDS) and its component ions, nutrients and some metals would increase in Snap Lake over the operational life of the Mine. Water quality in Snap Lake is changing over time predominantly due to influences from treated effluent discharge (De Beers 2012a). Specifically, TDS concentrations have increased as a result of mining operations liberating deep groundwater characterized by high salinity, and nitrate concentrations have increased as a result of using an emulsion type explosive as a blasting agent.

The observed, whole-lake average TDS concentration in Snap Lake has increased at a faster rate than predicted in the EAR due to greater than predicted TDS loading to Snap Lake from the treated effluent. Recent modelling (De Beers 2013a) predicts that the whole-lake average TDS concentration in Snap Lake will exceed the management compliance limit of 350 milligrams per litre (mg/L) specified in Water Licence MV2011L2-0004 (Water Licence). Nitrate concentrations in Snap Lake have increased as predicted and, in 2012, measured concentrations were above the aquatic effects monitoring program (AEMP) benchmark of 2.93 milligrams as nitrogen per litre (mg-N/L) (CCME 2003), which was implemented after the EAR was submitted.

As a result of those increasing trends, De Beers initiated tiered studies to investigate the potential effects of elevated TDS and nitrate concentrations on aquatic life in Snap Lake for the purpose of developing site-specific water quality objectives (SSWQOs) for TDS and nitrate. SSWQOs would then be used to establish effluent quality criteria (EQC) that would allow the Mine to discharge treated effluent into Snap Lake while maintaining constituent concentrations in the lake below SSWQOs, in other words, continuing to protect the ecological integrity of Snap Lake.

Effluent quality criteria are to be applied at the last point of discharge (i.e., they assess treated effluent quality from the permanent water treatment plant [WTP]). EQC represent values that, when maintained at the point of discharge, will be protective for aquatic life in the receiving environment (i.e., Snap Lake and downstream waterbodies). This is consistent with guidance provided by the Mackenzie Valley Land and Water Board's Effluent Quality Management Policy (the Policy) (MVLWB 2011), which also states (p 11) "the Boards will ensure that EQC are set at levels that the proponent can reasonably and consistently achieve."

1.2 Study Objectives

The Water Licence requires that a *TDS Response Plan* and *Nitrogen Response Plan* be submitted to address TDS (including chloride and fluoride) and nitrogen (i.e., ammonia and nitrate) management (MVLWB 2013a). Golder Associates Ltd. (Golder) was retained to review the EQC specified in the Water

Licence, evaluate the appropriateness of the existing limits, and, if warranted, identify opportunities for refining them or proposing new limits that would continue to provide protection to the aquatic environment.

The purpose of this report is to outline the process used to complete the review and develop revised EQC, and recommend EQC for consideration during the Water Licence Amendment process. Under Schedule 5: Part F, 3b (ii) and 4b (ii) of the Water Licence, recommendations and rationale for revised EQC are specifically required for TDS, chloride, fluoride, ammonia, and nitrate. For completeness, a similar evaluation was conducted for the remaining parameters with EQC specified in the Water Licence (Section 2.1). The EQC presented herein are based on expected operational changes identified since the Water Licence Hearing in 2011, updated modelling of conditions in Snap Lake over the life of the Mine, and recently developed SSWQOs.

The methods used to calculate EQC are described in Section 2. The proposed EQC for the Mine are presented in Section 3 along with a comparison of the proposed EQC to the existing EQC in the Water Licence, and a comparison of the proposed EQC to predictions of treated effluent discharge quality. Summary and recommendations are provided in Section 4, followed by a discussion of data gaps and uncertainty in Section 5.

2 METHODS

The Policy does not outline specific methods for establishing EQC; therefore, Golder reviewed the existing Snap Lake EQC with reference, as appropriate, to the methods used previously to establish EQC for the Mine (Golder 2003) and those recommended by other jurisdictions (USEPA 1991; AEP 1995).

Derivation of EQC for the Mine involved the following steps:

1) identify parameters for which EQC should be evaluated (Section 2.1);

2) select an appropriate benchmark for each parameter (Section 2.2);

3) select a location in Snap Lake where benchmarks should be met (i.e., the mixing zone boundary) (Section 2.3);

4) calculate an EQC that results in peak concentrations in Snap Lake being equal to or lower than SSWQOs or existing AEMP benchmarks (Section 2.4); and,

5) compare proposed EQC to existing EQC in the Water Licence and predicted treated effluent discharge concentrations (Section 3).

2.1 Parameter Identification

The first task in the EQC setting process involved identifying the relevant parameters for which EQCs would be refined or developed. Parameters already included in the Water Licence (Part F, Item 9) are:

- total suspended solids (TSS);
- chloride;
- fluoride;
- nitrate;
- ammonia;
- nitrite;
- sulphate;
- aluminum;
- arsenic;
- chromium;
- copper;
- lead;
- nickel;
- zinc; and,
- extractable petroleum hydrocarbons.

The Water Licence also specifies that the treated effluent discharge be pH-regulated, non-toxic, not cause a visible film from hydrocarbons in the vicinity of the outfall, and that phosphorus loadings remain within the annual limit.

As described in Sections 2.1.1 and 2.1.2, re-evaluation was mandatory for some parameters (i.e., "required parameters") under the *TDS Response Plan* and *Nitrogen Response Plan.* For other parameters (i.e., "remaining parameters"), the evaluation was conducted in response to operational changes identified since the 2011 Water Licence Hearing.

2.1.1 Required Parameters

Under Schedule 5: Part F, 3b (ii) and 4b (ii) of the Water Licence, recommendations and rationale for revised EQC are specifically required for five parameters: TDS, chloride, fluoride, ammonia, and nitrate. For TDS (not included in the list above) an in-lake compliance limit is currently set, not an end-of-pipe limit.

In their Reasons for Decision (MVEIRB 2003), the Mackenzie Valley Environmental Impact Review Board recognized that the current 350 milligrams per litre (mg/L) TDS limit was based on modelling predictions rather than a guideline value or toxicity data. There are no national water quality guidelines (WQGs) for TDS based on toxicity data. An SSWQO has been developed for TDS (De Beers 2013b) and it is proposed that the approach for managing TDS be consistent with other parameters in the Water Licence: the in-lake compliance limit be removed from the Water Licence and replaced with an end-of-pipe limit (i.e., an EQC) that would maintain TDS concentrations in Snap Lake below the SSWQO. The legal justification for this change is provided in Osler (2013). An EQC for TDS would provide the Mine with more operational control than is presently the case, as it would be clear what the TDS concentration in the treated effluent must be to maintain Snap Lake TDS concentrations below the SSWQO. A TDS EQC rather than a whole-lake-average is also better aligned with the AEMP Response Framework and proposed Action Levels (De Beers 2012b).

2.1.2 Remaining Parameters

Nitrite, sulphate, aluminum, arsenic, chromium, copper, lead, nickel, zinc, and total phosphorus were carried forward in the assessment to determine whether existing EQC are appropriate and conservative based on anticipated operational changes at the Mine. The most important operational change will be an increasing rate of treated effluent discharge beyond levels previously used to derive EQC (Section 2.3), thereby increasing loadings to Snap Lake.

Total suspended solids and pH were not carried forward in this assessment, as levels are maintained by best available technologies (i.e., the most effective and economically achievable technology). As such, they are not expected to change and the existing EQC are appropriate. The EQC for extractable petroleum hydrocarbons does not appear to be based on toxicity data, and this parameter is typically not detected in the treated effluent; consequently, it is recommended that monitoring of this parameter continue on a monthly basis but that the EQC be removed. Extractable petroleum hydrocarbons were, therefore, not carried forward in the assessment.

2.2 Summary of Benchmarks

The second task in the EQC setting process involved selecting appropriate benchmarks for the parameters outlined in Section 2.1. Benchmarks used for calculating EQC, collectively termed "AEMP Benchmarks", consistent with terminology used in the AEMP and in the associated Response Framework (De Beers 2012b), are presented in Table 2-1 from the following sources:

- generic CCME WQGs for the protection of aquatic life (CCME 1999 [with updates to 2012]);
- published WQGs from other jurisdictions (BCMOE 2013; USEPA 2013);

- site-specific water quality objectives developed during the EAR (De Beers 2002);
- site-specific water quality objectives developed subsequently (De Beers 2013b,c,d); and,
- phosphorous concentrations associated with maintaining mesotrophic status (Wetzel 2001).

The AEMP benchmarks selected for chloride, nitrate, sulphate, copper, lead, and nickel are hardness dependent, reflective of the inverse relationship that exists between the aquatic toxicity of each of these parameters and the amount of calcium and magnesium present in the water column. At the end of 2012, hardness concentrations in Snap Lake were approximately 140 mg/L, but are expected to increase to 450 mg/L (Appendix I). EQC were derived using the relationship between hardness and proportion of treated effluent in Snap Lake, for hardness levels ranging between 140 and 450 mg/L using the methods provided in Appendix I. A wasteload allocation (see Section 2.4) was calculated for each parameter at hardness increments of 10 mg/L; the most restrictive (i.e., conservative) allocation was carried forward and used to develop EQC for nitrate, chloride, sulphate, copper, lead, and nickel. Table 2-1 presents the benchmarks calculated using the hardness corresponding with the most restrictive EQC.

