Evaluation of the Proposed Monitoring to Evaluate Mine-Related Effects in the Vicinity of the DeBeers Canada Mining Inc. Snap Lake Project

Report Submitted to:

Core Group
Snap Lake Environmental Monitoring Agency
c/o T.D. Pearse Resource Consulting
C-9 Wilkes Road
RR1, Site 6, Compartment 9
Mayne Island, British Columbia
V0N 2J0

Report Submitted - March, 2005 - by:

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Nanaimo, British Columbia
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Executive Summary

Several documents were reviewed on the environmental monitoring programs that are being developed and implemented for the Snap Lake Diamond Project, which is being built and operated by DeBeers Canada Mining Inc. (DCMI). The results of this review indicated that the proposed groundwater, aquatic effects, and water quality monitoring programs are likely to provide a great deal of valuable information. More specifically, the data and information generated in these monitoring programs are likely to meet the needs of regulatory instruments and contribute to verification of the accuracy of impact predictions, to evaluation of the effectiveness of mitigation measures, to establishment of thresholds or early warning signs, and to implementation of adaptive management strategies at the site. However, the proposed monitoring programs have a number of deficiencies that will need to be addressed to ensure that they provide the information needed under the terms of the Environmental Agreement and DCMI's Class A water licence, including:

- The groundwater monitoring program does not provide provisions for assessing the quality and quantity of connate groundwater and recharge water from Snap Lake independently. Therefore, it may not be possible to evaluate the accuracy of impact predictions or to identify emerging groundwater quality or quantity issues;

- The fish health baseline special study does not provide a basis for determining the concentrations of bioaccumulative chemicals of potential concern (COPCs) in fish whole-body tissue. In addition, a number of bioaccumulative COPCs were not targeted for analysis. Therefore, it may not be possible to assess the risks to aquatic-dependent wildlife associated with consumption of fish from Snap Lake or to evaluate cumulative environmental effects;

- The benthic invertebrate community baseline special study is not sufficiently robust to provide information that can be used to evaluate spatial or temporal variability. In addition, the study does not appear to be designed to facilitate the collection of matching

sediment chemistry and benthic invertebrate community structure data. Therefore, it will be difficult to detect changes in benthic invertebrate community structure over time and space, and it will be difficult to identify the causes of any effects that are observed;

- The zooplankton and phytoplankton special study does not provide sufficient detail to permit comprehensive evaluation of the proposed methods. In addition, the study design did not include a reference lake or sufficient within-station replication. Therefore, it will be difficult to assess spatial variability in conditions within Snap Lake and to discriminate between project-related effects and regional changes in conditions;

- The periplankton special study does not include a reference lake or sufficient within-station replication. In addition, the methods that were selected may not provide reliable data. Therefore, it will be difficult to estimate biomass at each station, to assess spatial variability in conditions within Snap Lake, and to discriminate between project-related effects and regional changes in conditions;

- The water quality monitoring program does not provide sufficient rationale to permit comprehensive evaluation of the proposed approach and methods. In addition, the study design did not include a reference lake, sufficient sampling effort in the first year, or sufficient within-station replication. Therefore, it will be difficult to assess spatial and temporal variability in water quality conditions within Snap Lake and to discriminate between project-related effects and regional changes in conditions;

- The sediment quality monitoring program does not provide sufficient rationale to permit comprehensive evaluation of the proposed approach and methods. In addition, the study design did not include a reference lake, sufficient sampling effort in the first year, sufficient within-station replication, or a full list of COPCs. Therefore, it will be difficult to assess spatial

and temporal variability in water quality conditions within Snap Lake and to discriminate between project-related effects and regional changes in conditions;

- The ongoing fish health, benthic invertebrate community, and phytoplankton monitoring programs have similar deficiencies to those identified for the corresponding special studies;

- Provisions for monitoring zooplankton populations and periphyton communities were not included in the aquatic effects monitoring program. Therefore, the data needed to assess mine-related effects on these important ecosystem components will not be acquired;

- The fish habitat monitoring program may not have sufficient sampling frequency to assess project-related effects. In addition, no information was provided on how the monitoring results would be used in an adaptive management framework; and,

- The quality assurance/quality control (QA/QC) plan does not provide sufficient information to fully support field sampling and associated laboratory analytical activities.

The nature and severity of the deficiencies in the various monitoring programs have the potential to jeopardize DDMI's ability to generate environmental monitoring data and information needed to satisfy the stated objectives of these initiatives. Therefore, it is recommended that the various monitoring plans be refined to address the concerns stated above (as detailed in the following sections of this report).

1.0 Introduction

The Snap Lake Diamond Project is located on Snap Lake in the Western Arctic, approximately 220 km northeast of Yellowknife. The owner/operator of the project, DeBeers Canada Mining Inc. (DCMI), was recently issued a Class A Water Licence (MV2001L2-0002) by the Mackenzie Valley Land and Water Board (MVLWB) to enable the company to conduct mining and a variety of associated activities at the site (63°35'30"N, 110°52'00"W). As one of the terms and conditions of the water licence, DCMI is required to undertake certain monitoring activities to determine the short- and long-term effects in the water environment resulting from the project, to evaluate the accuracy of impact predictions, to assess the effectiveness of planned impact mitigation measures, and to identify additional impact mitigation measures to reduce or eliminate environmental effects. Accordingly, DCMI must develop and implement an Aquatic Effects Monitoring Program (AEMP) that will support acquisition of the requisite data and information.

In addition to the provisions included in the water licence, the need to conduct monitoring activities in the vicinity of the project is also identified in the Environmental Agreement, which was established between the Government of Canada (Indian and Northern Affairs Canada), the Government of the Northwest Territories (Resources, Wildlife, and Economic Development), DCMI, Dogrib Treaty 11 Council, Lutsel K'e Dene Band, Yellowknives Dene First Nation, and North Slave Metis Alliance. More specifically, the Environmental Agreement indicates that environmental monitoring programs shall include activities to meet the monitoring requirements of all Regulatory Instruments, to verify the accuracy of impact predictions, to determine the effectiveness of mitigation measures, to establish thresholds or early warning signs, and to trigger action by adaptive management measures where appropriate. The Environmental Agreement also emphasizes the importance of considering traditional knowledge and involving Aboriginal Parties in the monitoring programs.

