DEVELOPER'S ASSESSMENT REPORT

April 2012

NICO COBALT-GOLD-BISMUTH-COPPER PROJECT

Aquatic Risk Assessment

Submitted to:
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1.0 INTRODUCTION

1.1 Context

Fortune Minerals Limited (Fortune) proposes to develop a new underground and open pit cobalt, gold, copper, and bismuth mine and processing plant, hereinafter referred to as the NICO Cobalt-Gold-Copper-Bismuth Project (NICO Project). This report provides a detailed description of the aquatic risk assessment (RA) undertaken for the NICO Project. The aquatic RA provides an assessment of the potential health effects to aquatic life that may occur as a result of changes to the aquatic environment due to predicted discharges from the NICO Project.

1.2 Purpose and Scope

The purpose of the aquatic RA was to:

- satisfy the requirements of the Terms of Reference (TOR) issued by the Mackenzie Valley Review Board (MVRB 2009);
- satisfy the requirements of the Indian and Northern Affairs Canada (INAC) draft Aquatic Effects Monitoring Program (AEMP) guidelines (INAC 2009); and
- address the concerns raised by the Tłįchǫ Government and other citizens regarding the permitting of the NICO Project.

The MVRB approach to the TOR document included the identification of Key Lines of Inquiry (KLOI), which were defined as the "areas of greatest concern that require the most attention during the environmental assessment and the most rigorous analysis and detail in the Developer's Assessment Report (DAR)" (MVRB 2009). Additional detail regarding the MVRB approach to environmental assessment was provided in the DAR (Fortune 2011). Of the KLOI identified in the TOR for the NICO Project, 2 are relevant to the health of aquatic life and were addressed through the various components of the aquatic RA, including Water Quality and Closure and Reclamation (Table 1.2-1). The assessment and measurement endpoints for aquatic life for these KLOI were identified in the DAR (Sections 7.0 and 9.0) and are summarized in Table 1.2-1. In the DAR, assessment endpoints are defined as key properties that should be protected for their use by future human generations, while measurement endpoints are defined as quantifiable (i.e., measurable) expressions of changes to assessment endpoints.

Table 1.2-1: Assessment and Measurement Endpoints for the Key Lines of Inquiry that are Relevant for the Aquatic Risk Assessment

Key Line of Inquiry	Assessment Endpoints	Measurement Endpoints	Section in DAR[a]
KLOI: Water Quality	• Suitability of water to support a viable and self-sustaining aquatic ecosystem • Persistence of fish populations • Continued opportunity for traditional and non-traditional use of fish	Survival and reproduction	Section 7.0
KLOI: Closure and Reclamation	• Protection of surface water quality for aquatic ecosystems • Persistence of fish populations • Continued opportunity for traditional and non-traditional use of fish	Survival and reproduction	Section 9.0

[a] Developer's Assessment Report (Fortune 2011).

In general, the aquatic RA fits within the first 2 steps of the overall process described in the draft AEMP guidelines (INAC 2009). These are: (1) identification of issues and concerns associated with a development project relative to potential effects on the aquatic ecosystem; and (2) problem formulation for aquatic effects monitoring. The problem formulation process provides a basis for determining which components of the aquatic ecosystem may be at risk as a result of the proposed developmental activity and what the adverse effects on the aquatic environment may be. It involves the following key activities:

- refinement of the list of stressors of potential concern;
- evaluation of the potential effects of each physical, chemical, and/or biological stressor on aquatic ecosystems;
- evaluation of the transport and fate of chemicals of potential concern (CoPCs);
- characterization of potential exposure pathways;
- identification of receptors potentially at risk;
- development of a conceptual site model;
- selection of assessment and measurement endpoints; and
- development of a preliminary AEMP Analysis Plan.

These key activities are addressed in the aquatic RA framework (refer to Section 2.1 for a description of the framework).

Fortune has been in consultation with the Tłįchǫ Government over the potential impacts and benefits of the NICO Project. Of the concerns raised by the Tłįchǫ Government with respect to the NICO Project, 3 are relevant to the health of aquatic life and were addressed through the various components of the aquatic RA, including the importance of Hislop Lake and Marian River as traditional and recreational areas, potential cumulative effects due to the old Rayrock mine and Colomac mine, and concerns regarding the presence of the tailings and mine rock Co-Disposal Facility (CDF).

The TOR for the NICO Project notes that site-specific water quality objectives (SSWQOs) are to be proposed for all CoPCs identified for the NICO Project to protect downstream water quality (MVRB 2009). Section 4.0 details the approach used to develop the SSWQOs, as well as the proposed SSWQOs.

To address the TOR and the additional issues noted above, the aquatic RA focussed on the following:

- assessment of the potential risks to aquatic life due to emissions from the NICO Project, including those KLOI identified in the TOR as they pertain to the health of aquatic life;
- addressing the components identified in the draft AEMP Guidelines for the Northwest Territories (NWT) (INAC 2009);
- addressing the concerns raised by the Tłįchǫ Government and other citizens as they pertain to the health of aquatic life; and
- development of SSWQOs.

In mining projects, potential impacts can only occur where there is a direct link between project activity and the environment. Therefore, the aquatic RA focused on those aspects of the NICO Project that could result in Project-related discharges to the environment, thereby potentially impacting aquatic life where there is a complete exposure pathway between a source and a receptor. To facilitate an understanding of the NICO Project activities that could result in potential impacts to aquatic life, a brief description of the NICO Project, and the study areas used to analyze and assess effects to aquatic life is provided in the next section.

1.3 Project Description

1.3.1 Project Location

The NICO Project is located approximately 160 kilometres northwest of Yellowknife, NWT within the Marian River drainage basin, approximately 10 kilometres east of Hislop Lake at a latitude of 63°33' North, and a longitude of 116°45' West (Figure 1.2-1 of the DAR).

The NICO Project site is located in an area of rugged topography. The site topography is illustrated in Figure 1.2-4 of the DAR. Absolute elevations at the NICO Project site range from 150 to 350 meters above sea level. The ore body is located on the northern slope of a bowl-shaped depression referred to as the "Bowl Zone". The south end of the proposed mine is located on a ridge of exposed bedrock, which slopes down towards the north end of the proposed mine in the Grid Pond depression.

With the exception of Fortune's leases, all of the land surrounding the mine is within the Tłįchǫ settlement lands owned and managed as fee-simple lands by the Tłįchǫ Dèts'ô Kàowo as per the Tłįchǫ Agreement (Figure 1.2-2 of the DAR). The Tłįchǫ lands are within the Wek'èezhìi co-management lands, jointly managed with the Northwest Territory and Federal Government. Fortune's exploration leases were staked and brought to lease prior to settlement of the Tłįchǫ land claim and as Crown Land are administered by the Federal Government.

Subject to approvals, the plant site will be constructed approximately 500 metres west of Nico Lake, between Nico and Lou lakes.

1.3.2 The Proposed NICO Project

The NICO Project includes development of an underground mine and open pit. The current proposed site development for the NICO Project is summarized in Section 1.0 of the DAR (as shown in Figure 1.2-3 of the DAR) and briefly below. The detailed Project Description, including figures showing the proposed site development, is provided in Section 3.0 of the DAR (Fortune 2011).

In brief, proposed on-site infrastructure includes the following:

- mine site with open pit and underground operations;
- tailings and mine rock management area (presented as a single CDF);
- Mineral Process Plant (the Plant);
- Effluent Treatment Facility (ETF), with discharge into Peanut Lake through a diffuser;
- Sewage Treatment Plant (STP);
- drainage controls;

- camp;
- truck stop;
- fuel and chemical storage facilities;
- Materials Sorting Facility;
- Landfarm (a bioremediation cell that will be used to treat hydrocarbon contaminated soils; treated soils will be placed in the CDF);
- Explosives storage area;
- roads within the mine site and NICO Project Access Road with access to site via the proposed Tłı̨chǫ Road Route; and
- fresh water intake on Lou Lake and diffuser in Peanut Lake.

The NICO Project consists of 3 separate phases:

- Construction Phase, during which the supplies and equipment are transported to site, site preparation (clearing and grubbing) is undertaken, and the NICO Project infrastructure necessary for operation of the mine are constructed;
- Operations Phase, during which mining and primary processing of the ore is undertaken; and
- Closure and Post-Closure Phases, during which all mining activity ceases and the mine site is decommissioned.

During construction several activities could result in sediment releases to surface waters. To manage these releases the layout of the mine footprint will limit the area that is disturbed, sediment and erosion control measures will be used, construction run-off will be managed and any construction work completed in-stream (i.e., construction of the water intake at Lou Lake) will be completed under dry conditions. Air emissions during construction, including dust and associated metal deposition will be managed by limiting the area that is disturbed, ensuring compliance with regulatory emission requirements, and through implementation of best management practices for controlling fugitive and exhaust emissions and improving energy efficiencies.

During operation of the mine, the NICO Project will generate mine rock and tailings. The mine rock includes soil and overburden from pre-stripping above the ore body and mine rock from development of the Open Pit. Processing of the ore will result in generation of tailings. Mine rock and tailings will be disposed of in the CDF. At closure, the CDF will be capped.

Primary processing of the ore will be conducted on-site in the Plant, including crushing, grinding, and floatation (consisting of primary and secondary stages) to produce bulk concentrate. The concentrate will then be shipped off-site for final processing. Primary processing does not include cyanidation and therefore a cyanide destruction circuit has not been incorporated into the final NICO Project design.

Several mine activities will generate excess water, including ore processing and pumping from the Open Pit and underground workings. All water that comes into contact with the mine facilities during construction, operations, and closure will be managed. During operations, the CDF will house the water management facilities, the major components of which will include the following:

- Reclaim Pond on the CDF. This pond will be relocated throughout the mine's operating life as the CDF develops;
- 5 Seepage Collection Ponds (SCPs) located downstream of the CDF;
- Surge Pond near the Plant;
- Plant Site Runoff Pond;
- STP;
- ETF; and
- related water management facilities, including drainage ditches, emergency spillways, pump stations, and the reclaim water pipeline system.

During operations, all water that has been in contact with ore or mine waste will be collected in one of the following: the SCPs, the Open Pit sump, or the Reclaim Pond. Water collected in these ponds/sump will be pumped to the Surge Pond. Water will then be pumped from the Surge Pond either to the Plant for reuse or to the ETF for treatment. Treated effluent from the ETF and STP will be pumped through a diffuser directly into Peanut Lake.

The detailed closure and reclamation plan is provided in Sections 3.0 (Project Description) and 9.0 (KLOI: Closure and Reclamation) of the DAR (Fortune 2011). A brief description is provided here. During closure, pumping water out of the Open Pit will cease and the Open Pit will slowly fill with water. The rate of filling will increase by directing CDF runoff (and some seepage) into the Open Pit. The Project Description assumes that water that accumulates in some SCPs, as well as the Surge Pond, will be passively treated in Wetland Treatment Systems and then released directly into Nico Lake. Overflow from the Open Pit will be passively treated in Wetland Treatment Systems and released into Peanut Lake. This is subject to demonstrating the technical performance of the Wetland Treatment Systems.

Potential NICO Project activities that could result in emissions to the environment are listed below:

- emission of chemicals to air from fuel combustion sources such as mine equipment and vehicles during construction and operations;
- generation of road dust during transportation of supplies to the site during construction and operations and during transportation of concentrate to off-site processing facilities during operations;
- mining, crushing, and disposal of mine rock and tailings during operations;
- water discharges, including the following:
  - management and discharge of stormwater runoff;
  - discharge of water from the ETF and STP during operations;
  - seepage from the CDF during operations and post-closure; and

- flooding of the Open Pit during post-closure.

1.4 Study Areas

This section contains a brief description of the study areas used to analyze and assess effects to aquatic life with reference to sections and figures within the DAR (Fortune 2011).

1.4.1 General Setting

The NICO Project is located within the Marian River drainage basin, approximately 10 kilometres east of Hislop Lake at a latitude of 63°33' North and a longitude of 116°45' West, and within the Taiga Shield and Taiga Plains Ecoregions (Ecosystem Classification Group 2007, 2008). The NICO Project spans 2 Level II Ecoregions: Taiga Shield and Taiga Plains.

The NICO Project intersects both the Lou Lake and Burke Lake watersheds. Both drainage systems discharge water to the southwest to the Marian River. The Marian River generally flows towards the south joining first with the Emile River and second with LaMartre River. The Marian River drains into Marian Lake, which drains to the North Arm of Great Slave Lake (Section 7.0, Figure 7.1-1 and Section 12.0, Figure 12.1-1 of the DAR). Great Slave Lake is drained by the Mackenzie River, which discharges to the Beaufort Sea.

1.4.2 Regional and Local Study Areas

A conventional terminology was used: regional study area and local study area. These study areas differ depending on the NICO Project disciplines. The study areas for the aquatic RA were aligned with the study areas identified by the NICO Project disciplines that will predict potential NICO Project-related changes to water quality, or that provided information relevant to aquatic receptors. The reader is referred to the relevant sections of the DAR for detailed descriptions of the study areas for the water quality assessment (Section 7.0, Figure 7.1-1 of the DAR), and the fish and fish habitat assessment (Section 12.0, Figure 12.1-1 of the DAR).

1.5 Content

This report is generally organized as follows:

- Section 2.0: Risk Assessment Framework and General Approach, describes each component of the RA framework (problem formulation, exposure assessment, toxicity assessment, risk characterization) and the general approach used in the aquatic RA.
- Section 3.0: Data Used in the Aquatic Risk Assessment, summarizes the data used in support of the aquatic RA.
- Section 4.0: Site-specific Water Quality Objectives, provides the approach used to derive the water quality objectives and the proposed objectives for the NICO Project.
- Section 5.0: Aquatic Risk Assessment, provides the assessment of the potential health effects to aquatic life that may occur as a result of the changes to the aquatic environment due to predicted emissions from the NICO Project.
- Section 6.0: Summary of Aquatic Health Results and Conclusions, provides the overall assessment of NICO Project-related effects on aquatic life (including an assessment of the cumulative effects due to foreseeable projects, developments, activities, and natural factors that influence the environment).

- Section 7.0: References, provides the sources of information relied upon in the aquatic RA.
- Section 8.0: Acronyms and Abbreviations.
- Section 9.0: Glossary.

The following appendices are also included in this report to provide additional detailed information:

- Appendix A: Pathway Analysis
- Appendix B: Site-Specific Water Quality Objectives
- Appendix C: Surface Water Screening Tables
- Appendix D: Sediment Screening Tables
- Appendix E: Exposure Concentrations in Surface Water
- Appendix F: Exposure Concentrations in Sediment
- Appendix G: Derivation of Toxicity Benchmarks for Copper and Selenium for Burke Lake

2.0 RISK ASSESSMENT FRAMEWORK AND GENERAL APPROACH

2.1 Risk Assessment Framework

Risk assessment is a scientific tool used to characterize the nature and magnitude of potential risks, if any, associated with the exposure of receptors (e.g., aquatic life) to chemicals. For there to be a potential risk, the following 3 conditions must be met:

- a chemical must be present at levels that could be harmful;
- a receptor must be present; and
- there must be an exposure pathway by which the receptor can come into contact with the chemical.

These 3 conditions are illustrated in Figure 2.1-1, where risk is anticipated to occur when the 3 necessary conditions are met.

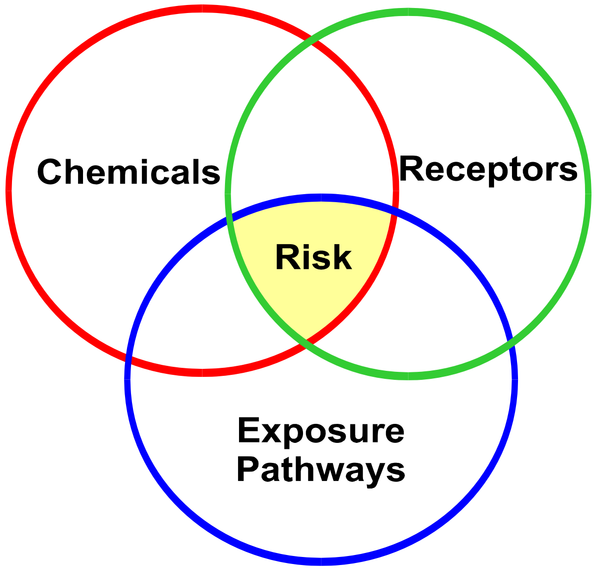


Figure 2.1-1: Venn Diagram Showing the Three Conditions that must Exist for there to be a Potential Health Risk (modified from CCME 1996)

To determine whether these conditions are present, the RA framework used in Canada typically involves 4 components, as described below:

i) Problem formulation: The problem formulation involves developing a focused understanding of how environmental (i.e., water and sediment) quality might affect the health of receptors (i.e., aquatic life) near the proposed NICO Project. The problem formulation identifies the following:

- chemicals that may be present at levels that may be harmful to receptors. These are termed CoPCs;
- a representative set of receptors (i.e., aquatic life) that may be present in the vicinity of the NICO Project; and
- pathways by which receptors may be exposed to CoPCs (e.g., through direct contact with surface water or sediment).

The information from the problem formulation is summarized in a conceptual site model which illustrates the pathways of the CoPCs from their sources, through the relevant environmental media and to the receptors of interest.

ii) Exposure assessment: The exposure assessment provides an estimate of the degree of exposure of receptors to the CoPCs. For aquatic life, exposure is expressed as the concentration of the CoPC in surface water and sediment.

iii) Toxicity assessment: The toxicity assessment provides the basis for assessing what is an acceptable exposure and what exposure may adversely affect the health of receptors. This involves identification of the potentially toxic effects of the CoPCs and determination of the concentration to which a receptor can be exposed without experiencing adverse health effects. This value is called the toxicity benchmark (or SSWQOs). This is expressed as an acceptable concentration of the CoPC in surface water or sediment.

iv) Risk characterization: The final component of an RA determines the potential for adverse health effects to occur. This is determined by comparing the estimated exposures (i.e., the surface water or sediment concentration from the exposure assessment) with the concentration that is determined to be acceptable (i.e., the toxicity benchmark from the toxicity assessment). The characterization of risks includes consideration of the uncertainty and conservatism in the RA.

2.2 General Approach

2.2.1 Pathway Analysis

In mining projects, potential impacts can only occur where there is a direct link between a project component or activity and the environment. Therefore, the aquatic RA focused on those components or activities of the NICO Project that could result in NICO Project-related emissions to surface waters and corresponding potential effects on aquatic life. Potential impacts on aquatic life may occur only where there is a complete exposure pathway between a source and an aquatic receptor. Those aspects of the NICO Project that could result in emissions to surface waters were determined based upon the Project Description (Section 3.0 of the DAR) and the potential for releases of Project-related CoPCs during the various phases of the Project (i.e., construction, operations, closure, and post-closure; as summarized in Section 1.3), considering all proposed environmental design features and mitigation measures outlined in the DAR (Fortune 2011). This pathway analysis (the identification of the linkages between the NICO Project components or activities and corresponding potential effects on aquatic life) is summarized in Appendix A. This pathway analysis was part of the assessment approach used to analyze and assess impacts for the NICO Project in the DAR (Section 6.0; Fortune 2011), and as such was also used as part of the assessment approach for the aquatic RA. As per the DAR, pathways were determined to be primary, secondary (minor), or as having no linkage, as described below:

- No linkage – pathway is removed by environmental design features and mitigation so that the NICO Project results in no detectable environmental change and effects to aquatic life relative to baseline or guidelines values;
- Secondary – pathway could result in a minor environmental change, but would have a negligible effect on aquatic life relative to baseline or guideline values; and
- Primary – pathway is likely to result in a measureable environmental change that could contribute to effects on aquatic life relative to baseline or guidelines values.

Primary pathways require further analysis to determine the environmental significance from the NICO Project on aquatic life. Pathways with no linkage to aquatic life or that are considered minor (secondary) are not analyzed further because environmental design features and mitigation will remove the pathway (no linkage) or effects to aquatic life can be determined to be negligible through a simple qualitative evaluation of the pathway. Pathways determined to have no linkage to aquatic life or those that are considered to be secondary are not predicted to result in environmentally significant effects to aquatic life.

As shown in Appendix A, effect pathways are primarily associated with dust generation and deposition to surface waters, as well as water discharges to surface waters. All primary pathways were assessed further in the aquatic RA. The primary pathways that were assessed are described below:

- Discharge of treated water from the ETF to Peanut Lake during operations, and potential impacts on downstream surface waters including Burke Lake and the Marian River;
- Particulate deposition to nearby surface waters during the construction and operations phases; and
- Seepage from the CDF during post-closure and potential impacts on downstream surface waters.

During operations, several mining activities (e.g., dewatering of mine workings) and mine site water management activities (e.g., management of process water, surface water runoff, pumping of water from the Open Pit, and discharge of effluent from the STP) could affect downstream surface waters; however, water from these activities will be captured and re-used or treated prior to discharge to the aquatic environment (Appendix A).

During closure and reclamation, water that accumulates in some of the SCPs, as well as the Surge Pond, will be passively treated in Wetland Treatment Systems and then released directly into Nico Lake (the detailed closure and reclamation plan is provided in Section 9.0 of the DAR; Fortune 2011). This is subject to the demonstration of the technical performance of the Wetland Treatment Systems. If the technical performance of the Wetland Treatment Systems is not demonstrated prior to closure, then the contingency will be to pump water from the SCPs, as well as from the Surge Pond, into the Open Pit. Initially, water will accumulate in the Open Pit. Just prior to pit overflow, the water quality at the top of the Flooded Open Pit will be evaluated, and a decision will be made about post-overflow treatment. The options include the following:

- providing the water quality is acceptable, overflow will be allowed to occur through wetland treatment system No. 4 into Peanut Lake with no further requirement for treatment;
- as a contingency, the Flooded Open Pit water can be treated in the pit by chemical or biological means, prior to the discharge of the overflow through wetland treatment system No. 4 into Peanut Lake; and
- as a contingency, a new ETF can be constructed and used to treat Flooded Open Pit water without spillover, with discharge through a diffuser into Peanut Lake.

Based on the above, overflow will not be a source of exposure for aquatic receptors and this pathway has not been considered further in the aquatic RA. As part of the closure and reclamation plan the Flooded Open Pit is not intended to be a functioning part of the ecosystem. As such, water quality in the Flooded Open Pit has not been considered further with respect to the aquatic RA. Potential exposures to wildlife (e.g., waterfowl) that may use the open pit is addressed in the Wildlife Health Risk Assessment (Golder 2012).

2.2.2 Assessment Scenarios

To determine the potential effects of NICO Project-related emissions on fish and other aquatic biota, 2 scenarios were assessed in the aquatic RA, as follows:

- quantitative assessment of exposure to emissions from existing and approved sources (i.e., the Baseline Case); and
- quantitative assessment of exposure to cumulative emissions from existing and approved sources and from the NICO Project during, construction, operations, active closure, and post-closure (i.e., the Project Case).

The scenarios are described further below:

- The Baseline Case was assessed to gain an understanding of the environment as it currently exists without the NICO Project. This scenario used measured concentrations of CoPCs in surface water and sediment collected from the study area.
- The Project Case represents the change to the environment as a result of NICO Project components or activities for all phases of the NICO Project (construction, operations, closure, and post-closure), considering all proposed environmental design features and mitigation measures. This scenario was assessed quantitatively and used predicted concentrations of CoPCs in environmental media (i.e., surface water and sediment) for the study area.

A qualitative assessment of exposure due to cumulative emissions was also included in the aquatic RA. The Cumulative Effects Case represents the cumulative change to the environment due to the NICO Project as described above and other foreseeable projects, developments, activities, and natural factors that influence the environment. Given that the potential changes to the environment as a result of other foreseeable projects, developments, activities, and natural factors could not be supported with numerical data, the Cumulative Effects Case was qualitatively evaluated.

3.0 DATA USED IN THE AQUATIC RISK ASSESSMENT

The assessment of potential impacts relied upon the following:

- detailed water quality data for Nico Lake, Peanut Lake, Burke Lake, and the Marian River collected during the aquatic baseline studies (Annex C of the DAR);
- detailed sediment quality data for Nico, Peanut, and Burke lakes collected during the aquatic baseline studies (Annex C of the DAR);
- aquatic species and communities present in surface waterbodies in the NICO Project area as identified in the aquatic baseline report (Annex C of the DAR);
- predicted surface water concentrations for Nico Lake, Peanut Lake, Burke Lake, and the Marian River for the construction, operations, closure, and post-closure phases of the NICO Project, as determined through surface water quality modelling (Section 7.0 of the DAR);
- predicted sediment concentrations for Nico, Peanut, and Burke lakes at closure, as determined through sediment quality modelling (Section 7.0 of the DAR); and
- water quality objectives developed specifically for the NICO Project (Section 4.0 and Appendix B).

4.0 SITE-SPECIFIC WATER QUALITY OBJECTIVES

Site-specific water quality objectives were derived to help guide the design of the water treatment system for the NICO Project. As well, the TOR for the NICO Project notes that SSWQOs are to be proposed for all CoPCs identified for the NICO Project to protect downstream water quality (MVRB 2009). This section details the approach used to develop the SSWQOs, as well as the proposed SSWQOs. Aluminum, ammonia, antimony, arsenic, cadmium, chloride, cobalt, copper, iron, lead, nitrate, selenium, sulphate, uranium, and zinc were initially identified as CoPCs because predicted concentrations in the influent to the ETF during operations and/or in the pit lake during post-closure were, at the time of the development of the SSWQOs, anticipated to be greater than baseline conditions and/or Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality

Guidelines (CWQGs) for the Protection of Aquatic Life, and SSWQOs were derived for these CoPCs. These SSWQOs were derived based on measured baseline water quality conditions (e.g., based on measured water hardness, dissolved organic carbon concentrations [DOC], concentrations of various cations and anions in the receiving waterbodies as determined during the baseline studies). This is because predicted concentrations in the receiving surface waters were not available at the time of the development of the site-specific water quality guidelines (i.e., the objectives were developed when the water treatment options for the NICO Project were being evaluated). Because water quality during the various phases of the NICO Project may be different than under baseline (current) conditions, the SSWQOs should be reviewed and revised as necessary once follow-up water quality monitoring data is available for the NICO Project.

It should be noted that since the development of the SSWQOs, ion exchange technology was selected as the water treatment option for the NICO Project. Site-specific water quality objectives were developed for some CoPCs that were not needed because predicted surface water concentrations with implementation of ion exchange technology were lower than CCME CWQGs and baseline conditions. At the same time, other chemicals were identified as CoPCs that were not initially identified during the development of the SSWQOs. As such, toxicity benchmarks have been developed for these chemicals in the Toxicity Assessment (Section 5.3.1). The aquatic RA only evaluates the risks to aquatic life associated with those CoPCs for which predicted surface water concentrations (based on implementation of ion exchange technology) are greater than CCME CWQGs and baseline conditions. Should the treatment option (and hence, water quality predictions) change, the list of CoPCs and the aquatic RA should be reviewed and revised as required.

4.1.1 Approach

The approach to the development of SSWQOs described herein is adopted from the approaches developed by the CCME and provincial agencies in the development of the CWQGs. The approach is based on the overall objective of the CWQGs for the protection of aquatic life: *to be protective of the most sensitive species, in the most sensitive life stage, over an indefinite period of exposure*, the policy objectives and guiding principles as described in the Mackenzie Valley Land and Water Board & Effluent Quality Management Policy, dated 29 April 2010, and the effluent discharge limits for mining projects in the NWT (INAC 2009).

The CWQGs are developed in consideration of the end water use, and protection of aquatic life is generally considered to be the most sensitive end use. The CCME has also developed drinking water guidelines, although these are generally less stringent, since these are based on consumption patterns.

The numerical CWQGs for the protection of aquatic life are considered generic, since they are intended for application in all regions of Canada and do not, in most cases, make allowance for regional differences (although the CCME (2003a) has provided methods for calculating site-specific objectives). Guidelines based on bulk water concentrations of metals can be overly conservative in some situations, due to the influence of local physico-chemical factors and the presence of natural complexing ligands. These include the presence of calcium, magnesium, and sodium ions that can effectively reduce metal toxicity in aquatic biota through competitive interactions at uptake sites, and natural complexing ligands such as the ubiquitous humic and fulvic material from plant decomposition that can reduce the bioavailable portion of a metal, and the presence of reactive sulphides. Where concentrations of the biologically active forms of a metal are high due to a paucity of competing ions or complexing ligands, or ingestion is a significant pathway, the guidelines may be under-protective.

The CWQGs for the protection of aquatic life are generally based on laboratory toxicity tests using laboratory or reconstituted water to which the metal is introduced in a highly soluble (and bioavailable) form. It is extremely difficult to simulate under laboratory conditions the variations in natural conditions that would reflect the influence of materials such as naturally occurring ligands on metal availability. As a result, in the laboratory tests used to develop the generic guidelines, the concentrations of a metal will typically exert a more profound effect on the organisms being tested than is likely to be the case within a natural setting. Due to the diverse geologic conditions within Canada, the natural distribution of metals, ions, and organic matter can be highly variable. Therefore, site-specific approaches to setting water quality guidelines have been developed to reflect this variability by incorporating into the guidelines locally occurring factors that can affect bioavailability and toxicity. For example, the CWQGs for the protection of aquatic life for copper and lead allow for the derivation of a site-specific guideline based on site water hardness.

Because direct toxicity tests cannot be undertaken for the NICO Project at this time, the development of site-specific objectives relied upon the existing water quality data in adjacent waterbodies to characterize levels of naturally occurring ions and ligands, and a review of the toxicity data from a variety of literature sources. In particular, recent studies in the scientific literature that have characterized levels of calcium, magnesium, and DOC with respect to their influence on the toxicity of specific metals were considered. Recent studies on copper, for example, have shown that the presence of these parameters can significantly increase the threshold concentrations at which copper becomes toxic to test organisms. While the roles of competing ions (sodium, calcium, and magnesium) and complexing ligands (such as DOC) in reducing metal toxicity have been studied extensively for some metals, the limited data available for sulphide suggest that sulphide can also significantly reduce the toxicity of metals (such as copper) to aquatic life. The availability of this type of data, therefore, permitted an approach that incorporated naturally occurring parameters that reduce toxicity into the development of SSWQOs for the NICO Project.

Based on this understanding, the development of SSWQOs for the NICO Project was generally conducted through the following step-wise approach:

- available toxicity literature was reviewed to characterize biological effect levels that correspond to concentrations of toxicity modifying parameters specific to each metal of concern;
- existing water quality was characterized with respect to these substances in Nico Lake and Peanut Lake;
- baseline aquatic ecology data was reviewed to identify species of aquatic biota that are present within Nico Lake and Peanut Lake; and
- site-specific toxicity concentrations were developed for each metal of concern that are protective of the most sensitive receptor in Nico Lake and Peanut Lake.

The SSWQOs provided herein have been derived for the discharge receivers (i.e., Nico and Peanut lakes). Since the water quality characteristics of each waterbody are different, water quality objectives have been developed for each waterbody. Potential impacts on Burke Lake and the Marian River were assessed relative to appropriate toxicity benchmarks that were derived on a similar basis to the SSWQOs.

The specific approaches used to derive the SSWQOs for the identified CoPCs is detailed in Appendix B. The water quality objectives were developed based on site-specific considerations; however, they were also developed using conservative assumptions, including the most sensitive endpoints for the most sensitive species. As such, exceedances of the SSWQOs do not necessarily indicate an adverse effect but rather warrants a more detailed examination of the potential for adverse effects.

4.1.2 Proposed Site-Specific Water Quality Objectives

Table 4.1.2-1 summarizes the proposed SSWQOs for the identified CoPCs for Nico Lake and Peanut Lake.

Table 4.1.2-1: Proposed Site-Specific Water Quality Objectives for the NICO Project

Chemicals of Potential Concern	CCME CWQG for the Protection of Aquatic Life[a] (µg/L)	Site-Specific Water Quality Objective (µg/L)	
		Nico Lake	Peanut Lake
Aluminum	100[b]	420 (dissolved aluminum)	410 (dissolved aluminum)
Ammonia	1,100 (µg-N/L)[c]	4,160 (µg-N/L)	
Antimony	NV	30	
Arsenic	5	50	
Cadmium	0.017[d]	0.15	
Chloride	NV	353,000	
Cobalt	NV	10	
Copper	2[e]	25 (dissolved copper)	22 (dissolved copper)
Iron	300	1,500	
Lead	1[e]	7.6	
Nitrate	13,000	133,000	
Selenium	1	5.0	
Sulphate	NV	500,000	
Uranium	NV	27	
Zinc	30	110	

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guideline (CWQGs) for the Protection of Aquatic Life.

[b] Based on the guideline for a pH of ≥6.5.

[c] Based on a temperature of 7 °C and a pH of 8.

[d] Based on a water hardness of 47 mg/L as $CaCO_3$.

[e] The minimum CCME CWQG, regardless of water hardness.

µg/L = microgram per litre; NV = No guideline value.

5.0 AQUATIC RISK ASSESSMENT

5.1 Problem Formulation

5.1.1 Identification of Chemicals of Potential Concern

Chemicals of potential concern in surface water and sediment were identified using a 2-tiered approach. First, CoPCs were identified by comparing the predicted concentrations of chemicals in surface water and sediment to applicable guidelines. Then, concentrations were compared to baseline concentrations. Chemicals were identified as CoPCs and evaluated in the aquatic RA if predicted concentrations were greater than guidelines and baseline concentrations. If guidelines were not available, the chemical was identified as a CoPC if the predicted concentration was greater than the baseline concentration. For surface water, a third tier of screening was conducted in which predicted surface water concentrations during construction, operations, closure and post-closure were compared to the SSWQOs that were developed for the NICO Project (Section 4.0 and Appendix B). The Tier 3 screening was completed for the receiving waterbodies only (i.e., Nico and Peanut lakes).

The screening of chemicals included elimination of essential elements that are fundamentally non-toxic substances such as calcium, magnesium, potassium, and sodium. Furthermore, as first described in Section 4.1.1, major ions such as calcium, magnesium, potassium, and sodium can effectively reduce metal toxicity in aquatic biota through competitive interactions at uptake sites. As such, increases in concentrations of these parameters above baseline would not constitute a potential adverse effect but would serve to ameliorate potential metal toxicity to aquatic biota.

For surface water, the chemical screening was completed for each waterbody (Nico, Peanut, and Burke lakes, and Marian River) for each phase of the NICO Project (construction, operations, active closure, and post-closure). The sediment quality predictions represent concentrations in sediment at closure and account for incremental deposition of suspended particulates and associated metals during the construction and operations phases. As such, for sediment, the results of the chemical screening have been applied to both the active closure and post-closure phases of the NICO Project.

5.1.1.1 Tier 1: Comparison to Guidelines

The 95th percentile (for surface water) and maximum concentrations (for sediments) of chemicals were compared to applicable regulatory guidelines. The 95th percentile is considered to be more representative of a conservative upper bound of concentrations that could be expected to occur during a dry year, and for this reason the water quality predictions were presented at the 95th percentile level (Section 7.0 of the DAR) and these concentrations were used for surface water in the aquatic RA.

The applicable regulatory guidelines for surface water and sediment used for the aquatic RA were the CCME CWQGs for the Protection of Aquatic Life and the Canadian Sediment Quality Guidelines (CSQGs) for the Protection of Aquatic Life, respectively. The CCME CSQGs include Interim Sediment Quality Guidelines (ISQGs) and Probable Effect Levels (PELs). The PELs represent the concentrations above which adverse effects on aquatic organisms are expected to occur frequently, whereas the ISQGs were developed to protect the most sensitive organisms. While both guidelines have been used to evaluate the sediment chemistry data, emphasis has been placed on the PELs because ISQGs are based on limited data with known information gaps, and so do not necessarily indicate an ecological effect.

It should be noted that chromium concentrations in surface water were screened against the CCME CWQG for hexavalent chromium of 0.001 milligrams per litre (mg/L). The maximum predicted surface water concentration for all waterbodies considered in this assessment for all phases of the NICO Project was 0.002 mg/L, just above the CWQG for hexavalent chromium [Cr(VI)] and well below the CWQG for trivalent chromium [Cr(III)] of 0.0089 mg/L. In fact, most chromium in surface waters is likely to be present as Cr(III) given that Cr(VI) is reduced to Cr(III) in the presence of natural organic carbons (humic and fulvic acids, tannic acids). As such, chromium was not considered further in this assessment.

The guidance framework for total phosphorus provided by the CCME (2004) was followed with respect to screening for total phosphorus. First, predicted concentrations were screened against the trigger range for mesotrophic lakes and rivers of 10 to 20 micrograms per litre (µg/L), which is a desired concentration range for total phosphorus. Based on total phosphorus concentrations, Nico, Peanut, and Burke lakes and the Marian

River are classified as mesotrophic (moderately productive) at baseline conditions. Second, predicted concentrations were compared to baseline concentrations as per the guidance framework. Up to a 50% increase in phosphorus above the baseline is acceptable (CCME 2004). Predicted total phosphorus concentrations were within the trigger range or less than 50% above the baseline concentration. As such, total phosphorus was not considered further in the assessment.

Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

Total dissolved solids (TDS) is a measure of inorganic salts, organic matter, and other dissolved materials in water. There is no CCME guideline for TDS for the protection of freshwater aquatic life. There are guidelines for the protection of agricultural uses which are 500 to 3500 mg/L for irrigation and 3000 mg/L for livestock (CCME 2011a, internet site). The United States Environmental Protection Agency (U.S. EPA) does not have a national criterion for TDS for freshwater aquatic life but 15 states have developed criteria. Of the 15 states, values ranged from 100 to 1500 mg/L. Chapman et al. (2000) studied the toxicity of TDS to early life stages of rainbow trout and chironomid larvae using synthetic mine effluents that were formulated to match the ionic composition of effluents from two mines. No toxicity was observed at >2000 mg/L with rainbow trout embryos or developing fry. No observed adverse effect concentrations for chironomids were 1134 mg/L and 1220 mg/L for the 2 effluents. A screening value of 500 mg/L, which is the CCME guideline for the protection of agricultural uses, was used in the Tier 1 screening for TDS in this assessment. Although not directly applicable to aquatic life, this value appears to be protective of both benthic invertebrates and fish exposed to mine effluents and it is within the range of reported guideline values used by various state agencies in the U.S.

Comparison to guidelines was considered to represent a conservative screening of the potential for the predicted concentrations to elicit adverse effects. Therefore, predicted chemical concentrations that are below guidelines can be assumed to pose no risk to aquatic life.

If 95th percentile and maximum concentrations in surface water and sediment, respectively were greater than applicable guidelines, the CoPC was carried forward to the next tier of the screening process. Likewise, chemicals that lacked guidelines were carried forward to the next tier of the screening process.

5.1.1.2 Tier 2: Comparison to Baseline Concentrations

A second tier screening was conducted by comparing the 95th percentile predicted concentrations in surface water and maximum predicted sediment concentrations to baseline concentrations. The second tier screening included only those metals that were above CWQGs or CSQGs, or for which guidelines were not available, as determined during the first tier of screening. Where a metal was predicted to be elevated 10 percent (%) or more above the mean baseline concentration, the metal was retained as a CoPC. Metals, for which guidelines were not available, were retained as CoPCs if predicted concentrations in surface water or sediment were 10% higher than mean baseline concentrations.

Comparison to a threshold of 10% above baseline concentrations was considered to represent a conservative evaluation of whether a measurable NICO Project-related impact on surface water/sediment quality could occur. Given spatial and temporal variability, field sampling variability, variability in laboratory methods, and the conservatism applied in the predictive water and sediment quality models, any predicted increase of less than 10% above baseline concentrations was considered unlikely to reflect a "significant" change in environmental quality as a result of the NICO Project.

5.1.1.3 Tier 3: Comparison to Site-specific Water Quality Objectives

For Nico Lake and Peanut Lake, a third tier screening was conducted by comparing the 95th percentile predicted concentrations in surface water to SSWQOs derived for the NICO Project. The third tier screening included only those metals with predicted concentrations 10% higher than mean baseline concentrations. If predicted concentrations in surface water were greater than SSWQOs, the CoPC was carried forward in the aquatic RA.

5.1.1.4 Results of the Chemical Screening

5.1.1.4.1 Surface Water

5.1.1.4.1.1 Construction

Chemicals with predicted concentrations in surface water during the construction phase greater than guidelines, mean baseline concentrations plus 10% and SSWQOs (for Nico Lake and Peanut Lake only) were identified as CoPCs. The detailed screening tables are provided in Appendix C (Tables C-1, C-2, C-3, and C-4 for Nico Lake, Peanut Lake, Burke Lake, and the Marian River, respectively). A summary of the results of the chemical screening are provided in Table 5.1.1-1.

Table 5.1.1-1: Contaminants of Potential Concern in Surface Waters of Nico Lake, Peanut Lake, Burke Lake, and Marian River during Construction

Chemical	Nico Lake	Peanut Lake	Burke Lake	Marian River
Aluminum	×	✓	✓	×
Arsenic	×	×	✓	×
Barium	✓	✓	✓	✓
Cobalt	×	×	✓	×
Manganese	×	✓	×	✓
Mercury	×	×	×	✓
Vanadium	✓	✓	×	✓

Notes:

✓ = chemical exceeds the Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guideline (CWQG) for the Protection of Aquatic Life and is greater than 10% over mean baseline concentrations and is greater than the site-specific water quality objective (for Nico Lake and Peanut Lake only) and therefore was retained for assessment.

× = chemical does not exceed the CCME CWQG for the Protection of Aquatic Life or/and is less than 10% over mean baseline concentrations or/and is less than the site-specific water quality objective (for Nico Lake and Peanut Lake only) and therefore was not retained for assessment.

5.1.1.4.1.2 Operations

Chemicals with predicted concentrations in surface water during the operations phase greater than guidelines, mean baseline concentrations plus 10% and SSWQOs (for Nico Lake and Peanut Lake only) were identified as CoPCs. The detailed screening tables are provided in Appendix C (Tables C-5, C-6, C-7, and C-8 for Nico Lake, Peanut Lake, Burke Lake, and the Marian River, respectively). A summary of the results of the chemical screening are provided in Table 5.1.1-2.

