DE BEERS

GROUP OF COMPANIES

May 28, 2014

File: L020

Ms. Joanne Deneron
Chairperson
Mackenzie Valley Review Board
200 Scotia Centre; 5102-50th Ave
Box 938, Yellowknife, NT X1A 2N7

[via E-mail]

Dear: Ms. Deneron

Re: De Beers Canada Inc. Response to Technical Reports EA1314-02

De Beers Canada Inc. (De Beers) has reviewed the Technical Reports submitted by Deninu K'ue First Nation, Environment Canada, Government of the Northwest Territories, Lutsel K'e Dene First Nation, North Slave Métis Alliance, Yellowknives Dene First Nation and Ecometrix Incorporated, respecting the De Beers Water Licence Amendment Environmental Assessment EA1314-02. De Beers provides the following response to these Technical Reports as they pertain to the scope of the Environmental Assessment as described in the Reasons for Decision of March 28, 2014. De Beers would be pleased to address topics raised within the Technical Reports that are outside the defined scope of this Environmental Assessment in other appropriate regulatory forums, or during on-going community meetings.

De Beers' Development Proposal at issue in this proceeding is the change of the quality of minewater allowed to be discharged to Snap Lake. Specifically, De Beers is proposing that the requirement to maintain a whole-lake average concentration of total dissolved solids (TDS) below 350 mg/L be rescinded based on evidence that a site specific water quality objective (SSWQO) of 684 mg/L is protective of the environment. On this basis we conclude this amendment will not result in any significant adverse environmental effects. This proposal has been referred to environmental assessment on the basis that the change would require modification of a measure arising out of a previous environmental assessment, and on the basis that the impact of the development on the environment has not previously been assessed. The scope of the environmental assessment includes the proposed change to TDS, including its constituent parameters.

De Beers' Development Proposal derives from the requirement in the current Water Licence MV2011L2-0004 to develop and recommend to the Mackenzie Valley Land and Water Board (MVLWB) appropriate water quality objectives for TDS (including chloride and fluoride), nitrogen, and strontium, which are derived from site-specific toxicity testing, and effluent quality criteria (EQC) that would be protective of aquatic life in Snap Lake. De Beers recognizes that, while the mandate of the Mackenzie Valley Review Board (Review Board) in this environmental assessment is to make a determination whether the proposed development will result in significant impacts to the environment, it is also the responsibility of the MVLWB to determine whether the proposed SSWQOs and EQC are appropriate and protective. De Beers specifically proposes that the requirement to maintain TDS concentrations in Snap Lake below 350 mg/L as derived from the original environmental assessment, be replaced with a recommendation that allows the MVLWB to make a determination regarding appropriate SSWQOs and associated EQC that are protective of the aquatic environment of Snap Lake.

De Beers has submitted all of the information necessary to meet the water licence requirements regarding the development of appropriate water quality objectives based on site-specific research and testing. The results support the proposed SSWQOs and EQC. Based on these recommendations, and additional evidence that De Beers has filed, De Beers confirms that rescinding the existing SSWQO for TDS of 350 mg/L will not result in any significant adverse environmental effects.

De Beers continues to undertake studies and testing such as grouting and treatment, as described in the TDS Response Plan, which are intended to control TDS loadings to the environment. As discussed during the Joint Technical Session and subsequent information requests, in order to allow for the completion of these studies and feasibility testing, De Beers requests that the MVLWB apply an interim EQC for TDS, inclusive of its parameters, that will allow De Beers to complete feasibility and engineering designs and implementation of appropriate mitigation to achieve SSWQOs and EQC as prescribed by the MVLWB through the subsequent regulatory process. This interim TDS EQC can be higher than the final EQC for a period of time, while still ensuring that the proposed SSWQO is not exceeded. De Beers commits to providing regular updates to the MVLWB regarding the progress of the feasibility testing, decisions, and designs of best available mitigation technology applicable to the unique characteristics and constraints of Snap Lake Mine, including grouting and water treatment. This will include summaries of the consideration of factors such as reliability, scalability, effectiveness, waste generation and management, energy consumption and recycling, emissions and infrastructure requirements.

A number of parties have provided comments on models that depict water quality within Snap Lake based on unregulated effluent discharge (the “unmitigated scenario”). While De Beers has presented this information to allow reviewers to appreciate that unregulated effluent might cause significant effects to the aquatic environment, the unmitigated scenario is unrealistic in light of De Beers’ proposal. De Beers does not intend to discharge effluent to a level beyond an approved EQC, and, in this regard, has proposed appropriate SSWQOs and EQC that will ensure that there are no significant impacts to the aquatic environment. De Beers will implement technologically, environmentally, and economically appropriate means to ensure that the SSWQOs and EQC approved by the MVLWB in the subsequent regulatory process are met over the life of mine.

De Beers has considered the concerns and recommendations of reviewers regarding the quality of water in relation the Canadian Drinking Water Quality Guidelines. De Beers realizes that the taste of Snap Lake water during the time when effluent is being discharged to Snap Lake may be perceived as “fair” if the development proposal is approved. However, the water will remain safe for human consumption. Up to 700 people working at the Mine rely on Snap Lake water for drinking; De Beers is required to monitor and report on drinking water quality to the Territorial Health Inspector. Modeling indicates that the water within Snap Lake will return to “good” (<500 mg/L) and “excellent” taste levels (<300 mg/L) within 4 and 10 years, respectively, of the cessation of effluent discharge post-mining.

