Kiggavik Project

Environmental Impact Statement

Tier 2 Volume 5

Aquatic Environment

December 2011

FOREWORD

The enclosed document forms part of the Kiggavik Project Environmental Impact Statement (EIS) submission. The submission has been prepared for the Nunavut Impact Review Board by AREVA Resources Canada Inc to fulfill the requirements of the "Guidelines for the Preparation of an Environmental Impact Statement for AREVA Resources Canada Inc's Kiggavik Project (NIRB File No. 09MN003)".

The EIS submission consists of a number of documents, as shown in the attached road map. These documents have been categorized into tiers, as follows:

- Tier 1 document (Volume 1) provides a plain language summary of the Environmental Impact Statement.

- Tier 2 documents (Volumes 2 to 10) contain technical information and provide the details of the assessments of potential Project environmental effects for each environmental compartment.

- The Tier 2 documents each have a number of technical appendices, which comprise the Tier 3 supporting documents. These include the environmental baseline reports, design reports, modelling reports and details of other studies undertaken to support the assessments of environmental effects.

ROAD MAP TO THE ENVIRONMENTAL IMPACT STATEMENT

Volume 1
Main Document

Volume 2 Project Description
- Governance and Regulatory Oversight
- Project Description
- Assessment Basis

2A Alternatives Assessment
2B Drilling and Blasting Design
2C Explosives Management Plan
2D Design of Ore and Mine Rock Pads and Ponds
2E Water Diversion and Collection Design
2F Design of Andrew Lake Dewatering Structure
2G Kiggavik-Sissons Access Road Report
2H Ore Storage Management Plan
2I Water Management Plan
2J Marine Transportation
2K Winter Road Report
2L All-season Road Report
2M Roads Management Plan
2N Borrow Pits and Quarry Management Plan
2O Airstrip Design Report
2P Occupational Health and Safety Plan
2Q Radiation Protection Plan
2R Preliminary Decommissioning Plan
2S Waste Management Plan
2T Environmental Management Plan
2U Hazardous Materials Management Plan

Volume 3 Public Engagement & Inuit Qaujimajatuqangit
- Public Engagement
- Inuit Qaujimajatuqangit

3A Public Engagement Documentation
3B Inuit Qaujimajatuqngit Documentation
3C Community Involvement Plan

Volume 4 Atmospheric Environment
- Air Quality and Climate Change
- Noise and Vibration

4A Climate Baseline
4B Air Quality
4C Air Quality Monitoring Plan
4D Long-term Climate Change
4E Noise and Vibration
4F Noise Abatement Plan

Volume 5 Aquatic Environment
- Surface Hydrology
- Hydrogeology
- Water and Sediment Quality
- Aquatic Organisms
- Fish and Fish Habitat

5A Hydrology Baseline
5B Geology and Hydrogeology Baseline
5C Aquatics Baseline
5D Groundwater Flow Model
5E Prediction of Mine Inflows
5F Mine Rock Characterization and Management
5G Thermal and Water Transport Modelling
5H Mine Rock Water Balance
5I Hydrology of Waste Rock Piles in Cold Climates
5J Tailings Characterization and Management
5K Historical and Climate Change Water Balance
5L Conceptual Fish Habitat Compensation Plan
5M Aquatics Effects Monitoring Plan
5N Hydrology Assessments

Volume 6 Terrestrial Environment
- Terrain
- Soils
- Vegetation
- Terrestrial Wildlife

6A Surficial Geology and Terrain Baseline
6B Vegetation and Soils Baseline
6C Wildlife Baseline
6D Wildlife Mitigation and Monitoring Plan

Volume 7 Marine Environment
- Marine Water and Sediment Quality
- Marine Mammals
- Marine Fish

7A Marine Environment Baseline
7B Underwater Acoustic Modelling

Volume 8 Human Health
- Occupational Dose Assessments
- Human Health Risk Assessment

8A Ecological and Human Health Risk Assessment
8B Radiation Protection Support Document

Volume 9 Socio-economics & Community
- Archaeology
- Socio-economics

9A Socio-economic Baseline
9B Archaeology Baseline
9C Human Resources Plan
9D Archaeological Mitigation Plan

Volume 10 Accidents and Malfunctions
- Risk Assessments
- Effects of the Environment on the Project

10A Transportation Risk Assessment
10B Spill Contingency Plan
10C Emergency Response Plan

KEY:

Tier 2 Document
Environmental Effects Assessment Report

Tier 3 Documents
List of Technical Appendices

EXECUTIVE SUMMARY – AQUATIC ENVIRONMENT

The Kiggavik Project Environmental Impact Statement (EIS) was developed in accordance with the guidelines issued by the Nunavut Impact Review Board (NIRB) to identify and assess potential environmental effects resulting from the proposed Kiggavik Project. This volume of the EIS focuses on the potential environmental effects of the proposed Project activities on the aquatic environment. The primary issues included in the assessment of effects to the aquatic environment included surface and groundwater quantity and quality; sediment quality; and project-related effects on aquatic organisms, fish, and fish habitat.

Scope of the Assessment

The scope of assessment for the Kiggavik Project was developed in consultation with regulatory agencies, Nunavut residents, resource users, and the general public. Key issues resulting from the project that were identified as pertinent to the aquatic environment included the possible effect of water extraction, storage and discharge on the downstream environment; alteration of drainage patterns and construction of diversion channels by project infrastructure; dewatering of the Andrew Lake Pit; increase in constituents of potential concern (COPC) in surface water and groundwater; effects of discharges from Project wastewater treatment plants; effects from the deposition of dust and metals; fish passage impediments at water crossings along access roads; and effects on fish due to blasting in or near water bodies.

Environmental legislation pertaining to the assessment of effects to the aquatic environment includes the Fisheries Act (which protects fish and fish habitat) and the Species at Risk Act (SARA; which protects species of conservation concern). While no SARA listed species were identified as a result of baseline studies, a number of sections of the *Fisheries Act* do apply to the proposed activities and developments associated with the Kiggavik Project. The Project must comply with Department of Fisheries and Oceans (DFO) Policy for the Management of Fish Habitat as well as a number of other controls on effluent release, fish passage, water withdrawals and diversions. As a metal mine, the Project will also be required to submit to the Metal Mining Effluent Regulations (MMER). These regulations stipulate discharge limits on harmful substances and require monitoring of effluent chemistry, water quality, and the health of aquatic organisms in the receiving environment. A number of federal and provincial environmental quality guidelines for surface water and sediment were also considered in the aquatic assessment, namely for the evaluation of the suitability of water for drinking, and its potential toxicity to aquatic organisms.

Inuit stakeholders have played a fundamental role in raising awareness of potential project interactions with the aquatic environment. Specific concerns that were raised with respect to the aquatic environment included; water quantity and its influence on such factors as water quality, sediment quality, aquatic organisms, fish habitat, fish, and species at risk; water quality as a direct value, and as a requirement for healthy aquatic ecosystems; healthy fish populations as an important component of environmental quality, and for domestic and commercial use by local residents; and protection of aquatic habitat for spawning, rearing and foraging by local fish species. Inuit Stakeholders also identified the presence of climate change through various observations, suggesting that the rate of change is relevant to the timeframe of the Project and therefore should be incorporated into aquatic assessments.

Several steps were taken to evaluate the potential effects of the Project on components of the environment which were identified as being valuable. Based on the feedback received during the consultation process, the following Valued Ecosystem Components (VECs) have been identified as important physical and biological constituents of the aquatic environment; hydrogeology, surface hydrology, water quality, sediment quality, aquatic organisms and fish habitat, and fish populations.

The assessment of effects to the aquatic environment is spatially bound by three assessment areas: the Project footprint, the Local Assessment Area (LAA), and the Regional Assessment Area (RAA). For the purposes of the Environmental Assessment, the Project footprint is the physical area covered by the Kiggavik and Sissons Mine Sites, as well as any associated Project infrastructure (i.e. utility corridors, roadways, water intake and treated water discharge structures, and airstrip). The LAA for the Project is bound by two separate regions; one that includes the lakes and tributary streams that may potentially be affected by Project activities or infrastructure, and another that includes the watercourses that could potentially be affected by the proposed winter access road corridor and the option to develop an all-season access road corridor. It is expected that any Project related effects would originate and be measurable within these boundaries. The Regional Assessment Area (RAA) for most of the aquatic VECs coincides with the LAA because all effects are contained within the LAA watersheds.

The temporal boundaries for the assessment of effects on the aquatic environment are defined based on the timing and duration of potential effects associated with the construction (3 years), operation (25 years), final closure (10 years) and post-closure phases of the project. Most effects to the aquatic environment are expected to occur during the construction and operation phases with residual effects to some VEC persisting to the post-closure period.

Existing Environment

Surface Hydrology

The hydrological environment near the Kiggavik Project is characterized by an arctic nival regime. Most streams are frozen to the stream bed throughout the winter and become active at the onset of spring snowmelt in mid-June. During the early stages of spring melt, stream discharge increases rapidly, reaching a peak level that is largely a function of the upstream watershed size. Flows gradually recede over the remainder of the open water season. Rainfall events throughout the summer may temporarily reactivate flow in small channels or cause secondary peaks in larger drainage systems. Lakes in the region are typically ice covered from October through June, with ice thicknesses of approximately 2 m. Lake levels and volumes reflect inflow and outflow characteristics and thus reach their peaks during the spring freshet in mid-June with levels and volumes typically decreasing throughout the remainder of the open-water season.

Hydrogeology

The Kiggavik Project lies within the Canadian Shield in an area of continuous permafrost. Permafrost depth is estimated to range from about 210 m depth in the area of the Main Zone, Centre Zone, and East Zone deposits to about 250 m depth in the area of the Andrew Lake deposit and End Grid deposit.

In areas of continuous permafrost, there are generally two groundwater flow regimes: a deep groundwater flow regime beneath permafrost and a shallow groundwater flow regime located in the active (seasonally thawed) layer near the ground surface. Because of the thick, low permeablility permafrost, there is little to no hydraulic connection between the two groundwater flow systems. The shallow groundwater flow regime at the Project site has little to no hydraulic connection with the groundwater regime located below deep permafrost.

In areas of continuous permafrost, the deep groundwater regime is connected by taliks (unfrozen ground) located beneath large lakes. Taliks are formed beneath lakes that do not freeze to the bottom in winter. Groundwater flow in the area of the Main Zone, Centre Zone and East Zone deposits is inferred to be south towards Fox Lake, Pointer Lake, Jaeger Lake, and Judge Sissons Lake. Groundwater in this area may also discharge to Sleek Lake, located to the southwest, and Scotch Lake, located to the southeast. In the area of the Andrew Lake, and End Grid deposits, the predominant groundwater flow direction is inferred to be southeast towards Boulder Lake, and Judge Sissons Lake.

Relatively competent rock comprises the majority of the rock domain both within and below the layer of permafrost. The hydraulic conductivity of the deep bedrock in the Project area is low and is expected to decrease at greater depths as observed at other sites in the Canadian Shield. Hydraulic tests indicate that the hydraulic conductivity (K) of the rock at the Project site might be partially related to the rock type, with syenitic gneiss and granitic rock generally having a higher K than the metasediments. The majority of testing at the site indicates low hydraulic conductivity values on the order of 1×10^{-9} m/s with greater hydraulic conductivities of up to 10^{-6} m/s measured in a few boreholes. No correlation was found between areas of greater fracturing and intervals with greater hydraulic conductivity.

Groundwater sources from both the active layer and from the deep groundwater below the permafrost are generally not presently used for drinking water in continuous permafrost regions. This is mainly due to the presence of deep permafrost, the seasonal nature of the active layer, and the availability of good quality drinking water from surface water sources. In addition in the

Kiggavik Project area it is considered unlikely that groundwater will be used as a drinking water source in the near future due to the low hydraulic conductivity of the deep aquifer, groundwater salinity, and the potential for elevated background iron and radium concentrations.

Water Quality

Lakes and streams in the mine site local study area (LSA; the local spatial boundary of the aquatic baseline studies) identified were similar to each other in terms of their water chemistry. Waterbodies were characterized by low conductivity. The pH of water was neutral to basic, indicating that the water has little to no acidity. The acid sensitivity of the water, a measure of the ability of a waterbody to buffer against acidification, was considered low to high. The total hardness, which is primarily a measure of dissolved compounds of calcium and magnesium and is mainly considered to be an aesthetic concern, indicated that the waters had very soft to soft water hardness. Nutrient concentrations, which are important in determining how biologically productive a waterbody can be, were typical of nutrient poor (oligotrophic) waterbodies in subarctic regions. Baseline water quality parameters were less than Saskatchewan Surface Water Quality Objectives (SSWQO) and Canadian Water Quality Guidelines (CWQG) with the exception of some parameters (i.e., field and laboratory measured pH, ammonia, aluminum, cadmium, chromium, cobalt, copper, iron, lead, silver, and zinc) in some lakes. Radionuclides (radioactive elements), were generally not detected or were detected in lake or stream waters near the lowest levels that can be measured (analytical detection limits).

Sediment Quality

Overall, total metal concentrations in sediment were similar among the lakes in the mine site LSA and the site access LSA. Baseline sediment quality parameters were generally less than the sediment quality guidelines (SQGs) established by the Canadian Council of Ministers of the Environment (CCME; interim Sediment Quality Guidelines, ISQG; and probable effect levels, PEL). These guidelines are considered to be benchmarks for the potential for toxicity to aquatic organisms. By design, these are conservative guidelines and are generally considered intentionally overprotective of the aquatic environment. Thus, if concentrations are below SQGs that predict minimal effects (i.e., ISQGs), then there is likely negligible ecological risk. Some sediment samples collected during the baseline program had metal concentrations (arsenic, cadmium, chromium, copper, mercury, and zinc) that were higher than one or both of these guidelines. Exceedances of arsenic, cadmium, chromium, copper, mercury, and zinc ISQGs, and mercury and zinc PELs were observed in some samples, but there were no trends evident. This indicates that background levels of these elements are naturally elevated in these sediments, and at baseline levels likely do not cause toxicity to the local aquatic biota.

Aquatic Organisms and Fish Habitat

The number of free floating algal species observed varied across the sampled lakes, with chlorophytes (green algae) and chrysophytes (golden algae) exhibiting the greatest diversity. Cyanobacteria (blue green algae) biomass was typically low in lakes sampled within the Project area. Algae possessing a cell wall made of silica (diatoms) were likewise consistently low in abundance and biomass in all lakes. Chlorophyll *a*, a pigment that can be used to estimate algal biomass, was typically measured at low concentrations. The number of free floating invertebrate species (zooplankton) observed was also variable among the sampled lakes. In general, smaller bodied zooplankton (rotifers) exhibited the highest relative density and biomass in all lakes sampled. A number of other larger crustacean zooplankton (cladoceran and calanoid copepod species) were also observed in variable densities. Overall, bottom dwelling (benthic) invertebrate communities in lakes in the LSA were characterized by low to moderate density and diversity, with midge larvae (chironomids) typically being the dominant group, followed by fingernail clams. The number of stream dwelling invertebrate groups observed was generally higher than that of the lakes of the LSA. None of the organisms identified during the benthic invertebrate and plankton surveys are federally listed as being endangered or at risk species.

Results of the fish surveys completed in the Kiggavik mine site LSA indicate that the fish community assemblages of Project area lakes are typical of those described for subarctic region Lakes. The most widely distributed fish species captured in mine site LSA lakes was Arctic grayling, which were captured in more than 70% of the 35 sampled lakes. Other commonly identified fish species included burbot, cisco, lake trout, ninespine stickleback, round whitefish and slimy sculpin. An additional 4 species were captured only in Bake Lake; Arctic char, four horn sculpin, lake whitefish and longnose sucker.

Commonly observed fish species in mine site LSA streams and at proposed stream crossings in the site access LSA included Arctic grayling, lake trout, ninespine stickleback, and slimy sculpin. burbot, cisco, lake whitefish and round whitefish were also captured in a smaller number (i.e. >3) of streams, while Arctic char and longnose sucker were captured only in the Thelon River. Stream width and proximity to overwintering lakes appeared to influence the distribution of fish species in Project area streams. The diversity of fish species in streams is highest close to over-wintering lakes, and decreases in the upper reaches of the watershed (unless a deep, over-wintering lake exists in the headwaters of a drainage system). Large-bodied fish species including Arctic grayling and lake trout were usually found in streams with bankfull widths of approximately 3 m or more, while ninespine stickleback and slimy sculpin were present in streams greater than 2 m wide.

Habitat assessment of lakes and streams in the mine site and site access LSAs was completed between 2007 and 2010. Lakes in the mine site LSA are typically shallow (many with maximum depths less than 3 m) and the water is generally well mixed with similar temperature and oxygen levels at all sampled depths. Water clarity was usually greater than 2 m and was often equal to total depth. Shoreline substrate in all lakes consisted primarily of boulder, cobble, sand and silt substrates. The shoreline slope varied from low to moderately steep. Shoreline vegetation was primarily grasses and low shrubs. In-lake cover for fish consisted of immersed vegetation along the shoreline, and/or spaces between the coarse substrate, as well as some lakes containing areas of emerging and/or underwater aquatic vegetation. Since ice thickness ranged from 1.8 m to 2.1 m by the end of the winter; it is expected that many of the shallow lakes would freeze to the bottom during winter. Smaller lakes generally start to become ice free in early June, with larger lakes becoming ice free in late June or early July. Because most lakes and ponds in the mine site LSA are shallow, most provide only seasonal foraging and rearing habitat for fish. Overwintering habitat is found in a few deeper (i.e., > 3 m) lakes in the area.

Streams in the mine site and site access LSAs were typically dominated by run and flat habitats, while pool, pond, riffle and backwater habitats were observed less frequently. Some areas of high flow (i.e., cascades, rapids), and nearly dry or standing water conditions were also observed later in the open water season. On average, streams were less than 1 m deep, however, depths ranged from a few cm to greater than 7 m in the Thelon River. Substrate consisted primarily of gravel, cobble, boulder and silt. Overhead cover consisted of undercut banks, overhanging vegetation, and ledges. In-stream cover consisted of submerged vegetation and spaces between coarse substrates, with some streams containing areas of emerging and/or underwater vegetation. Many of the larger stream systems in the LSA support Arctic grayling spawning runs, while other fish species move into the streams during the open water period to forage, or to escape predatory fish in the over-wintering lakes.

Effects Assessment for the Aquatic Environment

Surface Hydrology

Key issues for surface hydrology identified by stakeholder consultation include changes to streamflow rates and lake levels and volumes that may affect other components of the aquatic, terrestrial, and socioeconomic environments. Specific activities include the dewatering of ponds and standing water during site clearing and pad construction, dewatering the pit area of Andrew Lake, freshwater withdrawal from lakes, the collection of site and stockpile drainage, and the discharge of treated effluents.

The Project has been designed and mitigation measures have been incorporated to most effectively minimize effects to surface hydrology. For example, large waterbodies have been selected for withdrawal and discharge locations so that changes to surface hydrology are minimized. The site water management system has been designed to recycle water where possible to limit withdrawal requirements and discharge quantities. Activities associated with water withdrawal follow Fisheries and Oceans Canada procedures that indicate that no more than 10% of the under-ice volume is withdrawn from a lake during one ice covered season. Freshwater diversion channels will be constructed to route clean water around the mine sites and sedimentation ponds will be used to limit sediment loading to the receiving aquatic environment from otherwise uncontaminated runoff collection from within the mining area. Best Management Practices (BMP) will be adopted for erosion control and sediment transport on all disturbed sites including the core facilities areas and access roads during construction, through the period of operations, and during decommissioning.

Mitigation measures and project designs are predicted to effectively minimize effects to surface hydrology. Effects to flow rates are predicted to remain below 3% of the baseline peak flow. Changes in lake levels are predicted to be highest at Andrew Lake, with a short-term increase of approximately 24 cm during dewatering of the Andrew Lake Pit area, however this will occur after the spring freshet when water levels are naturally declining. All other potential changes in lake level are estimated to remain below 8 cm. Changes to under-ice volumes will follow Fisheries and Oceans Canada protocol and will remain below 10% during an ice-covered season. Runoff contributing drainage areas for Pointer Lake Outflow and Andrew Lake Outflow (the receiving environments for the Kiggavik and Sissons Sites, respectively) are predicted to decrease by less than 1% and 3%.

During construction, and through operations and decommissioning, water levels, flow rates and waterbody volumes will be monitored at locations potentially affected by project activities. These include Andrew Lake, Siamese Lake, Mushroom Lake, Judge Sissons Lake, and their outflow channels as a continuation of the baseline hydrology monitoring program.

Hydrogeology

In assessing Project effects on hydrogeology, two measureable parameters were selected. The first indicator is the elevation of lakes potentially affected by the dewatering of mines extending beneath the permafrost. This is considered to be an indicator of groundwater quantity because dewatering activities of open pit and underground mines commonly result in depressed groundwater levels in the vicinity of the mines and have the potential to impact lake levels in the study area. The second indicator is the quality of the receiving surface water bodies potentially connected hydraulically to the deep groundwater system. Groundwater represents a pathway for potential interactions between dissolved constituents in water originating from the mining activities and the surface water where the groundwater discharges. Because groundwater is not used in the Kiggavik Project area, surface water quality is considered to be the main measurable parameter of the potential long-term effects of the Project on the aquatic environment.

Effects of mine dewatering activities on groundwater levels below permafrost are predicted to be continuous during the mining period, but reversible in the medium-term, and are anticipated to have negligible ecological and socio-economic implications. The low hydraulic conductivity of the rock mass and the permafrost conditions will result in limited groundwater inflows to the proposed mines and lake levels will not be affected by mine dewatering activities. Therefore, the residual adverse effects from the Project on groundwater quantity are considered not significant.

The assessment of potential long-term effects of groundwater and COPC to surface waters from the Kiggavik and Sissons areas indicates minimal effects on background concentrations of constituents of concern in local lakes, with predicted concentrations well below water quality guidelines or comparable to baseline concentrations. Potential effects to surface waters are expected to fall within the range of background concentrations (i.e., low magnitude). Model results show that effects on groundwater and surface water receptors where groundwater discharges resulting from Project activities are expected to be low, for both current permafrost conditions and potential no-permafrost conditions that would result from dramatic warming conditions.

Given the project design features and the low hydraulic conductivity of the rock mass, all project effects on hydrogeology are predicted to be not significant.

Water Quality

Key issues for water quality identified by stakeholder consultation include changes to surface water chemistry from treated effluent discharge from the Kiggavik and Sissons Water Treatment Plants (WTP); increased dust emissions and subsequent deposition of metals and particulates as a result of mine construction and operation; and acid deposition resulting from increased air emissions. Potential alteration to surface water chemistry from these sources has the potential to affect the aquatic organisms residing in LAA waterbodies.

A number of mitigation measures and project design features will be implemented to limit effects to surface water quality. In order to reduce the potential effects of effluent release in the receiving environment, treated discharge water will be recycled to the mill for use in mill processes. The design of the WTP will also ensure that effluent quality meets or exceeds appropriate regulations. Best management practices for dust control on roads and during the pit mining operation will be implemented in order to reduce particulate and metals deposition in the Kiggavik Project area. In order to mitigate the release of acid generating materials to the atmosphere, scrubbers will be installed on emissions from the sulphuric acid plant, and emission control systems will be installed on the oil-fired power generators and/or product driers.

Modeling data indicate that changes to water quality due to effluent discharge from the Kiggavik and Sissons Water Treatment Plants are expected to occur during the operation and final closure stages of the project, but return to baseline levels post closure. For those constituents of potential concern (COPC), the concentrations are expected to be below guideline values with the exception of cadmium. For cadmium, the maximum concentrations within Judge Sissons Lake are expected to be within a factor of 2 of the appropriate threshold. Baseline levels of cadmium are, however, below detection and depending on the exact level, the concentration change may not be measureable. Other COPCs (e.g. sulphate) are expected to change relative to baseline but no appropriate threshold is available. Mitigation measures and project design features are predicted to effectively minimize effects to surface water quality. Overall, no significant adverse effects on water quality are expected.

Changes in water quality due to dust deposition are predicted to be minor and will occur primarily during the period of high flows during spring runoff. The annual minor increases in metals, radionuclides and total suspended solids (TSS; suspended sediment in the water) will occur over the operational life of the mine (about 25 years), but are not expected to exceed any applicable water quality guideline or objective, or be measurable above natural background variation. Overall, no significant adverse effects on water quality are expected due to dust deposition.

Variation in lake pH is expected to occur naturally over the operational life of the Kiggavik mine (about 25 years). These changes are in response to deposition of acids by precipitation, and the effects of seasonal freeze-thaw cycles on lake chemistry. Potential changes to lake pH due to increased acid deposition as a result of the Project are predicted to occur primarily during the summer open water period. However, any potential changes would be small (i.e., below the critical load value) and likely brief, due to the fast movement of water through exposed lakes. In conclusion, no significant adverse effects on water quality are expected, and no long-term trend towards increasing lake acidification as a result the Project is expected to occur.

Wastewater and effluent water quality will be analysed and documented regularly according to Nunavut regulatory requirements throughout mine operations, decommissioning, and after mine closure as part of compliance and follow-up monitoring. Water quality in each section of Judge Sissons Lake receiving treated effluent, as well as at the outlet of Judge Sissons Lake, will be monitored during the operations, closure and post-closure phases of the Project. Water withdrawal and wastewater/effluent discharge rates will be continually documented during the construction, operations, and closure phases of the mine. Air and dust emission levels, and dust deposition will be monitored on a regular basis near both the Kiggavik and Sissons mining operations, and adjacent to the ore haul road between the two sites to determine whether observed levels are similar to predicted levels; water quality in lakes and streams adjacent to and downstream of the Mine LAA will be monitored to confirm that metals and radionuclide concentrations, TSS and acid deposition, and lake acidification are not increasing above acceptable levels. This monitoring will occur during the construction, operational and closure phases of the Project.