In accordance with the terms of the Environmental Agreement, a multi-project environmental monitoring agency (MPEMA) will be established. Pending establishment of the MPEMA, the Snap Lake Environmental Monitoring Agency (SLEMA) was assigned the responsibility of monitoring the project. Soon after its establishment, the SLEMA Core Group convened a Science Panel to assist it by reviewing and evaluating documentation related to environmental monitoring in the vicinity of the project. More specifically, the Science Panel is charged with the responsibility of providing the scientific and technical input needed by the SLEMA Core Group to provide adequate oversight of monitoring activities that are planned for and conducted in the vicinity of the Snap Lake Diamond Project.

This document represents one in a series of scientific and technical reviews of the documents that DCMI has prepared to support monitoring activities at the Snap Lake mine site. The documents that were reviewed include:

- Aquatic Effects Monitoring Plan (DCMI 2004a);
- Sampling Plan for Total Dissolved Solids, Calcium, and Chloride (DCMI 2004b);
- Groundwater Quantity and Quality Monitoring Program (DCMI 2004c); and,
- Quality Assurance and Quality Control (QA/QC) Plan (DCMI (2004d).

Detailed guidance for designing and implementing environmental monitoring programs has not been developed by the MVLWB or by any of the parties to the Environmental Agreement. In the absence of such specific guidance, the adequacy of these four documents was evaluated relative to the general requirements articulated in the water licence and the Environmental Agreement. In addition, various evaluations of DCMI's environmental assessment of the project were reviewed to identify the issues and concerns that needed to be addressed in the monitoring programs that are implemented at the site. Furthermore, various guidance documents that have been developed to guide monitoring activities in other jurisdictions were consulted to provide a basis for establishing a technical standard against which the proposed monitoring activities could be evaluated (e.g., USEPA 1997; 2000).

2.0 Environmental Issues and Concerns at the Snap Lake Mine Site

During the Environmental Assessment (EA), stakeholders identified a number of environmental issues and concerns related to the Snap lake Diamond Project. Some of the key issues and concerns that were identified included:

- The quantity of minewater from the facility could be greater than predicted in the EA, which would result in higher than anticipated discharges of wastewater to Snap Lake;
- The concentrations of certain substances (e.g., total dissolved solids, major ions, chloride, and phosphorus) in minewater from the facility could be higher than predicted in the EA, which would result in

larger than anticipated changes in surface water chemistry in Snap Lake;

- The baseline environmental quality data were insufficient to support statistical evaluations to identify subtle environmental impacts;
- The benchmarks that were used to predict the impacts of the project were derived using procedures that were inconsistent with those recommended by the Canadian Council of Ministers of the Environment, which resulted in benchmarks that were too high and in underestimates of the impacts of the project;
- The impacts of total dissolved solids (and associated major ions) were not adequately assessed;
- The impacts of the project on zooplankton populations in Snap Lake were not adequately evaluated;
- The nutrient modelling that was conducted to evaluate the potential for lake eutrophication was not adequate;
- The secondary impacts of lake eutrophication on aquatic organisms was not adequately evaluated; and,
- The cumulative environmental effects of the project were not adequately evaluated.

To be responsive to the terms and conditions of the water licence and the Environmental Agreement, the environmental monitoring programs that are designed and implemented in the vicinity of the Snap Lake Diamond Project must, at minimum, provide the information needed to address these key issues and concerns. Therefore, the adequacy of the proposed monitoring programs was evaluated relative to these information requirements.

3.0 Groundwater Quantity and Quality Monitoring Program

Under the terms and conditions of its water licence, DCMI is required to design and implement a groundwater quality and quantity monitoring program that:

- Describes the methods for monitoring groundwater quality and quantity as the working areas of the mine advance for comparison against predictions made in the EA report; and,

- Provides a means for managing groundwater quantities within the range of these predictions.

The groundwater monitoring program that was developed by the project proponent is described in DCMI (2004c). According to DCMI (2004c), the groundwater monitoring program is designed to provide information that will allow DeBeers to assess the mine water and seepage water quality for comparison against predictions made in the EA report and to comply with the water licence. The study design consists of two main elements, including underground mine water monitoring and seepage monitoring.

Underground mine water monitoring includes mine water quantity and mine water quality monitoring. To assess mine water quantity, water discharge from the mine will be continuously monitored at the final mine water collection sump (Surveillance Network Program SNP 02-01). Underground mine water quality will be monitored by continuously monitoring flow, temperature, pH, conductivity, and turbidity. In addition, weekly samples will be collected and analysed for pH, turbidity, total dissolved solids (TDS), chloride, total suspended solids (TSS), total ammonia and calcium, while monthly samples will be collected and analysed for pH, turbidity, TSS, conductivity, major ions, nutrients, total and dissolved metals, total mercury, total arsenic, extractable petroleum hydrocarbons, and BTEX (benzene, toluene, ethylbenzene, and xylenes). Furthermore, additional sampling of sump water and water from specific boreholes may be conducted periodically if triggered by significant trends in groundwater quality.

In addition to mine water sampling, seepage water will also be sampled to evaluate quality and quantity. More specifically, the quality and quantity of seepage water from the North Pile and shallow groundwater flow in the vicinity of the water management pond dams will be evaluated through the monitoring wells and a seepage survey. The seepage survey will be designed to meet the requirements specified in Part E, Section 9 of the water licence.

