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28 February 2003

Mackenzie Valley Environmental Impact Review Board (MVEIRB)
Box 938, 5102 – 50th Avenue
Yellowknife, NT X1A 2N7

Attention: Glenda Fratton, Environmental Assessment Coordinator

Dear: Glenda

SUBJECT: Potential Overall Effects of the Changes in Water and Sediment on the Aquatic Communities of Snap Lake

Please accept the attached technical memo titled "Snap Lake Diamond Project - Potential Overall Effects of the Changes in Water and Sediment on the Aquatic Communities of Snap Lake" for submission to the Public Registry. This memo was compiled in response to issues raised by Dogrib Treaty 11 Council and Indian and Northern Affairs Canada (INAC) during the MVEIRB Technical Sessions.

Additionally, information contained within this memo should address the outstanding concerns identified by INAC in their Request for Ruling to the Board dated 22 January 2003.

Should you have any questions, please feel free to contact the undersigned.

Sincerely,
SNAP LAKE DIAMOND PROJECT

ORIGINAL SIGNED BY

Robin Johnstone
Senior Environmental Manager

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TECHNICAL MEMORANDUM

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TO:	Robin Johnstone De Beers Canada Mining Inc.	**DATE:**	February 28, 2003
FROM:	Dawn Kelly and Rick Schryer	**JOB NO:**	03-1322-017/5410
Prepared By:	Geetha Ramesh, Stella Swanson and Rick Schryer		
RE:	Snap Lake Diamond Project - Potential Overall Effects of the Changes in Water and Sediment on the Aquatic Communities of Snap Lake		

1.0 INTRODUCTION

The environmental assessment report (EAR) for the De Beers Snap Lake Diamond Project predicts changes to nutrients (phosphorus), algal biomass (chlorophyll a), total dissolved solids (TDS), dissolved oxygen (DO) and metals (cadmium and hexavalent chromium) in Snap Lake (De Beers 2002) as a result of the treated water discharge. Considered individually, the changes were not predicted to alter the overall integrity of the aquatic ecosystem of Snap Lake. However, during the Mackenzie Valley Environmental Impact Review Board (MVEIRB) Technical Sessions on the EAR conducted in November and December 2002, issues were raised regarding the potential for these individual changes to have a combined or interactive effect on the aquatic ecosystem of Snap Lake.

This document addresses the potential for combined effects of changes in water and sediment quality in Snap Lake.

2.0 SCOPE AND OBJECTIVES

This technical memorandum has two objectives:

- to identify changes in the aquatic environment of Snap Lake due to the treated effluent discharge; and
- to examine the potential for combined effects of these changes.

The following resources were used:

- baseline information from the EAR (De Beers 2002) on the physical, chemical and biological characteristics of Snap Lake;
- quantitative predictions of cadmium, chromium, TDS, calcium and chloride loading, using the GoldSim model, conducted for the EAR (De Beers 2002); and
- technical memoranda submitted to the public registry on TDS, trophic change, mine water discharge and dissolved oxygen.

3.0 IDENTIFYING CHANGES IN SNAP LAKE

The following section identifies the changes in Snap Lake and gives a brief account of the potential impact of these changes to the aquatic ecosystem. A more detailed account of each the changes listed below is available on the public registry in separate Technical Memoranda. They include:

- Snap Lake Diamond Project - Dissolved Oxygen Baseline for Snap Lake – 2003 Program
- Snap Lake Diamond Project - Snap Lake Algal Modelling Update
- Potential Effects of Increased Total Dissolved Solids on Aquatic Communities in Snap Lake
- Snap Lake Diamond Project - Mine Water Assessment and Variability

3.1 PRIMARY PRODUCTIVITY

The current concentration of phosphorus is moderately low in Snap Lake water and within the range typically observed in other lakes in the region (Puznicki 1996; Pienitz et al. 1997). Mean total phosphorus (TP) concentrations in Snap Lake ranged from 4 to 12 micrograms per litre (µg/L) among three years of baseline study. The trophic status of Snap Lake is in the upper oligotrophic to lower mesotrophic (oligo-mesotrophic) range based on the results of technical memorandum submitted by De Beers to the public registry on trophic change where all trophic indicators were considered. Based solely on chlorophyll a (open water average 0.8 ug/l), Snap Lake can be classified as oligotrophic (<2.5 ug/l). This indicates that the lake has a moderately low biological productivity under baseline conditions.