Sediment Quality

The key issue identified for sediment quality as a result of the project is the potential for changes to sediment chemistry from the release of treated effluent from the Kiggavik and Sissons Water Treatment Plants. Effluent discharge can affect water quality in the receiving environment and subsequently affect the sediment through processes such as settling and absorption. Contaminant levels in sediment can have an effect on biota that reside in sediment (e.g., bottom dwelling invertebrates), as well as wildlife that may incidentally ingest sediment while feeding on other aquatic biota. Because the potential effects to sediment are potentially accumulative in response to an alteration of water chemistry, the mitigation and project design features implemented to limit potential affects to sediment quality are similar to those described for water quality.

Mitigation measures and project design features are predicted to effectively minimize effects to sediment quality. Modeling data indicate that sediment concentrations of all COPC with sediment quality guidelines are predicted to be below threshold concentrations in all segments of Judge Sissons Lake with the exception of nickel. The concentration of nickel in sediment is expected to be slightly elevated compared to the conservative guidelines which predict minimal effects to aquatic organisms during all phases of the assessment, including baseline. Given that baseline nickel levels in sediment are similar to those predicted by the future effluent release scenarios, it is not expected that the project will have a substantial effect on the levels of nickel in sediment.

Monitoring efforts planned in relation to sediment quality in the Kiggavik Project Area include periodic ongoing follow-up monitoring of sediment quality from reference and potentially impacted areas to confirm that metals, radionuclide concentrations, and lake sedimentation rates are not increasing above predicted levels in lakes adjacent to and downstream of the Mine site LAA. Sediment quality monitoring will occur during the operational and closure phases of the Project.

Aquatic Organisms and Fish Habitat

Key issues for aquatic organisms and fish habitat identified by stakeholder consultation include toxicity effects to aquatic biota from treated effluent discharge from the Kiggavik and Sissons Water Treatment Plants (WTP); and potential effects to fish and fish habitat from Project development activities. A number of instream construction activities are expected to result in the alteration, disruption and or loss of fish habitat. These include diversion and infilling of a section of the Mushroom-End Grid Stream to accommodate the Sissons Mine site; construction of a berm across the north-east portion of Andrew Lake, and subsequent dewatering of this area for construction of the Andrew Lake Pit; installation and removal of water intake structures in Siamese and Mushroom Lakes; installation and removal of effluent diffusers at two locations in Judge Sissons Lake; installation, and eventual removal, of watercourse crossings during the construction of the Sissons-Kiggavik Ore Haul Road, the potential North All-Season Road, and a number of other associated infrastructure roads.

Potential toxicity to aquatic biota from effluent release will be mitigated by environmental control features incorporated into the design of the WTP. The design of the WTP will focus on the production of effluent which meets and/or exceeds appropriate water quality guidelines. The roads constructed in association with the Project will be designed so that the natural flow paths intercepted by the route are preserved with adequately designed cross-drainage structures (i.e. culverts). Construction of stream crossings will be completed in such a way that potential effects to fish and fish habitat are mitigated. In order to compensate for the fish habitat altered by the culvert installation’s footprint, improvements to instream habitat will be made by increasing the availability of limiting fish habitat types within each affected stream. Best management practices will be utilized during the construction of the Andrew Lake Berm; sediment curtains will be installed prior to construction of the berm and before dewatering; and a fish rescue will be carried out prior to dewatering in order to minimize the potential for fish mortalities.

The assessment of change to the distribution (i.e., presence/absence of species) and abundance of aquatic organisms identified potential issues with cadmium and sulphate exposure to zooplankton. It is expected that cadmium and sulphate concentrations in select areas of Judge Sissons Lake will be elevated compared to baseline conditions. It is possible that in certain areas of the lake some of the more sensitive zooplankton species will be affected; however considering the low to moderate toxicity values predicted for zooplankton and the geographic extent of the effect, the zooplankton population of Judge Sisson Lake is expected to continue to function. Although there are residual effects, no appreciable adverse effects on the abundance and distribution of aquatic biota are expected due to changes in COPC concentrations in the receiving environment.

Several Project development activities are expected to result in the alteration, disruption and/or loss of fish habitat. Although the instream construction activities identified earlier will be designed to reduce effects to fish habitat, it is expected that these activities will result in a harmful alteration, disruption or loss (HADD) of fish habitat and the subsequent need for compensation under DFO's "no-net-loss" Policy. In order to address the concerns relating to fish habitat, a conceptual Fish Habitat Compensation Plan (FHCP) will be prepared in consultation with DFO. Following approval of the FHCP, and subsequent implementation of the various compensation works proposed therein, no additional residual uncompensated losses of fish habitat are anticipated. All habitat losses resulting from the Kiggavik Project will be fully compensated.

Aquatic organism populations and diversity will be monitored regularly during mine operation, closure, and post-closure to determine whether effluent discharge from the WTP is having measurable effects on valued ecosystem components such as phytoplankton, zooplankton, and benthic macro-invertebrate populations. This monitoring program will be combined with a similar water quality monitoring program in each section of Judge Sissons Lake receiving treated effluent, as well as at the outlet of Judge Sissons Lake.

Under MMER, AREVA is also required to conduct Environmental Effects Monitoring (EEM) to determine if effluent release is having an effect on the receiving environment. These regulations require monitoring of effluent chemistry, effluent toxicity, and water quality in the receiving environment. Biological monitoring of benthic invertebrate communities from areas exposed and unexposed to effluent is also required. These studies will be implemented according to the guidelines specified under MMER and will be designed as an adaptive approach taking into account the special issues in Northern Canada.

The FHCP will specify all mitigation and or compensation that will be required to address the expected loss of fish habitat related to the Project. Once the approved Fish Habitat Compensation works are constructed, a compliance and effectiveness monitoring program will be carried out in order to show that the compensation works have been built as specified and approved, and that they are functioning as effectively as designed. In essence, it will be shown that the compensation works have met the DFO requirement that the Project result in "no-net-loss" of fish habitat.

Fish Populations

Key issues for Aquatic Organisms and Fish Habitat identified by stakeholder consultation include; possible effects from blasting in or near water which can result damage to the internal organs of fish, kill or injure fish eggs and larvae, and alter fish behaviour; and the potential for toxicity effects to fish from treated effluent discharge from the Kiggavik and Sissons Water Treatment Plants.

DFO Guidelines state that the instantaneous pressure change (IPC) produced by blasting cannot be greater than 50 kPa in order to provide adequate protection for fish populations. Therefore, setback distances must ensure that explosive charges meet the 50 kPa guideline. Modelling for the Andrew Lake Pit construction indicated that blasting activities occurring in the portions of the pit located near the bermed edge, are too close to the lake to buffer the pressure change, and will therefore require mitigation. In addition, DFO also requires that the vibrations produced from explosions not exceed 13 mm/sec peak particle velocity in a spawning bed during the period of egg incubation. Vibration modeling indicated that the Arctic grayling spawning habitat identified in the Andrew Lake outlet stream is too close to the blasting to be protected from vibration; therefore blasting in this area will require mitigation. Potential mitigation measures available for blasting near Andrew Lake and Andrew Lake outlet stream include the use of smaller charge sizes during the open water and/or incubation season to reduce the blasting setback distance; or to complete the blasting program during the frozen water period to protect Andrew Lake fish populations, and outside of the incubation period to protect Arctic grayling egg development in the Andrew Lake outlet stream.

Potential toxicity to fish from effluent release will be mitigated by environmental control features incorporated into the design of the WTP. The design of the WTP will focus on the production of effluent which meets and or exceeds appropriate water quality guidelines. Operational measures and other mitigation measures have also been incorporated into the current Project plans which will minimize project-associated emissions.

Providing effective mitigation measures are enacted, and neither the IPC of 50 kPa, nor the vibration threshold of 13mm/sec peak particle velocity are exceeded, no residual effect to fish populations is expected.

The assessment of change to fish populations identified potential issues with cadmium exposure to predator fish (i.e., lake trout, burbot) and copper exposure to both predator and forage fish (i.e., cisco). It is expected that cadmium and copper concentrations in some shallow areas of Judge Sissons Lake will be elevated compared to baseline conditions. Due to winter ice cover, in-water cadmium and copper concentrations are predicted to increase because of a reduced volume of free-flowing water. Although residual effects are possible, no appreciable adverse effects on the abundance and distribution of predator and forage fish are expected due to changes in COPC concentrations in the receiving environment.

Monitoring programs will be developed and carried out on site at locations away from fish-bearing waterbodies to calibrate and refine the ground vibration and IPC models. This would provide site-tested ground vibration and IPC setback distance thresholds, prior to blasting programs commencing near fish sensitive waterbodies.

Fish populations will be monitored throughout the life of the Project to determine whether effluent discharge from the WTP is having measurable effects on fish health. Under MMER, AREVA is required to conduct EEM to determine if effluent release is having an effect on the receiving environment. The objective of EEM is to evaluate the effects of effluents on fish, fish habitat and the use of fisheries resources by humans. These regulations require monitoring of effluent chemistry, effluent toxicity, and water quality in the receiving environment. Biological monitoring of fish health and bottom dwelling invertebrate communities is also required. Effects on the use of fisheries resources are assessed by comparing COPC concentrations in fish tissue against fish health consumption guidelines. The design of the aquatic receiving environment programs at the Kiggavik and Sissons Mines will be compliant with EEM guidelines but will be designed as an adaptive process taking into account the special issues in Northern Canada.

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1 INTRODUCTION

1.1 BACKGROUND

The Kiggavik Project (Project) is a proposed uranium ore mining and milling operation located in the Kivalliq region of Nunavut approximately 80 km west of the community of Baker Lake (Figure 1.1-1). The Project is operated by AREVA Resources Canada Inc. (AREVA), in joint venture partnership with JCU (Canada) Exploration Co., Ltd. and Daewoo International Corp.

Within the Kiggavik Project there are two general site areas referred to herein as the Kiggavik site and the Sissons site. The two sites are located approximately 17 km apart. Three uranium ore deposits will be mined at the Kiggavik site: East Zone, Centre Zone and Main Zone. A uranium mill, related facilities, main accommodations, and landing strip will also be located at the Kiggavik site. The Sissons site has two uranium ore deposits to be mined: Andrew Lake and End Grid. Open pit mining will be used to extract the ore from the three Kiggavik deposits as well as the Andrew Lake deposit. Mining of End Grid ore will require underground methods.

All ore extracted from the mine sites will be processed through the Kiggavik mill. Mined out pits at the Kiggavik site will sequentially be used as tailings management facilities (TMFs) with East Zone being the initial TMF. The uranium product will be packaged and transported via aircraft to southern transportation networks. Initially, mill reagents, fuel and other supplies will be transported by barge to Baker Lake and then by truck to the mine site over a winter access road. An all-season road between Baker Lake and the Kiggavik Site is carried as a secondary option proposed as a contingency in case the winter road cannot adequately support the Project over its life-span.

Decommissioning of the Project will include demolition of site facilities, clean up and reclamation of any disturbed areas, closure of the TMFs and reclamation of mine rock piles to promote vegetative growth and to provide wildlife access.

The Kiggavik Project is subject to the environmental review and related licensing and permitting processes established by the Nunavut Land Claims Agreement (NLCA) (NIRB 2011), and to the licensing requirements of the Canadian Nuclear Safety Commission (CNSC). The Minister of Indian and Northern Affairs Canada referred the Kiggavik Project to the Nunavut Impact Review Board (NIRB) for a Review under Part 5 of Article 12 of the NLCA in March of 2010. Pursuant to Section 12.5.2 of the Nunavut Land Claims Agreement (NLCA):

“When a project proposal has been referred to NIRB by the Minister for review, NIRB shall, upon soliciting any advice it considers appropriate, issue guidelines to the Proponent for the preparation of an impact statement. It is the responsibility of the Proponent to prepare an impact statement in accordance with any guidelines issued by NIRB...” (NIRB 2011)

The final NIRB “Guidelines for the Preparation of an Environmental Impact Statement for AREVA Resources Canada Inc’s Kiggavik Project (NIRB File No. 09MN003)” (NIRB 2011) were issued in May of 2011.

Projection: NAD 1983 UTM Zone 14N
Creator: CDC
Date: 09/01/2011 Scale: 1:16,000,000
File:
Data Sources: *Natural Resources Canada, Geobase®, Nation Topographic Database, Geological Survey of Canada, AREVA Resources Canada Inc.*

FIGURE 1.1-1
GENERAL LOCATION OF PROPOSED KIGGAVIK PROJECT IN CANADA

ENVIRONMENTAL IMPACT STATEMENT TIER 2 VOLUME

Kiggavik Project
AREVA

AREVA Resources Canada Inc - P.O. Box 9204 - 817 - 45th Street West - Saskatoon, SK - S7K 3X5

1.2 NUNAVUT IMPACT REVIEW BOARD GUIDELINES FOR THE ENVIRONMENTAL IMPACT STATEMENT

This volume is intended to address Section 8.1.6 to 8.1.10 of the NIRB “Guidelines for the Preparation of an Environmental Impact Statement for AREVA Resources Canada Inc’s Kiggavik Project (NIRB File No. 09MN003)” (NIRB 2011).

The location of information related to each individual guideline is noted in the EIS Conformity Table (Appendix 1).

1.3 PURPOSE AND SCOPE

The EIS has been prepared in fulfillment of the requirements of the NIRB Guidelines.

The purpose of this document is to describe the Project components and activities that have the potential to interact with the aquatic environment and result in a potential environmental effect to surface hydrology, hydrogeology, water quality, sediment quality, aquatic organisms, fish habitat and fish populations. The overall objective of the Assessment is to identify the potential residual environmental effects to the aquatic environment resulting from the Project and to determine the significance of such effects.

1.4 REPORT CONTENT

In addition to this introduction, this volume consists of the following sections:

- Section 2: An overview of the Project and associated assessment basis
- Section 3: A description of the environmental assessment approach and methodology used to assess potential effects of the Project
- Section 4: A description of the scope of assessment and the methodology used for the Effects Assessment
- Section 5: A summary of the existing aquatic environment
- Section 6: An assessment of Project effects and cumulative effects to surface hydrology
- Section 7: An assessment of Project effects and cumulative effects to hydrogeology
- Section 8: An assessment of Project effects and cumulative effects to water quality
- Section 9: An assessment of Project effects and cumulative effects to sediment quality

- Section 10: An assessment of Project effects and cumulative effects to aquatic organisms and fish habitat
- Section 11: An assessment of Project effects and cumulative effects to fish populations
- Section 12: A summary of residual effects
- Section 13: A summary of mitigation measures
- Section 14: A summary of monitoring for the aquatic environment

Tier 3 documents are appended to this Volume to provide further details. These Technical Appendices are as follows:

- 5A – Hydrology Baseline
- 5B – Geology and Hydrogeology Baseline
- 5C – Aquatics Baseline
- 5D – Groundwater Flow Model
- 5E – Prediction of Water Inflows to Kiggavik Project Mines
- 5F – Mine Rock Characterization and Management
- 5G – Thermal and Water Transport Modelling
- 5H – Waste Rock Water Balance
- 5I - Hydrology of Waste Rock Piles in Cold Climates
- 5J - Tailings Characterization and Management
- 5K – Historical and Climate Change Water Balance
- 5L – Fish Habitat Compensation Plan
- 5M – Aquatics Effects Monitoring Plan
- 5N – Hydrology Assessments

2 PROJECT OVERVIEW

2.1 PROJECT FACT SHEET

Location	• Kivalliq Region of Nunavut, approximately 80 km west of Baker Lake. • The Project includes two sites: Kiggavik and Sissons (collectively called the Kiggavik Project). • The Kiggavik site is located at approximately 64°26'36.14"N and 97°38'16.27"W. • The Sissons site is located approximately 17 km southwest of Kiggavik at 64°20'17.61"N and 97°53'14.03"W. • The Kiggavik and Sissons sites are composed of 37 mineral leases, covering 45,639 acres.
Resources	• The total quantity of resources is currently estimated at approximately 51,000 tonnes uranium (133 million lbs U_3O_8) at an average grade of 0.46% uranium.
Life of Mine	• Approximately 12 years of operation, based on studies to date. It is anticipated that pre-operational construction will require 3 years while remaining post-operational decommissioning activities will require 5 years. • Under favourable market conditions, construction of the Project could begin as early as 2017.
Mining	• There are five individual mines proposed for the Project: East Zone, Center Zone and Main Zone at the Kiggavik site; End Grid and Andrew Lake at the Sissons site. • The three Kiggavik deposits and the Andrew Lake deposit will be mined by truck-shovel open pit, while End Grid will be an underground mine.
Mine Rock	• Mine rock will be segregated into material suitable for use in construction (Type 1), non-acid generating (Type 2), and potentially problematic material (Type 3). • Type 2 and Type 3 rock will be managed in surface stockpiles during operation. • Upon completion of mining, Type 3 mine rock will be backfilled into mined-out pits.
Mill	• The ore will be processed in a mill at the Kiggavik site to produce approximately 3,800 tonnes uranium (9.9 million lbs U3O8) per year as a uranium concentrate, commonly referred to as yellowcake.
Tailings	• The mill tailings will be managed at in-pit tailings management facilities constructed using the mined-out East Zone, Centre Zone and Main Zone open pits at the Kiggavik site. • Administrative and action levels will be used to control and optimize tailings preparation performance for key parameters.
Water Management	• A purpose-built-pit will be constructed at the Kiggavik site to optimize water management, storage, and recycling. • All mill effluent, tailings reclaim, and site drainage will be treated prior to discharge to meet the Metals Mining Effluent Regulations and site-specific

	derived effluent release targets. • Administrative and action levels will be used to control and optimize water treatment plant performance for key elements.
Site Infrastructure	• Power will be supplied by on-site diesel generators. • The operation will be fly-in/fly-out on a 7 to 14 day schedule with on-site employees housed in a permanent accommodations complex.
Access	• Access to the site will be provided by either a winter or all-season road between Baker Lake and Kiggavik. Supplies will be shipped to a dock facility at Baker Lake during the summer barge season and trucked to Kiggavik via the road. • An airstrip will be constructed and operated at site for transportation of personnel and yellowcake.
Environment	• Site-specific environmental studies have been on-going since 2007 • Public engagement and collection of Inuit Qaujimajatuqangit has been on-going since 2006; this information is integrated into the environmental effects assessment reports • AREVA's approach has been to integrate environmental assessment and decommissioning requirements into the Project design cycle to enhance mitigation of effects by design and to support the development of management, mitigation, and contingency plans to protect the environment
Benefits	• AREVA is negotiating an Inuit Impact Benefit Agreement with the Kivalliq Inuit Association • The total taxes and royalties to be paid on the Kiggavik project would be approximately $1 billion, payable to Nunavut Tunngavik Inc., Government of Nunavut, and Government of Canada. • The Project is expected to employ up to 750 people during construction and 400-600 people during operation.

2.2 ASSESSMENT BASIS

The purpose of the assessment basis section is to define how the expected average design parameters detailed in the Project Description (Volume 2) have been bounded to ensure the effects assessments are adequately conservative.

The assessment basis is summarized in Table 2.2-1. For biophysical and some socio-economic effects, the range value with the greatest potential to result in an adverse effect is used. In the case of socio-economic benefits, the range value resulting in the lowest benefit is used.

Table 2.2-1 Project Assessment Basis

Project Activities/Physical Works	Parameter	Units	Parameter / Assumption Values	
			Base Case (PD)	Assessment Case
Overall	Production Rate	Tonnes U per year	3,200 – 3,800	3,200 - 4,000
	Mill Feed Rate	Kilotonnes per year	69 – 946	Senes max
	Project Operating Life	Years	14	25
	Project Footprint	ha	938	1,021
Milling	Flowsheet	N/A	No SX	SX Possibly calciner
	Final Product	N/A	Non-calcined	Calcined and non-calcined
Tailings Management	Containment volume	Mm^3	28.4	30.0
	Total tailings volume (un-consolidated)	Mm3	21	30.0
	Design		Natural surround, no drain	Various design contingencies
Water Management	Freshwater requirements – no permeate or site drainage recycle	m^3/day	7,910	8,000
	Freshwater requirements – permeate and site drainage recycle	m^3/day	2,000	8,000
	Freshwater requirements - Sissons	m^3/day	500	600
	Treated effluent discharge at base quality – Kiggavik	m^3/day	2,707	3,000
	Treated effluent discharge – Sissons	m^3/day	1,700	1,700
Power Generation	Kiggavik peak load	MW	12.5	12.5 – 16.6
	Sissons peak load	MW	4.1	0 – 4.1
Logistics & Transportation	Number of barge trips – 5000t & 270 containers	Barge trips / year	9 - 31	31
	Number of barge trips – 7500t & 370 containers	Barge trips / year	7 - 22	22
	Number of truck trips – 50,000L & 48t	Truck trips / year	328 - 3233	3300

	Number of truck trips – 76,000L & 60t	Truck trips / year	243 - 2405	2500
	Number of yellowcake flights	Flights / year	310 - 350	355
	Road Route	N/A	Winter road S	Winter road S Winter road N All-season road N with cable ferry
	Dock location		Site 1	Sites 1, 2,3,4
Decommissioning	Period	Years	10	10

3 ASSESSMENT APPROACH AND METHODS

3.1 INTRODUCTION

This section describes the methods used in the assessment of environmental and socio-economic effects associated with the Kiggavik Project. The methods meet the applicable regulatory requirements while focusing the assessment on the matters of greatest environmental, social, cultural, economic and scientific importance. The methodological approach also recognizes the iterative nature of project-level environmental assessment, considering the integration of engineering design and mitigation and monitoring programs into comprehensive environmental management planning for the life of the Project.

The environmental effects assessment method is based on a structured approach that:

- Considers the factors that are required under Nunavut Land Claim Agreement,
- Focuses on issues of greatest concern,
- Affords consideration of all territorial and federal regulatory requirements for the assessment of environmental effects,
- Considers issues raised by the Inuit, regulators, government agencies and public stakeholders, and
- Integrates Project design and programs for mitigation and monitoring into a comprehensive environmental planning.

The environmental assessment focuses on specific environmental components called Valued Environmental Components (VECs) or Valued Socio-economic Components (VSECs) that are of particular value or interest to Inuit, regulators, government agencies and stakeholders. The term Valued Components (VCs) refers collectively to VECs and VSECs. Valued Components are selected based on regulatory issues and guidelines, consultation with Inuit, regulators, government agencies and stakeholders, field studies, and professional judgment of the study team. Where a VC has various sub-components that may interact in different manners with the Project, the environmental assessment may consider the environmental effects on individual Key Indicators (KIs).

The term “environmental effect” is used throughout the Application and broadly refers to the response of the biophysical or human system or a component of these systems to a disturbance from a Project action or activity or other regional actions (i.e., projects and activities).

The environmental assessment methods address Project-related and cumulative environmental effects. Project-related environmental effects are changes to the biophysical or socio-economic environment that are caused by the Project or activity arising solely because of the proposed principal works and activities, as defined by the Scope of the Project. This includes consideration of the environmental effects of malfunctions or accidents that may occur in connection with the Project. Cumulative environmental effects are changes to the biophysical or socio-economic environment that are caused by an action of the Project in combination with other past, present and future projects and activities.

In this assessment, Project-related environmental effects and cumulative environmental effects are assessed sequentially. The mechanisms through which a Project-specific environmental effect may occur are discussed first, taking into account Project design measures and mitigation that help to reduce or avoid environmental effects. The residual environmental effect is then characterized taking into account planned mitigation. At a minimum, all Project environmental effects are characterized using specific criteria (e.g., magnitude, geographic extent, duration) that are defined for each VC.

A cumulative environmental effects screening is then conducted to determine if there is potential for the Project residual environmental effect to act in a cumulative manner with similar environmental effects from other projects and activities. If there is potential for the Kiggavik Project to contribute to cumulative environmental effects, the environmental effect is assessed to determine if it has the potential to shift a component of the natural or socio-economic environment to an unacceptable state.

The environmental effects assessment approach used in this assessment involves the following steps:

- **Scoping:** Scoping of the overall assessment, which includes: issues identification; selection of VCs (and KIs, if required); description of measurable parameters; description of temporal, spatial, administrative and technical boundaries; definition of the parameters that will be used to characterize the Project-related environmental effects and cumulative environmental effects; and identification of the standards or thresholds that will be used to determine the significance of environmental effects.
- **Assessment of Project-related environmental effects:** The assessment of Project-related environmental effects, which includes: description of the mechanism(s) by which an environmental effect will occur; mitigation and environmental protection measures to reduce or eliminate the environmental effect; and evaluation and characterization of the residual environmental effects (i.e., environmental effects remaining after application of mitigation measures) of the Project on the biophysical and socio-economic environment for each development phase.
- **Evaluation of cumulative environmental effects:** The evaluation of cumulative environmental effects, which involves two tasks: screening for potential cumulative environmental effects and, if there is potential for cumulative environmental effects, assessment of cumulative environmental effects. Where an assessment of potential cumulative environmental effects is required, the residual cumulative environmental

effects of the Project are evaluated in combination with other past, present and future projects and activities.

- **Determination of significance:** The significance of Project-related and cumulative residual environmental effects is determined using standards or thresholds that are defined for each VC.
- **Monitoring:** Several different types of monitoring may be required to confirm compliance with mitigation measures or Project design features, address uncertainties or verify environmental effects predictions and/or assess the effectiveness of mitigation measures.
- **Summary:** The last step of the assessment of environmental effects on a VC is the development of summaries on Project and cumulative environmental effects (including combined Project environmental effects and combined cumulative environmental effects), mitigation measures and Project design features, and monitoring.

3.2 SCOPE OF THE ASSESSMENT

3.2.1 Valued Components, Indicators and Measurable Parameters

Valued Components are defined as broad components of the biophysical and socio-economic environments, which if altered by the Project, would be of concern to regulators, Inuit, resource managers, scientists, and public stakeholders.

VECs for the biophysical environment typically represent major components or aspects of the physical and biological environment that might be altered by the Project, and are widely recognized as important for ecological reasons.

