DE BEERS
GROUP OF COMPANIES

December 27, 2013

File: L020

Marc Casas, Regulatory Officer
Mackenzie Valley Land and Water Board
PO Box 2130
Yellowknife, Northwest Territories
X1A 2P6

Dear: Mr. Casas:

Re: De Beers Canada Inc. Snap Lake Mine Water License #MV2011L2-0004 Strontium Response Plan

De Beers Canada Inc. (De Beers) is pleased to submit the enclosed *Strontium Response Plan* required per Water Licence MV2011L2-0004; Part F, Item 15 and Schedule 5, Item 2. The Plan includes:

1. *A quantitative description of strontium sources and forms of strontium in the effluent stream from different mine activities (Section 2);*
2. *A review of potential mitigation and treatment technology to establish the feasibility and costs of reducing strontium loading to Snap Lake from the Project (Section 3);*
3. *Recommendations and supporting rationale for an appropriate water quality objective for strontium in Snap Lake which is derived from toxicity testing conducted by the Licensee and/or published toxicology studies (Section 4); and,*
4. *Recommendations and further actions to be taken in response to increasing levels of strontium in Snap Lake and a timeline for implementation (Section 5).*

Should you have any questions, comments or require further clarification, please do not hesitate to contact me at (867) 766-7308 or e-mail me at the following address: Alexandra.Hood@debeerscanada.com.

Sincerely,

DE BEERS CANADA INC.

A. Hood

Alexandra Hood
Permitting and Environmental Superintendent
Snap Lake Mine

cc. D. Putnam, E. Bonhomme (DBCI)

Attachments

DE BEERS CANADA INC.

SNAP LAKE MINE

STRONTIUM RESPONSE PLAN

MV2011L2-0004

December 2013

PLAIN LANGUAGE SUMMARY

De Beers Canada Inc. (De Beers) owns and operates the Snap Lake Mine (Mine), a diamond mine located approximately 220 kilometres northeast of Yellowknife, Northwest Territories. This document, the Strontium Response Plan, fulfills the requirements of Part F, Item 15 and Schedule 5, Item 2 of Water Licence MV2011L2-0004 for the Mine.

Strontium is present in the minerals comprising kimberlite and processed kimberlite at Snap Lake Mine. As a result of mining activities, strontium concentrations in Snap Lake have been increasing since Mine operations began in 2005. De Beers initiated studies to investigate the potential effects of elevated strontium concentrations on aquatic life in Snap Lake for the purpose of developing a site-specific water quality objective (SSWQO). As a result of the studies, the proposed SSWQO for strontium is 14,130 micrograms per litre (µg/L).

Modelling completed by De Beers (2013b,d) indicates that strontium concentrations in Snap Lake are predicted to remain well below the proposed SSWQO throughout the life of the Mine. Under the worst-case modelling scenario, average strontium concentrations have been predicted to increase to 4,000 µg/L by 2028.

No further actions will be taken by the Mine at this time in response to increasing concentrations of strontium in Snap Lake because the evidence does not indicate that there is a present or future risk from strontium to the aquatic life of Snap Lake. The Aquatic Effects Monitoring Program Response Framework outlines Action Levels should parameter concentrations increase to levels that may be of concern. Strontium concentrations will continue to be monitored; should an action level be triggered, follow-up actions may include special studies approved by the MVLWB, mitigation, and/or treatment studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

Term	Definition
CEB	chronic effect benchmarks
De Beers	De Beers Canada Inc.
EAR	Environmental Assessment Report
ELS	early life stage
LC50	concentration that is lethal to 50% of organisms
MDEQ	Michigan Department of Environmental Quality
Mine	Snap Lake Mine
MVLWB	Mackenzie Valley Land and Water Board
NWT	Northwest Territories
SNP	Surveillance Network Program
SSD	species sensitivity distribution
SSWQO	site-specific water quality objective
TDS	total dissolved solids
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
WMP	water management pond
WQGs	water quality guidelines
WTP	water treatment plant

UNITS OF MEASURE

Term	Definition
%	percent
µg/L	micrograms per litre
d	day
dw	dry weight
h	hour
kg/d	kilograms per day
km	kilometre
m^3/d	cubic metres per day
mg/kg	milligrams per kilogram
ww	wet weight

1 INTRODUCTION

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 Mine operates under current land use permit and water licence issued by the Mackenzie Valley Land and Water Board (MVLWB).

Water quality in Snap Lake is changing over time predominantly due to influences from treated effluent discharge from the Mine (De Beers 2013a). Strontium, which is present in the kimberlite and processed kimberlite at Snap Lake, is a constituent of this treated Mine effluent. Strontium concentrations have been increasing in Snap Lake since Mine operations began in 2005. Because there are no national water quality guidelines (WQGs) for strontium, and no established benchmark in the Environmental Assessment Report (EAR; De Beers 2002), De Beers has quantified strontium loadings to the receiving environment and developed a proposed site-specific water quality objective (SSWQO) for strontium in Snap Lake.

De Beers' self-initiated efforts regarding strontium are consistent with the principles of adaptive management and the Response Framework and provide the basis for the present *Strontium Response Plan* required in the current Water Licence (MVLWB 2013; Part F, Item 15 and Schedule 5, Item 2):

1. *A quantitative description of strontium sources and forms of strontium in the effluent stream from different mine activities (Section 2);*
2. *A review of potential mitigation and treatment technology to establish the feasibility and costs of reducing strontium loading to Snap Lake from the Project (Section 3);*
3. *Recommendations and supporting rationale for an appropriate water quality objective for strontium in Snap Lake which is derived from toxicity testing conducted by the Licensee and/or published toxicology studies (Section 4); and,*
4. *Recommendations and further actions to be taken in response to increasing levels of strontium in Snap Lake and a timeline for implementation (Section 5).*

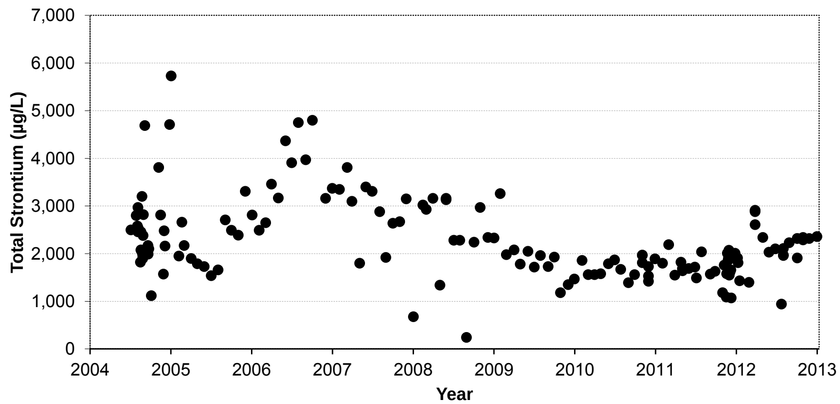
2 QUANTITATIVE DESCRIPTION OF STRONTIUM SOURCES

2.1 Historical Total Strontium Data

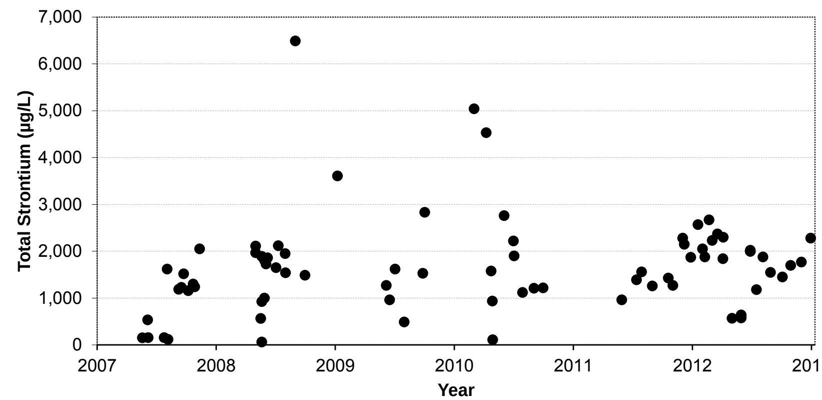
Strontium is present in the granite, metavolcanic, and kimberlite rocks at Snap Lake (De Beers 2002). Plots of monitored strontium concentrations are presented in Figure 2-1. The plots show data from 2004 to 2012 for the final minewater collection sump (i.e., Surveillance Network Program [SNP 02-01]), the North Pile collection ditch (i.e., SNP 02-02), the water management pond (WMP) (i.e., SNP 02-14), and the treated effluent discharge from the temporary water treatment plant (WTP) (i.e., SNP 02-17) and the permanent WTP (i.e., SNP 02-17B) (Figure 2-2). A rapid increase in concentrations of strontium was observed at the final minewater collection sump when mining operations began in 2005 and 2006. As mining progressed, strontium concentrations in the minewater were diluted by seepage of water from Snap Lake and a decrease in concentrations was observed from 2006 to 2010.