As detailed in the algal modelling Technical Memorandum (see public registry), predicted mean, open water phosphorus concentrations for the EA Case, the upper loading scenarios and the maximum potential loading scenarios for years 17-19 (13-22 ug/L) fall within the lower to middle range of the mesotrophic conditions. Predicted mean, open water chlorophyll a concentrations for all cases in years 17 through 19 (1.5-2.2 ug/L) fall within the range of oligotrophic conditions. Years 17 through 19 were selected because they are representative of the period of maximum concentrations in Snap Lake. These concentrations are within the accepted range for oligo-mesotrophic lakes. The baseline phytoplankton community in Snap Lake is characteristic of an oligo-mesotrophic lake and therefore a major shift in community structure is unlikely to occur because the predicted change in primary productivity remains within the same trophic range. Zooplankton biomass may increase due to the change in primary productivity but overall community structure should not be affected because of the level of change to primary productivity anticipated and the inefficiency of energy transfers among trophic levels. In addition, the baseline zooplankton community in Snap Lake is characteristic of a mesotrophic lake and therefore a major shift in community structure is unlikely to occur because the predicted change in primary productivity remains near the same trophic range. Benthic invertebrates may or may not respond to the increase in primary productivity, although any changes that may occur would be minor.

No major changes in food availability to fish inhabiting Snap Lake are anticipated. In general, all of the fish species in Snap Lake feed upon benthic invertebrates and/or zooplankton. Lake trout, burbot, and Arctic grayling become generalized "opportunistic" feeders as they grow/age, such that they include fish in their diet (*i.e.*, become more piscivorous with size). An increase in the biomass of either zooplankton or benthic invertebrates may occur which would increase foraging opportunities for fish, however, the community structure of both zooplankton or benthic invertebrates will not likely be altered.

Overall, it is expected that the integrity and function of the aquatic ecosystem in Snap Lake will remain intact for the range of phosphorus loadings evaluated (the EA Case, the upper loading scenarios and the maximum potential loading scenarios). The most likely effect will be an increase in algal biomass and, to a lesser extent, zooplankton and benthic invertebrate biomass, with no loss of species richness in Snap Lake, and no changes to the overall oligo-mesotrophic status of the lake.

3.2 Total Dissolved Solids (TDS)

Effects of increased TDS were examined for phytoplankton, zooplankton, benthic invertebrates, and fish in Snap Lake. Expected changes in Snap Lake are addressed for the period of mine construction and operation as well as for post-closure.

Chloride and calcium are the principal constituent ions that will increase TDS in Snap Lake during mine operation and construction. There are no Canadian Council of Ministers of the Environment (CCME) water quality guidelines or site-specific water quality benchmarks established for TDS, calcium and chloride (CCME 2002). However, there is a United States Environmental Protection Agency (EPA) criterion for chloride as well as one for the province of Quebec.

The maximum predicted concentration of chloride in Snap Lake is below the EPA and Quebec water quality criterion of 230 mg/L (U.S. EPA 1988). This criterion is intended to prevent significant toxic effects in chronic exposures when chloride is associated with sodium. This criterion may not be adequately protective when the chloride is associated with potassium, calcium, or magnesium (U.S. EPA 1988).

The average baseline concentrations for calcium and chloride are very low at 1.34 mg/L and <0.2 mg/L, respectively. The proposed Snap Lake Diamond Project is expected to raise lake-wide water-column calcium concentrations to a maximum of 88 mg/L in Snap Lake during winter ice cover. The maximum concentration of calcium is expected to be 113 mg/L in 1% (*i.e.*, within

250 m of the diffuser) of the lake area during the summer. The 113 mg/L maximum concentration is a product of effluent concentration and wind dynamics in years 15-25. The maximum lake-wide chloride concentration is expected to reach 137 mg/L in Snap Lake during the winter. Chloride concentration in 1% (*i.e.*, within 250 m of the diffuser) of Snap Lake during the summer months is expected to reach 177 mg/L.