Table 5.1.1-2: Contaminants of Potential Concern in Surface Waters of Nico Lake, Peanut Lake, Burke Lake, and Marian River during Operations

Chemical	Nico Lake	Peanut Lake	Burke Lake	Marian River
Aluminum	✓	✓	✓	✓
Antimony	×	×	✓	×
Arsenic	×	×	✓	×
Barium	✓	✓	✓	✓
Cobalt	×	×	✓	×
Copper	×	×	✓	×
Iron	✓	✓	✓	✓
Manganese	×	✓	×	✓
Mercury	×	×	×	✓
Vanadium	✓	✓	×	✓

Notes:

✓ = chemical exceeds the Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guideline (CWQG) for the Protection of Aquatic Life and is greater than 10% over mean baseline concentrations and is greater than the site-specific water quality objective (for Nico Lake and Peanut Lake only) and therefore was retained for assessment.

× = chemical does not exceed the CCME CWQG for the Protection of Aquatic Life or/and is less than 10% over mean baseline concentrations or/and is less than the site-specific water quality objective (for Nico Lake and Peanut Lake only) and therefore was not retained for assessment.

5.1.1.4.1.3 Active Closure

Chemicals with predicted concentrations in surface water during active closure greater than guidelines, mean baseline concentrations plus 10% and SSWQOs (for Nico Lake and Peanut Lake only) were identified as CoPCs. The detailed screening tables are provided in Appendix C (Tables C-9, C-10, C-11, C-12 for Nico Lake, Peanut Lake, Burke Lake, and the Marian River, respectively). A summary of the results of the chemical screening are provided in Table 5.1.1-3.

5.1.1.4.1.4 Post-Closure

Chemicals with predicted concentrations in surface water during post-closure greater than guidelines, mean baseline concentrations plus 10% and SSWQOs (for Nico Lake and Peanut Lake only) were identified as CoPCs. The detailed screening tables are provided in Appendix C (Tables C-13, C-14, C-15 and C-16 for Nico Lake, Peanut Lake, Burke Lake, and the Marian River, respectively). A summary of the results of the chemical screening are provided in Table 5.1.1-4.

Table 5.1.1-3: Contaminants of Potential Concern in Surface Waters of Nico Lake, Peanut Lake, Burke Lake, and Marian River during Active Closure

Chemical	Nico Lake	Peanut Lake	Burke Lake	Marian River
Aluminum	✓	✓	✓	×
Antimony	×	×	✓	×
Arsenic	×	×	✓	×
Barium	✓	✓	✓	✓
Cobalt	×	×	✓	×
Copper	×	×	✓	×
Iron	✓	×	✓	×
Manganese	×	✓	×	✓
Mercury	×	×	×	✓
Selenium	×	×	✓	×
Vanadium	✓	✓	×	✓

Notes:

✓ = chemical exceeds the Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guideline (CWQG) for the Protection of Aquatic Life and is greater than 10% over mean baseline concentrations and is greater than the site-specific water quality objective (for Nico Lake and Peanut Lake only) and therefore was retained for assessment.

× = chemical does not exceed the CCME CWQG for the Protection of Aquatic Life or/and is less than 10% over mean baseline concentrations or/and is less than the site-specific water quality objective (for Nico Lake and Peanut Lake only) and therefore was not retained for assessment.

Table 5.1.1-4: Contaminants of Potential Concern in Nico Lake, Peanut Lake, Burke Lake, and Marian River during Post-Closure

Chemical	Nico Lake	Peanut Lake	Burke Lake	Marian River
Aluminum	×	×	✓	×
Antimony	×	×	✓	×
Barium	✓	✓	✓	✓
Manganese	×	✓	×	✓
Mercury	×	×	×	✓
Vanadium	✓	✓	×	✓

Notes:

✓ = chemical exceeds the Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guideline (CWQG) for the Protection of Aquatic Life and is greater than 10% over mean baseline concentrations and is greater than the site-specific water quality objective (for Nico Lake and Peanut Lake only) and therefore was retained for assessment.

× = chemical does not exceed the CCME CWQG for the Protection of Aquatic Life or/and is less than 10% over mean baseline concentrations or/and is less than the site-specific water quality objective (for Nico Lake and Peanut Lake only) and therefore was not retained for assessment.

5.1.1.4.2 Sediment

Chemicals with predicted concentrations in sediments at closure greater than guidelines and mean baseline concentrations plus 10% were identified as CoPCs. It should be noted that concentrations in sediments were predicted at closure because these concentrations would represent the cumulative impact of the entire operating phase of the mine. The detailed screening tables are provided in Appendix D (Tables D-1, D-2, and D-3 for Nico Lake, Peanut Lake, and Marian River, respectively). A summary of the results of the chemical screening are provided in Table 5.1.1-5. Because the sediment quality predictions represent conditions in sediment at closure, the results of the chemical screening has been applied to both the active closure and post-closure phases of the NICO Project.

Table 5.1.1-5: Contaminants of Potential Concern in Sediments of Nico Lake, Peanut Lake, and Burke Lake at Closure

Chemical	Nico Lake	Peanut Lake	Burke Lake
Antimony	✓	✓	✓
Arsenic	✓	×	×
Barium	✓	✓	✓
Beryllium	✓	×	×
Cobalt	×	✓	✓
Molybdenum	✓	✓	✓
Nickel	✓	×	✓
Selenium	×	✓	✓
Uranium	×	×	✓
Vanadium	✓	×	✓

Notes:

✓ = chemical exceeds the Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guideline (CSQG) for the Protection of Aquatic Life (Probable Effects Level; PEL) and is greater than 10% over mean baseline concentrations and therefore was retained for assessment.

× = chemical does not exceed the CCME CSQG for the Protection of Aquatic Life (PEL) or/and is less than 10% over mean baseline concentrations and therefore was not retained for assessment.

5.1.2 Identification of Aquatic Receptors

5.1.2.1 Criteria for Selection

The aquatic baseline report identified several aquatic communities and species present in surface waterbodies in the NICO Project area, including the following:

- Phytoplankton: Cyanobacteria (blue-green algae), Chlorophyta (green algae), and Chrysophyta (golden-brown algae) dominated the phytoplankton communities in most waterbodies;
- Zooplankton: Cladocera, Calanoida, Cyclopoida, and Rotifera;
- Benthic invertebrates: Chironomids, molluscs (snails and fingernail clams), and, to a lesser extent, ostracods (seed shrimp) and amphipods dominated the benthic invertebrate communities of waterbodies within the NICO Project area; and
- Fish: 10 species of fish were reported in the NICO Project area (Table 5.1.2-1). Northern pike (jackfish) and lake whitefish were the only species of fish common to most fish-bearing waterbodies in the NICO Project area.

Table 5.1.2-1: Fish Species Captured in the NICO Project Area (1998 to 2009)

Family	Common Name	Scientific Name
Catostomidae	Longnose sucker	*Catostomus catostomus* (Forster)
	White sucker	*Catostomus commersonii* (Lacepède)
Cottidae	Slimy sculpin	*Cotus cognatus* Richardson
Esocidae	Northern pike	*Esox lucius* Linnaeus
Gasterosteidae	Ninespine stickleback	*Pungitius pungitius* (Linnaeus)
Lotidae	Burbot	*Lota lota* (Linnaeus)
Percidae	Walleye	*Sander vitreus* (Mitchill)
Salmonidae	Arctic grayling	*Thymallus arcticus* (Pallas)
	Cisco	*Coregonus artedi* Lesueur
	Lake trout	*Salvelinus namaycush* (Walbaum)
	Lake whitefish	*Coregonus clupeaformis* (Mitchill)

Based upon the results of the aquatic baseline report, there are several aquatic species present in waterbodies in the NICO Project area that may be exposed to CoPCs emitted by the NICO Project; however, it is not practical or necessary to evaluate all species. Instead, groups of receptors were selected (e.g., aquatic plants, phytoplankton, zooplankton, and benthic invertebrates) or individual species were selected to represent groups of species within the same trophic level (e.g., fish). In this way, the same receptor groups as are considered in the development of the CCME CWQGs and ISGQs are considered in the aquatic RA.

Receptors were generally chosen to represent a typical food chain that would be found in an aquatic system and based on the following considerations:

- species observed in the NICO Project area as summarized in the aquatic baseline report;
- species that are of social or cultural significance to local communities;
- ecological relevance (i.e., species that play important roles in community structure or function [e.g., top predators or primary producers]);
- potential for exposure;
  - diet, habitat preferences and behaviours that make species likely to come into contact with the contaminants;
  - a highly mobile species that is exposed to multiple contaminant sources may not be the most appropriate receptor;
  - organisms are exposed to CoPCs through a number of pathways; the selected receptors of concern should cover multiple pathways to ensure a complete risk characterization;
- sensitivity to CoPCs;
- availability of ecotoxicological and exposure related data; and

- local species that are of concern to Federal and Provincial regulatory agencies (i.e., Species at Risk [SAR]).

5.1.2.2 Species at Risk

Consideration was given in the aquatic RA to SAR in accordance with CCME guidance to protect and conserve rare flora and fauna. Aquatic SAR were identified using the document "*Species at Risk in the Northwest Territories*". The document is a guide to species in the NWT currently listed, or considered for listing, under federal and territorial species at risk legislation.

The data obtained from the document were used to determine the potential for SAR in the NICO Project area and their current status (i.e., endangered, threatened, special concern) as listed federally on Schedule 1 of the *Species at Risk Act* (SARA) or listed territorially under the *Northwest Territories Endangered Species Act*. Under SARA, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) develops prioritized candidate lists of species requiring assessment. Aquatic species assessed as being at risk by COSEWIC and those listed in the COSEWIC Group 1 (High Priority) Candidate List, which contains species who are expected to be at high risk for extirpation from Canada, were also included in the potential SAR assessment. As well, Northwest Territories General Status Rank (i.e., at risk, may be at risk, sensitive, secure, undetermined, not assessed, alien, extirpated/extinct, vagrant, presence expected) were included in the assessment.

The review of the document identified four aquatic SAR that occur in the NWT (Table 5.1.2-2); however, based on species range information and the results of the aquatic resources baseline studies, the potential for these species to occur within the NICO Project area is considered to be low. As such, these species have not been considered further in the assessment.

5.1.2.3 Selected Receptors

The receptor groups or species identified as receptors for the NICO Project area are provided in Table 5.1.2-3. The table also provides rationale for selection of these receptors for the aquatic RA.

Lake whitefish and northern pike are the most common species in the local study area and regional study area are species of social and cultural significance to local communities (e.g., these species are harvested by local communities). Other species are also harvested, including white sucker, lake trout, loche, coney, pickerel, and grayling. Lake whitefish and northern pike were selected as surrogates for other fish species that may be harvested by local communities (Section 5.0 of the DAR).

Table 5.1.2-2: Aquatic Species at Risk in the Northwest Territories and their Potential to Occur in the NICO Project Area

Scientific Name	Common Name	NWT General Status Rank	COSEWIC	SARA	NWT Region Where the Species is Found	Potential for Species to Occur in the NICO Project Area	
Salvelinus confluentus	Bull Trout	May be at Risk	N/A	No Status	North Slave/Tłı̨chǫ; Dehcho; Sahtu	Low	Distribution in the NWT falls within the NICO Project area; however, this species was not identified in the NICO Project area during the aquatic baseline studies.
Stenodus leucichthys	Inconnu	May be at Risk	N/A	No Status	North Slave/Tłı̨chǫ; Dehcho; South Slave; Dehcho	Low	Distribution in the NWT falls within the NICO Project area; however, this species was not identified in the NICO Project area during the aquatic baseline studies.
Anarhichas denticulatus	Northern Wolffish	Undetermined	Threatened	Threatened	Reported in Prince Albert sound on Western Victoria Island and Mould Bay on Prince Patrick Island	Low	Distribution in the NWT falls outside the NICO Project area. Species lives in marine water exclusively.
Coregonus zenithicus	Shortjaw Cisco	At Risk	Threatened	No Status	Reported in Great Slave Lake and Tazin River. Unconfirmed reports from Great Bear Lake.	Low	Distribution in the NWT falls outside the NICO Project area.

Notes: No species have been assessed or listed under the *Species at Risk (NWT) Act*.

COSEWIC = Committee on the Status of Endangered Wildlife in Canada; SARA = *Species at Risk Act*; NWT = Northwest Territories

Table 5.1.2-3: Receptors Evaluated

Receptor Group	Receptor	Trophic Level	Rationale for Selection
Aquatic Plants	Note [a]	Primary Producers	• Important food source for other aquatic organisms • Provide habitat to other aquatic organisms • Directly exposed to CoPCs in surface water and sediments
Phytoplankton	Note [a]	Primary Producers	• Important food source for zooplankton that feed on them • Various species identified within the NICO Project area • Plankton are not mobile but will drift with lake currents and wave/wind action. As a result, exposure may be variable depending on the extent of contamination. • Directly exposed to CoPCs in surface water
Zooplankton	Note [a]	Primary Consumers	• Important food source for other zooplankton and fish • Various species identified within the NICO Project area • Directly exposed to CoPCs in surface water (dietary exposure is negligible)
Benthic Invertebrates	Note [a]	Primary Consumers	• Play a vital role in nutrient cycling and the breakdown of detritus in the aquatic environment • Important food source for fish • Various species identified within the NICO Project area • Both live and feed in sediments and therefore, may be exposed to contamination through ingestion of sediment-bound contaminants and through exposure via interstitial water within the sediment • Small home range so exposure is maximized • Sensitive to a large variety of disturbances, including contamination
Fish	Ninespine stickleback (*Pungitius pungitius*)	Secondary Consumer	• Small-bodied • Identified in waterbodies in the NICO Project area (Peanut and Burke lakes) • Small home range so exposure is maximized • Directly exposed to CoPCs through water and dietary exposure • Serve as a vector for CoPC accumulation in higher trophic levels
Fish	Lake Whitefish (*Coregonus clupeaformis* (Mitchill))	Secondary Consumer	• Large-bodied • Identified in most waterbodies in the NICO Project area (Nico, Peanut, and Burke lakes, and Marian River) • Directly exposed to CoPCs through water, sediment and dietary exposure • Serve as a vector for CoPC accumulation in higher trophic levels • Suitable surrogate for other secondary consumers identified in the NICO Project area (e.g., white

Table 5.1.2-3: Receptors Evaluated (continued)

Receptor Group	Receptor	Trophic Level	Rationale for Selection
			sucker) • More likely to be exposed to sediment sources than some of the other secondary consumers identified in the Project area (e.g., cisco which feeds on plankton rather than benthic invertebrates) • Harvested by humans (including local communities)
Fish	Northern Pike (*Esox lucius*)	Tertiary Consumer	• Large-bodied • Identified in most waterbodies in the NICO Project area (Nico, Peanut, and Burke lakes, and Marian River) • Directly exposed to CoPCs through water and dietary exposure • As a tertiary consumer, integrates exposure from multiple pathways • Suitable surrogate for other tertiary consumers • Harvested by humans (including local communities)

[a] These groups were evaluated at the community level because it is not practical to evaluate individual species.

CoPCs = chemicals of potential concern

5.1.3 Identification of Exposure Pathways

Aquatic receptors may be exposed to CoPCs through several direct and indirect pathways as follows:

- ingestion of sediment by benthic invertebrates and fish (direct exposure);
- direct sorption from surface water and sediment pore water (e.g., through respiratory surfaces) by zooplankton, benthic invertebrates and fish;
- ingestion of diet items by zooplankton, benthic invertebrates and fish that have accumulated CoPCs from surface water and sediment (i.e., aquatic vegetation, zooplankton, benthic invertebrates, other fish) (indirect exposure);
- root uptake from surface water and sediment by aquatic vegetation; and
- foliar/stem uptake from surface water by aquatic vegetation.

The exposure pathways evaluated in the aquatic RA are summarized in Table 5.1.3-1. The table also provides rationale for the selection of the pathways for the assessment.

Table 5.1.3-1: Exposure Pathways

Receptor Group	Exposure Pathway	Included?	Rationale
Aquatic Plants	Direct contact with water	Yes	Rooted plants take-up CoPCs from the water column through their leaves.
	Direct contact with sediment	No	Rooted plants take-up CoPCs from sediment through their roots; however, most toxicity tests are based on water only exposures and toxicity benchmarks are not available for direct sediment exposure.
Phytoplankton	Direct contact with water	Yes	Non-rooted plants such as algae take-up CoPCs from the water column through their leaves.
Zooplankton	Direct contact with water	Yes	Exposed to CoPCs via absorption from the water column across respiratory surfaces.
	Food ingestion	No, exposure via this route assumed to be negligible	• Given the high rate at which water (and CoPCs) are passed over their respiratory surfaces and that the CoPCs identified for the Project do not bioaccumulate or biomagnify, exposure will be primarily from the water column. • Dietary models are not available for most chemicals. • Toxicity information on dietary exposures is often lacking.
Benthic Invertebrates	Direct contact with water	Yes	Exposed to CoPCs in the water column via adsorption to respiratory surfaces and subsequent uptake.
	Direct contact with sediment	Yes	Exposed to CoPCs in sediment through ingestion.
	Ingestion of food	No	• Exposure will be primarily via sorption from water through respiratory surfaces given the high rate of exposure of organisms to chemicals in the water that pass their respiratory surfaces and that the CoPCs identified for the NICO Project do not bioaccumulate or biomagnify. • Dietary models are not available for most chemicals. • Toxicity information on dietary exposures is often lacking.
Fish	Direct contact with water	Yes	The major route of exposure is considered to be from the water column via absorption to respiratory surfaces and subsequent uptake
	Ingestion of food	No, exposure via this route was assumed to be negligible	• Exposure will be primarily via sorption from water through respiratory surfaces given the high rate of exposure of organisms to chemicals in the water that pass their respiratory surfaces and that the CoPCs identified for the NICO Project do not bioaccumulate or biomagnify.

Table 5.1.3-1: Exposure Pathways (continued)

Receptor Group	Exposure Pathway	Included?	Rationale
			• Dietary models are not available for most chemicals. • Toxicity information on dietary exposures is often lacking. • The CCME CWQGs are based on toxicity tests in which organisms are unfed or fed clean food.
	Incidental sediment ingestion	No, exposure via this route was assumed to be negligible	• Data on the amount of sediment that is ingested during feeding is not available to allow this assessment. • Considered to be a minor pathway because fish typically eject sediment entrained during bottom-feeding through the gills.

CoPCs = chemicals of potential concern; CCME = Canadian Council of Ministers of the Environment; CWQG = Canadian Water Quality Guideline

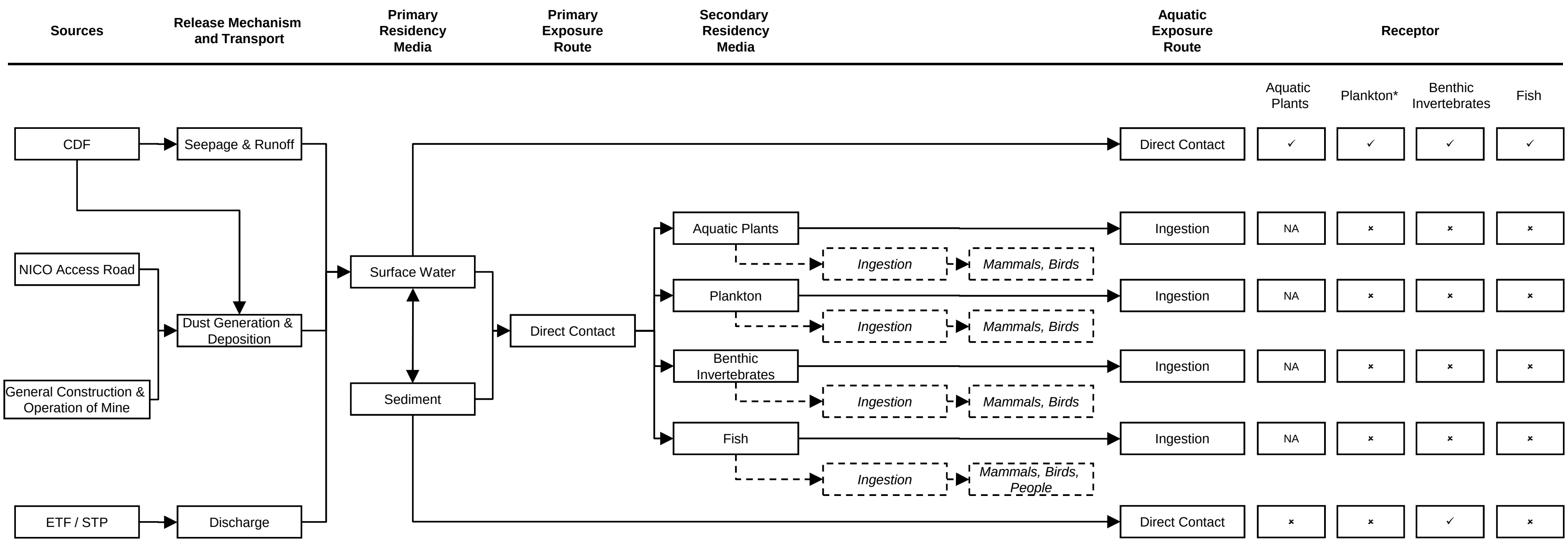
Typically there are 2 major routes for accumulation: direct sorption from the water column and transport across membrane surfaces (e.g., gills in fish, cell membranes in algae) and ingestion of food. The later is usually considered a minor route of uptake for metals in most water column organisms since accumulation of metals in prey is also regulated by the availability of metals from the environment, as well as active depuration mechanisms that actively regulate metals concentrations in organisms. The free metal ion has been identified as the most biologically reactive form of a metal, and is the basis of the development of the free ion activity model (Campbell et al. 2008; Paquin et al. 2002). Thus, solubility and speciation of the metals in the water column are critical factors that can affect toxicity. Based on this understanding, the toxicity benchmarks that are the basis of water quality guidelines such as the CCME CWQGs, and are also the basis of the SSWQOs developed for the NICO Project focus on direct exposure to the water column as the primary route of exposure. As a result, in this RA, exposure is considered to be primarily through direct exposure to metals in the water column. Nonetheless, the laboratory toxicity test results upon which the toxicity benchmarks are based include any exposure via ingestion, since the test procedures do not make any distinctions regarding the route of exposure, but simply assess the effects on the test organisms through all exposure routes that are applicable. Therefore, exposure via ingestion is considered to the extent that ingestion is incorporated into the toxicity benchmarks.

5.1.4 Conceptual Site Model

Taking into account the CoPCs, aquatic receptors and exposure pathways for the NICO Project area, a conceptual site model was developed for the aquatic RA (Figure 5.1.4-1). The model summarizes the NICO Project activities/sources, chemical fate and transport, exposure pathways, and receptors that were considered in the aquatic RA.

Conceptual Site Model for the NICO Project – Aquatic Life

FIGURE 5.1.4-1



LEGEND

× Pathway not evaluated in the aquatic risk assessment

✓ Pathway evaluated in the aquatic risk assessment

- - ▶ Pathway evaluated in the human health and wildlife risk assessments

CDF = Co-disposal Facility

ETF = Effluent Treatment Facility

STP = Sewage Treatment Plant

•Phytoplankton and Zooplankton

NA = Not Applicable

Date: April 2012	Golder Associates	CAD: TMG
Project: 10-1373-0037 (4000)		CKD: RJ

5.1.5 Assessment and Measurement Endpoints

In the context of RA, assessment endpoints are narrative statements that describe the environmental values to be protected but rarely can they be measured directly. The assessment endpoint in this aquatic RA was the protection of aquatic life that may be exposed to chemicals emitted from the NICO Project from adverse effects on survival, growth, or reproduction. Measurement endpoints are the studies, tests, or models that can be performed that serve as a proxy for the assessment endpoints and are the means by which the risk assessor achieves the assessment endpoint. The measurement endpoints specify what types of data will be collected and how they will be used in the RA. Associated with the measurement endpoints are decision criteria, which specify how the results will be interpreted to help achieve the assessment endpoint. The assessment and measurement endpoints as well as decision criteria used in the aquatic RA are summarized in Table 5.1.5-1.

Table 5.1.5-1: Assessment Endpoints, Measurement Endpoints, and Decision Criteria

Assessment Endpoint	Measurement Endpoint	Decision Criteria
• Survival, reproduction and growth of aquatic life	• Comparison of surface water concentrations to literature-derived values without deleterious effects on survival, growth, or reproduction • Comparison of sediment concentrations to literature-derived values without deleterious effects on survival, growth, or reproduction	• The assessment considered site-specific factors that may influence bioavailability/toxicity to aquatic life as well as species representative of the NICO Project area • Hazard quotients (HQs) greater than 1 were considered to indicate the potential for adverse effects • For chemicals for which HQs were predicted to exceed 1, a magnitude of effect assessment was conducted to determine if the NICO Project has a negligible, low, moderate, or high risk of adverse effect on aquatic life

5.2 Exposure Assessment

5.2.1 Contaminant Transport and Fate

The risk posed by metals in the aquatic environment is determined by the amount of biologically available metal (i.e., the free metal ion). Under the free ion activity model, the toxicity of metals is considered to be controlled by the availability of the metal in a biologically reactive form. However, for most metals, a number of factors such as pH and the presence of reactive ligands govern the availability of free ions, with the result that the concentration of the free metal ion can often be lower than predicted. Even where free or readily ionisable species are present in the water column, the presence of other competing ions can influence the potential toxicity of a metal in solution.

Therefore, the amount of biologically available metal in the water column is controlled by a number of other factors that are usually specific to the body of water. The presence of other ligands that can complex metals can reduce the potentially bioavailable fraction. In the water column, these include the presence of other ions, such as calcium and magnesium, that can compete with metals for uptake sites in the organism, and the presence of organic ligands, such as humic and fulvic acids and inorganic ligands such as reactive sulphides and iron/manganese hydroxides that can complex metals, and reduce biological availability. As a result, essential elements for physiological functioning, such as calcium and magnesium can result in a reduction in exposure to other metals in the water column.

Uptake of metals from the water column by aquatic organisms can occur directly from water or indirectly through the diet. In pelagic organisms such as fish, the major route of exposure is considered to be from the water column, and therefore absorption via respiratory surfaces has been identified as the major route of uptake for most metals. For most water column organisms, ingestion of metals has been considered a minor pathway of uptake, and the focus has been on those forms of metals taken-up through the waterborne route and that can interfere with respiration (usually through adsorption to gill surfaces as can occur with aluminum and iron), or induce toxicity at the cellular level after being absorbed through respiratory, and sometimes dermal, surfaces as is the case for more divalent metals (Barron et al. 2002; Paquin et al. 2002).

Metal behaviour in sediments is similarly complex, and is affected by a number of factors, such as pH, particle size and type, and presence of other complexing agents, the most important of which appears to be organic matter. The factors that control the presence or release of free metal ions in the water column also control metals bioavailability and hence control toxicity of metals in sediments (i.e., the metals have to be available in order to be toxic). As a result, metals bound to sediments are typically much less bioavailable (Tessier and Campbell 1987). A number of constituents in sediments have been identified as controlling bioavailability, with the primary ones being organic carbon, sulphides, iron and manganese hydroxides and carbonates (Tessier et al. 1984). The importance of these factors depends, in turn, on other environmental conditions, with pH and redox typically the most important (Mok and Wai 1990).

Under oxic conditions, most of the metals of concern for the NICO Project are bound to iron and manganese complexes (hydroxides and oxides). The ability of iron and manganese hydroxides to scavenge other metals and effectively bind them within the hydroxide shell of the molecule has been shown in many instances (e.g., Förstner and Witmann 1981; Förstner 1990). In most surficial sediments, the zone of oxygen penetration of the sediment is confined to the top 2 or 3 centimetres, and it is within this zone that the solubility of metals is controlled primarily by iron and manganese hydroxides.

Below this level, oxygen concentrations in sediment decrease rapidly, and a reducing environment develops within a few centimetres of the sediment surface. Under reducing (anoxic) conditions, the iron and manganese hydroxides undergo reductive dissolution. As a result, the iron, manganese, and other bound metals are released to the pore water as the oxygen is consumed. In sulphide-rich sediments, these metals are usually quickly bound up in metal sulphide complexes which, in undisturbed conditions, are very stable. Over time, these complexes will mineralise. Some studies suggest that the release of metals from sediments under reducing conditions is limited by the available sulphide and low sulphide may result in release of some compounds through migration of dissolved species up through the sediment (Di Toro et al. 1996).

Under reducing conditions, most metals, such as copper and nickel tend to form insoluble complexes with sulphide. Left undisturbed, these are very stable complexes and little metal is cycled back into the environment. The result is that little free metal ion is available in these environments, relative to the bulk sediment concentration of metals.

Therefore, under stable redox conditions, the solubility of most metals, and hence the biological availability in sediments, appears to be low and is controlled primarily by the iron/manganese hydroxides under oxic conditions, and by sulphide under anoxic conditions. The major releases of metals appear to occur with changes in redox (i.e., when conditions change from oxidised to reducing or vice versa). Because toxicity is determined by the availability of free metal ions, it is those changes, such as alteration of redox conditions, that result in release of free ions into the pore water that appear to have the most significant biological consequences.

Thus, in aquatic environments, most metals will exist as a complex balance between free ions, that are biologically reactive, and complexed metals, that are generally unavailable. The approach to conducting the aquatic RA has recognized the various pathways through which metals can affect aquatic biota and has included these in the assessment.

5.2.2 Exposure Estimates

The exposure assessment provides an estimate of the degree of exposure of receptors to CoPCs via the identified exposure pathways. For aquatic life, exposure is expressed as the concentrations of the CoPCs in water or sediment. This permits the evaluation of exposure relative to environmental quality guidelines and toxicity benchmarks that are expressed in this way.

Exposures of aquatic receptors to CoPCs were assessed based on predicted (Project Case) CoPC concentrations in surface water and sediment in the NICO Project area (Nico, Peanut, and Burke lakes, and Marian River). The methods for determining predicted surface water and sediment concentrations and the summary statistics are provided in the DAR (Sections 7.0 and 12.0).

Exposure estimates were calculated considering both the upper-bound estimate (95^{th} percentile for surface water and maximum concentration for sediment) and the central-tendency estimates (mean concentration for surface water and median concentration for sediment). Use of an upper-bound estimate represents potential effects to individuals. As such, exposure estimates were also calculated considering the central-tendency estimate because this provides a measure of the potential risks to local communities and populations for the NICO Project. The exposure estimates are provided in Appendix E for surface water and Appendix F for sediment.

5.3 Toxicity Assessment

The toxicity assessment provides the basis for evaluating what is an acceptable exposure and what level of exposure may adversely affect aquatic health. This involves the identification of the potentially toxic effects of the CoPCs and determination of the concentration that a receptor can be exposed to without experiencing adverse effects. This value is called the toxicity benchmark. For aquatic life, this is expressed as an acceptable concentration of the CoPC in the media to which the receptor is exposed (i.e., water or sediment). There is negligible risk of adverse health effects if a receptor is exposed to a concentration below the toxicity benchmark for a CoPC.

5.3.1 Surface Water

The approach to the development of toxicity benchmarks for surface water generally followed the approach used in the development of the SSWQOs, as described in Section 4.1.1 and Appendix B. In brief, the approach is consistent with the approaches developed by the CCME in the development of the CWQGs and provincial/territorial agency. The benchmarks were derived to be protective of all forms of aquatic life (all species, all life stages) for indefinite exposure periods (i.e., chronic, sublethal exposure). The development of the benchmarks also considered the influence of toxicity-modifying factors and species present in the waterbodies of the NICO Project area. The toxicity benchmarks are provided in Table 5.3.1-1.

Table 5.3.1-1: Toxicity Benchmarks for Surface Water

CoPC	Units	Benchmark			
		Nico Lake	Peanut Lake	Burke Lake	Marian River
Aluminum	µg/L	480	410	480	1100
Antimony	µg/L	NA	NA	30	NA
Arsenic	µg/L	NA	NA	50	NA
Barium	µg/L	1000	1000	1000	1000
Cobalt	µg/L	NA	NA	10	NA
Copper	µg/L	NA	NA	23	NA
Iron	µg/L	1500	1500	1500	1500
Manganese	µg/L	700	700	NA	700
Mercury	µg/L	NA	NA	NA	0.26
Selenium	µg/L	NA	NA	5	NA
Vanadium	µg/L	6	6	NA	6

NA = This parameter was not identified as a CoPC in this waterbody.
CoPC = Chemical of potential concern; µg/L = microgram per litre.

5.3.1.1 Aluminum

The toxicity benchmark for aluminum for Burke Lake and the Marian River has been derived using the equation that is currently used by the British Columbia Ministry of Water, Land and Air Protection (BCMWLAP) to derive water quality guidelines (30-day mean value) for dissolved ammonia at a pH of less than 6.5 (BCMWLAP 2001a), as follows:

Dissolved aluminum benchmark (mg/L) = $e^{(1.6-3.327\text{ median pH} + 0.402\text{ K})}$

Where:

K = median pH^2

In Burke Lake and the Marian River, the median pH is 7.5 and 7.8, respectively. Using the equation provided above, values of 4800 µg/L and 1100 µg/L dissolved aluminum are calculated for Burke Lake and the Marian River. The objectives derived for dissolved aluminum can be conservatively applied to total aluminum. It should be noted that the toxicity benchmarks for Nico and Peanut lakes are simply the SSWQOs that were derived for aluminum for these waterbodies using the same approach (Section 4.1.2, Table 4.1.2-1 and Appendix B).

There is some uncertainty in the application of the equation provided above in the development of the SSWQOs and toxicity benchmarks for aluminum. This is because the guideline is based on a pH of less than 6.5. Median pH is 7.5, 7.44, 7.5, and 7.8 in Nico Lake, Peanut Lake, Burke Lake, and the Marian River, respectively. The BCMWLAP (2001a) provides a guideline (30-day mean) of 50 µg/L dissolved aluminum at a pH ≥6.5. Still, the SSWQOs are considered protective of aquatic life.

The toxicity of aluminum is highly dependent on pH. The toxicity data provided in the CCME guideline derivation for aluminum was reviewed. There were few studies included in the guideline derivation in the pH ranges measured in surface waters of the NICO Project. Adverse effects on survival (37% mortality) were observed using the chironomid *Tanytarius dissimilis* following 55 days of exposure to 800 µg/L aluminum at pH 6.8 (Lamb and Bailey 1981; as cited in CCREM 1987). Reproduction in *Daphnia magna* was impaired by 50% at a concentration of 680 µg/L aluminum at pH 6.5 to 7.5 following 3 weeks of exposure (Schofield and Trojnar 1980, as cited in CCREM 1987). The results of the study by Biesinger and Christensen (1972) were not included in the CCME guideline derivation; however, they demonstrated a 50% and 16% impairment in reproduction in *Daphnia magna* following 21 days of exposure to 680 µg/L and 320 µg/L aluminum, respectively at pH 7.4 to 8.2. This result is consistent with that of the Schofield and Trojnar study (1980, as cited in CCREM 1987). *Daphnia magna* appear to be more sensitive to the effects of aluminum than other cladocerans. For example, *Holopedium gibberum*, the most abundant cladoceran in Nico Lake (Annex C of the DAR) was found in an acidified Ontario lake with an aluminum concentration of 490 µg/L (Bleiwas 1983; as cited in Havas and Likens 1985). This species has also been shown to be tolerant to aluminum in laboratory tests. Exposure to 1000 µg/L at pH 6.5 resulted in no adverse effects on survival (Havas and Likens 1985).

There were no studies cited in the CCME guideline derivation for aluminum for fish in the pH range measured in surface waters of the NICO Project, and in general these studies are lacking for fish. The available data suggests that fish are more sensitive to the effects of aluminum than invertebrates. Hunn et al. (1987) exposed eyed embryos of book trout (*Salvelinus fontinalis*) to a pH value of 7.81 without and with aluminum (283 µg/L) in soft water (hardness <9 mg/L as $CaCO_3$, which is consistent with hardness measured in Nico and Peanut lakes) for 60 days. Exposure to aluminum significantly decreased the growth of brook trout after 45 and 60 days. There were no significant effects of aluminum on embryo mortality and hatchability. Kane and Rabeni (1987) exposed small mouth bass (*Micropterus dolomieui*) larvae to 252 µg/L aluminum at pH 7.3 in a 30 day chronic test. There were no significant effects of aluminum on survival or growth. Sublethal effects on fish were demonstrated, including deformities, reduced activity and abnormal swimming behaviour. Roy et al. (2000) studied the toxicity of aluminum in the Saquenay River, Quebec, in relation to discharges from an aluminum smelter. In waters downstream of the effluent outfalls, concentrations ranging from 470 to 540 µg/L in soft neutral-pH (pH 7.0 to 7.3) waters had no significant effect on *Ceriodaphnia dubia* survival and growth and fathead minnow (*Pimephales promelas*) survival and growth.

Complexation is an important factor in reducing aluminum bioavailability and toxicity. For example, the complexation of aluminum by DOC matter reduces the bioavailability and toxicity of aluminum to fish in neutral to slightly basic water (Gundersen et al. 1994; Winter et al. 2004). As well, the formation of dissolved aluminosilicates has been shown to reduce the bioavailability and toxicity of aluminum to fish (Burchall et al. 1989).

Dissolved organic carbon concentrations in both Nico Lake and Peanut Lake are relatively high (ranging from approximately 10 to 20 mg carbon/L). Aluminum in both the solid phase of the tailings and waste rock for the NICO Project is primarily bound with silicate minerals (Annex A of the DAR). Based on these mineralogical results, the aluminum-bearing particulate in water is most likely in the form of silicates (Section 5.14 of Annex A of the DAR). As well, dissolved aluminum is likely to be present bound to DOC or as dissolved aluminosilicates which forms at pH values greater than or equal to 4. This is in contrast to most of the toxicity tests described above which used soluble aluminum salts that speciate to Al^{3+} or $Al(OH)_4^-$, which are considered the most toxic forms of aluminum.

Given the mitigating effects of DOC and silicates on aluminum toxicity and that toxic effects on invertebrates and fish were not noted in waters of similar hardness, and pH to surface waters of the NICO Project receiving effluent discharges from an aluminum smelter, the SSWQOs are considered protective of aquatic life.

5.3.1.2 Antimony

The CCME has not derived a CWQG for antimony for the protection of freshwater aquatic life. Antimony has been identified as a CoPC and a toxicity benchmark has been derived for this metal because predicted concentrations are greater than baseline conditions in Burke Lake during operations, active closure, and post-closure.

Data on the chronic toxicity of antimony to freshwater aquatic life is limited. The U.S. EPA reported a 96-hour median effective concentration (EC50) (chlorophyll) for the green alga *Selenastrum capricornutum* of 730 µg/L (1978; as cited in the U.S. EPA 2010, internet site). In a life-cycle test with the cladoceran *Daphnia magna*, a 28-day median lethal concentration (LC50) of 4510 µg/L was calculated for exposure to antimony trichloride in water of hardness 220 mg/L as $CaCO_3$ (Kimball 1978; as cited in the U.S. EPA 2010, internet site). There were no effects on reproduction at 4160 µg/L but there was a significant decrease in the number of progeny at 7050 µg/L. A maximum acceptable toxicant concentration of 5420 µg/L was calculated.

Chronic studies for vertebrates include 28-d LC50 values for rainbow trout (*Oncorhynchus mykiss*) eggs of 580 and 660 µg/L (Birge 1978; Birge et al. 1980; as cited in the U.S. EPA 2010, internet site). In aquatic toxicity tests with fathead minnow (*Pimephales promelas*) eggs, growth was the most sensitive endpoint (Kimball 1978; as cited in the U.S. EPA 2010, internet site). The 28-d lowest observed effect concentration (LOEC) for effects on growth (length) was 2310 µg/L. There were no significant effects on growth at 1130 µg/L. The maximum acceptable toxicant concentration was calculated to be 1620 µg/L. Birge (1978; as cited in U.S. EPA 2010, internet site) conducted studies on the mortality of antimony trichloride on embryo-larval stages of the toad *Gastrophryne carolinensis*. The calculated LC50 for the toad was 300 µg/L.

The Ontario MOE (Ministry of the Environment) has derived an aquatic protection value (APV) for antimony of 1600 µg/L based on a final chronic criterion provided by the U.S. EPA (1986; as cited in MOE 2011).

The U.S. EPA provides a draft freshwater national ambient water quality criterion (NAWQC) for antimony of 30 µg/L (U.S. EPA 1988). In brief, the final acute value of 175 µg/L was divided by an acute-to-chronic ratio of 5.871 to derive a final chronic value of 30 µg/L.

A toxicity benchmark for antimony of 30 µg/L was used in this assessment based on the draft freshwater ambient water quality criteria for antimony provided by the U.S. EPA (1988) (Table 5.3.1-1).

5.3.1.3 Arsenic

A toxicity benchmark has been derived for arsenic because predicted concentrations are greater than the CCME CWQG for the protection of freshwater life and baseline concentrations for Burke Lake during construction, operations, and active closure.

The CCME freshwater aquatic life guidelines for arsenic is 5 µg/L, based on the results of a chronic algal bioassay, which was the most sensitive endpoint measured (CCME 2001). The CCME guideline is based on growth reduction (as an EC50, over a 14-day exposure) in the green algae *Scenedesmus obliquus* at 50 µg/L (as discussed below, green algae, including *Scenedesmus* sp., have been identified in Burke Lake (Annex C of the DAR). The guideline of 5 µg/L was derived by applying a safety factor of 10 to this endpoint. The CCME (2001b) notes that the lowest estimate for fish toxicity was 550 µg/L (28-day LC50 for rainbow trout embryos and larvae), while the lowest estimate for invertebrates was 320 µg/L.

The lowest exposure concentrations of arsenic to induce mortality in fish were observed in rainbow trout, which is one of most sensitive fish to dissolved arsenic exposure (CCME 2001). Rankin and Dixon (1994) calculated an LC50 (96-hour, flow through bioassay design) for this species at 20 200 µg/L, which was adjusted using a 0.1 times safety factor to provide an estimated acute lowest observed adverse effect concentration value of 2020 µg/L.