Plots of monitored strontium concentrations for the North Pile collection ditch and the WMP indicate that concentrations vary considerably because the North Pile collection ditch and the WMP are influenced by surface runoff water, mining activities, and performance of the WTP. Plots of monitored total strontium concentrations at the treated effluent discharge point show a similar pattern to concentrations in the final minewater collection sump where untreated minewater is pumped directly to the WTP.

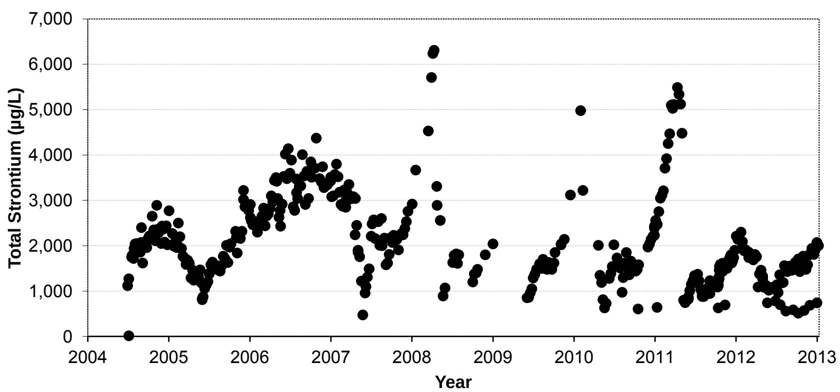
Figure 2-1 Monitored Total Strontium Concentrations for the Snap Lake Mine



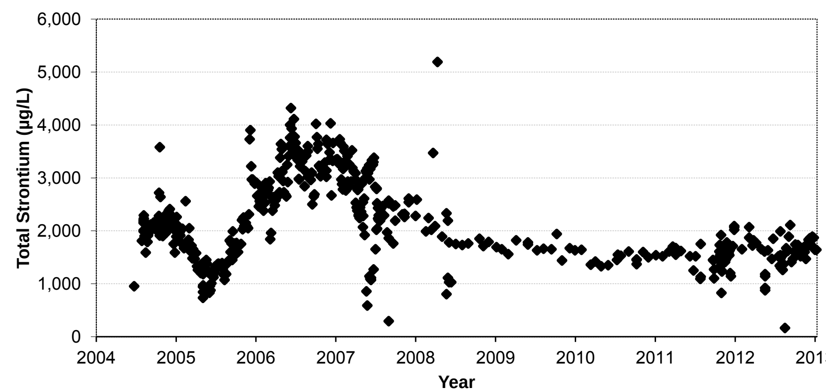
(a) Final minewater collection sump, SNP 02-01



(b) North Pile drainage collection ditch, SNP 02-02



(c) WMP, SNP 02-14



(d) Treated effluent discharge, SNP02-17 and SNP 02-17B

µg/L = micrograms per litre; SNP = Surveillance Network Program; WMP = water management pond.

2.2 Assessment and Quantification of Sources of Strontium Loadings

Mass loadings of strontium from 2012 to 2028 at the final minewater collection sump (i.e., SNP 02-01), the North Pile drainage collection ditch (i.e., SNP 02-02), the WMP (i.e., SNP 02-14), and the treated effluent discharge from the permanent WTP (i.e., SNP 02-17B) (Figure 2-2) were predicted using the Snap Lake site model (De Beers 2013b) for the following four modelling scenarios (Itasca 2013):

- Upper Bound Scenario A;
- Upper Bound Scenario B;
- Lower Bound Scenario A; and,
- Lower Bound Scenario B.

Upper Bound Scenarios were based on minewater inflows from Scenario 4 of the Itaska (2013) groundwater model, and Lower Bound Scenarios were based on minewater inflows from the Base Case of the groundwater model (Figure 2-3) (Itasca 2013). Scenarios A and B were developed based on total dissolved solids (TDS) concentration differences from the deep groundwater (Itasca 2013). Strontium concentrations in the minewater were directly correlated to TDS concentrations.

Figure 2-2 Aerial View of the Mine Site

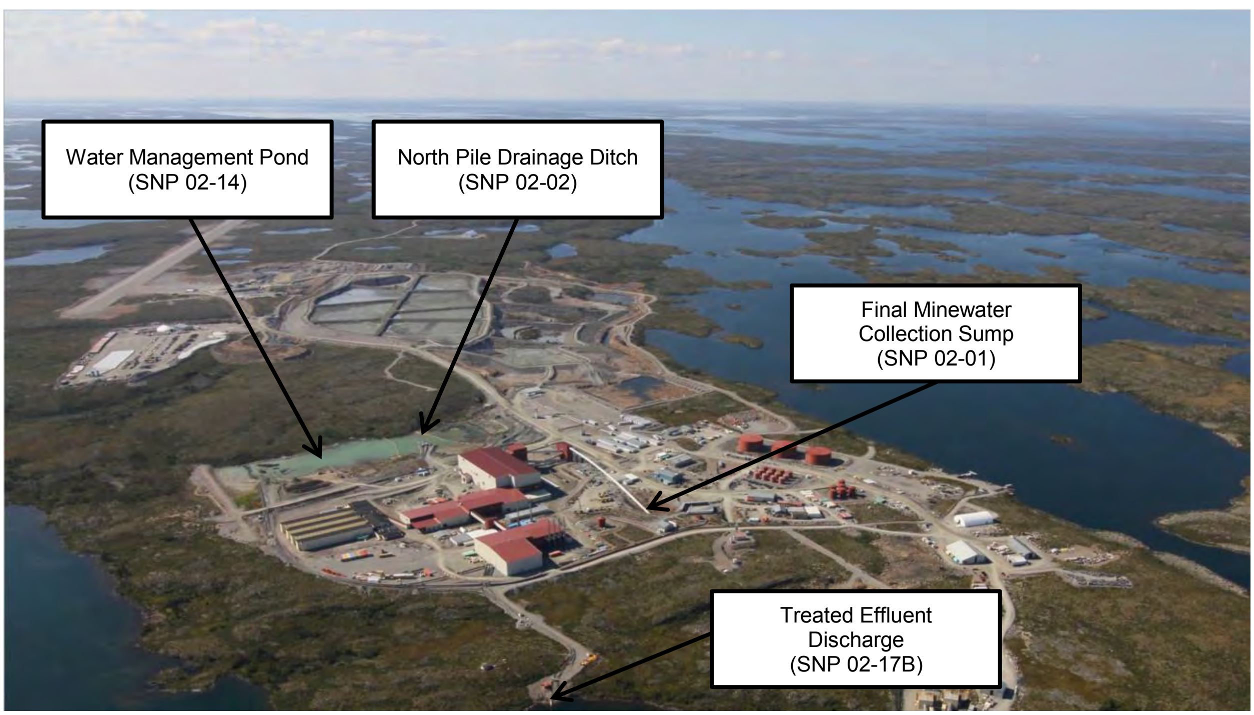
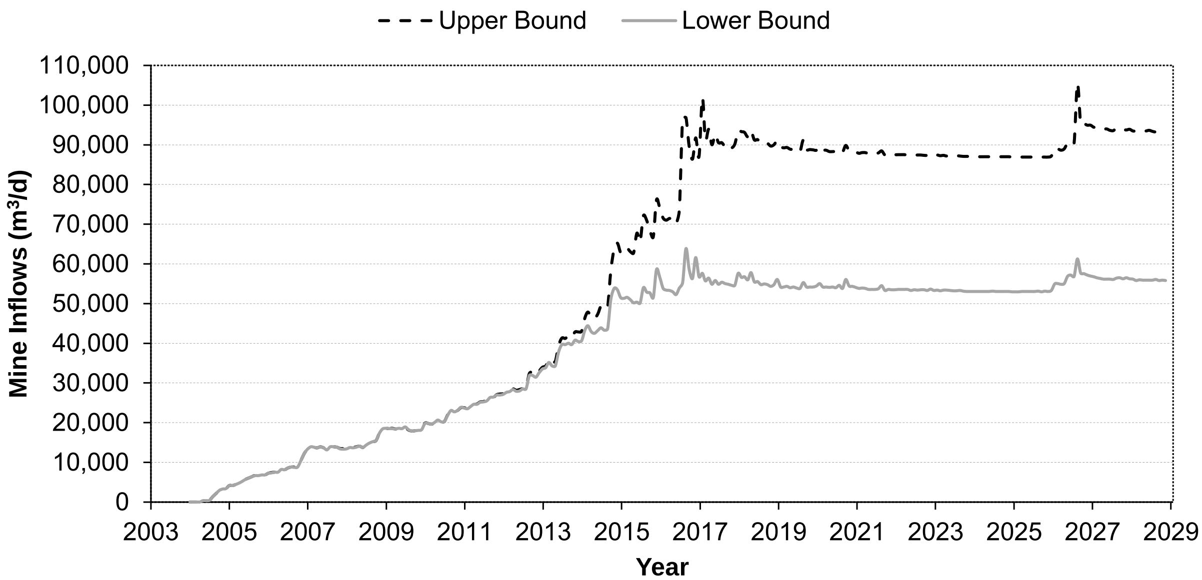