Criteria for selection of VCs include:

- Do they represent a broad environmental, ecological or human environment component that may be altered by the Project?
- Are they vulnerable to the environmental effects of the Project and other activities in the region?
- Have they been identified as important issues of concerns of Inuit or stakeholders, or in other assessments in the region?
- Were they identified by the Nunavut Impact Review Board (NIRB), Inuit organizations or departments within the territorial or federal government?

Key indicators (KIs) are species, species groups, resources or ecosystem functions that represent components of the broader VCs. They are selected using the same criteria as described above for VCs. For practical reasons, KIs are often selected where sufficient information is available to assess the potential Project residual environmental effects and cumulative environmental effects.

For each VC or KI, one or more measurable parameters are selected to quantitatively or qualitatively measure the Project environmental effects and cumulative environmental effects. Measurable parameters provide the means of determining the level or amount of change to a VC or KI. The degree of change in the measurable parameter is used to characterize project-related and cumulative environmental effects, and evaluate the significance of these effects. Thresholds or standards are identified for each measurable parameter, where possible, to assist in determining significance of the residual environmental effect.

3.2.2 Key Issues

Issues identification focuses the assessment on matters of greatest importance related to the Project, and assists in determining which factors and the scope of those factors that will be considered in the assessment.

Issues and concern about the possible biophysical or socio-economic effects of the Project have been identified from a variety of sources, including:

- The regulatory requirements applicable to the Project,
- Discussions with technical experts from various territorial and federal government agencies,
- Input from Inuit and public stakeholders during engagement activities in relation to the Project,
- Existing regional information and documentation regarding environmental components found near the Project,
- Baseline and assessment studies conducted in the area of the Project, and
- Professional judgment of the assessment team, based on experience with similar projects elsewhere and other mining project and activities in Nunavut.

Key Project-related issues are summarized in the scoping section for each discipline considered in the assessment.

3.2.3 Project – Environment Interactions and Environmental Effects

Key Project-related activities that are likely to result in environmental effects are considered for each VC. A matrix of Project activities and environmental components is provided in the scoping section for each discipline to identify where interactions are likely to occur based on the spatial and temporal overlap between Project activities and the VC. Each interaction is ranked according to the potential for an activity to cause an environmental effect. The interactions are ranked according to the following:

- If there is no interaction or no potential for substantive interaction between a Project activity and the VC to cause a potential environmental effect, an assessment of that environmental effect is not required. These interactions are categorized as 0, and are not considered further in the EA. The environmental effects of these activities are thus, by definition, rated not significant.
- If there is likely to be a potential interaction between a Project activity and a VC but not likely to be substantive in light of planned mitigation, the interaction is categorized as 1. Such interactions are well understood and are subject to prescribed mitigation or codified practices. These interactions are subject to a less detailed environmental effects assessment and are rated as not significant. Justification is provided and the mitigation is described for such categorizations. Such interactions can be mitigated with a high degree of certainty with proven technology and practices.
- If a potential interaction between a Project activity and a VC could result in more substantive environmental effects despite the planned mitigation, if there is less certainty regarding the effectiveness of mitigation, or if there is high concern from regulatory agencies, Inuit or stakeholders, the interaction is categorized as 2. These potential interactions are subject to a more detailed analysis and consideration in the environmental assessment in order to predict, mitigate and evaluate the potential environmental effects.

The ranking takes a precautionary approach, whereby interactions with a meaningful degree of uncertainty are assigned a rank of 2 to ensure that a detailed analysis of the potential environmental effect is undertaken.

Justification for ranking the Project-environmental interactions considered for each VC is provided in the scoping section for each discipline.

3.2.4 Assessment Boundaries

Boundaries of the assessment are defined for each VC to allow for a meaningful analysis of the significance of environmental effects. The assessment boundaries are described in terms of temporal, spatial and administrative and technical boundaries.

3.2.4.1 Spatial Boundaries

Spatial boundaries are established for assessing the potential Project-related environmental effects and cumulative environmental effects on each VC. The primary consideration in establishing these boundaries is the probable geographical extent of the environmental effects (i.e., the zone of influence) on the VC.

Spatial boundaries represent the geographic extent of the VC, as they pertain to potential Project-environment interactions. Spatial boundaries are selected for each VC to reflect the geographic extent over which Project activities will or are likely to occur, and as such, they may be different from one VC to another depending on the characteristics of the VC. For this assessment, the spatial boundaries are referred to as 'assessment areas' to differentiate the areas from the local and regional study areas referred to in many baseline studies.

Three assessment areas are defined for each VC.

The ***Project Footprint*** is the most immediate area of the Project. The Project Footprint includes the area of direct physical disturbance associated with the construction or operation of the Project.

The ***Local Assessment Area (LAA)*** is the maximum area within which Project-related environmental effects can be predicted or measured with a reasonable degree of accuracy and confidence. The LAA includes the Project Footprint and any adjacent areas where Project-related environmental effects may be reasonably expected to occur.

The ***Regional Assessment Area (RAA)*** is a broader area within which cumulative environmental effects on the VC may potentially occur. This will depend on physical and biological conditions (e.g., air sheds, watersheds, seasonal range of movements, population unit), and the type and location of other past, present or reasonably foreseeable projects or activities. For the socio-economic environment, the RAA may be much broader (planning areas, regions, territories etc.) based on the potential geographic extent over which socio-economic effects are likely to occur. It is also the area where, depending on conditions (e.g., seasonal conditions, habitat use, more intermittent and dispersed Project activities), Project environmental effects may be more wide reaching.

3.2.4.2 Temporal Boundaries

The temporal boundaries for the assessment are defined based on the timing and duration of Project activities and the nature of the interactions with each VC. Temporal boundaries encompass those periods during which the VCs and KIs are likely to be affected by Project activities.

For the Kiggavik Project, temporal boundaries include the following Project phases.

- Construction;
- Operations;
- Final closure; and
- Post closure.

The operations phase includes consideration of maintenance, planned exploration and temporary closure (care & maintenance) of the Project. The final closure phase considers decommissioning and reclamation, and post-closure phase includes management of restored sites.

In some cases, temporal boundaries are refined to a specific period of time beyond simply limiting them to a specific phase of the Project. This is carried out as necessary within each environmental effects analysis section. Temporal boundaries for the assessment may reflect seasonal variations or life cycle requirements of biological VCs, long-term population cycles for some biological VECs, or forecasted trends for socio-economic VSECs.

3.2.4.3 Administrative and Technical Boundaries

Administrative and technical boundaries are identified and justified for each VC or KI, as appropriate. Administrative boundaries include specific aspects of provincial, territorial and federal regulatory requirements, standards, objectives, or guidelines, as well as regional planning initiatives that are relevant to the assessment of the Project's environmental effects on the VC. Administrative boundaries may be selected to establish spatial boundaries.

Technical boundaries reflect technical limitations in evaluating potential environmental effects of the Project, and may include limitations in scientific and social information, data analyses, and data interpretation.

3.2.5 Environmental Effects Criteria

Where possible, the following characteristics are described quantitatively for each VC to assist in the assessment of residual environmental effects. Where these residual environmental effects cannot be defined quantitatively, they are described using qualitative terms. If qualitative descriptions are used, definitions are provided for each VC or KI, as appropriate, in the scoping section of the environmental assessment for that VC or KI.

- ***Direction:*** the ultimate long-term trend of the environmental effect (e.g., positive, neutral or adverse)
- ***Magnitude:*** the amount of change in a measurable parameter or variable relative to the baseline case (i.e., low, moderate, high)
- ***Geographical Extent:*** the geographic area within which an environmental effect of a defined magnitude occurs (site-specific, local, regional, territorial, national, international)
- ***Frequency:*** the number of times during the Project or a specific Project phase that an environmental effect may occur (i.e., once, sporadically, regular, continuous)
- ***Duration:*** this is typically defined in terms of the period of time that is required until the VC returns to its baseline condition or the environmental effect can no longer be measured or otherwise perceived (i.e., short term, medium term, long term, permanent)
- ***Reversibility:*** the likelihood that a measurable parameter for the VC will recover from an environmental effect (i.e., reversible, irreversible)
- ***Ecological or socio-economic context:*** the general characteristics of the area in which the Kiggavik Project is located (i.e., undisturbed, disturbed, urban setting)

3.2.6 Standards or Thresholds for Determining Significance

Where possible, threshold criteria or standards for determining the significance of environmental effects are defined for each VC or KI to represent that limit beyond which a residual environmental effect would be considered significant. In some cases, standards or thresholds are also defined for specific environmental effects on a VC or KI.

Standards are recognized federal and territorial regulatory requirements or industry objectives that are applicable to the VC, and that reflect the limits of an acceptable state for that component. Where standards, guidelines or regulatory requirements do not specifically exist, thresholds are defined for the measurable parameters for an environmental effect on a VC based on resource management objectives, community standards, scientific literature, or ecological processes (e.g., desired states for fish or wildlife habitats or populations).

Potential changes in a measurable parameter or VC resulting from residual Project or cumulative environmental effects are evaluated against these standards or thresholds. Environmental effects are rated as either *significant or not significant*.

3.2.7 Influence of Engagement on the Assessment

Engagement undertaken to date with regulators, Inuit and public stakeholders in relation to the Project is described in Volume 3. Issues raised during these engagement activities and Inuit Qaujimajatuqangit (IQ) sessions were documented, and were reviewed for consideration in each discipline-specific assessment, including scoping of baseline data collection, selection of VC and KIs, use of TEK and IQ in the environmental effects assessment, mitigation and monitoring.

3.3 ASSESSMENT OF PROJECT ENVIRONMENTAL EFFECTS

3.3.1 Existing Conditions

The existing conditions for each VC are described according to the status and characteristics of the VC within its defined spatial and temporal assessment boundaries. This is based on a variety of sources, including:

- Information from past research conducted in the region;
- Inuit Qaujimajatuqangit (IQ); and
- Knowledge gained from the collection of baseline data through literature review, qualitative and quantitative analyses, and field programs carried out as part of the environmental assessment.

In general, the description of existing conditions is limited to information directly relevant to the potential VC interactions with the Project to support the environmental effects analysis.

3.3.2 Project Effect Linkages

The mechanisms or linkages through which the Project components and activities could result in an environmental effect on a VC, and the spatial and temporal extent of this interaction is described based on the existing conditions of the VC. Because the assessment focuses on residual environmental effects, effects prior to mitigation are not characterized or quantified and the significance of the effect is not determined.

3.3.3 Mitigation Measures and Project Design

Where Project activities are likely to cause an environmental effect on a VC, mitigation measures are identified to minimize or avoid environmental effects of the Project. This includes measures or strategies that are technically and economically feasible and that would reduce the extent, duration or magnitude of the environmental effect.

Mitigation includes Project design features to change the spatial or temporal aspect of the Project, specialized mitigation, environmental protection measures and protocols, and compensation (habitat compensation, replacement or financial compensation).

Where mitigation is identified, a brief discussion of how the measure(s) will help to minimize the residual environmental effect on the VC is provided. Where possible, this includes a description of how effective the measure is expected to be in minimizing the change in the measurable parameters for the environmental effect.

3.3.4 Residual Project Effects Assessment

Taking into account the mitigation and expected effectiveness of the measure(s), the residual environmental effects of the Project are described according to their probable magnitude, geographic scope, duration, frequency, reversibility and ecological context, where appropriate. The residual effect is characterized in the context of the existing condition for the measureable parameter(s) and how it is likely to change as a result of the Project environmental effect. For some residual environmental effects, the change in the measurable parameter is described relative to each Project phase.

Where possible, the magnitude, geographic extent and duration of the residual environmental effect are quantified. If a residual effect cannot be quantified, qualitative terms are used to describe the attributes of the effect.

3.3.5 Significance of Residual Project Environmental Effects

Significance of a residual Project environmental effect is determined based on standards or thresholds that are specific to the VEC, KI and/or the measurable parameters used to assess the environmental effect. Determination of whether a residual environmental effect is considered to be significant or not significant is based on a comparison of the predicted change in the VC or measurable parameter to the defined threshold or standard. This includes an indication of the likelihood that a residual environmental effect on a VC will occur based on probability of occurrence (i.e., based on past experience) and level of scientific uncertainty.

Determination of significance also includes a discussion of the confidence of the prediction with respect to:

- The characterization of environmental effects, and
- The success of Project design features, mitigation measures, and environmental protection measures in effectively reducing the environmental effect.

Prediction confidence for the environmental effect and the success of mitigation measures is ranked as low, moderate or high.

3.3.6 Monitoring of Residual Project Environmental Effects

Based on analysis of the residual Project environmental effect, it may be necessary to conduct a monitoring program. Monitoring is recommended in cases where there is a need to address Project-related issues of public concern, test the accuracy of the assessment predictions, verify the success of the mitigation measures, or gain additional scientific knowledge related to prediction of the Project environmental effect.

Two types of monitoring are considered: compliance and follow-up environmental monitoring.

Compliance monitoring is undertaken to confirm that Project design features, mitigation measures, environmental protection measures, or benefit agreements are being effectively implemented.

Biophysical and socio-economic monitoring programs are used to:

- Verify predictions of environmental effects;
- Determine the effectiveness of mitigation measures, environmental protection measures or benefits agreements in order to modify or implement new measures where required;
- Support the implementation of adaptive management measures to address previously unanticipated adverse environmental effects; and
- Support environmental management systems used to manage the environmental effects of projects.

Where a monitoring program for a specific VC or KI is identified, the following aspects of the program are defined:

- Parameters to be measured,
- Methods and equipment to be used,
- Location and timing of surveys, and
- How the results of the monitoring will be applied, including consideration of an adaptive management approach.

3.4 ASSESSMENT OF CUMULATIVE ENVIRONMENTAL EFFECTS

3.4.1 Screening for Potential Cumulative Effects

Cumulative environmental effects are only assessed if the following criteria are met for the residual Project effect under consideration:

- The Project will result in a measurable, demonstrable or reasonably-expected residual environmental effect on a component of the biophysical or socio-economic environment,
- The Project-specific residual environmental effect on the component will likely act in a cumulative fashion with the environmental effects of other past or future projects or activities that are likely to occur (i.e., Is there overlap of environmental effects?), and
- There is a reasonable expectation that the Project's contribution to cumulative environmental effects will be substantive, measurable or discernible such as that it will affect the viability or sustainability of the resource.

If, based on these criteria, there is potential for cumulative environmental effects, the effect is assessed further to determine if it is likely to shift the component to an unacceptable state. Where there is no potential for the environmental effect of the Project to spatially or temporally overlap with similar effects of other project and activities, justification for not carrying these environmental effects forward to the assessment of cumulative environmental effects is provided.

3.4.2 Project Inclusion List

The project inclusion list includes all past, present and reasonable foreseeable projects, activities and actions in the region of the Kiggavik Project. Only projects and activities that overlap with the Project residual environmental effects both spatially and temporally are considered in the assessment of potential cumulative environmental effects.

The specific projects, activities and action considered for each environmental effect are described in the assessment for the VC or KI.

3.4.3 Description of Cumulative Environmental Effects

The first step in the assessment of cumulative environmental effects involves describing the environmental effect, the mechanisms by which the Project environmental effect may interact cumulatively with other projects and activities in the RAA (from the Project Inclusion List), and the geographic and temporal scope of the cumulative environmental effect.

For this assessment, cumulative environmental effects are described for four cases. A more detailed description of the assessment cases is provided within the Project Inclusion List (Volume 1, Appendix 2).

3.4.3.1 Base Case

The current status of the measurable parameters for the environmental effects at baseline (i.e., prior to the Project). Baseline includes all past and present projects and activities in the RAA that may result in similar environmental effects to the Project environmental effect, including ongoing mineral exploration. Existing projects include projects that have received environmental approval and are in some form of planning, construction and/or commissioning.

3.4.3.2 Project Case

The status of the measurable parameters for the environmental effect with the Project in place, over and above the Base Case. This is usually assessed using the peak environmental effect of the Project or maximum active footprint for the Project.

3.4.3.3 Future Case

The status of the measurable parameters for the environmental effect because of the Project Case, in combination with all reasonable foreseeable projects, activities and actions. Reasonably foreseeable projects are defined as future projects, activities and actions that will occur with certainty, including projects that are in some form of regulatory approval or have made a public announcement to seek regulatory approval.

For this assessment, future projects include proposed mines that are currently under NIRB review:

- Meadowbank
- Doris North 1
- Doris North 2
- Meliadine
- Mary River
- Hackett River
- Back River
- Hackett River
- High Lake

The combination of the Project Case with the Future Case allows determination of the Project's contribution to cumulative effects of all past, present and reasonably-foreseeable projects and activities.

3.4.3.4 Far Future Case

The status of the measurable parameters for the environmental effect because of the Future Case, in combination with possible far future developments in the Kiggavik region.

It is recognized that exploration activities will continue in the vicinity of the Kiggavik Project, and that there is the potential for additional resources to be discovered during the life of the Project. To address such a possibility, a potential far future development scenario was developed. This scenario assumes additional deposits within a 200 km radius of the Kiggavik site, and the development of a non-uranium operation located within the Kiggavik RSA. The Meadowbank gold operation is used as the model for this. It assumes additional resources are found in the Meadowbank area, and that operation of Meadowbank continues. The following projects and activities are included in the development scenario.

Component	Locations
Uranium mines	3 mines within 200 km of Kiggavik
Uranium mills	Kiggavik mill
Gold mines	1 mine within Kiggavik RSA Meadowbank region
Gold mills	Meadowbank region Additional mill within Kiggavik RSA
Access Roads	Meadowbank region Additional mill within Kiggavik RSA
Exploration	Induced exploration near the access road(s) and in the Kiggavik area

Due to the lack of information regarding the specific details of potential future developments (i.e., footprint of projects and activities), the assessment of cumulative environmental effects under this Case is by definition qualitative and is limited to a description of how these projects, activities and actions could affect the magnitude, duration and extent of cumulative environmental effects.

3.4.4 Mitigation of Cumulative Environmental Effects

Mitigation measures that would reduce the Project's environmental effects are described for cumulative environmental effects, with emphasis on measures that should limit the interaction of environmental effects of the Project with similar environmental effects from other projects. Three types of mitigation measures are considered, where appropriate:

- Measures that can be implemented solely by AREVA;
- Measures that can be implemented by AREVA, in cooperation with other project proponents, government, Aboriginal organizations and/or public stakeholders; and

- Measures that can be implemented independently by other project proponents, government, Aboriginal Organizations and/or public stakeholders.

For the latter two types of mitigation, the degree to which AREVA can or cannot influence the implementation of these measures is noted.

Mitigation measures that could assist in reducing potential cumulative environmental effects are identified for each environmental effect, including a discussion of how these measures may potentially modify the characteristics of an environmental effect.

3.4.5 Residual Cumulative Environmental Effects Assessment

Residual cumulative environmental effects are described, taking into account how the mitigation will change the environmental effect. Where possible, cumulative environmental effects are characterized quantitatively or qualitatively in terms of the direction, magnitude, duration, geographic extent, frequency and reversibility. This includes characterization of:

- The total residual cumulative environmental effects based on the Future Case (i.e., the environmental effects of all past, present and reasonably foreseeable project and activities), in combination with the environmental effects of the Project; and
- The contribution of the Project to the total residual cumulative effects (i.e., how much of the total residual cumulative effects can be attributed to the Project).

3.4.6 Significance of Residual Cumulative Environmental Effects

The significance of cumulative environmental effects is determined using standards or thresholds that are specific to the VC, KI and/or measurable parameters used to assess the Project environmental effect. Determinations of significance are made for:

- The significance of the total residual cumulative environmental effect, and
- The significance of the contribution of the Project to the total residual cumulative environmental effect.

The determination of residual cumulative environmental effects includes a discussion of the confidence of the prediction based on scientific certainty relative to:

- Quantifying or estimating the environmental effect (i.e., quality and/or quantity of data, understanding of the effects mechanisms), and
- The effectiveness of the proposed mitigation measures.

As for residual Project environmental effects, prediction confidence for the cumulative environmental effect and the success of mitigation measures is ranked as low, moderate or high.

3.4.7 Monitoring of Cumulative Environmental Effects

Based on the evaluation of residual cumulative environmental effects, it may be necessary to conduct monitoring programs. Monitoring programs are designed to:

- Confirm the effectiveness of a broad range of approved mitigation techniques,
- Determine whether different or an increased level of mitigation is required to achieve the mitigation or reclamation goals, and
- Identify and address any cumulative effects that occur but were not predicted.

Two types of monitoring are considered:

- Compliance Monitoring: to confirm that Project design features, mitigation measures, environmental protection measures, or benefit agreements are being effectively implemented.
- Biophysical or Socio-economic Monitoring: to confirm the environmental effect prediction and/or effectiveness of a Project design feature, mitigation measure, environmental protection measure, or benefit agreement.

3.5 SUMMARY OF RESIDUAL ENVIRONMENTAL EFFECTS

Residual Project and cumulative environmental effects are briefly summarized for each VC. This includes a discussion of the overall combined environmental effect of the Project on the VC and its significance, as well as a discussion of the overall combined effect of all cumulative effects on the VC and its significance. For biophysical VECs, this relates to the sustainability of the resource or populations being considered. For socio-economic VSECs, this relates to the ability of the community, the Kivalliq region and/or Nunavut to adapt to or manage the environmental effect. A discussion of the Project's contribution to the combined cumulative effect is also provided.

In addition, this summary section presents an assessment of the effects of climate change on residual Project and cumulative effects. Where possible, the effects are described quantitatively, and include a description of how likely climate changes in the region will likely influence Project and cumulative residual effects.

3.6 ASSESSMENT OF TRANSBOUNDARY EFFECTS

As required by the NIRB EIS Guidelines, the assessment includes consideration of transboundary effects, where residual environmental effects are likely to extend beyond the Nunavut into federal waters and/or other provincial or territorial jurisdictions. As this is based largely on the cumulative effects assessment, the transboundary effects are characterized qualitatively or semi-quantitatively.

3.7 SUMMARY OF MITIGATION

A detailed description of the mitigation measures proposed to minimize or avoid project-related and cumulative effects on VCs is provided based on the scoping and effects analyses. This includes:

- Relevant Project design features to reduce environmental effects;
- Project policies (e.g., Inuit hiring policy);
- Specialized mitigation measures to minimize environmental effects on VECs;
- Social or community programs to minimize environmental effects on VSECs;
- Environmental Protection plans;
- Broader agreements (e.g., benefits agreements); and
- Compensation.

3.8 SUMMARY OF MONITORING

Monitoring programs to address uncertainties associated with the environmental effects predictions and environmental design features and mitigation proposed for residual Project effects and cumulative effects are described in detail. This includes all compliance monitoring and environmental monitoring that may be applied during the life of the Project, and that will form the:

- Compliance Monitoring Program Framework;
- Environmental Monitoring Program Framework;
- Socio-Economic Monitoring Program Framework;
- Post-Project Analysis Program Framework; and
- Follow-up Monitoring Programs.

4 SCOPE OF THE ASSESSMENT

The Kiggavik Project Environmental Impact Assessment (EIA) was developed in accordance with the Nunavut Impact Review Board's (NIRB) "Guidelines for the Preparation of an Environmental Impact Statement for AREVA Resources Canada Inc.'s Kiggavik Project" (NIRB File No. 09MN003) (NIRB 2011). NIRB's project specific EIS guidelines were developed based on information contained within the Kiggavik Project Proposal (AREVA 2008), and on the public scoping process carried out by NIRB. Public scoping sessions were conducted in a number of potentially affected Nunavut communities, to solicit input and advice on Valued Ecosystem Components (VECs) that should be addressed in the development of the EIS.

This section describes the scope of the assessment for the aquatic environment. Construction, operation, and decommissioning of the Kiggavik mine has the potential to result in environmental effects on the aquatic environment. The environmental effects of routine operations on the aquatic environment are addressed in Sections 6 through 11. The environmental effects of accidents and malfunctions are addressed in Volume 10.

4.1 ISSUES AND CONCERNS IDENTIFIED DURING INUIT, GOVERNMENT, AND STAKEHOLDER ENGAGEMENT

Issues and concerns identified during Inuit, government, and stakeholder engagement formed the basis for the establishment of VECs upon which the assessment is based.

Issues identified for the aquatic environment by the NIRB were included in NIRB (2011), sections 8.1.7 through 8.1.10. These issues focused on the effect of the Project on surface and groundwater quantity and quality, and on sediment quality through water extraction, surface runoff, and waste disposal. Issues also included Project effects on aquatic organisms, fish, and fish habitat associated with changes to water and sediment quality and waterbody disturbance. Specific issues related to routine project components and activities, as identified by NIRB include:

- The effect of water supply, storage and discharge locations, and quantities on the downstream environment;
- The alteration of drainage patterns and diversion channels by project facilities;
- Erosion, sedimentation, and runoff during construction and operation;
- Effects on navigability of watercourses from proposed water crossings;
- Dewatering of the Andrew Lake open pit;

- Effects of ice damming;
- Effects of permafrost and the active layer on surface water;
- Increases in contaminants and radionuclides in groundwater and surface water;
- Water quality degradation due to runoff from mine rock stockpiles, ore stockpiles, construction fills, road embankments, and open quarry sites;
- Water quality degradation associated with open pit dewatering;
- Contaminant transport due to faults in the bedrock;
- Effects of discharges from Project wastewater treatment plants;
- Effects from other waste management activities including storage and handling of waste;
- Effects of nutrient input from blasting activities;
- Effects from the deposition of particulate matter resulting from the incomplete combustion of wastes from incineration;
- Effects on riparian environments due to in-water or near-water activities;
- Effects on aquatic invertebrates and habitat from planned containment structures (e.g., sediment control structured and fuel containment structures);
- Effects on fish from changes to the aquatic or riparian environment;
- Effects on fish due to blasting in or near water bodies; and
- Fish passage impediments at water crossings along access roads.