A search of the U.S. EPA ECOTOX Database revealed 2 arsenic no observed effect concentrations (NOECs) of 2650 µg/L and 9500 µg/L for a 10 day and 3 day exposure, respectively (Holland et al. 1960; as cited in the U.S. EPA 2010, internet site). These toxicity tests were performed on pink salmon.

The U.S. EPA provides a Criterion Continuous Concentration (CCC) of 150 µg/L for arsenic (U.S. EPA 2009). This recommended water quality criterion was derived from data for arsenic (III), but was applied to total arsenic, which might imply that arsenic (III) and arsenic (V) are equally toxic to aquatic life and that their toxicities are additive. In the arsenic criteria document (U.S. EPA 1985a), Species Mean Acute Values are given for both arsenic (III) and arsenic (V) for 5 species and the ratios of the Species Mean Acute Values for each species range from 0.6 to 1.7. Chronic values are available for both arsenic (III) and arsenic (V) for one species; for the fathead minnow, the chronic value for arsenic (V) is 0.29 times the chronic value for arsenic (III). No data are known to be available concerning whether the toxicities of the forms of arsenic to aquatic organisms are additive (U.S. EPA 2009).

All of the toxicity tests referenced above were performed in laboratory environments with laboratory fresh water that does not contain the ligands present in natural waters. Therefore, as shown in the discussions above, toxicity tests in laboratory settings do not account for possible interactions of metals with organic matter that can reduce arsenic availability and toxicity. Therefore, the EC50 of 50 µg/L over a 14-day exposure to the green algae *Scenedesmus obliquus* has been chosen as the toxicity benchmark for arsenic. Green algae (Phylum Chlorophyta), including *Scenedesmus* sp., were identified in Burke Lake (Annex C of the DAR). The safety factor of 10 that was used by CCME in the derivation of their water quality guideline is considered overly conservative for the waterbodies surrounding the NICO Project, and therefore 50 µg/L is considered to be protective of the receptors that may be present in Burke Lake. Based on the review of the toxicity data above, the chosen toxicity benchmark of 50 µg/L (Table 5.3.1-1) is well below the concentrations that would be expected to result in adverse effects on fish species.

5.3.1.4 Barium

The CCME has not derived a CWQG for barium for the protection of freshwater aquatic life. Barium has been identified as a CoPC and a toxicity benchmark has been derived for this metal because predicted concentrations are greater than baseline conditions for Nico, Peanut, and Burke lakes, and the Marian River during all 4 phases of the NICO Project.

The Ontario MOE has derived an APV for barium of 2300 µg/L based on a lowest observed adverse effect level (LOAEL) for reduced growth in *Chlorella vulgaris* following 91.3 days of exposure (De Jong 1985; as cited in MOE 2011). This value is the most conservative LOAEL identified for barium as determined through a review of the U.S. EPA ECOTOX Database.

The BCMOE (2006) provides working water quality guidelines for barium for freshwater aquatic life of 1000 µg/L (chronic) and 5000 µg/L (acute).

Suter and Tsao (1996) provide a secondary chronic value (SCV) for aquatic life of 4 µg/L. In brief, the SCV was derived using the Tier II method used by the U.S. EPA for developing benchmarks when there is not enough information to develop a benchmark using the approach used in the development of the NAWQC.

A toxicity benchmark for barium of 1000 µg/L was used in this assessment based on the BCMOE (2006) chronic guideline (Table 5.3.1-1).

5.3.1.5 Cobalt

There is currently no CCME CWQG for cobalt to protect freshwater aquatic life. Cobalt has been identified as a CoPC and a toxicity benchmark has been derived for this metal because predicted concentrations are greater than baseline conditions in Burke Lake during construction, operations, and active closure.

The Ontario MOE has derived an APV of 5.2 µg/L for cobalt based on a 28-day lowest observed effect level of 5.2 µg/L for effects on reproduction (number of progeny) in *Daphnia magna* (Kimball 1978; as cited in MOE 2011). The New York State Department of Environmental Conservation (NYSDEC) water quality standard for surface and groundwater for cobalt is 5 µg/L (NYSDEC 1986). The province of Quebec has adopted a surface water quality guideline for the protection of freshwater aquatic life from the chronic effects of cobalt of 5 µg/L. The Quebec guideline is based on the NYSDEC (1986) standard.

The British Columbia Ambient Water Quality Guidelines provide 2 values for cobalt (BCMWLAP 2004). It is recommended that to protect aquatic life in the freshwater environment from the acute effects of cobalt, the maximum concentration of total cobalt should not exceed 110 µg/L. The recommended maximum guideline is based on a LOEC causing 50% mortality in *Daphnia magna* exposed to 1110 µg/L cobalt for 48 hours and a safety factor of 10. The safety factor was selected to protect from possible delayed mortality of the organisms exposed to the metal and is consistent with the British Columbia protocols for guideline development.

The British Columbia Ambient Water Quality Guidelines also recommend that to protect aquatic life from the chronic effects of cobalt, the 30-day average concentration of total cobalt (based on 5 weekly samples) should not exceed 4 µg/L (BCMWLAP 2004). This is based on the invertebrates *Daphnia magna* and *Ceriodaphnia dubia* that exhibited chronic effects when exposed to low concentrations of cobalt. A LOEC (geometric mean) of about 8 µg/L total cobalt was determined to cause reproductive effects in these organisms. The 30-day average concentration to protect aquatic life from the chronic effects of cobalt was obtained by applying a safety factor of 2 to the LOEC. A lower (than 10) safety factor was justified because cobalt is essential in the synthesis of vitamin B_{12} which is necessary for animal and human nutrition (BCMWLAP 2004).

Fish and aquatic plants are less sensitive to the effects of cobalt than daphnids. Chronic LC50 values for 28-day embryo-larval tests using rainbow trout (*Oncorhynchus mykiss*), the most sensitive fish species to cobalt, were reported at 470 µg/L and 490 µg/L. A value of 520 µg/L was reported for a 144-hour test using rainbow trout fry. 14-day NOEC and LOECs for effects on growth and survival in rainbow trout were reported to be 132 and 255 µg/L, respectively. Ten- to 14-day LOECs for growth of 500 µg/L were reported for the most sensitive plant species, *Chlamydomonas eugametos* (BCMWLAP 2004). Given the greater sensitivity of daphnids to cobalt, the development of the toxicity benchmark for cobalt in this assessment has focused on these organisms.

The toxicity data available from the literature for cobalt for daphnids is limited to 3 key studies. Kimball (1978; as cited in BCMWLAP 2004) reported a NOEC of 2.8 µg/L and a LOEC of 9.3 µg/L for reproduction from two 28-day tests using *Daphnia magna*. Kimball (1978; as cited in BCMWLAP 2004) also conducted a screening test on

Daphnia magna prior to the 28-day chronic toxicity tests and identified a NOEC of 10 µg/L and a LOEC of 20 µg/L for reproductive effects. Biesinger and Christensen (1972; as cited in BCMWLAP 2004) conducted 21-day chronic toxicity tests with *Daphnia magna* and reported a 21-day EC16 of 10 µg/L for reproduction at a water hardness of 45.3 mg/L as $CaCO_3$. Diamond et al. (1992; as cited in BCMWLAP 2004) investigated cobalt toxicity to *Ceriodaphnia dubia* using a range of water hardnesses. At water hardnesses of 57 and 256 mg/L $CaCO_3$, the 7-day NOECs were <50 µg/L. At water hardnesses of 470 and 882 mg/L as $CaCO_3$, the 7-day NOECs were 50 and 600 µg/L, respectively.

In support of the development of the BCMOE guideline for cobalt, Golder/EVS performed additional toxicity testing using *Daphnia magna* and *Ceriodaphnia dubia* (BCMWLAP 2004). In brief, a 21-day *Daphnia magna* toxicity test and a 7-day *Ceriodaphnia dubia* toxicity test examining reproductive and survival endpoints were performed. *Daphnia magna* and *Ceriodaphnia dubia* were exposed to five nominal concentrations of 3.13, 6.25, 12.5, 25, and 50 µg/L cobalt at each water hardness of 50, 100, and 200 mg/L as $CaCO_3$. *Ceriodaphnia dubia* were also exposed to a nominal concentration of 100 µg/L cobalt at each water hardness. The LOEC for reproduction for *Daphnia magna* was 50 µg/L at a water hardness of 50 mg/L as $CaCO_3$. The NOEC at this water hardness was 25 µg/L. The results of the 7-day *Ceriodaphnia dubia* test indicated a NOEC for reproduction of 12.5 µg/L at a water hardness of 50 mg/L as $CaCO_3$ and a LOEC of 25 µg/L at the same water hardness. The results of the *Daphnia magna* test are consistent with the results of Biesinger and Christensen (1972; as cited in BCMWLAP 2004) who reported an EC16 of 10 µg/L at a water hardness of 45.3 mg/L as $CaCO_3$.

Because there is some evidence to suggest that cobalt toxicity in freshwater organisms may be influenced by water hardness (Diamond et al. 1992; as cited in BCMWLAP 2004), the development of the toxicity benchmark for cobalt has relied upon the results of the toxicity tests for which the water hardness is similar to that of the NICO Project area. Available surface water data for Burke Lake indicates that water hardness ranges from 22 to 61.3 mg/L as $CaCO_3$ (mean = 35 mg/L as $CaCO_3$). As such, a toxicity benchmark of 10 µg/L was used for cobalt (Table 5.3.1-1). This value is based on the work of Biesinger and Christensen (1972; as cited in BCMWLAP 2004) using *Daphnia magna*. The data from the Kimball study (1978; as cited in BCMWLAP 2004) was not used because water hardness was not reported in this study and consistent results were obtained in the other 2 studies which were considered in the derivation of benchmark (i.e., Biesinger and Christensen 1978; Golder/EVS as cited in BCMWLAP 2004).

5.3.1.6 Copper

The CCME guideline for copper is based on water hardness, as provided below (CCME 2011b, internet site):

Copper guideline = 2 µg/L at water hardness of 0 to 120 mg/L as $CaCO_3$

= 3 µg/L at water hardness of 120 to 180 mg/L as $CaCO_3$

= 4 µg/L at water hardness >180 mg/L as $CaCO_3$

In brief, the guideline was derived using the regression equation of chronic toxic copper concentrations versus hardness developed by the U.S. EPA (1985b), as follows:

Cu conc. = $e^{(0.8545[\ln(\text{hardness})] - 1.465)}$ µg/L

The lowest hardness within each hardness category was used to calculate the copper guideline for that hardness category. The guideline for the hardness category of 0 to 120 mg/L as $CaCO_3$ is based on the guideline recommended by Demayo and Taylor (1981; as cited in CCREM 1987) for soft water (0 – 60 mg/L as $CaCO_3$) of 2 µg/L and the calculated value based on a hardness of 60 mg/L as $CaCO_3$ of 2 µg/L.

The equation for chronic toxicity derived by the U.S. EPA was derived from an final acute value and an acute-to-chronic ratio. In the development of the guideline for copper, the CCREM (1987) considered the effects of hardness on chronic copper toxicity to be inconclusive and the result from the equation was multiplied by an application factor of 0.2 to derive the guideline.

Predicted concentrations in Burke Lake exceed the CCME CWQG for copper and baseline concentrations during operations and active closure. As such, a toxicity benchmark has been derived for copper for Burke Lake.

Recently, the U.S. EPA revised the aquatic life ambient freshwater quality criteria for copper (U.S. EPA 2007). In the revision, a Biotic Ligand Model (BLM)-based approach was used in place of the formerly applied hardness-based approach to calculate the water quality criteria for copper. The BLM approach offers a vast improvement over the hardness-based approach because in addition to water hardness, it incorporates the protective effects of other water chemistry parameters on copper toxicity, including the competitive influences of various cations (e.g., calcium, hydrogen, magnesium, and sodium), as well as the influence of important copper complexing anions (e.g., DOC and chloride).

In essence, the BLM predicts acute metal toxicity by estimating metal accumulation at the "biotic ligand", which is the site of metal accumulation and acute toxicity on an aquatic organism, taking into consideration the protective effects of water chemistry. The model assumes that accumulation of metal at the biotic ligand at or above a critical threshold concentration leads to acute toxicity. This critical accumulation at the biotic ligand is also termed the LA50 (lethal accumulation of metal at the biotic ligand that results in 50% mortality). For example, complexing anions (such as DOC and chloride) bind metal, thereby decreasing accumulation at the biotic ligand. Similarly, competing cations (such as calcium, hydrogen, magnesium, and sodium) compete with metal for binding sites at the biotic ligand, decreasing metal accumulation at the biotic ligand. Because water hardness is primarily a function of calcium and magnesium ions in the water, the protective effect of water hardness on metal toxicity is addressed in the BLM through the competitive interaction between metal and the hardness cations (i.e., calcium and magnesium) at the biotic ligand. Depending on water chemistry, the amount of metal in the water required to reach the LA50 will vary. In this way, the BLM can be used to predict the concentration of metal that would result in acute toxicity to aquatic life based on water chemistry.

Accordingly, the BLM is a useful tool for deriving site-specific water quality criteria (and toxicity benchmarks) for metals, and for this reason, the U.S. EPA revised the water quality criteria for copper based on the BLM. The U.S. EPA also plans to update the water quality criteria for other metals, including silver and zinc, using the BLM approach.

The BLM-based approach developed by the U.S. EPA was used to derive the toxicity benchmarks for copper for Burke Lake. The same approach was used to derive the SSWQOs for copper for Nico and Peanut lakes (Appendix B). The BLM, Windows Interface, Version 2.2.1 (HydroQual 2007) was used.

The U.S. EPA does not provide any specific recommendation on data requirements for use of the BLM, except that enough data should be collected to characterize the spatial and temporal variability in water chemistry of a waterbody (Training Materials on Copper BLM: Data Requirements, accessed on-line at http://www.epa.gov/waterscience/criteria/copper/faq/data-requirements.pdf). Water quality samples were collected from Burke Lake from 4 sampling locations, including a shallow location, a deep location, and the Burke Lake inflow and outflow. Water quality was monitored during open water from 2005 to 2008 (spring and summer) and in winter (under ice) in March 2008. In total, the water chemistry from 11 samples was used in the calculation of the toxicity benchmark for Burke Lake (3 samples from the deep basin, 5 samples from the shallow basin, 1 sample from the Burke Lake inflow, and 1 sample from the Burke Lake outflow). The surface water quality input parameters used in the model for Burke Lake are provided in Appendix G, Table G-1.

The BLM generates acute (Criterion Maximum Concentration) and chronic (CCC) water quality criteria for copper (based on dissolved copper). The chronic water quality criterion is calculated using an acute-to-chronic ratio. For Burke Lake the calculated chronic water quality criteria ranged from 23 to 46 µg/L (Appendix G, Table G-2). The lowest calculated criterion calculated for copper of 23 µg/L was used in this assessment (Table 5.3.1-1). It should be noted that the BLM provides a criterion based on dissolved copper but this value was applied to predicted total copper concentrations. This is a conservative approach.

5.3.1.7 Iron

The CCME has established a guideline for iron of 300 µg/L based on a guideline developed by the International Joint Commission (IJC) and the Ontario MOE (CCREM 1987). This value is based on the concentration of iron in water that could result in precipitation of iron hydroxides on stream substrates and potentially smother habitat and not toxicological responses. Predicted iron concentrations in Nico, Peanut, and Burke lakes, and the Marian River exceed the CCME CWQG during operations. As well, predicted concentrations in Nico and Burke lakes and the Marian River exceed the CCME CWQG during active closure. As such, a toxicity benchmark has been derived for this metal for Burke Lake and the Marian River.

The same rationale for the development of the SSWQOs for aluminum for Nico and Peanut lakes has been applied. In brief, Suter and Tsao (1996) note that the U.S. EPA chronic guideline for iron of 1000 µg/L is based on a field study at a site receiving acid mine drainage (the guideline is cited in the 1985 EPA “Gold Book” but due to the specific conditions under which the guideline was developed, is not included in more recent guidelines). Thus, both guidelines (the CCME guideline and the U.S. EPA guideline) are based on specific conditions under which iron precipitates are a concern, but may not be applicable in natural waters.

Suter and Tsao (1996) indicate that a concentration of 4380 µg/L that resulted in reproductive impairment of 16% in *Daphnia magna* exposed to $FeCl_2$ was more applicable to natural waters, while a chronic value for fish of 1300 µg/L was applicable. Guay et al. (2000) undertook a review of toxicity data for iron and noted that iron toxicity generally occurred at much higher concentrations than those associated with precipitation effects (chronic NOECs, ranged upwards from 1500 µg/L for trout).

The CCREM (1987) cites acute values for iron for aquatic insects that ranged from 320 to 16000 µg/L. However, the most sensitive species was the mayfly (*Ephemerella subvaria*) and this species (and family) has not been identified in the NICO Project area. *Gamarus minus* did not exhibit any adverse effects on reproduction and growth at an iron concentration of <3 mg/L (Sykora et al. 1972; as cited in CCREM 1987) and this family of benthic invertebrates has been identified in the NICO Project area. The CCREM goes on to note that chronic toxicity to fathead minnows was recorded in a study by Sykora et al. (1972; as cited in CCREM 1987) at an acid mine drainage site at 1500 µg/L (50% reduction in egg hatchability) (similar responses were noted in brook trout eggs at 12000 µg/L, indicating that brook trout were much less sensitive than fathead minnows). The CCREM cites the safe concentration for brook trout juveniles as ranging between 7500 and 12500 µg/L.

Based on this toxicity review, a toxicity benchmark of 1500 µg/L has been used for iron in this assessment (Table 5.3.1-1). This value is well below other chronic toxicity values reported above.

5.3.1.8 Manganese

The CCME has not derived a CWQG for manganese for the protection of freshwater aquatic life. Manganese has been identified as a CoPC and a toxicity benchmark has been derived for this metal because predicted concentrations are greater than baseline conditions in Peanut Lake and the Marian River during all 4 phases of the NICO Project.

The BCMWLAP guideline (acute and chronic) for total manganese is based on water hardness, as provided below for the chronic guideline (BCMWLAP 2001b):

Manganese guideline (chronic) = 700 µg/L at water hardness of 25 mg/L as $CaCO_3$

= 800 µg/L at water hardness of 50 mg/L as $CaCO_3$

= 1000 µg/L at water hardness of 100 mg/L as $CaCO_3$

= 1300 µg/L at water hardness of 150 mg/L as $CaCO_3$

= 1900 µg/L at water hardness of 300 mg/L as $CaCO_3$

In brief, the guideline (acute and chronic guideline) was derived using data from toxicity tests commissioned in support of the guideline development as well as toxicity data from the literature. Toxicity tests commissioned in support of the guideline development included acute and chronic toxicity tests on fish (rainbow trout), invertebrates (*Daphnia magna*, *Chironomus tentans*, *Hyalella azteca*) and algae (*Selenastrum capricornutum*). Acute tests included 48- and 96-hour LC50s and chronic tests included reproduction, growth, and survival endpoints. Tests were conducted over a range of water hardnesses (25, 100, and 250 mg/L as $CaCO_3$). Acute and chronic regression equations were developed based upon the most sensitive species and endpoint for various water hardness values considering both the commissioned toxicity tests and toxicity data from the literature. The equations were then used to predict manganese concentrations at various water hardness levels. An uncertainty factor of 0.25 was applied to the predicted manganese concentration to account for uncertainty. The resulting manganese concentrations were then proposed as the guideline for manganese at that water hardness. The regression equation for the chronic guideline is provided below:

Manganese guideline (chronic) $\leq 0.0044 \times \text{hardness} + 0.605$

Suter and Tsao (1996) provide an SCV for manganese for aquatic life of 120 µg/L. In brief, the SCV was derived using the Tier II method used by the U.S. EPA for developing benchmarks when there is not enough information to develop a benchmark using the approach used in the development of the NAWQC.

Given the demonstrated relationship between water hardness and chronic manganese toxicity to freshwater life (BCMWLAP 2001b) and that the BCMOE guideline permits the incorporation of site-specific water quality characteristics in the development of the toxicity benchmark, the benchmark used for manganese in this assessment is based on the guideline provided by the BCMWLAP (BCMWLAP 2001b). Based on the guideline provided by the BCMWLAP (2001b) and water hardness measured in Nico Lake, Peanut Lake, and the Marian River (minimum values of 26, 27, 22, and 31 mg/L as $CaCO_3$, respectively), a toxicity benchmark of 700 µg/L was derived and used in the assessment for manganese (Table 5.3.1-1).

5.3.1.9 Mercury

A toxicity benchmark has been derived for mercury because predicted concentrations are greater than the CCME CWQG for the protection of freshwater life and baseline concentrations in the Marian River during all phases of the NICO Project.

The CCME freshwater aquatic life guideline for mercury is 0.026 µg/L, and is based on the results of a chronic study using juvenile fathead minnows (*Pimephales promelas*) which demonstrated reduced growth in offspring (weight) and reproductive impairment (reduces spawning and egg production), which was the most sensitive endpoint (LOAEL) identified by the CCME (Snarski and Olson 1982; as cited in CCME 2003b). The guideline of 0.026 µg/L was derived by applying a safety factor of 10 to this endpoint.

The U.S. EPA provides a NAWQC CCC of 0.77 µg/L for mercury (U.S. EPA 2009). The Ontario MOE has derived an APV for mercury of 0.77 µg/L based on the CCC derived by the U.S. EPA (MOE 2011). Suter and Tsao (1996) provide a SCV of 1.3 µg/L.

Given that the guideline for mercury derived by the CCME involved the application of an arbitrary safety factor, and that without the application of the safety factor, the LOAEL calculated by Snarski and Olson (1982; as cited in CCME 2003b) is within the same magnitude of the guideline values adopted by other regulatory agencies, a toxicity benchmark of 0.26 µg/L has been used in this assessment for mercury (Table 5.3.1-1).

5.3.1.10 Selenium

A toxicity benchmark has been derived for selenium because predicted concentrations are greater than the CCME CWQG for the protection of aquatic life for Burke Lake during active closure.

The CCME guideline for selenium is 1.0 µg/L (CCME 2011c, internet site). This value was adopted from the IJC which introduced the value to protect aquatic life in the Great Lakes based on field studies which indicated that waterborne selenium concentrations of 5 to 10 µg/L were associated with food web contamination that caused acute lethality to predatory fish (IJC 1981; as cited in CCREM 1987).

The U.S. EPA has developed a chronic water quality criterion for selenium of 5 µg/L (total recoverable selenium in the water column) (U.S. EPA 2009). It should be noted that the U.S. EPA recently developed a draft chronic water quality criterion for selenium that is based on the concentration of selenium in fish tissue rather than the concentration of selenium in the water (U.S. EPA 2004). However, since there is much controversy with respect to the draft criterion, the currently accepted chronic water quality criterion of 5 µg/L was used as the toxicity benchmark for selenium in this assessment (Table 5.3.1-1).

5.3.1.11 Vanadium

The CCME has not derived a CWQG for vanadium for the protection of freshwater aquatic life. Vanadium has been identified as a CoPC and a toxicity benchmark has been derived for this metal because predicted concentrations are greater than baseline conditions in Nico Lake, Peanut Lake, and the Marian River during all phases of the NICO Project.

The BCMOE (2006) provides working water quality guidelines for total vanadium for freshwater aquatic life of 6 µg/L and 20 µg/L. The values were adopted from the Ontario Ministry of Environment and Energy (MOEE 1994) and Suter and Tsao (1996). A benchmark of 6 µg/L was used for vanadium in this assessment (Table 5.3.1-1).

5.3.2 Sediment

Sediment toxicity benchmarks were based on the CCME CSQGs (Table 5.3.2-1). Where CCME CSQGs were not available, other benchmarks were also used, including the MOEE Provincial Sediment Quality Guidelines (MOEE 1993) and benchmarks specific to the NWT (GNWT 2003). As well, natural metal concentrations (i.e., background) in sediment in the NICO Project area were also considered.

Table 5.3.2-1: Toxicity Benchmarks for Sediment

Chemicals of Potential Concern	Benchmark (mg/kg)	Endpoint	Source
Antimony	3	Apparent effects threshold for freshwater sediments (based on Microtox bioassay)	LANL 2005
Arsenic	150	Remediation objective based on average natural background concentrations in and around Yellowknife, and was developed for non-residential, publically-accessible areas (i.e., public boat launch)	GNWT 2003
Barium	NV	-	-
Beryllium	NV	-	-
Cobalt	NV	-	-
Molybdenum	NV	-	-
Nickel	16	Lowest Effect Level	MOEE 1993
Selenium	NV	-	-
Uranium	100	Probable No Effect Concentration	Sheppard et al. 2005
Vanadium	NV	-	-

NV = No guideline value; mg/kg = milligram per kilogram

The toxicity benchmarks for sediment used in this assessment are derived to protect those organisms directly impacted by contaminated sediment, namely the sediment-dwelling (benthic) species. In fact, a review of the literature indicates that for aquatic plants, which may also be exposed to contaminated sediments through root uptake, toxicity benchmarks are generally provided for surface water but not for sediments. As a result, sediment toxicity benchmarks for aquatic plants are not provided in the assessment but rather sediment toxicity benchmarks that are protective of benthic species are considered to be protective of aquatic plants that may be exposed to CoPCs in sediment. This is a reasonable approach given the close association of benthic invertebrates with sediments and their sensitivity to contamination.

5.4 Risk Characterization

Risk was estimated on a quantitative basis by calculating an HQ for each CoPC in surface water and sediment. The HQ is a ratio of the concentration of the CoPC in the environmental media (i.e., surface water or sediment) to the toxicity benchmark.

The standard HQ threshold for evaluation is 1. That is, an HQ of less than 1 indicates that the level of exposure in the environment is less than the level of exposure that could adversely affect the heath of the receptor. Therefore, the health of the receptor should not be adversely affected by exposure to that CoPC. An HQ greater than 1 indicates that the level of exposure in the environment may exceed a critical level where adverse effects on the receptor may occur. The actual risks are usually less than the predicted risks, since the risk assessment approach typically incorporates a number of conservative assumptions that tend to over-estimate the actual risks.

Based on the magnitude of calculated HQs, risks were categorized as follows:

- Negligible risk: HQ less than or equal to 1. This conclusion is consistent with standard practice in risk assessment.
- Low risk and likely to be negligible: HQ greater than 1 but less than or equal to 10. This conclusion is generally true but should be reviewed on a chemical-specific basis, as the conservatism of the analysis varies dependent on a number of factors used in the assessment.
- Potentially elevated risk: HQ greater than 10; harmful effects are possible due to the substance in question.

For chemicals for which HQs were predicted to exceed 1, a magnitude of effect assessment was conducted to determine if the NICO Project has a negligible, low, moderate, or high effect on the potential for unacceptable exposures. The following analyses were conducted to determine the magnitude of effects:

- comparison of the magnitude of exceedances for the upper-bound and central-tendency estimates;
- comparison of Project Case concentrations to Baseline Case concentrations;
- evaluation of the uncertainty and conservatism in the exposure estimates;
- evaluation of the conservatism in the toxicity benchmark for the CoPC; and
- evaluation of the potential for adverse aquatic health effects at predicted risk levels.

5.4.1 Surface Water

5.4.1.1 Risk Analysis

For all CoPCs, potential adverse effects to aquatic life were evaluated by comparing predicted surface water concentrations in Nico, Peanut, and Burke lakes, and the Marian River to toxicity benchmarks for surface water using both an upper bound estimate of exposure (predicted 95th percentile concentration) and a central tendency estimate of exposure (predicted average concentration).

When HQs were calculated using an upper bound estimate of exposure (predicted 95th percentile concentration), the following HQs were greater than the target HQ of 1, suggesting risks of an adverse effect to aquatic life:

- Construction: aluminum in Peanut Lake (HQ=1.2) (Table 5.4.1-1).
- Operations: aluminum (HQ=2.7) and iron (HQ=2.2) in Nico Lake, aluminum (HQ=1.8) and iron (HQ=1.2) in Peanut Lake, and aluminum (HQ=1.2) in Burke Lake (Table 5.4.1-2).

- Active Closure: aluminum (HQ=2.3) and iron (HQ=1.9) in Nico Lake and aluminum (HQ=1.3) in Peanut Lake (Table 5.4.1-3).
- Post-Closure: there were no exceedances of the target HQ of 1 during post-closure in any of the 4 waterbodies included in the assessment (Table 5.4.1-4).

Table 5.4.1-1: Hazard Quotients for Surface Water during Construction

CoPC	Upper-Bound Estimate[a]				Central-Tendency Estimate[b]			
	Nico Lake	Peanut Lake	Burke Lake	Marian River	Nico Lake	Peanut Lake	Burke Lake	Marian River
Aluminum	-	**1.2**	0.44	-	-	0.80	0.38	-
Arsenic	-	-	0.13	-	-	-	0.12	-
Barium	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.02
Cobalt	-	-	0.09	-	-	-	0.07	-
Manganese	-	0.06	-	0.09	-	0.04	-	0.04
Mercury	-	-	-	0.31	-	-	-	0.04
Vanadium	0.12	0.13	-	0.19	0.11	0.10	-	0.07

[a] Based on 95th percentile predicted surface water concentration.

[b] Based on mean predicted surface water concentration.

CoPC = Chemical of potential concern; "-" = this parameter was not identified as a CoPC in this waterbody; Shaded + bold text = hazard quotient >1.

Table 5.4.1-2: Hazard Quotients for Surface Water during Operations

CoPC	Upper-Bound Estimate[a]				Central-Tendency Estimate[b]			
	Nico Lake	Peanut Lake	Burke Lake	Marian River	Nico Lake	Peanut Lake	Burke Lake	Marian River
Aluminum	**2.7**	**1.8**	**1.2**	0.10	**1.7**	1.0	0.71	0.04
Antimony	-	-	0.01	-	-	-	0.01	-
Arsenic	-	-	0.36	-	-	-	0.20	-
Barium	0.02	0.02	0.01	0.03	0.02	0.01	0.01	0.02
Cobalt	-	-	0.25	-	-	-	0.14	-
Copper	-	-	0.11	-	-	-	0.08	-
Iron	**2.2**	**1.2**	0.99	0.21	**1.5**	0.75	0.63	0.10
Manganese	-	0.08	-	0.09	-	0.04	-	0.04
Mercury	-	-	-	0.30	-	-	-	0.04
Vanadium	0.21	0.15	-	0.19	0.15	0.10	-	0.07

[a] Based on 95th percentile predicted surface water concentration.

[b] Based on mean predicted surface water concentration.

CoPC = Chemical of potential concern; "-" = this parameter was not identified as a CoPC in this waterbody; Shaded + bold text = hazard quotient >1.

Table 5.4.1-3: Hazard Quotients for Surface Water during Active Closure

CoPC	Upper-Bound Estimate[a]				Central-Tendency Estimate[b]			
	Nico Lake	Peanut Lake	Burke Lake	Marian River	Nico Lake	Peanut Lake	Burke Lake	Marian River
Aluminum	**2.3**	**1.3**	1.0	-	**1.3**	0.71	0.52	-
Antimony	-	-	0.02	-	-	-	0.01	-
Arsenic	-	-	0.30	-	-	-	0.14	-
Barium	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.02
Cobalt	-	-	0.22	-	-	-	0.10	-
Copper	-	-	0.10	-	-	-	0.07	-
Iron	**1.9**	-	0.87	0.20	**1.2**	-	0.49	0.10
Manganese	-	0.08	-	0.09	-	0.04	-	0.04
Mercury	-	-	-	0.31	-	-	-	0.04
Selenium	-	-	0.22	-	-	-	0.11	-
Vanadium	0.20	0.16	-	0.19	0.15	0.09	-	0.07

[a] Based on 95th percentile predicted surface water concentration.

[b] Based on mean predicted surface water concentration.

CoPC = Chemical of potential concern; "-" = this parameter was not identified as a CoPC in this waterbody; Shaded + bold text = hazard quotient >1.

Table 5.4.1-4: Hazard Quotients for Surface Water during Post-Closure

CoPC	Upper-Bound Estimate[a]				Central-Tendency Estimate[b]			
	Nico Lake	Peanut Lake	Burke Lake	Marian River	Nico Lake	Peanut Lake	Burke Lake	Marian River
Aluminum	-	-	0.29	-	-	-	0.22	-
Antimony	-	-	0.02	-	-	-	0.02	-
Barium	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.02
Manganese	0.11	0.09	-	0.09	0.08	0.05	-	0.04
Mercury	-	-	-	0.30	-	-	-	0.04
Vanadium	0.16	0.14	-	0.18	0.12	0.07	-	0.07

[a] Based on 95th percentile predicted surface water concentration.

[b] Based on mean predicted surface water concentration.

CoPC = Chemical of potential concern; "-" = this parameter was not identified as a CoPC in this waterbody; Shaded + bold text = hazard quotient >1.

When HQs were calculated using a central tendency estimate of exposure (predicted average concentration), the following HQs were greater than the target HQ of 1, suggesting risks of an adverse effect to aquatic life:

- Construction: there were no exceedances of the target HQ of during construction in any of the 4 waterbodies included in the assessment (Table 5.4.1-1).
- Operations: aluminum (HQ=1.7) and iron (HQ=1.5) in Nico Lake (Table 5.4.1-2).
- Active Closure: aluminum (HQ=1.3) and iron (HQ=1.2) in Nico Lake (Table 5.4.1-3).

- Post-Closure: there were no exceedances of the target HQ of 1 during post-closure in any of the 4 waterbodies included in the assessment (Table 5.4.1-4).

5.4.1.2 Magnitude of Effect Assessment

For CoPCs in surface water, locations and phases of the NICO Project where HQs were greater than 1 (aluminum and iron) (Tables 5.4.1-1 to 5.4.1-4), additional analysis was performed to determine if the NICO Project has a negligible, low, moderate, or high effect on the potential for unacceptable risks to aquatic life (Tables 5.4.1-5 and 5.4.1-6).

Table 5.4.1-5: Further Analysis of Aluminum in Surface Water and Determination of Magnitude of Effect

Analysis Criteria	Discussion		
	Nico Lake	Peanut Lake	Burke Lake
Magnitude of hazard quotients	Construction: There were no exceedances of the target HQ of 1 Operations: • The UB estimate was 2.7 • The CT estimate was 1.7 Active Closure: • The UB estimate was 2.3 • The CT estimate was 1.3 Post Closure: There were no exceedances of the target HQ of 1	Construction: • The UB estimate was 1.1 • The CT estimate was 0.8 Operations: • The UB estimate was 1.8 • The CT estimate was 1.0 Active Closure: • The UB estimate was 1.3 • The CT HQ was 0.71 Post-Closure: There were no exceedances of the target HQ of 1	Construction: There were no exceedances of the target HQ of 1 Operations: • The UB estimate was 1.2 • The CT estimate was 0.71 Active Closure: There were no exceedances of the target HQ of 1 Post-Closure: There were no exceedances of the target HQ of 1
Comparison of baseline and impact cases	The mean and maximum baseline concentrations are less than the toxicity benchmark (480 µg/L)	The mean and maximum baseline concentrations are less than the toxicity benchmark (410 µg/L)	The mean and maximum concentrations are less than the toxicity benchmark (480 µg/L)
Uncertainty and conservatism in exposure estimates	• With respect to the sediment and water quality modelling, predicted changes in metal concentrations in lakes (surface water and sediment) are considered to be conservative estimates of the maximum predicted changes that could occur during the NICO Project (for a summary of the conservative assumptions used in the sediment and water quality modelling, refer to Section 7.0 of the DAR) • Of particular note is the following: The predictive air modelling results that fed into the sediment and water quality modelling considered that aluminum is adhered to dust (or TSP), which is generated by the NICO Project through processing and road dust during the operations phase. Most of the TSP generated during the operations phase is due to road dust rather than processing. The predictive air modelling assumed that dust suppression would only occur during the summer period (i.e., 1 May to 30 September) and that fugitive dust generation is possible during the winter period (i.e., 1 October to 30 April) despite frozen ground conditions and/or snow-covered roads. As a result, much higher concentrations of aluminum were predicted for the winter period compared to the summer period. It is anticipated that road dust would be negligible during the winter period due to snow cover over the roads and the ground being frozen; thus, the predicted concentrations of aluminum used in the sediment and water quality modelling and the results of the sediment and water quality modelling used in the aquatic RA are associated with a high degree of conservatism.		

Table 5.4.1-5: Further Analysis of Aluminum in Surface Water and Determination of Magnitude of Effect (continued)

Analysis Criteria	Discussion		
	Nico Lake	Peanut Lake	Burke Lake
Uncertainty and conservatism in the toxicity benchmark	• There is some uncertainty in the application of the equation provided by the BCMWLAP (2001a) to develop benchmarks for aluminum because the pH in Nico, Peanut, and Burke lakes is outside the range for which the equation is applicable • Still, the benchmarks provided for aluminum are likely protective based on a review of the toxicity literature and given that the guidelines do not take into consideration the demonstrated mitigative effects of DOC and hardness/calcium on aluminum toxicity • A BLM for freshwater aquatic life that incorporates the protective effects of water chemistry on aluminum toxicity (including the influences of calcium and DOC) is currently under development for aluminum • Application of BLM for copper resulted in an approximate 10-fold increase in the benchmark for copper relative to the CCME CWQG (Table 5.3.1-1) • The benchmarks derived for aluminum are for dissolved aluminum but they have been applied to predicted total aluminum concentrations which is a conservative approach. • If the maximum predicted UB estimate of dissolved aluminum concentrations (considering all phases of the NICO Project) in Nico, Peanut, and Burke lakes are compared to the benchmarks, there are no exceedances of the target HQ of 1		
Potential adverse effects	• Ionoregulatory and osmoregulatory dysfunction and various respiratory problems related to aluminum precipitation on the gills		
Magnitude of effect	• Various conservative assumptions are used in the water quality modelling • There is some uncertainty related to the toxicity benchmarks used for aluminum but they likely overestimate potential risks • Aluminum in circum-neutral waters is likely to be present in complexed form (mainly oxyhydroxides), which significantly reduces the potential for precipitation on respiratory surfaces • There is low and likely negligible NICO Project-related risk to aquatic life from aluminum in Nico, Peanut, and Burke lakes		

BLM = Biotic Ligand Model; CT= Central Tendency; DAR = Developer's Assessment Report; DOC = Dissolved Organic Carbon; HQ = Hazard Quotient; UB = Upper Bound; µg/L = microgram per litre

Table 5.4.1-6: Further Analysis of Iron and Magnitude of Effect Assessment

Analysis Criteria	Nico Lake	Peanut Lake
Magnitude of hazard quotients	Construction: There were no exceedances of the target HQ of 1 Operations: • The UB estimate was 2.2 • The CT estimate was 1.5 Active Closure: • The UB estimate was 1.9 • The CT estimate was 1.2 Post Closure: There were no exceedances of the target HQ of 1	Construction: There were no exceedances of the target HQ of 1 Operations: • The UB estimate was 1.2 • The CT estimate was 0.75 Active Closure: There were no exceedances of the target HQ of 1 Post-Closure: There were no exceedances of the target HQ of 1
Comparison of baseline and impact cases	• The mean baseline concentration (644.8 µg/L) is less than the toxicity benchmark (1500 µg/L) but the maximum baseline concentration (6990 µg/L) exceeds the	• The mean baseline concentration (323.2 µg/L) and the maximum baseline concentration (761 µg/L) are less than the toxicity benchmark (1500 µg/L)

Table 5.4.1-6: Further Analysis of Iron and Magnitude of Effect Assessment (continued)

Analysis Criteria	Nico Lake	Peanut Lake
	benchmark by almost a factor of 5, suggesting that an exceedance of the benchmark may not necessarily represent a risk of adverse effect to the resident biota • The maximum predicted concentrations during operations (3300 µg/L) and active closure (2890 µg/L) are above the mean baseline concentration (644.8 µg/L but within the range of baseline concentrations measured (80 to 6690 µg/L)	
Uncertainty and conservatism in exposure estimates	• With respect to the sediment and water quality modelling, predicted changes in metal concentrations in lakes (surface water and sediment) are considered to be conservative estimates of the maximum predicted changes that could occur during the NICO Project (for a summary of the conservative assumptions used in the sediment and water quality modelling, refer to Section 7.0 of the DAR) • Of particular note is the following: The predictive air modelling results that fed into the sediment and water quality modelling considered that aluminum is adhered to dust (or TSP), which is generated by the NICO Project through processing and road dust during the operations phase. Most of the TSP generated during the operations phase is due to road dust rather than processing. The predictive air modelling assumed that dust suppression would only occur during the summer period (i.e., 1 May to 30 September) and that fugitive dust generation is possible during the winter period (i.e., 1 October to 30 April) despite frozen ground conditions and/or snow-covered roads. As a result, much higher concentrations of aluminum were predicted for the winter period compared to the summer period. It is anticipated that road dust would be negligible during the winter period due to snow cover over the roads and the ground being frozen; thus, the predicted concentrations of aluminum used in the sediment and water quality modelling and the results of the sediment and water quality modelling used in the aquatic RA are associated with a high degree of conservatism.	
Uncertainty and conservatism in the toxicity benchmark	• There is some evidence to suggest that humic acids (Peuranen et al. 1994) and hardness (BCMOE 2008) have an ameliorating effect on the toxicity of total iron but there are insufficient studies to determine the actual relationship between these parameters and iron toxicity • The benchmark used in this assessment is consistent with those recommended by others. Linton et al. (2007) proposed a benchmark of 1700 µg/L that allowed for a slight to moderate change in community population structure because of loss of some rare species and/or replacement of sensitive ubiquitous taxa with more tolerant taxa. Randall et al. (1999) also derived a benchmark for iron of 1700 µg/L in their work	
Potential adverse effects	• Damage to the gills of fish from the corrosive effects of the ferric iron, however, ferric iron is unlikely to persist in the water column as a free ion due to complexation reactions and will likely precipitate as an oxyhydroxide • Smothering of eggs or organisms which live in the sediment where the iron is deposited • Decreased visibility in the water, which can affect feeding success and other behaviour	
Magnitude of effect	• The CT estimates for Nico Lake during operations and active closure only slightly exceed 1 and the CT estimates for Peanut Lake do not exceed 1 during any phase of the NICO Project • Various conservative assumptions are used in the predictive water quality modelling • The benchmark used is consistent with that proposed by others but may be slightly conservative because it does not incorporate the protective effect of hardness and DOC on iron toxicity • There is low and likely negligible NICO Project-related risk to aquatic life from iron in Nico and Peanut lakes	

CT= Central Tendency; DAR = Developer's Assessment Report; DOC = Dissolved Organic Carbon; HQ = Hazard Quotient; UB = Upper Bound; µg/L = microgram per litre

5.4.1.3 Summary of Aquatic Health Risks from Chemicals of Potential Concern in Water

During construction, all of the CoPCs identified in surface water (arsenic, barium, cobalt, manganese, mercury, and vanadium), with the exception of aluminum did not exceed target risk levels (i.e., HQs were 1 or less), indicating negligible risk of adverse effects to aquatic health as a result of the NICO Project. Aluminum exhibited exceedances of target risk levels during construction in Peanut Lake. However, a magnitude of effect assessment indicated that risk from this CoPC is low and likely to be negligible given the degree of conservatism used in the derivation of the risk levels.