Increased TDS in Snap Lake during mine construction and operations is expected to have a negligible impact on resident aquatic communities. Based on a review of the literature, phytoplankton and benthic invertebrates are tolerant of the TDS levels expected in Snap Lake and no toxicity impacts are predicted to occur. Salinity ranges and optima of dominant genera and species indicate that major shifts in community composition would not occur, although the relative abundance of phytoplankton and benthic invertebrate species may change slightly (for citations see Technical Memorandum on TDS on public registry). Increased TDS concentrations may cause a minor change in zooplankton community structure due to the stimulation of growth of calcium-limited species or the inhibitory effects of TDS constituents on some species; however, the increase in TDS will be gradual enough to allow ample opportunity for communities to adapt (for citations see Technical Memorandum on TDS on public registry).

Laboratory toxicological studies on salmonids indicate lake trout will not be adversely affected by increased TDS concentrations (for citations see Technical Memorandum on TDS on public registry). These laboratory results are supported by field observations of lake trout populations in high TDS lakes (>300 mg/L for citations see Technical Memorandum on TDS on public registry). Salmonids are able to acclimate to higher TDS and the slow increase in TDS in Snap Lake will provide sufficient time to allow lake trout to acclimate (for citations see Technical Memorandum on TDS on public registry). No major changes in diet are expected, although higher TDS may result in greater abundance of zooplankton, providing more food for plankton feeding fish and juvenile lake trout. Juvenile and adult lake trout have flexible diets and are able to opportunistically prey on a wide range of organisms (for citations see Technical Memorandum on TDS on public registry).

In conclusion, the expected increase in TDS is well within ranges seen in other Canadian lakes with lake trout populations (for citations see Technical Memorandum on TDS on public registry). No toxicological effects to fish in Snap Lake are predicted. Invertebrate communities are predicted to remain diverse and may slightly increase in abundance. Gradual, subtle changes in the relative abundance and dominance of some zooplankton species may be seen if some species are better able to utilize the available calcium.

3.3 Dissolved Oxygen

During winter, nitrification of ammonia (conversion from ammonia to nitrites and nitrates via the addition of oxygen) and breakdown of organic matter by bacteria have the potential to alter the natural dissolved oxygen (DO) regime in Snap Lake. DO measurements were taken from Snap Lake during February 2003 (see DO Technical memorandum on public registry). Under current conditions, DO concentrations were high near the surface at all sampling sites and concentrations remained above the CCME guideline for coldwater fish (6.5 mg/L) throughout the water column in 29 of the 50 sampling locations. However, DO concentrations in the lower portion of the water column were below the CCME guideline for coldwater fish in 21 of the 50 sampling locations in Snap Lake in 2003. The winter baseline study results show that DO concentrations below 3.0 mg/L near the lake bottom (i.e., 0.25 or 0.5 m above sediments) were encountered in ten of the 50 sample sites. Fish are known to avoid areas with low DO. Thus fish in Snap Lake likely migrate to suitable overwintering habitat in other areas of the lake. This behaviour is expected to continue during mine operations.

Although the physiological DO limits for the benthic invertebrates inhabiting the deep waters of Snap Lake are not known, it can be presumed from the February 2003 DO data that any species present in these areas are adapted to, or extremely tolerant of, low DO conditions. Several deep waters of Snap Lake were observed to have DO levels at or below 1 mg/L. The field survey was conducted in February. Ice cover does not leave Snap Lake until mid-June. Consequently, under natural conditions, with at least three more months for decomposition to further reduce oxygen levels in the deep waters of Snap Lake, DO will likely decrease further. Since the lower limit of DO requirements for these benthic species is not known, a conservative estimate is that some benthic invertebrate species may be affected by an additional reduction of 1 to 2 mg/L during mine operations. This effect would be limited in its spatial extent.

3.4 Metals

Predicted cadmium concentrations were above the conservatively derived benchmark where 5% of aquatic species may be affected (the HC5) in less than 1% of Snap Lake. The impact to aquatic biota is considered negligible since the HC5 benchmark is below any known lowest observable effect concentration (LOEC) and the area affected is very small. The potential for the bioaccumulation of cadmium and other metals in fish was calculated and found to be negligible (EAR Section 9.5.2.4).