In response to concerns raised about Snap Lake discharge potentially affecting Lady of the Falls, De Beers is very confident that Snap Lake effluent will not affect this very special place. Models of the flow of effluent in lakes downstream of Snap Lake show that Snap Lake effluent will only be detectable, over the life of mine, up to about 54 km downstream from the mine. Parry Falls is 421 km downstream of Snap Lake, with Lady of the Falls a further 15 km downstream. Continued monitoring at designated monitoring stations downstream of Snap Lake as identified in the Aquatic Effects Monitoring Program will continue to assess and report on this prediction.

Finally, to ensure that the Development Proposal once approved, ensures protection of the environment, De Beers will continue to undertake and report on monitoring and studies required to be undertaken as part of the water licence, including any amendments arising from measures recommended by the Review Board. This includes water quality and effects monitoring, plume studies, and other evaluations of the health of the fish and the food they depend on.
De Beers agrees that there have been unforeseen changes at the Snap Lake Mine since pre-construction predictions were considered during the original environmental assessment. The Mine is unique in the NWT. It is a wholly underground mine under a lake. There have been many learnings over the current life of the Mine; however, the health of Snap Lake remains unimpaired. The fish are safe to eat and the water is safe to drink. De Beers has made many operational improvements since construction and operations began 9 years ago in order to pro-actively recognize and manage water-related concerns. Through comprehensive aquatic effects monitoring, hydrogeological studies, aquatic effects studies, and improvement in mining practices, De Beers continues to be committed to the sustainable operation of the Snap Lake Mine.

In regards to engagement on this proposal, De Beers has been meeting with regulators and other parties since the water licence renewal process in 2011 to develop an appropriate methodology to establish protective SSWQOs. As part of an integrated approach to engagement De Beers has provided regular updates to communities and regulators on the progress of the site-specific studies, has held topic-specific meetings with all interested parties, and has presented results at scientific meetings. De Beers commits, in 2014, to continuing engagement, including providing project updates to each of the affected communities, as well as to hosting each community at the Snap Lake Mine. Meetings with Tlicho communities (Behchoko, Wekwe’eti), North Slave Métis Alliance, Northwest Territories Métis Nation, and Deninu K’ue First Nation were conducted May 20 – 28, and a meeting with Yellowknives Dene First Nation will be held May 29. Chiefs Sangris and Betsina, and youth and Elders of the Yellowknives Dene First Nation visited the Snap Lake Mine site on May 28. Records of meetings will be provided to the Review Board and MVLWB by June 23.

In addition to the above comments, De Beers includes in Attachment 1, a Technical Memorandum from Golder Associates Ltd. that addresses technical matters raised in the Parties’ Technical Reports relevant to the scope of this Environmental Assessment. De Beers thanks all

Parties for their submissions and looks forward to fully participating in the upcoming Public Hearing June 5-6.

Sincerely,
DE BEERS CANADA INC.

Erica Bonhomme
Manager, Environment
Snap Lake Mine

cc	R. Bjornson	DKFN
	S. Lacey-MacMillan	EC
	M. Sanderson, S. Whitaker, R. Walbourne, P. Green	GNWT
	M. Tollis	LKDFN
	M. Casas, R. Nicol, R. Chouinard, L. Cymbalisty	MVLWB
	M. Hoover	NSMA
	T. Heron	NWTMN
	P. di Pizzo, Z. Liu	SLEMA
	K. Garner	Tlicho
	T. Slack, S.Gault	YKDFN

TECHNICAL MEMORANDUM

DATE	May 28, 2014	**PROJECT No.**	13-1349-0003
TO	Erica Bonhomme De Beers Canada Inc.		
CC	David Putnam, De Beers Canada Inc.		
FROM	Peter Chapman, Tasha Hall, Alison Snow, Hilary Machtans	**EMAIL**	Peter_Chapman@golder.com, Tasha_Hall@golder.com, Alison_Snow@golder.com, Hilary_Machtans@golder.com

SNAP LAKE MINE – RESPONSES TO TECHNICAL ISSUES ARISING FROM PARTIES' TECHNICAL REPORTS

1.0 INTRODUCTION

The purpose of this Technical Memorandum is to provide responses to issues raised by Parties in their Technical Reports, within the scope of the Environmental Assessment.

2.0 TECHNICAL RESPONSES

2.1 Proposed Site-Specific Water Quality Objectives (SSWQOs)

The proposed SSWQOs for total dissolved solids (TDS) and constituent ions (including fluoride and chloride) were derived based on appropriate scientific investigations as documented in the evidence presented. The species to be tested and endpoints to be tested for the proposed TDS SSWQO were agreed to by all parties, following extensive discussion and consultation that began during the Water License (WL) Renewal Process in 2011. Particular emphasis was placed by Fisheries and Oceans Canada (DFO) on the fish species to be tested, procedures, and endpoints, which involved novel testing of key fish species found in Snap Lake. All of the recommendations from DFO for testing of fish species were followed. Independent peer review by the Board's consultant, Ecometrix, supports the proposed TDS and other SSWQOs.

Additional testing is underway, as outlined during the Technical Session (April 15 to 16, 2014), to determine the level of conservatism in the proposed TDS SSWQO of 684 mg/L. Specifically, TDS tolerance testing is being conducted with: copepods, which were not previously tested; and, waterfleas (*Daphnia magna*) to provide additional replicated information for determining a geometric mean value including, as requested by SLEMA, testing by a different laboratory than conducted the initial testing.

Misunderstandings related to the SSWQO process noted in some of the Parties' Technical Reports are corrected below.