During operations, many of the CoPCs identified in surface water (antimony, arsenic, barium, cobalt, copper, manganese, mercury, and vanadium) did not exceed target risk levels (i.e., HQs were 1 or less), indicating negligible risk of adverse effects to aquatic health as a result of the NICO Project. Aluminum exceeded target risk levels during operations in Nico, Peanut, and Burke lakes. However, a magnitude of effect assessment indicated that risk from this CoPC is low and likely to be negligible given the degree of conservatism used in the derivation of the risk levels. Iron exceeded target risk levels during operations in Nico and Peanut lakes. However, a magnitude of effect assessment indicated that risk from this CoPC is also low and likely to be negligible given the degree of conservatism used in the derivation of the risk levels.

Many of CoPCs identified in surface water (antimony, arsenic, barium, cobalt, copper, manganese, mercury, selenium, and vanadium) did not exceed target risk levels (i.e., HQs were 1 or less) during active closure, indicating negligible risk of adverse effects to aquatic health as a result of the NICO Project. Aluminum and iron in surface water exceeded target risk levels in Nico Lake during active closure. Iron in surface water also exceeded target risk levels in Peanut Lake during active closure. However, magnitude of effect assessments for both metals indicated that risk from these CoPCs is low and likely negligible given the degree of conservatism used in the derivation of the risk levels. In particular, effects from both iron and aluminum on aquatic life are related to potential for precipitation on respiratory surfaces, such as gills, and interference with respiration. However, under circum-neutral pH conditions, neither is likely to be present in the water column as a free ion, and the potential for interference with respiration is considered to be low. The effects of aluminum and iron precipitation have been noted mainly at low pH where both metals can exist as free ions.

During post-closure, all of the CoPCs identified in surface water (aluminum, antimony, barium, manganese, mercury, and vanadium) did not exceed target risk levels (i.e., HQs were 1 or less), indicating negligible risk of adverse effects to aquatic health as a result of the NICO Project during this phase.

5.4.2 Sediment

5.4.2.1 Risk Analysis

Potential adverse effects to benthic invertebrates were evaluated by comparing predicted sediment concentrations in Nico, Peanut, and Burke lakes to sediment toxicity benchmarks for benthic invertebrates (Table 5.4.2-1). When HQs were calculated using maximum predicted sediment concentrations, the calculated HQs were greater than 1 for arsenic (HQ = 7.3) and nickel (HQ = 2.0) in Nico Lake. In Burke Lake, the calculated HQs were greater than 1 for nickel (HQ = 3.2) only. When HQs were calculated using median predicted sediment concentrations, the calculated HQs were greater than 1 for arsenic (HQ = 2.9) and nickel (HQ = 1.9) in Nico Lake. The calculated HQs were greater than 1 in Burke Lake for nickel (HQ = 2.7). Because the sediment quality predictions represent concentrations in sediment at closure, the results of the risk analysis can be applied to both the active closure and post-closure phase of the NICO Project. Given that the highest concentrations in sediment are likely to occur at the end of operations (i.e., at closure), sediment quality will improve over time, once the sources of the deposition are gone and new sediment accumulates during the post-closure phase of the NICO Project.

Table 5.4.2-1: Hazard Quotients for Sediments

CoPC	Upper-Bound Estimate			Central-Tendency Estimate		
	Nico Lake	Peanut Lake	Burke Lake	Nico Lake	Peanut Lake	Burke Lake
Antimony	0.86	0.17	0.14	0.11	0.10	0.08
Arsenic	**7.3**	NA	NA	**2.9**	NA	NA
Barium	NV	NV	NV	NV	NV	NV
Beryllium	NV	NA	NV	NV	NA	NV
Cobalt	NV	NV	NV	NV	NV	NV
Molybdenum	NV	NA	NV	NV	NA	NV
Nickel	**2.0**	NA	**3.2**	**1.9**	NA	**2.7**
Selenium	NV	NV	NV	NV	NV	NV
Uranium	NA	NA	0.09	NA	NA	0.07
Vanadium	NV	NV	NV	NV	NV	NV

CoPC = Chemical of potential concern; NV = No value. A toxicity benchmark is not available for this CoPC; NA = Not applicable. The parameter was not identified as a CoPC in sediment in this waterbody; Shaded + bold text = hazard quotient >1.

The HQs for uranium did not exceed the target HQ of 1 for any waterbody at closure. For CoPCs for which HQs greater than 1 were calculated (i.e., arsenic and nickel), further analyses were completed. The further analyses completed for arsenic and nickel are summarized in Section 5.4.2.2.

Sediment toxicity benchmarks are not available for barium, beryllium, cobalt, molybdenum, selenium, and vanadium so HQs could not be calculated. Still, unacceptable risks to aquatic life are not expected from exposure to these chemicals in sediments based on the discussion provided in the following subsection.

5.4.2.2 Magnitude of Effect Assessment

For CoPCs in sediment and locations where HQs were greater than 1 (arsenic in Nico Lake and nickel in Nico Lake and Burke Lake) (Table 5.4.2-1), additional analysis was performed to determine if the NICO Project has a negligible, low, moderate, or high effect on the potential for unacceptable risks to aquatic life (Tables 5.4.2-2 and 5.4.2-3). In support of the magnitude of effect assessment, a number of other studies were reviewed, including Ontario MOE studies where sediment bioassay testing had been conducted in metal-contaminated sites. Where there was an exceedance of the toxicity benchmarks, the potential for adverse effects was considered with respect to the concentrations of metals in sediments associated with toxicity in these other studies. A brief discussion of the Ontario MOE sediment studies is provided below.

The Ontario MOE has conducted sediment toxicity studies at a number of metals-contaminated sites in Ontario, following the protocol developed by the Ontario MOE (Bedard et al. 1992). The tests directly assess toxicity as changes in survival or growth of the test species. The test species were mayfly (*Hexagenia* sp.) larvae, chironomid (*Chironomus tentans*) larvae, and young fathead minnow (*Pimephales promelas*). Because the tests use naïve laboratory cultured organisms, there is no possibility that the organisms would be acclimated to elevated levels of metals, and the tests are considered conservative. The data have been published in a number of publically available Ontario MOE technical reports, from which the data for this assessment have been obtained. This data provides a suitable basis from which to assess whether there are risks to benthic organisms at the predicted sediment concentrations for the NICO Project.

The data used are derived from studies at 4 separate sites: the Welland River, downstream of a specialty steel manufacturing site that had elevated levels of chromium and nickel in sediments (Jaagumagi and Bedard 1995); Junction Creek, downstream of the copper and nickel mining and smelting complexes in Sudbury (Jaagumagi and Bedard 2001a); the Porcupine River downstream of a copper-zinc smelter (Jaagumagi and Bedard 2001b), and in lakes in the Bancroft area at former uranium mining sites (Jaagumagi and Bedard 2003).

The dataset is based on testing of field-collected sediments and therefore consists of mixtures of metals that can potentially act additively, synergistically, or antagonistically. As a result, the no effects numbers discussed and presented in the following tables include the possible effects of other metals, and thus can be considered as conservative benchmarks.

Table 5.4.2-2: Further Analysis of Arsenic in Sediment and Determination of Magnitude of Effect

Analysis Criteria	Discussion
Magnitude of hazard quotients	• The upper bound HQ was 7.3 • The central tendency HQ was 2.9
Comparison of baseline and impact cases	• The mean baseline concentration in Nico Lake (482 mg/kg) exceeds the toxicity benchmark (150 mg/kg) by a factor of 3, suggesting that an exceedance of the benchmark may not necessarily represent a risk of adverse effect to the resident biota • In fact, there was no statistically significant relationship between benthic invertebrate abundance and richness and arsenic concentrations. This suggests that background sediment arsenic concentrations do not strongly influence benthic communities despite the occasionally elevated metal concentrations (Section 12.0 of the DAR; Fortune 2011) • The maximum predicted concentration (1090 mg/kg) is approximately 2 times the mean baseline concentration (482 mg/kg) but within the range of baseline concentrations measured (145 to 1590 mg/kg) • Concentrations of arsenic in Nico Lake are predicted to increase by less than 2% from observed baseline concentrations. This potential level of change is well within the limits of analytical uncertainty and would be indistinguishable from existing natural variability.
Uncertainty and conservatism in exposure estimates	• With respect to the sediment and water quality modelling, predicted changes in metal concentrations in lakes (surface water and sediment) are considered to be conservative estimates of the maximum predicted changes that could occur during the NICO Project (for a summary of the conservative assumptions used in the sediment and water quality modelling, refer to Section 7.0 of the DAR)
Uncertainty and conservatism in the toxicity benchmark	• The benchmark used in this assessment is based on the GNWT Remediation Objective (GNWT 2003) • A review of available toxicity data for arsenic indicates that sediment concentrations up to 500 mg/kg (maximum concentration tested in sediments collected in the Porcupine River in Timmins, Ontario), with co-occurring copper and nickel resulted in no significant effects on survival and growth in the mayfly, midge or fathead minnow (Jaagumagi and Bedard 2001b) • The maximum predicted sediment concentration of arsenic is 1090 mg/kg and the median predicted sediment concentration is 436 mg/kg • Based on the benchmark of 500 mg/kg, the upper bound HQ is 2.2, above the target HQ of 1 • Based on the benchmark of 500 mg/kg, the central tendency HQ is 0.9, below the target HQ of 1 • Because the sediment toxicity tests used naïve laboratory cultured organisms, there is no possibility that the organisms would be acclimated to elevated levels of metals, and the benchmark is considered conservative • The benchmark includes the possible effects of other metals, and thus can be considered a conservative benchmark
Magnitude of effect	• Predicted sediment arsenic concentrations are within the range of measured baseline concentrations in Nico Lake • Various conservative assumptions are used in the predictive water quality modelling • The toxicity benchmark is considered conservative relative to other available benchmarks • The conservative nature of the benchmark is evidenced by the fact that mean measured baseline concentrations exceed the benchmark • There is low and likely to be negligible NICO Project-related risk to aquatic life from arsenic in sediment in Nico Lake at closure

DAR = Developer's Assessment Report; HQ = Hazard Quotient; mg/kg = milligram per kilogram

Table 5.4.2-3: Further Analysis of Nickel in Sediment and Determination of Magnitude of Effect

<table>
<tr><th rowspan="2">Analysis Criteria</th><th colspan="2">Discussion</th></tr>
<tr><th>Nico Lake</th><th>Burke Lake</th></tr>
<tr><td>Magnitude of hazard quotients</td><td>• The upper bound HQ was 2.0
• The central tendency HQ was 1.9</td><td>• The upper bound HQ was 3.2
• The central tendency HQ was 2.7</td></tr>
<tr><td>Comparison of baseline and impact cases</td><td>• The mean baseline concentration in Nico Lake (27.5 mg/kg) exceeds the toxicity benchmark (16 mg/kg) by almost a factor of 2, suggesting that an exceedance of the benchmark may not necessarily represent a risk of adverse effect to the resident biota
• The maximum predicted concentration (32 mg/kg) is marginally above the mean baseline concentration (27.5 mg/kg) and within the range of baseline concentrations measured (21 to 35 mg/kg)</td><td>• The mean baseline concentration in Burke Lake (43 mg/kg) exceeds the toxicity benchmark (16 mg/kg) by more than a factor of 2, suggesting that an exceedance of the benchmark may not necessarily represent a risk of adverse effect to the resident biota
• The maximum predicted concentration (51 mg/kg) is marginally above the mean baseline concentration (43 mg/kg) and within the range of baseline concentrations measured (34 to 50 mg/kg)</td></tr>
<tr><td>Uncertainty and conservatism in exposure estimates</td><td colspan="2">• With respect to the sediment and water quality modelling, predicted changes in metal concentrations in lakes (surface water and sediment) are considered to be conservative estimates of the maximum predicted changes that could occur during the NICO Project (for a summary of the conservative assumptions used in the sediment and water quality modelling, refer to Section 7.0 of the DAR)</td></tr>
<tr><td>Uncertainty and conservatism in the toxicity benchmark</td><td colspan="2">• The benchmark used in this assessment is based on the Ontario MOE LEL which is derived using the Screening Level Concentration Approach (MOEE 1994)
• In 1998, the Ontario MOE conducted a sediment study in the Porcupine River in Timmins, Ontario, downstream of a copper-zinc smelter (Jaagumagi and Bedard 2001b). The tests directly assessed toxicity as changes in survival or growth of mayfly (Hexagenia sp.) larvae, chironomid (Chironomus tentans) larvae, and young fathead minnow (Pimephales promelas). Nickel sediment concentrations of 63 µg/g did not result in adverse effects on any of the test organisms
• In 1999, the Ontario MOE conducted a study in Junction Creek (Sudbury), downstream of the Inco and Falconbridge nickel mining and smelting operations (Jaagumagi and Bedard 2001a). Sediment bioassay testing was undertaken as part of the investigation using the same species and endpoints identified above. The highest concentration of nickel that did not result in adverse effects on the test organisms was 500 µg/g
• Borgmann (2003) performed a study on contaminated sediments from both the Sudbury and Noranda-Rouyn areas. Both are regions with long histories of metal mining and processing and are known to be contaminated with often very high concentrations of metals. The probable effect level for the amphipod Hyalella azteca, calculated from studies using field-collected data and the same procedure as used in setting the CCME ISQGs, was reported at 577 µg/g. An independently derived LC_{25} concentration, obtained by quantifying bioavailable metals and comparing it to known toxic effect levels, was higher at 880 µg/g. A threshold effect level was also reported in the study for nickel of 55 µg/g. The independently derived LC_{25} concentration based on bioavailability and toxic effects was 100 µg/g
• Using the lowest concentration from the above-noted studies, a sediment benchmark of 55 mg/kg can be derived
• Using a sediment benchmark of 55 mg/kg, the upper bound HQs for Nico Lake and Burke Lake are 0.6 and 0.9, respectively below the target HQ of 1
• The benchmark includes the possible effects of other metals, and thus can be considered a conservative benchmark</td></tr>
</table>

Table 5.4.2-3: Further Analysis of Nickel in Sediment and Determination of Magnitude of Effect (continued)

Analysis Criteria	Discussion	
	Nico Lake	Burke Lake
Magnitude of effect	• Predicted sediment nickel concentrations are within the range of measured baseline concentrations • Various conservative assumptions are used in the predictive water quality modelling • The toxicity benchmark is considered conservative relative to other available benchmarks • The conservative nature of the benchmark is evidenced by the fact that mean measured baseline concentrations exceed the benchmark • There is negligible NICO Project-related risk to aquatic life from nickel in sediment in Nico and Burke lakes at closure	

DAR = Developer's Assessment Report; HQ = Hazard Quotient; mg/kg = milligram per kilogram; µg/g = microgram per gram

With respect to those chemicals that do not have sediment toxicity benchmarks (barium, beryllium, cobalt, molybdenum, selenium, and vanadium), unacceptable risks to aquatic life are not expected from exposure to these chemicals in sediments, based on the following:

- Maximum predicted sediment concentrations are greater than mean baseline concentrations; however, median predicted sediment concentrations are within the range of baseline concentrations reported for these metals in each waterbody.
- With respect to the sediment and water quality modelling, predicted changes in metal concentrations in lakes (surface water and sediment) are considered to be conservative estimates of the maximum predicted changes that could occur during the NICO Project (for a summary of the conservative assumptions used in the sediment and water quality modelling, refer to Section 7.0 of the DAR).
- In the Ontario MOE Porcupine River study (Jaagumagi and Bedard 2001b), no effects on growth or survival were found on any of the 3 test species at a maximum selenium concentration of 2.4 mg/kg. In the same study, cobalt concentrations up to 40 mg/kg and beryllium concentrations up to 2.1 mg/kg were also not associated with any adverse effects on growth and survival in the test organisms. These concentrations are higher than the predicted concentrations in sediments at closure in Nico, Peanut, and Burke lakes.
- Molybdenum concentrations of up to 17 mg/kg had no adverse effects on the test organisms in the Bancroft study (Jaagumagi and Bedard 2003). In the same study, vanadium concentrations of up to 72 mg/kg did not result in any adverse effects on the test organisms. These concentrations are higher than the predicted concentrations in sediments at closure in Nico, Peanut, and Burke lakes.

5.4.2.3 Summary of Aquatic Health Risks from Chemicals of Potential Concern in Sediments

Antimony, arsenic, barium, beryllium, cobalt, molybdenum, nickel, selenium, uranium, and vanadium were identified as CoPCs in sediment at closure. Toxicity benchmarks are not available for several of these metals, including barium, beryllium, cobalt, molybdenum, selenium, and vanadium. However, based the results of sediment toxicity testing at former smelting and mining sites, the conservative assumptions used in the sediment quality modeling predictions and the range of baseline values, potential risks to aquatic life from these metals in sediments is considered to be negligible.

Antimony and uranium did not exceed target risk levels of 1, indicating negligible risk of adverse effects to aquatic health at closure.

Arsenic and nickel exceeded target risk levels in Nico Lake. Nickel also exceeded target risk levels in Burke Lake. Still, magnitude of effect assessments for both metals indicated that risk from these CoPCs are low and likely to be negligible (for arsenic) and negligible (for nickel) based on baseline conditions in the NICO Project area and the degree of conservatism used in the derivation of the risk levels. Furthermore, because the highest concentrations in sediment are likely to occur at the end of operations (i.e., at closure), sediment quality will improve over time, once the sources of the deposition are gone and new sediment accumulates during the post-closure phase of the NICO Project. As noted in Section 5.2.1, toxicity depends on availability of arsenic and nickel from sediments that in turn is governed by sediment geochemical conditions. The highly organic sediments in these lakes are expected to minimize availability of metals to biota through complexation with sediment constituents. The RA is therefore likely to over-estimate the actual risks to biota.

6.0 SUMMARY OF RISKS TO AQUATIC HEALTH AND CONCLUSIONS

An aquatic risk assessment was completed for the NICO Project to determine the potential impacts on aquatic life (including aquatic plants, plankton, benthic invertebrates, and fish) from Projected-related emissions to surface waterbodies. The assessment was based on water quality predictions for Nico Lake and downstream waterbodies (Peanut and Burke lakes and the Marian River). It considered chemical releases associated with dust generation and deposition to surface water, as well as water discharges to surface water. Potential aquatic health impacts were determined during the construction, operations, active closure, and post-closure phases of the NICO Project. The assessment included the development of SSWQOs for the NICO Project.

A summary of risk to aquatic health associated with the CoPCs identified for each phase of the NICO Project is provided in the following subsections. Overall, for all CoPCs, the NICO Project-related risks to aquatic life are concluded to be either negligible, or low and likely negligible.

6.1 Construction

During construction, all of the CoPCs identified in surface water (arsenic, barium, cobalt, manganese, mercury, and vanadium), with the exception of aluminum did not exceed target risk levels (i.e., HQs were 1 or less), indicating negligible risk of adverse effects to aquatic health as a result of the NICO Project.

Aluminum exhibited exceedances of target risk levels during construction in Peanut Lake. However, a magnitude of effect assessment indicated that risk from this CoPC is low and likely to be negligible given the degree of conservatism used in the derivation of the risk levels. At circum-neutral pH, aluminum would not be present in the water column as a free ion, but rather would form complexes (oxyhydroxides) and/or bind to particulate matter and thus would be biologically unavailable to react with respiratory surfaces. As noted in Section 5.2.1, the free ion is the biologically reactive form that is associated with toxic effects in biota.

6.2 Operations

During operations, many of the CoPCs identified in surface water (antimony, arsenic, barium, cobalt, copper, manganese, mercury, and vanadium) did not exceed target risk levels (i.e., HQs were 1 or less), indicating negligible risk of adverse effects to aquatic health as a result of the NICO Project.

Aluminum exceeded target risk levels during operations in Nico, Peanut, and Burke lakes. However, a magnitude of effect assessment indicated that risk from this CoPC is low and likely to be negligible given the degree of conservatism used in the derivation of the risk levels.

Iron exceeded target risk levels during operations in Nico and Peanut lakes. However, a magnitude of effect assessment indicated that risk from this CoPC is also low and likely to be negligible given the degree of conservatism used in the derivation of the risk levels.

At circum-neutral pH, both iron and aluminum would not be present in the water column as free ions, but rather would form complexes (oxyhydroxides) and/or bind to particulate matter and thus would be biologically unavailable to react with respiratory surfaces. As noted in Section 5.2.1, the free ion is the biologically reactive form that is associated with toxic effects in biota.

6.3 Active Closure

Many of CoPCs identified in surface water (antimony, arsenic, barium, cobalt, copper, manganese, mercury, selenium, and vanadium) did not exceed target risk levels (i.e., HQs were 1 or less) during active closure, indicating negligible risk of adverse effects to aquatic health as a result of the NICO Project.

Aluminum and iron in surface water exceeded target risks levels in Nico Lake during active closure. Iron in surface water also exceeded target risk levels in Peanut Lake during active closure. However, magnitude of effect assessments for both metals indicated that risk from these CoPCs is low and likely negligible given the degree of conservatism used in the derivation of the risk levels. At circum-neutral pH, both iron and aluminum would not be present in the water column as free ions, but rather would form complexes (oxyhydroxides) and/or bind to particulate matter and thus would be biologically unavailable to react with respiratory surfaces. As noted in Section 5.2.1, the free ion is the biologically reactive form that is associated with toxic effects in biota.

Antimony, arsenic, barium, beryllium, cobalt, molybdenum, nickel, selenium, uranium, and vanadium were identified as CoPCs in sediment at closure. Toxicity benchmarks are not available for several of these metals, including barium, beryllium, cobalt, molybdenum, selenium, and vanadium. However, based the results of sediment toxicity testing at former smelting and mining sites, the conservative assumptions used in the sediment quality modelling predictions and the range of baseline values, potential risks to aquatic life from these metals in sediments is considered to be negligible. Antimony and uranium did not exceed target risk levels of 1, indicating negligible risk of adverse effects to aquatic health at closure. Arsenic and nickel exceeded target risk levels in Nico Lake. Nickel also exceeded target risk levels in Burke Lake. Still, magnitude of effect assessments for both metals indicated that risk from these CoPCs are low and likely to be negligible (for arsenic) and negligible (for nickel) based on baseline conditions in the NICO Project area and the degree of conservatism used in the derivation of the risk levels. Furthermore, because the highest concentrations in sediment are likely to occur at the end of operations (i.e., at closure), sediment quality will improve over time, once the sources of the deposition are gone and new sediment accumulates during the post-closure phase of the NICO Project. Given that these conclusions are based on predicted conditions at closure in general, these conclusions also apply to the post-closure phase of the NICO Project.

6.4 Post-Closure

During post-closure, all of the CoPCs identified in surface water (aluminum, antimony, barium, manganese, mercury, and vanadium) did not exceed target risk levels (i.e., HQs were 1 or less), indicating negligible risk of adverse effects to aquatic health as a result of the NICO Project during this phase.

6.5 Cumulative Effects Assessment

Given the NICO Project is proposed to be constructed at the upstream end of the Marian watershed, the effects of the NICO Project were considered in combination with other developments (current and foreseeable) that may also influence the health of aquatic life within the study area. Of the reasonably foreseeable projects identified in the DAR (Fortune 2011), none are expected to result in changes to water quality.

Particular concern has been expressed by the Tłįchǫ Government with respect to the potential cumulative effects due to the old Rayrock and Colomac mines. However, impacts to water quality are considered negligible downstream of Burke Lake (Section 7.0 of the DAR), and the risk of adverse effects to aquatic health are also considered negligible downstream of Burke Lake. The former Rayrock Mine is located at least 15 kilometres downstream of Burke Lake, so the cumulative effects on aquatic life are also considered negligible. The former Colomac Mine is located 120 km to the northeast in another drainage system (Section 7.0 of the DAR), which eliminates the potential for a cumulative effect to water quality and subsequently aquatic life. Therefore, the potential for a cumulative effect on aquatic health is considered to be negligible.

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8.0 ACRONYMS AND ABBREVIATIONS

%	percent
<	less than
>	more than
≤	less than or equal to
µg/g	micrograms per gram
µg/L	micrograms per litre
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
AEMP	Aquatic Effects Monitoring Program
APV	Aquatic Protection Value
BCMWLAP	British Columbia Ministry of Water, Land and Air Protection
BCMOE	British Columbia Ministry of Environment
BLM	Biotic Ligand Model

$CaCO_3$	Calcium carbonate
CCC	Criterion Continuous Concentration
C	Carbon
CCME	Canadian Council of Ministers of the Environment
CCREM	Canadian Council of Resource and Environment Ministers
CDF	Co-Disposal Facility
CoPC	Chemicals of Potential Concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CSQG	Canadian Sediment Quality Guideline
CT	Central Tendency
CWQG	Canadian Water Quality Guideline
DAR	Developer's Assessment Report
DOC	Dissolved Organic Carbon
EC50	Median Effective Concentration
e.g.	For example (from Latin exempli gratia)
ETF	Effluent Treatment Facility
et al.	and others (from Latin et alia)
Fortune	Fortune Minerals Limited
GNWT	Government of the Northwest Territories
HQ	Hazard Quotient
i.e.	that is (from Latin id est)
IJC	International Joint Commission
INAC	Indian and Northern Affairs Canada
ISQG	Interim Sediment Quality Guideline
KLOI	Key Lines of Inquiry
LA50	Lethal accumulation of metal at the biotic ligand that results in 50% mortality
LC50	Median Lethal Concentration
LEL	Lowest Effect Level
LOAEL	Lowest Observed Adverse Effect Level
LOEC	Lowest Observed Effect Concentration
MOE	Ontario Ministry of the Environment
MOEE	Ontario Ministry of Environment and Energy
MVRB	Mackenzie Valley Review Board
NAWQC	National Ambient Water Quality Criterion
NICO Project	NICO Cobalt-Gold-Copper-Bismuth Project
NOEC	No Observed Effect Concentration
NWT	Northwest Territories

NYSDEC	New York State Department of Environmental Conservation
PELs	Probable Effect Levels
the Plant	Mineral Process Plant
RA	Risk Assessment
SAR	Species at Risk
SARA	*Species at Risk Act*
SCP	Seepage Collection Pond
SCV	Secondary Chronic Value
sp.	Species
SSWQO	Site-specific Water Quality Objective
STP	Sewage Treatment Plant
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TOR	Terms of Reference
UB	Upper Bound
U.S. EPA	United States Environmental Protection Agency

9.0 GLOSSARY

Absorption	The process by which a chemical enters the circulatory system following ingestion, inhalation or dermal exposure.
Acute	A stimulus severe enough to rapidly induce an effect; in aquatic toxicity tests, an effect observed in 96 hours or less is typically considered acute. When referring to aquatic toxicology, an acute effect is not always measured in terms of lethality.
Adverse effect	Means one or more of, (a) impairment of the quality of the natural environment for any use that can be made of it, (b) injury or damage to aquatic life, (c) rendering any aquatic life unfit for human use, and (d) loss of enjoyment of normal use of the property.
Ambient	The conditions surrounding an organism or area.
Background concentration	The ambient concentration of a chemical in the surface water or sediment in the local environment which is representative or typical of the conditions.
Baseline	A surveyed or estimated condition that serves as a reference point to which results of later surveys or predictions are compared.

Baseline Case	The assessment case that includes the environment as it currently exists without the NICO Project.
Bioaccumulation	Refers to the accumulation of a compound in an organism. It occurs when an organism absorbs a compound from the environment at a rate greater than at which the compound is lost from the organism.
Bioaccumulation Factor (BAF)	This is a measure of accumulation of a chemical in animal tissue, and is defined as the ratio of chemical concentration in the animal tissue to the chemical concentration in the environmental medium (e.g. soil).
Bioavailability	The portion of a substance, such as a chemical, that is immediately available for uptake by organisms.
Biota	Plant and animal life of a region.
Biotic	The living organisms in an ecosystem.
Biotic ligand model (BLM)	A tool to quantitatively evaluate metal speciation and predict metal toxicity in aquatic systems.
Chronic	The development of adverse effects after extended exposure to a given substance. In chronic toxicity tests, the measurement of a chronic effect can be reduced growth, reduced reproduction or other non-lethal effects, in addition to lethality. Chronic should be considered a relative term depending on the life span of the organism.
Complete exposure pathway	An exposure pathway that does not have any natural or man-made barriers that prevents a receptor from being exposed to a contaminant.
Concentration	The quantifiable amount of a chemical in environmental media.
Conceptual Site Model (CSM)	A diagram that illustrates the exposure pathways between contaminant sources, through the relevant environmental media and to the aquatic receptors of interest.
Contaminant	Any solid, liquid, gas, odour, heat, sound, vibration, radiation or combination of any of them resulting directly or indirectly from human activities that may cause an adverse effect.
Contaminant of potential concern (CoPC)	A chemical that is emitted or released into the environment and poses a potential risk of exposure to aquatic receptors.
Contamination	A chemical which is present in soil, groundwater or surface water (or other material) at a concentration greater than background, or which is not naturally occurring in the soil, groundwater or surface water (or other material).
Ecosystem	An integrated and stable association of living and non-living resources functioning within a defined physical location. A community of organisms and its environment functioning as an ecological unit.

Endpoint	Means an effect on an aquatic receptor that can be measured or modeled and described in some quantitative fashion.
Exposure	The contact between a contaminant and an individual or population. The exposure may occur through pathways such as ingestion, dermal absorption or inhalation.
Exposure assessment	The qualitative or quantitative determination or estimation of the magnitude, frequency, duration and routes of exposure for the contaminant, including assessment of the uncertainties associated with the determination.
Exposure pathway	The route by which a receptor comes in to contact with a contaminant.
Fauna	An association of animals living in a particular place or at a particular time.
Habitat	The place or environment where a plant or animal naturally or normally lives or occurs.
Hazard	The adverse impact on health or property which results from the presence of or exposure to a substance. In some instances the substance itself is also referred to as the hazard, rather than the adverse impact which the substance causes.
Hazard quotient (HQ)	The ratio of a single substance exposure level over a specified period of time to a toxicity benchmark for that substance derived from similar exposure characteristics (for example, duration, frequency, route, etc.).
Home range	The geographic extent (area or linear distance) over which an animal travels to satisfy its normal daily requirements for food, water and shelter.
Interim Sediment Quality Guideline (ISQG)	ISQGs are derived when data are available but limited. These values represent numerical limits or narrative statements recommended to support and maintain designated uses of the aquatic environment.
Invertebrates	Any animal lacking a backbone, including all species not classified as vertebrates.
Lowest effect level (LEL)	The level of contamination which has no effect on the majority of the sediment-dwelling organisms.
Lowest observed adverse effect level (LOAEL; equivalent to lowest observed effect concentration/level (LOEC/LOEL)	The lowest concentration at which there is a statistically significant adverse effects between the exposed population and its appropriate control group.
National Ambient Water Quality Criteria (NAWQC)	Chronic and acute water chemical concentrations considered protective of aquatic biota.

No Observed Adverse Effect Level (NOAEL; equivalent to no observed effect concentration/level (NOEC/NOEL))	The highest concentration that does not cause a statistically significant adverse effect in comparison to controls.
pH	The degree of acidity (or alkalinity) of soil or solution. The pH scale is generally presented from 1 (most acidic) to 14 (most alkaline). A difference of one pH unit represents a ten-fold change in hydrogen ion concentration.
Project Case	Represents the change to the environment as a result of NICO Project components or activities for all phases of the NICO Project (construction, operations, closure, and post-closure), considering all proposed environmental design features and mitigation measures.
Provincial Sediment Quality Guideline (PSQG)	The PSQG are a set of numerical guidelines developed for the protection of aquatic life and are derived to protect those organisms that are directly impacted by contaminated sediment, namely the sediment-dwelling (benthic) species.
Receptor	The plant, phytoplankton, zooplankton, benthic invertebrate or fish subjected to chemical exposure.
Regional Study Area (RSA)	Defines the spatial extent related to the cumulative effects resulting from the project and other regional developments.
Risk	The likelihood or probability that harmful effects associated with a contaminant or other stressor will be produced in populations of individuals under their actual conditions of exposure.
Risk Assessment (RA)	Process that evaluates the probability of adverse effects that may occur, or are occurring on target organism(s) as a result of exposure to one or more stressors.
Risk Characterization	The process of evaluating the potential risk to a receptor based on comparison of the estimated exposure to the toxicity benchmark.
Secondary Chronic Value (SCV)	The SCV is a Tier II aquatic benchmark that is calculated by dividing the FAV (Final Acute Value) or SAV (Secondary Acute Value) by the SACR (Secondary Acute-Chronic Ratio). Exceedance of an SCV implies low risk to aquatic organisms.
Sediment	Solid material that is transported by, suspended in, or deposited from water. It originates mostly from the weathering of rocks, but also includes chemical and biochemical precipitates and decomposed organic material, such as humus.
Soil	The unconsolidated material on the immediate surface of the earth that serves as a natural medium for the growth of plants.

Taxa	A group of organisms of any taxonomic rank (e.g., family, genus, or species).
Threshold	The exposure below which no harmful effect is expected to occur.
Toxicity	The inherent potential or capacity of a material to cause harmful effects in a living organism. May also be used to describe the observation of an adverse response in an organism due to contaminant exposure.
Toxicity Assessment	The process of determining the amount (concentration) of a chemical to which a receptor may be exposed without the development of adverse effects.
Trophic	Related to feeding habits or food relationship of different organisms in a food chain. Animals occupying different positions in a food chain are described as occupying a trophic level (e.g., primary producers, tertiary consumers).
Uptake	Means in exposure assessment, the amount of a contaminant crossing the biological boundaries (for example, gills) of an organism and reaching the systemic circulation.
Water quality	The physical, chemical and biological characteristics of water. The term is most frequently used in reference to a set of numeric guidelines or standards against which achievement or compliance can be assessed.

APPENDIX A

Pathway Analysis

Table A-1: Pathway Analysis for the Aquatic Risk Assessment

Project Component/Activity	Effect Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Construction & Operations: Mine infrastructure footprint (e.g., open pit, site roads, tailings, and Co-Disposal Facility)	No effects pathways based on mine footprint that would expose receptors to chemicals.		No linkage
Construction & Operations: NICO Project Access Road	Dust generated from road traffic may deposit to surface water. Aquatic receptors could be exposed to metals by direct contact pathways with surface water and sediment, and indirectly through food consumption.	Access road will be as narrow as possible, while maintaining safe construction and operation practices. Watering of roads will suppress dust production. Enforcing speed limits will assist in reducing dust.	Primary
Operations: Operation of Co-Disposal Facility	Dust generated from the co-disposal facility may deposit to surface water. Aquatic receptors could be exposed to metals by direct contact pathways with surface water and sediment, and indirectly through the food chain.	No current mitigation proposed; however, the tailings will be deposited wet so dust generation is unlikely.	Primary
	Seepage may impact surface water quality around downstream waterbodies.	Runoff from the tailings and co-disposal area will be captured and diverted to the Effluent Treatment Facility. Any potential acid-generating waste rock will be sequestered within the interior of the co-disposal area in a location that will isolate them from the exterior environment. Overburden directed to the co-disposal area will be used to cover any areas in the core of the pile where potentially acid-generating waste rock is to be sequestered to reduce any infiltration.	Secondary

Table A-1: Pathway Analysis for the Aquatic Risk Assessment (continued)

Project Component/Activity	Effect Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Construction & Operations: Process water and potable water supply during operation of mine	No effect pathways that would expose receptors to chemicals.		No linkage
Construction & Operations: General construction and operation of mine and supporting infrastructure *Site water management*	Discharge of water (e.g. runoff, process water, effluent from sewage treatment plant, and dewatering of open pit) to surface water could affect surface water quality. Aquatic receptors could be exposed to metals by direct contact pathways with surface water and sediment and indirectly through food consumption.	The site Water Management Plan will ensure that discharged water is contained on-site. Runoff from the mine site will be captured and diverted to the effluent treatment facility. The site will have sufficient storage capacity to store both operating flows and storm events. Sewage will be treated and the effluent discharged to Peanut Lake. Capture and reuse site water to reduce fresh water requirements. Water from tailings thickener and from the tailings basin will be recycled for grinding operations. Excess water from the collection pond (tailings basin) will be recycled in mill operations.	Secondary
Construction & Operations: General construction and operation of mine and supporting infrastructure *Site water management*	Discharge of effluent from the effluent treatment facility could affect surface water quality	Treated water from the effluent treatment facility will be pumped through a diffuser directly to Peanut Lake. If additional settling, polishing or further treatment is required, then the treated water from the Effluent Treatment Facility will be discharged to the Surge Pond.	Primary

Table A-1: Pathway Analysis for the Aquatic Risk Assessment (continued)

Project Component/Activity	Effect Pathways	Environmental Design Features and Mitigation	Pathway Assessment
<u>Construction & Operations:</u> General construction and operation of mine and supporting infrastructure *Air emissions and dust deposition*	Air emissions, including dust, generated from onsite activities including, but not limited to, blasting, rock crushing, traffic, operation of equipment and trucks, are a source of direct and indirect exposure to surface water and sediment by aquatic receptors.	Watering of roads will suppress dust production. Enforcing speed limits will assist in reducing dust. Regular maintenance of equipment to limit emissions. Processing equipment will use high efficiency scrubbers to limit emissions of particulate matter. Dust control systems on rock crushing and other dust generating equipment will limit dust emissions. Operating procedures will be developed that reduce dust generation.	Primary
<u>Construction & Operations:</u> General construction and operation of mine and supporting infrastructure *Noise and general disturbance*	No effects pathways that would expose receptors to chemicals.		No linkage
<u>Construction & Operations:</u> General construction and operation of mine and supporting infrastructure *Collisions*	Collision with vehicles or aircraft causing injury or mortality will not result in chemical exposure to receptors.		No linkage

Table A-1: Pathway Analysis for the Aquatic Risk Assessment (continued)

Project Component/Activity	Effect Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Construction & Operations: General construction and operation of mine and supporting infrastructure *Spills*	Potential direct access to spills could affect aquatic receptors. However, given that spills cannot be predicted, it is not possible to assess spills within the RA.	The current Spill Response Plan will be augmented. This Plan and any design features will include measures to block or minimize exposure to potential receptors through the use of fencing, booming, or other means to protect potential receptors. Emergency spill kits will be available wherever toxic materials or fuel are stored and transferred. Construction and mining equipment, machinery, and vehicles will be regularly maintained. Hazardous materials and fuel will be stored according to regulatory requirements to protect the environment and workers (i.e., Materials and Waste Management Plan). Smaller storage tanks (e.g., engine oil, hydraulic oil, and waste oil and coolant) will be double walled, and located in lined and bermed containment areas. Reagents and double-walled larger fuel Enviro-Tanks will be located in a bermed, lined storage area. Separate areas will be established for the handling and temporary storage of hazardous wastes. Domestic and recyclable waste dangerous goods will be stored on site in appropriate containers to prevent exposure until they are shipped off site to an approved facility. Individuals working on site and handling hazardous materials will be trained in the Transportation of Dangerous Goods. Soils from petroleum spill areas will be deposited and spread in a lined landfarm cell for bioremediation.	No Linkage

Table A-1: Pathway Analysis for the Aquatic Risk Assessment (continued)

Project Component/Activity	Effect Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Closure and Reclamation: Co-Disposal Facility	Long-term seepage from the Co-Disposal Facility can change surface water quality	Develop a closure and reclamation plan (including water quality management post-closure such that water left on-site meets site-specific quality criteria protective of aquatic health). Co-Disposal Facility will be capped during closure to isolate tailings and prevent direct exposure.	Primary
Closure and Reclamation: Pit lake	Final water level in the pit lake and subsequent runoff may affect surface water quality. Aquatic receptors could be exposed to metals by direct contact pathways with surface water and sediment, and indirectly through food consumption.	Establish an active (water treatment plant) or passive treatment system (wetlands) to treat pit discharge waters before discharging to surface waters.	Secondary
	Water quality in pit lake and outflow may be a source of exposure for aquatic receptors. Aquatic receptors could be exposed to metals by direct contact pathways with surface water and sediment, and indirectly through food consumption.	Flooded mine pit will be a sterile waterbody because of its physical dimensions with minimal primary production and habitat features capable of supporting aquatic life. As part of the closure plan, the flooded mine pit is not intended to be a functioning part of the ecosystem.	Secondary
Closure and Reclamation: Water treatment plant	Decommissioning of the water treatment plant may result in increased chemical concentrations in surface water	The effluent treatment plant will be re-started and water will be treated, if necessary.	Secondary

Notes:

No linkage – pathway is removed by environmental design features and mitigation so that the NICO Project results in no detectable environmental change and effects to aquatic life relative to baseline or guidelines values; Secondary – pathway could result in a minor environmental change, but would have a negligible effect on aquatic life relative to baseline or guideline values, and; Primary – pathway is likely to result in a measureable environmental change that could contribute to effects on aquatic life relative to baseline or guidelines values.