Hexavalent chromium concentrations in the combined discharge were predicted to exceed the HC10 benchmark (where 10% of species may be affected) in less than 0.1% of Snap Lake and the HC5 benchmark in less than 1% of Snap Lake. The impact from hexavalent chromium to aquatic organisms was classified as negligible in the EAR because of the very small area affected and the conservative nature of the effect benchmarks.

Aquatic organisms could also be exposed to hexavalent chromium through sediments, since chromium present in fine particulate matter is expected to settle to the bottom. To provide conservative estimates of impact magnitude in the EAR, Snap Lake sediment and pore water concentrations were assumed to be similar to water column concentrations. The magnitude of the impact of hexavalent chromium on phytoplankton, zooplankton and benthos via sediments was predicted to be negligible in the EAR (Section 9.5).

4.0 PREDICTION OF RISK FROM MULTIPLE STRESSORS IN SNAP LAKE

4.1 Definition of Multiple Stressors

The phrase "multiple stressors" is often used to describe a situation where several changes in environmental parameters (such as water or sediment quality) are predicted. The term "stressor" is usually associated with a change that causes a negative response in an organism. However, this document uses a broad definition of "stressor" as any change in a parameter from a baseline condition. Stressors can be chemical (e.g., a change in metal concentrations), physical (e.g., a change in water temperature or sediment texture) or biological (e.g., change in algal biomass). This definition includes the possibility that almost every stressor may be stimulatory as well as inhibitory. For example, an increase in nutrients in a lake where nutrients are limiting will be stimulatory. The ultimate consequence of this stimulation on the lake ecosystem will depend upon the nature of the changes in the primary producer community; however, small increases in nutrients are rarely associated with overall negative effects at the ecosystem level. Similarly, increases in metal concentrations may not be sufficient to reach levels associated with toxicity and many metals are essential trace nutrients (and can thus be stimulatory in small quantities).

The combined effect of a stressor that is in the stimulatory range and a stressor in the inhibitory range is very difficult to predict. This difficult combination of stimulatory and inhibitory stressors is what is expected in Snap Lake. The state of the science of multiple stressors does not allow a quantitative prediction of the net effect of the combination of predicted stimulatory and inhibitory changes in Snap Lake.

The state-of-the-science in multiple stressor research has not progressed to the stage where there are accepted theories that can be used as the basis for prediction of effects (Foran and Ferenc 2000; Golder 2001, 2002). Therefore, the potential for cumulative effects from multiple stressors in Snap Lake can only be discussed in the most general terms.

4.2 Weight of Evidence Approach

A weight of evidence approach can be useful in situations where there are several predicted changes and multiple potential combinations of effects. Formal guidance for the use of the weight of evidence approach has recently been provided by the U.S. EPA in their Stressor Identification guidance manual (U.S. EPA 2000).

The weight of evidence approach uses several sources of information (or lines of evidence) in order to assemble as broad an understanding as possible of the cumulative effects of environmental changes. Each line of evidence is specific to a particular measurement of the status of the ecosystem (e.g. the number and type of species of phytoplankton; the growth of fish). A general, consistent scoring system is applied to each line of evidence, assigning a qualitative score describing the direction of the response (positive, negative or neutral) and the duration, extent and strength of that response. Symbols, numeric scores, or adjectives such as "high, medium, low" can be used in the weight of evidence summary table. This summary table can then be examined visually or numerically to provide an overall qualitative description of the cumulative effects of all of the predicted changes. These summary tables are similar to the familiar "Consumer Reports" style summary tables describing the performance of automobiles or other consumer products against several criteria.

Each line of evidence is examined for:

- the strength of the evidence for a cause/effect relationship between the stressor and the predicted response;
- the size of the areas affected by the change compared to the overall habitat size for the species of concern (*e.g.*, affected areas may be small relative to areas used by species that use the entire lake such as lake trout);
- the duration and frequency of exposure of the aquatic plants and animals to the predicted changes (continuous exposure over the entire life of an animal will produce different responses than occasional exposure over portions of the life of the animal); and
- direct effects from exposure to changes in water or sediment quality versus indirect effects via changes in habitat or food supply will alter population characteristics (such as birth rate and death rate).

The qualitative "sum" of predicted responses for each line of evidence then forms the basis for predicting cumulative effects on the sustainability of aquatic populations and communities. Some lines of evidence may be assigned a greater weight, particularly if there is a more rigorous scientific basis for that line of evidence or if there is greater ecological relevance.