While the groundwater monitoring program is generally well designed and will contribute to our understanding of quantity and quality of groundwater and seepage at the site, there are a number of deficiencies that should be addressed, including:

- Mine water at the Snap Lake site will consist of recharge water from Snap Lake and connate groundwater. While the proposed

monitoring program will provide information on the quality and quantity of combined mine water, it may not provide information on the quality and quantity of two primary sources of mine water. This is important because the EA report included predictions of mine water quality and quantity that could be wrong due to higher than anticipated concentrations of major ions and phosphorus in connate groundwater, higher than anticipated concentrations of major ions and phosphorus in recharge water (i.e., due to possible recharge by incompletely mixed mine water), and higher than anticipated quantities of connate groundwater. By monitoring only the quality and quantity of combined mine water, it will be difficult to evaluate the accuracy of the EA predictions. In addition, it will be difficult to isolate the source of elevated COPC concentrations without information on the quality and quantity of each source of mine water. Hence, development of mitigation options will be difficult (i.e., grouting vs. water treatment). It is uncertain if the additional sump sampling referred to in DCMI (2004c) will be sufficient to provide the required information as this component of the sampling program is incompletely described (i.e., triggers are not described, flow is not included on the list of measurements, etc.);

- Sampling of seepage from the North Pile is to be conducted using piezometers that will be installed as part of the Ore Storage, Waste Rock, and Processed Kimberlite Management Plan. As the number and locations of these peizometers are not specified in the Groundwater Management Plan, it is uncertain if the resultant data will be sufficient to assess the quantity of seepage that emerges from the North Pile. In addition, the lack of details on the analytes that will be measured in North Pile seepage and the frequency of sampling makes it difficult to determine if sufficient water chemistry data will be available to assess seepage quality and to contribute to mass loading calculations;

- As part of the SNP requirements, two boreholes downgradient of Dam 1 and one borehole downgradient of Dam 2 will be monitored to evaluate seepage from the water management pond. While DCMI (2004c) indicates that the boreholes will be evaluated to assess their suitability, no details were provided on how such an evaluation will be conducted. Importantly, such an evaluation should focus on determining if the existing boreholes are in the right location to intercept seepage from the structure and if additional boreholes are needed; and,

- The groundwater monitoring program is intended to provide a basis for managing minewater and seepage in a manner that prevents greater than predicted impacts to Snap Lake and/or other receiving water bodies. However, very little information is provided on how the results of the monitoring program will contribute to mine water or seepage management at the site or on what mitigative actions might be taken in response to the data collected in the monitoring program.

4.0 Baseline Environmental Quality Monitoring

The Aquatic Effects Monitoring Program (DCMI 2004a) includes several studies that are designed to provide baseline information on and/or variability in environmental quality conditions in the vicinity of the Snap Lake mine site, including:

- Fish health baseline special study;
- Benthic invertebrate community baseline special study;
- Zooplankton and phytoplankton special study; and,
- Periphyton special study.

Comments on each of these elements of the AEMP are provided in the following sections of this document.

4.1 Fish Health Baseline Special Study

The fish health baseline special study is designed to fill data gaps in the baseline data that are available for Snap Lake and the Reference Lake. Consistent with the Environmental Effects Monitoring program, this study is designed to monitor fish to "determine if there are differences in the growth, reproduction, survival or condition of the fish population ... in order to determine whether or not mine effluent is having an effect on fish" (DCMI 2004a). Accordingly, 80 mature fish will be collected from Snap Lake, Northeast Lake, and Reference Lake (i.e., at locations where lake trout and round whitefish are known or expected to reside) and examined to collect the following data:

- physical abnormalities (e.g., tumours, surficial lesions, obvious parasites);
- fork length;
- total body length;
- liver weight;
- age;
- sex;
- gonad weight;
- egg weight/fecundity; and,
- status of reproductive development (histological categories).

Supporting environmental variables will also be measured daily, including dissolved oxygen (DO), water temperature, pH, conductivity, turbidity, air temperature, and weather conditions. Fish fillets will also be taken and analysed for trace metals and major ions. This study will be conducted over one season only. The quality assurance/quality control procedures that will be followed during the study are also described in the document.

While the study described in the AEMP report (DCMI 2004a) will be useful, it is likely to fall short of providing the baseline data needed to assess project effects on fish health. Some of the modifications to the study that are needed to increase its potential relevance for future impact assessment activities include:

- The external examinations should be expanded to include deformities;
- The list of species examined should be expanded to include at least one benthic fish species (e.g., sculpin; i.e., because certain project-related COPCs are likely to become associated with bed sediments; therefore, benthic fish species are likely to have among the highest exposure levels;
- Whole body concentrations of COPCs should be measured in fish species that are consumed by other fish, piscivorus birds, and piscivorus mammals, targeting size classes that are relevant to

predator species (whole body tissue residue concentrations will also be needed to support comparisons to critical body burdens for fish);

- Data on moisture and lipid content of fish tissues will be required to interpret the tissue residue data;

- Data should be collected on the concentrations of other bioaccumulative COPCs (e.g., PCBs, organochlorine pesticides) to support an assessment of the cumulative effects of the mine (i.e., eutrophication of Snap Lake has the potential to alter the bioaccumulation in fish of COPCs that originate from sources removed from the mine site);

- No indication is provided regarding where supporting environmental variables will be measured in each lake; and,

- The study design does not provide a basis for evaluating within lake or between year random variability in the measurement endpoints selected. This deficiency will make it difficult to discriminate between random variability and project-related effects.

4.2 Benthic Invertebrate Community Baseline Special Study

The benthic invertebrate community baseline special study is designed to provide baseline information against which future monitoring data can be compared. As was the case for the fish health baseline special study, the design of this investigation is intended to be consistent with the procedures established under the Environmental Effects Monitoring program. In this study, ten stations in the main basin and two stations in the northeast arm of Snap Lake will be sampled (including at least three replicate samples at each station) using a six inch Ekman dredge. Samples will then be field sieved and the organisms retained on the sieve preserved in 10% formalin. The supporting environmental variables that will be measured at each station include sampling date and time, UTM coordinates, landscape features, habitat type, water depth, DO, water temperature, pH, conductivity, turbidity, air temperature, weather conditions, and substrate type and particle size. Invertebrates will be identified to the lowest taxonomic level practicable, and the resultant data will be used to calculate species composition, total invertebrate density, taxon abundance, and biomass.