Table 2-1 AEMP Benchmarks Used for Calculating Effluent Quality Criteria

Parameter	AEMP Benchmark (mg/L)	Description	Source
Total dissolved solids[a,b]	684	Site-specific water quality objective (SSWQO)	De Beers (2013b)
Chloride[a]	388	Hardness dependent SSWQO developed for the EKATI Diamond Mine, at a hardness of 160 mg/L[c] as $CaCO_3$	Elphick et al. (2011); De Beers (2013b); Appendix I
Fluoride[a]	2.46	SSWQO calculated from chronic toxicity data	De Beers (2013d)
Nitrate as N[a]	16.4	Hardness dependent SSWQO developed for the EKATI Diamond Mine, at a hardness of 160 mg/L[c] as $CaCO_3$	Rescan (2012); De Beers (2013c); Appendix I
Ammonia as N[a]	5.21 (chronic)[d]	WQG for total ammonia for the protection of aquatic life based on the conditions present in Snap Lake (i.e., pH = 7.14 and temperature 13.7 degrees Celsius)[d]	CCME (1999); USEPA (2013)
	21 (acute)[d]		
Nitrite as N	0.06	Generic WQG for the protection of aquatic life	CCME (1999)
Sulphate	429	Hardness dependent WQG calculated at a hardness of 250 mg/L[e] as $CaCO_3$	BCMOE (2013); Appendix I
Aluminum	0.1	pH dependent WQG based on the range of pH values observed in Snap Lake during the 2012 reporting period	CCME (1999); De Beers (2013e)
Arsenic	0.005	Generic WQG for the protection of aquatic life	CCME (1999)
Chromium (hexavalent)	0.0021	SSWQO developed as part of the Snap Lake EAR (more restrictive than trivalent)	CCME (1999)
Copper	0.0064	Hardness dependent SSWQO derived as part of the Snap Lake EAR and calculated at a hardness of 140 mg/L[f] as $CaCO_3$	De Beers (2002); Appendix I
Lead	0.007	Hardness dependent WQG calculated at a hardness of 450 mg/L[g] as $CaCO_3$	CCME (1999); Appendix I
Nickel	0.15	Hardness dependent WQG calculated at a hardness of 450 mg/L[g] as $CaCO_3$	CCME (1999); Appendix I
Zinc	0.03	Generic WQG for the protection of aquatic life	CCME (1999)

Table 2-1 AEMP Benchmarks Used for Calculating Effluent Quality Criteria

Parameter	AEMP Benchmark (mg/L)	Description	Source
Total phosphorus	0.011	Mesotrophic status defined by phosphorus levels of 10.9 to 95.6 micrograms per litre. Refers to the low end of this range (i.e., 0.011 mg/L).	(Wetzel 2001).

a) Denotes parameters for which recommendations and rationale for revised EQC are specifically required under Schedule 5: Part F, 3b (ii) and 4b (ii) of the Water Licence.

b) Total dissolved solids refers to calculated values, rather than measured values. Under Annex A: Part D, 2a of the Water Licence, calculated total dissolved solids (i.e., calculated based on ionic constituent concentrations) should be used. The major constituents used to calculate TDS are alkalinity, sodium, magnesium, potassium, calcium, sulphate, chloride, nitrate, fluoride, and silicate (APHA 2005).

c) The SSWQO is based on a maximum hardness of 160 mg/L (Elphick et al. 2011; Rescan 2012). Toxicity-hardness relationships were not defined for hardness concentrations beyond 160 mg/L.

d) The ammonia WQG is pH and temperature dependent and was calculated based on the 85th percentile values for pH and temperature of 7.14 and 13.7 degrees Celsius (^{o}C), respectively. The chronic ammonia WQG protects organisms from potential toxicity as a result of long exposures to ammonia in the water column (CCME 1999). The acute ammonia guideline protects organisms from potential toxicity as a result of short exposures to ammonia in the water column. The acute ammonia guideline is based on ammonia concentrations averaged over a one hour time period (USEPA 2013).

e) Hardness concentrations are predicted to reach 450 mg/L; however, toxicity tests were only conducted on water hardness up to 250 mg/L. Further testing is recommended should water hardness exceed 250 mg/L (BCMOE 2013).

f) Calculated at the 2012 hardness value of 140 mg/L because the most restrictive EQC corresponds to hardness levels of 140 mg/L (Appendix I).

g) Calculated at the maximum hardness value predicted to occur in Snap Lake (i.e., 450 mg/L; De Beers 2013a) because the most restrictive EQC corresponds to hardness levels of 450 mg/L.

mg/L = milligrams per litre; AEMP = Aquatic Effects Monitoring Program; CCME = Canadian Council of Ministers of the Environment; USEPA = United States Environmental Protection Agency; WQG = water quality guideline; Golder = Golder Associates Ltd. BCMOE = British Columbia Ministry of the Environment; De Beers = De Beers Canada Inc.; $CaCO_3$ = calcium carbonate.

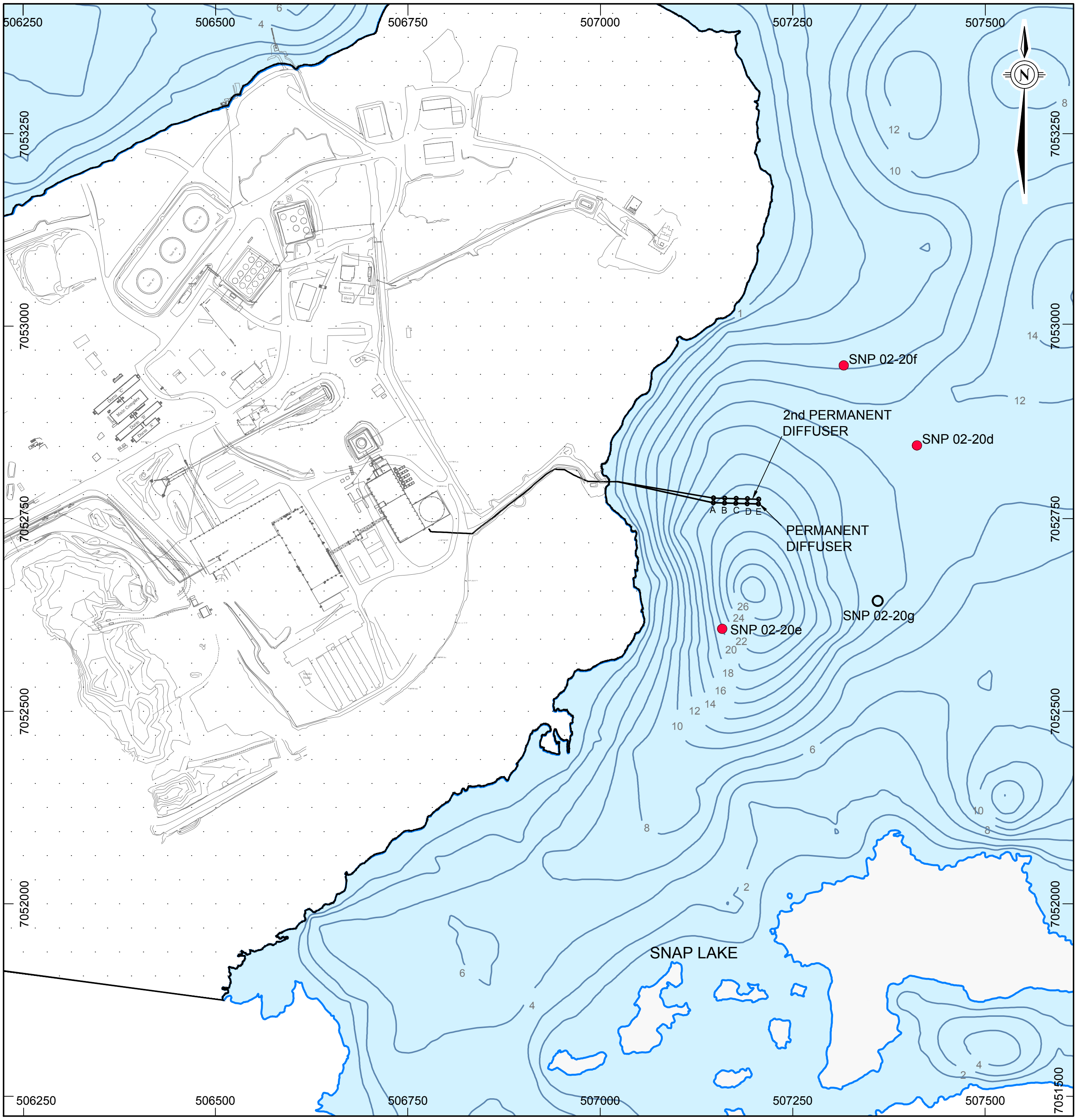
2.3 Mixing Zone Considerations

The third task in the EQC setting process involved re-visiting mixing zone considerations. The Policy allows for the consideration of allocated mixing zones. A mixing zone is the region in which initial dilution of treated effluent occurs. The mixing zone boundary represents the location where the initial turbulent mixing area (i.e., active mixing) ends and further mixing occurs naturally due to ambient factors such as wind-driven currents (i.e., passive mixing). The most restrictive mixing conditions occur during ice-cover when wind-driven currents are absent; conservative EQC were derived using the most restrictive winter conditions. Dilution efficiency achieved within the mixing zone is discussed in Section 2.4.

The mixing zone in Snap Lake, which extends 200 metres (m) from the diffuser, was established based on predictions of initial mixing using the United States Environmental Protection Agency (USEPA) Cormix Mixing Zone Model and a maximum treated effluent discharge rate of 26,000 cubic metres per day (m^3/d) (De Beers 2002). The model results indicated that the diffuser would result in an initial turbulent mixing area around the diffuser with a radius between 80 and 150 m. For Snap Lake, the mixing zone boundary also represents the location at which AEMP benchmarks should be met, so Surveillance Network Program (SNP) monitoring stations have been positioned accordingly (Figure 2-1).

For the present study, the mixing zone was assumed to be the same as that established in the EAR (De Beers 2002). However, since mid-2012, treated effluent discharge rates from the Mine have been greater than the maximum treated effluent discharge rate used to establish the mixing zone boundary (i.e., 26,000 m^3/d). Treated effluent discharge rates from the Mine have increased beyond the capacity of the permanent diffuser (i.e., 35,000 m^3/d). A second identical diffuser (i.e., maximum discharge capacity 35,000 m^3/d) has been approved (MVLWB 2013b), and is now operational. Discharge from this second diffuser is expected to increase slowly over several years, from approximately 10,000 m^3/d to 35,000 m^3/d.