Figure 2-3 Minewater Inflows from Upper Bound and Lower Bound Scenarios



m^3/d = cubic metres per day.

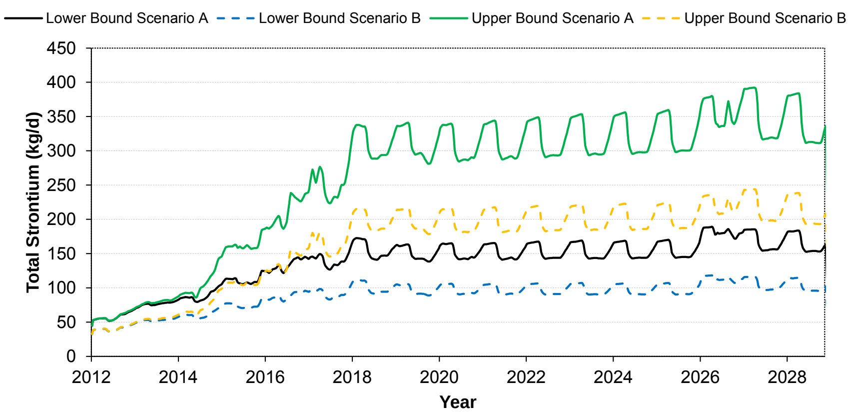
Average loadings of strontium (Table 2-1 and Figure 2-4) were predicted to increase from 2014 to 2028. On average, 92 percent (%) and 91% of the strontium loadings in the treated effluent discharge from the WTP to Snap Lake were predicted to originate from minewater for the Upper Bound and Lower Bound scenarios, respectively.

Table 2-1 Average Strontium Loadings for the Snap Lake Mine

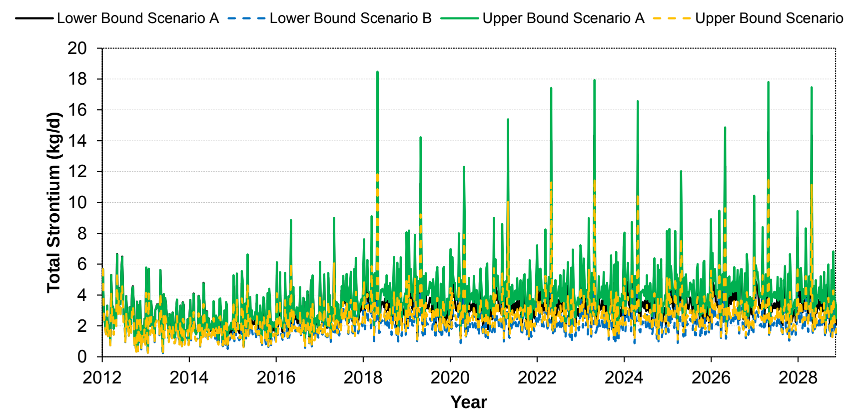
Location	Description	Average Strontium Load (kg/d)							
		Upper Bound Scenario A		Upper Bound Scenario B		Lower Bound Scenario A		Lower Bound Scenario B	
		2014	2028	2014	2028	2014	2028	2014	2028
SNP 02-01	Final minewater collection sump	105	328	72	204	88	159	61	99
SNP 02-02	North Pile drainage collection ditch	2	4	2	3	2	4	2	2
SNP 02-14	Water management pond	11	7	7	5	9	7	6	5
SNP 02-17B	Treated effluent discharge	115	344	79	214	96	170	66	106

kg/d = kilograms per day; SNP = Surveillance Network Program.

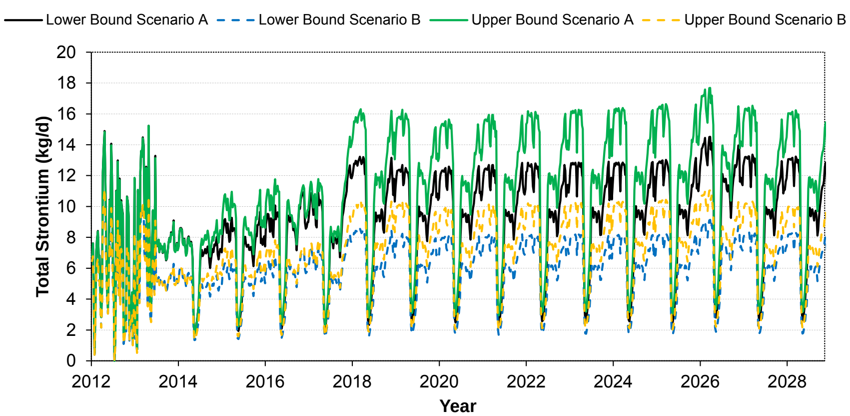
Figure 2-4 Strontium Loading Estimates for the Snap Lake Mine



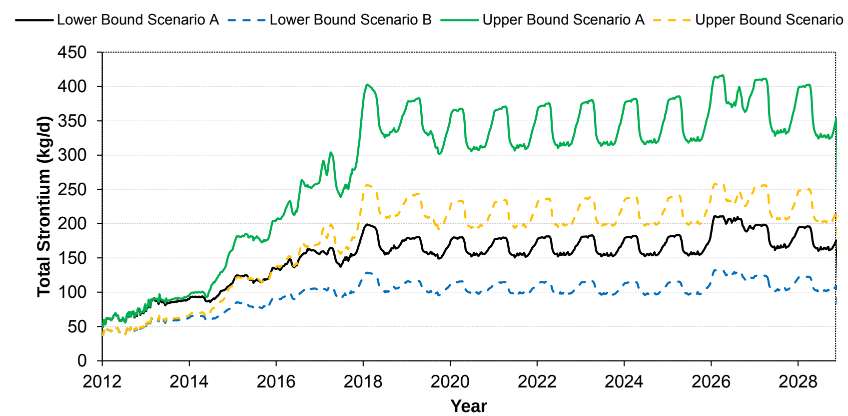
(a) Final minewater collection sump, SNP 02-01



(b) North Pile drainage collection ditch, SNP 02-02



(c) WMP, SNP 02-14



(d) Treated effluent discharge, SNP 02-17B

kg/d = kilograms per day; SNP = Surveillance Network Program; WMP = water management pond.