AREVA's public consultation program included a community tour in 2009; open houses in 2010 and a blog on AREVA's website for the Kiggavik project. Thirty-one percent of respondents expressed concern over fresh water and 17 percent expressed concern over freshwater fish and fish habitat. Specific aspects of the aquatic environment presented at the consultation events that elicited responses were water flow, water quality, algae, aquatic plants, sediment, bottom feeding fish, and predatory fish. Comments from the blog surveys included the statement that water is an essential component of life and a concern that drinking water may become contaminated by the Project. Predatory fish (trout, Arctic char, and Arctic grayling) were identified as an important food source.

4.1.1 Influence of Inuit and Stakeholder Engagement on the Assessment

4.1.1.1 Groundwater

Inuit and Stakeholder engagement was used to design Project components associated with potential groundwater-related issues. Concerns related to groundwater and surface water quality were raised in the context of mine rock and tailings management. Specifically, the current cold weather conditions as well as the potential for climate change and its impact on permafrost were identified as uncertainties associated with the performance of the proposed in pit disposal of tailings.

As a result the thermal behaviour of the tailings and the rock mass surrounding the Tailings Management Facility (TMF) was simulated for several climate change scenarios and the long-term performance of the TMFs was estimated for an ultimate no-permafrost case. This approach was used to ensure that the performance of the tailings management approach during operation is not impeded by the cold weather conditions while the long-term performance of the TMFs does not rely upon the current permafrost conditions.

4.1.1.2 Surface Hydrology

Inuit stakeholders have been integral in raising awareness of potential project-environment interactions. Concerns related to water quantity were made in the context of its assessment endpoints in other disciplines such as water quality, sediment quality, aquatic organisms, fish habitat, fish, and species at risk. Concerns were also raised regarding specific project activities such as water withdrawal, wastewater discharge, water crossings, and the Andrew Lake Pit. As concerns were raised, appropriate baseline data were collected to ensure that data were available to accurately and confidently assess potential effects. Specifically, hydrological data were collected at each major stream and lake in the Local Assessment Area (LAA) in which Project activities may affect water quantity, including Andrew Lake, Siamese Lake, Pointer Lake, Mushroom Lake, Judge Sissons Lake, Jaegar Lake, and their respective outflows. Several other lakes and streams were monitored to capture a variety of flow conditions that can be used to better estimate hydrological characteristics at unmonitored locations in the region as new concerns are raised.

4.1.1.3 Water and Sediment Quality and Aquatic Organisms

Inuit and stakeholder engagement has consistently identified water and sediment quality as well as aquatic organisms as indicators of environmental quality, and, therefore, Valued Ecosystem Components (VECs). Water quality has been identified as a VEC based on its direct value, as well as its value as a pre-requisite for healthy aquatic ecosystems and healthy fish populations. Baseline data collection surveys for water and sediment quality, and aquatic organisms were completed over a number of seasons and years to provide information related to the existing environmental quality characteristics in the LAA. Baseline data were collected at all major lakes and streams in the LAA where Project activities might affect water or sediment quality, and aquatic organisms.

4.1.1.4 Fish and Fish Habitat

Numerous Inuit and other stakeholders in all surveyed communities identified healthy fish populations as an important component of environmental quality. Concerns identified ranged from maintenance of healthy fish and fish populations in the general Baker Lake region, to maintenance of regional and local fish populations for domestic and commercial use by local residents, to concerns related to the protection of fish habitat, including continued access to spawning areas where Project activities might affect mine site or mine access LAA streams and lakes. In order to address these concerns, baseline fish and fish habitat data were collected at all major lakes and streams in the LAA where Project activities could potentially affect watercourses or waterbodies.

4.1.2 Influence of Inuit Qaujimajatuqangit on the Assessment

Inuit Qaujimajatuqangit (IQ) indicates that water quality in area lakes and streams does not appear to have changed (BL12 2008), however there is concern that fish are not in as good condition as they used to be (BL02 2008; BL12 2008). Perceived reduction in water quantity (water levels and flows) as well as declines in water quality was also noted (McDonald et al. (1997). Issues and concerns identified in the review of IQ information have been considered in scoping the aquatic assessment. Baseline data on water quantity and quality, as well as fish presence and fish health have been collected at all major lakes and streams in the LAA in response to these observations and concerns.

Information gathered from Inuit Stakeholders has also played a central role in inclusion of climate change issues in surface hydrology assessments. Inuit Stakeholders identified the presence of climate change through various observations, suggesting that the rate of change is relevant to the timeframe of the Project and therefore should be incorporated in the assessment. A variety of climatic variables were modeled in detail to quantify the rates and magnitude of the change and the information gathered from Stakeholders was used to validate results. For example, climate models for the area typically predict warmer and shorter winters in the 2080s, which is supported by Inuit Stakeholders who have observed a similar warming trend in recent years.

4.2 REGULATORY SETTING

4.2.1 Metal Mining Effluent Regulations (Canada)

Environment Canada administers the Metal Mining Effluent Regulations (MMER). The MMER were developed under Section 36 of the Fisheries Act (Canada) to regulate the deposit of mine tailings and other waste matter produced during mining operations into natural fish bearing water bodies. These regulations apply to both existing and new mines, and are among the most comprehensive and stringent standards for mining effluents in the world. The MMER require metal mines to undertake environmental effects monitoring (EEM) to ensure the adequate protection of all receiving aquatic environments by assessing effects on fish, fish habitat, and the usability of fisheries resources.

4.2.2 Fisheries Act (Canada)

Fisheries and Oceans Canada (DFO) administers the federal Fisheries Act which regulates activities that may affect the conservation and protection of fish and fish habitat, or that may result in the pollution of fish-bearing waters. A number of sections of the Fisheries Act apply to activities and developments associated with the proposed Kiggavik Project. Section 35 of the Act states that “no person shall carry on any work or undertaking that results in the harmful alteration, disruption, or destruction of fish habitat”. The Project must also comply with DFO’s Policy for the Management of Fish Habitat (DFO 1986) which sets out compensation mechanisms that allow for development to occur in or near water, while achieving an overall objective of no net loss in the productive capacity of fish habitat.

Section 36 of the Fisheries Act prohibits the deposit of deleterious substances of any type in waters frequented by fish, or in waters flowing into fish-bearing waters. Section 22 of the Act requires that fish passage (upstream and downstream) not be blocked during construction activities, and that sufficient water flows be maintained in streams to submerge spawning areas. Section 30 requires that water intakes be screened to prevent fish from being drawn into water intake systems. As well, water withdrawals must comply with conditions specified within the DFO Protocol for Winter Water Withdrawal in the Northwest Territories (DFO 2005). This Policy specifies the maximum quantities of water allowed to be withdrawn from individual ice-covered lakes.

4.2.3 Species at Risk Act (Canada)

The Species at Risk Act (SARA) provides federal legislation to prevent Canada’s wildlife species (including birds, mammals, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens) from becoming extinct, and to provide for the recovery of endangered and threatened species. SARA establishes an official list of wildlife species, sub-species, or populations at risk, and categorizes them as being extirpated, endangered, threatened, or of special concern. Once listed, measures to protect the species at risk and assist with its recovery can be instituted. These measures can include protection of critical habitats. Fisheries and Oceans Canada is responsible for the protection of any listed fish species, as well as any listed aquatic arthropods and molluscs.

4.2.4 Groundwater and Surface Water Administration

Federal agencies that are involved in groundwater and surface water related issues include Environment Canada, with the mandate to preserve and enhance the quality of the natural environment, Natural Resources Canada with the mandate to describe the geological structure of Canada, which includes the delineation of aquifers and the study of ground and surface water quantity, Health Canada, and the Department of Indian and Northern Affairs. Nunavut governs groundwater and surface water by the Nunavut Waters and Nunavut Surface Rights Tribunal Act. The Department of Environment applies the Nunavut Water Board By-Laws.

Although there are currently no Canadian Environmental Quality Guidelines for groundwater or surface water, the following sets of guidelines may be relevant for ground and surface water related issues:

- The Guidelines for Canadian Drinking Water Quality (Health Canada, 2010) that apply for potable water source;
- The Canadian Water Quality Guidelines for the Protection of Aquatic Life that are summarized in the Canadian Environmental Quality Guidelines (CCME, 2011);
- The Canadian Sediment Quality Guidelines for the Protection of Aquatic Life that are summarized in the Canadian Environmental Quality Guidelines (CCME, 2011) and may be relevant for sediments in the groundwater-surface water transition zone; and
- The Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses (CCME, 2011) that may be relevant for groundwater that could be used as a source of irrigation.

4.3 VALUED ENVIRONMENTAL COMPONENTS, INDICATORS AND MEASURABLE PARAMETERS

Valued environmental components (VECs) are major physical and biological components of the environment considered to be important (or valued) by regulators, Inuit, local residents and resource users, and the general public. VECs for the aquatic environment represent major, well recognized divisions that are ecologically distinct, and may be affected by different aspects of the Kiggavik Project development. The aquatic environment VECs identified for this assessment are:

- Groundwater;
- Surface hydrology;
- Water quality;
- Sediment quality,
- Aquatic organisms and fish habitat; and
- Fish populations.

Assessment indicators represent the key aspects of the VEC that should be protected to maintain the continued health of all aspects of the aquatic environment and to protect its value for use by future generations of Nunavut residents and the general public. Measurable parameters refer to quantifiable and measurable aspects of each assessment indicator that can be used to determine the magnitude and direction of environmental change associated with Project activities. Changes to the measureable parameters will be assessed to determine the significance of Project activities on assessment indicators and ultimately, on VECs. Indicators and measurable parameters are discussed for each VEC in the individual VEC sections.

4.4 PROJECT-ENVIRONMENT INTERACTIONS

Interactions are expected to occur between project activities and physical works and the aquatic environment during the construction, operations, and decommissioning phases of the Project. Table 4.4-1 presents a summary table of interactions between the Project and the aquatic VECs. These activities and physical works have been ranked according to their potential to interact with one or more of the aquatic environment VECs. Interactions were assigned a ranking as follows:

- Category 0 activities are those with no interaction with the aquatic environment.
- Category 1 activities are those having an interaction with the aquatic environment; however, based on past experience and professional judgment, the resulting effect can be managed to acceptable levels through standard operating practices and/or through the application of best management or codified practices. No further assessment is warranted.
- Category 2 activities are those activities that do interact with the aquatic environment and the resulting effect may exceed acceptable levels without implementation of specified mitigation. Further assessment of the effects of these interactions on the aquatic environment is warranted and is presented in this environmental assessment report.

The project-environment interactions for each VEC are discussed in more detail in the VEC sections and the rationale for ranking the interactions is presented there.

Table 4.4-1 Identification of Project - Environment Interactions: Aquatic VECs

	Project Activities/Physical Works	Groundwater	Surface Hydrology	Water Quality	Sediment Quality	Aquatic Organisms and Fish Habitat	Fish Populations
Construction:							
Economic Activities	Construction workforce management; Contracts and taxes; Advance training of operations workforce	0	0	0	0	0	0
In-Water Construction	Construct freshwater diversions and site drainage containment systems (dykes, berms, collection ponds)	0	1	1	1	2	1
	Construct in-water/shoreline structures	0	1	1	1	2	0
	Water transfers and discharge	0	2	1	1	2	1
	Freshwater withdrawal	0	2	0	0	1	0
On-Land Construction	Site clearing and pad construction (blasting, earth moving, loading, hauling, dumping, crushing	0	2	1	1	2	1
	Construct foundations	1	0	0	0	0	0
	Construct buildings	0	0	0	0	0	0
	Install equipment	0	0	0	0	0	0
	Install and commission fuel tanks	0	0	0	0	0	0
	Mill dry commissioning (water only)	0	0	0	0	0	0
Supporting Activities	Transport fuel and construction materials	0	0	0	0	0	0
	Air transport of personnel and supplies	0	0	0	0	0	0
	Hazardous materials storage and use	0	0	0	0	0	0
	Explosives storage and use	0	0	0	0	0	0
	Waste incineration and disposal	0	0	0	0	0	0
	Industrial machinery operation	0	0	0	0	0	0
	Power generation	0	0	0	0	0	0
Operation:							
Economic Activities	Workforce management; Employment; Contracts and taxes	0	0	0	0	0	0

	Project Activities/Physical Works	Groundwater	Surface Hydrology	Water Quality	Sediment Quality	Aquatic Organisms and Fish Habitat	Fish Populations
Mining	Mining ore (blasting, loading, hauling)	0	0	2	1	0	2
	Ore stockpiling	1	0	0	0	0	0
	Mining special waste (blasting, loading, hauling)	0	0	2	1	0	2
	Special waste stockpiling	2	0	0	0	0	0
	Mining clean waste (blasting, loading, hauling)	0	0	2	1	0	2
	Clean rock stockpiling	2	0	0	0	0	0
	Mine dewatering	2	0	1	0	0	0
	Underground ventilation	0	0	0	0	0	0
	Backfill production and underground placement	0	0	0	0	0	0
Milling	Transfer ore to mill	0	0	0	0	0	0
	Crushing and grinding	0	0	0	0	0	0
	Leaching and U recovery	0	0	0	0	0	0
	U purification	0	0	0	0	0	0
	Yellowcake drying and packaging	0	0	0	0	0	0
	Tailings neutralization	0	0	0	0	0	0
	Reagents preparation and use	0	0	0	0	0	0
Tailings Management	Pumping and placement of tailings slurry	2	0	0	0	0	0
	Consolidation of tailings	2	0	0	0	0	0
	Pumping of TMF supernatant	2	0	0	0	0	0
Water Management	Create and maintain water levels	0	0	0	0	0	0
	Freshwater withdrawal	1	2	0	0	1	0
	Potable water treatment	0	0	0	0	0	0
	Collection of site and stockpile drainage	0	2	1	0	1	0
	Water and sewage treatment	0	0	1	0	1	0
	Discharge of treated effluents (including greywater)	1	2	2	2	2	2

	Project Activities/Physical Works	Groundwater	Surface Hydrology	Water Quality	Sediment Quality	Aquatic Organisms and Fish Habitat	Fish Populations
Waste Management	Disposal of industrial waste	0	0	0	0	0	0
	Management of hazardous waste	0	0	0	0	0	0
	Management of radiologically contaminated waste	0	0	0	0	0	0
	Disposal of domestic waste	0	0	0	0	0	0
	Incineration and handling of burnables	0	0	0	0	0	0
	Disposal of sewage sludge	0	0	1	0	0	0
General Services	Generation of power	0	0	0	0	0	0
	Operate accommodations complex	0	0	0	0	0	0
	Recreational activities	0	0	0	0	0	0
	Maintain vehicles and equipment	0	0	0	0	0	0
	Maintain infrastructure	0	2	0	0	0	0
	Operate airstrip	0	0	0	0	0	0
	Hazardous materials storage and handling (reagents, fuel and hydrocarbons)	0	0	0	0	0	0
	Explosives storage and handling	0	0	0	0	0	0
Transportation	Marine transportation	0	0	0	0	0	0
	Truck transportation	0	0	2	1	2	0
	General traffic (project-related)	0	0	2	1	0	0
	Controlled public traffic	0	0	0	0	0	0
	Air transportation of personnel, goods and supplies	0	0	0	0	0	0
	Air transportation of yellowcake	0	0	0	0	0	0
	General air transportation support	0	0	0	0	0	0
Ongoing exploration	Aerial surveys	0	0	0	0	0	0
	Ground surveys	0	0	0	0	0	0
	Drilling	1	1	0	0	0	0
Final Closure:							

	Project Activities/Physical Works	Groundwater	Surface Hydrology	Water Quality	Sediment Quality	Aquatic Organisms and Fish Habitat	Fish Populations
Economic Activities	Decommissioning Workforce management; Employment; Contracts, and taxes	0	0	0	0	0	0
General	Hazardous materials storage	0	0	0	0	0	0
	Industrial machinery operation	0	0	0	0	0	0
	Ongoing withdrawal, treatment and release of water, including domestic wastewater	0	2	2	2	2	2
In-water Decommis-sioning	Remove freshwater diversions; re-establish natural drainage	1	2	1	1	2	0
	Remove surface drainage containment	1	1	1	1	2	0
	Remove in-water/shoreline structures	1	1	1	1	2	0
	Water transfers and discharge	1	2	1	1	0	0
	Construct fish habitat as per FHCP	0	2	1	1	2	0
On-land Decommissioning	Remove site pads (blasting, earth moving, loading, hauling, dumping)	1	2	1	1	2	0
	Backfilling	0	0	0	0	0	0
	Contouring	0	0	0	0	0	0
	Covering	0	0	0	0	0	0
	Revegetation	0	0	0	0	0	0
	Remove foundations	0	0	0	0	0	0
	Remove buildings	0	0	0	0	0	0
	Remove equipment	0	0	0	0	0	0
	Remove fuel tanks	0	0	0	0	0	0
Post Closure:							
	Management of restored site	0	0	0	0	0	0

4.5 ASSESSMENT BOUNDARIES

4.5.1 Spatial Boundaries

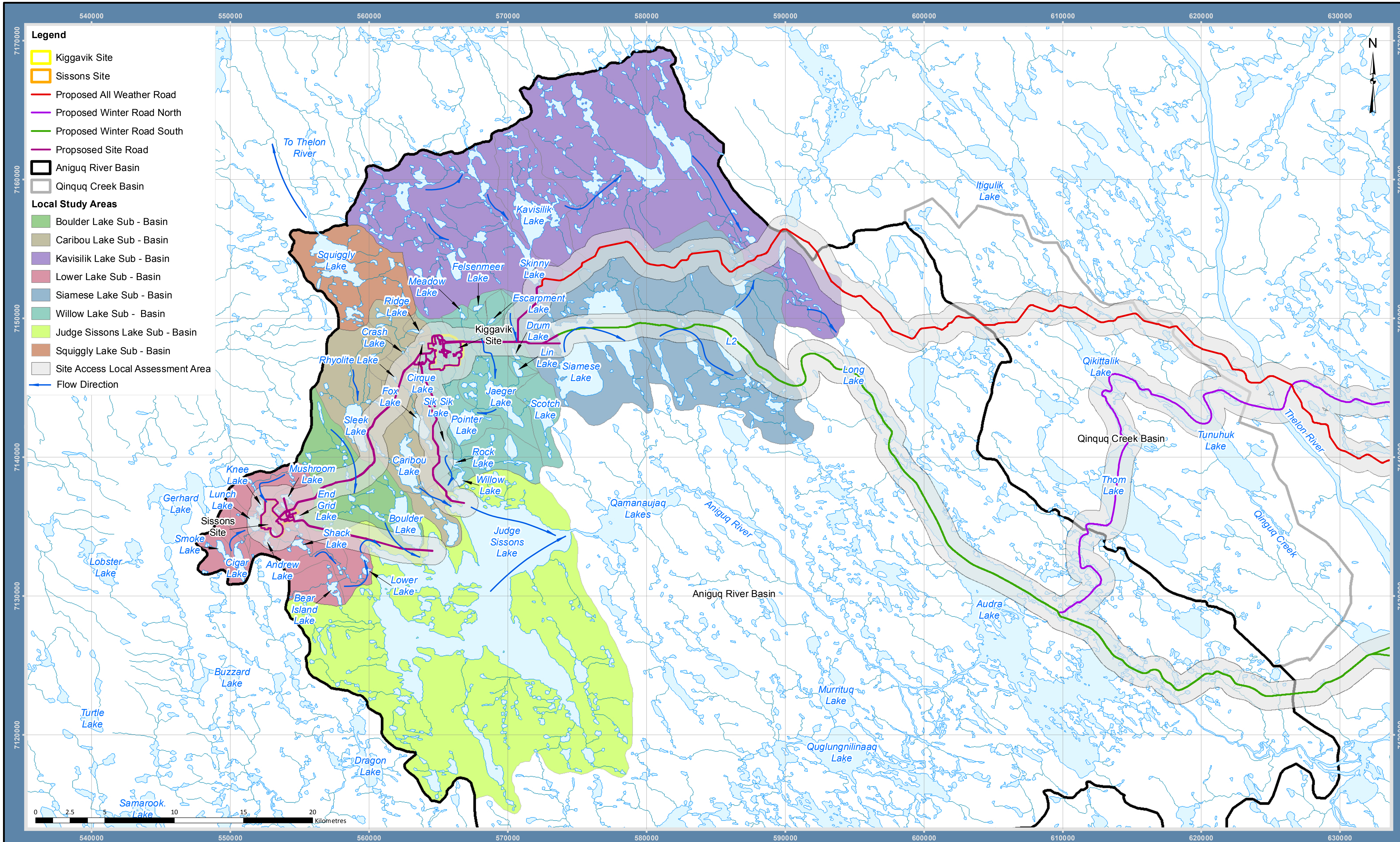
The environmental effects of the Kiggavik Project were assessed for two local assessment areas (LAA), one that encompasses the Kiggavik and Sissons areas, and one that includes the proposed winter access road corridor (and alternate all-season access road corridor). The assessment area, which was the same for all aquatic components, was based on watershed boundaries, as fish can access all lakes within a watershed unless a permanent obstacle (e.g., fall or cascade) impedes the fish migration. Figures 4.5-1 and 4.5-2 present the spatial boundaries for the aquatic assessment.

4.5.1.1 Project Footprint

For the purposes of this Environmental Assessment, the Project footprint is the physical area covered by the Kiggavik mine and mill complex, the Sissons Mine Site, the Kiggavik-Sissons Haul Road, the airstrip and its associated access road, the water intakes, pipelines, and water intake access roads, and the treated effluent discharge pipeline and diffuser in Judge Sissons Lake, and its associated access road.

The majority of the Project footprint (Figure 4.5-3) is located in the Judge Sissons Lake watershed which includes the Willow Lake, Lower Lake, Boulder Lake, and Caribou Lake sub-basins. A smaller portion of the Project footprint affects the Siamese Lake, Skinny Lake, and Kavisilik Lake sub-basins which flow into the Aniguq River, as does the Judge Sissons Lake watershed. The proposed site access road crosses a number of watersheds including the Anigug River, Thelon River, and Baker Lake. Judge Sissons Lake and Siamese Lake are part of the Aniguq River watershed.

The Project footprint for the mine access road consists of the two possible locations of the winter access road, as well as the alternate north all-season access road.



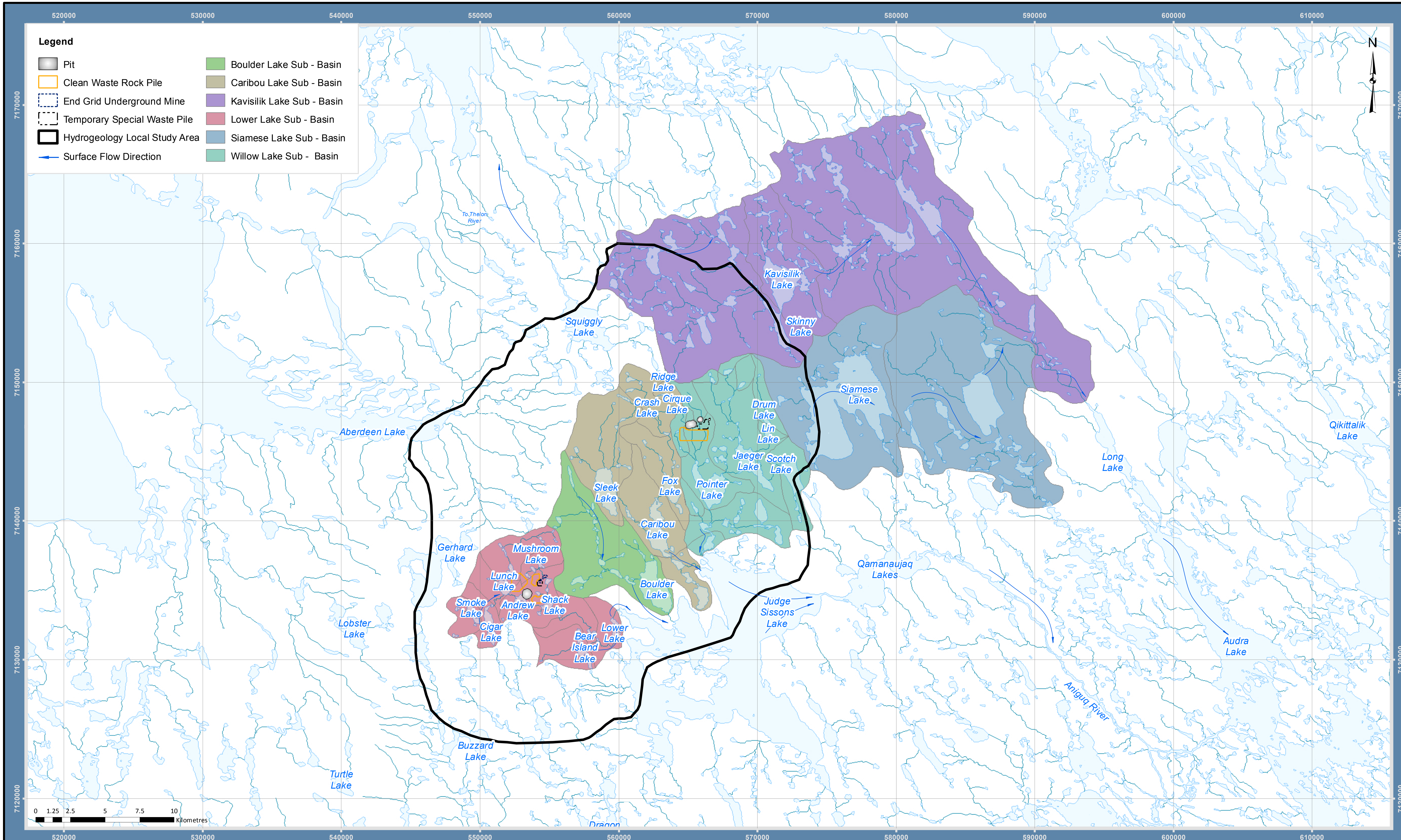
Projection: NAD 1983 UTM Zone 14N
Creator: JRC
Date: 07/12/2011 Scale: 1:250,000
File: KI08C349
Data Sources: NTS Mapsheet 56D, 66A, 66B, AREVA Resources Canada Inc.