APPENDIX B

Derivation of Site-Specific Water Quality Objectives

B.1 INTRODUCTION

Site-specific water quality objectives (SSWQOs) were derived to help guide the design of the water treatment system for the NICO Project. As well, the Terms of Reference for the NICO Project notes that SSWQOs are to be proposed for all chemicals of potential concern (CoPCs) identified for the NICO Project to protect downstream water quality (MVRB 2009). This section details the approach used to develop the SSWQOs as well as the proposed SSWQOs. Aluminum, ammonia, antimony, arsenic, cadmium, chloride, cobalt, copper, iron, lead, nitrate, selenium, sulphate, uranium, and zinc were initially identified as CoPCs because predicted concentrations in the influent to the Effluent Treatment Facility during operations and/or in the pit lake during post-closure were, at the time of the development of the SSWQOs, anticipated to be greater than baseline conditions and/or Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life, and SSWQOs were derived for these CoPCs. These SSWQOs were derived based on measured baseline water quality conditions (e.g., based on measured water hardness, dissolved organic carbon concentrations (DOC), concentrations of various cations and anions in the receiving water bodies as determined during the baseline studies). This is because predicted concentrations in the receiving surface waters were not available at the time of the development of the site-specific water quality guidelines (i.e., the objectives were developed when the water treatment options for the NICO Project were being evaluated). Because water quality during the various phases of the NICO Project may be different than under baseline (current) conditions, the SSWQOs should be reviewed and revised as necessary once follow-up water quality monitoring data is available for the NICO Project.

It should be noted that since the development of the SSWQOs, ion exchange technology was selected as the water treatment option for the NICO Project. Site-specific water quality objectives were developed for some CoPCs that were not needed because predicted surface water concentrations with implementation of ion exchange technology were lower than CCME CWQGs and baseline conditions. At the same time, other chemicals were identified as CoPCs that were not initially identified during the development of the SSWQOs. As such, toxicity benchmarks have been developed for these chemicals in the Toxicity Assessment (Section 5.3.1). The aquatic risk assessment only evaluates the risks to aquatic life associated with those CoPCs for which predicted surface water concentrations (based on implementation of ion exchange technology) are greater than CCME CWQGs and baseline conditions. Should the treatment option (and hence, water quality predictions) change, the list of CoPCs and the aquatic risk assessment should be reviewed and revised as required.

B.2 APPROACH TO DEVELOPMENT OF SITE-SPECIFIC WATER QUALITY OBJECTIVES

The approach to the development of SSWQOs described herein is adopted from the approaches developed by the CCME and provincial agencies in the development of the CWQGs. The approach is based on the overall objective of the CWQGs for the protection of aquatic life: *to be protective of the most sensitive species, in the most sensitive life stage, over an indefinite period of exposure*, the policy objectives and guiding principles as described in the Mackenzie Valley Land and Water Board & Effluent Quality Management Policy, dated 29 April 2010, and the effluent discharge limits for mining projects in the Northwest Territories (NWT) (INAC 2009).

The CWQGs are developed in consideration of the end water use, and protection of aquatic life is generally considered to be the most sensitive end use. The CCME has also developed drinking water guidelines, although these are generally less stringent, since these are based on consumption patterns.

The numerical CWQGs for the protection of aquatic life are considered generic, since they are intended for application in all regions of Canada and do not, in most cases, make allowance for regional differences (although the CCME (2003a) has provided methods for calculating site-specific objectives). Guidelines based on bulk water concentrations of metals can be overly conservative in some situations, due to the influence of local physico-chemical factors and the presence of natural complexing ligands. These include the presence of calcium, magnesium, and sodium ions that can effectively reduce metal toxicity in aquatic biota through competitive interactions at uptake sites, and natural complexing ligands such as the ubiquitous humic and fulvic material from plant decomposition that can reduce the bioavailable portion of a metal, and the presence of reactive sulphides. Where concentrations of the biologically active forms of a metal are high due to a paucity of competing ions or complexing ligands, or ingestion is a significant pathway, the guidelines may be under-protective.

The CWQGs for the protection of aquatic life are generally based on laboratory toxicity tests using laboratory or reconstituted water to which the metal is introduced in a highly soluble (and bioavailable) form. It is extremely difficult to simulate under laboratory conditions the variations in natural conditions that would reflect the influence of materials such as naturally occurring ligands on metal availability. As a result, in the laboratory tests used to develop the generic guidelines, the concentrations of a metal will typically exert a more profound effect on the organisms being tested than is likely to be the case within a natural setting. Due to the diverse geologic conditions within Canada, the natural distribution of metals, ions and organic matter can be highly variable. Therefore, site-specific approaches to setting water quality guidelines have been developed to reflect this variability by incorporating into the guidelines locally occurring factors that can affect bioavailability and toxicity. For example, the CWQGs for the protection of aquatic life for copper and lead allow for the derivation of a site-specific guideline based on site water hardness.

Because direct toxicity tests cannot be undertaken for the NICO Project at this time, the development of site-specific objectives relied upon the existing water quality data in adjacent water bodies to characterize levels of naturally occurring ions and ligands, and a review of the toxicity data from a variety of literature sources. In particular, recent studies in the scientific literature that have characterized levels of calcium, magnesium and DOC with respect to their influence on the toxicity of specific metals were considered. Recent studies on copper, for example, have shown that the presence of these parameters can significantly increase the threshold concentrations at which copper becomes toxic to test organisms. While the roles of competing ions (sodium, calcium and magnesium) and complexing ligands (such as DOC) in reducing metal toxicity have been studied extensively for some metals, the limited data available for sulphide suggest that sulphide can also significantly reduce the toxicity of metals (such as copper) to aquatic life. The availability of this type of data, therefore, permitted an approach that incorporated naturally occurring parameters that reduce toxicity into the development of SSWQOs for the NICO Project.

Based on this understanding, the development of SSWQOs for the NICO Project was generally conducted through the following step-wise approach:

- Available toxicity literature was reviewed to characterize biological effect levels that correspond to concentrations of toxicity modifying parameters specific to each metal of concern;
- Existing water quality was characterized with respect to these substances in Nico Lake and Peanut Lake;

- Baseline aquatic ecology data was reviewed to identify species of aquatic biota that are present within Nico Lake and Peanut Lake; and
- Site-specific toxicity concentrations were developed for each metal of concern that are protective of the most sensitive receptor in Nico Lake and Peanut Lake.

The SSWQOs provided herein have been derived for the discharge receivers (i.e., Nico Lake and Peanut Lake). Since the water quality characteristics of each waterbody are different, water quality objectives have been developed for each waterbody. Potential impacts on Burke Lake and the Marian River were assessed relative to appropriate toxicity benchmarks that were derived on a similar basis to the SSWQOs.

The specific approaches used to derive the SSWQOs for the identified CoPCs is detailed in this appendix. The water quality objectives were developed based on site-specific considerations; however, they were also developed using conservative assumptions, including the most sensitive endpoints for the most sensitive species. As such, exceedances of the SSWQOs do not necessarily indicate an adverse effect but rather warrants a more detailed examination of the potential for adverse effects.

B.3 SITE-SPECIFIC WATER QUALITY OBJECTIVES

The specific approaches used to derive the SSWQOs for the identified CoPCs is detailed in the following sections. Table B-1 summarizes the draft SSWQOs for the identified CoPCs for Nico Lake and Peanut Lake.

Table B-1: Draft Site-Specific Water Quality Objectives for Nico Lake and Peanut Lake.

Chemicals of Potenial Concern	CWQG for the Protection of Aquatic Life (µg/L)	Site-Specific Water Quality Objective (µg/L)	
		Nico Lake	Peanut Lake
Aluminum	100[a]	420 (dissolved aluminum)	410 (dissolved aluminum)
Ammonia	Guideline based on temperature and pH	4160 (total ammonia-N/L)	
Antimony	NV	30 (dissolved antimony)	
Arsenic	5.0	50	
Cadmium	0.017	0.15	
Chloride	NV	353,000	
Cobalt	NV	10	
Copper	2[b]	25 (dissolved copper)	22 (dissolved copper)
Iron	300	1500	
Lead	1[c]	7.6	
Nitrate	13,000	133,000	
Selenium	1.0	5.0 (total selenium)	
Sulphate	NV	500,000	
Uranium	NV	27	
Zinc	30	110	

[a] Based on the guideline for a pH of ≥6.5.

[b] Based on the guideline for water hardness of 0-120 mg/L as $CaCO_3$.

[c] Based on the guideline for water hardness of 0-60 mg/L as $CaCO_3$.

CWQG = Canadian Water Quality Guideline; NV = No guideline value; µg/L = microgram per litre

B.3.1 Aluminum

The CCME guideline for aluminum is based on pH, as provided below (CCME 2007):

Aluminum guideline = 5 µg/L at pH <6.5

= 100 µg/L at pH ≥6.5

The guideline was divided based on pH in consideration of the work by Neville (1985; as cited in CCREM 1987) who demonstrated that at a pH of 6.1 the physiological response of juvenile rainbow trout to 75 µg/L aluminum is severe but minimal at a pH of 6.5. A guideline of 5 µg/L, which is based on a no observed effect concentration (NOEC) for the toad *Bufo americanus*, was recommended for waters with a pH below 6.5 (Clark and LaZerte 1985; as cited in CCREM 1987). *Bufo americanus* is not known to occur in the NWT. A guideline of 100 µg/L was recommended for waters with a pH equal to or greater than 6.5 based on a value first proposed by the United States Environmental Protection Agency (U.S. EPA) (1973; as cited in CCREM 1987).

The objective for aluminum has been derived using the equation that is currently used by the British Columbia Ministry of Environment, Lands and Parks to derive water quality guidelines for dissolved ammonia at a pH of less than 6.5 (BCMELP 1994), as follows:

Dissolved aluminum benchmark (mg/L) = $e^{(1.6\text{-}3.327\ pH\ +\ 0.402\ K)}$

Where:

$K = pH^2$

In Peanut Lake, the average pH is 7.44. In Nico Lake, the average pH is 7.45. Using the equation provided above, values of 0.41 mg/L and 0.42 mg/L dissolved aluminum are calculated for Nico Lake and Peanut Lake, respectively. These values are proposed as the SSWQOs for aluminum for Nico Lake and Peanut Lake. The objectives derived for dissolved aluminum can be conservatively applied to total aluminum.

In Nico Lake, the pH ranges from 7.1 to 7.8. In Peanut Lake, the pH ranges from 7.0 to 7.8. The pH ranges in Nico and Peanut lakes are outside the pH range for which the equation provided by the BCMELP is applicable. Still, the SSWQOs are considered protective of aquatic life in Nico and Peanut lakes.

The toxicity of aluminum is highly dependent on pH. The toxicity data provided in the CCME guideline derivation for aluminum was reviewed. There were few studies included in the guideline derivation in the pH ranges measured in Nico and Peanut lakes. Adverse effects on survival (37% mortality) were observed using the chironomid *Tanytarius dissimilis* following 55 days of exposure to 800 micrograms per litre (µg/L) aluminum at pH 6.8 (Lamb and Bailey 1981; as cited in CCREM 1987). Reproduction in *Daphnia magna* was impaired by 50% at a concentration of 680 µg/L aluminum at pH 6.5 to 7.5 following 3 weeks of exposure (Schofield and Trojnar 1980, as cited in CCREM 1987). The results of the study by Biesinger and Christensen (1972) were not included in the CCME guideline derivation; however, they demonstrated a 50% and 16% impairment in reproduction in *Daphnia magna* following 21 days of exposure to 680 µg/L and 320 µg/L aluminum, respectively at pH 7.4 to 8.2. This result is consistent with that of the Schofield and Trojnar study (1980, as cited in CCREM 1987). *Daphnia magna* appear to be more sensitive to the effects of aluminum than other cladocerans. For example, *Holopedium gibberum*, the most abundant cladocerna in Nico Lake (Annex C of the DAR) was found in an acidified Ontario lake with an aluminum concentration of 490 µg/L (Bleiwas 1983; as cited in Havas and

Likens 1985). This species has also been shown to be tolerant to aluminum in laboratory tests. Exposure to 1000 µg/L at pH 6.5 resulted in no adverse effects on survival (Havas and Likens 1985).

There were no studies cited in the CCME guideline derivation for aluminum for fish in the pH range measured in Nico and Peanut lakes, and in general these studies are lacking for fish. The available data suggests that fish are more sensitive to the effects of aluminum than invertebrates. Hunn et al. (1987) exposed eyed embryos of book trout (*Salvelinus fontinalis*) to a pH value of 7.81 without and with aluminum (283 µg/L) in soft water (hardness <9 mg/L as $CaCO_3$, which is consistent with hardness measured in Nico and Peanut lakes) for 60 days. Exposure to aluminum significantly decreased the growth of brook trout after 45 and 60 days. There were no significant effects of aluminum on embryo mortality and hatchability. Kane and Rabeni (1987) exposed small mouth bass (*Micropterus dolomieui*) larvae to 252 µg/L aluminum at pH 7.3 in a 30 day chronic test. There were no significant effects of aluminum on survival or growth. Sublethal effects on fish were demonstrated, including deformities, reduced activity and abnormal swimming behaviour. Roy et al. (2000) studied the toxicity of aluminum in the Saquenay River, Quebec, in relation to discharges from an aluminum smelter. In waters downstream of the effluent outfalls, concentrations ranging from 470 to 540 µg/L in soft neutral-pH (pH 7.0 to 7.3) waters had no significant effect on *Ceriodaphnia dubia* survival and growth and fathead minnow (*Pimephales promelas*) survival and growth.

Complexation is an important factor in reducing aluminum bioavailability and toxicity. For example, the complexation of aluminum by DOC matter reduces the bioavailability and toxicity of aluminum to fish in neutral to slightly basic water (Gundersen et al. 1994; Winter et al. 2004). As well, the formation of dissolved aluminosilicates has been shown to reduce the bioavailability and toxicity of aluminum to fish (Burchall et al. 1989).

Dissolved organic carbon concentrations in both Nico Lake and Peanut Lake are relatively high (ranging from approximately 10 to 20 mg carbon/L). Aluminum in both the solid phase of the tailings and waste rock for the NICO Project is primarily bound with silicate minerals (Annex A of the DAR). Based on these mineralogical results, the aluminum-bearing particulate in water is most likely in the form of silicates (Section 5.14 of Annex A of the DAR). As well, dissolved aluminum is likely to be present bound to DOC or as dissolved aluminosilicates which forms at pH values greater than or equal to 4. This is in contrast to most of the toxicity tests described above which used soluble aluminum salts that speciate to Al^{3+} or $Al(OH)_4^-$, which are considered the most toxic forms of aluminum.

Given the mitigating effects of DOC and silicates on aluminum toxicity and that toxic effects on invertebrates and fish were not noted in waters of similar hardness, and pH to Nico and Peanut lakes receiving effluent discharges from an aluminum smelter, the SSWQOs of 0.42 and 0.41 mg/L are considered protective of aquatic life.

B.3.2 Ammonia

In surface waters, ammonia exists as two chemical species: unionized ammonia (NH_3) and ionized ammonia (or ammonium ion, NH_4^+). The sum of NH_3 and NH_4^+ is termed “total ammonia”. In surface waters a chemical equilibrium exists between unionized and ionized ammonia, which is highly dependent on temperature and pH. For example, an increase in pH by one unit can increase the unionized ammonia concentration nearly tenfold. A temperature increase of 5 degrees Celsius (°C) can increase the unionized ammonia concentration by 40 to 50%.

Unionized ammonia is more toxic to aquatic organisms than the ammonium ion. This is because unionized ammonia is a neutral molecule so it is able to more easily diffuse across biological membranes and exert toxicity as compared to the ammonium ion.

The CWQG for ammonia for the protection of aquatic life was developed using the CCME protocol (CCME 1991; as cited in CCME 2010) and the community ecological risk criteria from Environment Canada (1999; as cited in CCME 2010). The rainbow trout (*Oncorhynchus mykiss*) was the most sensitive freshwater species identified by the CCME, with a lowest observed effect concentration (LOEC) of 0.04 mg/L for unionized ammonia in a 5 year (chronic) study. Exposure to this and higher concentrations resulted in lesions on the gills and kidney tissue degradation (Thurston *et al*. 1984; as cited in CCME 2010). Using 13 sublethal endpoints (EC_{20} values) for various freshwater species (including invertebrates and fish but not mussels of the family Unionidae, discussed further below) and a regression-based approach, Environment Canada showed that 5% of the species in an aquatic community would exhibit a 20% reduction in growth or reproduction at an unionized ammonia concentration of 0.041 mg/L (Environment Canada 1999; as cited in CCME 2010). This value (0.041 mg/L) is consistent with the value reported by the CCME (0.04 mg/L) for the sensitive rainbow trout. Environment Canada went on to predict 95% confidence intervals for the toxicity data which were 0.019 to 0.063 mg/L. The CCME adopted the lower 95% confidence limit of 0.019 mg/L as the guideline for unionized ammonia.

The CCME also provides a guideline for total ammonia (as mg/L NH_3). The guideline is a range of values over various pHs and temperatures (CCME 2010). The range of values is based upon the guideline for unionized ammonia of 0.019 mg/L and equations developed by others which calculate the concentration of unionized ammonia based on pH and temperature (Emerson et al. 1975; U.S. EPA 1998; as cited in CCME 2010). This was done in consideration of the influence of pH and temperature on the chemical speciation of ammonia (and hence toxicity to aquatic life) and the variability of pH and temperature in surface waters on a national level.

Recently, the U.S. EPA updated the freshwater national ambient water quality criteria (NAWQC) for ammonia (U.S. EPA 2009a). This is because recent toxicity tests indicated that ammonia is particularly toxic to freshwater mussel species in the family Unionidae. There was concern that the acute and chronic AWQC for ammonia were not adequately protective of freshwater mussels which are found in many waters of the United States. At a pH of 8 and a temperature of 25°C, a chronic criterion of 0.26 mg total ammonia-N/L or 1.8 mg total ammonia-N/L is proposed by the U.S. EPA, depending on whether freshwater mussels are present in the waterbody of concern.

Site-specific water quality objectives for ammonia for Nico Lake and Peanut Lake have been derived from the guideline for total ammonia (mg total ammonia-N/L) developed by the U.S. EPA based on pH and temperature (U.S. EPA 2009a). In brief, water quality objectives for ammonia were derived from the series of historical pH and temperature observations available for Nico Lake and Peanut Lake assuming that freshwater mussels are absent in the study area. Only 2 species of freshwater mussels are found in the NWT. The fatmucket (*Lampsilis siliquoidea*) is found in southern NWT and the giant floater (*Pyganodon grandis*) can be found at Shell Lake near Inuvik and may be found across the NWT (Working Group on General Status of NWT Species 2006). Both species belong to the family Unionidae, which as described above are the most sensitive freshwater species to ammonia. The Aquatic Baseline Report for the NICO Project did not identify these species (or any other species of freshwater mussel) in either Nico Lake or Peanut Lake (Annex C of the DAR).

Specifically, water quality objectives for ammonia were derived based on the average temperature and pH of the historical pH and temperature observations. For Nico Lake, the average temperature and pH were 11.5°C and 7.45, respectively. For Peanut Lake, the average temperature and pH were 11.3°C and 7.44, respectively.

Based on these measurements, the SSWQOs are 4.16 mg total ammonia-N/L for both Nico Lake and Peanut Lake.

B.3.3 Antimony

The CCME has not derived a CWQG for antimony for the protection of freshwater aquatic life. Antimony has been identified as a CoPC and a site-specific objective has been derived for this metal because predicted concentrations are greater than baseline conditions.

Data on the chronic toxicity of antimony to freshwater aquatic life is limited. The U.S. EPA reported a 96-h EC50 (median effect concentration) (chlorophyll) for the green alga *Selenastrum capricornutum* of 730 µg/L (1978; as cited in the U.S. EPA ECOTOX Database). In a life-cycle test with the cladoceran *Daphnia magna*, a 28-d LC50 (median lethal concentration) of 4510 µg/L was calculated for exposure to antimony trichloride in water of hardness 220 mg/L as $CaCO_3$ (Kimball 1978; as cited in the U.S. EPA ECOTOX Database). There were no effects on reproduction at 4160 µg/L but there was a significant decrease in the number of progeny at 7050 µg/L. A maximum acceptable toxicant concentration (MATC) of 5420 µg/L was calculated.

Chronic studies for vertebrates include 28-day LC50 values for rainbow trout (*Oncorhynchus mykiss*) eggs of 580 and 660 µg/L (Birge 1978; Birge et al. 1980; as cited in the U.S. EPA ECOTOX Database). In aquatic toxicity tests with fathead minnow (*Pimephales promelas*) eggs, growth was the most sensitive endpoint (Kimball 1978; as cited in the U.S. EPA ECOTOX Database). The 28-day LOEC for effects on growth (length) was 2310 µg/L. There were no significant effects on growth at 1130 µg/L. The MATC was calculated to be 1620 µg/L. Birge (1978; as cited in the ECOTOX Database) conducted studies on the mortality of antimony trichloride on embryo-larval stages of the toad *Gastrophryne carolinensis*. The calculated LC50 for the toad was 300 µg/L.

The Ontario Ministry of Environment (MOE) has derived an aquatic protection value (APV) for antimony of 1600 µg/L based on a final chronic criterion provided by the U.S. EPA (1986; as cited in MOE 2009).

The U.S. EPA provides a draft freshwater national ambient water quality criteria for antimony of 30 µg/L (U.S. EPA 1988a). In brief, the final acute value (FAV) of 175 µg/L was divided by an acute-to-chronic ratio (ACR) of 5.871 to derive a final chronic value (FCV) of 30 µg/L.

A site-specific water quality objective for antimony of 30 µg/L is proposed based on the draft freshwater ambient water quality criteria for antimony provided by the U.S. EPA (1988a). Predicted antimony concentrations in surface water do not exceed the guideline values described above.

B.3.4 Arsenic

Arsenic and its compounds are widely distributed in the environment primarily in two oxidation states; arsenite (trivalent, III) and arsenate (pentavalent, V). Arsenic is a hazardous element and toxicity may occur even when biota are exposed to trace concentrations via ingestion or direct uptake across membranes (e.g., gill surfaces). The toxic effects are mediated through the trivalent (arsenite) form. Pentavalent arsenic (arsenate) forms are believed to be reduced to trivalent forms in vivo (Thomas et al. 2001). The main mode of arsenic toxicity is inhibition of enzyme activity by binding to the sulfhydryl groups (-SH) which inhibits succinic dehydrogenase activity, thereby uncoupling oxidative phosphorylation (Ellenhorn and Barceloux 1988). Arsenic is also substituted for phosphorus in the oxidative phosphorylation chain, further increasing the loss of production of high-energy phosphate bonds in ATP, which causes widespread multisystem effects (Thomas et al. 2001).

The speciation of arsenic in freshwater is strongly controlled by redox potential of the medium while the availability is influenced by the presence of iron oxyhydroxides (Senn and Hemond 2004), which have been shown to be effective scavengers of arsenic, rendering the latter unavailable for bioactive interactions with aquatic organisms. The presence of natural organic matter has also been shown to strongly influence arsenic mobility in freshwater (Redman and Macalady 2003). It has been generally found that arsenite is sorbed to, and co-precipitates with other metal sulphides while arsenate typically sorbs to iron and aluminum hydroxides (Senn and Hemond 2004). Arsenic can also be biologically transformed to methyl species, with bacteria acting as mediating agents (Faust et al. 1987). Arsenite reduction is reportedly mediated by bacteria, fungi, and algae (Faust et al. 1987).

Some studies (Senn and Hemond 2004) have indicated that arsenic released to overlying water from sediments occurs predominantly complexed to particulate matter. Arsenic in the water column also exhibits a strong affinity for particulate organic matter (POM) (operationally defined as organic matter larger than the 0.45 µm filter pore size), and complexation with dissolved and particulate organic matter (DOM and POM) are responsible for removal of most arsenic in surface waters.

The CCREM (1987) notes that humans are more sensitive to arsenic than fish, and the recommended arsenic concentration for raw water supplies (50 µg/L) was therefore lower than the recommended limit of 100 µg/L for protection of aquatic life proposed by the MOE (MOE 1984). The freshwater aquatic life guideline was subsequently revised to 5 µg/L, based on the results of a chronic algal bioassay, which was the most sensitive endpoint measured (CCME 2001). The CCME guideline is based on growth reduction (as an EC_{50}, over a 14-day exposure) in the green algae *Scenedesmus obliquus* at 50 µg/L (as discussed below, green algae, including *Scenedesmus* sp., have been identified in both Nico Lake and Peanut Lake in the Aquatic Baseline Report for the NICO Project [Annex C of the DAR]). The guideline of 5 µg/L was derived by applying a 0.1 safety factor to this endpoint. The CCME (2001) notes that the lowest estimate for fish toxicity was 550 µg/L (28-day LC_{50} for rainbow trout embryos and larvae), while the lowest estimate for invertebrates was 320 µg/L.

The lowest exposure concentrations of arsenic to induce mortality in fish were observed in rainbow trout, which is one of most sensitive fish to dissolved arsenic exposure (CCME 2001). Rankin and Dixon (1994) calculated an LC_{50} (96-hour, flow through bioassay design) for this species at 20 200 µg/L, which was adjusted using a 0.1 times safety factor to provide an estimated acute LOAEC (lowest-observed-adverse-effect concentration) value of 2020 µg/L.

A search of the US EPA ECOTOX Database revealed two arsenic NOECs of 2650 µg/L and 9500 µg/L for a 10 day and 3 day exposure, respectively (Holland et al. 1960; as cited in the U.S. EPA ECOTOX Database). These toxicity tests were performed on pink salmon.

The U.S. EPA provides a National Recommended Water Quality Criterion Continuous Concentration (CCC) of 150 µg/L for arsenic (U.S. EPA 2009b). This recommended water quality criterion was derived from data for arsenic (III), but was applied to total arsenic, which might imply that arsenic (III) and arsenic (V) are equally toxic to aquatic life and that their toxicities are additive. In the arsenic criteria document (U.S. EPA 1985a), Species Mean Acute Values (SMAVs) are given for both arsenic (III) and arsenic (V) for five species and the ratios of the SMAVs for each species range from 0.6 to 1.7. Chronic values are available for both arsenic (III) and arsenic (V) for one species; for the fathead minnow, the chronic value for arsenic (V) is 0.29 times the chronic value for arsenic (III). No data are known to be available concerning whether the toxicities of the forms of arsenic to aquatic organisms are additive (U.S. EPA 2009b).

All of the toxicity tests referenced above were performed in laboratory environments with laboratory fresh water that does not contain the ligands present in natural waters. Therefore, as shown in the discussions above, toxicity tests in laboratory settings do not account for possible interactions of metals with organic matter that can reduce arsenic availability and toxicity. Therefore, the EC_{50} of 50 µg/L over a 14-day exposure to the green algae *Scenedesmus obliquus* has been chosen as the site specific arsenic water quality objective. Green algae (Phylum Chlorophyta), including *Scenedesmus* sp., were identified in both Nico Lake and Peanut Lake in the Aquatic Baseline report for the NICO Project (Annex C of the DAR). The safety factor of 0.1 that was used by CCME in the derivation of their water quality guideline is considered overly conservative for the waterbodies surrounding the NICO Project, and therefore 50 µg/L is considered to be protective of the receptors that may be present in Nico Lake and Peanut Lake. Based on the review of the toxicity data above, the chosen site specific arsenic water quality guideline is well below the concentrations that would be expected to result in adverse effects on fish species.

B.3.5 Cadmium

The route of exposure and the form of cadmium are the 2 main factors that determine the toxicity of cadmium. The mechanism of action, however, is the same through all routes: the cadmium cation binds to metallothionein in body tissues, where it may be retained or excreted (Suzuki and Cherian 1987), can interfere with other divalent cationic metabolic processes (Petering et al. 1979), and can deplete various antioxidant enzymes (Jamall and Smith 1985).

The CWQG for the protection of aquatic life for cadmium has been set at 0.017 µg/L (CCME 1999). The CWQG is based on a chronic LOAEL (lowest observed adverse effect level) for *Daphnia magna* of 0.17 µg/L (based on a 21-d EC_{16} for effects on mobility) with application of a 0.1 safety factor. *Daphnia magna* was the most sensitive freshwater invertebrate to cadmium exposure identified by the CCME (1999). *Daphnia* sp. were identified in both Nico Lake and Peanut Lake in the Aquatic Baseline report for the NICO Project (Annex C of the DAR).

For fish, acute toxicity was noted in CCME (1999) at <0.5 µg/L for rainbow trout fry (96-hour and 168-hour tests), with other studies reporting acute lethality (10-50%) in the range of 0.8 to 1.4 µg/L for rainbow trout and other salmonids. Chronically exposed fish demonstrated toxic effects (i.e. mortality) at cadmium concentrations similar to those used in acute tests (CCME 1999). Rainbow trout exhibited a 200-hour LC_{50} and LC_{10} of 0.9 and 0.7 µg/L, respectively (Chapman 1979; cited in CCME 1999). The CCME (1999) notes that the lowest chronic toxicity endpoint for fish was 0.47 µg/L from a 48-d EC_{11} (11% reduction in body weight and fork length over a 48 day exposure period) in Atlantic salmon (*Salmo salar*) alevins. The most sensitive freshwater plant species identified by the CCME (1999) was the diatom *Tabellaria flocculosa*. At 1 and 10 µg/L, this species displayed changes in morphology and inhibition of growth, respectively, following a 14-day exposure.

Suter and Tsao (1996) calculated a chronic LOAEL of 0.15 µg/L for cadmium based on responses of both aquatic vertebrates and invertebrates (the LOAEL was driven by a low concentration for *Daphnia magna*).

The lowest acute LOAEL value found in the U.S. EPA ECOTOX Database for fish was 1.5 µg/L, calculated from a 96-hour flow through bioassay using rainbow trout exposed to inorganic cadmium (Goettl et al. 1974; cited in the U.S. EPA ECOTOX Database). A review of the toxicity data in the ECOTOX Database indicated that the toxicity of cadmium in the studies conducted is highly dependent on the form in which the cadmium was introduced. Cadmium introduced in the form of sulphates or oxides was toxic at much higher concentrations than elemental cadmium or cadmium chloride. Thus, the presence of natural ligands in receiving waters can significantly influence the availability and toxicity of cadmium.

The CCME data reported above suggests that salmonids may be the most sensitive family of fish to cadmium exposure, when compared to other families identified in Nico and Peanut Lakes. For example, estimated acute LOAEL values for several potential receptors for the NICO Project were 42, 220, and 280 µg/L for white sucker (*Catostomus commersoni*), pumpkinseed (*Lepomis gibbosus*), and golden shiner (*Notemigonus crysoleucas*), respectively (Benson et al. 1987; Hartwell et al. 1989; Munkittrick and Dixon 1988; all cited in the U.S. EPA ECOTOX Database). In the Aquatic Baseline report for the NICO Project (Annex C of the DAR), white sucker was identified in waterbodies in the NICO Project area. As a result, the selection of toxicity data from rainbow trout bioassays should be sufficiently conservative to protect those species of salmonids inhabiting Nico Lake and Peanut Lake.

Based on the above review, the chronic LOAEL value of 0.15 µg/L was selected as the cadmium site specific water quality objective.

B.3.6 Chloride

The CCME has not derived a CWQG for chloride for the protection of freshwater aquatic life. Chloride has been identified as a CoPC and a site-specific objective has been derived for this parameter because predicted concentrations are greater than baseline conditions.

The British Columbia Ministry of Environment (BCMOE) derived a chronic water quality guideline for chloride for the protection of freshwater aquatic life of 150 mg/L (as NaCl) (Nagpal et al. 2003). The value was derived by multiplying a LOEC of 735 mg/L for the cladoceran *Ceriodaphnia dubia* by a safety factor of 5. The LOEC for *Ceriodaphnia dubia* was the lowest LOEC from chronic toxicity tests representing nine different taxa. In the study, exposure for 7 days to 735 mg/L resulted in a 50% reduction in reproduction (brood size).

The U.S. EPA has derived a NAWQC for chloride. The CCC (4 day average) for chloride is 230 mg/L (as NaCl) and it is not to be exceeded more than once every 3 years on the average (U.S. EPA 1988b). The value was derived by dividing the FAV of 1720 mg/L by an ACR of 7.594. The ACR is based on the geometric mean of ACR values from tests with the rainbow trout (7.308), the fathead minnow (15.17) and *Daphnia pulex* (3.951).

Recently, the Iowa Department of Natural Resources worked closely with the U.S. EPA to revise Iowa's water quality standard for chloride. In brief, the U.S. EPA developed an equation to calculate the chronic chloride criteria based on water hardness and water sulphate levels, as follows (http://www.iowadnr.gov/water/standards/files/ws_fact.pdf):

$$\text{CCC (mg/L)} = 177.87\ [\text{hardness (mg/L as } CaCO_3)]^{0.205797}[\text{sulphate (mg/L)}]^{-0.07452}$$

For example, at a water hardness of 50 mg/L as $CaCO_3$ and a water sulphate concentration of 5 mg/L, which are comparable to values measured in Peanut Lake and Nico Lake, the CCC for chloride is 353 mg/L.

Given that the water quality standard for chloride used by the Iowa Department of Natural resources is based on site-specific considerations with respect to water hardness and sulphate concentration, a site-specific water quality objective for chloride of 353 mg/L is proposed for both Peanut Lake and Nico Lake. Predicted chloride concentrations in surface water do not exceed the guideline values described above.

B.3.7 Cobalt

The concentration of total cobalt in freshwaters is generally low (≤1 µg/L). Higher concentrations are generally associated with industrialized or mining areas. Concentrations of cobalt ranging from non-detectable (detection limit of 0.1 µg/L) to 27 000 µg/L have been measured; the total and dissolved concentrations in ambient, uncontaminated environments are, however, generally below 5 µg/L (BCMOE 2004).

There is currently no CCME CWQG for cobalt to protect freshwater aquatic life. The MOE has derived an APV of 5.2 µg/L for cobalt based on a 28-day LOEL of 5.2 µg/L for effects on reproduction (number of progeny) in *Daphnia magna* (Kimball 1978; as cited in MOE 2009).

The New York State Department of Environmental Conservation (NYSDEC) water quality standard for surface and ground water for cobalt is 5 µg/L (NYSDEC 1986). The province of Quebec has adopted a surface water quality guideline for the protection of freshwater aquatic life from the chronic effects of cobalt of 5 µg/L. The Quebec guideline is based on the NYSDEC (1986) standard.

The British Columbia Ambient Water Quality Guidelines provide 2 values for cobalt (BCMOE 2004). It is recommended that to protect aquatic life in the freshwater environment from the acute effects of cobalt, the maximum concentration of total cobalt should not exceed 110 µg/L. The recommended maximum guideline is based on a LOEC causing 50% mortality in *Daphnia magna* exposed to 1110 µg/L cobalt for 48 hours and a safety factor of 0.1. The safety factor was selected to protect from possible delayed mortality of the organisms exposed to the metal and is consistent with the British Columbia protocols for guideline development.

The British Columbia Ambient Water Quality Guidelines also recommend that to protect aquatic life from the chronic effects of cobalt, the 30-day average concentration of total cobalt (based on five weekly samples) should not exceed 4 µg/L (BCMOE 2004). This is based on the invertebrates *Daphnia magna* and *Ceriodaphnia dubia that* exhibited chronic effects when exposed to low concentrations of cobalt. A LOEC (geometric mean) of about 8 µg/L total cobalt was determined to cause reproductive effects in these organisms. The 30-day average concentration to protect aquatic life from the chronic effects of cobalt was obtained by applying a safety factor of 2 to the LOEC. A lower (than 10) safety factor was justified because cobalt is essential in the synthesis of vitamin B_{12} which is necessary for animal and human nutrition (BCMOE 2004).

Fish and aquatic plants are less sensitive to the effects of cobalt than daphnids. Chronic LC50 values for 28-day embryo-larval tests using rainbow trout (*Oncorhynchus mykiss*), the most sensitive fish species to cobalt, were reported at 470 µg/L and 490 µg/L. A value of 520 µg/L was reported for a 144-hour test using rainbow trout fry. Fourteen-day NOEC and LOECs for effects on growth and survival in rainbow trout were reported to be 132 and 255 µg/L, respectively. Ten- to 14-day LOECs for growth of 500 µg/L were reported for the most sensitive plant species, *Chlamydomonas eugametos* (BCMOE 2004). Given the greater sensitivity of daphnids to cobalt, the development of the site-specific water quality objective for cobalt has focused on these organisms.

The toxicity data available from the literature for cobalt for daphnids is limited to 3 key studies. Kimball (1978; as cited in Nagpal 2004) reported a NOEC of 2.8 µg/L and a LOEC of 9.3 µg/L for reproduction from two 28-day tests using *D. magna*. Kimball (1978; as cited in Nagpal 2004) also conducted a screening test on *Daphnia magna* prior to the 28-day chronic toxicity tests and identified a NOEC of 10 µg/L and a LOEC of 20 µg/L for reproductive effects. Biesinger and Christensen (1972; as cited in Nagpal 2004) conducted 21-day chronic toxicity tests with *Daphnia magna* and reported a 21-day EC16 of 10 µg/L for reproduction at a water hardness of 45.3 mg/L as $CaCO_3$. Diamond et al. (1992; as cited in Nagpal 2004) investigated cobalt toxicity to

Ceriodaphnia dubia using a range of water hardnesses. At water hardnesses of 57 and 256 mg/L $CaCO_3$, the 7-day NOECs were <50 µg/L. At water hardnesses of 470 and 882 mg/L as $CaCO_3$, the 7-day NOECs were 50 and 600 µg/L, respectively.

In support of the development of the BCMOE guideline for cobalt, Golder/EVS performed additional toxicity testing using *Daphnia magna* and *Ceriodaphnia dubia* (Nagpal 2004). In brief, a 21-day *Daphnia magna* toxicity test and a 7-day *Ceriodaphnia dubia* toxicity test examining reproductive and survival endpoints were performed. *Daphnia magna* and *Ceriodaphnia dubia* were exposed to five nominal concentrations of 3.13, 6.25, 12.5, 25, and 50 µg/L cobalt at each water hardness of 50, 100, and 200 mg/L as $CaCO_3$. *Ceriodaphnia dubia* were also exposed to a nominal concentration of 100 µg/L cobalt at each water hardness. The LOEC for reproduction for *Daphnia magna* was 50 µg/L at a water hardness of 50 mg/L as $CaCO_3$. The NOEC at this water hardness was 25 µg/L. The results of the 7-day *Ceriodaphnia dubia* test indicated a NOEC for reproduction of 12.5 µg/L at a water hardness of 50 mg/L as $CaCO_3$ and a LOEC of 25 µg/L at the same water hardness. The results of the *Daphnia magna* test are consistent with the results of Biesinger and Christensen (1972) who reported an EC16 of 10 µg/L at a water hardness of 45.3 mg/L as $CaCO_3$.

Because there is some evidence to suggest that cobalt toxicity in freshwater organisms may be influenced by water hardness (Diamond et al. 1992; as cited in Nagpal 2004), the development of the site-specific water quality objective for cobalt has relied upon the results of the toxicity tests for which the water hardness is similar to that of the NICO Project area. As such, a site-specific water quality objective of 10 µg/L is proposed for cobalt. This value is based on the work of Biesinger and Christensen (1972; as cited in Nagpal 2004) using *Daphnia magna*. The data from the Kimball study (1978; as cited in Nagpal 2004) was not used because water hardness was not reported in this study and consistent results were obtained in the other 2 studies which were considered in the derivation of the objective (i.e., Biesinger and Christensen 1978; Golder/EVS as cited in Nagpal 2004).

B.3.8 Copper

The CCME guideline for copper is based on water hardness, as provided below (CCME 2007):

Copper guideline = 2 µg/L at water hardness of 0-120 mg/L as $CaCO_3$

= 3 µg/L at water hardness of 120-180 mg/L as $CaCO_3$

= 4 µg/L at water hardness >180 mg/L as $CaCO_3$

In brief, the guideline was derived using the regression equation of chronic toxic copper concentrations versus hardness developed by the U.S. EPA (1985b), as follows:

Cu conc. = $e^{(0.8545[\ln(\text{hardness})] - 1.465)}$ µg/L

The lowest hardness within each hardness category was used to calculate the copper guideline for that hardness category. The guideline for the hardness category of 0 to 120 mg/L as $CaCO_3$ is based on the guideline recommended by Demayo and Taylor (1981; as cited in CCREM 1987) for soft water (0 to 60 mg/L as $CaCO_3$) of 2 µg/L and the calculated value based on a hardness of 60 mg/L as $CaCO_3$ of 2 µg/L.

The equation for chronic toxicity derived by the U.S. EPA was derived from a final acute value and an acute to chronic ratio. In the development of the guideline for copper, the CCREM (1987) considered the effects of hardness on chronic copper toxicity to be inconclusive and the result from the equation was multiplied by an application factor of 0.2 to derive the guideline.

Recently, the U.S. EPA revised the aquatic life ambient freshwater quality criteria for copper (U.S. EPA 2007). In the revision, a Biotic Ligand Model (BLM)-based approach was used in place of the formerly applied hardness-based approach to calculate the water quality criteria for copper. The BLM approach offers a vast improvement over the hardness-based approach because in addition to water hardness, it incorporates the protective effects of other water chemistry parameters on copper toxicity, including the competitive influences of various cations (e.g., calcium, hydrogen, magnesium, and sodium), as well as the influence of important copper complexing anions (e.g., DOC and chloride).

In essence, the BLM predicts acute metal toxicity by estimating metal accumulation at the "biotic ligand", which is the site of metal accumulation and acute toxicity on an aquatic organism, taking into consideration the protective effects of water chemistry. The model assumes that accumulation of metal at the biotic ligand at or above a critical threshold concentration leads to acute toxicity. This critical accumulation at the biotic ligand is also termed the LA50 (lethal accumulation of metal at the biotic ligand that results in 50% mortality). For example, complexing anions (such as DOC and chloride) bind metal, thereby decreasing accumulation at the biotic ligand. Similarly, competing cations (such as calcium, hydrogen, magnesium, and sodium) compete with metal for binding sites at the biotic ligand, decreasing metal accumulation at the biotic ligand. Because water hardness is primarily a function of calcium and magnesium ions in the water, the protective effect of water hardness on metal toxicity is addressed in the BLM through the competitive interaction between metal and the hardness cations (i.e., calcium and magnesium) at the biotic ligand. Depending on water chemistry, the amount of metal in the water required to reach the LA50 will vary. In this way, the BLM can be used to predict the concentration of metal that would result in acute toxicity to aquatic life based on water chemistry.