2.1.1 10% vs 20% Effect Levels

Some of the Parties, in their Reports, incorrectly cite 10% effect levels derived from the SSWQO testing that are not technically defensible. Evidence regarding appropriate effect levels (10 or 20%) for SSWQO development was provided in documentation previously submitted; no evidence has been presented for using different effect levels than proposed.

As discussed during the Technical Session, a 10% effect level can be difficult to determine accurately due to the level of variability that may occur at this low effect level and the test design. This is particularly the case when the 10% effect level is well below test concentrations having adverse effects that actually differ significantly from the control. This is less of an issue if nonlinear regression or maximum likelihood estimation (e.g., Probit) are used for the statistics, since these analyses have shape characteristics that define the sigmoidal dose-response relationship. However, in some cases the data obtained for continuous variables in chronic tests are unsuitable for calculation of point estimates by nonlinear regression and therefore linear interpolation must be used instead. Linear interpolation makes no assumptions about the shape of dose-response curves, and just interpolates point estimates based on lines that are drawn through the individual data points representing different concentrations of the substance tested. In other words, this method does not model the dose-response curve, and this makes calculation of endpoints highly subject to variability in the tails of the distribution (e.g., in calculating the 10% effect level).

Standardized toxicity tests are generally not designed to be able to detect a 10% change from the negative control and often do not have the statistical power (i.e., sufficient replication) to do so with a reasonable degree of confidence. Furthermore, the tests themselves generally allow an acceptable 10 or 20% "effect" in the control; in other words, a 10 or 20% effect is considered to fall within normal variability.

For example, in a *Ceriodaphnia* test the method exposes a total of 10 organisms to each test concentration, and the control can have up to 20% mortality and still be considered an acceptable test. If there was no mortality in the control and, by chance alone, the lowest test concentration had 10% mortality (i.e., one dead organism in that test concentration), the LC10 (10% lethal concentration) using interpolation would now be equivalent to the lowest test concentration, because there is a 10% "effect" at that concentration (since a dead *Ceriodaphnia* will not reproduce). However, one dead organism in the control would be within acceptable levels of test variability. Two dead organisms in the control (20% mortality) would also be within acceptable levels of test variability. Correcting data for either 10 or 20% allowable mortality in the control would result in cancelling out of similar effects if they occurred in test concentrations.

The point estimates included in the derivation of SSWQOs were those that were considered to be the best estimates of "thresholds" from the tests, based on examining the raw data and applying best professional judgment. Note that the Government of the Northwest Territories' (GNWT's) consultant (p 42 of that report) acknowledges "*considerable uncertainty*" in one of the 10% effect values derived from the TDS site-specific testing. Note also that the Canadian Council of Ministers of the Environment (CCME) water quality guideline (WQG) for nitrate incorporates 25% effect levels for three invertebrates (*Hyalella*, *Ceriodaphnia*, and *Chironomus*) in their species sensitivity distribution (SSD); thus, CCME accepted 25% effect levels as valid for determining the nitrate WQG. Note further that USEPA relies on 20% effect levels not 10% effect levels for determining their national water quality criteria and regards an aqueous-exposure 20% effect level as a substitute for a no effect concentration (Charles Delos and Marc Greenberg, USEPA, Washington, DC, USA – comments made during the SETAC Metals Advisory Group Meeting the evening of November 12, 2012 in Long Beach, CA, USA).

2.1.2 Ambient Hardness as an Exposure Toxicity Modifying Factor (ETMF)

The GNWT have questioned hardness as an ETMF for nitrate and chloride, in particular using ambient hardness rather than background (i.e., pre-mining) hardness. It is incorrectly stated that the CCME does not agree with a hardness adjustment for generic national nitrate or chloride water quality guidelines. In fact, for both nitrate and chloride, CCME recognizes that just because there are insufficient data available for a "generic" guideline does not mean that there are insufficient data to develop a "site-specific" objective.

In the case of chloride CCME (2011, p4) states: "*Insufficient data was available in order to develop a hardness relationship for chronic toxicity and thus, a hardness based national CWQG was not developed. CCME will re-visit the chloride guidelines when sufficient studies are available. Jurisdictions have the option of deriving site-specific hardness adjusted water quality criteria if they so choose*." The chloride SSWQO is based on a peer-reviewed scientific publication (Elphick et al. 2011).

In the case of nitrate CCME (2012, p 14) states: "*Because the guideline is not corrected for any toxicity modifying factors (e.g. hardness), it is a generic value that does not take into account any site-specific factors. Moreover, since the guideline is mostly based on toxicity tests using naïve (i.e., non-tolerant) laboratory organisms, it is going to be a conservative value, by design. If an exceedence of the guideline is observed, it does not necessarily suggest that toxic effects will be observed, but rather indicates the need to determine whether or not there is a potential for adverse environmental effects. In some situations, such as where an exceedence is observed, it may be necessary or advantageous to derive a site-specific guideline that takes into account local conditions (water chemistry, natural background concentration, genetically-adapted organisms, community structure)*"

The use of ambient hardness for nitrate and chloride SSWQOs for the Ekati Mine was approved by the Wek'èezhìi Land and Water Board (W2012L2-0001) following extensive discussion and peer review. As documented in the evidence provided, the Snap Lake nitrate and chloride SSWQOs are based on those approved SSWQOs. With regard to discussion regarding the use of ambient ("*ambient*" is the word used by CCME), as opposed to background hardness concentrations, the Wek'èezhìi Land and Water Board in their Reasons for Decision (May 17, 2013, pp 11-12) stated:

"*AANDC's argument ignores the scientific fact that increased water hardness, no matter its source, does reduce the toxicity of some substances. When asked about the validity of using anthropogenically modified hardness values for calculating SSWQO, Dr. Don Hart replied: "As far as I'm concerned – and I recognize that there are various opinions out there. But as far as I'm concerned the organisms don't make a distinction as to where the hardness came from. So, yes, we're going to get a benefit from hardness that's released anthropogenically. It's still a benefit. I see no reason to ignore it."*

<u>References:</u>

CCME (Canadian Council of Ministers of the Environment). 2011. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Chloride. Winnipeg, MN, Canada.