3 POTENTIAL MITIGATION AND TREATMENT TECHNOLOGIES TO REDUCE STRONTIUM LOADINGS TO SNAP LAKE

A review of potential mitigation and treatment technologies to establish the feasibility and costs of reducing strontium loadings to Snap Lake was not performed because as discussed in Section 4, the evidence does not indicate that strontium presents a current or future risk to the aquatic life of Snap Lake. Hence, mitigation and treatment are not reasonably expected to be necessary. The Aquatic Effects Monitoring Program Response Framework outlines Action Levels should parameter concentrations increase to levels that may be of concern (De Beers 2012). Strontium concentrations will continue to be monitored; should an action level be triggered, follow-up actions may include special studies approved by the MVLWB, mitigation and/or treatment studies.

4 SITE-SPECIFIC WATER QUALITY OBJECTIVE FOR STRONTIUM IN SNAP LAKE

A benchmark for strontium was not established as part of the EAR (De Beers 2002) and there are no Canadian WQGs for strontium for protection of freshwater aquatic life or for drinking water. Strontium concentrations have increased in Snap Lake water relative to baseline conditions; therefore, it is appropriate to develop a site-specific strontium benchmark for Snap Lake (De Beers 2013c) to determine whether there is a risk of adverse effects to aquatic life and to adopt that new benchmark as a SSWQO for strontium in Snap Lake.

Water Quality Benchmarks for Strontium

There are currently no national WQGs for strontium for protection of freshwater aquatic life in Canada or the United States.

The Michigan Department of Environmental Quality (MDEQ 2008) developed acute and chronic benchmarks for strontium, although it was not clear whether these had been formally adopted as state water quality standards. Development of these water quality benchmarks involved rejecting all of the data available in the literature at the time, and relying on data from six unpublished studies to derive an acute benchmark of 40,300 micrograms per litre (µg/L) and a chronic benchmark of 21,000 µg/L. According to Chowdhury and Blust (2012), that chronic threshold was also adopted by Ohio (Ohio EPA 2009) and Quebec.

The Indiana Department of Environmental Management (IDEM 2001) calculated Tier II acute and chronic values for strontium of 4,800 and 530 µg/L, respectively. These benchmarks were calculated using acute data from two studies with *Daphnia magna* and *Tubifex tubifex* (Khangarot 1991; Khangarot and Ray 1989); it appears that the *Daphnia magna* data were used incorrectly in that 24-hour (h) and 48-h LC50s from the same test were used. Calculation of the acute and chronic values involved use of application factors and a default acute-to-chronic ratio because of the lack of data.

Ecometrix (2011) proposed a SSWQO for strontium in Snap Lake of 500 µg/L; the same value was also proposed as an EQC for treated mine effluent, making no allowance for effluent mixing and dilution following discharge. This value was calculated as the geometric mean of the two lowest LC50[1] values in their database: a 28-day (d) LC50 for Rainbow Trout (*Oncorhynchus mykiss*) of 250 µg/L (Birge et al. 1980) and a 7-d LC50 for the amphipod *Hyalella azteca* of 1,000 µg/L (Borgmann et al. 2005). Ecometrix (2011) identified issues with both these test results.

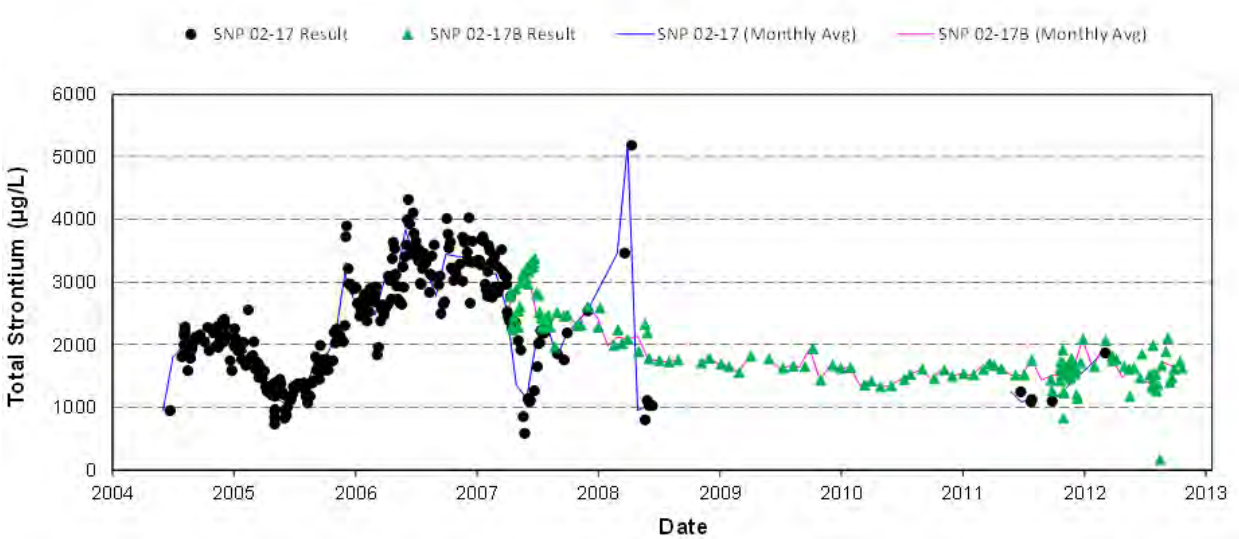
Strontium Concentrations in Treated Effluent and Snap Lake

Concentrations of total strontium measured in treated effluent from the temporary WTP (i.e., SNP 02-17) and the permanent WTP (i.e., SNP 02-17B) between 2004 and 2012 are shown in Figure 4-1. Individual measurements and monthly moving averages are shown for each discharge point. Although measured concentrations have decreased in recent years as less areas of kimberlite are open relative to the amount

[1] The LC*p* is the concentration of test material estimated to be lethal to a specific percentage ("*p*") of the test organisms. The LC50, or median lethal concentration, is the concentration estimated to be lethal to 50% of the test organisms.

of inflow and are on a downward trend; modelling completed in 2013 (De Beers 2013b) indicated that maximum total strontium concentrations in the treated effluent discharge were predicted to range between 2,400 and 3,800 µg/L under Lower Bound Scenarios and between 2,900 and 4,700 µg/L under Upper Bound Scenarios.

Figure 4-1 Concentrations of Total Strontium Measured in Treated Mine Effluent from Snap Lake Mine, June 2004 to October 2012



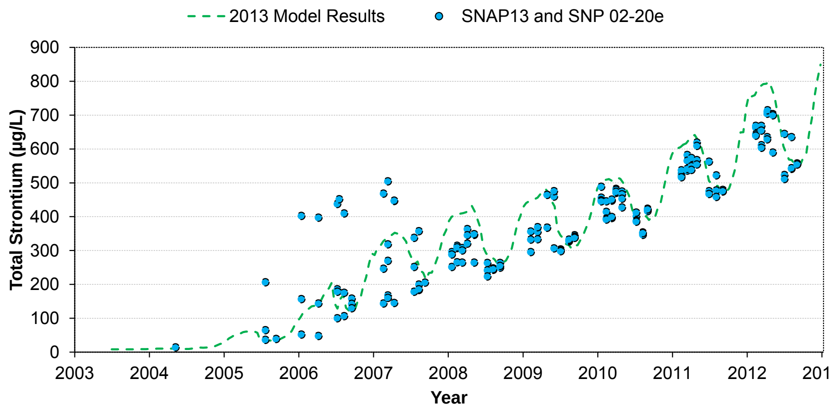
Monthly Avg = monthly average; SNP 02-17 = treated effluent from the temporary water treatment plant; SNP 02-17B = treated effluent from the permanent water treatment plant; SNP = Surveillance Network Program; µg/L = micrograms per litre.