The effect of the increased discharge rate and two separate diffusers on mixing has not been quantified, but is expected to result in a larger physical mixing zone. However, the present report used the existing mixing zone for EQC calculations, which is a conservative assumption: concentrations at the existing diffuser stations (i.e., SNP 02-20) would be required to meet AEMP benchmarks, even though complete mixing (i.e., increased dilution) of the effluent may not occur within that area. Uncertainty regarding near-field mixing and the size of the mixing zone will be investigated as part of the plume characterization study to be completed post-construction in summer 2014. As part of that study, the mixing zone in Snap Lake will be modelled to the extent possible, based on the updated diffuser configuration and predicted maximum treated effluent discharge rates using existing information. In addition, data from the diffuser stations will continue to be collected and summarized as part of the SNP program, and that information will be used to calculate dilution factors.



LEGEND

- SNP Station Location
- New Monitoring Station
- Bathymetric Contour (2 m interval)
- Mine Infrastructure
- Permanent Diffuser Location
- Snap Lake Mine Footprint
- Waterbody

REFERENCES

Digital map from Mackay Lake, Northwest Territories, produced by Department of Energy, Mines and Resources. map 75M, original scale 1:250,000, NAD 83 UTM Zone 12.
Snap Lake outline and islands were corrected to LANDSAT 7 satellite image 45/15, dated September 2, 2000. provided by geobase.
Bathymetry was created in surfer 8 using sonar data from the 2002 north lakes program (Golder) and 2005 transect data from the reference lake search program (golder) and 2011 data from the spill response program (golder).
Snap Lake Plantsite drawing obtained from client. DATE: JUNE 12, 2012. "SNAPLAKE-08_STATMAP_2012". drawn by NampcySolutionsLtd.
Outfall pipe and diffuser as-built survey by Golder Construction, September 2011.

NOTES

1. Map moved to NAD83 coordinate system.
2. Monitoring at SNP 02-20g will begin once the 2nd diffuser is operational

SNAP LAKE MINE

Monitoring Stations in Snap Lake Near the Diffuser

PROJECTION: UTM Zone 12	DATUM: NAD83		DE BEERS GROUP OF COMPANIES
150 0 150 SCALE 1:7,500 METRES			
FILE No: 13134900019100-01			DATE: October 11, 2013
JOB No: 13-1349-0001.9100	REVISION No: 0		Figure 2-1
OFFICE: GOLDER VICTORIA	DRAWN: JEF	CHECK: AS	

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2.4 Calculation of Effluent Quality Criteria

The fourth task in the EQC setting process was calculating the water quality-based EQC. The Water Licence accounts for treated effluent variability using two types of EQC:

1) Maximum daily limit (MDL), which represents the maximum concentration of a parameter measured in a single grab sample of the treated effluent; and,

2) Average monthly limit (AML), which represents the average concentration of a parameter that the Mine may release into Snap Lake, determined by averaging consecutive samples collected over six-day intervals over a thirty-day period.

An MDL and an AML are required because the quality of the treated effluent discharge to Snap Lake varies over time. For example, in 2012, the calculated TDS concentrations in the treated effluent discharge ranged from 432 to 744 mg/L. Variability in treated effluent quality can be due to:

- changing input conditions, such as fluctuations in the amount of ions or nutrients flowing into the WTP;
- changing system performance, such as variations in suspended sediment removal in response to variable input concentrations; and,
- changing seasonal conditions, such as more surface runoff flowing into the WTP in the spring and summer, compared to fall and winter.

Long-term accumulation of a parameter in Snap Lake is dependent on both the concentration and volume of treated effluent discharged to Snap Lake, which is represented by an annual loading limit (ALL). Historically, ALL have been specified in the Water Licence for nutrients (phosphorus, ammonia, nitrate) to prevent the accumulation of these parameters in Snap Lake.

The EQC (i.e., AML, MDL, and ALL) were derived using the following four steps (USEPA 1991; AEP 1995):

1) Calculating the waste load allocation (WLA) for each parameter – The WLA represents the maximum concentration of a parameter that can be discharged to Snap Lake while maintaining the AEMP benchmark under “worst-case” or most limiting conditions. The WLA calculation considers the average treated effluent discharge to Snap Lake during the year of maximum discharge, the average natural inflows to Snap Lake during the year of maximum treated effluent discharge, baseline parameter concentrations in Snap Lake, and the dilution of treated effluent provided by the diffuser. The WLA is a deterministic or fixed value that does not consider treated effluent or sampling variability. Details of the WLA calculation are provided in Section 2.4.1.

2) Deriving long term average (LTA) concentrations for each parameter from the WLAs – The LTA concentration is a derived value that is smaller than the WLA. It takes into account the potential for parameter concentrations to vary in the treated effluent. It is calculated from the WLA using the equations and assumptions presented in Section 2.4.2.

3) Calculating the MDL and AML from the LTA – The MDL and AML are derived values that explicitly account for expected variability in treated effluent quality. They are generated from the LTA using the equations and assumptions presented in Section 2.4.3.

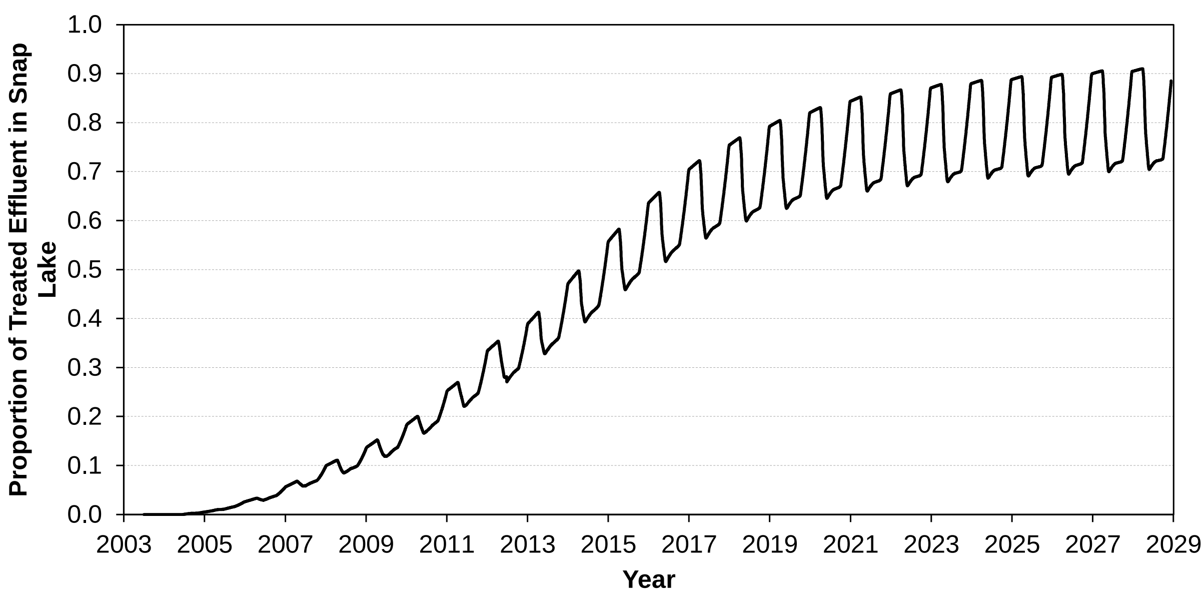
4) Calculating the ALL from the LTA where applicable – the ALL limits the accumulation of material in Snap Lake over time and is expressed in terms of mass loading (e.g., kilograms per year [kg/yr]), rather than concentration. ALL values are calculated using the equations presented in Section 2.4.4.

2.4.1 Waste Load Allocation Concentrations

To assess how the accumulation of treated effluent within Snap Lake will affect its assimilative capacity, the three-dimensional hydrodynamic and water quality model developed for Snap Lake was run using a generic parameter. Concentrations in the treated effluent discharge and natural inflows were set to 1 and 0 mg/L, respectively. The initial concentration within Snap Lake was set to zero, and the time series of treated effluent discharge to Snap Lake was set at values predicted by the Snap Lake site model (De Beers 2013f). Treated effluent discharge flows were predicted using the Snap Lake site model for the Lower Bound Scenario minewater flows from Base Case of the groundwater model (Itasca 2013). In the Lower Bound Scenario, average treated effluent discharge flows are predicted to peak at 57,013 m^3/d.

Effluent quality criteria were calculated based on predicted treated effluent discharge flows from the Lower Bound Scenario. Results of this model simulation indicated that conditions in Snap Lake approach steady-state conditions near the end of mining, with the main basin containing approximately 90 percent (%) treated effluent (Figure 2-2).

Figure 2-2 Proportion of Treated Effluent in Snap Lake Based on Predicted Treated Effluent Discharge Rates from the Lower Bound Scenario



Note: Based on whole-lake average concentrations in Snap Lake; predicted treated effluent discharge rates are from De Beers (2013f).

To define WLAs, the onset of steady-state conditions represent, for most parameters, the most restrictive period when the assimilative capacity of Snap Lake is at a minimum and the associated WLA will also be at a minimum. At steady-state, parameter concentrations within Snap Lake can be calculated using Equation 1:

$$C_{SL} = \frac{(C_{IN} \times Q_{IN}) + (C_{TE} \times Q_{TE})}{Q_{IN} + Q_{TE}} \qquad \text{Equation 1}$$

Where:

C_{SL} = concentration of parameter “x” in Snap Lake

C_{IN} = average baseline concentration of parameter “x” in natural inflows to Snap Lake

Q_{IN} = natural inflows to Snap Lake

C_{TE} = concentration of parameter “x” in treated effluent discharge to Snap Lake

Q_{TE} = flow of treated effluent to Snap Lake

C_{IN} was set equal to the average baseline concentrations observed in Snap Lake (Table 2-2), rather than those observed in the sampled inflows. This substitution was done to account for settling of suspended sediment and associated particulate materials in Snap Lake. Settling is a physical process in which the suspended sediment and particulate materials that are heavier than water sink to the bottom of the water column.