CCME. 2012. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Nitrate Ion. Winnipeg, MN, Canada.

Elphick JRF, Bergh KD, Bailey HC. 2011. Chronic toxicity of chloride to freshwater species: effects of hardness and implications of water quality guidelines. Environ Toxicol Chem 30:239-246.

2.1.3 Appropriate Safety Factor

The GNWT in their Technical Report state (p36) "*CCME has specifically identified that applying a safety factor of 1.0 is inadequate, as the proposed safety factor in the 2007 CCME guidance ranges from 2-10*". Presumably the GNWT is referencing CCME (2007) for this statement since no other reference citation is provided. We are unable to find anywhere in CCME (2007) where a safety factor of 1.0 is identified as "*inadequate*". CCME (2007, Part II, Section 3.1-5) refers to the use of an appropriate safety factor citing Chapman et al. (1998). Chapman et al. (1998), cited three times in CCME (2007), suggest principles for the use of safety factors including the following, which are directly applicable to the proposed TDS SSWQO:

- *"Data supersede extrapolation. When appropriate data are available, they should be used rather than safety factors.*"
- *"Unnecessary overprotection is not useful."*

The latter point regarding unnecessary overprotection is illustrated by the inappropriate application of a species sensitivity distribution (SSD) approach to selected TDS test data by the GNWT's consultant. The selected test data (9 data points as outlined on pp 41-42 of the consultant's report) include: an inappropriate IC10 (inhibition concentration having a 10% effect level) (Section 2.1.1, 10% vs 20% Effect Levels, above); an endpoint not derived from site-specific testing with Snap Lake TDS; and, 2 other questionable data points. The resulting recommended long-term water quality objective for TDS in Snap Lake resulting from that SSD (Table 13 of the consultant's report) is the lowest value derived from four different plots: 194 mg/L, which is below the default TDS limit of 500 mg/L (ADEC 2012; Wek'èezhìi Land and Water Board 2013) and below concentrations, as reported in the Snap Lake 2013 Aquatic Effects Monitoring Program (AEMP), at which TDS has no effects to sensitive test organisms exposed to Snap Lake water at the edge of the mixing zone.

<u>References:</u>

ADEC (Alaska Department of Environmental Conservation). 2012. 18 AAC 70-Water Quality Standards. www.dec.alaska.gov/commish/regulations/pdfs/18%20AAC%2070.pdf. Accessed May 25, 2014.

CCME (Canadian Council of Ministers of the Environment). 2007. A protocol for the derivation of water quality guidelines for the protection of aquatic life 2007. In Canadian Water Quality Guidelines for the Protection of Aquatic Life. Winnipeg, MN, Canada.

Chapman PM, Fairbrother A, Brown D. 1998. A critical evaluation of safety (uncertainty) factors for ecological risk assessment. Environ Toxicol Chem 17: 99-108.

Wek'èezhìi Land and Water Board. 2013. Decision from Wek'èezhìi Land and Water Board Issued Pursuant to Section 26 of the Northwest Territories Act, R.S.C. 1992, c39. Yellowknife, NWT, Canada [for additional information, see De Beers Response to MVRB/MVLWB_IR#7, April 30, 2014, pp 9-10]

2.1.4 Changes and Impacts in Snap Lake

The GNWT in their Technical Report state (p17) "*AEMP monitoring results have identified changes and impacts to Snap Lake that are beyond the original predictions and impacts in the 2003 Report of EA*". This statement is not correct.

AEMP monitoring results have identified changes to water quality in Snap Lake; however, the Snap Lake aquatic ecosystem (the fish and the food chain on which they rely) has not been adversely affected. The water is still safe to drink and the fish are still safe to eat. The AEMP Re-Design is scheduled for November 2017; in 2017 the AEMP will be revised as necessary and appropriate based on monitoring results through 2016, following initiation of mitigation by De Beers.

2.2 Seepages from the North Pile and Water Management Pond (WMP)

Environment Canada recommended in their Technical Report that "*De Beers assess the seepages from the North Pile and the Water Management Pond and quantify the amount of TDS and chloride that are entering Snap Lake from these seepages.*" This recommendation would not provide significant additional information on TDS and chloride concentrations entering Snap Lake.

Increasing TDS including chloride concentrations in Snap Lake are a result of the release of underground connate waters. The North Pile and Water Management Pond (WMP) seepages are not significant sources of TDS including chloride to Snap Lake compared to direct inputs from the mine effluent, as illustrated in the figures presented as part of the Snap Lake model presentation during the Technical Session (April 15 and 16, 2014). Data on seepage quality are provided in the annual Acid Rock Drainage (ARD) reports. The extensive groundwater monitoring program necessary to fully quantify TDS including chloride in seepage from the North Pile and WMP would not substantially alter current predictions of TDS including chloride in Snap Lake. The Site and Lake models used seepage volumes from the North Pile directly to Snap Lake and seepage volumes from the WMP directly to Snap Lake as estimated in the Environmental Assessment Report (EAR).