Total strontium concentrations have been increasing in Snap Lake since Mine operations began in 2005 (Figure 4-2). Baseline strontium concentrations in the main basin of Snap Lake ranged from 7.3 to 13.3 µg/L in 1998 and 2001; in 2012, strontium concentrations peaked at 716 µg/L in the diffuser area, and were approximately 500 to 700 µg/L in the rest of the lake. Modelling completed in 2013 (De Beers 2013d) indicated that predicted total strontium concentrations in Snap Lake from 2013 until planned Mine closure would range from an average of 2,000 to 3,000 µg/L under Lower Bound Scenarios and from an average of 2,500 to 4,000 µg/L under Upper Bound Scenarios (Figure 4-3).

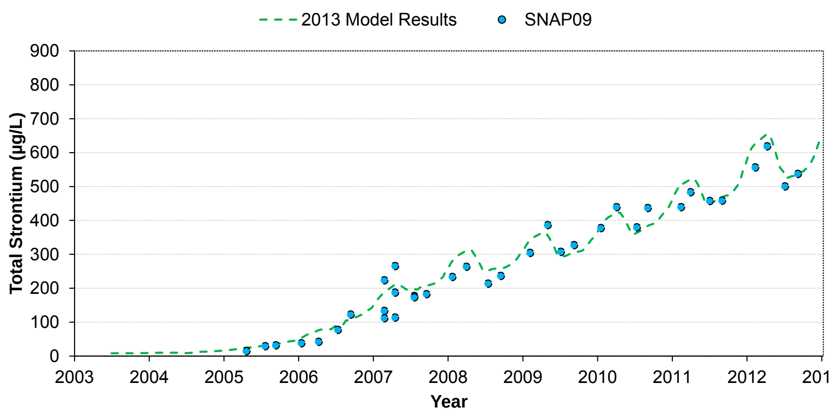
Background strontium water concentrations in the area around Snap Lake are typically less than 15 µg/L. In contrast, the World Health Organization (WHO 2010) reported that natural strontium concentrations ranged from 1 to 13,600 µg/L in European rivers (median concentration of 110 µg/L), and from 400 to 1,500 µg/L in surface waters in the United States.

Figure 4-2 Strontium Concentrations in Snap Lake, 2004 to 2012

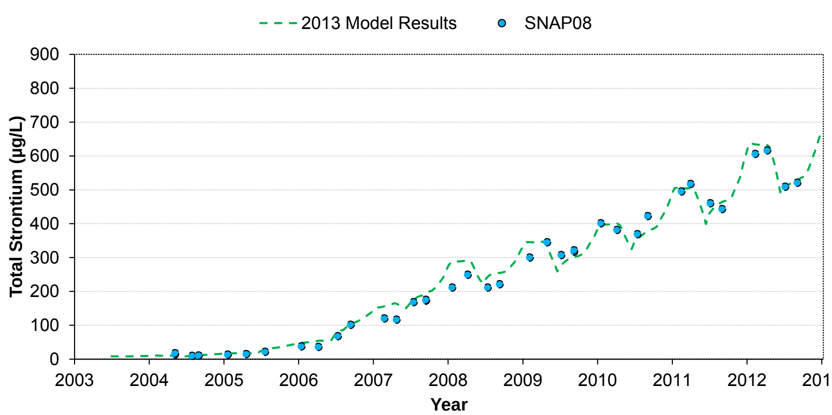
a. Diffuser Area



b. Main Basin



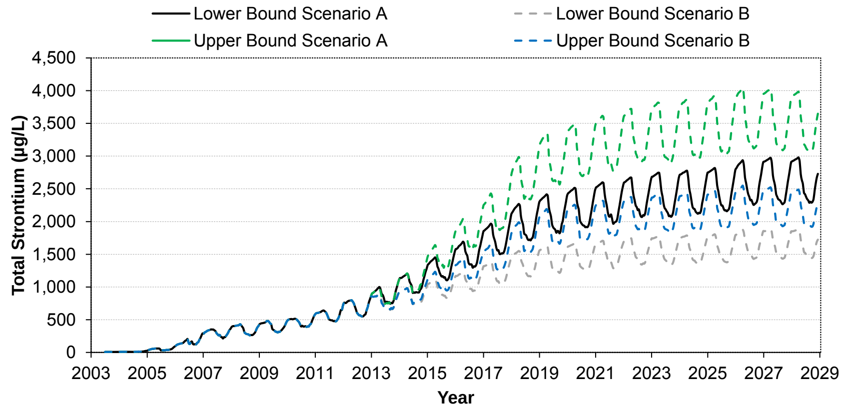
c. Outlet



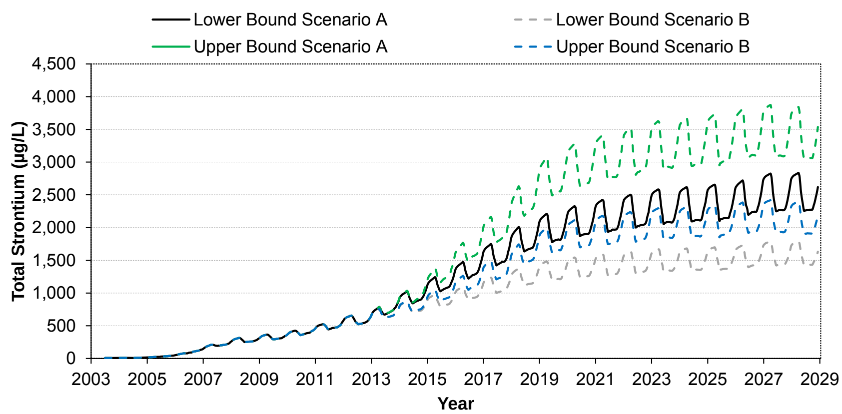
Note: Data shown are from representative stations within Snap Lake: Diffuser Area = SNAP13 (2004 to April 2006) and SNP 02-20e (July 2006 to 2012); Main Basin = SNAP09; Outlet = SNAP08; µg/L = micrograms per litre.

Figure 4-3 Predicted Total Strontium Concentrations in Snap Lake, 2004 to 2029

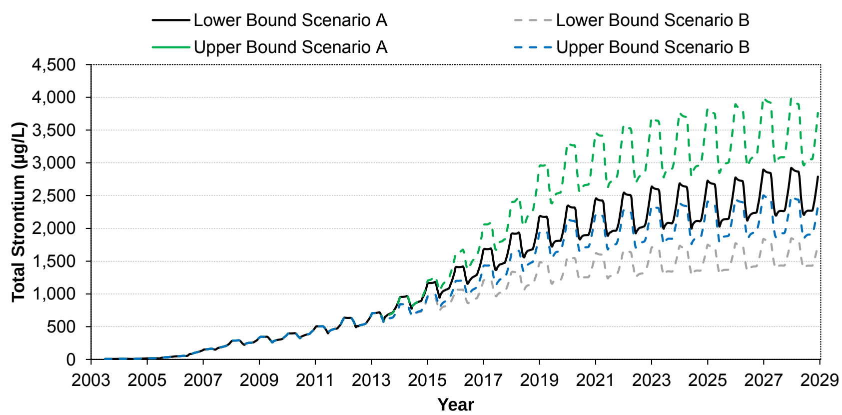
a. Diffuser Area



b. Main Basin



c. Outlet



Note: Data shown are from representative stations within Snap Lake: Diffuser Area = SNAP13 (2004 to April 2006) and SNP 02-20e (July 2006 to 2012); Main Basin = SNAP09; Outlet = SNAP08; µg/L = micrograms per litre.