Table 2-2 Average Baseline Concentrations in Snap Lake

Constituent	Units	Average Baseline Concentrations in Snap Lake(b)
Total dissolved solids(a)	mg/L	10
Chloride(a)	mg/L	0.50
Fluoride(a)	mg/L	0.05
Nitrate(a)	mg-N/L	0.013
Ammonia(a)	mg-N/L	0.02
Nitrite	mg-N/L	0.001
Sulphate	mg/L	2
Aluminum	mg/L	0.011
Arsenic	mg/L	0.0001
Chromium	mg/L	0.0007
Copper	mg/L	0.0011
Lead	mg/L	0.0005
Nickel	mg/L	0.0004
Zinc	mg/L	0.0045

a) Denotes parameters for which recommendations and rationale for revised EQC are specifically required under Schedule 5: Part F, 3b (ii) and 4b (ii) of the Water Licence.

b) Average baseline concentrations were calculated using data from Snap Lake prior to June 2004.

mg/L = milligrams per litre; mg-N/L = milligrams as nitrogen per litre.

Concentrations at the mixing zone boundary can be calculated using Equation 2:

$$C_{MZ} = \frac{DF \times C_{SL} + C_{TE}}{DF + 1} \qquad \text{Equation 2}$$

Where:

C_{MZ} = concentration of parameter “x” at the mixing zone boundary in Snap Lake (i.e., the selected AEMP benchmark)

DF = dilution factor (i.e., volumes of lake water mixing with each volume of treated effluent discharged through the diffuser into Snap Lake)

Combining Equations 1 and 2, and replacing C_{MZ} with the selected AEMP benchmark, yields Equation 3, which was used to calculate the waste load allocation for each parameter:

$$WLA = \frac{(DF+1) \times C_{WQG} \times (Q_{IN} + Q_{TE}) - (DF \times C_{IN} \times Q_{IN})}{(DF+1) \times Q_{TE} + Q_{IN}} \qquad \text{Equation 3}$$

Where:

C_{WQG} = selected AEMP benchmark

The efficiency of the diffuser, or dilution factor (DF), was set to 12, consistent with EAR predictions that:

- During the first seven years of construction and operations, treated effluent discharge flows would be sufficiently low that a bulk DF of 34 to 1 (i.e., volumes of lake water that mix with one volume of treated effluent) would be achievable for the entire ice covered period.
- During the remaining years of operations, treated effluent discharge flows would be sufficiently high such that background concentrations in Snap Lake would limit the amount of near-field dilution that can be achieved to approximately 12 to 1.

The influence of increasing the treated effluent discharge rate and installing the 2^{nd} diffuser on near-field mixing is uncertain, specifically the achievable minimum DF at the existing mixing zone boundary. Implementation of the plume study in 2014 will provide necessary information to determine the DF with the two diffusers in operation. Using a DF of 12 was considered appropriate for the present study because minimum DFs during ice-covered conditions in 2012 and 2013 were higher (18:1 and 16:1, respectively [De Beers 2013e; Golder 2013]).

The volume of treated effluent discharging to Snap Lake (i.e., Q_{TE}) was set to 57,013 m^3/d, which is equivalent to the average predicted treated effluent discharge during the year of maximum discharge (2026) (De Beers 2013f) in the Lower Bound Scenario.

The volume of natural inflows available for mixing (i.e., Q_{IN}) was defined by solving Equation 1 (above) using results from the initial, generic model simulation where concentrations in the treated effluent discharge and natural inflows were set to 1 and 0 mg/L, respectively. The volume of natural inflows available for mixing was, therefore, calculated using Equation 4:

$$C_{SL} = \frac{(C_{IN} \times Q_{IN}) + (C_{TE} \times Q_{TE})}{Q_{IN} + Q_{TE}} \qquad \text{Equation 4}$$

Where:

$C_{SL} = 0.9\ (upper\ end\ of\ the\ steady - state\ range)$

$C_{IN} = 0$

$C_{TE} = 1$

$Q_{TE} = 57{,}013\ m^3/d$

So:

$0.9 = \frac{(0 \times Q_{IN}) + (1 \times Q_{TE})}{Q_{IN} + Q_{TE}}$

$0.9 = \frac{Q_{TE}}{Q_{IN} + Q_{TE}}$

$Q_{IN} = \frac{(1 - 0.90)}{0.90} \times Q_{TE}$

$Q_{IN} = 6{,}335\ m^3/d$

Ammonia and nitrite are non-conservative parameters; when released into Snap Lake they are rapidly oxidized to nitrate, limiting the rate of increase in the lake. The waste load allocations for nitrite and ammonia were, therefore, calculated with:

$C_{MZ} = C_{WQG}$

Equation 2 becomes:

$$C_{WQG} = \frac{DF \times C_{SL} + WLA}{DF + 1} \qquad \text{Equation 5}$$

Which simplifies to:

$$WLA = ((DF + 1) \times C_{WQG} - (DF \times C_{SL})) \qquad \text{Equation 6}$$

2.4.2 Long-Term Average Concentrations

The LTA concentrations were derived for each parameter using Equations 7 and 8 (AEP 1995).

$$LTA = WLA \cdot e^{[0.5\sigma_n{}^2 - Z\sigma_n]} \quad \text{Equation 7}$$

$$\sigma_n{}^2 = \ln(\frac{CV^2}{ap} + 1) \quad \text{Equation 8}$$

Where:

σ_n = the standard deviation of the treated effluent discharge quality

CV = coefficient of variation, describing the expected variation of treated effluent discharge quality around the average treated effluent discharge quality

ap = averaging period for AEMP benchmark

z = z score for the normal distribution

The coefficient of variation for a given parameter was set to the observed coefficient of variation based on treated effluent discharge samples collected from 2004 to 2013. The averaging period was set to the four day default and the z statistic was set to 2.326 (99^{th} percentile occurrence probability) for all parameters, as recommended by Alberta Environmental Protection (AEP 1995) and the USEPA (1991).

2.4.3 Maximum Daily Limit and Average Monthly Limit Concentrations

The MDL concentrations were derived using Equations 9 and 10 (AEP 1995).

$$MDL = LTA \cdot e^{[Z\sigma - 0.5\sigma^2]} \quad \text{Equation 9}$$

$$\sigma_n{}^2 = \ln(cv^2 + 1) \quad \text{Equation 10}$$

The coefficient of variation and the z statistic were set as described in Section 2.4.2.

The AML concentrations were derived using Equations 11 and 12 (AEP 1995).

$$AML = LTA \cdot e^{[Z\sigma_n - 0.5\sigma_n{}^2]} \quad \text{Equation 11}$$

$$\sigma_n{}^2 = \ln(\frac{CV^2}{n} + 1) \quad \text{Equation 12}$$

Where:

n = number of samples collected per month

The coefficients of variation used to derive the AMLs are identical to those used to calculate MDLs. The z statistic was set to 1.642 (95th percentile occurrence probability) for all parameters, as recommended by AEP (1995) and USEPA (1991), and it was assumed that four samples per month would be collected. At the Mine, physical parameters, major ions, and nutrients are measured every six days; metals are analyzed approximately once per month.

2.4.4 Annual Loading Limits

An ALL was calculated for nitrate, ammonia and phosphorus using the LTA described in Section 2.4.2 and Equation 13:

$$ALL = LTA \cdot Q_{TE} \cdot CF \qquad \text{Equation 13}$$

Where:

CF = unit conversion factor

3 EFFLUENT QUALITY CRITERIA FOR SNAP LAKE MINE

Effluent quality criteria calculated for all parameters are presented in Table 3-1; key findings from the comparison to existing values are provided in Sections 3.1.1 and 3.1.2. Section 3.2 presents a comparison of the proposed EQC to measured and predicted treated effluent concentrations. Finally, Section 3.3 presents a summary of proposed EQC for inclusion in the Water Licence Amendment.

3.1 Comparison of Proposed Effluent Quality Criteria to Existing Effluent Quality Criteria

3.1.1 Required Parameters

Key findings for TDS, chloride, fluoride, ammonia, and nitrate were:

- A new EQC was calculated for TDS which was based on the SSWQO (De Beers 2013b). For the reasons outlined in Section 2.1.1, developing an EQC for TDS at the Mine affords De Beers more operational control, as it would be clear what the TDS concentration in the treated effluent must be to maintain Snap Lake TDS concentrations below the SSWQO.
- The AMLs and MDLs proposed for nitrate, chloride, and fluoride are greater than the existing AMLs and MDLs and than those that will come into effect on January 1, 2015. The increase was a result of moving to more realistic, site-specific, protective benchmarks from conservative, generic benchmarks when deriving EQC. As described in Table 2-1, the site-specific benchmarks for nitrate and chloride were based on hardness-dependent equations developed for the EKATI diamond mine and approved by the Wek’èezhìi Land and Water Board (WLWB 2013).
- With the exception of ammonia, proposed AMLs were essentially equivalent to the AEMP benchmarks (Table 2-1). Therefore, the Mine must meet proposed AMLs approximately equal to the AEMP benchmarks at the end-of-pipe.
- The ALL for nitrate is lower than the existing loading limit, primarily due to using a more realistic, site-specific, protective benchmark instead of a conservative, generic benchmark when deriving EQC. The ALL for ammonia is higher than the existing limit because of the increase in treated effluent discharge rates.

3.1.2 Remaining Parameters

Key findings for nitrite, sulphate, aluminum, arsenic, chromium, copper, lead, nickel, zinc, and total phosphorus are:

- The new AMLs and MDLs for nitrite, sulphate, aluminum, chromium, copper, lead, nickel, and zinc are greater than or equal to the existing AMLs and MDLs in the Water Licence. These results demonstrate that the existing AMLs and MDLs were unnecessarily restrictive for protecting aquatic life under the previous, lower, treated effluent discharge volumes.