The benthic invertebrate baseline study is generally well-designed. However, there are a number of deficiencies that could impact its utility for assessing project-related impacts on benthic invertebrate community structure, including:

- Benthic invertebrate community structure metrics typically exhibit a substantial amount of variability. Therefore, benthic ecologists typically recommend collecting a minimum of five replicate samples at each sampling station. By targeting on the collection of a minimum of three replicate samples per station, it is likely that the current sampling program design will not be sufficiently robust to characterize natural variability at each sampling station. When these baseline data are compared to data collected in the future, the limited number of replicates will make it difficult to identify project-related effects;

- The current sampling program design does not provide provisions for collecting key supplemental data that are required to interpret the benthic invertebrate community structure data. For this reason, it would be advisable to collect supplemental data on pore-water hydrogen sulfide, pore-water ammonia, total organic carbon (TOC), metals, and other COPCs. Importantly, matching sediment chemistry and benthic invertebrate community structure data should be collected at each sampling site (replicate sampling location). This can be accomplished by fitting the Ekman dredge (9") with a poly core (4"), using the sediment in the core for benthic invertebrate community structure analysis, and using the sediment outside the core for other analyses;

- Consideration should be given to including sediment toxicity (28-d survival and growth tests with *Hyalella azteca*) as a metric in the baseline benthic program, as this species tends to provide more consistent and reliable data than benthic invertebrate community structure;

- The monitoring program did not provide provisions for sampling a Reference Lake to assess benthic invertebrate community structure characteristics. The absence of data for Reference Lake will make it difficult to determine if shifts in community structure in Snap Lake over time are associated with project-related effects or due to stressors that are regional in nature (e.g., climate change);

- The description of sampling frequency did not provide an adequate basis for determining when or how frequently the sampling program

would be conducted. Data on the seasonal variability of benthic invertebrate communities is needed to determine appropriate timing and frequency for sampling activities; and,

- The QA/QC program should include provisions for a 10% re-analysis of the samples by a second taxonomist to confirm the accuracy of the results (including species identification).

4.3 Zooplankton and Phytoplankton Special Study

Under the terms of the water licence, a special study is to be designed and implemented to evaluate the natural variability in zooplankton and phytoplankton community structure and population characteristics. More specifically, this study is intended to assess whether a critical effect size for cyanobacterial species in Snap Lake can be determined and to monitor chlorophyll *a* and phytoplankton biomass and composition as indicators of nutrient enrichment in Snap Lake. Zooplankton community composition and biomass will also be monitored in this study.

Phytoplankton samples will be obtained by collecting water samples at 2-m intervals within the photic zone and compositing them to provide a single sample for each of the 12 sampling stations. Additional water will be collected for chlorophyll *a* analysis at each station. Zooplankton samples will be collected by deploying tow nets two times at a total of 12 sampling locations (24 samples altogether). Zooplankton and phytoplankton will be identified to the lowest taxonomic level practicable and the resulting data will be used to evaluate abundance and percent composition of each taxon and total biomass. Sampling will be conducted every two weeks during the open water period.

The study design presented in the AEMP report (DCMI 2004a) provides a good basis for monitoring phytoplankton and zooplankton populations in the vicinity of the Snap Lake mine site. However, the monitoring program would be strengthened by considering the following comments:

- The monitoring program did not provide provisions for sampling a Reference Lake to assess phytoplankton and zooplankton community structure characteristics. The absence of data for Reference Lake will make it difficult to determine if shifts in community structure in Snap Lake over time are associated with project-related effects or due to stressors that are regional in nature (e.g., climate change);

- The rationale for selecting the number and locations of sampling stations within Snap Lake is not provided. Therefore, it is not possible to evaluate the adequacy of the spatial coverage offered by the proposed sampling program design;

- The term "critical effect size" is not defined as it applies to cyanobacterial species;

- The collection methods are not clear about how zooplankton sampling will be conducted. Vertical towing represents the preferred sampling method;

- The collection methods do not describe how water will be collected, the quantities of water that will be collected, or the procedures that will be used to process samples (i.e., field filtration) at each sampling station;

- The number of samples collected at each station will not provide a basis for statistically evaluating differences between years by sampling station (i.e., data from multiple stations will need to be pooled). This could represent a problem if substantial spatial variability in phytoplankton and/or zooplankton population metrics are evident in Snap Lake; and,

- The QA/QC program should include provisions for a 10% re-analysis of the samples by a second taxonomist to confirm the accuracy of the results (including species identification).

4.4 Periphyton Special Study

Under the terms and conditions of its water licence, DCMI is required to conduct a special periphyton community study to examine the natural variability in community structure and biomass during the open-water season. The study is also intended to determine whether a critical effect size for periphyton can be determined. The monitoring program will focus on collection of the data needed to evaluate the status and variability of periphyton community composition and biomass, and to assess the quality of periphyton as a food source for aquatic organisms in Snap Lake. The applicability of periphyton as a monitoring tool will also be evaluated in this study.

In this study, periphyton samples will be collected from a total of 12 sampling stations. At each station, shallow rocks (at 1 m and 2 m depths) will be scraped *in situ* by divers using special scraping tools. Sampling will be conducted at three times during the year, including spring, summer, and fall. Although this study is important for assessing baseline conditions in Snap Lake and providing a basis for assessing mine-related effects in the future, its design would be improved by considering the following:

- The monitoring program did not provide provisions for sampling a Reference Lake to assess periphyton community structure characteristics. The absence of data for Reference Lake will make it difficult to determine if shifts in community structure in Snap Lake over time are associated with project-related effects or due to stressors that are regional in nature (e.g., climate change);

- The term "critical effect size" is not defined as it applies to cyanobacterial species;

- The selected sampling methods will provide a basis for evaluating the composition of periphyton communities in Snap Lake. However, it is likely that the selected methods will not provide an accurate basis for assessing biomass or variability in community composition and biomass among sampling stations. An alternate approach that would provide a more reliable basis for estimating biomass and assessing differences between stations and between years would be to deploy artificial substrates in the lake;

- The number of samples collected at each station will not provide a basis for statistically evaluating differences between years by sampling station (i.e., data from multiple stations will need to be pooled). This could represent a problem if substantial spatial variability in periphyton population metrics are evident in Snap Lake; and,

- The QA/QC program should include provisions for a 10% re-analysis of the samples by a second taxonomist to confirm the accuracy of the results (including species identification).