2.3 Potential Stratification of Snap Lake

Environment Canada in their Technical Report state (p13) "*According to CCME's Chloride Factsheet, increased chloride in surface water has been linked to reducing the vertical mixing of surface waters by way of changing the density gradient in lakes. This phenomenon is referred to as meromixis (layers of water that do not experience complete overturn or complete vertical mixing). One of the outcomes of stable stratification of deep and surface water layers is that the deep layer (monimolimnion) can become quite depleted of oxygen and can limit the survival of aquatic life in this layer*."

"*Since TDS, including chloride, in Snap Lake is increasing at a faster rate than predicted in the Environmental Assessment Report, EC is concerned that there is a potential for stratification in Snap Lake as a result of the increase in TDS and chloride load*."

Environment Canada also recommended in their Technical Report that "*De Beers monitor water quality parameters, such as, temperature, pH, specify conductance, dissolved oxygen, and any other parameters that would help to identify water quality conditions related to the potential for stratification of Snap Lake, and that De Beers develop contingency mitigation measures which can be implemented in the event this is observed*."

De Beers monitors water quality parameters including temperature, pH, specific conductivity, and dissolved oxygen in Snap Lake as part of the AEMP. There is no evidence that Snap Lake is becoming meromictic (De Beers 2014). The Snap Lake hydrodynamic and water quality model predictions do not indicate that Snap Lake will become meromictic during Mine operations.

<u>Reference:</u>

De Beers (De Beers Canada Inc.) 2014. 2013 Annual Report in Support of the Aquatics Effects Monitoring Program Water License (MV2001L2-0002), Snap Lake Project. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

2.4 Duration and Reversibility

The GNWT in their Technical Report state (p27) "*The GNWT notes that De Beers has not provided a duration and reversibility assessment for EA1314-02. However, De Beers has provided a single graph in response to Information Request MVRB/MVLWB #11. This figure (11-1) appears to suggest that conditions in Snap Lake, based upon a 1700 mg/L whole lake average, are reversible after 40 years. The proponent has not provided rationale on how this was derived, but based upon the GNWT's review, it appears that De Beers has utilized a 7.5-8 year water replacement time. The proponent has not provided a sufficient rationale to justify this change from the 13 year time used in the 2003 EA*."

With regard to the above comment, please note the following:

- De Beers has not proposed or utilized a 7.5 - 8 year water retention time in Snap Lake;
- the water retention time in the main basin of Snap Lake is 13 years; and,
- the concentrations presented in Table 2 on page 28 by the GNWT are not in agreement with the Snap Lake Site Model predictions. The GNWT assumes that in one residence time concentrations in Snap Lake will be reduced by 50%. The Snap Lake Site Model assumes that there is an exponential decay in concentration with time.

Figure MVRB/MVLWB_IR#11-1 presents predicted whole-lake average TDS concentrations in Snap Lake from 2012 to 2130 for unmitigated model scenarios. The Snap Lake Site Model was used to make long-term water quality predictions in Snap Lake after Mine closure. In the model, the inputs and outputs to Snap Lake include: precipitation, natural inflows that have not been affected by mining, Mine site runoff, seepage from the Water Management Pond and North Pile, effluent discharge from the water treatment plant (WTP), evaporation, water pumped from Snap Lake for domestic use, seepage from Snap Lake to the underground Mine, and outflow from Snap Lake downstream. The predicted whole-lake average TDS concentrations in Snap Lake from the Snap Lake Site Model were calibrated to the predicted whole-lake average TDS concentrations in Snap Lake from the Snap Lake hydrodynamic and water quality model for the period from 2012 to 2028. In the model starting on January 1, 2029, discharge from the underground Mine to the WTP and seepage of water from Snap Lake to the underground Mine are set equal to zero.

The Snap Lake Site Model includes water balance and mass balance components and was developed using GoldSim. In GoldSim, Snap Lake was modelled as a completely mixed flow reactor (CMFR). In a CMFR, there is flow into the reactor (i.e., Snap Lake), flow out of the reactor, and complete and instantaneous mixing throughout the reactor. A mass balance for TDS in Snap Lake from January 1, 2029 to 2130 is presented below:

$$\text{Mass Rate of Accumualtion of TDS} = \text{Mass Rate of TDS}_{\text{IN}} - \text{Mass Rate of TDS}_{\text{OUT}} + \text{Mass Rate of TDS}_{\text{PRODUCED}} - \text{Mass Rate of TDS}_{\text{CONSUMED}} \quad \text{Equation 1}$$

TDS in Snap Lake was modelled as a conservative parameter. Therefore, the mass rates of TDS produced and consumed in Equation 1 were set equal to zero. Equation 1 was re-written (Equation 2):

$$\frac{d\text{TDS}_{\text{SNAP LAKE}}}{dt}\text{V} = \text{Q}_{\text{IN}}\text{TDS}_{\text{IN}} - \text{Q}_{\text{OUT}}\text{TDS}_{\text{OUT}} \quad \text{Equation 2}$$

, where:

$\frac{dTDS_{SNAP\ LAKE}}{dt}$	= change in concentration of TDS in Snap Lake with time
V	= volume of Snap Lake
Q_{IN}	= inflow to Snap Lake
Q_{OUT}	= outflow from Snap Lake
TDS_{IN}	= TDS concentration in the inflow to Snap Lake
TDS_{OUT}	= TDS concentration in the outflow from Snap Lake