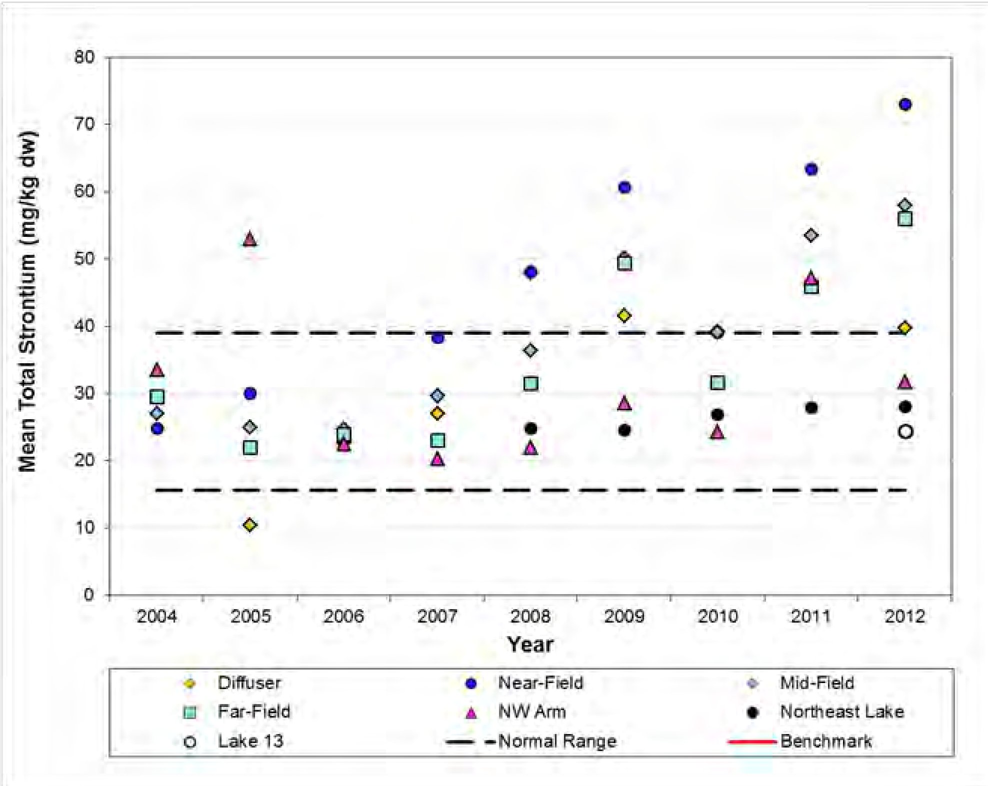
Mean concentrations of strontium have increased in Snap Lake sediments over time (Figure 4-4). The baseline lake-wide mean strontium concentration in Snap Lake sediments in 1999 and 2004 was 27.2 milligrams per kilogram (mg/kg) dry weight (dw). Since 2006, mean sediment concentrations have increased in the diffuser and main basin (formerly near-field, mid-field, and far-field) areas. Mean concentrations have fluctuated in northwest arm sediments. The 2012 lake-wide mean strontium concentration in Snap Lake sediments was 58.2 mg/kg dw, and individual stations ranged from 24.2 to 84.4 mg/kg dw. In contrast, mean strontium concentrations in reference lake sediments were similar to baseline Snap Lake sediment concentrations: 28.0 mg/kg dw in Northeast Lake; and, 24.5 mg/kg dw in Lake 13 in 2012.

Mean concentrations of strontium measured in muscle tissue from Lake Trout (*Salvelinus namaycush*) and Round Whitefish (*Prosopium cylindraceum*) captured from Snap Lake and two reference lakes in 1999, 2004, and 2009 are shown in Figure 4-5. For Lake Trout, strontium concentrations in Snap Lake fish were lower in 2004 than in 1999 and then increased in 2009, but were not as high as strontium concentrations in fish from the reference lakes. For Round Whitefish, strontium concentrations in Snap Lake fish were similar in 1999 and 2009, but lower in 2004; no Northeast Lake fish data were available from 2009 for comparison, but the concentrations measured in 1999 and 2004 Reference Lake fish were higher than fish from Snap Lake in both those years.

Mean concentrations of strontium measured in carcasses[2] of Lake Chub (*Couesius plumbeus*) captured from Snap Lake and two reference lakes in 2012 were 49.6 mg/kg wet weight (ww) for fish from Snap Lake, as compared to mean concentrations of 39.6 and 33.3 mg/kg ww for Northeast Lake and Lake 13, respectively. The mean concentration for Snap Lake fish was within the local normal range calculated based on reference lake concentrations. These studies show that Snap Lake fish are not accumulating elevated strontium concentrations.

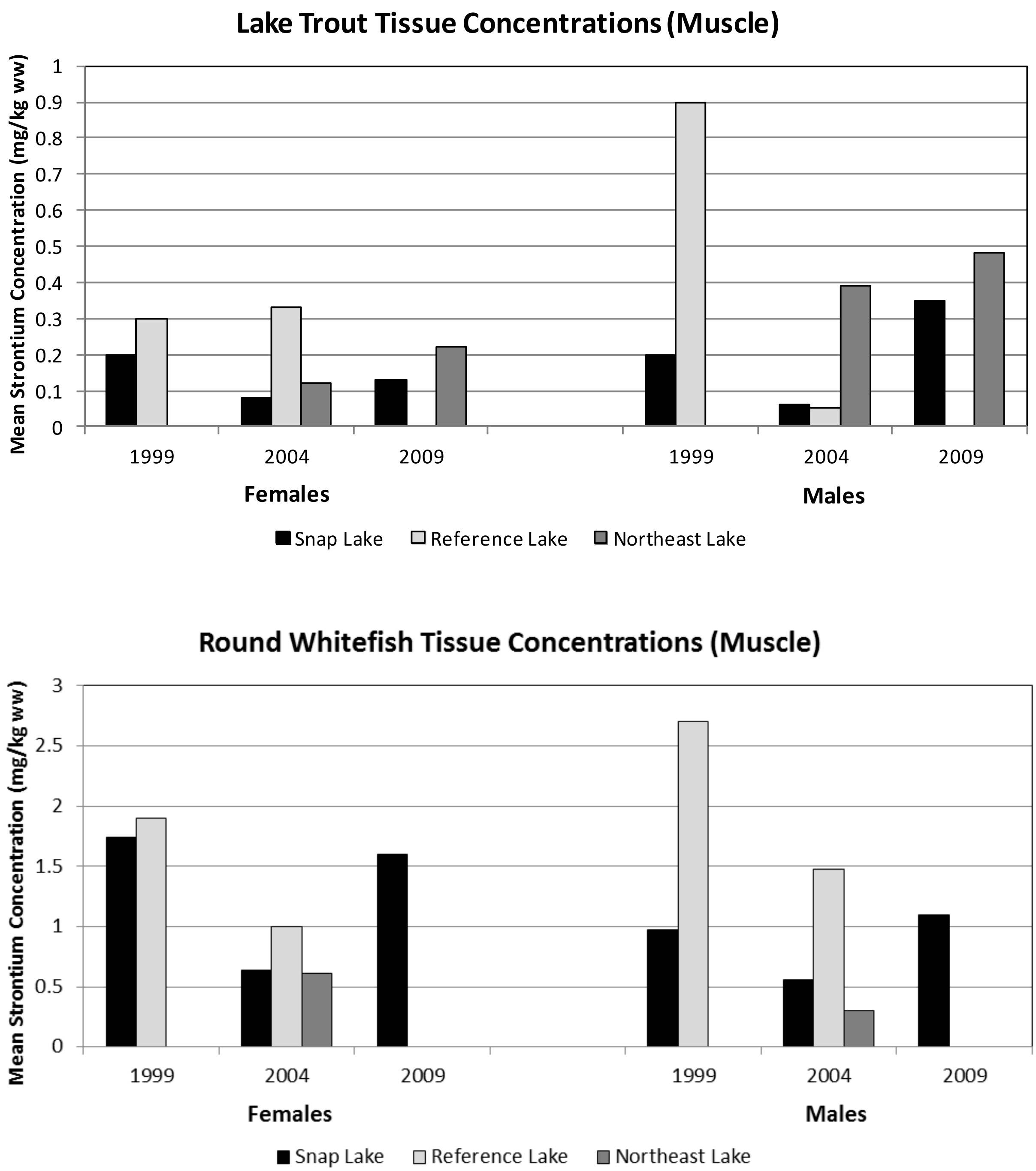
[2] Carcasses consisted of flesh and bone, but not viscera, liver, or gonad tissues.

Figure 4-4 Strontium Concentrations in Sediments in Snap Lake from 2004 to 2012, in Northeast Lake from 2008 to 2011, and in Lake 13 in 2012



Note: mg/kg dw = milligrams per kilogram dry weight; normal range is based on baseline data collected in 2004, with the upper and lower range calculated as the mean ± 2 standard deviations.