- The new AML for total arsenic is slightly lower than the existing AML in the Water Licence.
- The EQC developed for total metals are conservative because they were developed assuming that any metal released into Snap Lake would remain in the water column. This conservative approach ignores the natural processes of adsorption to suspended or bottom sediments and settling, which would serve to limit the cumulative increase in metal concentrations in Snap Lake water as well as their bioavailability and thus potential toxicity.
- The total annual phosphorus loading limit calculated for this study was lower than the existing loading limit. The lower loading limit results from increased treated effluent discharge rates (i.e., higher discharge volume) and adjusting the AEMP benchmark to reflect the low end of the mesotrophic range (Wetzel 2001), consistent with the Response Framework for nutrient enrichment in the AEMP (De Beers 2012b). To meet the lower ALL for total phosphorus, the Mine should maintain long-term average total phosphorus concentrations in the treated effluent below 0.01 mg-P/L.

Table 3-1 Comparison of Existing and Proposed[(a)] Effluent Quality Criteria for Snap Lake Mine

Parameter	EQC (mg/L)						Annual Loading Limit (kg/yr)		
	AML		Existing >Proposed (Y/N)	MDL		Existing >Proposed (Y/N)			
	Existing	Proposed[(a)]		Existing	Proposed[(a)]		Existing	Proposed[(a)]	Existing >Proposed (Y/N)
Total dissolved solids[(b)]	N/A	684	N/A	N/A	1,003	N/A	N/A	N/A	N/A
Chloride[(b)] (to December 31, 2014)	310	N/A	N/A	620	N/A	N/A	N/A	N/A	N/A
Chloride[(b)] (from January 1, 2015)	160	378	N	320	607	N	N/A	N/A	N/A
Fluoride[(b)] (from January 1, 2015)	0.15	2.43	N	0.30	3.73	N	N/A	N/A	N/A
Nitrate as N[(b)] (to December 31, 2014)	22	N/A	N/A	44	N/A	N/A	219,000	N/A	Y
Nitrate as N[(b)] (from January 1, 2015)	4	14	N	8	32	N	219,000	161,000	Y
Ammonia as N[(b)]	10	21[(c)]	N	20	21[(c)]	N	187,000	208,000[(d)]	N
Nitrite as N	0.5	1.4	N	1	3	N	N/A	N/A	N/A
Sulphate	75	427	N	150	640	N	N/A	N/A	N/A
Aluminum	0.1	0.1	N	0.2	0.2	N	N/A	N/A	N/A
Arsenic	0.007	0.004	Y	0.01	0.01	N	N/A	N/A	N/A
Chromium	0.01	0.02	N	0.02	0.04	N	N/A	N/A	N/A
Copper	0.003	0.01	N	0.006	0.03	N	N/A	N/A	N/A
Lead	0.005	0.005	N	0.01	0.01	N	N/A	N/A	N/A
Nickel	0.05	0.1	N	0.1	0.3	N	N/A	N/A	N/A
Zinc	0.01	0.02	N	0.02	0.06	N	N/A	N/A	N/A
Total phosphorus	N/A	N/A	N/A	N/A	N/A	N/A	256	229	Y

a) The final list of recommended EQC for inclusion in the Water Licence is presented in Section 3.3; the final list was developed based on the comparisons of existing and proposed EQC presented in Tables 3-1 and 3-2.

b) Denotes parameters for which recommendations and rationale for revised EQC are specifically required under Schedule 5: Part F, 3b (ii) and 4b (ii) of the Water Licence.

c) The AML and MDL for ammonia were set equal to the acute benchmark, which protects against acute effects prior to discharge and against chronic effects in Snap Lake. The acute benchmark is more restrictive than calculating an MDL and AML based on the chronic benchmark.

d) The annual loading limit for ammonia was derived by setting the long-term average to the recommended AML (Section 3.3).

mg/L = milligrams per litre; kg/yr = kilograms per year; N = nitrogen; >greater than; Y = yes; N = no; EQC = effluent quality criteria; MDL = maximum daily limit; AML = average monthly limit; N/A = not applicable.

3.2 Comparison of Proposed Effluent Quality Criteria to Treated Effluent Discharge Quality

Comparisons of proposed EQC to treated effluent discharge quality in 2012 and to predicted treated effluent discharge quality (De Beers 2013g) are presented in Table 3-2.

3.2.1 Required Parameters

Key findings for TDS, chloride, fluoride, ammonia, and nitrate are:

- Based on the treated effluent discharge quality in 2012, the Mine can currently meet the proposed EQC.
- Based on the predicted treated effluent discharge quality, the Mine will be able to meet the proposed EQC for all parameters, with the exceptions of TDS, chloride, and nitrate.
- Based on the predicted treated effluent discharge quality, De Beers will not be able to meet proposed EQC for TDS. Based on calculations of the predicted average monthly concentrations of TDS in the treated effluent discharge, mitigation will be required prior to 2015 to meet the proposed AML for TDS. The average monthly concentrations of TDS in the treated effluent discharge are predicted to exceed the proposed AML during ice-covered conditions in 2015 and exceed the proposed AML every month from 2016 to 2028. The maximum average monthly concentration of TDS in the treated effluent discharge is predicted to be 1,066 mg/L.
- Based on the predicted treated effluent discharge quality, the Mine will be able to meet the proposed MDL for chloride. Based on calculations of the predicted average monthly concentrations of chloride in the treated effluent discharge, mitigation will be required prior to 2017 to meet the proposed AML for chloride. The average monthly concentrations of chloride in the treated effluent discharge are predicted to exceed the proposed AML during ice-covered conditions between 2017 and 2028. The maximum average monthly concentration of chloride in the treated effluent discharge is predicted to be 473 mg/L.
- Based on the predicted treated effluent discharge quality, the Mine will be able to meet the proposed MDL for nitrate. Based on calculations of the predicted average monthly concentrations of nitrate in the treated effluent discharge, mitigation will be required prior to 2025 to meet the proposed AML for nitrate. The average monthly concentrations of nitrate in the treated effluent discharge are predicted to exceed the proposed AML periodically during ice-covered conditions between 2025 and 2028. The maximum average monthly concentration of nitrate in the treated effluent discharge is predicted to be 14.4 mg-N/L.

3.2.2 Remaining Parameters

Key findings for nitrite, sulphate, aluminum, arsenic, chromium, copper, lead, nickel, zinc, and total phosphorus are:

- Based on treated effluent discharge quality in 2012, the Mine can currently meet the proposed EQC for these parameters. The flow-weighted average arsenic, chromium, copper, lead, nickel, and zinc concentrations in 2012 are at least an order of magnitude lower than proposed and existing EQC.

- Based on the predicted treated effluent discharge quality, the Mine will be able to meet proposed EQC for sulphate, aluminum, arsenic, chromium, copper, lead, nickel, and zinc.
- Nitrite concentrations in the treated effluent discharge were not modelled due to the instability of nitrite resulting from changing redox conditions. However, nitrite concentrations in the effluent can be maintained below EQC by adjusting pH levels, thereby controlling redox potential and lowering nitrite concentrations.

Table 3-2 Comparisons of Proposed[(a)] Effluent Quality Criteria to Treated Effluent Discharge Quality in 2012 and to Predicted Treated Effluent Discharge Quality for Snap Lake Mine

Parameter	Proposed[(a)] EQC (mg/L)		Treated Effluent Discharge Quality in 2012[(c)]			Predicted Treated Effluent Discharge Quality[(d)]	
	AML	MDL	Flow-weighted Average (mg/L)	Maximum (mg/L)	n	Maximum (mg/L)	Year
Total dissolved solids[(b)]	684	1,003	570	744	94	1,081	2026
Chloride[(b)] (from January 1, 2015)	378	607	246	335	96	475	2026
Fluoride[(b)] (from January 1, 2015)	2.43	3.73	0.35	0.60	95	0.57	2028
Nitrate as N[(b)] (from January 1, 2015)	14	32	10	22	96	16.6	2028
Ammonia as N[(b)]	21	21	1.97	4.71	96	5.7	2028
Nitrite as N	1.4	3	0.16	0.69	96	<1.4[(e)]	-[(e)]
Sulphate	427	640	54	74	95	74	2026
Aluminum	0.1	0.2	0.03	0.23	61	0.053	2028
Arsenic	0.004	0.01	0.0001	0.0008	61	0.00025	2026
Chromium	0.02	0.04	0.0006	0.003	61	0.0004	2026
Copper	0.01	0.03	0.0004	0.002	61	0.002	2014
Lead	0.005	0.01	0.0001	0.001	61	0.00009	2028
Nickel	0.1	0.3	0.01	0.022	61	0.021	2028
Zinc	0.02	0.06	0.004	0.01	61	0.005	2028

Notes: Shaded cells represent parameters for which, based on calculations of the predicted average monthly concentrations in the treated effluent discharge, the Mine will not be able to meet the proposed AML.

a) The final list of recommended EQC for inclusion in the Water Licence is presented in Section 3.3; the final list was developed based on the comparisons of existing and proposed EQC presented in Tables 3-1 and 3-2.

b) Recommendations and rationale for revised EQC are specifically required under Schedule 5: Part F, 3b (ii) and 4b (ii) of the Water Licence.

c) De Beers (2013e)

d) De Beers (2013g)

e) Nitrite concentrations were not modelled in the treated effluent discharge due to the instability of nitrite resulting from changing redox conditions. However, nitrite concentrations in treated effluent can be maintained below 1.4 mg/L by adjusting pH levels.

mg/L = milligrams per litre; N = nitrogen; EQC = effluent quality criteria; MDL = maximum daily limit; AML = average monthly limit; n = number of samples collected.