FIGURE 4.5-1A
MINESITE LOCAL ASSESSMENT AREA

KIGGAVIK PROJECT - EIS

Golder Associates AREVA

AREVA Resources Canada Inc - P.O. Box 9204 - 817 - 45th Street West - Saskatoon, SK - S7K 3X5



Projection: NAD 1983 UTM Zone 14N
Creator: JRC
Date: 12/05/2011 Scale: 1:250,000
File: KI08M006
Data Sources: *NTS Mapsheet 56D, 66A, 66B, AREVA Resources Canada Inc.*

FIGURE 4.5-1
HYDROGEOLOGY LOCAL STUDY AREA

KIGGAVIK PROJECT - EIS

Golder Associates
AREVA

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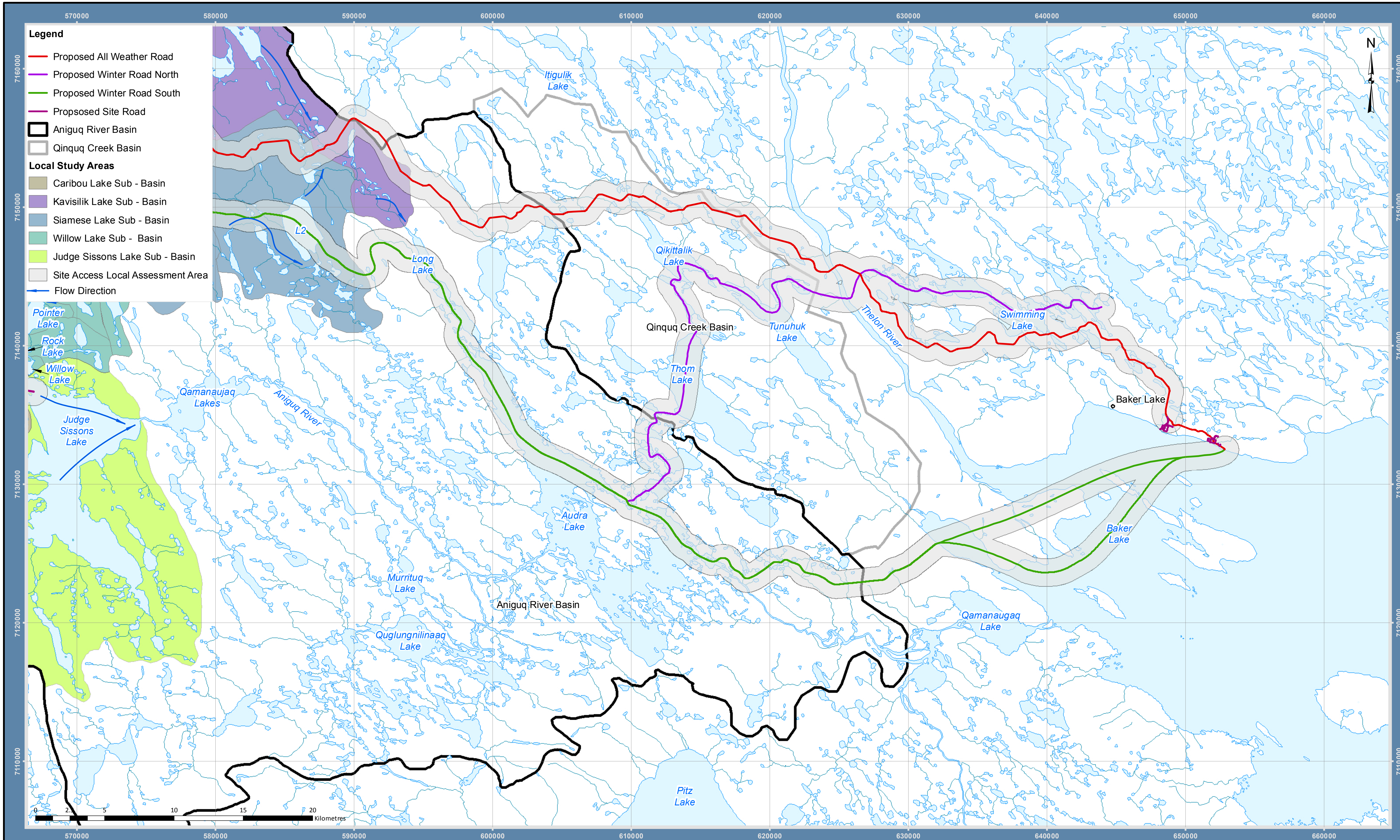

Projection: NAD 1983 UTM Zone 14N
Creator: JRC
Date: 07/12/2011 Scale: 1:250,000
File: KI08C350
Data Sources: *NTS Mapsheet 56D, 66A, 66B, AREVA Resources Canada Inc.*

FIGURE 4.5-2
SITE ACCESS LOCAL ASSESSMENT AREA

KIGGAVIK PROJECT - EIS

Golder Associates AREVA

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Projection: NAD 1983 UTM Zone 14N
Creator: TAH
Date: 08/12/11
Scale: 1:75,000
File: KI08C353
Data Sources: *Site layout provided by AREVA, June 3, 2011*
NTS Mapsheet 66A 05, 06, 10& 11

FIGURE 4.5-3
KIGGAVIK PROJECT FOOTPRINT

KIGGAVIK PROJECT

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4.5.1.2 Local Assessment Area

The mine site LAA includes lakes and their tributary streams that may potentially be directly affected by Project activities or infrastructure. The mine site LAA includes the main basin of Judge Sissons Lake, as well as the Willow Lake, Lower Lake, Boulder Lake, and Caribou Lake sub-basins. The LAA also includes the Siamese Lake watershed sub-basin that flows into the Aniguq River.

The site access LAA includes two optional corridors for the proposed winter access road from Baker Lake to the Kiggavik mine site. The site access LAA overlaps portions of the Aniguq and Thelon River watersheds. Additionally, the environmental effects of an optional all-season access road were assessed relative to the winter access road option. The optional all-season access road overlaps portions of the Baker Lake, Thelon River, and Aniguq River watersheds. The extent of the LAA for the various access roads assessed consists of a 200 m wide corridor, extending 100 m on each side of the proposed access road route. It is expected that any Project related effects would originate and be measurable within this corridor.

The LAA for groundwater is also presented in Figure 4.5-1. The LAA covers an area of approximately 740 km2. The extent of the LAA was selected based on observed topography, location of surface waterbodies, surface water drainage patterns and Project activities. The LSA includes the following key features:

- The Lower Lake, Boulder Lake, Caribou Lake and Willow Lake surface drainage basins, where most of the Project development will occur, are entirely included.
- A portion of the Kavisillik Lake and Siamese Lake sub-basins is included.
- A portion of the largest lakes in the area of Andrew Lake and End Grid is included. These lakes are Aberdeen Lake, Gerhard Lake, and Judge Sissons Lake.

The depth of the LAA is also relevant for groundwater because of the depth of the proposed mining activities and the depth of the permafrost below which most of the groundwater flow takes place. A maximum LAA depth of 1,000 m below ground surface was selected to account for the maximum depth of the proposed underground mine (approximately 500 m) and the maximum depth to which potential change in groundwater flow conditions are expected to occur.

4.5.1.3 Regional Assessment Area

The Regional Assessment Area (RAA) for most of the aquatic VECs coincides with the LAA because all effects are contained within the LAA watersheds. The Surface Hydrology VEC has defined a specific RAA and this is discussed in the assessment of that VEC.

The RAA for groundwater is equivalent to the one selected for the surface hydrology which is based on surface water divides. The reason for this is that the elevations of large lakes provide the driving force for groundwater flow. Therefore, surface drainage patterns provide a reasonably conservative approximation of the extent of the potential effects. Deep groundwater migration, however, is limited in spatial and temporal extent as a result of permafrost and low conductivities of the rock mass. As a result, the RAA for groundwater is of limited use for this assessment.

4.5.2 Temporal Boundaries

The temporal boundaries for the assessment of effects on the aquatic environment are related to Project activities associated with the construction, operation, final closure, and post closure phases of the Project. The Project construction period is expected to take three years and the mine is expected to be in operation for up to 25 years. The final closure phase of the Project is expected to require up to ten years. Most Project related effects to the aquatic environment are expected to occur during the construction and operation phases. Water quality, sediment quality and aquatic organisms, and fish habitat are expected to have residual effects in the post-closure period, associated with WTP effluent release as the system recovers.

Temporal boundaries for hydrogeological assessments include daily, annual, century and millennial time periods associated with the operations, decommissioning and post-decommissioning phases of the Project. The potential effects on groundwater quantity are anticipated to last throughout the active mining period, following which dewatering activities will cease, and the groundwater system will recover to conditions similar to the natural pre-mining conditions.

During the post-decommissioning period, groundwater will be the pathway for potential interactions between dissolved constituents of potential concern (COPC) in the water within the pore spaces of the tailings, within the pore spaces of the mine rock, and in the surface water where the groundwater discharges. As a result, the assessment of the long-term effects of the Project focuses on the post-decommissioning groundwater flow regime, the long-term behaviour of the constituents of both the tailings and the mine rock, and the migration of the constituents to the receiving surface water bodies. Because the Project area is located in the zone of continuous permafrost the assessment of the long-term effects of the Project is dependent on climate change scenarios and their impact on permafrost.

4.6 RESIDUAL ENVIRONMENTAL EFFECTS CRITERIA

NIRB has outlined specific terms to describe environmental effects. Whenever possible, the magnitude, geographic extent, frequency, and duration of an environmental effect were described quantitatively. If quantitative measures were not available to describe an environmental effect, qualitative terms (e.g., low, moderate, and high) were used. When qualitative descriptions were used, specific definitions were provided for the pertinent VEC.

- **Direction:** the ultimate long-term trend of the environmental effect (e.g., positive, neutral, or adverse).

- **Magnitude:** the amount of change in a measureable parameter or variable relative to the baseline case.
- **Geographical Extent:** the geographic area within which an environmental effect of a defined magnitude occurs (e.g. stream segment, lake, local watershed, regional watershed).
- **Frequency:** the number of times during a project or a specific project phase that an environmental effect may occur. Frequency is described as isolated, periodic, or continuous. An environmental effect has an isolated frequency if the effect is confined to a specific discrete period; an environmental effect has a periodic frequency if the effect occurs intermittently or may repeat over the assessment period; an environmental effect is continuous if the effect occurs continually over the assessment period.
- **Duration:** the period of time that is required until the VEC returns to its baseline condition or the environmental effect can no longer be measured or otherwise perceived (construction phase, operations phase, final closure phase, post-closure phase).
- **Reversibility:** the likelihood that a measurable parameter for the VEC will recover from an environmental effect
    - Reversible: the VEC is able to recover from an environmental effect to a state similar to that existing before the VEC was affected. Depending on the effect considered, reversibility may be assessed on both an individual (immediate) and population (long-term) level; or
    - Irreversible: the VEC is unable to recover from the effect).
- **Likelihood:** the probability that a significant effect will occur during the lifetime of the Kiggavik Project (i.e., unlikely, moderately likely, or very likely).

These criteria apply to all the aquatic VECs. Definitions specific to individual VECs are presented in the VEC sections.

4.7 STANDARDS OR THRESHOLDS FOR DETERMINING SIGNIFICANCE

Under the NIRB Project Specific Guidelines the environmental assessment must include a determination of the significance of environmental effects. Threshold criteria or standards for determining the significance of environmental effects were identified for each VEC, beyond which a residual environmental effect would be considered significant. Where available, these were selected in consideration of federal and territorial regulatory requirements, standards, objectives, or guidelines applicable to the VEC.

Potential changes in a measurable parameter or VC resulting from Project or cumulative effects were evaluated against these standards or thresholds, and were rated as either *significant or not significant.*

5 SUMMARY OF EXISTING ENVIRONMENT

The following sections provide an overview of the existing aquatic environmental conditions of the Project area. This overview sets the basis for the assessment of the Project effects on the aquatic Valued Ecosystem Components (VECs) that follows. The reader is referred to the folowing reports for additional information on baseline data:

- Surface Hydrology Technical Appendix 5A
- Geology and Hydrogeology Technical Appendix 5B
- Surface Water Aquatic Environment Technical Appendix 5C

5.1 SURFACE HYDROLOGY

Surface water provides the link between the atmosphere, soil, and groundwater. Streams, lakes, and wetlands provide habitat for aquatic and terrestrial plants and animals. Surface water systems receive inputs of precipitation from the atmosphere and also inputs of runoff from upstream and upland areas. Losses of surface water typically occur through drainage, evapotranspiration from the watershed (including soils and vegetation), evaporation from waterbodies, the sublimation of snow, and infiltration. Shallow infiltration provides soil moisture and can return to the surface water environment while deep infiltration or percolation recharges groundwater.

Surface hydrology includes the spatial and temporal distribution of surface water, and is typically described as water quantity. Lakes and streams in the vicinity of the Project were investigated and regional hydrological data were compiled during baseline studies in 2007-2010. The hydrological data obtained during the baseline hydrology program describe the local and regional hydrological conditions and include streamflow records, lake level and volume measurements, drainage basin boundaries, and flood magnitude and frequency estimates.

A total of 16 locations of stream discharge measurement were monitored from 2007 to 2010 (Table 5.1-1). At each stream, a continuous water level sensor was installed, and/or instantaneous discharge and water level measurements were taken according to the following methods:

- Instantaneous stream discharge: instantaneous stream discharge was determined by measuring velocity at 5% intervals along a stream cross section at 60% of the total depth, or 80% and 20% if the total depth was greater than 0.70 m.

- Water level: water level was measured using an engineer's rod and level relative to an arbitrary benchmark. Typically, large, stable boulders were selected as benchmarks near each cross section or lake.
- Continuous water level sensors: Pressure transducers and datalogger systems were installed at monitoring stations and were set to record water level at 30 minute intervals. These data were compensated using data from a similar transducer that was set to record local barometric pressure.

At each stream and lake where sufficient data were collected, a stage-discharge rating curve was developed and the continuous water level record was applied to create a continuous discharge record.

Historic data from regional hydrometric stations were analyzed to derive flood flow magnitude and frequency values, flow durations, and the following general basin characteristics:

- Mean annual discharge and drainage area can be described by: $Q = 0.0065A^{0.9862}$ (Where Q = Mean annual discharge (m3/s) and A is area(m2)
- The unit area runoff values for nearby Qinguq Creek and Aniguq River are 0.0060 m3/s/km2 and 0.0062 m3/s/km2, respectively.
- Qinguq Creek and Aniguq River have annual basin yields of 190 mm/year and 197 mm/year, respectively.

The data obtained during baseline studies indicate that streams near the Project display arctic nival characteristics; their hydrographs reflect a steep rising limb, peaking in approximately mid June due to the onset of spring snowmelt, followed by receding flows for the remainder of the open water period. Rainfall events throughout the summer may temporarily reactivate the channels or cause secondary peaks. Streamflow typically ceases during winter months.

Lakes near the Project are typically ice covered from approximately October through June, with mean maximum thickness near 2 m. Lake levels and volumes reflect inflow and outflow characteristics and thus reach their peaks during the spring freshet in mid-June with levels and volumes typically decreasing throughout the remainder of the open-water season.

Table 5.1-1 Stream and Lake Monitoring Locations

Description	Continuous Monitoring	Instantaneous Discharge and/or Level Measurements	Number of level-discharge measurements	Stage – Discharge Equation
Outflow of Skinny Lake	-	2007-2009	7	$Q = (3.6219H - 355.4353)^{2.2378}$
Outflow of Unnamed Lake Downstream of Cirque Lake	2007-2009	2007-2010	13	$Q = (1.7812H - 175.3652)^{6.0864}$
Northeast Inflow of Pointer Lake	2008-2009	2007-2010	12	$Q = (2.0838H - 207.2244)^{2.3236}$
Outflow of Sik Sik Lake	2007-2009	2007-2009	10	$Q = (2.5800H - 256.3844)^{2.0817}$
Outflow of Pointer Lake	2007-2010	2007-2010	9	$Q = (3.8491H - 378.6436)^{2.1128}$
Outflow of Shack Lake	2007-2009	2007-2009	10	$Q = (1.9091H - 188.9689)^{4.0064}$
Outflow of Judge Sissons Lake	2007-2010	2007-2010	12	$Q = (5.3706H - 526.8786)^{2.6448}$
Outflow of Siamese Lake	2007-2010	2007-2010	10	$Q = (3.7908H - 375.2070)^{2.6809}$
Outflow of Squiggly Lake	2007-2008	2007-2008	5	$Q = 7.2622H - 718.5715$ $Q = \left(\frac{H}{99.1467}\right)^{648}$
Tributary to the Northeast Inflow of Pointer Lake	-	2007-2010	12	$Q = (1.2765H - 357.2286)^{2.8100}$
Northwest Inflow of Pointer Lake	-	2007-2009	11	$Q = (3.7388H - 371.7432)^{2.1381}$
Outflow of Jaeger Lake	-	2007-2008	3	$Q = 2.8794H - 285.4555$
Aniguq River	2008-2010	-		-
Qinguq Creek	2008-2010	2009		-
Outflow of Andrew Lake	2009-2010	2009-2010	5	$Q = (1.7889H - 176.8673)^{2.2496}$
Outflow of Mushroom Lake	-	2009-2010	5	$Q = (0.2155H - 20.4858)^{24.968}$
Pointer Lake	-	2007-2010	10	$Q = (3.5149H - 344.7986)^{2.1218}$
Unnamed Lake Downstream of Cirque Lake	-	2007-2010	14	$Q = (2.5800H - 254.6963)^{2.1496}$
Judge Sissons Lake	-	2007-2010	12	$Q = 104.1667H - 10,374.0938$
Squiggly Lake	-	2007-2008	5	$Q = (12.9334H - 1248.3052)$
Skinny Lake	-	2007-2009	7	$Q = (6.9541H - 689.7928)^{1}.8695$
Kavisilik Lake	-	2007-2009	7	-
Siamese Lake	-	2007-2010	8	$Q = (2.5589H - 247.4094)^{2}.9036$
Andrew Lake	-	2009-2010	6	$Q = (1.6667H - 164.2823)^{3}.6982$
Mushroom Lake	-	2009-2010	5	$Q = ((0.8956H - 88.3442))^{7}.9108$

5.2 HYDROGEOLOGY

5.2.1 Introduction

Both the project site and the community of Baker Lake are located in the zone of continuous permafrost. The uranium ore bodies occur in areas of deep permafrost.

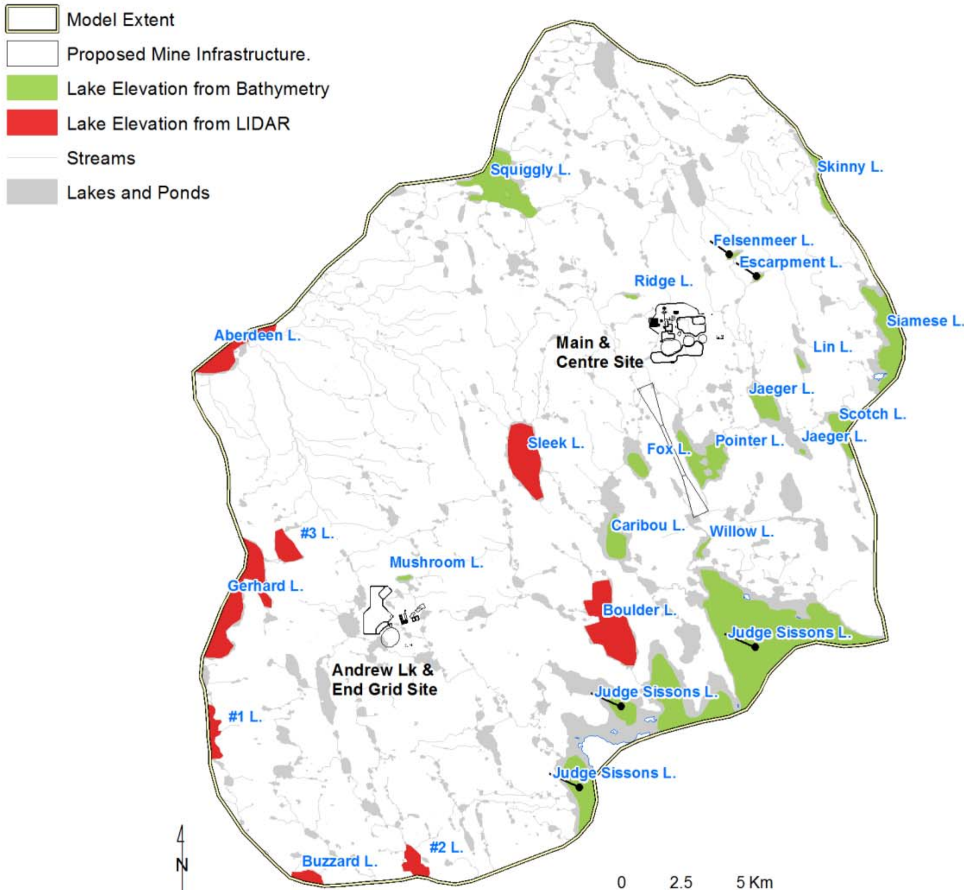
In areas of continuous permafrost, unfrozen ground conditions can develop beneath lakes that do not freeze to the bottom in winter. This unfrozen ground is referred as “talik”. If a lake is large and deep enough, the talik extends down to the deep sub-permafrost groundwater regime (“open talik”). To support a talik, a lake must be deep enough to maintain an unfrozen bottom throughout the winter. A two metre thick ice coverage is assumed to be developed in lakes at the Project site during the winter months; therefore lakes must be greater than two metres deep to support a talik.

The depth of the talik formed beneath a lake is dependent on the size of the lake. When the size of a lake is above a critical value, the talik beneath the lake will be an open talik, which hydraulically connects to the deep groundwater flow regime beneath the permafrost. Beneath smaller lakes, which do not freeze to the bottom over the winter, a talik bulb that is not connected to the deep groundwater flow system will form.

Most lakes in the Kiggavik Project area are relatively shallow and many freeze to the bottom in winter. However several lakes near the Project site satisfy both the minimum dimensional and depth requirements to support an open talik extending to the deep groundwater flow system. Figure 5.2-1 identifies lakes that satisfy these requirements. Taliks beneath larger lakes extend down to the deep groundwater regime. The elevations of these lakes provide the principal driving force for deep groundwater flow. Generally, groundwater will flow from higher elevation lakes to lower elevation lakes.

5.2.2 Permafrost

Figure 5.2-2 shows examples of recent ground temperature profiles recorded in the Kiggavik Project area. The data indicates that the depth of permafrost near the Main Zone, Centre Zone, and East Zone deposits is shallower than in the area of the Andrew Lake and End Grid deposits. Permafrost extends to a depth of about 210 m below ground surface in the area of the Main Zone, Centre Zone, and East Zone deposits. Data collected at Sissons Mine Site indicate that permafrost extends to a depth ranging from 240 m to 260 m below ground surface in the area of the Andrew Lake and End Grid deposits.