To maintain a water balance in Snap Lake:

$$Q_{IN} = Q_{OUT} = Q \qquad \text{Equation 3}$$

Because Snap Lake was modelled as a CMFR with complete and instantaneous mixing throughout:

$$TDS_{Snap\ Lake} = TDS_{OUT} \qquad \text{Equation 4}$$

For simplification in this mass balance, the TDS concentration in the inflow to Snap Lake from January 1, 2029 to 2130 was assumed to be equal to 10 mg/L.

$$TDS_{IN} = 10\ mg/L \qquad \text{Equation 5}$$

Equations 3, 4, and 5 were substituted into Equation 2 to produce Equation 6.

$$\frac{dTDS_{SNAP\ LAKE}}{dt} = \frac{Q}{V}(10) - \frac{Q}{V}TDS_{SNAP\ LAKE} \qquad \text{Equation 6}$$

The water retention time in Snap Lake is defined as:

$$\tau = \frac{V}{Q} \qquad \text{Equation 7}$$

, where:

τ	= water retention time

Equation 7 was substituted into Equation 6 and Equation 6 was re-arranged to produce Equation 8. Equation 8 represents a linear, first-order differential equation.

$$\frac{dTDS_{SNAP\ LAKE}}{dt} + \frac{1}{\tau}TDS_{SNAP\ LAKE} = \frac{1}{\tau}(10) \qquad \text{Equation 8}$$

Equation 8 can be solved using the integrating factor in Equation 9.

$$u(t) = \exp \int \frac{1}{\tau} dt = \exp^{\frac{1}{\tau}t} \qquad \text{Equation 9}$$

, where:

exp	= exponential function
t	= time

The integrating factor in Equation 9 is multiplied by Equation 8 to produce Equation 10.

$$\exp^{\frac{1}{\tau}t}\left[\frac{\mathrm{dTDS_{SNAP\ LAKE}}}{\mathrm{dt}}\right] + \exp^{\frac{1}{\tau}t}\left[\frac{1}{\tau}\mathrm{TDS_{SNAP\ LAKE}}\right] = \left[\frac{1}{\tau}(10)\right]\exp^{\frac{1}{\tau}t} \qquad \text{Equation 10}$$

Equation 10 simplifies to Equation 11.

$$\frac{d}{dt}\left[\exp^{\frac{1}{\tau}t} \times \mathrm{TDS_{SNAP\ LAKE}}\right] = \frac{1}{\tau}(10)\exp^{\frac{1}{\tau}t} \qquad \text{Equation 11}$$

Integrating Equation 11 produces Equation 12.

$$\exp^{\frac{1}{\tau}t} \times \mathrm{TDS_{SNAP\ LAKE}} = 10\exp^{\frac{1}{\tau}t} + K \qquad \text{Equation 12}$$

, where:

K = constant.

Equation 12 is simplified to produce Equation 13.

$$\mathrm{TDS_{SNAP\ LAKE}}(t) = 10 + \mathrm{K}\exp^{-\frac{1}{\tau}t} \qquad \text{Equation 13}$$

To solve for K, the following substitutions were made into Equation 13:

At t = 0 (i.e., January 1, 2029) for Upper Bound Scenario A:

$$\mathrm{TDS_{SNAP\ LAKE}}(0) = \text{approximately } 1{,}700 \text{ mg/L}$$

$$1{,}700 = 10 + \mathrm{K}\exp^{0}$$

$$1{,}690 \text{ mg/L} = \mathrm{K}$$

Solving for K produces Equation 14.

$$\mathrm{TDS_{SNAP\ LAKE}}(t) = 10 + (1{,}690)\exp^{-\frac{1}{\tau}t} \qquad \text{Equation 14}$$

After 13 years (i.e., one water retention time), the TDS concentration in Snap Lake is predicted to be approximately 632 mg/L, which represents a reduction in concentration of 63% not 50% as shown in Table 2 on page 28.

At $t = \bar{t}$

$$\mathrm{TDS_{SNAP\ LAKE}}(\bar{t}) = 10 + (1{,}690)\exp^{-1}$$

$$\mathrm{TDS_{SNAP\ LAKE}}(\bar{t}) = 632 \text{ mg/L}$$

After approximately 9.1 years, the TDS concentration in Snap Lake is predicted to be approximately 850 mg/L, which represents a reduction in concentration of 50%.