3.3 Recommended Effluent Quality Criteria

The EQC presented in Table 3-3 represent the recommended values for inclusion in the Water Licence Amendment. A description of the changes recommended to the Water Licence is provided in Sections 3.3.1 and 3.3.2.

3.3.1 Required Parameters

For TDS, chloride, fluoride, ammonia, and nitrate, the following EQC are recommended:

- Remove the whole-lake average TDS Water Licence limit of 350 mg/L; replace with an AML of 684 mg/L and an MDL of 1,003 mg/L for TDS.
- Increase the AML to come into effect on January 1, 2015 from 4 to 14 mg-N/L for nitrate, from 160 to 378 mg/L for chloride, and from 0.15 to 2.43 mg/L for fluoride.
- Increase the MDL to come into effect on January 1, 2015 from 8 to 32 mg-N/L for nitrate, from 320 to 607 mg/L for chloride, and from 0.30 to 3.73 mg/L for fluoride.
- Retain the AML and MDL for ammonia. De Beers can achieve the existing values (i.e., 10 and 20 mg-N/L) throughout operations.
- Reduce the ALL from 219,000 to 161,000 kg/yr for nitrate; retain the ALL of 187,000 kg/yr for ammonia.

3.3.2 Remaining Parameters

For nitrite, sulphate, aluminum, arsenic, chromium, copper, lead, nickel, zinc, total phosphorus, and extractable petroleum hydrocarbons, the following EQC are recommended:

- Increase the existing AML and MDL (0.5 and 1 mg-N/L, respectively) for nitrite to 1.4 and 3 mg-N/L, respectively.
- Increase the AML and MDL for sulphate from 75 to 427 mg/L and 150 to 640 mg/L, respectively.
- Retain the AML and MDL for aluminum. The proposed EQC were equal to the existing EQC in the Water Licence. Aluminum concentrations in the treated effluent discharge have been variable and have, on occasion, exceeded the existing EQC. Total aluminum concentrations are correlated to TSS, which has a best available technologies limit. If TSS levels are maintained at low concentrations through operational processes (i.e., sedimentation or filtering), aluminum concentrations should, correspondingly, remain low.
- Eliminate EQC for other metals and metalloids from the Water Licence. The flow-weighted average arsenic, chromium, copper, lead, nickel, and zinc concentrations in 2012 are at least an order of magnitude lower than proposed and existing EQC. Modelling indicates that those metals will remain well below benchmarks throughout the operational period and are therefore unlikely to pose a threat to aquatic health. Additionally, concentrations are not even expected to exceed the more conservative AEMP benchmarks in treated effluent (De Beers 2013g). Monitoring of these metals should continue to investigate on-going trends. However, monitoring frequency could be reduced from every six days to monthly.
- Eliminate EQC for F1 (C_6-C_{10}) and F2 (C_{11}-C_{16}) extractable petroleum hydrocarbons.
- Reduce the ALL for total phosphorus.

Table 3-3 Recommended EQC for Snap Lake Mine

Parameter	Proposed EQC (mg/L)		Annual Loading Limit (kg/yr)
	AML	MDL	
Total dissolved solids[(a)]	684 mg/L	1,003 mg/L	-
Chloride[(a)] (from January 1, 2015)	378 mg/L	607 mg/L	-
Fluoride[(a)] (from January 1, 2015)	2.43 mg/L	3.73 mg/L	-
Nitrate as N[(a)] (from January 1, 2015)	14 mg-N/L	32 mg-N/L	161,000
Ammonia as N[(a)]	10 mg-N/L	20 mg-N/L	187,000
Nitrite as N	1 mg-N/L	3 mg-N/L	-
Sulphate	427 mg/L	640 mg/L	-
Aluminum	0.1 mg/L	0.2 mg/L	-
Arsenic	-	-	-
Chromium	-	-	-
Copper	-	-	-
Lead	-	-	-
Nickel	-	-	-
Zinc	-	-	-
Total phosphorus	N/A	N/A	229
Total suspended solids	7 mg/L	14 mg/L	-

a) Recommendations and rationale for revised EQC are specifically required under Schedule 5: Part F, 3b (ii) and 4b (ii) of the Water Licence.

mg/L = milligrams per litre; kg/yr = kilograms per year; N = nitrogen; EQC = effluent quality criteria; MDL = maximum daily limit; AML = average monthly limit; "-" = not recommended (i.e., to be removed from Water Licence); N/A = not applicable.

4 SUMMARY AND RECOMMENDATIONS

Effluent quality criteria were calculated for the Mine based on the most recent information available. The proposed EQC were compared to existing EQC in the Water Licence, treated effluent discharge quality in 2012, and predicted treated effluent discharge quality. Based on those comparisons, it is recommended that the:

- Water Licence be updated to include the EQC summarized in Table 3-3, retain the same TSS limits, and continue to specify that the treated effluent discharge be pH-regulated and non-acutely toxic;
- EQC be applied to treated effluent discharge at SNP station SNP02-17B;
- Monitoring requirements at SNP02-17B remain the same with the exception of reducing the frequency of metal analyses from every six days to monthly; and,
- Wording used to describe the EQC Table in Part F, 9a of the Water Licence be changed from “maximum average” to “average monthly limit” to improve clarity.

In regards to the achievability of the EQC listed above, it is recommended that:

- Mitigation be implemented prior to 2015 to meet the proposed EQC for TDS, prior to 2017 to meet the proposed AML for chloride, and prior to 2025 to meet the proposed AML for nitrate.

5 UNCERTAINTIES

Two uncertainties were recognized in this study:

- EQC were calculated based on the mixing zone established in the EAR (De Beers 2002). Since mid-2012, treated effluent discharge rates from the Mine have been greater than the maximum treated effluent discharge rate used to establish the mixing zone boundary (i.e., greater than 26,000 m^3/d). The Mine is now discharging treated effluent into Snap Lake through two separate diffusers. Effluent mixing has not been quantified, but is expected to result in a larger physical mixing zone. The present report used the existing mixing zone for EQC calculations, which is a conservative assumption: concentrations at the existing diffuser stations (i.e., SNP 02-20) would be required to meet AEMP benchmarks, even though complete mixing (i.e., increased dilution) of the effluent may not occur within that area. Near-field mixing and the size of the mixing zone will be assessed as part of the plume characterization study scheduled for summer 2014. As part of that study, the mixing zone in Snap Lake will be modelled based on the updated diffuser configuration and predicted maximum treated effluent discharge rates. Data from the diffuser stations will continue to be collected and summarized as part of the SNP program, and used to calculate dilution factors.
- The influence of increasing the treated effluent discharge rate and installing the 2nd diffuser on near-field mixing is uncertain, specifically the achievable minimum dilution factor (DF) at the existing mixing zone boundary. Implementation of the plume study in 2014 should refine this value; however using a DF of 12 was considered appropriate for the present study because minimum DFs during ice-covered conditions in 2012 and 2013 were larger: 18:1 and 16:1, respectively (De Beers 2013e; Golder 2013).

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Appendix I

Hardness Dependent Parameters

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ACRONYMS

Acronym	Description
AEMP	Aquatic Effects Monitoring Program
BCMOE	British Columbia Ministry of Environment
$CaCO_3$	calcium carbonate
CCME	Canadian Council of Ministers of the Environment
De Beers	De Beers Canada Inc.
EQC	Effluent Quality Criteria
SSWQO	site-specific water quality objective

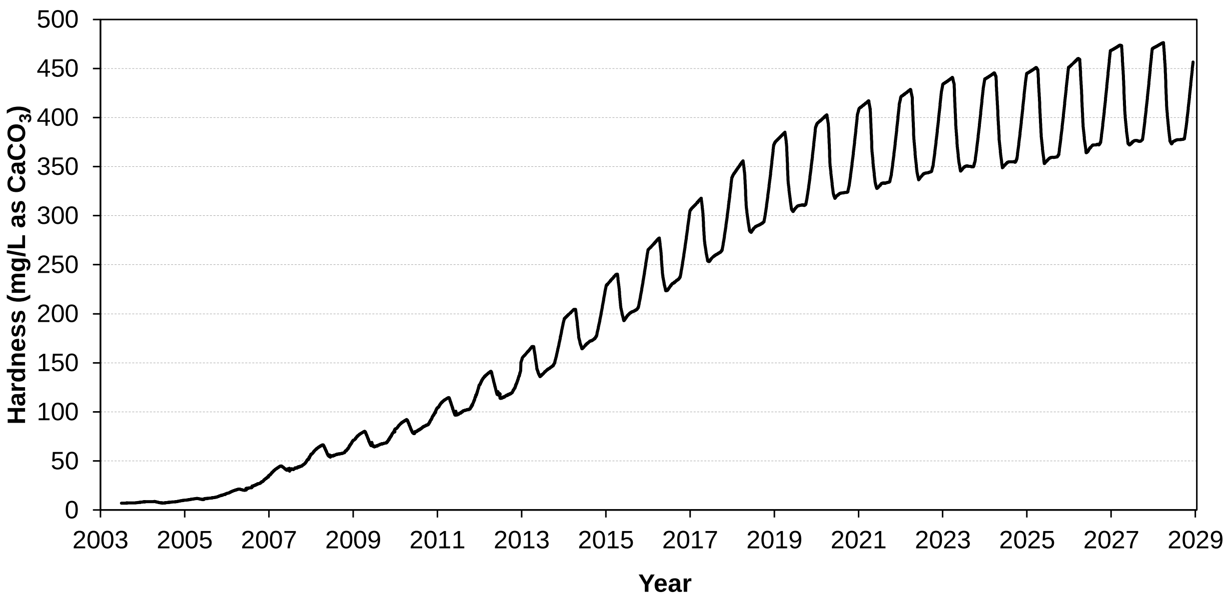
UNITS OF MEASURE

Unit	Description
µg/L	micrograms per litre
$CaCO_3$	calcium carbonate
kg-N/d	kilograms of nitrogen per day
m^3/d	cubic metres per day
mg/L	milligrams per litre
mg-N/L	milligrams as nitrogen per litre

I.1 DERIVATION OF EFFLUENT QUALITY CRITERIA FOR HARDNESS DEPENDENT PARAMETERS

The benchmarks selected for chloride, nitrate, sulphate, copper, lead, and nickel are hardness dependent, reflective of the inverse relationship that exists between the aquatic toxicity of each of these parameters, and the amount of calcium and magnesium present in the water column. At the end of 2012 hardness concentrations in Snap Lake were approximately 140 milligrams per litre (mg/L), but are expected to increase to 450 mg/L (Figure I-1). Waste load allocations and Effluent Quality Criteria (EQC) were, therefore, derived using the relationship between hardness, and proportion of treated effluent in Snap Lake, for hardness levels ranging between 140 and 450 mg/L (Figure I-2). The calculations were completed using Equation 3 (Section 2.4.1), and adjusting the aquatic thresholds for each parameter based on the hardness as per the formulas presented in Sections I1.1.1 to I1.1.5. Of the waste load allocation estimates developed for each parameter at hardness increments of 10 mg/L, the most restrictive was carried forward and used to develop EQC for nitrate, chloride, sulphate, copper, lead, and nickel.