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Aquatic Environment
December 2011

Figure 5.2-1
Location of lakes supporting taliks within numerical flow model domain

Kiggavik Project

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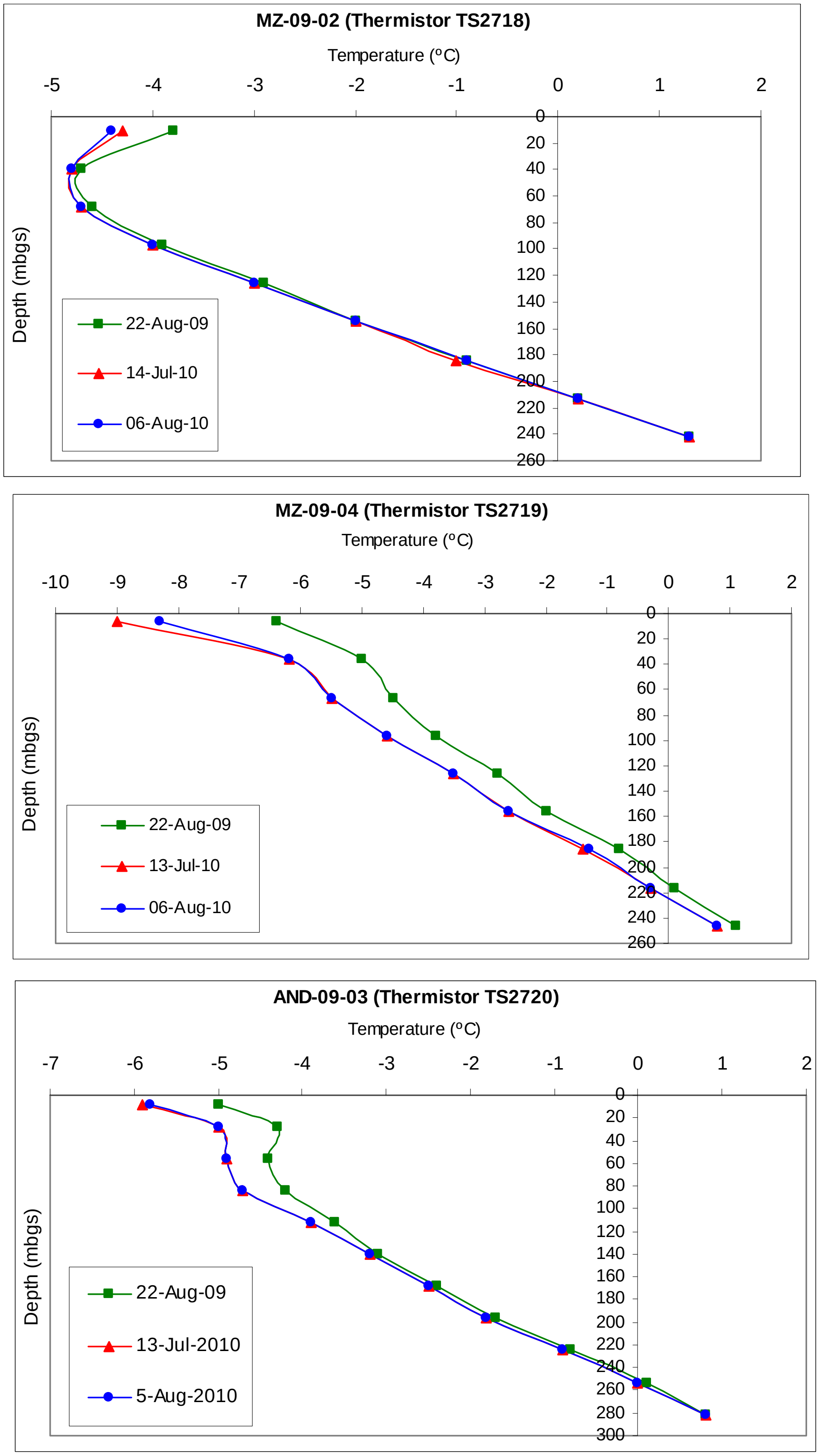


Figure 5.2-2
Example of Permafrost temperature profiles with depth

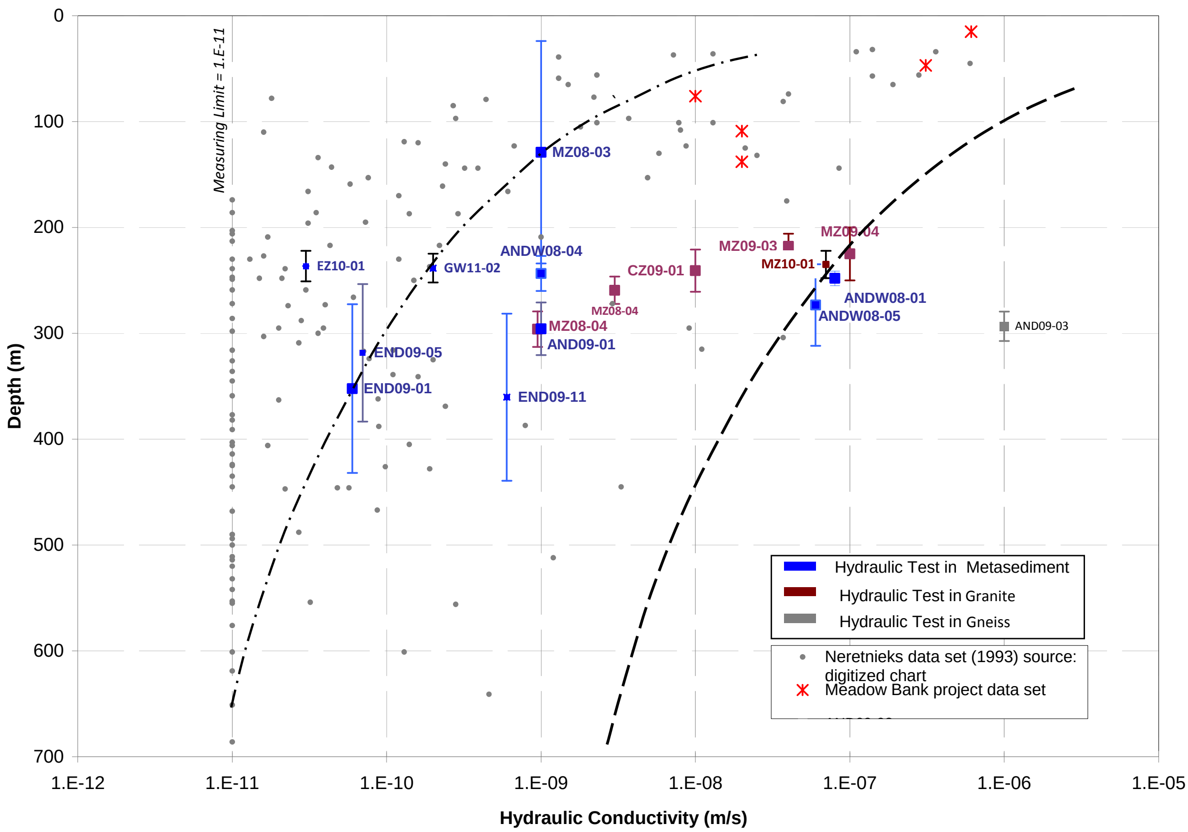
5.2.3 Hydrostratigraphy

The deep groundwater flow regime was characterized during hydrogeological testing undertaken in deep boreholes drilled through permafrost to the unfrozen ground below. A compilation of the hydraulic conductivity values derived from the tests conducted during the 2008 – 2011 field program is presented in Figure 5.2-3. Hydraulic tests conducted to data indicate that the hydraulic conductivity (K) of the rock at the Project site is low.

Figure 5.2-3 also compares the Kiggavik Project results to hydraulic conductivity measurements from the Meadowbank Project (Cumberland Resources Ltd 2005) and from a data set measured in metamorphic rock in Colorado, collected by Neretnieks (1993). The Neretnieks and the Meadowbank Project results are both considered to be reasonably representative of the Kiggavik deep rock mass. The dashed line in Figures 5.2-3 indicates a possible upper bound for the K values at depth. Hydraulic conductivities from the Neretniek and Meadowbank data sets range from 1x10-7 to 3x10-10 m/s at 200 m depth and 2x10-8 to 7x10-11 m/s at 300 m depth. The tests at Kiggavik fall within this range with the exception of one test measurement completed in 2009; AND09-03 was tested at 1x10-6 m/s between 297 and 327 mbgl.

Based on the review of site geology, hydraulic test results, and measurements of groundwater table elevation, the following hydrostratigraphic units were identified for the Project area:

- Overburden: this unit does not substantially affect the deep groundwater flow system as it has been shown to be discontinuous, limited to 5 m depth or less, and is only active during the summer when the soil has temporarily thawed. The overburden was modelled with an hydraulic conductivity of 5 x10-5 m/s and specific storage of 1x10-5 m-1.
- Permafrost: the permafrost was considered to be an effective aquitard, laterally continuous, except under lakes that support open taliks. The permafrost was modelled with a very low hydraulic conductivity (1x10-12 m/s). Specific storage was assumed to be zero.
- Sub-permafrost units: the unfrozen rock “aquifers” were subdivided according to the following sub-geological units: Metasediments, Granite, Orthoquartzite, Syenite, Gneiss, and Barrensland Group. Hydraulic properties of each of the hydrostratigraphic units are detailed in Figure 5.2-4



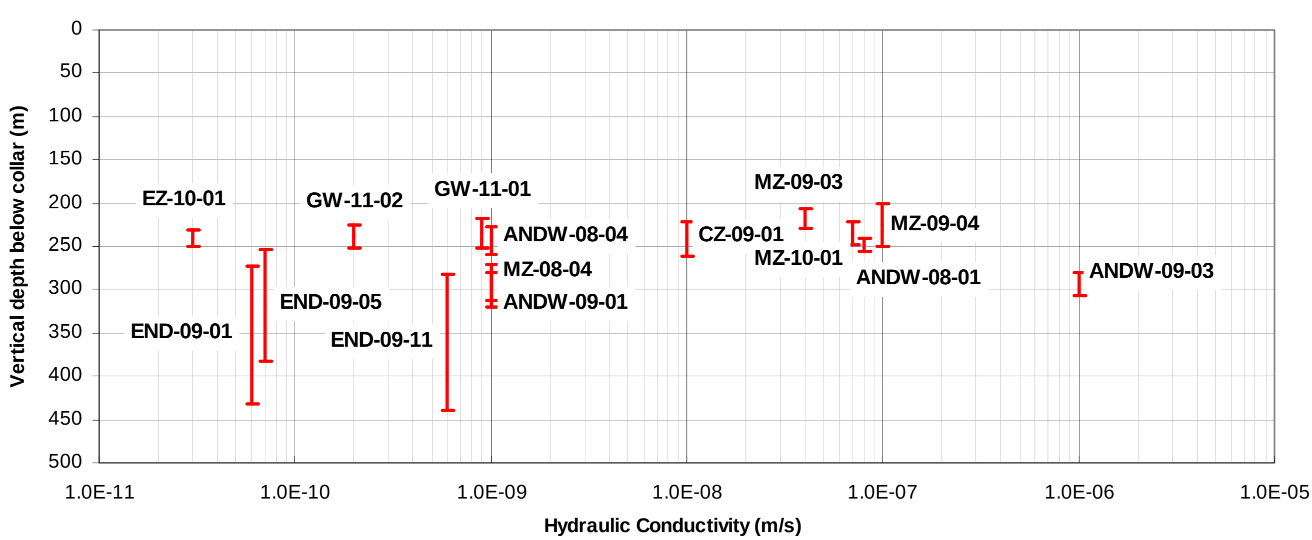
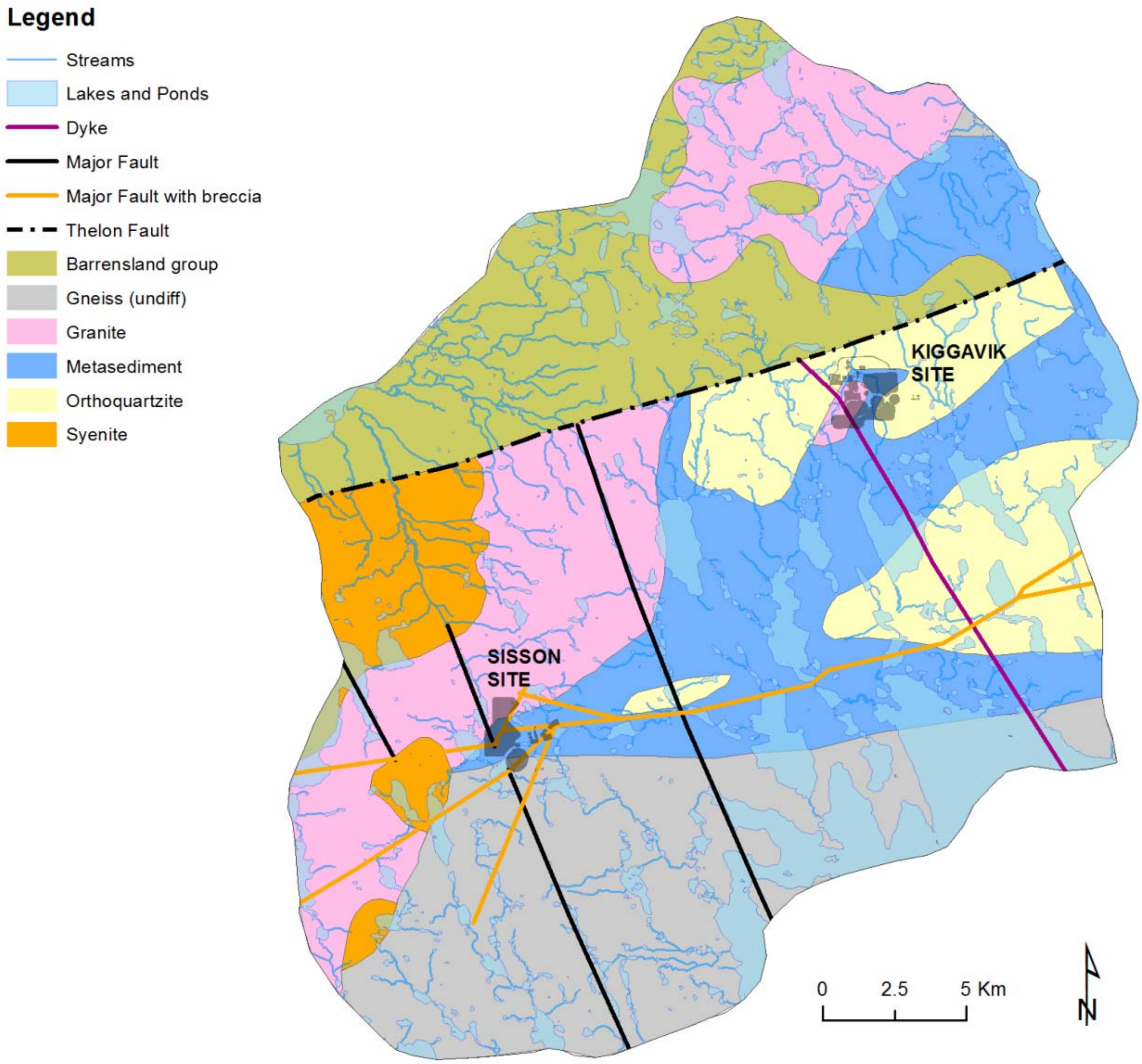


Figure 5.2-3
Compilation of single well pressure response tests results K(m/s) versus Depth (m)



	Depth (m)				
Unit	0-5m	5m-100m	100m-215m	215m-450m	450m-900m
Permafrost	1x10-12	1x10-12	1x10-12	-	-
Major Fault	1x10-7	1x10-7	1x10-7	1x10-7	1x10-7
Barrensland	5x10-5	3x10-7	3x10-8	8x10-9	8x10-10
Gneiss	5x10-5	5x10-8	5x10-9	1x10-9	1x10-10
Granite	5x10-5	5x10-7	5x10-8	1x10-8	1x10-9
Meta-sediment	5x10-5	5x10-9	5x10-10	1x10-10	1x10-11
Ortho-quartzite	5x10-5	1x10-7	1x10-8	5x10-9	5x10-10
Syenite	5x10-5	8x10-8	8x10-9	3x10-9	3x10-10

Hydraulic conductivity (m/s)

Kx=Ky=10Kz

Figure 5.2-4
Geology units and hydraulic conductivity distribution

5.2.4 Groundwater Flow Regime

Flow directions in the deep groundwater flow regime were first inferred from the elevations of the lakes supporting taliks. The results indicate that the predominant groundwater flow in area of the Main Zone, Centre Zone, and East Zone deposits is south towards Fox Lake, Pointer Lake, Jaeger Lake, and Judge Sissons Lake. Groundwater in this area may also discharge to Sleek Lake, located to the southwest, and Scotch Lake, located to the southeast. In the area of the Andrew Lake and End Grid deposits, the predominant groundwater flow direction is inferred to be southeast towards Boulder Lake, and Judge Sissons Lake.

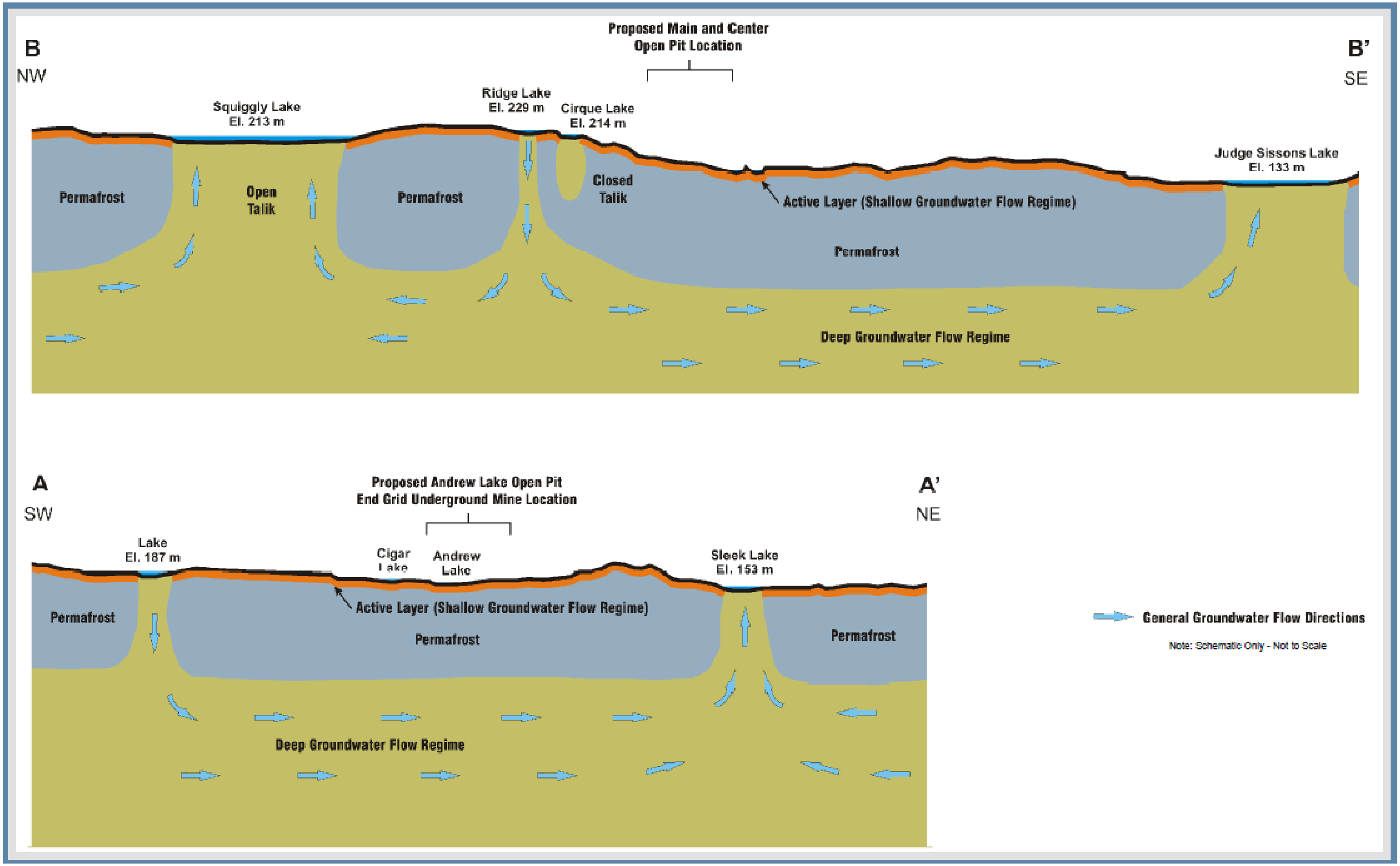
Figures 5.2-5 shows cross section views of the conceptual model of groundwater flow in the Kiggavk and Sissons areas. Figure 5.2-6 shows the simulated steady-state hydraulic head distribution in the sub-permafrost aquifer under pre-mining conditions. The figure also shows the areas where groundwater is predicted to be flowing artesian.

5.2.5 Groundwater Quality

Groundwater sampling in a low hydraulic conductivity environment is challenging because of the longer time required to obtain the volume of water necessary for sampling. In continuous permafrost areas, the difficulties increase due to concerns regarding freezing of the drill hole. Only one hole was successfully sampled for groundwater quality at Main Zone in 2009. Additional groundwater samples were collected in 2010 and 2011 from artesian flowing exploration boreholes in the Bong area, between Kiggavik and Sissons sites.

Cross-plots of major elements chloride vs. calcium and chloride vs. sodium were used to compare the collected groundwater samples with other samples in the area over the previous 20 years. This analysis shows that there is a distinct chemical signature, indicated from the presence of major ions (i.e., calcium, chloride and sodium), in the groundwater samples, compared to lake samples, a rig circulation tank sample, and historic drill return samples, which all have very low major element concentrations. TDS for the groundwater sample and the historic samples were calculated with the principal major element contributors to TDS (i.e., calcium, magnesium, sodium, alkalinity, potassium, sulphate, and chloride). The TDS resulting from laboratory analysis of the groundwater sample collected at about 250 m below ground surface is 3,500 milligrams per litre (mg/L). This TDS is consistent with the composition of deep groundwater in the Canadian Shield (Frape and Fritz 1987) at the depth that the sample was collected.

Based on these results the groundwater samples are considered to be representative of the formation water because of the high purge volume of the well by natural formation water prior to sampling, the consistency of water quality during development and sampling, and the concentration of sodium in groundwater which is associated with bedrock salinity but present in only trace amounts in the calcium chloride drilling water additive.



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December 2011

Figure 5.2-5
Conceptual model of groundwater flow Kiggavik and SIssons areas - Cross section view

Kiggavik Project

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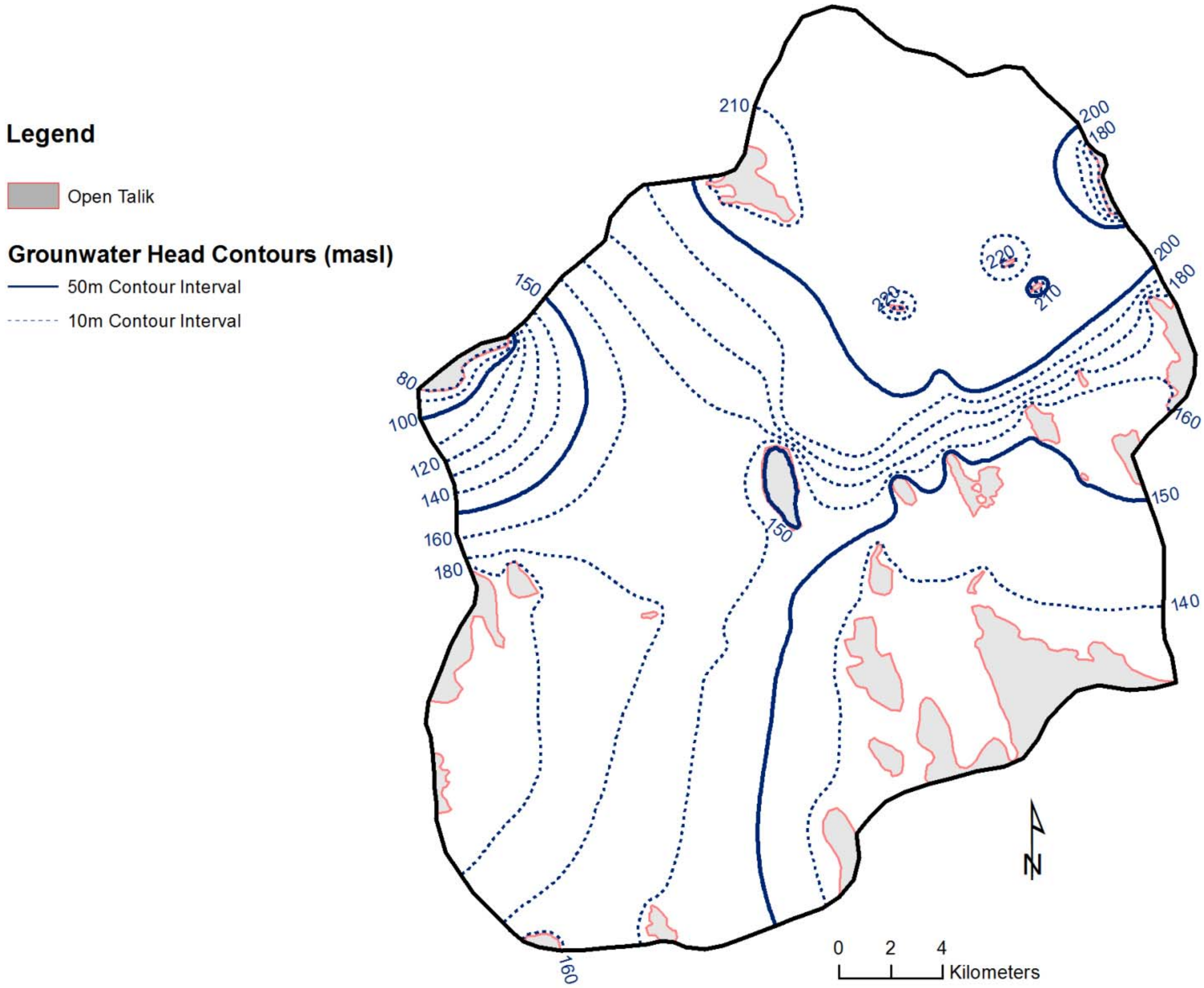


Figure 5.2-6
Calibrated Steady-State Head Distribution

The chemical groundwater isotope signature is similar to that of arctic precipitation (Clark and Fritz 1997). The isotopic signature of the groundwater may be suggestive of dilution with surface water, for example, through a hydrogeologically conductive fracture system as documented elsewhere (Clark et al. 2000; Frape and Fritz 1987). This could have an attenuating effect on groundwater salinity (the deep groundwater away from the effect of water-conductive fractures may be more saline than measured).

A comparison of the groundwater sample results with Canadian water quality guidelines suggests that iron concentrations in the vicinity of the Bong and Main Zone deposits exceed the CCME water quality guideline of 0.3 mg/L for the protection of aquatic life while radium-226 concentrations exceed the Health Canada guideline of 0.5 Bq/L for drinking water quality.

5.2.6 Groundwater Use

Groundwater sources from both the active layer and from the deep groundwater below the permafrost are generally not presently used for drinking water in continuous permafrost regions. This is mainly due to the presence of deep permafrost, the seasonal nature of the active layer, and the availability of good quality drinking water from surface water sources. In addition in the Kiggavik Project area it is considered unlikely that groundwater will be used as a drinking water source in the near future due to the low hydraulic conductivity of the deep aquifer, groundwater salinity, and the potential for elevated background iron and radium concentrations.