$$850 = 10 + (1{,}690)\exp^{-\frac{t}{13}}$$

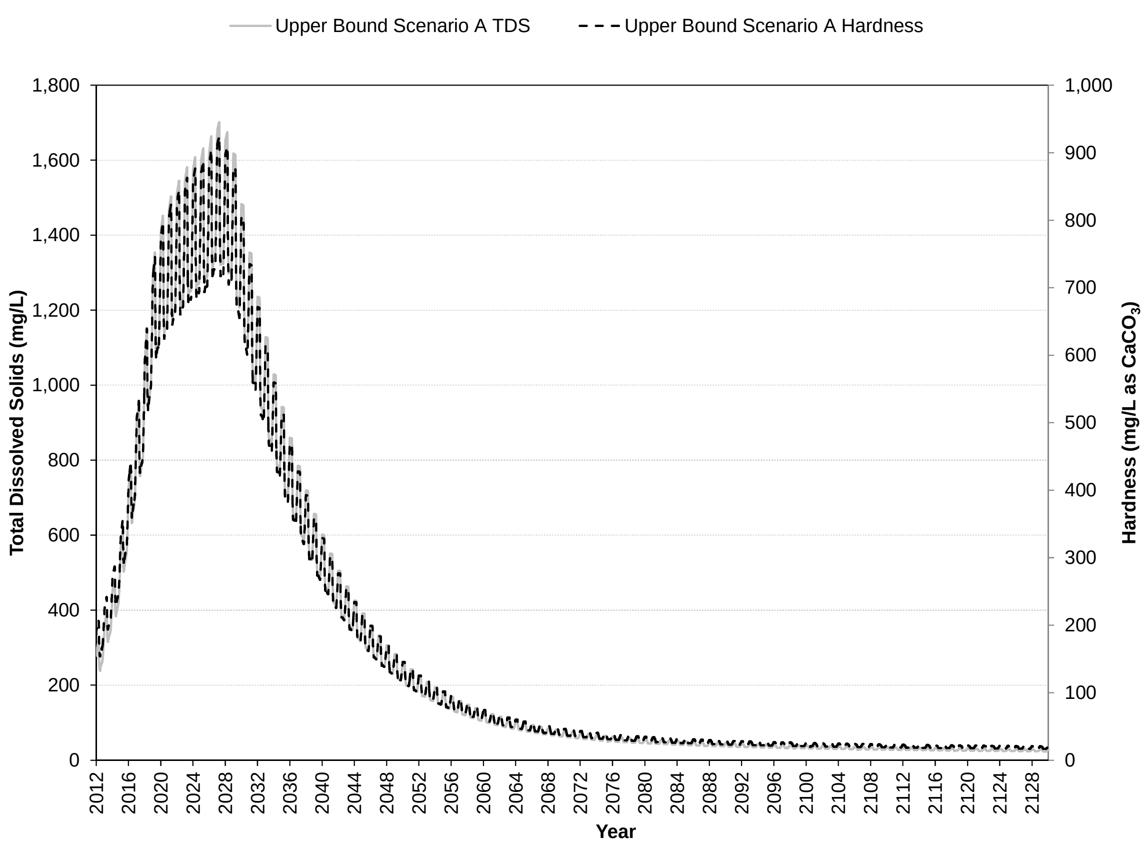
$$\ln\left(\frac{840}{1{,}690}\right) = -\frac{t}{13}$$

$$t = 9.1 \text{ years}$$

The GNWT in their Technical Report state (p28) "*The GNWT further notes that the proponent has not provided an assessment of the mechanism for the reversibility of each mine effluent constituent. The GNWT has concerns that there is a potential for TDS, and therefore hardness (which is composed of the constituents of TDS), to decrease at an accelerated rate relative to other parameters after mine closure. The proponent has used hardness as a modifying factor for the toxicity to aquatic organisms (for parameters like aluminum, copper and nitrate), so if hardness is reduced at an accelerated rate, the possible protection afforded by hardness will no longer be realized. This may be of particular concern for parameters that are accumulating in sediment, and which will continue to cycle once effluent discharge ceases*."

The Snap Lake Site Model was used to make long-term water quality predictions in Snap Lake after Mine closure. All parameters in Snap Lake including TDS, calcium, magnesium, and nitrate were modelled as conservative constituents. Conservative constituents were assumed not to undergo chemical reactions or physical processes such as settling. Because all parameters were modelled as conservative constituents and Snap Lake was modelled as a completely mixed flow reactor, all parameters will experience the same exponential percent decrease in concentration with time. For example, the predicted exponential percent decrease in hardness concentration is equivalent to the predicted exponential percent decrease in TDS concentration (Figure 1). The Snap Lake Site Model and the Snap Lake model do not contain sediment compartments.

Figure 1. Predicted Whole-lake Average Total Dissolved Solids and Hardness Concentrations in Snap Lake, 2012 to 2130 (Unmitigated Scenario)



mg/L = milligrams per litre; $CaCO_3$ = calcium carbonate; TDS = total dissolved solids.

2.5 Revised Ammonia and Nitrate Effluent Quality Criteria for the Snap Lake Mine

In the Ecometrix Technical Report (Ecometrix 2014), it was stated that "*DBCI did not explicitly use loss rates when calculating effluent quality criteria (EQC) for ammonia and nitrite. However, the equation presented in the EQC report for these parameters (Equation 5), contains an implicit assumption that ammonia and nitrite concentrations will remain at baseline levels in Snap Lake over time. This implicit assumption directly contradicts the Snap lake Hydrodynamic Model results, which predict a steady increase of ammonia in the lake even with loss mechanisms in place (no predictions were available to verify this trend for nitrites).*" Ecometrix recommended that De Beers re-derive EQC for ammonia and nitrites to account for accumulation of these chemicals in Snap Lake and for losses consistent with the Snap Lake model.

Ecometrix also identified an error in the calculation of the water quality guideline (WQG) used to derive the EQC for ammonia (4.6 mg-N/L vs. 5.21 mg-N/L). We respond to these comments in the three sub-sections (2.5.1 to 2.5.3) below.

2.5.1 Ammonia Effluent Quality Criteria

Ecometrix is correct, the chronic CCME water quality guideline (WQG) calculated at the 85th percentile pH and temperature values is 4.6 mg-N/L, not 5.21 mg-N/L. We thank them for catching this error and apologize for having made it. The EQC were re-calculated using the revised WQG. As well, a test scenario with a limited rate of increased ammonia concentrations in Snap Lake, similar to those predicted in the Snap Lake Hydrodynamic Model, was considered. On the basis of the re-calculation and test scenario, no changes to the ammonia EQC are proposed. An average monthly limit (AML) = 10 mg-N/L; and, maximum daily limit (MDL) = 21 mg-N/L is appropriate.