Accordingly, the BLM is a useful tool for deriving site-specific water quality criteria for metals, and for this reason, the U.S. EPA revised the water quality criteria for copper based on the BLM. The U.S. EPA also plans to update the water quality criteria for other metals, including silver and zinc using the BLM approach.

The BLM-based approach developed by the U.S. EPA was used to derive SSWQOs for copper for the NICO Project, specifically for Nico Lake and Peanut Lake. The Biotic Ligand Model, Windows Interface, Version 2.2.1 (HydroQual 2007) was used.

The U.S. EPA does not provide any specific recommendation on data requirements for use of the BLM, except that enough data should be collected to characterize the spatial and temporal variability in water chemistry of a water body (Training Materials on Copper BLM: Data Requirements, accessed on-line at http://www.epa.gov/waterscience/criteria/copper/faq/data-requirements.pdf). Water quality samples were collected from Nico Lake from 4 sampling locations, including the Nico Lake inflow, a shallow location, a deep location, and the Nico Lake outflow. Water quality was monitored during open water from 2005 to 2008 (April, June, and August) and under ice in March 2008. In total, the water chemistry from 12 samples were used in the calculation of the site-specific water quality objective for copper for Nico Lake (2 samples from the Nico Lake inflow, 5 samples from the deep basin, 3 samples from the shallow basin, and 2 samples from the Nico Lake outflow).

Water quality samples were collected from Peanut Lake from 3 sampling locations, including a shallow location, a deep location, and the Peanut Lake outflow. As with Nico Lake, water quality was monitored during open water from 2005 to 2008 (April, June, and August) and under ice in March 2008. In total, the water chemistry from 8 samples was used in the calculation of the site-specific water quality objective for copper for Peanut Lake (4 samples from the deep basin, 2 samples from the shallow basin, and 2 samples from the Peanut Lake outflow).

The BLM generates acute (Criterion Maximum Concentration, CMC) and chronic (CCC) water quality criteria for copper (based on dissolved copper). The chronic water quality criterion is calculated using an ACR. For Nico Lake, the calculated chronic water quality criteria ranged from 25.8 to 57.2 µg/L. For Peanut Lake, the calculated chronic water quality criteria ranged from 22.4 to 54.7 µg/L. The lowest calculated criteria are proposed as the SSWQOs for copper, which are 25.8 µg/L and 22.4 µg/L for Nico Lake and Peanut Lake, respectively.

Based on a water hardness of 23 mg/L as $CaCO_3$ for Nico Lake and 27 mg/L as $CaCO_3$ for Peanut Lake, the CCME guideline for copper for these water bodies is 2 µg/L. The calculated site-specific values are approximately 10 times higher than the CCME guideline.

B.3.9 Iron

The CCME has established a guideline for iron of 300 µg/L, based on a guideline developed by the International Joint Commission (IJC) and the MOE (CCREM 1987). This value is based on the concentration of iron in water that could result in precipitation of iron hydroxides on stream substrates and potentially smother habitat and not toxicological responses. Suter and Tsao (1996) note that the U.S. EPA chronic guideline for iron of 1000 µg/L is based on a field study at a site receiving acid mine drainage (the guideline is cited in the 1985 EPA “Gold Book” but due to the specific conditions under which the guideline was developed, is not included in more recent guidelines). Thus, both guidelines are based on specific conditions under which iron precipitates are a concern, but may not be applicable in natural waters.

Suter and Tsao (1996) indicate that a concentration of 4380 µg/L that resulted in reproductive impairment of 16% in *Daphnia magna* exposed to FeCl was more applicable to natural waters, while a chronic value for fish of 1300 µg/L was applicable. Guay et al. (2000) undertook a review of toxicity data for iron and noted that iron toxicity generally occurred at much higher concentrations than those associated with precipitation effects (chronic NOECs, ranged upwards from 1.5 mg/L for trout).

The CCREM (1987) cites acute values for iron for aquatic insects that ranged from 320 to 16 000 µg/L. The CCREM goes on to note that chronic toxicity to fathead minnows was recorded in a study by Sykora et al. (1972; as cited in CCREM 1987) at an acid mine drainage site at 1500 µg/L (50% reduction in egg hatchability) (similar responses were noted in brook trout eggs at 12 000 µg/L, indicating that brook trout were much less sensitive than fathead minnows). The CCREM cites the safe concentration for brook trout juveniles as ranging between 7500 and 12 500 µg/L.

The site specific iron water quality objective is 1.5 mg/L, based on the toxicity review by Guay et al. (2000). This value is well below other chronic toxicity values reported above.

B.3.10 Lead

Lead speciation in surface water has been shown to be sensitive to pH. In the pH range 6 to 8 that characterizes most surface waters, solubility depends on CO_2 and sulphur species present. At low pH ($pH < 6$), solubility appears to depend on sulphate concentration. Therefore, pH and hardness appear to be interrelated, with increased CO_3 concentration resulting in a decrease in solubility throughout the pH range (Wershaw 1976). Lead also shows a very strong affinity to suspended matter, and readily complexes with organic matter, humic substances and inorganic minerals (clays) to form insoluble compounds (Hem 1976).

Both the U.S. EPA and CCME note that lead toxicity is hardness–dependent (CCREM 1987). Toxicity of lead is reduced by the low solubility of many forms of lead in the natural environment, particularly in alkaline waters. As noted above, since lead is strongly complexed by a variety of ligands, lead in surface waters is typically present in bound forms.

Lead is believed to potentially interfere with calcium accumulation at the gills resulting in reduction of calcium in bones, with some studies indicating spinal scoliosis in fish exposed to high levels. Phillips and Russo (1978) note that lead accumulation in exposed fish is highest in the gill and kidney, followed by liver (site of most detoxification). The results suggest that most lead uptake is through the gill. Citing studies by Merlini and Pozzi (1977; as cited in Phillips and Russo 1978) they note that lead uptake was higher at lower pH (6.0) than higher pH (7.5) which was attributed to the higher concentration of divalent lead at the lower pH, and that there was a direct correlation between the ionic concentration of lead and accumulation by sunfish. The study concluded that the conditions that prevailed in most natural waters rendered lead generally unavailable for uptake.

Recent experiments by Borgmann et al. (2005) indicate that lead toxicity to *Hyalella azteca* (as LC_{50}) decreased from 1 µg/L in soft water to 11 µg/L in hard water (Lake Ontario water). Similarly, Besser et al. (2005) found that hardness reduced toxicity of lead in their tests with *H. azteca*, but noted that the effects of hardness were reduced at very high hardness (275 mg/L $CaCO_3$) (the effect of hardness was noted as being greatest at medium-hardness of 126 to138 mg/L $CaCO_3$). The authors noted that in their tests, dissolved lead constituted less than 50% of total lead. Schwartz et al. (2004) found that the addition of natural organic matter (as a mix of humic and fulvic acids) significantly reduced toxicity of lead to rainbow trout, while Richards et al. (2001) have noted that the type of organic matter affects the degree of toxicity modification.

Of the approximately 100 data points available for lead toxicity to fish available in the ECOTOX Database, the lowest acute (1190 µg/L) and chronic (7.6 µg/L) LOEC values for lead were from 96-hour and 19-month flow through bioassays, respectively, for rainbow trout exposed to dissolved inorganic lead (Goettl et al. 1976; as cited in U.S. EPA ECOTOX Database).

There is limited information on lead toxicity derived from bioassays using non-salmonid species. A chronic LC_{50} (24-day, flow through design) for northern pike (*Esox lucius*) was observed at 253 µg/L (Sauter et al. 1976; as cited in the U.S. EPA ECOTOX Database). The northern pike is a fish species relevant to the Site; it was identified in Nico Lake and Peanut Lake in the Aquatic Baseline report for the NICO Project (Annex C of the DAR). An acute LC_{50} for smallmouth bass under static test conditions was calculated at 2,200 µg/L (Coughlan et al. 1986; as cited in the U.S. EPA ECOTOX Database).

Suter and Tsao (1996) provide lowest chronic values of 12.26 and 25.46 µg/L for daphnids and non-daphnid invertebrates, respectively. They also provide lowest chronic values of 500 and 18.88 µg/L for aquatic plants and fish, respectively.

In addition to the available toxicity data, the available aquatic freshwater life criteria for lead were reviewed. The Canadian lead water quality guideline was developed in 1987 by the CCREM and has not been updated since. The lead guideline is adjusted for hardness based on the U.S. EPA algorithm developed in 1985 for chronic toxicity (CCREM 1987). The adjustment factors are based on specific guideline values for defined ranges of hardness:

- 1 µg Pb/L at [$CaCO_3$] in the range of 0 to 60 mg/L;
- 2 µg Pb/L at [$CaCO_3$] in the range of 60 to 120 mg/L;
- 4 µg Pb/L at [$CaCO_3$] in the range of 120 to 180 mg/L;
- 7 µg Pb/L at [$CaCO_3$] greater than 180 mg/L.

The CCREM notes that the guideline for soft water was calculated using a hardness of 50 mg $CaCO_3$/L since toxicity data for very soft water was not available and that therefore, the guideline may be under-protective in these waters. The CCREM (1987) does not specifically mention how the values in each range were derived, but it is assumed that the same method as used for deriving the copper guidelines (by selecting the calculated value corresponding to the lowest hardness in each category) was followed in deriving the lead hardness-adjusted guidelines.

Water hardness measured at Nico Lake ranged from 23 to 57 mg/L as $CaCO_3$, while water hardness at Peanut Lake ranged from 27 to 37 mg/L as $CaCO_3$ (Annex C of the DAR). Therefore, based on the CCME guideline, the site specific lead water quality objective is 1 µg/L. Based on the lowest of chronic values reported above, a site-specific water quality objective of 7.6 µg/L is proposed for the Site based on chronic effects in rainbow trout. This value is well below the chronic value for northern pike of 253 µg/L (LC_{50}, 24-day, flow-through design), a resident fish in the lakes surrounding the mines but the value is likely protective of salmonids in general and lake whitefish (a salmonid) has been identified in Peanut Lake (Annex C of the DAR).

B.3.11 Nitrate

The CCME CWQG for nitrate (NO_3^-) is 13 mg/L. This guideline is for the protection of aquatic life due to direct toxic effects. The guideline does not consider the indirect effects due to eutrophication.

The CCME guideline was derived by multiplying a 10-day LOEC of 133 mg/L for the pacific tree frog (*Pseudacris regilla*) (Schuytema and Nebeker 1999) by a safety factor of 0.1. In general, amphibians were the most sensitive receptors to chronic nitrate exposure (CCME 2003b). A 16-day LOEC of 129 mg/L is reported for the red-legged frog (*Rana aurora*) for embryo growth reduction and a 56-d LOEC of 133 mg/L is reported for the northern leopard frog (*Rana pipiens*) for larval growth reduction. In the African clawed frog (*Xenopus laevis*), a 10-day LOEC of 2190 mg/L for growth reduction in tadpoles and a 5-day LOEC of 251 mg/L for growth reduction in embryos are reported. The CCME did not consider the endpoints for the red-legged frog and northern leopard frog to be ecologically significant because the reductions in growth represented only 3 to 6%. As such, the data available for the pacific tree frog was used by the CCME to derive the guideline.

Fathead minnow larvae exposed to NO_3^- for 7-day resulted in a range of LOECs from 3176 mg/L to 6363 mg/L for growth and mortality endpoints, respectively (Scott and Crunkilton 2000). The lowest effect concentration reported for salmonids for chronic exposure (7-day LC_{50}) were 4700 and 4800 mg/L for rainbow trout and Chinook salmon early life stages (fingerlings), respectively (Westin 1974).

The most, and least sensitive invertebrates were *Ceriodaphnia dubia* and *Daphnia magna*, which exhibited 7-d LOECs for reduced reproductive effort of 189 and 3176 mg/L, respectively (Scott and Crunkilton 2000).

Nitrate is used by aquatic primary producers, such as plants and algae, and does not limit their growth (Pinar et al. 1997). Aquatic plants and algae do not appear to be adversely effected by elevated concentrations of nitrate. Growth was not inhibited for the green alga *Scenedesmus subspicatus* exposed to 283 mg/L of NO_3^- (Hund 1997). Nitrate is not considered to be toxic to aquatic primary producers and the plant toxicity protocols were waived in the development of the CWQG (CCME 2003b).

The reviewed toxicity data shows that amphibians may be the most sensitive receptor to nitrate. In Canada, the pacific tree frog and red-legged frog are found in British Columbia only. The northern leopard frog is found in the NWT; however, its range is limited to between the Alberta border and Great Slave Lake, which is well south of the NICO Project. As such, it is not likely that these species of frogs will be found in the waters near the Site. In fact, of the 4 species of frogs found in the NWT, only one is known to occur in the vicinity of the NICO Project, the wood frog (*Rana sylvatica*).

Still, a study on the effects of ammonium nitrate on the survivorship and behaviour of wood frog tadpoles suggests that this species has a similar sensitivity to nitrate as other species of frogs (Burgett et al. 2007). Therefore, the site specific water quality objective is based on the 10-day LOEC of 133 mg/L for the pacific tree frog. The safety factor of 0.1 that was used by the CCME in the derivation of the CWQG is considered overly conservative for the waterbodies surrounding the NICO Project, and therefore, 133 mg/L is considered to be protective of the receptors that may be present in Nico Lake and Peanut Lake. Based on the review of the toxicity data above, the chosen site specific water quality objective for nitrate is well below the concentrations that would be expected to result in adverse effects on fish species. It is lower than the chronic value for the most sensitive salmonid reported, rainbow trout, even when the 7-day LC_{50} (4700 mg/L) is adjusted to 470 mg/L using an uncertainty factor of 0.1.

B.3.12 Selenium

The CCME guideline for selenium is 1.0 µg/L (CCME 2007). This value was adopted from the IJC which introduced the value to protect aquatic life in the Great Lakes based on field studies which indicated that waterborne selenium concentrations of 5 to 10 µg/L were associated with food web contamination that caused acute lethality to predatory fish (IJC 1981; as cited in CCREM 1987).

The U.S. EPA has developed a chronic water quality criterion for selenium of 5 µg/L (total recoverable selenium in the water column) (U.S. EPA 2009b). It should be noted that the U.S. EPA recently developed a draft chronic water quality criterion for selenium that is based on the concentration of selenium in fish tissue rather than the concentration of selenium in the water (U.S. EPA 2004). The U.S. EPA believes, as do other experts in the field, that a tissue-based criterion better addresses the highly bioaccumulative nature of selenium than a water-based criterion. The U.S. EPA’s proposed tissue-based criterion of 7.91 µg/g is founded on the whole-body concentration of selenium in juvenile bluegill associated with winter mortality. Fish are the most sensitive aquatic organisms to chronic selenium exposure, and for this reason, the chronic criterion is based on fish and not other aquatic organisms such as plants and aquatic invertebrates. However, there is much controversy with respect to the draft criterion and for this reason, the currently accepted chronic water quality criterion of 5 µg/L is proposed as the site-specific water quality objective for selenium for both Nico Lake and Peanut Lake.

B.3.13 Sulphate

The CCME has not derived a CWQG for sulphate for the protection of freshwater aquatic life. Sulphate has been identified as a CoPC and a site-specific objective has been derived for this parameter because predicted concentrations are greater than baseline conditions.

The BCMOE derived a chronic water quality guideline for sulphate for the protection of freshwater aquatic life of 100 mg/L for dissolved sulphate (as SO_4), which represents a maximum concentration that should not be exceeded at any time (Singleton 2000). A guideline value of 50 mg/L for dissolved sulphate (as SO_4) is also provided as an "alert" level because some aquatic mosses appear to be particularly sensitive to the toxic effects of dissolved sulphate. The BCMOE recommends that when dissolved sulphate concentrations exceed 50 mg/L, the health of aquatic mosses should be monitored.

Three studies were used as the basis for the guideline values. In the first, 1-, 2-, 3-, and 4-day LC50s of 2000, 1000, 500, and 250 mg/L, respectively, were reported for striped bass (*Morone saxitilus*) larvae. LC0's of 500, 100, 100, and 100 mg/L, respectively, were also reported. In the second, 96-hour LC50s of 205, 3711, and 6787 mg/L in soft, medium (100 mg/L as $CaCO_3$) and hard (250 mg/L as $CaCO_3$) water, respectively, were reported for the amphipod, *Hyallela azteca*. In the final study, a concentration of 100 mg/L was toxic to the aquatic moss, *Fontinalis antipyretica*. Toxicity ranged from 100 to >250 mg/L for 4 other species of aquatic moss.

Working with the U.S. EPA, the Iowa Department of Natural Resources recently revised Iowa's water quality standard for sulphate (http://www.iowadnr.gov/water/standards/files/ws_fact.pdf). For waters with hardness of less than 100 mg/L, or chloride concentrations of less than 5 mg/L (as for Peanut Lake and Nico Lake), the water criteria for sulphate is 500 mg/L.

Given that the water quality standard for sulphate used by the Iowa Department of Natural resources is based on site-specific considerations with respect to water hardness and chloride concentration, a site-specific water quality objective for sulphate of 500 mg/L is proposed for Peanut Lake and Nico Lake. Predicted sulphate concentrations in surface water do not exceed the guideline values described above.

B.3.14 Uranium

There is currently no CCME CWQG for uranium to protect freshwater aquatic life. Uranium has been identified as a CoPC and a site-specific objective has been derived for this metal because predicted concentrations are greater than baseline conditions.

In 1983, a water quality objective for uranium for aquatic life and wildlife of 300 µg/L was established by the Inland Waters Directorate, Water Quality Branch (Environment Canada 1983). Provincial guidelines for uranium range from 5 to 15 µg/L (MOEE 1994; Boudreau and Guay 2002; Saskatchewan Environment 2006). The MOE has developed an APV for uranium of 33 µg/L (MOE 2009), which is based on an IC25 for reproduction in *Ceriodaphnia dubia* as determined from the Vizon SciTec Inc. (2004) uranium aquatic toxicity investigation.

In 2003, Environment Canada and Health Canada assessed the toxicity of uranium to human health and the environment as part of the *Canadian Environmental Protection Act, 1999, Priority Substances List Assessment Report for Releases of Radionuclides from Nuclear Facilities* (Environment Canada and Health Canada 2003). The assessment included an assessment of the toxicity of uranium to freshwater aquatic life, including the identification of chronic toxicity values. For fish, a chronic toxicity value of 280 µg/L was derived based on a

96-hour LC50 for *Pimephales promelas* (fathead minnow) in water with hardness 20 mg/L as $CaCO_3$ and an ACR of 10. For phytoplankton and zooplankton, a chronic toxicity value of 3 µg/L was derived for *Ceriodaphnia dubia*, a value of 13 µg/L was derived for *Chorella* sp. and a value of 22 µg/L was derived for *Daphnia pulex*. These values were derived for water with hardness less than 100 mg/L as $CaCO_3$.

Vizon SciTec Inc. (2004) investigated the toxicity of uranium to freshwater plants. In 72-hour growth inhibition tests with *Selenastrum capricornutum* (green algae), IC25 estimates ranged from 27 to 150 µg/L depending on hardness (the water hardnesses tested were 5, 15, 64, 122, and 228 mg/L as $CaCO_3$). NOECs ranged from 14 to 220 µg/L and LOECs ranged from 29 to 430 µg/L, depending on water hardness. In 7-day growth inhibition tests using *Lemna minor* (duck weed) in water with hardness 35 and 137 mg/L as $CaCO_3$, IC25 values ranged from 4700 to 12 300 µg/L based on frond number and from 6400 to 13 300 µg/L based on dry weight. Water hardness was observed to have an effect on toxicity to duck weed.

For invertebrates, 14-day LC25 values ranging from 100 to 130 µg/L were calculated in water with hardnesses ranging from 61 to 238 mg/L as $CaCO_3$ for *Hyallela azteca*, demonstrating an effect of increasing water hardness on uranium toxicity (Vizon SciTec Inc. 2004). Borgmann et al. (2005) calculated an LC50 of 21 µg/L for the same species in soft water (18 mg/L as $CaCO_3$) after 7 days of exposure. Based on reproduction, a LOAEL of 520 µg/L was derived for *Daphnia magna* in water with hardness of 66 to 73 mg/L as $CaCO_3$ after 21 days of exposure to uranium (Poston et al. 1984). The midge, *Chirnomus tentans*, is the least sensitive of the invertebrates. A 10-day LC50 of 6400 µg/L and a NOEC and LOEC based on mortality of 421 and 1519 µg/L, respectively, were reported for this species (Burnett and Liber 2006). An IC50 value for effects on growth of 10 200 µg/L was also reported in the study. In 7-day tests with *Ceriodaphnia dubia*, LC25 values were 54 to 150 µg/L depending on hardness (hardness varied from 17 to 252 mg/L as $CaCO_3$) (Vison SciTec Inc. 2004). Based on effects on reproduction, a 7-day NOEC and LOEC of 1970 µg/L and 3910 µg/L, respectively, were determined (Vizon SciTec Inc. 2004). IC25s for reproduction ranged from 33 to 79 µg/L depending on water hardness. Pickett et al. (1993) reported lower NOEC and LOEC values for *Ceriodaphnia dubia*. Based on reproduction over 7 days, NOEC and LOEC values were 1.5 and 2.7 µg/L, respectively in water with hardness 6.1 mg/L as $CaCO_3$.

For fish, in 7-day survival and growth tests with *Pimephales promelas* (fathead minnow) early life stages there were no effects of water hardness on toxicity (Vizon SciTec Inc. 2004). Based on survival, NOECs ranged from 810 to 1200 µg/L and LOECs ranged from 1300 to 2000 µg/L, depending on water hardness. 7-d LC50 values ranged from 1500 (in water with hardness 244 mg/L as $CaCO_3$) to 2100 (in water with hardness 72 mg/L as $CaCO_3$). IC25 values based on growth ranged from 1300 to >2000 µg/L, depending on water hardness. Two early life stage tests were also conducted with rainbow trout. Rainbow trout embryos were exposed for 31 and 30 days, from day of fertilization, to uranium at 2 water hardnesses (6 and 61 mg/L as $CaCO_3$). LOECs for survival of 280 and 610 µg/L were derived for water with hardness of 6 and 61 mg/L as $CaCO_3$, respectively. An EC25 value for reproduction of 340 µg/L was derived for water with hardness of 6 mg/L as $CaCO_3$. Toxicity was higher in the softer water. In 30-day toxicity tests with white sucker (*Catostomus commersoni*) at a water hardness of 72 mg/L as $CaCO_3$, a NOEC of 7330 µg/L and a LOEC of 27860 µg/L for effects on growth were determined (Liber et al. 2004b). In 141-day tests with lake trout (*Salvelinus namaycush*) at a water hardness of 74 to 80 mg/L as $CaCO_3$, a NOEC of 6050 µg/L and a LOEC of 29 780 µg/L were determined based on a number of endpoints (survival, reproduction, and growth) (Liber et al. 2004a).

Based on the review of the aquatic toxicity of uranium provided above, a site-specific water quality objective for uranium of 27 µg/L is proposed, which is based on an IC25 value for effects on growth in the green algae. It should be noted that a LOEC of 2.7 µg/L was determined for *Ceriodaphnia dubia* in water of hardness 6.1 mg/L as $CaCO_3$ by Pickett et al. (1993); however, IC25s for effects on reproduction in this species are also available and for waters with hardness that approximate the water hardness of Nico Lake and Peanut Lake (Vizon SciTec Inc. 2004). The water used in the Pickett et al. (1993) study was much softer than the waters of Nico Lake and Peanut Lake. Toxicity to *Ceriodaphnia dubia* was lower at water hardnesses that approximate those in Nico Lake and Peanut Lake (Vizon SciTec Inc 2004).

B.3.15 Zinc

Zinc is an essential element for humans and animals and is required for the proper function of a variety of metalloenzymes (alcohol dehydrogenase, alkaline phosphatase, carbonic anhydrase, leucine aminopeptidase, super-oxide dismutase, and DNA and RNA polymerases). Zinc is required for normal nucleic acid, protein and membrane function and metabolism, as well as proper gene structure (zinc finger phenomenon), and zinc deficiency is associated with a variety of pathologies (ATSDR 1994).

Zinc is a naturally-occurring metal in the earth's crust, and it can be released by both natural and anthropogenic sources. It does not readily volatilise, but rather adsorbs to soil and sediment, as well as particulates in groundwater. Leaching is not common, though it has been at some sites of contamination. Zinc may bioconcentrate in organisms, particularly aquatic organisms such as higher crustaceans and bivalve species, but not particularly in fish and other vertebrates as body content is modulated by homeostatic mechanisms that act principally on absorption and liver levels (ATSDR 1994).

Taylor et al. (1982), note that model calculations indicate that at pH <7, Zn^{2+} was the dominant species (though this may be present as ionic complexes), while at pH > 7 the complexation with OH, CO_3 and humic substances increased. Zinc also formed complexes with suspended inorganic (clay) and organic (humic) matter and levels of dissolved and suspended organic matter in most freshwaters are generally sufficient to remove zinc toxicity. As noted above, the concentrations may not be similarly affected in very soft waters of low hardness or pH, since this can affect the complexation with organic ligands.

Bodar et al. (2005), note that in Dutch waters, approximately 25% of the Zn present is in "dissolved" form, while approximately 75% is present adsorbed to particulate matter. De Schamphelaere et al. (2005), found that the percentage of zinc calculated to be bound to DOC varied between 5 and 89%, with a tendency for more zinc to be complexed to DOC at lower zinc concentrations. In their study, they calculated that the other zinc species, $ZnOH^+$, $Zn(OH)_2$, $ZnSO_4$, $ZnCl^+$, and $ZnHCO_3$ generally accounted for only up to 12% of the zinc present in the dissolved phase. At higher pH (~8) and alkalinity, $ZnCO_3$ accounted for approximately 10% of the dissolved zinc.

The CWQG for zinc of 30 µg/L is based on the IJC limit (CCREM 1987). While most studies have indicated that acute toxicity is based on water hardness, the CCREM (1987) notes that chronic toxicity is not, and hence there is no CCME site-specific adjustment provided for zinc based on water hardness. The CCREM (1987) notes that acute toxicity to rainbow trout swim-up fry was observed at 93 µg/L (96-hr LC_{50}). However, a wide range of toxicities was noted in studies with rainbow trout (96-hour LC50s ranged from 90 to 7210 µg/L) (CCREM 1987). Maximum acceptable toxicant concentrations (MATCs) cited by CCREM (1987) based on spawning and hatching success and fry survival of fathead minnows ranged from 30 to 180 µg/L.

A review of toxicity studies in the U.S. EPA ECOTOX Database indicated that algae are generally less sensitive to zinc than are fish or invertebrates. No response concentrations in algae ranged from 100 to 250 µg/L, while LC50 concentrations were typically over 1000 µg/L.

Daphnia species (including *Ceriodaphnia*) were more sensitive, with LOEC values of 120 µg/L up to 1000 µg/L in waters of moderate hardness (225 mg $CaCO_3$/L) in 21-day tests. NOEC values were reported in the range of 101 to 140 µg/L (Carlson and Rouch 1985; as cited in the U.S. EPA ECOTOX Database).

Rainbow trout were generally more sensitive than fathead minnows to the effects of zinc. Reported LOECs for rainbow trout ranged from 110 to 3600 µg/L, in waters of hardness ranging from 22 to 314 mg $CaCO_3$/L. LOECs for fathead minnows ranged from 270 to 2730 µg/L. Reported NOECs were few for rainbow trout and ranged from 36 µg/L (at hardness of 30 mg $CaCO_3$/L) to 320 µg/L (at hardness of 350 mg $CaCO_3$/L). NOECs for fathead minnows ranged between 117 and 291 µg/L for growth as an endpoint and between 100 and 940 µg/L for mortality as an endpoint.

The zinc site specific water quality guideline has been set at 110 µg/L, based on the rainbow trout LOEC and is likely to be sufficiently protective of the aquatic receptors that are expected to occur in Nico Lake and Peanut Lake. No safety factor was applied to the LOEC value for rainbow trout as the application of safety factors is considered overly conservative, since the laboratory tests upon which these thresholds are based do not incorporate the effects of naturally present ligands that would reduce the bioavailability and toxicity of zinc. The U.S. EPA is in the process of developing a BLM for zinc to specifically account for the modifying effects of other ligands in freshwaters. Also, rainbow trout are considered to be more sensitive than resident fish expected to be present in the waterbodies surrounding the mines.

B.4 SUMMARY AND CONCLUSIONS

Site-specific water quality objectives were developed for the following CoPCs for the NICO Project: aluminum, ammonia, antimony, arsenic, cadmium, chloride, copper, iron, lead, nitrate, selenium, sulphate, uranium, and zinc. Site-specific water quality objectives were developed for Nico Lake and Peanut Lake, if relevant, and are presented in Table B-1.

B.5 REFERENCES

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Table B-2: Suface Water Quality Input Parameters for Nico Lake for the Copper Biotic Ligand Model

Water Body	Sampling Date	Temperature	pH	Cu	DOC	HA [1]	Ca	Mg	Na	K	SO4	Cl	Alkalinity	S [1]
		°C		ug/L	mg C/L	%	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L $CaCO_3$	mg/L
Nico Lake Inflow	18-Jun-2009	13.7	7.06	***1***	18.4	10	5.4	2.38	1.7	0.86	***0.5***	0.63	21.4	1E-10
Nico Lake Inflow	28-Aug-2009	12.2	7.35	***1***	22.2	10	7.41	3.46	2.4	0.68	***0.5***	1.07	35.1	1E-10
Nico Lake-Deep Top	15-Jun-2007	15.9	7.6	3.8	15.2	10	8.79	3.42	2.23	1.05	1.7	0.7	29	1E-10
Nico Lake-Deep Top	24-Mar-2008	1.35	7.5	1.9	18.4	10	11	4.9	3.2	1.5	6	***1***	43	1E-10
Nico Lake-Deep Top	18-Jun-2009	15.7	7.16	1.2	18.1	10	8.52	3.19	2.2	1.03	3.94	1.38	28.7	1E-10
Nico Lake-Deep Top	28-Aug-2009	14.7	7.67	2.3	19	10	7	3.28	2	0.82	3.44	0.51	31	1E-10
Nico Lake-Deep Top	05-Apr-2010	0.77	7.38	1.3	19.4	10	9.97	4.48	2.6	1.09	4.91	0.8	38.1	1E-10
Nico Lake-Shallow	18-Jun-2009	15.2	7.28	1.2	17.7	10	8.57	3.17	2.2	1.05	3.79	1.26	31.1	1E-10
Nico Lake-Shallow	28-Aug-2009	14.8	7.66	1.2	18.5	10	7.36	3.38	2.2	0.91	3.44	0.52	31.4	1E-10
Nico Lake-Shallow	05-Apr-2010	1.23	7.46	1.4	19	10	9.78	4.44	2.6	1.14	4.66	0.75	38.4	1E-10
Nico-Peanut Creek Outflow	18-Jun-2009	15.5	7.31	1.2	17	10	8.3	3.05	2.1	0.97	3.41	0.72	30.6	1E-10
Nico-Peanut Creek Outflow	28-Aug-2009	14.8	7.63	1.2	18.3	10	7.17	3.29	2.1	0.89	3.42	0.51	30.5	1E-10

Notes:

1. Assumed value (BLM User's Guide and Reference Manual, February 2007).

Bold/Italicized text = <method detection limit (mdl).

Table B-3: Suface Water Quality Input Parameters for Peanut Lake for the Copper Biotic Ligand Model

Water Body	Sampling Date	Temperature	pH	Cu	DOC	HA [1]	Ca	Mg	Na	K	SO4	Cl	Alkalinity	S [1]
		°C		ug/L	mg C/L	%	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L $CaCO_3$	mg/L
Peanut Lake-Deep Top	16-Jun-2007	15.9	7.6	1.7	12.2	10	6.86	3.16	2.57	1.23	*0.5*	0.8	31	1E-10
Peanut Lake-Deep Top	23-Mar-2008	7	7.5	1.1	13.5	10	8.5	4.2	3.7	1.7	1	***1***	41	1E-10
Peanut Lake-Deep Top	18-Jun-2009	16.8	7.34	***1***	14.8	10	7.25	2.91	2.4	1.12	1.63	1.12	31.6	1E-10
Peanut Lake-Deep Top	05-Apr-2010	1.02	7.42	***1***	13.1	10	8.6	4.08	3	1.37	1.05	0.87	40.8	1E-10
Peanut Lake-Shallow	18-Jun-2009	16.8	7.32	***1***	14.7	10	7.37	2.93	2.4	1.21	1.49	0.82	30.3	1E-10
Peanut Lake-Shallow	05-Apr-2010	0.77	7.32	***1***	12.2	10	8.37	4	3	1.51	0.62	0.89	41.7	1E-10
Peanut Lake Outflow	18-Jun-2009	16.2	7.37	***1***	14.1	10	6.45	3.05	2.3	1.14	1.33	0.76	31.6	1E-10
Peanut Lake Outflow	30-Aug-2009	17.4	7.77	***1***	16.1	10	6.8	3.26	2.4	0.98	1.15	0.63	34	1E-10

Notes:

1. Assumed value (BLM User's Guide and Reference Manual, February 2007).

Bold/Italicized text = <method detection limit (mdl).

Table B-4: Suface Water Quality Input Parameters for Burke Lake for the Copper Biotic Ligand Model

Water Body	Sampling Date	Temperature	pH	Cu	DOC	HA [1]	Ca	Mg	Na	K	SO4	Cl	Alkalinity	S [1]
		°C		ug/L	mg C/L	%	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L $CaCO_3$	mg/L
Burke Lake Inflow	17-Jun-2009	16.4	7.41	6.9	15.1	10	7.98	3.24	2.4	1.24	1.48	0.68	30.9	1E-10
Burke Lake Inflow	08-Apr-2010	0.43	7.5	***1***	13.9	10	8.99	4.22	3	1.41	1.51	0.95	42	1E-10
Burke Lake-Deep Top	17-Jun-2009	15.6	7.36	***1***	11.7	10	6.29	2.72	2	0.94	3.04	1.53	30.1	1E-10
Burke Lake-Deep Top	29-Aug-2009	14.8	7.74	***1***	14.3	10	7.57	3.08	2.4	1.12	1.76	1.02	31.5	1E-10
Burke Lake-Deep Top	04-Apr-2010	1.29	7.4	***1***	16.2	10	10.7	4.88	3.4	1.54	1.8	1.25	46.8	1E-10
Burke Lake-Shallow	15-Jun-2007	15.8	7.6	1.6	11.7	10	6.57	2.81	2.13	1.07	*0.5*	1	28	1E-10
Burke Lake-Shallow	22-Mar-2008	1E-10	7.5	0.9	16.2	10	11	4.6	3.9	1.7	3	2	47	1E-10
Burke Lake-Shallow	17-Jun-2009	15.4	7.42	***1***	12.6	10	6.28	2.69	2	0.99	2.14	1.13	29.8	1E-10
Burke Lake-Shallow	29-Aug-2009	15.8	7.75	***1***	14.4	10	7.62	3.16	2.6	1.2	1.78	1.04	32	1E-10
Burke Lake-Shallow	04-Apr-2010	0.96	7.39	1	15.8	10	11.5	4.9	3.2	1.4	2.42	1.74	48.3	1E-10
Burke Lake Outflow	17-Jun-2009	15.8	7.39	1.8	12.7	10	6.73	2.87	1.9	1.13	1.83	0.97	28.6	1E-10
Burke Lake Outflow	08-Apr-2010	1.32	7.59	1	15.5	10	12.8	5.51	3.5	1.53	2.44	1.66	51.1	1E-10

Notes:

1. Assumed value (BLM User's Guide and Reference Manual, February 2007).

Bold/Italicized text = <method detection limit (mdl).

Table B-5: Water Quality Criteria for Copper for Nico Lake

Water Body	Sampling Date	Final Acute Value (FAV), ug/L	CMC[1] (CMC=FAV/2), ug/L	CCC[2] (CCC=FAV/ACR), ug/L	Cu Concentration[3] ug/L	Acute Toxic Units (Acute TU=Cu/CMC)
Nico Lake Inflow	18-Jun-09	83.2453	41.6226	25.8526	1	0.024
Nico Lake Inflow	28-Aug-09	146.9819	73.4909	45.6466	1	0.0136
Nico Lake-Deep Top	15-Jun-07	133.3831	66.6915	41.4233	3.8	0.057
Nico Lake-Deep Top	24-Mar-08	138.5303	69.2651	43.0218	1.9	0.0274
Nico Lake-Deep Top	18-Jun-09	89.7905	44.8952	27.8852	1.2	0.0267
Nico Lake-Deep Top	28-Aug-09	184.474	92.237	57.2901	2.3	0.0249
Nico Lake-Deep Top	5-Apr-10	126.7743	63.3871	39.3709	1.3	0.0205
Nico Lake-Shallow	18-Jun-09	103.3893	51.6947	32.1085	1.2	0.0232
Nico Lake-Shallow	28-Aug-09	176.9121	88.456	54.9416	1.2	0.0136
Nico Lake-Shallow	5-Apr-10	137.0052	68.5026	42.5482	1.4	0.0204
Nico-Peanut Creek Outflow	18-Jun-09	103.3258	51.6629	32.0888	1.2	0.0232
Nico-Peanut Creek Outflow	28-Aug-09	169.0959	84.548	52.5143	1.2	0.0142

Notes:

ug/L = micrograms per litre.

[1] CMC = Criterion Maximum Concentration.

[2] CCC = Criterion Continuous Concentration.

[3] Cu = Copper.

Table B-6: Water Quality Criteria for Copper for Peanut Lake

Water Body	Sampling Date	Final Acute Value (FAV), ug/L	CMC[1] (CMC=FAV/2), ug/L	CCC[2] (CCC=FAV/ACR), ug/L	Cu Concentration[3] ug/L	Acute Toxic Units (Acute TU=Cu/CMC)
Peanut Lake-Deep Top	16-Jun-07	106.9479	53.474	33.2136	1.7	0.0318
Peanut Lake-Deep Top	23-Mar-08	102.4362	51.2181	31.8125	1.1	0.0215
Peanut Lake-Deep Top	18-Jun-09	94.0481	47.024	29.2075	1	0.0213
Peanut Lake-Deep Top	5-Apr-10	88.6467	44.3233	27.53	1	0.0226
Peanut Lake-Shallow	18-Jun-09	90.9343	45.4672	28.2405	1	0.022
Peanut Lake-Shallow	5-Apr-10	72.3789	36.1894	22.4779	1	0.0276
Peanut Lake Outflow	18-Jun-09	93.2855	46.6428	28.9707	1	0.0214
Peanut Lake Outflow	30-Aug-09	176.2766	88.1383	54.7443	1	0.0113

Notes:

ug/L = micrograms per litre.

[1] CMC = Criterion Maximum Concentration.

[2] CCC = Criterion Continuous Concentration.

[3] Cu = Copper.

Table B-7: Water Quality Criteria for Copper for Burke Lake

Water Body	Sampling Date	Final Acute Value (FAV), ug/L	CMC[1] (CMC=FAV/2), ug/L	CCC[2] (CCC=FAV/ACR), ug/L	Cu Concentration[3] ug/L	Acute Toxic Units (Acute TU=Cu/CMC)
Burke Lake Inflow	17-Jun-09	104.8509	52.4255	32.5624	6.9	0.1316
Burke Lake Inflow	8-Apr-10	103.6435	51.8218	32.1874	1	0.0193
Burke Lake-Deep Top	17-Jun-09	74.7936	37.3968	23.2278	1	0.0267
Burke Lake-Deep Top	29-Aug-09	147.1725	73.5863	45.7058	1	0.0136
Burke Lake-Deep Top	4-Apr-10	107.774	53.887	33.4702	1	0.0186
Burke Lake-Shallow	15-Jun-07	102.3091	51.1545	31.773	1.6	0.0313
Burke Lake-Shallow	22-Mar-08	121.627	60.8135	37.7724	0.9	0.0148
Burke Lake-Shallow	17-Jun-09	87.9477	43.9738	27.3129	1	0.0227
Burke Lake-Shallow	29-Aug-09	150.9218	75.4609	46.8701	1	0.0133
Burke Lake-Shallow	4-Apr-10	103.0081	51.504	31.9901	1	0.0194
Burke Lake Outflow	17-Jun-09	85.0245	42.5123	26.4051	1.8	0.0423
Burke Lake Outflow	8-Apr-10	128.2994	64.1497	39.8445	1	0.0156

Notes:

ug/L = micrograms per litre.

[1] CMC = Criterion Maximum Concentration.

[2] CCC = Criterion Continuous Concentration.

[3] Cu = Copper.