5.3 SURFACE WATER QUALITY

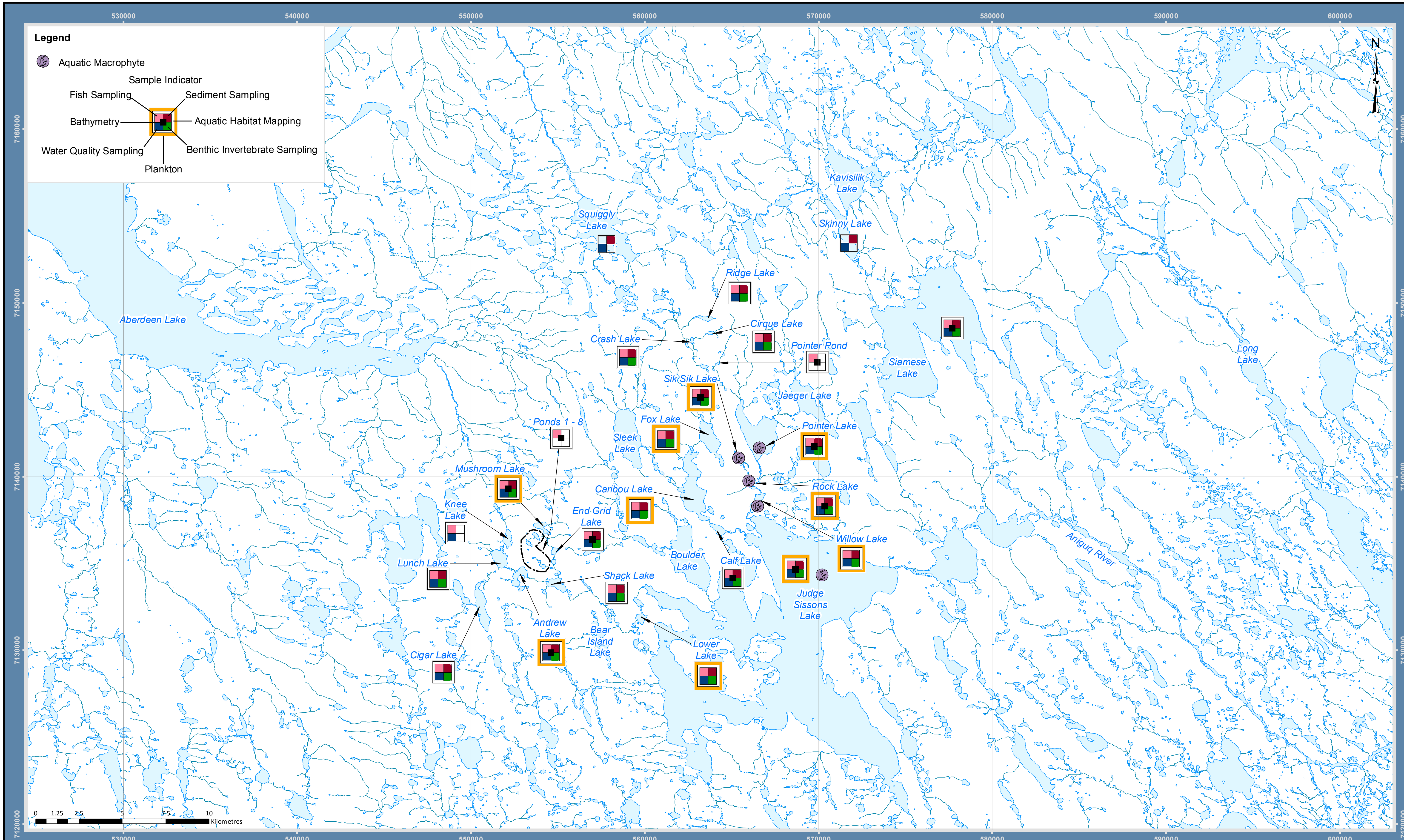
Surface water quality is influenced by natural environmental conditions (e.g., groundwater quality and quantity, hydrology, and sediment and soil chemistry), as well as by activities related to human development (e.g., road and mine construction and operations, installation of water intakes, stream diversions, effluent discharges, etc.). Changes to surface water quality can affect aquatic and terrestrial organisms, human health, and traditional and non-traditional land use activities (e.g., fishing, trapping, and hunting).

This section presents the historical and current information available on surface water quality within the mine site local study area (LSA) (Table 5.3-1). Baseline surface water quality information is used in conjunction with information on hydrogeology, hydrology, and air quality to determine whether aquatic resources will be directly or indirectly influenced by the Project. Detailed methods and results can be found in Technical Appendix 5C (Section 4.0).

Baseline water quality data were collected from 23 lakes (including Baker Lake) and 21 streams (including the Aniguq River) between fall 2007 and fall 2009 (Figures 5.3-1, 5.3-2,and 5.3-3). A number of lakes and streams were sampled multiple times. The following water quality parameters were measured:

- Limnology (i.e., pH, dissolved oxygen [DO], water temperature, and specific conductivity);

- Conventional parameters (i.e., pH, specific conductivity, total alkalinity, total hardness, total dissolved solids, total suspended solids, and turbidity);
- Nutrients (i.e., total ammonia, ammonia as nitrogen, nitrate, nitrite, total Kjeldahl nitrogen, total nitrogen, total and dissolved phosphorus, total carbon, total inorganic carbon, total organic carbon, and dissolved organic carbon);
- Major ions by inductively coupled plasma atomic emission spectroscopy (ICP-AES) scan (i.e., bicarbonate, calcium, carbonate, chloride, fluoride, hydroxide, magnesium, potassium, sodium, sulphate, and sum of ions);
- Organics (i.e., chlorophyll a);
- Total and dissolved metals and metalloids by ICP-mass spectroscopy (ICP-MS) scan including aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, tin, titanium, uranium, vanadium, and zinc; and
- Radionuclides including lead-210, polonium-210, radium-226, thorium-228, thorium-230, and thorium-232.



Projection: NAD 1983 UTM Zone 14N
Creator: JRC
Date: 12/05/2011 Scale: 1:200,000
File: KI08C342
Data Sources: *NTS Mapsheet 66A 02*
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FIGURE 5.3-1
AQUATIC BASELINE LAKE SAMPLING
2007 TO 2010

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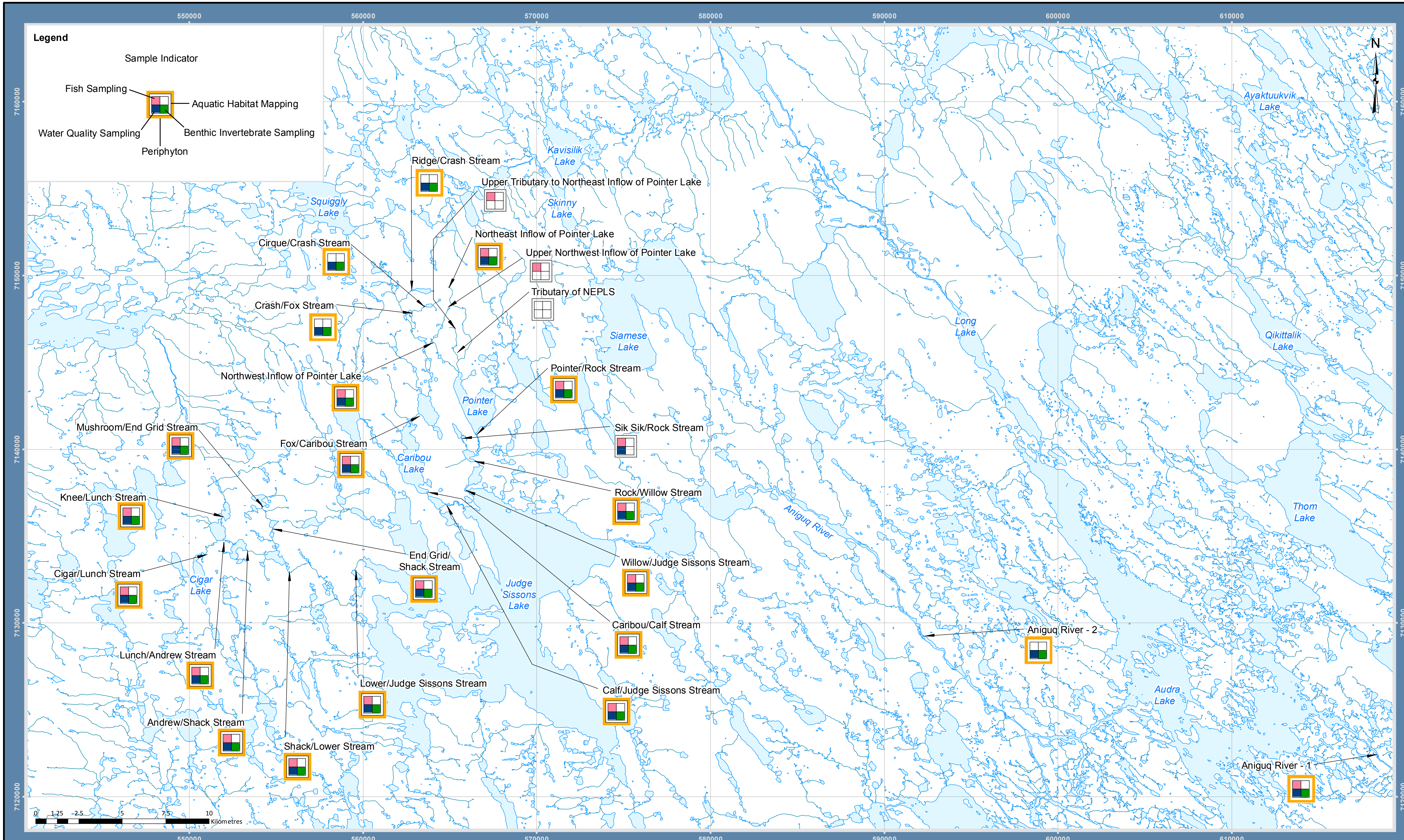

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Data Sources: *NTS Mapsheet 66A 02*
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FIGURE 5.3-2
AQUATIC BASELINE STREAM SAMPLING
2007 TO 2010

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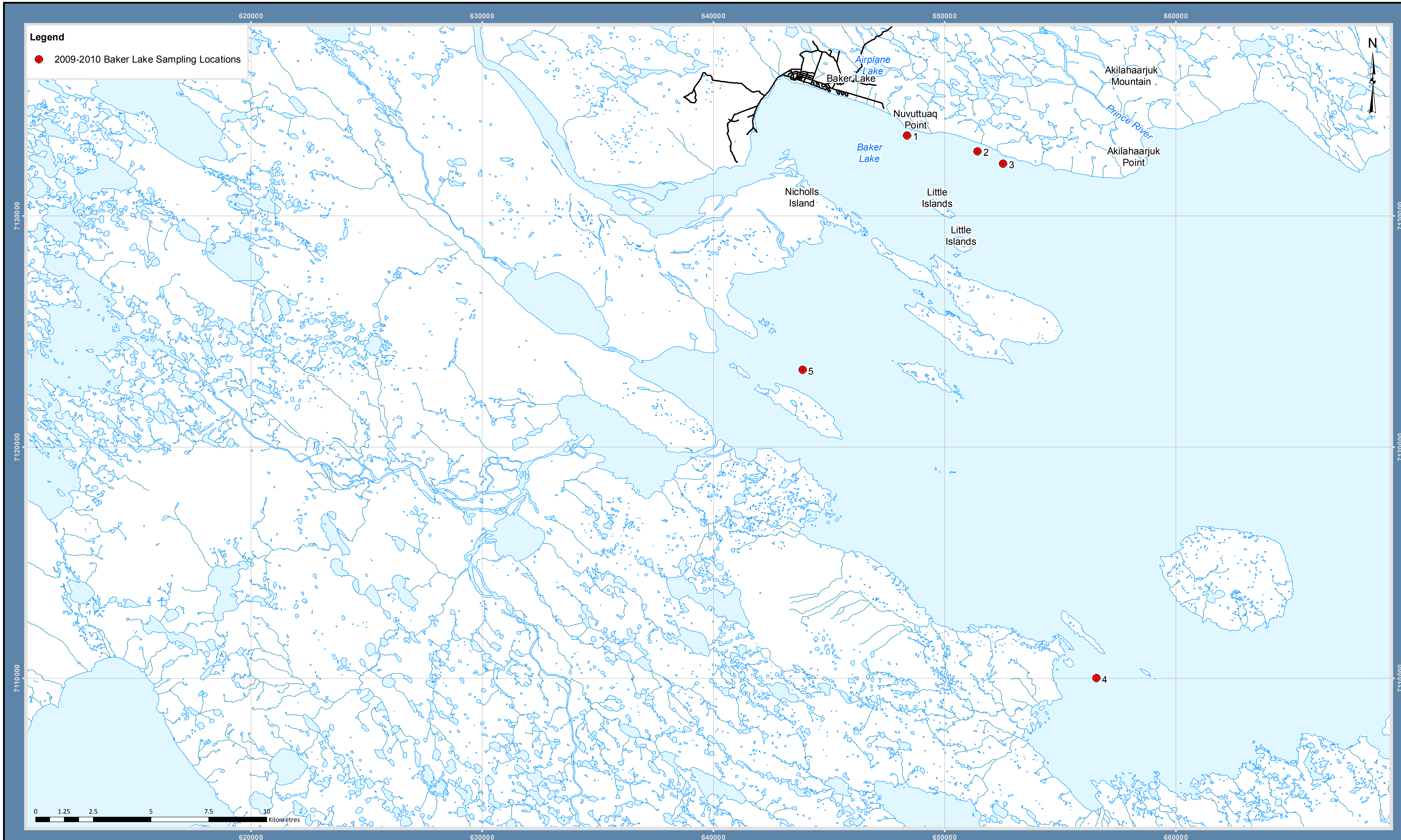

Projection: NAD 1983 UTM Zone 14N
Creator: JRC
Date: 05/18/2011 Scale: 1:150,000
File: KI08C344
Data Sources: *NTS Mapsheet 66A 02*
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FIGURE 5.3-3
SAMPLING SITE LOCATIONS - BAKER LAKE, 2008/2009

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Historical water quality data were collected in 22 lakes and 5 streams between 1974 and 1991. Eight of these lakes (i.e., Meadow, Felsenmeer, Escarpment, Drum, Lin, Scotch, Jaeger, and Kavisilik lakes) were not re-sampled during the 2007 to 2010 field programs because of their location upstream of the proposed mine site. Dissolved metals were not analyzed as part of the historical water quality sampling program, however; results for most other water quality parameters were available.

Water quality data were assessed for spatial and seasonal trends, and were compared to established objectives and guidelines for the protection of aquatic life. Specific objectives and guidelines included:

- Saskatchewan Surface Water Quality Objectives (SSWQO); supported by Saskatchewan Ministry of Environment (SE 2006); and
- Canadian Water Quality Guidelines (CWQG) for the protection of freshwater aquatic life, supported by the Canadian Council of Ministers of the Environment (CCME 2007).

5.3.1 Water Uses

To date, water used as source of drinking water in the LSA has been limited to a small pond near the AREVA working camp. Because the LSA is only accessible by helicopter during the open water season, use of other area lakes and streams as drinking water sources has been negligible.

Water used for recreational purposes within the area of influence of the project includes some limited use of Judge Sissons Lake in the mine site LSA. Access to Judge Sissons Lake during the open water period is very limited. Historically, camping (summer and winter) near Judge Sissons Lake allowed for fishing (summer and winter), hunting (e.g., caribou), and trapping (e.g., fox) in the area. These activities occurred by families traveling back and forth between areas or by families who regularly used the area (2008 Baker Lake interviews BL01, BL02, BL04, BL05, BL08, BL12, BL13, BL14, BL16; Attachment II.B). A cabin located on the north shore of Judge Sissons Lake belongs to the Baker Lake Hunting and Trapping Organization (HTO) (BL02 2008; Attachment II.B). Camping and domestic fishing around Judge Sissons Lake by residents of Baker Lake occurs occasionally.

Baker Lake and the Thelon River in the mine access LSA receive higher levels of recreational use, due to their being located nearer the community of Baker Lake and the Thelon River being part of the Canadian Heritage Rivers System (Economic Development and Tourism of Northwest Territories 1990). The Thelon River provides opportunities for camping; fishing (e.g., Arctic grayling and trophy sized lake trout and Arctic char); hiking and viewing (e.g. barren lands), wildlife viewing (e.g., muskoxen, barren-ground caribou, barren-ground grizzly bear, wolf, tundra swans, moose, and other animals), human heritage viewing (e.g., Hornby's cabin, cabins at Wardens Grove, and tents rings) (Economic Development and Tourism of Northwest Territories 1990); and hunting and picking up goose eggs (BL06 2008; Attachment II.B). Domestic fishing, canoeing, boating, and skidooing on Baker Lake are the most common recreational uses.

5.3.2 Physical Characteristics of Surface Water

Lakes in the Judge Sissons Lake watershed are generally small and shallow (Table 5.3-1). The majority have mean depths of less than 2 metres (m). Andrew Lake is one of the shallowest lakes in the mine site LSA with a maximum depth of 1 m and a surface area of 54 ha. Judge Sissons Lake is the largest (9,550 hectares [ha]) and deepest (20 m) of the lakes sampled in the mine site LSA. Baker Lake is the largest (189,000 ha) lake in the site access LSA.

Lakes are frozen for most of the year; smaller lakes generally start to become ice free in early June, with larger lakes becoming ice free in late June or early July. Ice thickness is known to reach about 2 m in depth; hence most lakes in the mine site LSA likely freeze to the bottom each winter. The smaller lakes start to freeze over in early to mid September with larger lakes freezing in late September or early October.

Table 5.3-1 Summary of Lake Characteristics in the Kiggavik Project Area

Watershed	Sub-Basin	Waterbody	Source	Drainage Area $(km^2)^{(a)}$	Surface Area $(ha)^{(b)}$	Maximum Depth $(m)^{(c)}$	Mean Depth $(m)^{(d)}$	Total Volume $(m^3)^{(e)}$	Ice Thickness (May 09) (m)	Main Shoreline Perimeter $(m)^{(a)}$	Shoreline Development[e]	Fish Observed/Captured (BEAK; McLeod et al. 1976; 2007 to 2010)
Aniguq River	Willow Lake	Meadow Lake	BEAK 1990	1.2	14.0	2.0	0.8	1.12E+05	-	1,507	1.1	none
		Felsenmeer Lake	BEAK 1990	1.3	20.8	6.0	2.0	4.16E+05	-	2,030	1.3	Arctic grayling; lake trout; round whitefish
		Escarpment Lake	BEAK 1990	2.7	12.7	8.0	2.2	2.79E+05	-	1,798	1.4	Arctic grayling; lake trout; round whitefish
		Drum Lake	BEAK 1990	5.6	25.0	2.0	1.3	3.25E+05	-	2,481	1.4	Arctic grayling
		Lin Lake	BEAK 1990	7.2	48.0	2.0	1.3	6.24E+05	-	3,016	1.2	Arctic grayling
		Scotch Lake	BEAK 1990	11.7	195	6.0	3.6	7.02E+06	-	7,645	1.5	lake trout; ninespine stickleback; round whitefish; slimy sculpin
		Jaegar Lake	BEAK 1987	50.4	281	4.0	1.6	4.50E+06	-	13,339	2.2	Arctic grayling
		Pointer Pond	2010	-	3.09	4.5	1.5	44,831	-	815	1.3	no fish observed or captured in pond; slimy sculpin captured in the stream immediately upstream
		Pointer Lake	2007	79.0	393	3.0	1.4	5.46E+06	-	11,756	1.7	Arctic grayling; cisco; lake trout; ninespine stickleback
		Sik Sik Lake	2009	1.8	17.5	1.7	0.9	1.63E+05	2.0[g]	2,155	1.5	ninespine stickleback
		Rock Lake	2008	99.2	32.4	1.5	0.7	2.29E+05	1.5[g]	3,648	1.8	Arctic grayling; lake trout
		Willow Lake	BEAK 1990	101.9	54.9	2.0	1.4	7.69E+05	2.0[g]	4,321	1.6	Arctic grayling; lake trout; ninespine stickleback
	Lower Lake	Mushroom Lake	2009	4.4	32.0	8.9	1.9	6.05E+05	2.0	3,416	1.7	Arctic grayling; cisco; lake trout; round whitefish
		Pond 1	2010	-	9.94	1.5	0.7	70,589	-	1,897	1.7	no fish observed or captured
		Pond 2	2010	-	6.56	1.2	0.6	38,683	-	1,348	1.5	no fish observed or captured
		Pond 3	2010	-	0.26	0.5	0.3	762	-	245	1.3	no fish observed or captured
		Pond 4	2010	-	0.67	0.7	0.3	1,866	-	354	1.2	no fish observed or captured
		Pond 5	2010	-	1.62	1.0	0.4	6,948	-	615	1.4	no fish observed or captured
		Pond 6	2010	-	1.76	1.2	0.7	11,422	-	636	1.4	no fish observed or captured
		Pond 7	2010	-	6.53	1.2	0.6	41,770	-	1,102	1.2	no fish observed or captured
		Pond 8	2010	-	0.44	0.7	0.4	1,748	-	259	1.1	no fish observed or captured
		End Grid Lake	2008	7.1	13.2	1.4	0.8	1.03E+05	-	1,551	1.2	Arctic grayling
		Smoke Lake	BEAK 1992a	5.6	63.5	1.0	1.3	8.26E+05	-	4,460	1.6	Arctic grayling; cisco
		Cigar Lake	BEAK 1992a	11.8	113	3.6	1.5	1.70E+06	-	7,590	2.0	Arctic grayling; burbot; cisco; lake trout; round whitefish
		Knee Lake	BEAK 1992a	11.6	34.9	0.8	0.2	6.98E+04	-	3,331	1.6	Arctic grayling
		Lunch Lake	BEAK 1992a	29.6	77.8	1.6	0.6	4.67E+05	-	4,492	1.4	Arctic grayling; lake trout; round whitefish
		Andrew Lake	2009	33.6	54.3	1.0	0.2	9.78E+04	1.0[g]	5,029	1.9	Arctic grayling; burbot; cisco; round whitefish
		Shack Lake	BEAK 1992a	47.2	60.0	1.6	0.6	3.60E+05	-	4,983	1.8	Arctic grayling
		Bear Island Lake	BEAK 1992a	9.2	36.5	1.0	0.5	1.83E+05	-	6,365	3.0	Arctic grayling
		Lower Lake	BEAK 1992a	69.0	49.0	1.4	0.4	1.96E+05	-	4,828	1.9	Arctic grayling; burbot; cisco; ninespine stickleback; round whitefish
	Caribou Lake	Ridge Lake	BEAK 1990	2.1	16.7	7.1	2.3	3.84E+05	-	2,643	1.8	lake trout
		Cirque Lake	BEAK 1990	0.7	5.6	5.2	2.6	1.46E+05	-	946	1.1	Arctic grayling; ninespine stickleback
		Crash Lake	BEAK 1990	10.6	8.1	2.0	1.1	8.91E+04	-	1,078	1.1	Arctic grayling
Aniguq River	Caribou Lake	Rhyolite Lake	NTS	0.6	7	no bathymetry	no bathymetry	-	-	1,263	1.3	not sampled
		Fox Lake	BEAK 1990	28.9	128	2.7	1.7	2.18E+06	-	5,194	1.3	Arctic grayling; cisco; lake trout; ninespine stickleback
		Sleek Lake	NTS	31.8	376	no	no	-	-	9,429	1.4	not sampled

Watershed	Sub-Basin	Waterbody	Source	Drainage Area (km^2)[(a)]	Surface Area (ha)[(b)]	Maximum Depth (m)[(c)]	Mean Depth (m)[(d)]	Total Volume (m^3)[(e)]	Ice Thickness (May 09) (m)	Main Shoreline Perimeter (m)[(a)]	Shoreline Development[(e)]	Fish Observed/Captured (BEAK; McLeod et al. 1976; 2007 to 2010)
						bathymetry	bathymetry					
		Caribou Lake	BEAK 1990	80.9	341	2.7	1.4	4.77E+06	-	14,485	2.2	Arctic grayling; burbot; cisco; lake trout; ninespine stickleback; round whitefish
		Calf Lake	2008	88.2	35.8	1.2	0.6	2.14E+05	-	2,662	1.3	burbot; cisco; ninespine stickleback
	Boulder Lake	Boulder Lake	NTS	68.6	478	no bathymetry	no bathymetry	-	-	12,949	1.7	not sampled
	Judge Sissons Lake	Judge Sissons Lake	BEAK 1990, 2009	704.6	9,550	20.6	4.6	4.39E+08	1.8	119,370	3.4	Arctic grayling; burbot; cisco; lake trout; ninespine stickleback; round whitefish; slimy sculpin
	Siamese Lake	Siamese Lake	2008	85.2	2,792	12.0	4.1	1.14E+08	2.1	45,877	2.4	lake trout
	Skinny Lake	Skinny Lake	BEAK 1990	111.7	197	12.8	3.1	6.11E+06	-	12,474	2.5	Arctic grayling; cisco; lake trout; round whitefish
	Kavisilik Lake	Kavisilik Lake	BEAK 1990	148.4	564	12.0	4.2	2.37E+07	-	22,034	2.6	Arctic grayling; cisco; lake trout; round whitefish
Thelon River	Squiggly Lake	Squiggly Lake	BEAK 1990	41.8	638	17.6	6.0	3.83E+07	-	27,568	3.1	Arctic char; Arctic grayling; burbot; lake trout; round whitefish
Baker Lake	Baker Lake	Baker Lake	NTS, McLeod et al. 1976	-	189,000	no bathymetry	15.0	2.84E+10	-	-	-	Arctic char; Arctic grayling; burbot; fourhorn sculpin; cisco; lake trout; lake whitefish; longnose sucker; ninespine stickleback; round whitefish; slimy sculpin
Winter Access Road		L2	NTS	66.9	792.4	8.0(f)	no bathymetry	-	1.8	13,257	1.3	not sampled
		Long Lake	NTS	355.7	614.4	2.5(f)	no bathymetry	-	1.8	23,804	2.7	not sampled
		Audra Lake	NTS	2,740	9,520	6.8(f)	4.0	3.81E+08	2.0	-	-	not sampled
		Qinguq Bay	NTS	465.9	998	4.5(f)	no bathymetry	-	1.8	17,147	1.5	not sampled

Source: Modified from Appendix 5C, Table X.VIII-1.
(a) Estimated from digital NTS coverage.
(b) Based on bathymetric data as presented in BEAK (1987; 1990; 1992a) or McLeod et al. (1976) unless recent bathymetric information was available. If no bathymetry was available at all, value was estimated from digital NTS coverage.
(c) Maximum depth is the maximum depth either collected at sampling stations, noted on recent bathymetry if information was available, or shown on bathymetry maps from BEAK (1987; 1990; 1992a).
(d) Based on bathymetric data as presented in BEAK (1987; 1990; 1992a) or McLeod et al. (1976) unless recent bathymetric information was available.
(e) Calculated from available data.
(f) Maximum depth is the maximum depth collected at sampling stations during winter sampling session of May 2009. Value was not corrected for ice thickness.
(g)Lake frozen to the bottom.
km^2=square kilometres; ha = hectares; m = metres; NTS = National Topogoraphic System; - = not applicable.