Figure 4-5 Strontium Concentrations in Muscle Tissue of Lake Trout (top panel) and Round Whitefish (bottom panel) in Snap Lake and Two Reference Lakes in 1999, 2004, and 2009



mg/kg ww = milligrams per kilogram wet weight

Derivation of the Site-Specific Water Quality Objective for Strontium

Available data on the acute and chronic toxicity of strontium to freshwater aquatic life were reviewed and compiled (De Beers 2013c). No studies on the toxicity of strontium in freshwater sediments were identified. Acute toxicity occurred at strontium concentrations ranging from 75,000 to 15,000,000 µg/L; fish and invertebrates exhibited similar acute toxicity to strontium. Only chronic studies were considered for development of the chronic effect benchmarks (CEB).

Two chronic toxicity studies were identified as contributing uncertainty to the strontium CEB determination. Birge (1978) and Birge et al. (1980) reported 28-d Rainbow Trout test results that were orders of magnitude lower than other test results performed with a range of aquatic species, and Borgmann et al. (2005) reported 7-d *Hyalella azteca* test results that did not use high enough strontium concentrations to calculate point estimates. Additional Rainbow Trout early life stage (ELS) tests were conducted to determine whether the Birge results were reproducible, and additional testing with *Hyalella azteca* was performed to determine sensitivity to higher strontium concentrations (Nautilus 2012, 2013).

Chronic toxicity tests with three species were excluded from the CEB calculation. Goldfish (Birge 1978; Birge et al. 1979) are not found in Snap Lake, are not native to North America, and the tests from these studies produced results that overlapped with background strontium concentrations (i.e., were questionable).

The Birge (1978) and Birge et al. (1980) tests with Rainbow Trout were not reproducible, also overlapped background concentrations, and had previously been considered unreliable. These two studies also reported results for testing of other metals, in addition to strontium. The United States Environmental Protection Agency's (USEPA) water quality criteria for aluminum, arsenic, cadmium, chromium, copper, and selenium listed these two studies as 'other data' not included in the datasets used for criteria derivation; no reason was given for this exclusion. Ecometrix (2011) stated: "There is evidence for other metals that the Birge et al. tests are not reproducible…confidence in the trout result is low." Thus, the more recent data for Rainbow Trout (Nautilus 2013) were used instead in the CEB calculation.

The *Hyalella azteca* tests by Borgmann et al. (2005), when redone using additional test concentrations and an additional endpoint, provided less uncertain data for this amphipod. The study design and data processing used by Borgmann et al. (2005) were such that clearly defined point estimates could not be determined and the responses that were reported were likely overly conservative because they were not corrected for potentially similar control responses. Ecometrix (2011) stated that these results, like the results of the studies by Birge and colleagues discussed above, were low outliers in the literature. In contrast, Nautilus (2012) reported that effects on *Hyalella* occurred at concentrations at least 30 times higher than those reported by Borgmann et al. (2005). These more recent data were used in the CEB calculation.

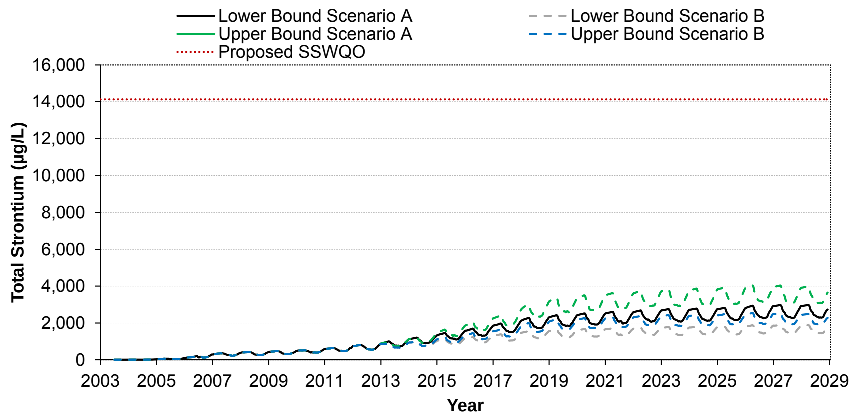
Data from 10 chronic studies with 12 species (representing 4 fish, 7 invertebrates, and 1 algal species) were used to generate a species sensitivity distribution (SSD) for strontium, and the associated CEB of 14,130 µg/L (De Beers 2013c). This CEB is a more realistic chronic threshold than the SSWQO of 500 µg/L calculated by Ecometrix (2011) using the geometric mean of the unreliable (as demonstrated in repeat testing) Birge et al. (1980) and Borgmann et al. (2005) studies. This CEB of 14,130 µg/L is conservative when considered relative to the endpoints used to generate it. The six lowest endpoints used to generate this chronic threshold ranged from approximately 16,000 to 71,000 µg/L and were calculated from point estimates that represented effect levels between 10 and 20%, with the majority being 10% effect levels. This CEB is also lower than the chronic threshold of 21,000 µg/L adopted for strontium by Michigan and Ohio in the US (MDEQ 2008; Ohio EPA 2009) and subsequently by Quebec (Chowdhury and Blust 2012).

Modelling completed in 2013 (De Beers 2013d) indicated that total strontium concentrations in Snap Lake were predicted to range from an average of 2,000 to 3,000 µg/L under Lower Bound Scenarios and from an average of 2,500 to 4,000 µg/L under Upper Bound Scenarios (Figure 4-6), which is well below the SSWQO of 14,130 µg/L proposed for strontium in Snap Lake.

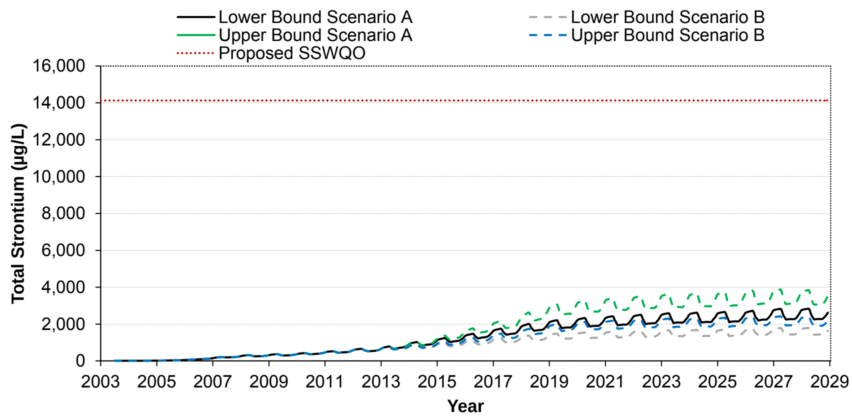
Calcium and strontium share many common pathways; strontium uptake and toxicity decrease as calcium concentrations increase (Blust 2011; Chowdhury and Blust 2012). This was evident in the results reported by Nautilus (2013) for Rainbow Trout ELS tests at two different water hardness concentrations; strontium was less toxic at the higher hardness. Calcium concentrations, as a major component of TDS, are increasing in Snap Lake. Thus, it is considered unlikely that there is an imminent or future hazard to aquatic life in Snap Lake from strontium toxicity.

Figure 4-6 Predicted Total Strontium Concentrations in Snap Lake Compared to the Site-Specific Water Quality Objective, 2004 to 2029

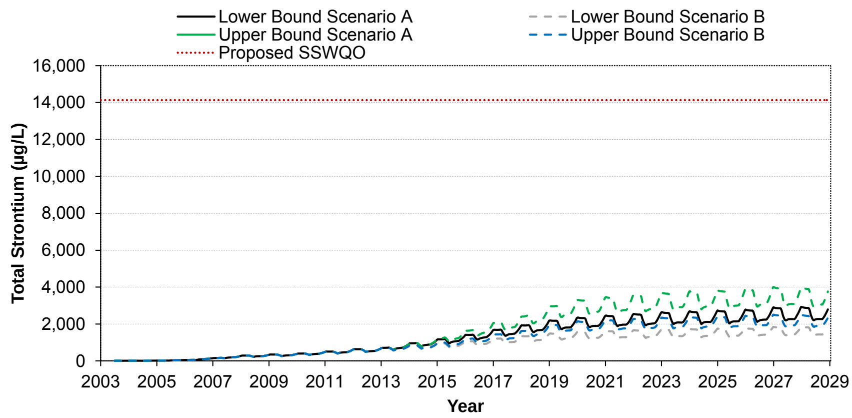
a. Diffuser Area



b. Main Basin



c. Outlet



Note: Data shown are from representative stations within Snap Lake: Diffuser Area = SNAP13 (2004 to April 2006) and SNP 02-20e (July 2006 to 2012); Main Basin = SNAP09; Outlet = SNAP08; µg/L = micrograms per litre; SSWQO = site-specific water quality objective.