5.0 Ambient Environmental Quality Monitoring

The Aquatic Effects Monitoring Program (DCMI 2004a) includes a number of monitoring activities that are intended to provide the information needed to evaluate project-related effects in the vicinity of the Snap Lake mine site, including:

- Water quality monitoring;
- Sediment quality monitoring;
- Fish health monitoring;
- Fish tasting
- Benthic invertebrate monitoring;
- Zooplankton and phytoplankton monitoring; and,
- Fish habitat monitoring.

Comments on each of these elements of the AEMP are provided in the following sections of this document.

5.1 Water Quality Monitoring

As part of the overall AEMP, DCMI (2004a) has designed a water quality monitoring program to evaluate changes in conditions in Snap Lake resulting from the construction, operation, and closure of the project. In addition, the information acquired in this program is intended to support adaptive management of chemical mass loadings that could impact the water quality of Snap Lake. The monitoring program focusses on four main categories of changes, including:

- nutrient enrichment;
- dissolved oxygen;
- total dissolved solids (TDS) and major ions; and,
- metals, ammonia, nitrate, and other COPCs.

Sampling for water quality will include stations located near the diffuser outfall, throughout Snap Lake, the outlet from Snap Lake, and downstream of Snap Lake (12 stations). Water quality sampling will be conducted four times per year at each of these stations, with target analytes including nutrients, conventionals, major ions, and metals. Water samples will be collected at three depths at each station, including surface, middle, and bottom using Kemmerer or Van Dorn samplers. At the three stations near the outfall, the samples collected at each depth will be analysed individually; however, the samples collected at various depths will be composited unless vertical gradients in conductivity are observed. Vertical profiles will be taken for field variables at each station. Eight additional stations will be established to provide measurements of TDS, calcium, and chloride.

The water quality monitoring program is likely to provide useful information for assessing the status and trends in water quality conditions in the vicinity of the mine site. However, there are several important issues that need to be addressed to ensure that the monitoring program will provide the information needed to establish baseline conditions and evaluate mine-related effects on water quality in Snap Lake, including:

- The monitoring program did not provide provisions for sampling a Reference Lake to assess water quality conditions. The absence of data for Reference Lake will make it difficult to determine if shifts in water quality in Snap Lake over time are associated with project-related effects or due to stressors that are regional in nature (e.g., climate change);

- The rationale for selecting the number and location of sampling stations within Snap Lake is not provided. Therefore, it is not possible to evaluate the adequacy of the spatial coverage offered by the proposed sampling program design. For the purposes of calculating lake-wide average concentrations of COPCs, a stratified random sampling design should have been used. However, a biassed sampling design would be more appropriate for evaluating project-related impacts. More information on the rationale for the selection of sampling stations is required;

- The rationale for using conductivity as a basis for making decisions regarding the compositing of water samples collected at a station is not provided. Importantly, samples collected for DO analysis should never be composited. In addition, other variables could exhibit vertical gradients in the absence of conductivity gradients. Therefore, it is important to demonstrate that critical information

needed to assess impacts will not be lost through the compositing of samples within a station;

- In the first year of the sampling program, a special survey should be designed and implemented that will provide the basis for a long-term monitoring program design. Such a survey should be designed to provide information on small-scale variability in water quality (i.e., by collecting at least three samples at each water depth at a station), variability with depth (i.e., by collecting water samples at least three water depths), variability within the lake (i.e., by collecting samples at multiple locations virtually simultaneously through the lake), variability over time (i.e., by collecting multiple samples over 24-hours, 7-days, 4-weeks, and 4-seasons). This year-one data set needs to be sufficiently robust that statistical comparisons of the data can be made to identify the minimum number of samples that need to be collected to discriminate between natural variability and mine-related effects (i.e., through a statistical power analysis);

- The number of samples collected at each station will not provide a basis for statistically evaluating differences between years by sampling station (i.e., data from multiple stations will need to be pooled);

- The list of target analytes should be expanded to include total and unionized ammonia; it may also be reasonable to include BTEX, extractable petroleum hydrocarbons, and oil and grease in surficial samples collected near the outfall to confirm that these substances are present at low levels only;

- The detection limits that will be achieved for the various COPCs were not reported in DCMI (2004a). While ETL and Taiga detection limits are reported in the QA/QC Plan, it is not clear what detection limits have been selected for the monitoring program;

- Visual inspection of the lake surface should be made at each site to confirm that a film on the surface of the lake has not resulted from discharge of the effluent or from other activities at the mine site;

- From the information presented, it is not clear how sensitive the monitoring program will be in terms of detecting project-related effects (i.e., will changes of 10%, 20% or 50% magnitude be able to be detected). This is important because the monitoring program should be sensitive enough to detect subtle changes in water quality

conditions in Snap Lake to support adaptive management at the site; and,

- Although DCMI (2004a) provides some description of the QA/QC measures that will be implemented to assure data quality, it is not clear how the resultant data will be evaluated. For a monitoring program of this magnitude, it is important to establish data quality objectives (DQOs) on an *a priori* basis. At minimum, such DQOs should clearly indicate acceptable levels of accuracy, precision, limits of detections, representativeness, and completeness of the data.