APPENDIX C

Surface Water Screening Tables

Table C-1: Comparison of Predicted Chemical Concentrations in Surface Waters of Nico Lake during Construction to Guidelines, Baseline Concentrations and Site-Specific Water Quality Objectives

Nico Lake								
Chemical	**Units**	**CCME Fresh Water Aquatic Life Guidelines[a]**	**Baseline Concentration**	**+10% Baseline[b]**	**Site Specific Water Quality Objectives[c]**	**Predicted Concentrations Construction Phase[d]**	**COPC?[e]**	**Rationale[f]**
Nutrients								
Ammonia	mg-N/L	1.1[k]	0.0541	0.0595	4.16	0.035	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0916	0.1008	30,022	0.12	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.8079	0.8887		0.90	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0225	0.0248		0.022	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS								
Calcium	mg/L		8.7641	9.6405		9.7	no	Essential and non-toxic
Chloride	mg/L		1.1097	1.2206	353	1.14	no	<B+10%
Magnesium	mg/L		3.7994	4.1793		4.57	no	Essential and non-toxic
Potassium	mg/L		1.0859	1.1945		1.32	no	Essential and non-toxic
Sodium	mg/L		2.4169	2.6586		2.98	no	Essential and non-toxic
Sulphate	mg/L		4.0811	4.4892	500	4.38	no	<B+10%
Total Dissolved Solids	mg/L	500[n]	67.2143	73.9357		74.3	no	<G
Total Metals								
Al	mg/L	0.1[l]	0.0430	0.0473	0.42	0.33	no	<SSWQO
Sb	mg/L		0.0002	0.0002	0.03	0.00035	no	<SSWQO
As	mg/L	0.005	0.0209	0.0230	0.05	0.021	no	<B+10%
Ba	mg/L		0.0083	0.0091		0.013	yes	>B+10%
Be	mg/L		0.0005	0.0006		0.000038	no	<B+10%
B	mg/L	1.5	0.0185	0.0204		0.009	no	<G
Cd	mg/L	0.000017[i]	0.0002	0.0002	0.00015	0.000025	no	<B+10%
Cr	mg/L	0.001[j]	0.0013	0.0014		0.00072	no	<G
Co	mg/L		0.0009	0.0010	0.01	0.0019	no	<SSWQO
Cu	mg/L	0.002[h]	0.0017	0.0019	0.025	0.0025	no	<SSWQO
Fe	mg/L	0.3	0.6851	0.7536	1.50	0.95	no	<SSWQO
Pb	mg/L	0.001[h]	0.0006	0.0007	0.0076	0.00014	no	<G
Mn	mg/L		0.0742	0.0816		0.034	no	<B+10%
Hg	mg/L	0.000026	0.0001	0.0001		0.000011	no	<G
Mo	mg/L	0.073	0.0015	0.0017		0.00053	no	<G
Ni	mg/L	0.025[h]	0.0008	0.0009		0.0008	no	<G
Se	mg/L	0.001	0.0002	0.0003	0.005	0.00023	no	<G
Ag	mg/L	0.0001	0.0006	0.0007		0.000010	no	<G
Tl	mg/L	0.0008	0.0055	0.0061		0.0000051	no	<G
U	mg/L	0.015	0.0057	0.0063	0.027	0.00037	no	<G
V	mg/L		0.0004	0.0005		0.00073	yes	>B+10%
Zn	mg/L	0.03	0.0026	0.0028	0.11	0.0049	no	<G

Notes:

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.

[b] Mean measured baseline concentration plus 10 percent.

[c] As derived in Section 6.3.

[d] Predicted 95th percentile concentration.

[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.

[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.

[g] Guideline for nitrate.

[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.

[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$

[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.

[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7^{o}C and a pH of 8.

[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

[n] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-2: Comparison of Predicted Chemical Concentrations in Surface Waters of Peanut Lake during Construction to Guidelines, Baseline Concentrations and Site-Specific Water Quality Objectives

Peanut Lake								
Chemical	Units	CCME Fresh Water Aquatic Life Guidelines[a]	Baseline Concentration	+10% Baseline[b]	Site Specific Water Quality Objectives[c]	Predicted Concentration Construction Phase[d]	COPC?[e]	Rationale[f]
Nutrients								
Ammonia	mg-N/L	1.1[k]	0.0286	0.0314	4.16	0.04	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0808	0.0889	30,022	0.13	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.6270	0.6897		0.89	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0155	0.0171		0.019	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS								
Calcium	mg/L		7.6224	8.3847		9.5	no	Essential and non-toxic
Chloride	mg/L		1.3885	1.5273	353	1.18	no	<B+10%
Magnesium	mg/L		3.5200	3.8720		4.62	no	Essential and non-toxic
Potassium	mg/L		1.2500	1.3750		1.46	no	Essential and non-toxic
Sodium	mg/L		2.7203	2.9924		3.32	no	Essential and non-toxic
Sulphate	mg/L		1.4128	1.5541	500	1.95	no	<SSWQO
Total Dissolved Solids	mg/L	500[n]	61.2500	67.3750		68.2	no	<G
Total Metals								
Al	mg/L	0.1[l]	0.1023	0.1125	0.41	0.51	yes	>SSWQO
Sb	mg/L		0.0002	0.0002	0.03	0.00036	no	<SSWQO
As	mg/L	0.005	0.0040	0.0044	0.05	0.017	no	<SSWQO
Ba	mg/L		0.0102	0.0112		0.013	yes	>B+10%
Be	mg/L		0.0005	0.0006		0.000037	no	<B+10%
B	mg/L	1.5	0.0196	0.0215		0.009	no	<G
Cd	mg/L	0.000017[i]	0.0002	0.0002	0.00015	0.000029	no	<B+10%
Cr	mg/L	0.001[j]	0.0014	0.0015		0.0010	no	<B+10%
Co	mg/L		0.0006	0.0007	0.01	0.0019	no	<SSWQO
Cu	mg/L	0.002[h]	0.0010	0.0010	0.022	0.0022	no	<SSWQO
Fe	mg/L	0.3	0.3232	0.3556	1.5	1.20	no	<SSWQO
Pb	mg/L	0.001[h]	0.0007	0.0007	0.0076	0.00015	no	<G
Mn	mg/L		0.0388	0.0426		0.043	yes	>B+10%
Hg	mg/L	0.000026	0.0001	0.0001		0.000013	no	<G
Mo	mg/L	0.073	0.0015	0.0016		0.00027	no	<G
Ni	mg/L	0.025[h]	0.0009	0.0010		0.0012	no	<G
Se	mg/L	0.001	0.0003	0.0003	0.005	0.00024	no	<G
Ag	mg/L	0.0001	0.0007	0.0007		0.000011	no	<G
Tl	mg/L	0.0008	0.0061	0.0067		0.0000063	no	<G
U	mg/L	0.015	0.0062	0.0068	0.027	0.00026	no	<G
V	mg/L		0.00043	0.0005		0.0008	yes	>B+10%
Zn	mg/L	0.03	0.0037	0.0041	0.11	0.006	no	<G

Notes:

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.

[b] Mean measured baseline concentration plus 10 percent.

[c] As derived in Section 6.3.

[d] Predicted 95[th] percentile concentration.

[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.

[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.

[g] Guideline for nitrate.

[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.

[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$

[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.

[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7^{o}C and a pH of 8.

[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

[n] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-3: Comparison of Predicted Chemical Concentrations in Surface Waters of Burke Lake during Construction to Guidelines and Baseline Concentrations

			Burke Lake				
Chemical	**Units**	**CCME Fresh Water Aquatic Life Guidelines[a]**	**Baseline Concentration**	**+10% Baseline[b]**	**Predicted Concentration Construction Phase[d]**	**COPC?[e]**	**Rationale[f]**
Nutrients							
Ammonia	mg-N/L	1.1[k]	0.0362	0.0398	0.029	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0663	0.0729	0.11	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.7003	0.7704	0.75	no	[See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0183	0.0201	0.020	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS							
Calcium	mg/L		8.1300	8.9430	10.2	no	Essential and non-toxic
Chloride	mg/L		1.7581	1.9339	1.74	no	<B+10%
Magnesium	mg/L		3.4894	3.8383	4.22	no	Essential and non-toxic
Potassium	mg/L		1.2050	1.3255	1.37	no	Essential and non-toxic
Sodium	mg/L		2.6494	2.9143	3.19	no	Essential and non-toxic
Sulphate	mg/L		1.9914	2.1905	2.37	no	Essential and non-toxic
Total Dissolved Solids	mg/L	500[n]	65.7647	72.3412	68.0	no	<G
Total Metals							
Al	mg/L	0.1[l]	0.0715	0.0786	0.21	yes	>B+10%
Sb	mg/L		0.0003	0.0003	0.00030	no	<B+10%
As	mg/L	0.005	0.0035	0.0038	0.007	yes	>B+10%
Ba	mg/L		0.0091	0.0100	0.011	yes	>B+10%
Be	mg/L		0.0005	0.0006	0.000019	no	<B+10%
B	mg/L	1.5	0.0189	0.0208	0.008	no	<G
Cd	mg/L	0.000017[i]	0.0002	0.0002	0.000020	no	<B+10%
Cr	mg/L	0.001[j]	0.0014	0.0015	0.0008	no	<G
Co	mg/L		0.0007	0.0008	0.0009	yes	>B+10%
Cu	mg/L	0.002[h]	0.0013	0.0014	0.0017	no	<G
Fe	mg/L	0.3	0.6596	0.7255	0.63	no	<B+10%
Pb	mg/L	0.001[h]	0.0008	0.0008	0.00013	no	<G
Mn	mg/L		0.1253	0.1378	0.036	no	<B+10%
Hg	mg/L	0.000026	0.0001	0.0001	0.000012	no	<G
Mo	mg/L	0.073	0.0015	0.0016	0.00024	no	<G
Ni	mg/L	0.025[h]	0.0008	0.0009	0.0011	no	<G
Se	mg/L	0.001	0.0002	0.0003	0.00021	no	<G
Ag	mg/L	0.0001	0.0007	0.0008	0.000009	no	<G
Tl	mg/L	0.0008	0.0068	0.0075	0.0000034	no	<G
U	mg/L	0.015	0.0070	0.0077	0.00028	no	<G
V	mg/L		0.0019	0.0021	0.0007	no	<B+10%
Zn	mg/L	0.03	0.0049	0.0053	0.0053	no	<G

Notes:

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.

[b] Mean measured baseline concentration plus 10 percent.

[c] As derived in Section 6.3.

[d] Predicted 95th percentile concentration.

[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.

[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.

[g] Guideline for nitrate.

[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.

[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$

[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.

[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7°C and a pH of 8.

[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

[n] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-4: Comparison of Predicted Chemical Concentrations in Surface Waters of Marian River during Construction to Guidelines and Baseline Concentrations

Marian River							
Chemical	**Units**	**CCME Fresh Water Aquatic Life Guidelines[a]**	**Baseline Concentration**	**+10% Baseline[b]**	**Predicted Concentration Construction Phase[d]**	**COPC?[e]**	**Rationale[f]**
Nutrients							
Ammonia	mg-N/L	1.1[k]	0.0251	0.0276	0.07	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0497	0.0547	0.15	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.6680	0.7348	1.52	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0124	0.0137	0.018	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS							
Calcium	mg/L		20.8600	22.9460	50.8	no	Essential and non-toxic
Chloride	mg/L		2.4692	2.7161	5.38	no	Essential and non-toxic
Magnesium	mg/L		9.1088	10.0197	22.1	no	Essential and non-toxic
Potassium	mg/L		1.5908	1.7499	3.87	no	Essential and non-toxic
Sodium	mg/L		3.2540	3.5794	7.5	no	Essential and non-toxic
Sulphate	mg/L		16.7000	18.3700	42	no	Essential and non-toxic
Total Dissolved Solids	mg/L	500[n]	120.1818	132.2000	239	no	<G
Total Metals							
Al	mg/L	0.1[l]	0.0728	0.0801	0.07	no	<G
Sb	mg/L		0.0002	0.0002	0.00005	no	<B+10%
As	mg/L	0.005	0.0006	0.0007	0.0012	no	<G
Ba	mg/L		0.0142	0.0157	0.030	yes	>B+10%
Be	mg/L		0.0005	0.0006	0.000032	no	<B+10%
B	mg/L	1.5	0.0234	0.0257	0.035	no	<G
Cd	mg/L	0.000017[i]	0.0001	0.0001	0.000047	no	<B+10%
Cr	mg/L	0.001[j]	0.0014	0.0016	0.00076	no	<G
Co	mg/L		0.0006	0.0007	0.00022	no	<B+10%
Cu	mg/L	0.002[h]	0.0007	0.0008	0.0017	no	<G
Fe	mg/L	0.3	0.1636	0.1799	0.28	no	<G
Pb	mg/L	0.001[h]	0.0005	0.0005	0.00029	no	<G
Mn	mg/L		0.0246	0.0270	0.06	yes	>B+10%
Hg	mg/L	0.000026	0.000036	0.000039	0.000080	yes	>B+10%
Mo	mg/L	0.073	0.0015	0.0016	0.00043	no	<G
Ni	mg/L	0.025[h]	0.0010	0.0011	0.0020	no	<G
Se	mg/L	0.001	0.0003	0.0003	0.0007	no	<G
Ag	mg/L	0.0001	0.0005	0.0005	0.000012	no	<G
Tl	mg/L	0.0008	0.0040	0.0044	0.0000023	no	<G
U	mg/L	0.015	0.0046	0.0051	0.0017	no	<G
V	mg/L		0.0006	0.0006	0.0011	yes	>B+10%
Zn	mg/L	0.03	0.0062	0.0068	0.02	no	<G

Notes:
[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.
[b] Mean measured baseline concentration plus 10 percent.
[c] As derived in Section 6.3.
[d] Predicted 95th percentile concentration.
[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.
[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.
[g] Guideline for nitrate.
[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.
[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$
[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.
[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7 ^oC and a pH of 8.
[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.
[n] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]
Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-5: Comparison of Predicted Chemical Concentrations in Surface Waters of Nico Lake during Operations to Guidelines, Baseline Concentrations and Site-Specific Water Quality Objectives

Nico Lake								
Chemical	**Units**	**CCME Fresh Water Aquatic Life Guidelines[a]**	**Baseline Concentration**	**+10% Baseline[b]**	**Site Specific Water Quality Objectives[c]**	**Predicted Concentration Operations Phase[d]**	**COPC?[e]**	**Rationale[f]**
Nutrients								
Ammonia	mg-N/L	1.1[k]	0.0541	0.0595	4.16	0.65	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0916	0.1008	30,022	0.68	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.8079	0.8887		1.28	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0225	0.0248		0.023	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS								
Calcium	mg/L		8.7641	9.6405		8.3	no	Essential and non-toxic
Chloride	mg/L		1.1097	1.2206	353	2.10	no	<SSWQO
Magnesium	mg/L		3.7994	4.1793		4.38	no	Essential and non-toxic
Potassium	mg/L		1.0859	1.1945		7.6	no	Essential and non-toxic
Sodium	mg/L		2.4169	2.6586		3.48	no	Essential and non-toxic
Sulphate	mg/L		4.0811	4.4892	500	6.4	no	<SSWQO
Total Dissolved Solids	mg/L	500[o]	67.2143	73.9357		70.8	no	<G
Total Metals								
Al	mg/L	0.1[l]	0.0430	0.0473	0.42	1.31	yes	>SSWQO
Sb	mg/L		0.0002	0.0002	0.03	0.0013	no	<SSWQO
As	mg/L	0.005	0.0209	0.0230	0.05	0.044	no	<SSWQO
Ba	mg/L		0.0083	0.0091		0.023	yes	>B+10%
Be	mg/L		0.0005	0.0006		0.00011	no	<B+10%
B	mg/L	1.5	0.0185	0.0204		0.015	no	<G
Cd	mg/L	0.000017[i]	0.0002	0.0002	0.00015	0.000058	no	<B+10%
Cr	mg/L	0.001[j]	0.0013	0.0014		0.0018	no	see note [n]
Co	mg/L		0.0009	0.0010	0.01	0.0061	no	<SSWQO
Cu	mg/L	0.002[h]	0.0017	0.0019	0.025	0.0049	no	<SSWQO
Fe	mg/L	0.3	0.6851	0.7536	1.50	3.30	yes	>SSWQO
Pb	mg/L	0.001[h]	0.0006	0.0007	0.0076	0.00043	no	<G
Mn	mg/L		0.0742	0.0816		0.048	no	<B+10%
Hg	mg/L	0.000026	0.0001	0.0001		0.000015	no	<G
Mo	mg/L	0.073	0.0015	0.0017		0.0013	no	<G
Ni	mg/L	0.025[h]	0.0008	0.0009		0.0011	no	<G
Se	mg/L	0.001	0.0002	0.0003	0.005	0.0016	no	<SSWQO
Ag	mg/L	0.0001	0.0006	0.0007		0.00008	no	<G
Tl	mg/L	0.0008	0.0055	0.0061		0.00070	no	<G
U	mg/L	0.015	0.0057	0.0063	0.027	0.0040	no	<G
V	mg/L		0.00041	0.0005		0.0012	yes	>B+10%
Zn	mg/L	0.03	0.0026	0.0028	0.11	0.0079	no	<G

Notes:

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.

[b] Mean measured baseline concentration plus 10 percent.

[c] As derived in Section 6.3.

[d] Predicted 95th percentile concentration.

[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.

[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.

[g] Guideline for nitrate.

[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.

[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$

[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.

[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7^{o}C and a pH of 8.

[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

[n] Chromium was not retained as a COPC as it does not exceed the CCME CWQG for trivalent chromium [Cr(III)] of 0.0089 mg/L. Chromium in surface waters is likely to be present as Cr(III) given that Cr(VI) is reduced to Cr(III) in the presence of natural organic cations (humic and fulvic acids, tannic acids).

[o] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-6: Comparison of Predicted Chemical Concentrations in Surface Waters of Peanut Lake during Operations to Guidelines, Baseline Concentrations and Site-Specific Water Quality Objectives

Peanut Lake								
Chemical	**Units**	**CCME Fresh Water Aquatic Life Guidelines[a]**	**Baseline Concentration**	**+10% Baseline[b]**	**Site Specific Water Quality Objectives[c]**	**Predicted Concentration Operations Phase[d]**	**COPC?[e]**	**Rationale[f]**
Nutrients								
Ammonia	mg-N/L	1.1[k]	0.0286	0.0314	4.16	0.52	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0808	0.0889	30,022	0.53	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.6270	0.6897		1.19	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0155	0.0171		0.020	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS								
Calcium	mg/L		7.6224	8.3847		10.0	no	Essential and non-toxic
Chloride	mg/L		1.3885	1.5273	353	1.96	no	<SSWQO
Magnesium	mg/L		3.5200	3.8720		5.34	no	Essential and non-toxic
Potassium	mg/L		1.2500	1.3750		12.6	no	Essential and non-toxic
Sodium	mg/L		2.7203	2.9924		4.21	no	Essential and non-toxic
Sulphate	mg/L		1.4128	1.5541	500	5.0	no	<SSWQO
Total Dissolved Solids	mg/L	500[n]	61.2500	67.3750		70.2	no	<G
Total Metals								
Al	mg/L	0.1[l]	0.1023	0.1125	0.41	0.73	yes	>SSWQO
Sb	mg/L		0.0002	0.0002	0.03	0.0005	no	<SSWQO
As	mg/L	0.005	0.0040	0.0044	0.05	0.024	no	<SSWQO
Ba	mg/L		0.0102	0.0112		0.016	yes	>B+10%
Be	mg/L		0.0005	0.0006		0.00007	no	<B+10%
B	mg/L	1.5	0.0196	0.0215		0.016	no	<G
Cd	mg/L	0.000017[i]	0.0002	0.0002	0.00015	0.000040	no	<B+10%
Cr	mg/L	0.001[j]	0.0014	0.0015		0.0012	no	<B+10%
Co	mg/L		0.0006	0.0007	0.01	0.0035	no	<SSWQO
Cu	mg/L	0.002[h]	0.0010	0.0010	0.022	0.0029	no	<SSWQO
Fe	mg/L	0.3	0.3232	0.3556	1.5	1.81	yes	>SSWQO
Pb	mg/L	0.001[h]	0.0007	0.0007	0.0076	0.00020	no	<G
Mn	mg/L		0.0388	0.0426		0.06	yes	>B+10%
Hg	mg/L	0.000026	0.0001	0.0001		0.000014	no	<G
Mo	mg/L	0.073	0.0015	0.0016		0.0014	no	<G
Ni	mg/L	0.025[h]	0.0009	0.0010		0.0014	no	<G
Se	mg/L	0.001	0.0003	0.0003	0.005	0.0015	no	<SSWQO
Ag	mg/L	0.0001	0.0007	0.0007		0.00009	no	<G
Tl	mg/L	0.0008	0.0061	0.0067		0.00017	no	<G
U	mg/L	0.015	0.0062	0.0068	0.027	0.0019	no	<G
V	mg/L		0.0004	0.0005		0.0009	yes	>B+10%
Zn	mg/L	0.03	0.0037	0.0041	0.11	0.006	no	<G

Notes:

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.

[b] Mean measured baseline concentration plus 10 percent.

[c] As derived in Section 6.3.

[d] Predicted 95th percentile concentration.

[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.

[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.

[g] Guideline for nitrate.

[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.

[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$

[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.

[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7^{o}C and a pH of 8.

[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

[n] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-7: Comparison of Predicted Chemical Concentrations in Surface Waters of Burke Lake during Operations to Guidelines and Baseline Concentrations

Burke Lake							
Chemical	**Units**	**CCME Fresh Water Aquatic Life Guidelines[a]**	**Baseline Concentration**	**+10% Baseline[b]**	**Predicted Concentration Operations Phase[d]**	**COPC?[e]**	**Rationale[f]**
Nutrients							
Ammonia	mg-N/L	1.1[k]	0.0362	0.0398	0.22	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0663	0.0729	0.26	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.7003	0.7704	0.99	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0183	0.0201	0.018	no	<B+10%
Major Ions and TDS							
Calcium	mg/L		8.1300	8.9430	12.5	no	Essential and non-toxic
Chloride	mg/L		1.7581	1.9339	1.87	no	<B+10%
Magnesium	mg/L		3.4894	3.8383	5.25	no	Essential and non-toxic
Potassium	mg/L		1.2050	1.3255	5.5	no	Essential and non-toxic
Sodium	mg/L		2.6494	2.9143	4.11	no	Essential and non-toxic
Sulphate	mg/L		1.9914	2.1905	3.41	no	Essential and non-toxic
Total Dissolved Solids	mg/L	500[n]	65.7647	72.3412	66.5	no	<G
Total Metals							
Al	mg/L	0.1[l]	0.0715	0.0786	0.58	yes	>B+10%
Sb	mg/L		0.0003	0.0003	0.00043	yes	>B+10%
As	mg/L	0.005	0.0035	0.0038	0.018	yes	>B+10%
Ba	mg/L		0.0091	0.0100	0.015	yes	>B+10%
Be	mg/L		0.0005	0.0006	0.000041	no	<B+10%
B	mg/L	1.5	0.0189	0.0208	0.010	no	<G
Cd	mg/L	0.000017[i]	0.0002	0.0002	0.000031	no	<B+10%
Cr	mg/L	0.001[j]	0.0014	0.0015	0.0011	no	<B+10%
Co	mg/L		0.0007	0.0008	0.0025	yes	>B+10%
Cu	mg/L	0.002[h]	0.0013	0.0014	0.0026	yes	>B+10%
Fe	mg/L	0.3	0.6596	0.7255	1.49	yes	>B+10%
Pb	mg/L	0.001[h]	0.0008	0.0008	0.00017	no	<G
Mn	mg/L		0.1253	0.1378	0.05	no	<B+10%
Hg	mg/L	0.000026	0.0001	0.0001	0.000012	no	<G
Mo	mg/L	0.073	0.0015	0.0016	0.0006	no	<G
Ni	mg/L	0.025[h]	0.0008	0.0009	0.0012	no	<G
Se	mg/L	0.001	0.0002	0.0003	0.0007	no	<G
Ag	mg/L	0.0001	0.0007	0.0008	0.000042	no	<G
Tl	mg/L	0.0008	0.0068	0.0075	0.00009	no	<G
U	mg/L	0.015	0.0070	0.0077	0.0010	no	<G
V	mg/L		0.0019	0.0021	0.0009	no	<B+10%
Zn	mg/L	0.03	0.0049	0.0053	0.0059	no	<G

Notes:

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.

[b] Mean measured baseline concentration plus 10 percent.

[c] As derived in Section 6.3.

[d] Predicted 95^{th} percentile concentration.

[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.

[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.

[g] Guideline for nitrate.

[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.

[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$

[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.

[k] The CCME CWQG for Ammonia was derived assuming a temperature of $7^{o}C$ and a pH of 8.

[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

[n] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-8: Comparison of Predicted Chemical Concentrations in Surface Waters of Marian River during Operations to Guidelines and Baseline Concentrations

Chemical	Units	CCME Fresh Water Aquatic Life Guidelines[a]	Baseline Concentration	+10% Baseline[b]	Predicted Concentration Operations Phase[d]	COPC?[e]	Rationale[f]
			Marian River				
Nutrients							
Ammonia	mg-N/L	1.1[k]	0.0251	0.0276	0.07	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0497	0.0547	0.16	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.6680	0.7348	1.50	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0124	0.0137	0.018	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS							
Calcium	mg/L		20.8600	22.9460	50.8	no	Essential and non-toxic
Chloride	mg/L		2.4692	2.7161	5.33	no	Essential and non-toxic
Magnesium	mg/L		9.1088	10.0197	21.8	no	Essential and non-toxic
Potassium	mg/L		1.5908	1.7499	3.94	no	Essential and non-toxic
Sodium	mg/L		3.2540	3.5794	7.5	no	Essential and non-toxic
Sulphate	mg/L		16.7000	18.3700	42	no	Essential and non-toxic
Total Dissolved Solids	mg/L	500[n]	120.1818	132.2000	238	no	<G
Total Metals							
Al	mg/L	0.1[l]	0.0728	0.0801	0.11	yes	>B+10%
Sb	mg/L		0.0002	0.0002	0.00006	no	<B+10%
As	mg/L	0.005	0.0006	0.0007	0.002	no	<G
Ba	mg/L		0.0142	0.0157	0.030	yes	>B+10%
Be	mg/L		0.0005	0.0006	0.000032	no	<B+10%
B	mg/L	1.5	0.0234	0.0257	0.035	no	<G
Cd	mg/L	0.000017[i]	0.0001	0.0001	0.000047	no	<B+10%
Cr	mg/L	0.001[j]	0.0014	0.0016	0.00077	no	<G
Co	mg/L		0.0006	0.0007	0.00028	no	<B+10%
Cu	mg/L	0.002[h]	0.0007	0.0008	0.0017	no	<G
Fe	mg/L	0.3	0.1636	0.1799	0.31	yes	>B+10%
Pb	mg/L	0.001[h]	0.0005	0.0005	0.00029	no	<G
Mn	mg/L		0.0246	0.0270	0.06	yes	>B+10%
Hg	mg/L	0.000026	0.000036	0.00004	0.000077	yes	>B+10%
Mo	mg/L	0.073	0.0015	0.0016	0.00043	no	<G
Ni	mg/L	0.025[h]	0.0010	0.0011	0.0020	no	<G
Se	mg/L	0.001	0.0003	0.0003	0.0007	no	<G
Ag	mg/L	0.0001	0.0005	0.0005	0.000012	no	<G
Tl	mg/L	0.0008	0.0040	0.0044	0.0000057	no	<G
U	mg/L	0.015	0.0046	0.0051	0.0017	no	<G
V	mg/L		0.00058	0.0006	0.0011	yes	>B+10%
Zn	mg/L	0.03	0.0062	0.0068	0.02	no	<G

Notes:

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.

[b] Mean measured baseline concentration plus 10 percent.

[c] As derived in Section 6.3.

[d] Predicted 95th percentile concentration.

[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.

[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.

[g] Guideline for nitrate.

[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.

[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$

[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.

[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7 ^{o}C and a pH of 8.

[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

[n] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-9: Comparison of Predicted Chemical Concentrations in Surface Waters of Nico Lake during Active Closure to Guidelines, Baseline Concentrations and Site-Specific Water Quality Objectives

Nico Lake								
Chemical	Units	CCME Fresh Water Aquatic Life Guidelines[a]	Baseline Concentration	+10% Baseline[b]	Site Specific Water Quality Objectives[c]	Predicted Concentration Active Closure Phase[d]	COPC?[e]	Rationale[f]
Nutrients								
Ammonia	mg-N/L	1.1[k]	0.0541	0.0595	4.16	0.58	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0916	0.1008	30,022	0.61	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.8079	0.8887		1.18	no	see note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0225	0.0248		0.022	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS								
Calcium	mg/L		8.7641	9.6405		8.9	no	Essential and non-toxic
Chloride	mg/L		1.1097	1.2206	353	4.06	no	<SSWQO
Magnesium	mg/L		3.7994	4.1793		4.64	no	Essential and non-toxic
Potassium	mg/L		1.0859	1.1945		15.4	no	Essential and non-toxic
Sodium	mg/L		2.4169	2.6586		4.39	no	Essential and non-toxic
Sulphate	mg/L		4.0811	4.4892	500	13.9	no	<SSWQO
Total Dissolved Solids	mg/L	500[o]	67.2143	73.9357		82.9	no	<G
Total Metals								
Al	mg/L	0.1[l]	0.0430	0.0473	0.42	1.09	yes	>SSWQO
Sb	mg/L		0.0002	0.0002	0.03	0.0022	no	<SSWQO
As	mg/L	0.005	0.0209	0.0230	0.05	0.040	no	<SSWQO
Ba	mg/L		0.0083	0.0091		0.024	yes	>B+10%
Be	mg/L		0.0005	0.0006		0.00013	no	<B+10%
B	mg/L	1.5	0.0185	0.0204		0.020	no	<G
Cd	mg/L	0.000017[i]	0.0002	0.0002	0.00015	0.000050	no	<B+10%
Cr	mg/L	0.001[j]	0.0013	0.0014		0.0018	no	See note [n]
Co	mg/L		0.0009	0.0010	0.01	0.0055	no	<SSWQO
Cu	mg/L	0.002[h]	0.0017	0.0019	0.025	0.0048	no	<SSWQO
Fe	mg/L	0.3	0.6851	0.7536	1.50	2.89	yes	>SSWQO
Pb	mg/L	0.001[h]	0.0006	0.0007	0.0076	0.00078	no	<G
Mn	mg/L		0.0742	0.0816		0.057	no	<B+10%
Hg	mg/L	0.000026	0.0001	0.0001		0.000015	no	<G
Mo	mg/L	0.073	0.0015	0.0017		0.0028	no	<G
Ni	mg/L	0.025[h]	0.0008	0.0009		0.0012	no	<G
Se	mg/L	0.001	0.0002	0.0003	0.005	0.0026	no	<SSWQO
Ag	mg/L	0.0001	0.0006	0.0007		0.00007	no	<G
Tl	mg/L	0.0008	0.0055	0.0061		0.00051	no	<G
U	mg/L	0.015	0.0057	0.0063	0.027	0.0064	no	<G
V	mg/L		0.0004	0.0005		0.0012	yes	>B+10%
Zn	mg/L	0.03	0.0026	0.0028	0.11	0.0132	no	<G

Notes:
[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.
[b] Mean measured baseline concentration plus 10 percent.
[c] As derived in Section 6.3.
[d] Predicted 95th percentile concentration.
[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.
[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.
[g] Guideline for nitrate.
[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.
[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$
[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.
[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7 ^{o}C and a pH of 8.
[l] The CCME CWQG for Aluminum is for pH > 6.5
[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.
[n] Chromium was not retained as a COPC as it does not exceed the CCME CWQG for trivalent chromium [Cr(III)] of 0.0089 mg/L. Chromium in surface waters is likely to be present as Cr(III) given that Cr(VI) is reduced to Cr(III) in the presence of natural organic cations (humic and fulvic acids, tannic acids).
[o] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]
Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-10: Comparison of Predicted Chemical Concentrations in Surface Waters of Peanut Lake during Active Closure to Guidelines, Baseline Concentrations and Site-Specific Water Quality Objectives

Peanut Lake								
Chemical	**Units**	**CCME Fresh Water Aquatic Life Guidelines[a]**	**Baseline Concentration**	**+10% Baseline[b]**	**Site Specific Water Quality Objectives[c]**	**Predicted Concentration Active Closure Phase[d]**	**COPC?[e]**	**Rationale[f]**
Nutrients								
Ammonia	mg-N/L	1.1[k]	0.0286	0.0314	4.16	0.40	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0808	0.0889	30,022	0.42	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.6270	0.6897		1.21	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0155	0.0171		0.020	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS								
Calcium	mg/L		7.6224	8.3847		10.5	no	Essential and non-toxic
Chloride	mg/L		1.3885	1.5273	353	2.08	no	<SSWQO
Magnesium	mg/L		3.5200	3.8720		5.68	no	Essential and non-toxic
Potassium	mg/L		1.2500	1.3750		12.3	no	Essential and non-toxic
Sodium	mg/L		2.7203	2.9924		4.45	no	Essential and non-toxic
Sulphate	mg/L		1.4128	1.5541	500	6.5	no	<SSWQO
Total Dissolved Solids	mg/L	500[n]	61.2500	67.3750		72.9	no	<G
Total Metals								
Al	mg/L	0.1[l]	0.1023	0.1125	0.41	0.53	yes	>SSWQO
Sb	mg/L		0.0002	0.0002	0.03	0.0007	no	<SSWQO
As	mg/L	0.005	0.0040	0.0044	0.05	0.017	no	<SSWQO
Ba	mg/L		0.0102	0.0112		0.015	yes	>B+10%
Be	mg/L		0.0005	0.0006		0.00007	no	<B+10%
B	mg/L	1.5	0.0196	0.0215		0.018	no	<G
Cd	mg/L	0.000017[i]	0.0002	0.0002	0.00015	0.000032	no	<B+10%
Cr	mg/L	0.001[j]	0.0014	0.0015		0.0011	no	<B+10%
Co	mg/L		0.0006	0.0007	0.01	0.0026	no	<SSWQO
Cu	mg/L	0.002[h]	0.0010	0.0010	0.022	0.0025	no	<SSWQO
Fe	mg/L	0.3	0.3232	0.3556	1.5	1.41	no	<SSWQO
Pb	mg/L	0.001[h]	0.0007	0.0007	0.0076	0.00026	no	<G
Mn	mg/L		0.0388	0.0426		0.06	yes	>B+10%
Hg	mg/L	0.000026	0.0001	0.0001		0.000015	no	<G
Mo	mg/L	0.073	0.0015	0.0016		0.0015	no	<G
Ni	mg/L	0.025[h]	0.0009	0.0010		0.0015	no	<G
Se	mg/L	0.001	0.0003	0.0003	0.005	0.0017	no	<SSWQO
Ag	mg/L	0.0001	0.0007	0.0007		0.00006	no	<G
Tl	mg/L	0.0008	0.0061	0.0067		0.00015	no	<G
U	mg/L	0.015	0.0062	0.0068	0.027	0.0025	no	<G
V	mg/L		0.0004	0.0005		0.0009	yes	>B+10%
Zn	mg/L	0.03	0.0037	0.0041	0.11	0.007	no	<G

Notes:

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.

[b] Mean measured baseline concentration plus 10 percent.

[c] As derived in Section 6.3.

[d] Predicted 95th percentile concentration.

[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.

[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.

[g] Guideline for nitrate.

[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.

[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$

[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.

[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7^{o}C and a pH of 8.

[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

[n] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-11: Comparison of Predicted Chemical Concentrations in Surface Waters of Burke Lake during Active Closure to Guidelines and Baseline Concentrations

Burke Lake							
Chemical	**Units**	**CCME Fresh Water Aquatic Life Guidelines[a]**	**Baseline Concentration**	**+10% Baseline[b]**	**Predicted Concentration Active Closure Phase[d]**	**COPC?[e]**	**Rationale[f]**
Nutrients							
Ammonia	mg-N/L	1.1[k]	0.0362	0.0398	0.26	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0663	0.0729	0.29	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.7003	0.7704	1.00	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0183	0.0201	0.018	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS							
Calcium	mg/L		8.1300	8.9430	12.9	no	Essential and non-toxic
Chloride	mg/L		1.7581	1.9339	2.00	no	Essential and non-toxic
Magnesium	mg/L		3.4894	3.8383	5.38	no	Essential and non-toxic
Potassium	mg/L		1.2050	1.3255	8.8	no	Essential and non-toxic
Sodium	mg/L		2.6494	2.9143	4.23	no	Essential and non-toxic
Sulphate	mg/L		1.9914	2.1905	4.65	no	Essential and non-toxic
Total Dissolved Solids	mg/L	500[n]	65.7647	72.3412	68.3	no	<G
Total Metals							
Al	mg/L	0.1[l]	0.0715	0.0786	0.49	yes	>B+10%
Sb	mg/L		0.0003	0.0003	0.00047	yes	>B+10%
As	mg/L	0.005	0.0035	0.0038	0.015	yes	>B+10%
Ba	mg/L		0.0091	0.0100	0.014	yes	>B+10%
Be	mg/L		0.0005	0.0006	0.000048	no	<B+10%
B	mg/L	1.5	0.0189	0.0208	0.013	no	<G
Cd	mg/L	0.000017[i]	0.0002	0.0002	0.000028	no	<B+10%
Cr	mg/L	0.001[j]	0.0014	0.0015	0.0010	no	<G
Co	mg/L		0.0007	0.0008	0.0022	yes	>B+10%
Cu	mg/L	0.002[h]	0.0013	0.0014	0.0023	yes	>B+10%
Fe	mg/L	0.3	0.6596	0.7255	1.31	yes	>B+10%
Pb	mg/L	0.001[h]	0.0008	0.0008	0.00019	no	<G
Mn	mg/L		0.1253	0.1378	0.05	no	<B+10%
Hg	mg/L	0.000026	0.0001	0.0001	0.000013	no	<G
Mo	mg/L	0.073	0.0015	0.0016	0.0010	no	<G
Ni	mg/L	0.025[h]	0.0008	0.0009	0.0012	no	<G
Se	mg/L	0.001	0.0002	0.0003	0.0011	yes	>B+10%
Ag	mg/L	0.0001	0.0007	0.0008	0.000047	no	<G
Tl	mg/L	0.0008	0.0068	0.0075	0.00008	no	<G
U	mg/L	0.015	0.0070	0.0077	0.0014	no	<G
V	mg/L		0.0019	0.0021	0.0008	no	<B+10%
Zn	mg/L	0.03	0.0049	0.0053	0.0059	no	<G

Notes:

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.

[b] Mean measured baseline concentration plus 10 percent.

[c] As derived in Section 6.3.

[d] Predicted 95th percentile concentration.

[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.

[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.

[g] Guideline for nitrate.

[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.

[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$

[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.

[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7°C and a pH of 8.

[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

[n] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-12: Comparison of Predicted Chemical Concentrations in Surface Waters of Marian River during Active Closure to Guidelines and Baseline Concentrations

Marian River							
Chemical	Units	CCME Fresh Water Aquatic Life Guidelines[a]	Baseline Concentration	+10% Baseline[b]	Predicted Concentration Active Closure Phase[d]	COPC?[e]	Rationale[f]
Nutrients							
Ammonia	mg-N/L	1.1[k]	0.0251	0.0276	0.07	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0497	0.0547	0.16	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.6680	0.7348	1.51	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0124	0.0137	0.018	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS							
Calcium	mg/L		20.8600	22.9460	50.8	no	Essential and non-toxic
Chloride	mg/L		2.4692	2.7161	5.33	no	Essential and non-toxic
Magnesium	mg/L		9.1088	10.0197	22.0	no	Essential and non-toxic
Potassium	mg/L		1.5908	1.7499	3.96	no	Essential and non-toxic
Sodium	mg/L		3.2540	3.5794	7.4	no	Essential and non-toxic
Sulphate	mg/L		16.7000	18.3700	42	no	Essential and non-toxic
Total Dissolved Solids	mg/L	500[n]	120.1818	132.2000	240	no	<G
Total Metals							
Al	mg/L	0.1[l]	0.0728	0.0801	0.09	no	<G
Sb	mg/L		0.0002	0.0002	0.00006	no	<B+10%
As	mg/L	0.005	0.0006	0.0007	0.001	no	<G
Ba	mg/L		0.0142	0.0157	0.030	yes	>B+10%
Be	mg/L		0.0005	0.0006	0.000032	no	<B+10%
B	mg/L	1.5	0.0234	0.0257	0.035	no	<G
Cd	mg/L	0.000017[i]	0.0001	0.0001	0.000047	no	<B+10%
Cr	mg/L	0.001[j]	0.0014	0.0016	0.00077	no	<G
Co	mg/L		0.0006	0.0007	0.00026	no	<B+10%
Cu	mg/L	0.002[h]	0.0007	0.0008	0.0017	no	<G
Fe	mg/L	0.3	0.1636	0.1799	0.30	no	<G
Pb	mg/L	0.001[h]	0.0005	0.0005	0.00029	no	<G
Mn	mg/L		0.0246	0.0270	0.06	yes	>B+10%
Hg	mg/L	0.000026	0.0000	0.00004	0.00008	yes	>B+10%
Mo	mg/L	0.073	0.0015	0.0016	0.00044	no	<G
Ni	mg/L	0.025[h]	0.0010	0.0011	0.0020	no	<G
Se	mg/L	0.001	0.0003	0.0003	0.0007	no	<G
Ag	mg/L	0.0001	0.0005	0.0005	0.000012	no	<G
Tl	mg/L	0.0008	0.0040	0.0044	0.0000056	no	<G
U	mg/L	0.015	0.0046	0.0051	0.0017	no	<G
V	mg/L		0.0006	0.0006	0.0011	yes	>B+10%
Zn	mg/L	0.03	0.0062	0.0068	0.02	no	<G

Notes:
[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.
[b] Mean measured baseline concentration plus 10 percent.
[c] As derived in Section 6.3.
[d] Predicted 95th percentile concentration.
[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.
[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.
[g] Guideline for nitrate.
[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.
[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$
[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.
[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7 ^{o}C and a pH of 8.
[l] The CCME CWQG for Aluminum is for pH > 6.5
[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.
[n] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-13: Comparison of Predicted Chemical Concentrations in Surface Waters of Nico Lake during Post-closure to Guidelines, Baseline Concentrations and Site-Specific Water Quality Objectives

Nico Lake								
Chemical	**Units**	**CCME Fresh Water Aquatic Life Guidelines[a]**	**Baseline Concentration**	**+10% Baseline[b]**	**Site Specific Water Quality Objectives[c]**	**Predicted Concentration Post-Closure Phase[d]**	**COPC?[e]**	**Rationale[f]**
Nutrients								
Ammonia	mg-N/L	1.1[k]	0.0541	0.0595	4.16	0.17	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0916	0.1008	30,022	0.19	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.8079	0.8887		0.86	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0225	0.0248		0.020	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS								
Calcium	mg/L		8.7641	9.6405		10.8	no	Essential and non-toxic
Chloride	mg/L		1.1097	1.2206	353	9.7	no	<SSWQO
Magnesium	mg/L		3.7994	4.1793		5.18	no	Essential and non-toxic
Potassium	mg/L		1.0859	1.1945		27.8	no	Essential and non-toxic
Sodium	mg/L		2.4169	2.6586		4.88	no	Essential and non-toxic
Sulphate	mg/L		4.0811	4.4892	500	26.7	no	<SSWQO
Total Dissolved Solids	mg/L	500[o]	67.2143	73.9357		111	no	<G
Total Metals								
Al	mg/L	0.1[l]	0.0430	0.0473	0.42	0.20	no	<SSWQO
Sb	mg/L		0.0002	0.0002	0.03	0.0037	no	<SSWQO
As	mg/L	0.005	0.0209	0.0230	0.05	0.019	no	<B+10%
Ba	mg/L		0.0083	0.0091		0.021	yes	>B+10%
Be	mg/L		0.0005	0.0006		0.00015	no	<B+10%
B	mg/L	1.5	0.0185	0.0204		0.025	no	<G
Cd	mg/L	0.000017[i]	0.0002	0.0002	0.00015	0.000042	no	<B+10%
Cr	mg/L	0.001[j]	0.0013	0.0014		0.0020	no	See note [n]
Co	mg/L		0.0009	0.0010	0.01	0.0016	no	<SSWQO
Cu	mg/L	0.002[h]	0.0017	0.0019	0.025	0.0041	no	<SSWQO
Fe	mg/L	0.3	0.6851	0.7536	1.50	0.88	no	<SSWQO
Pb	mg/L	0.001[h]	0.0006	0.0007	0.0076	0.0018	no	<SSWQO
Mn	mg/L		0.0742	0.0816		0.078	no	<B+10%
Hg	mg/L	0.000026	0.0001	0.0001		0.000026	no	<G
Mo	mg/L	0.073	0.0015	0.0017		0.0059	no	<G
Ni	mg/L	0.025[h]	0.0008	0.0009		0.0016	no	<G
Se	mg/L	0.001	0.0002	0.0003	0.005	0.0018	no	<SSWQO
Ag	mg/L	0.0001	0.0006	0.0007		0.00010	no	<G
Tl	mg/L	0.0008	0.0055	0.0061		0.0009	no	<B+10%
U	mg/L	0.015	0.0057	0.0063	0.027	0.010	no	<G
V	mg/L		0.0004	0.0005		0.0010	yes	>B+10%
Zn	mg/L	0.03	0.0026	0.0028	0.11	0.028	no	<G

Notes:

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.