5 FURTHER ACTIONS TO BE TAKEN IN RESPONSE TO INCREASING LEVELS OF STRONTIUM IN SNAP LAKE

No further actions will be taken by the Mine at this time in response to increasing concentrations of strontium in Snap Lake because, as described in Section 4, the evidence does not indicate that there is a present or future risk of strontium to the aquatic life of Snap Lake:

- samples of fish tissue from Snap Lake and reference lakes, which showed that strontium concentrations in fish tissues from Snap Lake were lower than or within the normal range of strontium concentrations in fish tissues from reference lakes;
- a collection of chronic strontium toxicity literature and completion of strontium toxicity tests, which allowed for the development of a proposed SSWQO for strontium in Snap Lake of 14,130 µg/L; and,
- modelling completed by De Beers (2013b,d), which indicated that strontium concentrations in Snap Lake were predicted to remain well below the proposed SSWQO (i.e., worst-case average strontium concentrations of 4,000 µg/L).

The Aquatic Effects Monitoring Program Response Framework outlines Action Levels should parameter concentrations increase to levels that may be of concern (De Beers 2012). Strontium concentrations will continue to be monitored; should an action level be triggered, follow-up actions may include special studies approved by the MVLWB, mitigation, and/or treatment studies.

6 CONCLUSIONS

Strontium is present in the granite, metavolcanic, and kimberlite rocks at Snap Lake (De Beers 2002). Because strontium concentrations in Snap Lake are increasing, De Beers initiated studies to investigate the potential effects of elevated strontium concentrations on aquatic life in Snap Lake for the purpose of developing a SSWQO. As a result of the studies, the proposed SSWQO for strontium is 14,130 µg/L.

Modelling completed by De Beers (2013b,d) indicated that strontium concentrations in Snap Lake are predicted to remain below the SSWQO throughout the life of the Mine. Under the worst-case modelling scenario, average strontium concentrations are predicted to increase to 4,000 µg/L by 2028.

No further actions will be taken by the Mine at this time in response to increasing concentrations of strontium in Snap Lake because the evidence does not indicate that there is a present or future risk from strontium to the aquatic life of Snap Lake. The Aquatic Effects Monitoring Program Response Framework outlines Action Levels should parameter concentrations increase to levels that may be of concern (De Beers 2012). Strontium concentrations will continue to be monitored; should an action level be triggered, follow-up actions may include special studies approved by the MVLWB, mitigation, and/or treatment studies.

7 REFERENCES CITED

Birge WJ. 1978. Aquatic toxicology of trace elements of coal and fly ash. In Thorp JH, Gibbons JW (eds), Energy and Environmental Stress in Aquatic Systems: Selected Papers From a Symposium Held at Augusta, Georgia, November 2-4, 1977. Dep Energy Symp Ser 48: 219-240.

Birge WJ, Black JA, Westerman AG. 1979. Evaluation of aquatic pollutants using fish and amphibian eggs as bioassay organisms. In Nielsen SW, Migaki G, Scarpelli DG (eds), Animals as Monitors of Environmental Pollutants. National Academy of Science, Washington, DC, USA, pp 108-118.

Birge WJ, Black JA, Westerman AG, Hudson JE. 1980. Aquatic toxicity tests on inorganic elements occurring in oil shale. In Gale C (ed), EPA-600/9-80-022, Oil Shale Symposium: Sampling, Analysis and Quality Assurance, March 1979, USEPA, Cincinnati, OH, USA, pp 519-534.

Blust R. 2011. E-mail personal communication with Peter Chapman (Golder Associates Ltd.), October 31, 2011.

Borgmann U, Couillard Y, Doyle P, Dixon DG. 2005. Toxicity of sixty-three metals and metalloids to *Hyalella azteca* at two levels of water hardness. Environ Toxicol Chem 24: 641-652.

Chowdhury MJ, Blust R. 2012. Strontium. In Wood CM, Farrell AP, Brauner CJ (eds), Homeostasis and Toxicology of Non-Essential Metals. Volume 31B, Fish Physiology Series. Elsevier, New York, NY, USA. pp 351-390.

De Beers (De Beers Canada Inc.). 2002. Snap Lake Diamond Project. Submitted to the Mackenzie Valley Land and Water Board (MVLWB), Yellowknife, NWT, Canada.

De Beers. 2012. DRAFT – 2013 Aquatics Effects Monitoring Program Design Plan in Support of Water Licence (MV2011L2-0004), Snap Lake Project. Snap Lake Project. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

De Beers. 2013a. 2012 Annual Report in Support of the Aquatic Effects Monitoring Program Water Licence (MV2001L2-0002), Snap Lake Project. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

De Beers. 2013b. Snap Lake Site Model Water Quality Report. Submitted to the Mackenzie Valley Environmental Impact Review Board, Yellowknife, NWT, Canada.

De Beers. 2013c. Development of Strontium Chronic Effects Benchmark for Aquatic Life in Snap Lake. Submitted to De Beers Canada Inc. Yellowknife, NWT, Canada.

De Beers. 2013d. Snap Lake Hydrodynamic and Water Quality Model Report. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

Ecometrix. 2011. Suggested Effluent Quality Criteria for the Snap Lake Diamond Mine. Memorandum from Don Hart and Ian Collins (Ecometrix Inc.) to the MVLWB, Yellowknife, NWT, Canada. October 19, 2011.

IDEM (Indiana Department of Environmental Management). 2001. Tier II Acute and Chronic Aquatic Life Values. Strontium. Office of Water Quality, Water Quality Standards Section, Indianapolis, IN, USA.

Itasca Denver, Inc. 2013. Predicted TDS Concentration in Mine Water Discharge Based on Calculated TDS Values. Submitted to: De Beers Canada Inc., Yellowknife, NWT, Canada.

Khangarot BS, Ray PK. 1989. Investigation of correlation between physicochemical properties of metals and their toxicity to the water flea *Daphnia magna* Straus. Ecotox Environ Saf 18: 109-120.

Khangarot BS. 1991. Toxicity of metals to a freshwater tubificid worm, *Tubifex tubifex* (Müller). Bull Environ Contam Toxicol 46: 906-912.

MDEQ (Michigan Department of Environmental Quality). 2008. Rule 57 Water Quality Values 2008-12-10. Surface Water Quality Assessment Section.

MVLWB (Mackenzie Valley Land and Water Board). 2013. Mackenzie Valley Land and Water Board Water License # MV2011L2-0004. Yellowknife, NWT, Canada.

Nautilus (Nautilus Environmental). 2012. Evaluation of the Chronic Toxicity of Strontium to *Hyalella azteca*. Laboratory report for Golder Associates Ltd., Burnaby, BC, Canada. November 26, 2012.

Nautilus. 2013. Evaluation of the Chronic Toxicity of Strontium to Early Life Stages of Rainbow Trout. Laboratory report for Golder Associates Ltd., Burnaby, BC, Canada. January 11, 2013.

Ohio EPA (Environmental Protection Agency). 2009. Lake Erie Basin Aquatic Life and Human Health Tier I Criteria, Tier II Values and Screening Values (SV). Chapter 3745-1 of the Ohio Administrative Code. Division of Surface Water.

WHO (World Health Organization). 2010. Strontium and Strontium Compounds. Concise International Chemical Assessment Document 77. World Health Organization, Geneva, Switzerland.