5.2 Total Dissolved Solids, Calcium, and Chloride Monitoring

As part of the overall water quality monitoring program, a focussed sampling plan will be implemented to address concerns related to TDS, calcium, and chloride in Snap Lake (DCMI 2004b). More specifically, the monitoring program is designed to enable DCMI to calculate whole-lake average TDS concentrations to assess compliance with the water licence limits. In this element of the AEMP, water samples will be collected at a total of 15 stations in Snap Lake and analysed for TDS, calcium, chloride, and conductivity. Each of these stations will be sampled four times per year and water will be collected from three sampling depths using a Kemmerer or Van Dorn sampler. The three samples collected at each station will be composited if no gradient in conductivity is observed among the three samples.

This element of the overall water quality monitoring program is likely to provide useful information for assessing the water quality conditions in the vicinity of the mine site. However, there are several important issues that need to be addressed to ensure that the monitoring program will provide the information needed to evaluate trends in these variables and to calculate whole-lake average TDS levels in Snap Lake, including:

- The rationale for selecting the sampling stations within Snap Lake is not provided. Therefore, it is not possible to evaluate the adequacy of the spatial coverage offered by the proposed sampling program design. For the purposes of calculating lake-wide average concentrations of COPCs, a stratified random sampling design should have been used;

- The rationale for using conductivity as a basis for making decisions regarding the compositing of water samples collected at a station is not provided;

- There is little or no rationale for compositing water samples collected within a station for these variables. On the contrary, it makes sense to analyse all of the samples collected at each station to provide additional information on how TDS and related variables are increasing in Snap Lake. As these variables are inexpensive to analyse for, cost does not provide a reasonable rationale for not analysing all of the samples;

- The detection limits that will be achieved for the various COPCs were not reported in DCMI (2004a). While ETL and Taiga detection limits are reported in the QA/QC Plan, it is not clear what detection limits have been selected for the monitoring program;

- Criteria for implementing adaptive management activities related to TDS are not explicitly described in DCMI (2004b). Therefore, it is not possible to identify the triggers for action or the types of mitigative measures that could be undertaken to address concerns related to TDS; and,

- Although DCMI (2004a) provides some description of the QA/QC measures that will be implemented to assure data quality, it is not clear how the resultant data will be evaluated. For a monitoring program of this magnitude, it is important to establish data quality objectives (DQOs) on an *a priori* basis. At minimum, such DQOs should clearly indicate acceptable levels of accuracy, precision, limits of detections, representativeness, and completeness of the data.

5.3 Sediment Quality Monitoring

Sediment quality sampling will include four stations located in Snap Lake. Sediment stations will be monitored annually for metals and nutrients. Sediment samples will also be collected at all benthic invertebrate monitoring station and analysed for particle size and total organic carbon. Samples will be collected using Ekman or Ponar dredges. The samples collected at each station will be analysed for physical variables, nutrients, and metals.

The sediment quality monitoring program may provide some useful information for assessing sediment quality conditions in the vicinity of the mine site. However, there are several important issues that need to be addressed to ensure that the monitoring program will provide the information needed to establish baseline conditions and evaluate mine-related effects on sediment quality in Snap Lake, including:

- The monitoring program did not provide provisions for sampling a Reference Lake to assess sediment quality conditions. The absence of data for a reference lake will make it difficult to determine if shifts in water quality in Snap Lake over time are associated with project-related effects or due to stressors that regional in nature (e.g., climate change), particularly since insufficient information were collected prior to mine development to establish baseline sediment quality conditions;

- The rationale for selecting the number and location of sampling stations within Snap Lake is not provided. Therefore, it is not possible to evaluate the adequacy of the spatial coverage offered by the proposed sampling program design. More information on the rationale for the selection of sampling stations is required;

- In the first year of the sampling program, a special survey should be designed and implemented that will provide the basis for a long-term monitoring program design. Such a survey should be designed to provide information on the variability of sediment quality conditions within Snap Lake. This year-one data set needs to be sufficiently robust that statistical comparisons of the data can be made to identify the minimum number of samples that need to be collected to discriminate between natural variability and mine-related effects (i.e., through a statistical power analysis);

- The number of samples collected at each station will not provide a basis for statistically evaluating differences between years by sampling station (i.e., data from multiple stations will need to be pooled);

- The list of target analytes should be expanded to include pore water ammonia and hydrogen sulfide. In addition, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and organochlorine pesticides should be measured in sediments to provide a basis for interpreting sediment quality data and assessing the cumulative effects of the project and other human activities;

- The detection limits that will be achieved for the various COPCs were not reported in DCMI (2004a) or elsewhere;

- From the information presented, it is not clear how sensitive the monitoring program will be in terms of detecting project-related effects (i.e., will changes of 10%, 20% or 50% magnitude be able to be detected). This is important because monitoring program should be sensitive enough to detect subtle changes in water quality conditions in Snap Lake to support adaptive management at the site; and,

- Although DCMI (2004a) provides some description of the QA/QC measures that will be implemented to assure data quality, it is not clear how the resultant data will be evaluated. For a monitoring program of this magnitude, it is important to establish data quality objectives (DQOs) on an *a priori* basis. At minimum, such DQOs should clearly indicate acceptable levels of accuracy, precision, limits of detections, representativeness, and completeness of the data.

5.4 Fish Health Monitoring

Fish health monitoring will be conducted in the vicinity of the mine site to evaluate the effects of increased levels of TDS, increased levels of chromium in water and sediment, and reduced levels of DO in the lake. Every five years, 80 mature fish will be collected from Snap Lake and Reference Lake (i.e., at locations where lake trout and round whitefish are known or expected to reside) and examined to collect the following data:

- physical abnormalities (e.g., tumours, surficial lesions, obvious parasites);

- fork length;

- total body length;

- liver weight;

- age;

- sex;
- gonad weight;
- egg weight/fecundity; and,
- status of reproductive development (histological categories).

Supporting environmental variables will also be measured daily, including DO, water temperature, pH, conductivity, turbidity, air temperature, and weather conditions. Fish fillets will also be taken and analysed for trace metals and major ions. This study will be conducted over one season only. The quality assurance/quality control procedures that will be followed during the study are also described in the document.