[b] Mean measured baseline concentration plus 10 percent.

[c] As derived in Section 6.3.

[d] Predicted 95th percentile concentration.

[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.

[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.

[g] Guideline for nitrate.

[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.

[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$

[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.

[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7^{o}C and a pH of 8.

[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

[n] Chromium was not retained as a COPC as it does not exceed the CCME CWQG for trivalent chromium [Cr(III)] of 0.0089 mg/L. Chromium in surface waters is likely to be present as Cr(III) given that Cr(VI) is reduced to Cr(III) in the presence of natural organic cations (humic and fulvic acids, tannic acids).

[o] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-14: Comparison of Predicted Chemical Concentrations in Surface Waters of Peanut Lake during Post-closure to Guidelines, Baseline Concentrations and Site-Specific Water Quality Objectives

Peanut Lake								
Chemical	**Units**	**CCME Fresh Water Aquatic Life Guidelines[a]**	**Baseline Concentration**	**+10% Baseline[b]**	**Site Specific Water Quality Objectives[c]**	**Predicted Concentration Post-Closure Phase[d]**	**COPC?[e]**	**Rationale[f]**
Nutrients								
Ammonia	mg-N/L	1.1[k]	0.0286	0.0314	4.16	0.07	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0808	0.0889	30,022	0.16	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.6270	0.6897		1.08	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0155	0.0171		0.017	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS								
Calcium	mg/L		7.6224	8.3847	-	10.6	no	Essential and non-toxic
Chloride	mg/L		1.3885	1.5273	353	3.51	no	<SSWQO
Magnesium	mg/L		3.5200	3.8720		5.63	no	Essential and non-toxic
Potassium	mg/L		1.2500	1.3750		8.9	no	Essential and non-toxic
Sodium	mg/L		2.7203	2.9924		4.08	no	Essential and non-toxic
Sulphate	mg/L		1.4128	1.5541	500	8.5	no	<SSWQO
Total Dissolved Solids	mg/L	500[n]	61.2500	67.3750		75.0	no	<G
Total Metals								
Al	mg/L	0.1[l]	0.1023	0.1125	0.41	0.17	no	<SSWQO
Sb	mg/L		0.0002	0.0002	0.03	0.0012	no	<SSWQO
As	mg/L	0.005	0.0040	0.0044	0.05	0.006	no	<SSWQO
Ba	mg/L		0.0102	0.0112		0.013	yes	>B+10%
Be	mg/L		0.0005	0.0006		0.000051	no	<B+10%
B	mg/L	1.5	0.0196	0.0215		0.013	no	<G
Cd	mg/L	0.000017[i]	0.0002	0.0002	0.00015	0.000029	no	<B+10%
Cr	mg/L	0.001[j]	0.0014	0.0015		0.0010	no	<G
Co	mg/L		0.0006	0.0007	0.01	0.0006	no	<B+10%
Cu	mg/L	0.002[h]	0.0010	0.0010	0.022	0.0019	no	<G
Fe	mg/L	0.3	0.3232	0.3556	1.5	0.58	no	<SSWQO
Pb	mg/L	0.001[h]	0.0007	0.0007	0.0076	0.00058	no	<G
Mn	mg/L		0.0388	0.0426		0.06	yes	>B+10%
Hg	mg/L	0.000026	0.0001	0.0001		0.000016	no	<G
Mo	mg/L	0.073	0.0015	0.0016		0.0018	no	<G
Ni	mg/L	0.025[h]	0.0009	0.0010		0.0014	no	<G
Se	mg/L	0.001	0.0003	0.0003	0.005	0.0006	no	<G
Ag	mg/L	0.0001	0.0007	0.0007		0.00004	no	<G
Tl	mg/L	0.0008	0.0061	0.0067		0.00025	no	<G
U	mg/L	0.015	0.0062	0.0068	0.027	0.0029	no	<G
V	mg/L		0.0004	0.0005		0.0009	yes	>B+10%
Zn	mg/L	0.03	0.0037	0.0041	0.11	0.011	no	<G

Notes:

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.

[b] Mean measured baseline concentration plus 10 percent.

[c] As derived in Section 6.3.

[d] Predicted 95th percentile concentration.

[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.

[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.

[g] Guideline for nitrate.

[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.

[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$

[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.

[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7^{o}C and a pH of 8.

[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

[n] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-15: Comparison of Predicted Chemical Concentrations in Surface Waters of Burke Lake during Post-closure to Guidelines and Baseline Concentrations

Burke Lake							
Chemical	**Units**	**CCME Fresh Water Aquatic Life Guidelines[a]**	**Baseline Concentration**	**+10% Baseline[b]**	**Predicted Concentration Post-Closure Phase[d]**	**COPC?[e]**	**Rationale[f]**
Nutrients							
Ammonia	mg-N/L	1.1[k]	0.0362	0.0398	0.05	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0663	0.0729	0.13	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.7003	0.7704	0.93	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0183	0.0201	0.017	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS							
Calcium	mg/L		8.1300	8.9430	12.9	no	Essential and non-toxic
Chloride	mg/L		1.7581	1.9339	2.54	no	Essential and non-toxic
Magnesium	mg/L		3.4894	3.8383	5.44	no	Essential and non-toxic
Potassium	mg/L		1.2050	1.3255	5.2	no	Essential and non-toxic
Sodium	mg/L		2.6494	2.9143	3.99	no	Essential and non-toxic
Sulphate	mg/L		1.9914	2.1905	5.52	no	Essential and non-toxic
Total Dissolved Solids	mg/L	500[n]	65.7647	72.3412	68.7	no	<G
Total Metals							
Al	mg/L	0.1[l]	0.0715	0.0786	0.14	yes	>B+10%
Sb	mg/L		0.0003	0.0003	0.00073	yes	>B+10%
As	mg/L	0.005	0.0035	0.0038	0.004	no	<G
Ba	mg/L		0.0091	0.0100	0.012	yes	>B+10%
Be	mg/L		0.0005	0.0006	0.000031	no	<B+10%
B	mg/L	1.5	0.0189	0.0208	0.010	no	<G
Cd	mg/L	0.000017[i]	0.0002	0.0002	0.000022	no	<B+10%
Cr	mg/L	0.001[j]	0.0014	0.0015	0.0009	no	<G
Co	mg/L		0.0007	0.0008	0.0004	no	<B+10%
Cu	mg/L	0.002[h]	0.0013	0.0014	0.0016	no	<G
Fe	mg/L	0.3	0.6596	0.7255	0.52	no	<B+10%
Pb	mg/L	0.001[h]	0.0008	0.0008	0.00034	no	<G
Mn	mg/L		0.1253	0.1378	0.05	no	<B+10%
Hg	mg/L	0.000026	0.0001	0.0001	0.000014	no	<G
Mo	mg/L	0.073	0.0015	0.0016	0.0010	no	<G
Ni	mg/L	0.025[h]	0.0008	0.0009	0.0012	no	<G
Se	mg/L	0.001	0.0002	0.0003	0.0004	no	<G
Ag	mg/L	0.0001	0.0007	0.0008	0.000021	no	<G
Tl	mg/L	0.0008	0.0068	0.0075	0.00012	no	<G
U	mg/L	0.015	0.0070	0.0077	0.0016	no	<G
V	mg/L		0.0019	0.0021	0.0008	no	<B+10%
Zn	mg/L	0.03	0.0049	0.0053	0.0078	no	<G

Notes:

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.

[b] Mean measured baseline concentration plus 10 percent.

[c] As derived in Section 6.3.

[d] Predicted 95th percentile concentration.

[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.

[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.

[g] Guideline for nitrate.

[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.

[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$

[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.

[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7^{o}C and a pH of 8.

[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

[n] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

Table C-16: Comparison of Predicted Chemical Concentrations in Surface Waters of Marian River during Post-closure to Guidelines and Baseline Concentrations

Marian River							
Chemical	**Units**	**CCME Fresh Water Aquatic Life Guidelines[a]**	**Baseline Concentration**	**+10% Baseline[b]**	**Predicted Concentration Post-Closure Phase[d]**	**COPC?[e]**	**Rationale[f]**
Nutrients							
Ammonia	mg-N/L	1.1[k]	0.0251	0.0276	0.07	no	<G
Nitrate and Nitrite	mg-N/L	2.93[g]	0.0497	0.0547	0.15	no	<G
Total Kjeldahl Nitrogen	mg-N/L		0.6680	0.7348	1.50	no	See note [m]
Total Phosphorus	mg-P/L	Guidance Framework	0.0124	0.0137	0.018	no	<Trigger range for mesotrophic lakes and rivers and/or <B+50%
Major Ions and TDS							
Calcium	mg/L		20.8600	22.9460	50.7	no	Essential and non-toxic
Chloride	mg/L		2.4692	2.7161	5.37	no	Essential and non-toxic
Magnesium	mg/L		9.1088	10.0197	21.8	no	Essential and non-toxic
Potassium	mg/L		1.5908	1.7499	3.95	no	Essential and non-toxic
Sodium	mg/L		3.2540	3.5794	7.5	no	Essential and non-toxic
Sulphate	mg/L		16.7000	18.3700	42	no	Essential and non-toxic
Total Dissolved Solids	mg/L	500[n]	120.1818	132.2000	240	no	<G
Total Metals							
Al	mg/L	0.1[l]	0.0728	0.0801	0.07	no	<G
Sb	mg/L		0.0002	0.0002	0.00007	no	<B+10%
As	mg/L	0.005	0.0006	0.0007	0.001	no	<G
Ba	mg/L		0.0142	0.0157	0.030	yes	>B+10%
Be	mg/L		0.0005	0.0006	0.000032	no	<B+10%
B	mg/L	1.5	0.0234	0.0257	0.035	no	<G
Cd	mg/L	0.000017[i]	0.0001	0.0001	0.000047	no	<B+10%
Cr	mg/L	0.001[j]	0.0014	0.0016	0.00077	no	<G
Co	mg/L		0.0006	0.0007	0.00021	no	<B+10%
Cu	mg/L	0.002[h]	0.0007	0.0008	0.0017	no	<G
Fe	mg/L	0.3	0.1636	0.1799	0.28	no	<G
Pb	mg/L	0.001[h]	0.0005	0.0005	0.00029	no	<G
Mn	mg/L		0.0246	0.0270	0.06	yes	>B+10%
Hg	mg/L	0.000026	0.00004	0.00004	0.000078	yes	>B+10%
Mo	mg/L	0.073	0.0015	0.0016	0.00044	no	<G
Ni	mg/L	0.025[h]	0.0010	0.0011	0.0020	no	<G
Se	mg/L	0.001	0.0003	0.0003	0.0007	no	<G
Ag	mg/L	0.0001	0.0005	0.0005	0.000012	no	<G
Tl	mg/L	0.0008	0.0040	0.0044	0.0000081	no	<G
U	mg/L	0.015	0.0046	0.0051	0.0018	no	<G
V	mg/L		0.0006	0.0006	0.0011	yes	>B+10%
Zn	mg/L	0.03	0.0062	0.0068	0.02	no	<G

Notes:

[a] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQGs) for the Protection of Aquatic Life.

[b] Mean measured baseline concentration plus 10 percent.

[c] As derived in Section 6.3.

[d] Predicted 95^{th} percentile concentration.

[e] Yes = chemical exceeds the CCME CWQG for the Protection of Aquatic Life, is greater than 10% over baseline and is greater than the site-specific water quality objective and therefore was retained for assessment; No = chemical did not exceed the CCME CWQG for the Protection of Aquatic Life or/and was less than 10% over baseline or/and was less than the site-specific water quality objective and therefore was not retained for assessment.

[f] B = Mean measured baseline concentration plus 10 percent; G = CCME CWQG for the Protection of Aquatic Life; SSWQO = Site Specific Water Quality Objective.

[g] Guideline for nitrate.

[h] The minimum CCME CWQGs for Copper, Lead, and Nickle were used regardless of water hardness.

[i] The CCME CWQG for Cadmium is based on a water hardness of 48.5 mg/L $CaCO_3$

[j] No CCME CWQG was available for total Chromium, so the value for Chromium VI was used.

[k] The CCME CWQG for Ammonia was derived assuming a temperature of 7 ^{o}C and a pH of 8.

[l] The CCME CWQG for Aluminum is for pH > 6.5

[m] Total Kjeldahl nitrogen (TKN) is a measure of ammonia and inorganic forms of nitrogen. There is no CCME guideline for TKN for the protection of freshwater aquatic life. Still, potential adverse affects of ammonia on freshwater aquatic life has been addressed through the screening that was completed for ammonia. There is little toxicity information for organic forms of nitrogen; however, these are minor constituents and do not appear to affect water uses (BCMOE 2009). As such, TKN has not been considered further in the aquatic RA.

[n] CCME CWQG for the Protection of Agricultural Water Uses [(Irrigation, most stringent value (for strawberries, raspberries, beans and carrots)]

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

APPENDIX D

Sediment Screening Tables

Table D-1: Comparison of Predicted Chemical Concentrations in Sediments of Nico Lake at Closure to Guidelines and Baseline Concentrations

		CCME Sediment Quality Guidelines		Baseline Sediment Concentrations	+10% Baseline[e]	Predicted Sediment Concentrations at Closure[f]	CoPC?[g]	Rationale[h]
Parameter	**Units**	**ISQG[ad]**	**PEL[bd]**					
Aluminum[c]	mg/kg	-	-	-	-	NA	NA	NA
Antimony	mg/kg	-	-	0.4	0.44	2.58	Yes	> B+10%
Arsenic	mg/kg	5.9	17	482	530.2	1,090	Yes	> B+10%
Barium	mg/kg	-	-	119	130.35	241	Yes	> B+10%
Beryllium	mg/kg	-	-	1	1.1	1.7	Yes	> B+10%
Cadmium	mg/kg	0.6	3.5	0.5	0.55	0.53	No	<G
Chromium	mg/kg	37.3	90	38	41.8	45.3	No	<G (PEL)
Cobalt	mg/kg	-	-	70	77	54.6	No	< B+10%
Copper	mg/kg	35.7	197	208.5	229.35	65.2	No	< B+10%
Iron[c]	mg/kg	-	-	-	-	NA	NA	NA
Lead	mg/kg	35	91.3	7.1	7.81	9.1	No	<G
Manganese[c]	mg/kg	-	-	-	-	NA	NA	NA
Mercury	mg/kg	0.17	0.486	0.09	0.099	0.098	No	<G
Molybdenum	mg/kg	-	-	6.5	7.15	12.2	Yes	> B+10%
Nickel	mg/kg	-	-	27.3	30.03	32	Yes	> B+10%
Selenium	mg/kg	-	-	1.2	1.32	1.02	No	< B+10%
Silver	mg/kg	-	-	1	1.1	<1	No	< B+10%
Thallium	mg/kg	-	-	1	1.1	<1	No	< B+10%
Uranium	mg/kg	-	-	17.8	19.58	17.9	No	< B+10%
Vanadium	mg/kg	-	-	35.8	39.38	70.2	Yes	> B+10%
Zinc	mg/kg	123	315	135.0	148.5	189	No	<G (PEL)

Notes:

[a] Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Interim Sediment Quality Guideline (ISQGs) (CCME 2002).

[b] Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Probable Effects Level (PEL) (CCME 2002).

[c] Sediment samples for these waterbodies were not analyzed for the noted constituents.

[d] Both guidelines have been used to assess the data; however, more emphasis has been placed on the PEL because the ISQGs are based on limited data with known information gaps and so do not necessarily indicate an ecological effect.

[e] Mean measured baseline concentration plus 10%.

[f] Predicted maximum sediment concentration.

[g] Yes = chemical exceeds the CCME CSQG for the Protection of Aquatic Life and is greater than 10% over baseline and therefore was retained for assessment; No = chemical did not exceed the CCME CSQG for the Protection of Aquatic Life or/and was less than 10% over baseline and therefore was not retained for assessment.

[h] B+10% = Mean measured baseline concentration plus 10 percent; G = CCME CSQG for the Protection of Aquatic Life.

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

NA = Sediment samples for these waterbodies were not analyzed for the noted constituents, as such predicted sediment values were not calculated.

Table D-2: Comparison of Predicted Chemical Concentrations in Sediments of Peanut Lake at Closure to Guidelines and Baseline Concentrations

		CCME Sediment Quality Guidelines		Baseline Sediment Concentrations	+10% Baseline[e]	Predicted Sediment Concentrations at Closure[f]	CoPC?[g]	Rationale[h]
Parameter	**Units**	**ISQG[ad]**	**PEL[bd]**					
Aluminum[c]	mg/kg	-	-	-	-	NA	NA	NA
Antimony	mg/kg	-	-	0.38	0.418	0.50	Yes	> B+10%
Arsenic	mg/kg	5.9	17	47	51.7	82	No	<G (GNWT)
Barium	mg/kg	-	-	194.5	213.95	225	Yes	> B+10%
Beryllium	mg/kg	-	-	1	1.1	1.01	No	< B+10%
Cadmium	mg/kg	0.6	3.5	0.5	0.55	0.51	No	< G
Chromium	mg/kg	37.3	90	72	79.2	73.3	No	< G (PEL)
Cobalt	mg/kg	-	-	19.5	21.45	26.4	Yes	> B+10%
Copper	mg/kg	35.7	197	35.5	39.05	43.8	No	<G (PEL)
Iron[c]	mg/kg	-	-	-	-	NA	NA	NA
Lead	mg/kg	35	91.3	11.7	12.826	12	No	< G
Manganese[c]	mg/kg	-	-	-	-	NA	NA	NA
Mercury	mg/kg	0.17	0.486	0.065	0.0715	0.067	No	< G
Molybdenum	mg/kg	-	-	1.5	1.65	2.02	Yes	> B+10%
Nickel	mg/kg	-	-	41	45.1	44	No	< B+10%
Selenium	mg/kg	-	-	0.3	0.33	0.69	Yes	> B+10%
Silver	mg/kg	-	-	1	1.1	<1	No	< B+10%
Thallium	mg/kg	-	-	1	1.1	<1	No	< B+10%
Uranium	mg/kg	-	-	8	8.8	8.0	No	< B+10%
Vanadium	mg/kg	-	-	59	64.9	63	No	< B+10%
Zinc	mg/kg	123	315	251.7	276.87	159	No	< G

Notes:

[a] Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Interim Sediment Quality Guideline (ISQGs) (CCME 2002).

[b] Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Probable Effects Level (PEL) (CCME 2002).

[c] Sediment samples for these waterbodies were not analyzed for the noted constituents.

[d] Both guidelines have been used to assess the data; however, more emphasis has been placed on the PEL because the ISQGs are based on limited data with known information gaps and so do not necessarily indicate an ecological effect.

[e] Mean measured baseline concentration plus 10%.

[f] Predicted maximum sediment concentration.

[g] Yes = chemical exceeds the CCME CSQG for the Protection of Aquatic Life and is greater than 10% over baseline and therefore was retained for assessment; No = chemical did not exceed the CCME CSQG for the Protection of Aquatic Life or/and was less than 10% over baseline and therefore was not retained for assessment.

[h] B+10% = Mean measured baseline concentration plus 10 percent; G = CCME CSQG for the Protection of Aquatic Life.

\- = no data / no guideline.

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

NA = Sediment samples for these waterbodies were not analyzed for the noted constituents, as such predicted sediment values were not calculated.

Table D-3: Comparison of Predicted Chemical Concentrations in Sediments of Burke Lake at Closure to Guidelines and Baseline Concentrations

		CCME Sediment Quality Guidelines		Baseline Sediment Concentrations	+10% Baseline[e]	Predicted Sediment Concentrations at Closure[f]	CoPC?[g]	Rationale[h]
Parameter	Units	ISQG[ad]	PEL[bd]					
Aluminum[c]	mg/kg	-	-	-	-	NA	NA	NA
Antimony	mg/kg	-	-	0.2	0.22	0.42	Yes	> B+10%
Arsenic	mg/kg	5.9	17	24	26.4	40.8	No	<G (GNWT)
Barium	mg/kg	-	-	228	250.8	317	Yes	> B+10%
Beryllium	mg/kg	-	-	1	1.1	1.00	No	< B+10%
Cadmium	mg/kg	0.6	3.5	0.5	0.55	0.50	No	< G
Chromium	mg/kg	37.3	90	71	78.1	82.9	No	<G (PEL)
Cobalt	mg/kg	-	-	15.7	17.27	20.4	Yes	> B+10%
Copper	mg/kg	35.7	197	34	37.4	42.2	No	<G (PEL)
Iron[c]	mg/kg	-	-	-	-	NA	NA	NA
Lead	mg/kg	35	91.3	10.5	11.55	12	No	< G
Manganese[c]	mg/kg	-	-	-	-	NA	NA	NA
Mercury	mg/kg	0.17	0.486	0.06	0.066	0.060	No	< G
Molybdenum	mg/kg	-	-	1	1.1	1.41	Yes	> B+10%
Nickel	mg/kg	-	-	43	47.3	51	Yes	> B+10%
Selenium	mg/kg	-	-	0.2	0.22	0.59	Yes	> B+10%
Silver	mg/kg	-	-	1	1.1	<1	No	< B+10%
Thallium	mg/kg	-	-	1	1.1	<1	No	< B+10%
Uranium	mg/kg	-	-	7.5	8.25	9	Yes	> B+10%
Vanadium	mg/kg	-	-	61.7	67.87	72	Yes	> B+10%
Zinc	mg/kg	123	315	100	110	140	No	<G (PEL)

Notes:

[a] Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Interim Sediment Quality Guideline (ISQGs) (CCME 2002).

[b] Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Probable Effects Level (PEL) (CCME 2002).

[c] Sediment samples for these waterbodies were not analyzed for the noted constituents.

[d] Both guidelines have been used to assess the data; however, more emphasis has been placed on the PEL because the ISQGs are based on limited data with known information gaps and so do not necessarily indicate an ecological effect.

[e] Mean measured baseline concentration plus 10%.

[f] Predicted maximum sediment concentration.

[g] Yes = chemical exceeds the CCME CSQG for the Protection of Aquatic Life and is greater than 10% over baseline and therefore was retained for assessment; No = chemical did not exceed the CCME CSQG for the Protection of Aquatic Life or/and was less than 10% over baseline and therefore was not retained for assessment.

[h] B+10% = Mean measured baseline concentration plus 10 percent; G = CCME CSQG for the Protection of Aquatic Life.

\- = no data / no guideline.

Shaded chemicals have been identified as chemicals of potential concern (CoPCs).

NA = Sediment samples for these waterbodies were not analyzed for the noted constituents, as such predicted sediment values were not calculated.

APPENDIX E

Exposure Concentrations in Surface Water

Table E-1: Exposure Point Concentrations for Surface Water during Construction (Upper-Bound Estimate)

COPC	Units	Nico Lake		Peanut Lake		Burke Lake		Marian River	
		Mean Baseline Concentration	Predicted Surface Water Concentration[a]	Mean Baseline Concentration	Predicted Surface Water Concentration[a]	Mean Baseline Concentration	Predicted Surface Water Concentration[a]	Mean Baseline Concentration	Predicted Surface Water Concentration[a]
Aluminum	mg/L	-	-	0.1023	0.51	0.0715	0.21	-	-
Arsenic	mg/L	-	-	-	-	0.0035	0.007	-	-
Barium	mg/L	0.0083	0.013	0.0102	0.013	0.0091	0.011	0.0142	0.030
Cobalt	mg/L	-	-	-	-	0.0007	0.0009	-	-
Manganese	mg/L	-	-	0.0388	0.043	-	-	0.0246	0.06
Mercury	mg/L	-	-	-	-	-	-	0.000036	0.000080
Vanadium	mg/L	0.00041	0.00073	0.0004	0.0008	-	-	0.00058	0.0011

Notes:
- Not a COPC
[a] Predicted 95th percentile concentration.

Table E-2: Exposure Point Concentrations for Surface Water during Operations (Upper-Bound Estimate)

COPC	Units	Nico Lake		Peanut Lake		Burke Lake		Marian River	
		Mean Baseline Concentration	Predicted Surface Water Concentration[a]	Mean Baseline Concentration	Predicted Surface Water Concentration[a]	Mean Baseline Concentration	Predicted Surface Water Concentration[a]	Mean Baseline Concentration	Predicted Surface Water Concentration[a]
Aluminum	mg/L	0.043	1.31	0.1023	0.73	0.0715	0.58	0.0728	0.11
Antimony	mg/L	-	-	-	-	0.0003	0.00043	-	-
Arsenic	mg/L	-	-	-	-	0.0035	0.018	-	-
Barium	mg/L	0.0083	0.023	0.0102	0.016	0.0091	0.015	0.0142	0.030
Cobalt	mg/L	-	-	-	-	0.0007	0.0025	-	-
Copper	mg/L	-	-	-	-	0.0013	0.0026	-	-
Iron	mg/L	0.6851	3.30	0.3232	1.81	0.6596	1.49	0.1636	0.31
Manganese	mg/L	-	-	0.0388	0.06	-	-	0.0246	0.06
Mercury	mg/L	-	-	-	-	-	-	0.000036	0.000077
Vanadium	mg/L	0.00041	0.0012	0.0004	0.0009	-	-	0.00058	0.0011

Notes:
- Not a COPC
[a] Predicted 95th percentile concentration.

Table E-3: Exposure Point Concentrations for Surface Water during Active Closure (Upper-Bound Estimate)

COPC	Units	Nico Lake		Peanut Lake		Burke Lake		Marian River	
		Mean Baseline Concentration	Predicted Surface Water Concentration[a]	Mean Baseline Concentration	Predicted Surface Water Concentration[a]	Mean Baseline Concentration	Predicted Surface Water Concentration[a]	Mean Baseline Concentration	Predicted Surface Water Concentration[a]
Aluminum	mg/L	0.043	1.09	0.1023	0.53	0.0715	0.49	-	-
Antimony	mg/L	-	-	-	-	0.0003	0.00047	-	-
Arsenic	mg/L	-	-	-	-	0.0035	0.015	-	-
Barium	mg/L	0.0083	0.024	0.0102	0.015	0.0091	0.014	0.0142	0.030
Cobalt	mg/L	-	-	-	-	0.0007	0.0022	-	-
Copper	mg/L	-	-	-	-	0.0013	0.0023	-	-
Iron	mg/L	0.6851	2.89	-	-	0.6596	1.31	0.1636	0.30
Manganese	mg/L	-	-	0.0388	0.06	-	-	0.0246	0.06
Mercury	mg/L	-	-	-	-	-	-	0.000036	0.00008
Selenium	mg/L	-	-	-	-	0.0002	0.0011	-	-
Vanadium	mg/L	0.00041	0.0012	0.0004	0.0009	-	-	0.00058	0.0011

Notes:
- Not a COPC
[a] Predicted 95th percentile concentration.

Table E-4: Exposure Point Concentrations for Surface Water during Post-Closure (Upper-Bound Estimate)

COPC	Units	Nico Lake		Peanut Lake		Burke Lake		Marian River	
		Mean Baseline Concentration	Predicted Surface Water Concentration[a]	Mean Baseline Concentration	Predicted Surface Water Concentration[a]	Mean Baseline Concentration	Predicted Surface Water Concentration[a]	Mean Baseline Concentration	Predicted Surface Water Concentration[a]
Aluminum	mg/L	-	-	-	-	0.0715	0.14	-	-
Antimony	mg/L	-	-	-	-	0.0003	0.00073	-	-
Barium	mg/L	0.0083	0.021	0.0102	0.013	0.0091	0.012	0.0142	0.030
Manganese	mg/L	0.0742	0.078	0.0388	0.06	-	-	0.0246	0.06
Mercury	mg/L	-	-	-	-	-	-	0.000036	0.000078
Vanadium	mg/L	0.00041	0.0010	0.0004	0.0009	-	-	0.00058	0.0011

Notes:
- Not a COPC
[a] Predicted 95th percentile concentration.

Table E-5: Exposure Point Concentrations for Surface Water during Construction (Central-Tendancy Estimate)

COPC	Units	Nico Lake		Peanut Lake		Burke Lake		Marian River	
		Mean Baseline Concentration	Mean Predicted Surface Water Concentration	Mean Baseline Concentration	Mean Predicted Surface Water Concentration	Mean Baseline Concentration	Mean Predicted Surface Water Concentration	Mean Baseline Concentration	Mean Predicted Surface Water Concentration
Aluminum	mg/L	-	-	0.1023	0.33	0.0715	0.18	-	-
Arsenic	mg/L	-	-	-	-	0.0035	0.0059	-	-
Barium	mg/L	0.0083	0.011	0.0102	0.012	0.0091	0.010	0.0142	0.015
Cobalt	mg/L	-	-	-	-	0.0007	0.00073	-	-
Manganese	mg/L	-	-	0.0388	0.0249	-	-	0.0246	0.031
Mercury	mg/L	-	-	-	-	-	-	0.000036	0.000011
Vanadium	mg/L	0.00041	0.00063	0.0004	0.00057	-	-	0.00058	0.00042

Notes:
- Not a COPC

Table E-6: Exposure Point Concentrations for Surface Water during Operations (Central-Tendancy Estimate)

COPC	Units	Nico Lake		Peanut Lake		Burke Lake		Marian River	
		Mean Baseline Concentration	Mean Predicted Surface Water Concentration	Mean Baseline Concentration	Mean Predicted Surface Water Concentration	Mean Baseline Concentration	Mean Predicted Surface Water Concentration	Mean Baseline Concentration	Mean Predicted Surface Water Concentration
Aluminum	mg/L	0.043	0.84	0.1023	0.43	0.0715	0.34	0.0728	0.045
Antimony	mg/L	-	-	-	-	0.0003	0.00035	-	-
Arsenic	mg/L	-	-	-	-	0.0035	0.0099	-	-
Barium	mg/L	0.0083	0.018	0.0102	0.013	0.0091	0.012	0.0142	0.015
Cobalt	mg/L	-	-	-	-	0.0007	0.0014	-	-
Copper	mg/L	-	-	-	-	0.0013	0.0018	-	-
Iron	mg/L	0.6851	2.21	0.3232	1.12	0.6596	0.94	0.1636	0.16
Manganese	mg/L	-	-	0.0388	0.027	-	-	0.0246	0.031
Mercury	mg/L	-	-	-	-	-	-	0.000036	0.000011
Vanadium	mg/L	0.00041	0.00092	0.0004	0.00060	-	-	0.00058	0.00042

Notes:
- Not a COPC

Table E-7: Exposure Point Concentrations for Surface Water during Active Closure (Central-Tendancy Estimate)

COPC	Units	Nico Lake		Peanut Lake		Burke Lake		Marian River	
		Mean Baseline Concentration	Mean Predicted Surface Water Concentration	Mean Baseline Concentration	Mean Predicted Surface Water Concentration	Mean Baseline Concentration	Mean Predicted Surface Water Concentration	Mean Baseline Concentration	Mean Predicted Surface Water Concentration
Aluminum	mg/L	0.043	0.64	0.1023	0.29	0.0715	0.25	-	-
Antimony	mg/L	-	-	-	-	0.0003	0.00038	-	-
Arsenic	mg/L	-	-	-	-	0.0035	0.0068	-	-
Barium	mg/L	0.0083	0.018	0.0102	0.012	0.0091	0.011	0.0142	0.015
Cobalt	mg/L	-	-	-	-	0.0007	0.0010	-	-
Copper	mg/L	-	-	-	-	0.0013	0.0016	-	-
Iron	mg/L	0.6851	1.79	-	-	0.6596	0.73	0.1636	0.15
Manganese	mg/L	-	-	0.0388	0.030	-	-	0.0246	0.031
Mercury	mg/L	-	-	-	-	-	-	0.000036	0.000011
Selenium	mg/L	-	-	-	-	0.0002	0.00056	-	-
Vanadium	mg/L	0.00041	0.00089	0.0004	0.00051	-	-	0.00058	0.00042

Notes:
- Not a COPC

Table E-8: Exposure Point Concentrations for Surface Water during Post-Closure (Central-Tendancy Estimate)

COPC	Units	Nico Lake		Peanut Lake		Burke Lake		Marian River	
		Mean Baseline Concentration	Mean Predicted Surface Water Concentration	Mean Baseline Concentration	Mean Predicted Surface Water Concentration	Mean Baseline Concentration	Mean Predicted Surface Water Concentration	Mean Baseline Concentration	Mean Predicted Surface Water Concentration
Aluminum	mg/L	-	-	-	-	0.0715	0.11	-	-
Antimony	mg/L	-	-	-	-	0.0003	0.00052	-	-
Barium	mg/L	0.0083	0.016	0.0102	0.011	0.0091	0.010	0.0142	0.015
Manganese	mg/L	0.0742	0.059	0.0388	0.032	-	-	0.0246	0.031
Mercury	mg/L	-	-	-	-	-	-	0.000036	0.000011
Vanadium	mg/L	0.00041	0.00074	0.0004	0.00043	-	-	0.00058	0.00042

Notes:
- Not a COPC

APPENDIX F

Exposure Concentrations in Sediment

Table F-1: Exposure Point Concentrations for Sediments of Nico Lake, Peanut Lake and Burke Lake at Closure (Upper-Bound Estimate)

CoPC	Units	Nico Lake		Peanut Lake		Burke Lake	
		Mean Baseline Concentration	Maximum Predicted Sediment Concentration	Mean Baseline Concentration	Maximum Predicted Sediment Concentration	Mean Baseline Concentration	Maximum Predicted Sediment Concentration
Antimony	mg/kg	0.4	2.58	0.35	0.50	0.2	0.42
Arsenic	mg/kg	482	1,090	-	-	-	-
Barium	mg/kg	119	241	194.5	225	228	317
Beryllium	mg/kg	1	1.7	-	-	-	-
Cobalt	mg/kg	-	-	19.5	26.4	15.5	20.4
Molybdenum	mg/kg	6.5	12.2	1.5	2.02	1	1.41
Nickel	mg/kg	27.5	32	-	-	43	51
Selenium	mg/kg	-	-	0.3	0.69	0.2	0.59
Uranium	mg/kg	-	-	-	-	7.5	9
Vanadium	mg/kg	35.5	70.2	-	-	61.5	72

Notes:
"-" = Not a CoPC.

Table F-2: Exposure Point Concentrations for Sediments of Nico Lake, Peanut Lake and Burke Lake at Closure (Central Tendancy Estimate)

CoPC	Units	Nico Lake		Peanut Lake		Burke Lake	
		Mean Baseline Concentration	Median Predicted Sediment Concentration	Mean Baseline Concentration	Median Predicted Sediment Concentration	Mean Baseline Concentration	Median Predicted Sediment Concentration
Antimony	mg/kg	0.4	0.33	0.35	0.30	0.2	0.23
Arsenic	mg/kg	482	436	-	-	-	
Barium	mg/kg	119	142	194.5	193	228	231
Beryllium	mg/kg	1	1.0	-	-	-	-
Cobalt	mg/kg	-	-	19.5	19.5	15.5	15.9
Molybdenum	mg/kg	6.5	6.0	1.5	1.33	1	1.01
Nickel	mg/kg	27.5	30.2	-	-	43	43.5
Selenium	mg/kg	-	-	0.3	0.34	0.2	0.21
Uranium	mg/kg	-	-	-	-	7.5	7.1
Vanadium	mg/kg	35.5	41.1	-	-	61.5	61.5

Notes:
"-" = Not a CoPC.

APPENDIX G

Derivation of Toxicity Benchmarks for Copper for Burke Lake

Table G-1: Suface Water Quality Input Parameters for Burke Lake for the Copper Biotic Ligand Model

Water Body	Sampling Date	Temperature	pH	Cu	DOC	HA [1]	Ca	Mg	Na	K	SO4	Cl	Alkalinity	S [1]
		°C		ug/L	mg C/L	%	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L $CaCO_3$	mg/L
Burke Lake Inflow	17-Jun-2009	16.4	7.41	6.9	15.1	10	7.98	3.24	2.4	1.24	1.48	0.68	30.9	1E-10
Burke Lake Inflow	08-Apr-2010	0.43	7.5	***1***	13.9	10	8.99	4.22	3	1.41	1.51	0.95	42	1E-10
Burke Lake-Deep Top	17-Jun-2009	15.6	7.36	***1***	11.7	10	6.29	2.72	2	0.94	3.04	1.53	30.1	1E-10
Burke Lake-Deep Top	29-Aug-2009	14.8	7.74	***1***	14.3	10	7.57	3.08	2.4	1.12	1.76	1.02	31.5	1E-10
Burke Lake-Deep Top	04-Apr-2010	1.29	7.4	***1***	16.2	10	10.7	4.88	3.4	1.54	1.8	1.25	46.8	1E-10
Burke Lake-Shallow	15-Jun-2007	15.8	7.6	1.6	11.7	10	6.57	2.81	2.13	1.07	*0.5*	1	28	1E-10
Burke Lake-Shallow	22-Mar-2008	1E-10	7.5	0.9	16.2	10	11	4.6	3.9	1.7	3	2	47	1E-10
Burke Lake-Shallow	17-Jun-2009	15.4	7.42	***1***	12.6	10	6.28	2.69	2	0.99	2.14	1.13	29.8	1E-10
Burke Lake-Shallow	29-Aug-2009	15.8	7.75	***1***	14.4	10	7.62	3.16	2.6	1.2	1.78	1.04	32	1E-10
Burke Lake-Shallow	04-Apr-2010	0.96	7.39	1	15.8	10	11.5	4.9	3.2	1.4	2.42	1.74	48.3	1E-10
Burke Lake Outflow	17-Jun-2009	15.8	7.39	1.8	12.7	10	6.73	2.87	1.9	1.13	1.83	0.97	28.6	1E-10
Burke Lake Outflow	08-Apr-2010	1.32	7.59	1	15.5	10	12.8	5.51	3.5	1.53	2.44	1.66	51.1	1E-10

Notes:

1. Assumed value (BLM User's Guide and Reference Manual, February 2007).

Bold/Italicized text = <method detection limit (mdl).

mg/L = milligram per litre

Table G-2: Water Quality Criteria for Copper for Burke Lake

Water Body	Sampling Date	Final Acute Value (FAV), ug/L	CMC[1] (CMC=FAV/2), ug/L	CCC[2] (CCC=FAV/ACR), ug/L	Cu Concentration[3] ug/L	Acute Toxic Units (Acute TU=Cu/CMC)
Burke Lake Inflow	17-Jun-09	104.8509	52.4255	32.5624	6.9	0.1316
Burke Lake Inflow	8-Apr-10	103.6435	51.8218	32.1874	1	0.0193
Burke Lake-Deep Top	17-Jun-09	74.7936	37.3968	23.2278	1	0.0267
Burke Lake-Deep Top	29-Aug-09	147.1725	73.5863	45.7058	1	0.0136
Burke Lake-Deep Top	4-Apr-10	107.774	53.887	33.4702	1	0.0186
Burke Lake-Shallow	15-Jun-07	102.3091	51.1545	31.773	1.6	0.0313
Burke Lake-Shallow	22-Mar-08	121.627	60.8135	37.7724	0.9	0.0148
Burke Lake-Shallow	17-Jun-09	87.9477	43.9738	27.3129	1	0.0227
Burke Lake-Shallow	29-Aug-09	150.9218	75.4609	46.8701	1	0.0133
Burke Lake-Shallow	4-Apr-10	103.0081	51.504	31.9901	1	0.0194
Burke Lake Outflow	17-Jun-09	85.0245	42.5123	26.4051	1.8	0.0423
Burke Lake Outflow	8-Apr-10	128.2994	64.1497	39.8445	1	0.0156

Notes:

ug/L = micrograms per litre.

[1] CMC = Criterion Maximum Concentration.

[2] CCC = Criterion Continuous Concentration.

[3] Cu = Copper.

DEVELOPER'S ASSESSMENT REPORT

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