Steps for the ammonia EQC derivation are:

Step 1.

Calculate the acute (20.9 mg-N/L [USEPA 2013]) and chronic (4.6 mg-N/L [CCME 1999]) WQG to be applied at the edge of the mixing zone.

Step 2.

Apply the equations specified in Section 2.4.1 of the EQC Report to derive the waste load allocation, long-term average, average monthly limit (AML), and maximum daily limit (MDL) for ammonia. Equations 5 and 6 are specific to ammonia due to its rapid conversion to other nitrogenous forms in the presence of dissolved oxygen. As such, EQC for ammonia were calculated differently than, for example, chloride, a parameter that acts conservatively in the water column.

Calculations were completed using the CCME chronic WQG (the lower of the chronic and acute WQGs). Equation 6 implicitly assumes that ammonia will not accumulate in Snap Lake. A test was completed using C_{in} equal to 2.5 mg-N/L, the maximum predicted concentration at the edge of the mixing zone (De Beers 2013a), rather than the baseline concentration of 0.02 mg-N/L. This test represents a scenario where limited ammonia accumulation occurs in the lake.

Step 3.

Compare the EQC derived in Step 2 using the chronic WQG, including the accumulation test scenario, against the acute WQG of 21 mg-N/L. If the EQC were greater than the acute WQG, the AML and MDL were set equal to 21 mg-N/L, which protects against acute effects. In keeping with the Water and Effluent Quality Management Policy's waste minimization objective (MVLWB 2011), the proposed AML was adjusted to 10 mg/L, which is consistent with the current water licence and a MDL:AML ratio of 2:1. Therefore, the final proposed EQC were: AML = 10 mg-N/L; and, MDL = 21 mg-N/L (De Beers 2013b).

2.5.2 Nitrite Effluent Quality Criteria

On the basis of further investigation into the nitrite EQC, it is recommended that the current AML of 0.5 mg-N/L and MDL of 1 mg-N/L (MVLWB 2013) be retained, rather than the suggested increased values in De Beers (2013b).

Under Schedule 5: Part F, 3b (ii) and 4b (ii) of the Water Licence, recommendations and rationale for revised EQC were specifically required for five parameters: TDS, chloride, fluoride, ammonia, and nitrate. Nitrite was carried forward in the assessment to determine whether existing EQC (AML = 0.5 mg-N/L; MDL = 1 mg-N/L) are appropriate based on anticipated operational changes at the Mine.

The generic CCME WQG of 0.06 mg-N/L was used for re-deriving the EQC for nitrite (CCME 1999). Nitrite is a non-conservative parameter, so when released into Snap Lake it is rapidly oxidized to nitrate, limiting the rate of increase in the lake. Using the non-conservative equation similar to ammonia (Equation 5 in De Beers 2013b), a new AML of 1 mg-N/L and MDL of 3 mg-N/L was proposed; however, uncertainty in those values was identified as nitrite concentrations in the treated effluent discharge were not modelled due to the instability of nitrite resulting from changing redox conditions. After completing a test similar to that completed in Step 2[1] for ammonia above (i.e., limited increase in nitrite concentrations in the lake), it is possible that the originally proposed EQC may not be protective late in operations, so it is recommended that the current AML of 0.5 mg-N/L and MDL of 1 mg-N/L (MVLWB 2013) be retained. Those EQC are appropriate given the current understanding of nitrite dynamics in Snap Lake. The ability to simulate nitrite will continue to be investigated in advance of the MVLWB Water Licence Hearing, as well as the effect that potential mitigations may have on expected nitrite concentrations. Nitrite will continue to be monitored as part of the AEMP and SNP programs, included in the Response Framework (De Beers 2014), and subject to action level triggers should nitrite concentrations increase to levels near the CCME WQG.

2.5.3 Effluent Quality Criteria Summary

A summary of proposed EQC for ammonia and nitrite for the Snap Lake Mine are provided in Table 1. The values represent no change from the current Water Licence (MVLWB 2013). We thank EcoMetrix for their comprehensive review and valuable comments on the EQC report. The additional investigation into ammonia and nitrite provide greater confidence that the EQC proposed are appropriate.

Table 1 Summary of Proposed Effluent Quality Criteria for Ammonia and Nitrite for the Snap Lake Mine

Parameter	Proposed EQC (mg-N/L)		Annual Loading Limit (kg/yr)
	AML	MDL	
Ammonia as N[(a)]	10	20	187,000
Nitrite as N	0.5	1	-

(a) Recommendations and rationale for revised EQC for ammonia are specifically required under Schedule 5: Part F, 3b (ii) and 4b (ii) of the Water Licence (MVLWB 2013).

mg-N/L = milligrams per litre as nitrogen; kg/yr = kilograms per year; EQC = effluent quality criteria; MDL = maximum daily limit; AML = average monthly limit; "-" = not recommended.

[1] Nitrite concentrations have remained relatively stable for the past three years (i.e., maximum concentrations occurred in 2011), thus current levels were used in the test scenario. Future predictions were not available.

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USEPA. 2013. Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater 2013. Office of Water (4304T). EPA-822-R-13-001. Washington, DC, USA.

3.0 CLOSURE

We trust that the information presented in this Technical Memorandum satisfies your current requirements. Should you have any questions or comments, please do not hesitate to contact the undersigned.

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