While the monitoring program design described in the AEMP report (DCMI 2004a) will be useful, it is likely to fall short of providing the data needed to assess project effects on fish health. Some of the modifications to the study that are needed to increase its potential relevance for future impact assessment activities include:

- Although baseline data were collected in Northeast Lake, it is not included in the follow-up monitoring. No rationale is provided for excluding this lake from routine monitoring;
- The external examinations should be expanded to include deformities;
- The list of species examined should be expanded to include at least one benthic fish species (e.g., sculpin; i.e., because certain project-related COPCs are likely to become associated with bed sediments; therefore, benthic fish species are likely to have among the highest exposure levels;
- Whole body concentrations of COPCs should be measured in fish species that are consumed by other fish, piscivorus birds, and piscivorus mammals, targeting size classes that are relevant to predator species (whole body tissue residue concentrations will also be needed to support comparisons to critical body burdens for fish);
- Data on moisture and lipid content of fish tissues will be required to interpret the tissue residue data;

- Data should be collected on the concentrations of other bioaccumulative COPCs (e.g., PCBs, organochlorine pesticides) to support an assessment of the cumulative effects of the mine (i.e., eutrophication of Snap Lake has the potential to alter the bioaccumulation in fish of COPCs that originate from sources removed from the mine site);

- No indication is provided regarding where supporting environmental variables will be measured in each lake;

- The study design does not provide a basis for evaluating within lake or between year random variability in the measurement endpoints selected. This deficiency will make it difficult to discriminate between random variability and project-related effects.

5.5 Fish Taste Monitoring

No comments are offered on the fish tasting component of the AEMP.

5.6 Benthic Invertebrate Monitoring

Benthic invertebrate community monitoring is designed to evaluate the effects of increased levels of TDS, increased levels of chromium in water and sediment, and reduced levels of DO in the lake on the benthic invertebrate community. In this study, ten stations in the main basin and two stations in the northeast arm of Snap Lake will be sampled (including at least three replicate samples at each station) using a six inch Ekman dredge. Samples will then be field sieved and the organisms retained on the sieve preserved in 10% formalin. The supporting environmental variables that will be measured at each station include sampling date and time, UTM coordinates, landscape features, habitat type, water depth, DO, water temperature, pH, conductivity, turbidity, air temperature, weather, and substrate type and particle size. Invertebrates will be identified to the lowest taxonomic level practicable, and the resultant data will be used to calculate species composition, total invertebrate density, taxon abundance, and biomass. The levels of trace metals and major ions will also be measured in benthic invertebrate tissues.

The benthic invertebrate monitoring program is generally well-designed. However, there are a number of deficiencies that could impact its utility for

assessing project-related impacts on benthic invertebrate community structure, including:

- Benthic invertebrate community structure metrics typically exhibit a substantial amount of variability. Therefore, benthic ecologists typically recommend collecting a minimum of five replicate samples at each sampling station (Day *et al*. 1995; Reynoldson *et al*. 1997; Rosenberg *et al*. 1999; MacDonald *et al*. 2002). By targeting on the collection of a minimum number of replicate samples per station, it is likely that the current sampling program design will not be sufficiently robust to characterize natural variability at each sampling station;

- The sampling program design does not provide provisions for collecting key supplemental data that are required to interpret the benthic invertebrate community structure data. For this reason, it would be advisable to collect supplemental data on pore-water hydrogen sulfide, pore-water ammonia, total organic carbon, metals, and other COPCs. Acquisition of such data will support interpretations of the information that are targeted on identifying the factors that are causing any changes in benthic invertebrate community structure that are observed Importantly, matching sediment chemistry and benthic invertebrate community structure data should be collected at each sampling site (replicate sampling location). This can be accomplished by fitting the Ekman dredge with a poly core, using the sediment in the core for benthic invertebrate community structure analysis, and using the sediment outside the core for other analyses;

- Consideration should be given to including sediment toxicity (28-d survival and growth tests with *Hyalella azteca*) as a metric in the benthic invertebrate monitoring program;

- The monitoring program did not provide provisions for sampling a Reference Lake to assess benthic invertebrate community structure characteristics. The absence of data for a reference lake will make it difficult to determine if shifts in community structure in Snap Lake over time are associated with project-related effects or due to stressors that are regional in nature (e.g., climate change);

- The description of sampling frequency did not provide an adequate basis for determining when or how frequently the sampling program would be conducted. Data on the seasonal variability of benthic

invertebrate communities is needed to determine appropriate timing and frequency for sampling activities;

- Data on moisture and lipid content of invertebrate tissues will be required to interpret the tissue residue data;

- Data should be collected on the concentrations of other bioaccumulative COPCs (e.g., PCBs, organochlorine pesticides) to support an assessment of the cumulative effects of the mine (i.e., eutrophication of Snap Lake has the potential to alter the bioaccumulation in invertebrates of COPCs that originate from sources removed from the mine site); and,

- The QA/QC program should include provisions for a 10% re-analysis of the samples by a second taxonomist to confirm the accuracy of the results (including species identification).

5.7 Zooplankton and Phytoplankton Monitoring

Zooplankton and phytoplankton monitoring will be conducted to evaluate mine-related effects on these important ecosystem components. Phytoplankton samples will be obtained by collecting water samples at 2-m intervals within the photic zone and compositing them to provide a single sample for each of the sampling stations. Additional water will be collected for chlorophyll *a* analysis at each station. The number and location of sampling stations and sampling frequency will be determined based on the results of the special study that was conducted to assess variability in phytoplankton community composition and biomass.