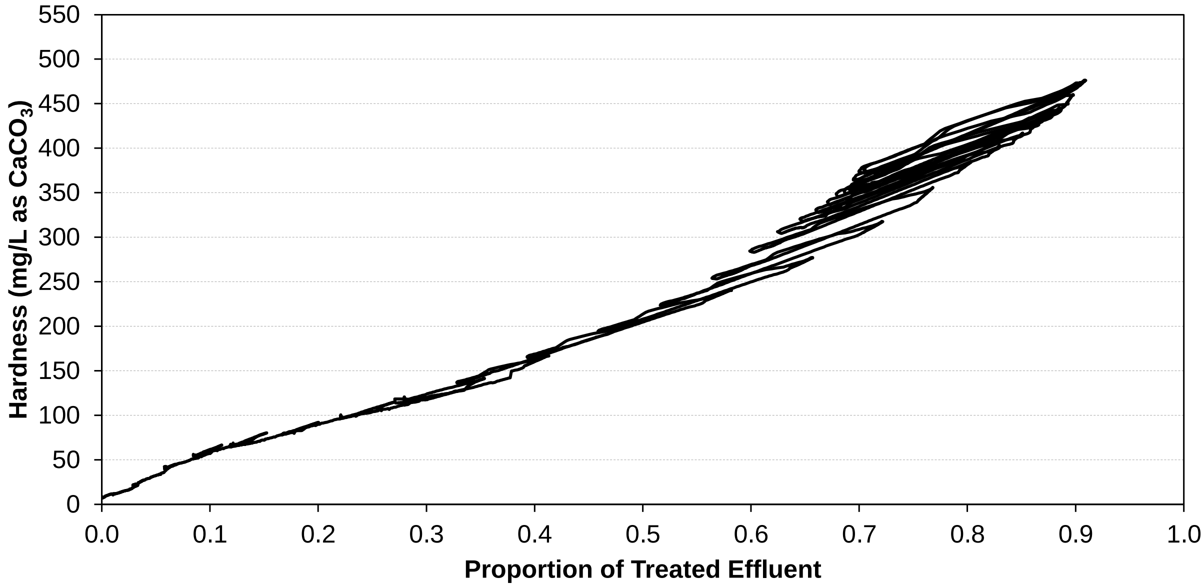
Figure I-1 Predicted Hardness Concentration in Snap Lake



Note: Based on whole-lake average concentrations in Snap Lake.

mg/L = milligrams per litre; $CaCO_3$ = calcium carbonate.

Figure I-2 Correlation between Hardness Concentrations and the Proportion of Treated Effluent in Snap Lake



Note: Based on whole-lake average concentrations in Snap Lake.
mg/L = milligrams per litre; $CaCO_3$ = calcium carbonate

I.1.1 Chloride

The chloride benchmark was calculated using the hardness-nitrate toxicity relationship presented in Elphick et al. (2011) and De Beers (2013a):

Chloride site-specific water quality objective (SSWQO) = 116.6 (ln[hardness])-204.1

This hardness-nitrate toxicity relationship was only established up to a water hardness of 160 mg/L as $CaCO_3$, and Elphick et al. (2011) cautioned against extrapolating above that limit. Therefore, when calculating the EQC at various proportions of treated effluent, the chloride benchmark was set to 388 mg/L at any hardness beyond 160 mg/L (Table I1-1). For chloride, the most restrictive EQC were calculated when the proportion of treated effluent was equivalent to 0.9 (Table I-1).

I.1.2 Nitrate

The nitrate benchmark was calculated using the hardness-nitrate toxicity relationship presented in Rescan (2012) and De Beers (2013b):

Nitrate SSWQO = $e^{(0.9518(\ln[\text{Hardness}])-2.032)}$

This hardness-nitrate toxicity relationship was only established up to a water hardness of 160 mg/L as $CaCO_3$, and Rescan (2012) cautioned against extrapolating above that limit. Therefore, when calculating the EQC at various proportions of treated effluent, the nitrate benchmark was set to 16.4 milligrams as nitrogen per litre (mg-N/L) at any hardness beyond 160 mg/L (Table I1-2). For nitrate, the most restrictive EQC were calculated when the proportion of treated effluent was equivalent to 0.9 (Table I-2).

I.1.3 Sulphate

The sulphate benchmark was calculated using the hardness-nitrate toxicity relationship presented in British Columbia Ministry of Environment (BCMOE 2013):

- for hardness between 76 and 180 mg/L, the SSWQO was 309 mg/L;
- for hardness between 181 and 250 mg/L, the SSWQO was 429 mg/L

For sulphate, the benchmark was set at a maximum of 250 mg/L as toxicity tests were only conducted on water hardness up to 250 mg/L. Further testing was recommended should water hardness exceed 250 mg/L (BCMOE 2013). The most restrictive EQC for sulphate was calculated when the proportion of treated effluent was equivalent to 0.9 (Table I-3).

I.1.4 Copper

The copper benchmark was calculated using the hardness-copper toxicity relationship presented in De Beers (2002):

$$Copper\ SSWQO = \left(\frac{Hardness}{50}\right)^{0.8545} \times \frac{7.9}{\left({}^{180}/_{50}\right)^{0.8545}}$$

For copper, the most restrictive EQC were derived when the treated effluent proportion in Snap Lake was 0.27, corresponding to a hardness level of 140 mg/L in the main basin of Snap Lake (Table I-4).

I.1.5 Lead and Nickel

The lead benchmark was calculated using the hardness-lead toxicity relationship presented in Canadian Council of Ministers of the Environment (CCME 1999):

$$Lead\ SSWQO = e^{1.273[\ln(hardness)]-4.705}$$

The nickel benchmark was calculated using the hardness-nickel toxicity relationship presented in CCME (1999):

$$Nickel\ SSWQO = e^{0.76[\ln(hardness)]-1.06}$$

For lead and nickel, the most restrictive EQC were derived when the proportion of treated effluent was equivalent to 0.9, corresponding to hardness levels of 450 mg/L in the main basin of Snap Lake (Table I-5 and A-6).

Table I-1 Effluent Quality Criteria for Chloride based on Increasing Snap Lake Hardness Concentrations

Parameter	Proportion of Treated Effluent in Snap Lake	Snap Lake Hardness (mg/L as $CaCO_3$)	AEMP Benchmark (mg/L)	Waste Load Allocation[(a)] (mg/L)	Long Term Average[(b)] (mg/L)	Maximum Daily Limit (mg/L)	Average Monthly Limit (mg/L)
Chloride	0.27	140	372	1,133	760	1,610	1,003
	0.29	150	380	1,095	734	1,556	969
	0.31	160	388	1,060	711	1,506	938
	0.33	170	388	1,008	676	1,433	893
	0.35	180	388	961	645	1,366	851
	0.37	190	388	919	616	1,306	814
	0.39	200	388	880	590	1,251	779
	0.41	210	388	844	566	1,200	747
	0.43	220	388	811	544	1,153	718
	0.45	230	388	781	524	1,110	691
	0.47	240	388	752	505	1,069	666
	0.50	250	388	726	487	1,032	643
	0.60	300	388	618	414	878	547
	0.70	350	388	538	361	765	476
	0.80	400	388	476	319	677	422
	0.90	450	388	427	287	607	378

Note: The effluent quality criteria in the highlighted row were recommended for the Mine.

a) Calculations were based on an average predicted treated effluent discharge of 57,013 cubic metres per day (m^3/d) (average predicted treated effluent discharge during the year of maximum discharge [2026]), a dilution factor of 12 (volumes of lake water that mix with one volume of treated effluent), and on the assumption that four samples were collected per month (equivalent to sampling frequency in De Beers Water Licence of once every six days).

b) Long term average concentrations were calculated assuming an averaging period of four days.

AEMP = Aquatic Effects Monitoring Program; mg/L = milligrams per litre; $CaCO_3$ = calcium carbonate.