Table 1 describes the predicted responses to changes in water quality in Snap Lake following the methodology provided in the Stressor Identification guidance manual (U.S. EPA 2001). Predicted changes in sediment quality are so minor that they are not considered further in this document.

Table 1
Summary of the Weight of Evidence of Cumulative Effects on the Sustainability of Populations and Communities

Ecological Endpoint	Phosphorus Increase	TDS Increase	DO Decrease in Winter in Deep Water	Cadmium Increase	Hexavalent Chromium Increase	Overall Effect
Phytoplankton Community Structure	↔	↔	↔	↔	↔	↔
Phytoplankton Productivity	❍	↔	↔	↔	↔	↔
Zooplankton Community Structure	↔	↔	↔	●	◘	◘
Zooplankton Productivity	❍	↔	↔	●	◘	◘
Benthic Invertebrate Community Structure	↔	↔	●	●	↔	↔
Benthic Invertebrate Productivity	❍	↔	●	●	↔	↔
Fish Populations	↔	↔	↔	↔	↔	↔
Fish Biomass	↔	❍	↔	↔	↔	↔

Legend:

↔	Neutral (no measurable effect)
❍	Small positive effect
❍ ❍	Moderate positive effect
❍ ❍ ❍	Strong positive effect
●	Small negative effect
● ●	Moderate negative effect
● ● ●	Strong negative effect
◘	Effect highly Uncertain because HC5 is less than LOEC for any test species

Definitions of effect ratings are as follows:

Small effects are those where:

- the strength of the evidence for a cause/effect relationship between the stressor and the organisms is weak; and/or
- the size of the affected area in Snap Lake is less than 1%; and/or
- there is a short or infrequent change in water or sediment quality; and/or
- effects are largely indirect (via shifts in habitat availability or food supply).

Moderate effects are those where:

- the strength of the evidence for a cause/effect relationship between the stressor and the organisms is quite strong because of adequate laboratory test data and field observations under similar circumstances; and/or

- the size of the affected area in Snap Lake is greater than 1% but less than 10%; and/or
- changes in water or sediment quality occur over more than one season of the year and are frequent; and/or
- effects are both direct and indirect

Strong effects are those where:

- the strength of the evidence for a cause/effect relationship between the stressor and the organisms is strong because of ample laboratory test data and several field studies conducted under analogous situations to those predicted for Snap Lake; and/or
- the size of the affected area in Snap Lake is greater than 10% of Snap Lake; and/or
- water or sediment quality changes occur year-round and are continuous; and/or
- effects are largely due to direct toxicity.

Following the US EPA guidance which results in the summary provided in the above table, it is apparent that the predicted concentrations of phosphorus, combined with a small and gradual increase in TDS, small decreases in DO in deep water during the winter and small increases in cadmium and chromium in a very small portion of the lake are unlikely to cause significant shifts in community structure or productivity in Snap Lake. This is because the changes in water quality parameters produce either neutral responses or small responses. However, this requires confirmation.

4.2.1 Confirming Predictions of Effects

Few tools exist for the scientific evaluation of the effects of multiple stressors and their limitations are well documented (Golder 2001). Monitoring is therefore critical to confirming the above predictions related to response to changes in nutrients, TDS, dissolved oxygen and selected metals. Detailed monitoring plans to confirm predictions will be developed as part of an overall aquatic effects monitoring program (AEMP) for the Snap Lake Diamond Project. However, perhaps the most straightforward approach to confirming the nature of the response to the multiple stressors in Snap Lake will be to combine toxicity testing with field monitoring. Toxicity tests conducted on "whole water" samples from Snap Lake will indicate whether the combination of chemical stressors in those water samples produce responses in the toxicant range in test organisms. Field monitoring could indicate whether indicator organisms such as benthic invertebrates are responding to the combination of chemical stressors and DO conditions. The toxicity test and field data lines of evidence would provide a useful "weight of evidence" for whether there are trends towards stimulatory or toxicant responses in the lake. Field surveys will need to focus on recognized and established endpoints (e.g. fish condition) in order for the weight of evidence approach to have the ability to detect trends towards either stimulatory or inhibitory responses.

5.0 REFERENCES

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