The study design presented in the AEMP report (DCMI 2004a) is unlikely to provide a basis for evaluating mine-related effects in Snap Lake for the following reasons:

- No provisions for conducting monitoring to assess zooplankton community structure characteristics are provided. This is a critical omission because a number of stakeholders specifically identified effects on the zooplankton community as a serious environmental concern. Therefore, the AEMP must be refined to include zooplankton monitoring;

- The monitoring program did not provide provisions for sampling a Reference Lake to assess phytoplankton community structure

characteristics. The absence of data for a reference lake will make it difficult to determine if shifts in community structure in Snap Lake over time are associated with project-related effects or due to stressors that are regional in nature (e.g., climate change);

- The collection methods do not describe how water will be collected, the quantities of water that will be collected, or the procedures that will be used to process samples (i.e., field filtration) at each sampling station;

- The number of samples collected at each station will not provide a basis for statistically evaluating differences between years by sampling station (i.e., data from multiple stations will need to be pooled). This could represent a problem if substantial spatial variability in phytoplankton population metrics is evident in Snap Lake; and,

- The QA/QC program should include provisions for a 10% re-analysis of the samples by a second taxonomist to confirm the accuracy of the results (including species identification).

5.8 Fish Habitat Monitoring

The fish habitat component of the AEMP is designed to monitor project activities that have the potential to harm fish habitat and will consist of four separate programs, including:

- Water intake and diffuser sedimentation monitoring program;

- Habitat compensation program;

- Blasting monitoring program; and,

- Uncontrolled runoff and airstrip runoff sedimentation monitoring program.

In the water intake and diffuser sedimentation monitoring program, a minimum of nine sampling stations will be established in the vicinity of two construction areas. The sampling stations will be established in Snap Lake at distances of 50m, 100m, and 250m from the construction areas in a radial pattern (i.e., at least three stations

at each distance). Two grab samples will be collected from each sampling station (at 30 cm below the water surface), with one analysed for turbidity and the other for TSS. Sediment traps may also be installed in five to 10 additional areas. Samples will be collected at least twice daily, with frequency increasing if variability in the results are observed. The following comments are offered on the water intake and diffuser sedimentation monitoring program:

- All reasonable efforts should be made to avoid the release of fine sediment to Snap Lake, including the use of silt curtains and related mitigation measures;

- The rationale for collecting water samples at a depth of 30 cm only is not provided. It would seem more logical to collect samples at multiple depths because turbidity and TSS are likely to vary with water depth;

- Depth averaging of TSS and turbidity data should not be conducted (i.e., measured concentrations in each sample should be compared to the selected benchmarks);

- Sampling twice per day is unlikely to provide a basis for characterizing turbidity and TSS levels associated with construction activities (i.e., because activities that result in releases of fine sediment are likely to be episodic in nature);

- No information is provided about how the results of such monitoring would be used within an adaptive management framework at the site (i.e., to trigger mitigative measures);

- Insufficient information is provided on the deployment of sediment traps to understand how they would be used in the monitoring program or how the resultant data would contribute to decision-making related to construction activities; and,

- No information is provided on how background levels of turbidity or TSS would be established.

No comments are offered on the habitat compensation program. Likewise, no comments are provided on the blasting monitoring program.

The uncontrolled runoff and airstrip runoff sedimentation monitoring program will be conducted to evaluate the effects of uncontrolled runoff from the bulk sample mine rock pad, quarry, winter access road, road to the emulsion plant, and the

emulsion plant area. As lengthening the airstrip also has the potential to generate sediment, it is also included in this component of the fish habitat monitoring program. Sampling stations (at least seven) will be established in Snap Lake adjacent to the above mentioned sediment sources. The sampling stations will be selected based on topography and areas of potential runoff. Two grab samples will be collected from each sampling station (at mid-depth), with one analysed for turbidity and the other for TSS. Samples will be collected at least twice weekly during freshet and daily during heavy rainfall events. The following comments are offered on the water intake and diffuser sedimentation monitoring program:

- All reasonable efforts should be made to avoid the release of fine sediment to Snap Lake, including the use of silt curtains and related mitigation measures;

- The rationale for collecting water samples at mid-depth only is not provided. It would seem more logical to collect samples at multiple depths because turbidity and TSS are likely to vary with water depth.

- Depth averaging of TSS and turbidity data should not be conducted (i.e., measured concentrations in each sample should be compared to the selected benchmarks);

- Sampling twice per week during freshet and daily during heavy rainfall events is unlikely to provide a basis for characterizing turbidity and TSS levels associated with these areas (i.e., TSS and turbidity vary significantly on a daily basis); and,

- No information is provided about how the results of such monitoring would be used within an adaptive management framework at the site (i.e., to trigger mitigative measures).

6.0 Quality Assurance/Quality Control Plan

A Quality Assurance/Quality Control (QA/QC) Plan (DCMI 2004d) was developed to provide details on the collection, handling, and analysis of samples collected under the Surveillance Network Program (SNP) that will be conducted in partial fulfillment of the terms and conditions of DCMI's Class A water licence. The QA/QC Plan identifies sampling locations, sampling equipment, sampling methods, and sampling frequency for water samples collected under the SNP. In addition, preservation requirements, sample identification methods and sample transportation procedures are described. Furthermore, laboratory methods (and

associated candidate detection limits) and reporting requirements are listed. Laboratory accreditation information is also provided. While the QA/QC Plan provides useful information and may be consistent with guidelines for developing such plans, it has a number of limitations that influence its utility in terms of assuring that high quality data are generated, including:

- The QA/QC Plan does not include systematically-developed data quality objectives (DQOs) that describe the questions that need to be answered through the collection of data at the site (nor are satisfactory DQOs included in the corresponding monitoring plans);

- The QA/QC Plan does not include DQOs for measurement data that provide a systematic basis for assessing data quality (i.e., target levels of accuracy, precision, analytical detection limits, representativeness, and completeness);

- Although the detection limits that can be achieved by two laboratories have been reported, specific detection limits have not been selected for use in the program;

- The system for generating unique sample identification numbers is not described in detail;

- The field quality control section should indicate that QC samples are to be identified in a manner such that they are submitted blind to the analytical laboratory;

- Sample preservation and transportation procedures should refer to standard operating procedures or standard methods; and,

- An example chain-of-custody form should be included in the QA/QC Plan.

7.0 References

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