Table I-2 Effluent Quality Criteria for Nitrate based on Increasing Snap Lake Hardness Concentrations

Parameter	Proportion of Treated Effluent in Snap Lake	Snap Lake Hardness	AEMP Benchmark	Waste Load Allocation[a]	Long Term Average[b]	Maximum Daily Limit	Average Monthly Limit	Annual Loading Limit
		(mg/L as $CaCO_3$)	(mg-N/L)	(mg-N/L)	(mg-N/L)	(mg-N/L)	(mg-N/L)	(kg-N/d)
Nitrate	0.27	140	14.5	44.0	18.9	78.1	33.5	1,073
	0.29	150	15.4	44.5	19.0	79.0	33.9	1,085
	0.31	160	16.4	44.9	19.2	79.7	34.2	1,094
	0.33	170	16.4	42.7	18.3	75.8	32.5	1,041
	0.35	180	16.4	40.7	17.4	72.3	31.0	993
	0.37	190	16.4	38.9	16.7	69.1	29.7	949
	0.39	200	16.4	37.3	16.0	66.2	28.4	909
	0.41	210	16.4	35.7	15.3	63.5	27.2	872
	0.43	220	16.4	34.4	14.7	61.0	26.2	838
	0.45	230	16.4	33.1	14.2	58.7	25.2	806
	0.47	240	16.4	31.9	13.6	56.6	24.3	777
	0.50	250	16.4	30.7	13.2	54.6	23.4	750
	0.60	300	16.4	26.2	11.2	46.5	19.9	638
	0.70	350	16.4	22.8	9.8	40.4	17.4	556
	0.80	400	16.4	20.2	8.6	35.8	15.4	492
	0.90	450	16.4	18.1	7.8	32.1	13.8	441

Note: The effluent quality criteria in the highlighted row were recommended for the Mine.

a) Calculations were based on an average predicted treated effluent discharge of 57,013 cubic metres per day (m^3/d) (average predicted treated effluent discharge during the year of maximum discharge [2026]), a dilution factor of 12 (volumes of lake water that mix with one volume of treated effluent), and on the assumption that four samples were collected per month (equivalent to sampling frequency in De Beers Water Licence of once every six days).

b) Long term average concentrations were calculated assuming an averaging period of four days.

AEMP = Aquatic Effects Monitoring Program; mg/L = milligrams per litre; mg-N/L = milligrams as nitrogen per litre; kg-N/d = kilograms of nitrogen per day; $CaCO_3$ = calcium carbonate.

Table I-3 Effluent Quality Criteria for Sulphate based on Increasing Snap Lake Hardness Concentrations

Parameter	Proportion of Treated Effluent in Snap Lake	Snap Lake Hardness (mg/L as $CaCO_3$)	AEMP Benchmark (mg/L)	Waste Load Allocation[(a)] (mg/L)	Long Term Average[(b)] (mg/L)	Maximum Daily Limit (mg/L)	Average Monthly Limit Concentration (mg/L)
Sulphate	0.27	140	309	937	669	1,269	846
	0.29	150	309	886	633	1,201	801
	0.31	160	309	841	601	1,140	760
	0.33	170	309	800	572	1,085	723
	0.35	180	309	763	546	1,035	690
	0.37	190	429	1,014	725	1,374	916
	0.39	200	429	971	694	1,316	877
	0.41	210	429	932	666	1,263	842
	0.43	220	429	895	640	1,213	809
	0.45	230	429	862	616	1,168	779
	0.47	240	429	831	594	1,126	750
	0.50	250	429	802	573	1,086	724
	0.60	300	429	683	488	925	617
	0.70	350	429	594	425	806	537
	0.80	400	429	526	376	713	476
	0.90	450	429	473	338	640	427

Note: The effluent quality criteria in the highlighted row were recommended for the Mine.

a) Calculations were based on an average predicted treated effluent discharge of 57,013 cubic metres per day (m^3/d) (average predicted treated effluent discharge during the year of maximum discharge [2026]), a dilution factor of 12 (volumes of lake water that mix with one volume of treated effluent), and on the assumption that four samples were collected per month (equivalent to sampling frequency in De Beers Water Licence of once every six days).

b) Long term average concentrations were calculated assuming an averaging period of four days.

AEMP = Aquatic Effects Monitoring Program; mg/L = milligrams per litre; $CaCO_3$ = calcium carbonate.

Table I-4 Effluent Quality Criteria for Copper based on Increasing Snap Lake Hardness Concentrations

Parameter	Proportion of Treated Effluent in Snap Lake	Snap Lake Hardness (mg/L as $CaCO_3$)	AEMP Benchmark (µg/L)	Waste Load Allocation[(a)] (µg/L)	Long Term Average[(b)] (µg/L)	Maximum Daily Limit (µg/L)	Average Monthly Limit Concentration (µg/L)
Copper	0.27	140	6.4	17.1	6.0	31.5	12.1
	0.29	150	6.8	17.4	6.1	32.0	12.3
	0.31	160	7.1	17.6	6.2	32.4	12.5
	0.33	170	7.5	17.8	6.2	32.7	12.6
	0.35	180	7.9	18.0	6.3	33.0	12.7
	0.37	190	8.3	18.1	6.3	33.3	12.8
	0.39	200	8.6	18.2	6.4	33.5	12.9
	0.41	210	9.0	18.3	6.4	33.7	13.0
	0.43	220	9.4	18.4	6.5	33.9	13.0
	0.45	230	9.7	18.5	6.5	34.0	13.1
	0.47	240	10.1	18.6	6.5	34.2	13.2
	0.50	250	10.5	18.6	6.5	34.3	13.2
	0.60	300	12.2	18.8	6.6	34.6	13.3
	0.70	350	13.9	18.9	6.6	34.8	13.4
	0.80	400	15.6	18.9	6.6	34.9	13.4
	0.90	450	17.3	18.9	6.6	34.8	13.4

Note: The effluent quality criteria in the highlighted row were recommended for the Mine.

a) Calculations were based on an average predicted treated effluent discharge of 57,013 cubic metres per day (m^3/d) (average predicted treated effluent discharge during the year of maximum discharge [2026]), a dilution factor of 12 (volumes of lake water that mix with one volume of treated effluent), and on the assumption that four samples were collected per month (equivalent to sampling frequency in De Beers Water Licence of once every six days).

b) Long term average concentrations were calculated assuming an averaging period of four days.

AEMP = Aquatic Effects Monitoring Program; mg/L = milligrams per litre; µg/L = micrograms per litre; $CaCO_3$ = calcium carbonate.

Table I-5 Effluent Quality Criteria for Lead based on Increasing Snap Lake Hardness Concentrations

Parameter	Proportion of Treated Effluent in Snap Lake	Snap Lake Hardness (mg/L as $CaCO_3$)	AEMP Benchmark (µg/L)	Waste Load Allocation[a] (µg/L)	Long Term Average[b] (µg/L)	Maximum Daily Limit (MDL) (µg/L)	Average Monthly Limit Concentration (AML) (µg/L)
Lead	0.27	140	4.0	11.2	4.0	20.5	8.0
	0.29	150	4.0	10.6	3.8	19.5	7.6
	0.31	160	4.0	10.1	3.6	18.5	7.2
	0.33	170	4.0	9.6	3.5	17.6	6.9
	0.35	180	7.0	16.6	6.0	30.5	11.9
	0.37	190	7.0	15.9	5.8	29.2	11.4
	0.39	200	7.0	15.3	5.5	28.0	10.9
	0.41	210	7.0	14.7	5.3	26.9	10.5
	0.43	220	7.0	14.1	5.1	25.9	10.1
	0.45	230	7.0	13.6	4.9	25.0	9.7
	0.47	240	7.0	13.1	4.7	24.1	9.4
	0.50	250	7.0	12.7	4.6	23.3	9.1
	0.60	300	7.0	10.9	3.9	19.9	7.8
	0.70	350	7.0	9.5	3.4	17.5	6.8
	0.80	400	7.0	8.5	3.1	15.6	6.1
	0.90	450	7.0	7.7	2.8	14.1	5.5

Note: The effluent quality criteria in the highlighted row were recommended for the Mine.

a) Calculations were based on an average predicted treated effluent discharge of 57,013 cubic metres per day (m^3/d) (average predicted treated effluent discharge during the year of maximum discharge [2026]), a dilution factor of 12 (volumes of lake water that mix with one volume of treated effluent), and on the assumption that four samples were collected per month (equivalent to sampling frequency in De Beers Water Licence of once every six days).

b) Long term average concentrations were calculated assuming an averaging period of four days.

AEMP = Aquatic Effects Monitoring Program; mg/L = milligrams per litre; µg/L = micrograms per litre; $CaCO_3$ = calcium carbonate.

Table I-6 Effluent Quality Criteria for Nickel based on Increasing Snap Lake Hardness Concentrations

Parameter	Proportion of Treated Effluent in Snap Lake	Snap Lake Hardness (mg/L as $CaCO_3$)	AEMP Benchmark (µg/L)	Waste Load Allocation[(a)] (µg/L)	Long Term Average[(b)] (µg/L)	Maximum Daily Limit (µg/L)	Average Monthly Limit Concentration (µg/L)
Nickel	0.27	140	110	334	171	556	271
	0.29	150	110	316	162	526	256
	0.31	160	110	300	154	500	243
	0.33	170	110	286	146	475	232
	0.35	180	150	372	190	618	301
	0.37	190	150	355	182	591	288
	0.39	200	150	340	174	566	276
	0.41	210	150	326	167	543	265
	0.43	220	150	314	161	522	254
	0.45	230	150	302	155	502	245
	0.47	240	150	291	149	484	236
	0.50	250	150	281	144	467	228
	0.60	300	150	239	122	398	194
	0.70	350	150	208	107	346	169
	0.80	400	150	184	94	307	149
	0.90	450	150	165	85	275	134

Note: The effluent quality criteria in the highlighted row were recommended for the Mine.

a) Calculations were based on an average predicted treated effluent discharge of 57,013 cubic metres per day (m^3/d) (average predicted treated effluent discharge during the year of maximum discharge [2026]), a dilution factor of 12 (volumes of lake water that mix with one volume of treated effluent), and on the assumption that four samples were collected per month (equivalent to sampling frequency in De Beers Water Licence of once every six days).

b) Long term average concentrations were calculated assuming an averaging period of four days.

AEMP = Aquatic Effects Monitoring Program; mg/L = milligrams per litre; µg/L = micrograms per litre; $CaCO_3$ = calcium carbonate.

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