5.3.3 Chemical Characteristics of Surface Water

Lakes in the mine site LSA were similar to each other in respect to their water chemistry (Table 5.3-2 in Attachment A). Lakes were characterized by low ionic strength and neutral to alkaline pH. The range of total alkalinity values during open water conditions indicated that the lake waters had low to high sensitivity to acid (Saffran and Trew 1996). Total hardness concentrations indicated that the waters had very soft to soft water hardness (McNeely et al. 1979). Measured nutrient concentrations (particularly nitrogen and phosphorus) were typical of oligotrophic (nutrient poor) waterbodies in subarctic regions. Baseline water quality parameters were less than Saskatchewan Surface Water Quality Objectives (SSWQO) and Canadian Water Quality Guidelines (CWQG) with the exception of some parameters (i.e., field and laboratory measured pH, ammonia, aluminum, cadmium, chromium, cobalt, copper, iron, lead, silver, and zinc) in some lakes. Radionuclides were generally not detected or were detected near the analytical detection limits.

Baseline water quality parameters for lakes of special interest (i.e., Mushroom, Andrew, Judge Sissons, Siamese, and Baker lakes) were less than SSWQO and CWQG with the exception of a few parameters (i.e., laboratory measured pH, aluminum, cadmium, chromium, copper, lead, silver, and zinc) (Table 5.3-2).

Streams of the study area were characterized by low ionic strength and neutral to alkaline pH (Table 5.3-2). The range of total alkalinity values measured during open water conditions indicated that the stream waters had low to high sensitivity to acid (Saffran and Trew 1996). Total hardness concentrations indicated that stream waters had very soft water hardness (McNeely et al. 1979). Measured nutrient concentrations were typical of oligotrophic waterbodies in subarctic regions. Baseline water quality parameters were less than SSWQO and CWQG with the exception of a few parameters (i.e., field and laboratory measured pH, aluminum, cadmium, chromium, copper, iron, lead, and zinc). Radionuclides were generally not detected or were detected near the analytical detection limits.

5.4 SEDIMENT QUALITY

Lake sediments consist of organic and inorganic matter introduced through erosion of soils and other geologic materials in the watershed, and through the deposition of particulate mineral matter and organic material produced in the lake (BEAK 1990). Studies of sediment quality in the Kiggavik area were carried out between 1979 and 1991. These historical studies broadly covered the study area. The objectives were to collect baseline information on sediment particle size characteristics, sediment chemistry, and sedimentation rates. Recent studies were conducted between 2007 and 2009 to expand and complement the previously collected baseline information on sediment chemistry and sediment particle size characteristics.

This section presents the historical and current information available on surface sediment quality within the mine site local study area. Detailed methods and results can be found in

Appendix 5C (Section 5.0). The seasonal variation in physical and chemical sediment quality was not addressed due to the low but variable sedimentation rates identified in Section 5.4.4.

5.4.1 Sediment Sampling

Baseline sediment quality data were collected in 22 lakes (including Baker Lake) between fall 2007 and fall 2009 (Figures 5.2-1, 5.2-2, 5.2-3). Two lakes from the Willow Lake sub-basin (i.e., Sik Sik and Willow lakes) and Andrew Lake from the Lower Lake sub-basin were sampled up to three times. The following parameters were measured for lakes sampled in the mine site LSA:

- Physical properties (i.e., particle size, moisture content, and loss on ignition);
- Nutrients (i.e., total nitrogen, ammonia as nitrogen, nitrite+nitrate as nitrogen, total phosphorus, and total organic carbon [TOC]);
- Major ions (i.e., calcium, magnesium, potassium, sodium, and sulphate);
- Metals and metalloids (i.e., aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, titanium, uranium, vanadium, and zinc); and
- Radionuclides (i.e., lead-210 [Pb-210], polonium-210 [Po-210], radium-226 [Ra-226], thorium-228 [Th-228], thorium-230 [Th-230], and thorium-232 [Th-232]).

Baker Lake sediment chemistry samples were analyzed for some or all of the following parameters in 2008 and 2009:

- Nutrients (i.e., total phosphorus [2008 only]);
- Major ions (i.e., calcium, magnesium, potassium, and sodium);
- Metals and metalloids (i.e., aluminum, arsenic, barium, beryllium, boron, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, strontium, titanium, uranium, vanadium, and zinc);
- Polycyclic aromatic hydrocarbons (PAHs) (acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(e)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, naphthalene, perylene, phenanthrene, and pyrene [2008 only]); and
- Radionuclides (i.e., lead-210, polonium-210, radium-226, and thorium-230).

Sample collection methods are detailed in Technical Appendix 5C (Section 5.1).

Historical sediment quality data were collected in 17 lakes between 1979 and 1991. Six of these lakes were not recently re-sampled (i.e. Felsenmeer, Escarpment, Lin, Scotch, Jaeger, and Boulder lakes) because of their location upstream of the proposed mine site. Particle sizes, moisture, total nitrogen, ammonia as nitrogen, nitrite+nitrate nitrogen, sulphate, antimony, thallium, and tin were not available in the historical sediment quality data, and arsenic, selenium, and tellurium results from samples collected in 1979 were reported in wet weight instead of dry weight. However, most other parameters were available, as well as cation exchange capacity, chemical oxygen demand, total Kjeldahl nitrogen, tellurium, polonium-220, and radium-228.

Following the protocols commonly used in analyzing data from environmental effects monitoring studies at uranium mines, sediment chemistry results were compared among sediment sampling stations as well as to the Canadian Council of Ministers of the Environment (CCME) Freshwater Interim Sediment Quality Guidelines (ISQG) and probable effects levels (PEL) (CCME 2002). Radionuclide results were compared with lowest effect level (LEL) and severe effect level (SEL) reference values reported in Thompson et al. (2004).

5.4.2 Physical Characteristics of Sediment

Kiggavik area lake bottom substrates varied from rock, boulder, and sand in shallow areas to organic-rich (soft light to dark brown) sediments in deeper depositional areas. The surficial light to dark brown sediments are typically 2 to 10 centimetres (cm) deep, and usually had an underlying layer of tan or grey deposits (BEAK 1987).

BEAK (1990) reported the results of quantitative assessment of sediment particle size that was conducted in 1988. Silt was the dominant particle size category in all lakes sampled except in Pointer Lake and Judge Sissons Lake. Surface sediment in the main body of Pointer Lake was dominated by dense clay, sand, and rock. Judge Sissons Lake sediment samples had nearly equal amounts of fine sand, very fine sand, silt and clay. BEAK (1990) presented quantitative results of particle size for only two lakes: Pointer Lake and Jaeger Lake (Table 5.4-1).

The core sample collected in Judge Sissons Lake in 1991 consisted of sticky glacial clay and no soft organic sediments (BEAK 1990, 1992a). The 1991 result suggests that sediment deposition occurs sporadically in Judge Sissons Lake (BEAK 1992a). Differences in sediment texture between smaller lakes and Judge Sissons Lake can be attributed to the much greater depth of Judge Sissons Lake, and the varying depositional environment provided in deep lakes (BEAK 1990).

Table 5.4-1 Particle Size of Surficial Lake Sediments in Pointer and Jaeger Lakes

Category	Size Range (mm)	Pointer Lake 1 (%)	Pointer Lake 2A(a) (%)	Pointer Lake 2B (%)	Pointer Lake 2C (%)	Jaeger Lake (%)
Coarse sand	0.5 - 1.0	0	0	0	0	1.01
Medium sand	0.25 - 0.5	0.62	1.28	1.08	7.66	2.54
Fine sand	0.088 - 0.025	3.71	3.2	3.54	12.31	16.71
Very fine sand	0.0625 - 0.088	49.41	13.15	13.67	26.29	39.49
Silt	0.0039 - 0.0625	37.69	71.53	70.18	42.96	27.69
Clay	<0.0039	8.59	10.82	11.54	10.77	12.47

Source: BEAK 1990.

[(a)] Pointer Lake samples 2A, 2B, and 2C are field replicates.

% = percent; mm = millimetres; < = less than.

5.4.3 Chemical Characteristics of Sediment

The historical dataset did not contain any information about moisture content, and very few values for TOC. More recent data (i.e., 2007 to 2009) indicates that these parameters were variable among lakes, with moisture content ranging from 18 to 88%, and TOC ranged from less than 0.01% to 7.7% (Table 5.4-4 is located in Attachment A).

Overall, total metal concentrations were similar among the lakes in the mine site LSA and the site access LSA. Arsenic concentrations usually exceeded the ISQG of 5.9 micrograms per gram of dry weight (µg/g dw), but not the PEL of 17.0 µg/g dw with the exception of one sample collected in 1986 from Escarpment Lake (30 to 34 µg/g dw), three samples collected in Ridge Lake (60 µg/g dw in 1986, 31 µg/g dw in 2007, and 45 µg/g dw in 2008) and one sample collected in 2009 from Judge Sissons Lake (39 µg/g dw). Cadmium concentrations in one sample collected in 2008 from Cirque Lake, and one sample from Squiggly Lake, were 0.6 µg/g dw, equal to the ISQG. Chromium concentrations also exceeded the ISQG of 37.3 µg/g dw, but not the PEL of 90 µg/g dw, with the exception of one sample collected in 1979 from Jaeger Lake (100 µg/g dw). A few exceedances of copper, mercury, and zinc ISQGs, and the mercury and zinc PEL were observed, but there were no trends evident (Table 5.4-4).

Radionuclides were detected in almost all sediment samples, except those from Baker Lake, and were generally reported at concentrations below 0.3 Becquerels per gram of dry weight (Bq/g dw). One recent sample collected in Squiggly Lake in 2008 had a Po-210 concentration of 0.45 Bq/g dw and Pb-210 concentration of 0.38 Bq/g dw. Three historical samples collected from Scotch, Pointer, and Judge Sissons lakes in 1979 were also reported at concentrations above 0.3 Bq/g dw for Pb-210, Ra-226, Th-228, Th-230, and Th-232. Two more samples were equal or in exceedance of the Thompson et al. (2004) lowest effects level value for Ra-226 concentration of 0.1 Bq/g dw, including Lunch Lake (0.11 Bq/g dw in 1990), Shack Lake (0.11 Bq/g dw in 1991), and Skinny Lake (0.1 Bq/g dw in 2007) (Table 5.4-4).

Individual polycyclic aromatic hydrocarbon (PAH) compounds were sampled in Baker Lake in 2008. Concentrations were mostly below analytical detection limits in all samples (Table 5.4-2), and all were well below ISQG. Total PAH levels were less than 0.1 µg/g.

Table 5.4-2 [Chemical Characteristics of Sediment]

Parameter	Units	CCME Sediment Quality Guidelines		Baker Lake Sub-Basin
				Baker Lake
				2008
		ISQG[(a)]	PEL[(b)]	n = 5
Polycyclic Aromatic Hydrocarbons (PAH)				
Total PAH	µg/g	-	-	<0.1 (5 < DL)
Acenaphthene	µg/g	6.71	88.9	<0.01 (5 < DL)
Acenaphthylene	µg/g	5.87	128	<0.01 (5 < DL)
Anthracene	µg/g	46.9	245	<0.01 (5 < DL)
Benzo(a)anthracene	µg/g	31.7	385	<0.02 (5 < DL)
Benzo(a)pyrene	µg/g	31.9	782	<0.1 (5 < DL)
Chrysene	µg/g	57.1	862	<0.02 (5 < DL)
Dibenzo(a,h)anthracene	µg/g	6.22	135	<0.1 (5 < DL)
Fluoranthene	µg/g	111	2355	<0.01 (5 < DL)
Fluorene	µg/g	21.2	144	<0.01 (5 < DL)
Naphthalene	µg/g	34.6	391	<0.01 (5 < DL)
Phenanthrene	µg/g	41.9	515	<0.01 - 0.03 (3 < DL)
Pyrene	µg/g	53	875	<0.01 - 0.01 (3 < DL)

Source: Modified from Appendix 5C, Table X.III-6.

Values greater than or equal to ISQGs are **bolded**.

Values greater than or equal to PELs are **bolded** and underlined.

Non-detect values that have detection limits that are greater than guidelines are italized.

(a) ISQG = Interim Freshwater Sediment Quality Guidelines (CCME 2002).

(b) PEL = Probable Effect Levels (CCME 2002).

CCME = Canadian Council of Ministers of the Environment; n = number of samples analyzed; µg/g = micrograms per gram;

< = less than; DL = detection limit.

5.4.4 Sedimentation Rates

Sedimentation rates were measured in Pointer Lake and Judge Sissons Lake using the Pb-210 method (BEAK 1990). Sediment chronologies can be determined from the Pb-210 method when the supply of Pb-210 occurs at a constant (or proportional) rate to the sedimentation rate (McKee et al. 1987). This method has been used to estimate sedimentation rates in other Arctic lakes (BEAK 1990).

Duplicate sediment cores were collected in 1988, using a Kajak-Brinkhurst (KB) corer equipped with 4.7 cm (inside diameter) polycarbonate core tubes. Cores were collected from two depths (11 and 13 m) in Judge Sissons Lake, and one depth (approximately 1.8 m) in Pointer Lake.

Attempts to collect cores from depths of 2 to 2.3 m in the main body of Pointer Lake and from depths greater than 10 m in the eastern basin of Judge Sissons Lake were unsuccessful due to the presence of rock, coarse sand, or dense clay on the sediment surface, which prevented the corer from penetrating the lake sediments. Core samples were sliced into 0.5 to 2 cm sections in a plastic collar.

Sedimentation rates were measured in Judge Sissons Lake and Pointer Lake, to assess the rate at which material in the water column settles out of suspension (BEAK 1990). The lakes were found to have low but variable sedimentation rates, reflecting the oligotrophic conditions of the aquatic ecosystem and possibly frequent wind-driven sediment re-suspension (BEAK 1990). Given the small volume of many of the lakes, it is also possible that there is a short water retention time in the lakes, which would also influence sedimentation rates.

Sedimentation rates in the mine site LSA cores were 1.6 millimetres per year (mm/y) in Pointer Lake and between 0.11 mm/y and 0.26 mm/y in Judge Sissons Lake (Table 5.4-3). The average annual depth of accumulation (mm/y) is based on mass accumulation rates and on the dry bulk densities for the four surface core slices collected from the top 2 to 2.5 cm (BEAK 1990).

Table 5.4-3 Sedimentation Rates in the Kiggavik Project Area Measured Before 1990

Unit	Pointer Lake	Judge Sissons Lake	
		11 m depth	13 m depth
Grams per square metre per year ($g/m^2/y$)	300	11	20
Millimetres per year (mm/y)	1.6	0.11	0.26

Source: BEAK 1990.
m = metre; g/m2/y = grams per square metre per year; mm/y = millimetres per year.

Within the Judge Sissons Lake cores taken at a depth of 22 m, a sticky grey clay was encountered below 18.4 cm. This is likely a layer deposited during deglaciation, which occurred in the area about 6,000 to 8,000 years before present (BEAK 1990). The total mass accumulated above this layer was 5.3 grams per square centimetre (g/cm2), which is equivalent to an overall average annual rate of 7.6 grams per square metre per year (g/m2/y) over 7,000 years. This is about 70% of the 11 g/m2/y measured in recent sediments by Pb-210 method, probably reflecting an increase in sedimentation rate in recent history relative to the post-glacial period. These changes can be attributed to various factors, including glacial rebound, changes in erosion rates, climatic vegetation changes, and changes in the lake basin itself (BEAK 1990).

5.5 FRESHWATER AQUATIC ENVIRONMENT

Various assessments of the aquatic environment have been undertaken over the history of the Project. The historical field studies were either carried out over a two year period (e.g., 1979 to

1980, 1988 to 1989, and 1990 to 1991), or in a single year (e.g., 1975 and 1986) (BEAK 1990, 1992a). A review of the available historical information is presented. Between 2007 and 2010, additional aquatic field studies were carried out to supplement and update the historical information.

This Freshwater Aquatic Environment section includes information on the limnology of LSA lakes and streams (i.e., description of the physical aquatic habitat conditions), as well as information about freshwater organisms from the following trophic levels:

- Primary producers (i.e., plants [macrophytes] and algae [phytoplankton and periphyton] which make their own food);
- Primary consumers (i.e., herbivores [zooplankton] that eat macrophytes, phytoplankton, and periphyton; and benthic detritivors [benthic invertebrates] that feed on detritus (decaying material) at the bottom of lakes and streams);
- Secondary consumers (i.e., fish and other aquatic organisms that eat zooplankton or benthic invertebrates); and
- Tertiary consumers (i.e., fish that eat other fish).

Water limnology and water chemistry are important components of aquatic ecosystem health. In order to sustain aquatic life, water requires specific physical characteristics to be present at appropriate levels, including temperature, dissolved oxygen, and ph (acidity/alkalinity). The chemical makeup of water is also important to the maintenance of conditions suitable for aquatic life. For example, bicarbonates, carbonates, sulphates, and chlorides are four major anions that influence the total ionic salinity of the water. Calcium is a nutrient important for the growth of underwater plants and other aquatic organisms including fish. Nitrogen and phosphorus are nutrients critical to the growth of aquatic primary producers (phytoplankton, periphyton, and aquatic macrophytes). The energy uptake and growth of primary producers is subsequently utilized by primary, secondary, and tertiary consumers (e.g., zooplankton, benthic and other aquatic invertebrates, and fish) (Wetzel 2001).

Aquatic macrophytes are an important component of aquatic systems, providing habitat for fish and invertebrates, offering protection against currents and predators, and forming a substrate for the deposition of eggs. As primary producers, macrophytes represent an important food resource for aquatic and non-aquatic organisms and they also play a significant role in the oxygen balance and nutrient cycle of many watercourses.

The term “plankton” is a general term referring to small, usually microscopic, organisms that live suspended in open water. For the purpose of the Project, the term “phytoplankton” refers to the open-water, algal component (i.e., non-vascular, photosynthetic plants) and includes the following seven major taxonomic groups:

- Cyanobacteria (blue-green algae);
- Chlorophyta (green algae);
- Chrysophyta (golden-brown algae);

- Cryptophyta (cryptomonads);
- Bacillariophyta (diatoms);
- Pyrrophyta (dinoflagellates); and
- Other taxa (which includes Xanthophyta and Haptophyta).

Chlorophyll a is the primary photosynthetic pigment contained in phytoplankton, although there are a number of secondary pigments (e.g., chlorophyll b, chlorophyll c, and carotenoids) (Wetzel 2001). Chlorophyll a concentration has been used to provide a practical and economical alternative to full taxonomic analysis of the phytoplankton community, and has been widely used as a measure of the trophic status (i.e., nutrient status and productivity) of lakes. Chlorophyll a concentrations can range from less than 8 micrograms per litre (µg/L) in unproductive waters to greater than 75 µg/L in highly productive waters (Mitchell and Prepas 1990). Chlorophyll a concentrations are known to vary seasonally and taxonomically (Wetzel 2001), which results in uncertainty in the use of chlorophyll a as a measure of phytoplankton biomass.

Periphyton consists of a biofilm of algae, bacteria, fungi, protozoa and associated non-cellular material that surround solid surfaces in aquatic systems (Lock et al. 1984). For the purpose of the Project, the term “periphyton” refers only to the algal component as opposed to the entire biofilm. Periphyton is the term used to describe the algal community that grows attached to the substrate (generally rocks) in streams and lakes. They are a primary producer, similar to phytoplankton; however, periphyton is attached to the substrate, where as phytoplankton are suspended in the water column.

The term “zooplankton” refers to microscopic animals that float, drift or swim weakly, and includes crustaceans (i.e., Cladocera [cladocerans], Calanoida, and Cyclopoida) and rotifers. Cyclopoid and calanoid copepods are considered separately because of taxonomic differences, but also because Calanoida are almost exclusively planktonic, while Cyclopoida are dominated by littoral species (Wetzel 2001). However, the few planktonic species of Cyclopoida can account for a major component of the plankton community (Wetzel 2001).

Benthic invertebrates are also referred to as “benthic macroinvertebrates” because of their relatively large size, with some species reaching a few centimetres in length. Benthic invertebrates are present in nearly all waterbodies, are typically abundant, and remain in a small area throughout the aquatic phase of their life cycle so exposure to any contaminants or enrichment is maximized (Rosenberg and Resh 1993).

Fish can be referred to as “planktivorous,” “benthivorous,” “piscivorous,” “omnivorous,” or “apex predator” depending on what they feed on and if they have predators (Table 5.5-1). A planktivorous fish (i.e., cisco) is an adult fish feeding mainly on zooplankton, phytoplankton, and periphyton. Often, young-of-the-year and juvenile fish will originally be planktivorous, but will change food sources as they grow larger. A benthivorous fish (i.e., longnose sucker, ninespine stickleback, round whitefish, and slimy sculpin) is an adult fish feeding mainly on benthic invertebrates. Fish like Arctic char and lake whitefish are both planktivorous and benthivorous. A piscivorous fish (i.e., lake trout) is an adult fish feeding mainly on other fish species. An omnivorous fish (i.e., burbot) is an adult fish that feeds on plankton, benthic invertebrates, as well as other fish species, depending on what food source is available. An apex predator (i.e., burbot and lake trout) is a fish that has no higher predator controlling its population, other than humans. Arctic grayling has a diet completely different from the other fish in the area, as it mainly feeds on aquatic and terrestrial insects.

Table 5.5-1 Summary of Trophic Levels Consumed by Fish Species That Occur in the Mine Site and Site Access Local Study Areas

Fish Species	Food Type by Fish Life Stage							Major Fish Type	Predator	Trophic Level Consumer
	Plants	Phytoplankton and Periphyton	Zooplankton	Benthic Invertebrates	Terrestrial Insects	Fish or Fish Eggs	Small Mammals			
Arctic char	-	-	juvenile, adult	juvenile, adult	-	adults eat small fish	-	planktivorous and benthivorous	seal	middle to high
Arctic grayling	-	-	-	juvenile, adult	adult	adults eat grayling fry, and lake trout and lake whitefish eggs	adult (lemming)	insectivorous	lake trout	middle
burbot	-	-	juvenile	juvenile, adult	-	adults eat ninespine stickleback	-	omnivorous	-	apex predator
cisco	-	juvenile, adult	juvenile, adult	adult	juvenile, adult	-	-	planktivorous	lake trout, burbot	middle
fourhorn sculpin	-	-	-	juvenile, adult	-	adults eat small fish and fish eggs (including of its own species)	-	benthivorous	lake trout, burbot	middle
lake trout	-	young-of-the-year	young-of-the-year	juvenile	-	adults eat cisco and longnose sucker	-	piscivorous	-	apex predator
lake whitefish		juvenile, adult	juvenile, adult	juvenile, adult	juvenile, adult	adults eat fish eggs and small fish	-	planktivorous and benthivorous	lake trout, ospreys, eagle, river otter	middle
longnose sucker	juvenile, adult	-	-	juvenile, adult	-	-	-	benthivorous	lake trout	low to middle
ninespine stickleback	-	juvenile, adult	juvenile, adult	juvenile, adult	-	-	-	benthivorous	lake trout, burbot	middle
round whitefish	-	juvenile, adult	juvenile, adult	juvenile, adult	-	adults eat fish eggs and small fish	-	benthivorous	lake trout	middle
slimy sculpin	-	-	juvenile, adult	juvenile, adult	-	adults eat fish eggs and small fish	-	benthivorous	lake trout, burbot	middle

Source: Morrow 1980; Scott and Crossman 1998; Scott and Scott 1988; Steward and Watkinson 2007.

5.5.1 Limnology

This section presents the historical and current information available on limnology within the local study area (LSA). Detailed methods and results can be found in Appendix 5C (Section 6.0).

Limnological measurements were collected as a component of other aquatic sampling efforts such as benthic invertebrate community sampling, aquatic macrophyte collection, and fish community sampling to provide supporting environmental information. The following parameters were recorded:

- depth (m);
- dissolved oxygen (DO; milligrams per litre [mg/L]);
- pH;
- temperature (degrees Celsius [oC]);
- specific conductivity (microSiemens per centimetre [µS/cm]);
- maximum water depth (m);
- Secchi depth (m); and
- ice thickness (m) (where applicable).

Vertical profiles (DO, water temperature, pH, and specific conductivity) were recorded for lakes greater than 3 m deep between 2007 and 2010. Table 5.5-2 summarizes the season and year that limnology information was collected from various lakes in the LSA. Streams in the LSA were also included in surface water limnological data collection. Table 5.5-3 summarizes the season and year that limnology information was collected from various stream segments or rivers (“streams”) in the mine site LSA.

In general, lakes in the mine site LSA were shallow (many with maximum depths less than 3 m), of very low specific conductivity (range of 6 to 35 µS/cm in the historical data and 11 to 61 µS/cm in the 2007 to 2010 data), and did not experience thermal stratification in summer. Secchi depth was usually greater than 2 m and was often equal to total depth. Since ice thickness ranged from 1.8 m to 2.1 m by the end of the winter; it is expected that many of the shallow lakes would freeze to the bottom during winter, similar to lakes sampled in the Willow Lake sub-basin.

Table 5.5-2 Summary of Limnology Data Collected from Lakes in the Kiggavik Project Area, 1979 to 2010

Watershed	Sub-Basin	Waterbody	197	198	198	199	200	2008	2009	2010
Aniguq River	Willow Lake	Escarpment Lake			X		-	-	-	-
		Scotch Lake	X	X			-	-	-	-
		Jaeger Lake	X		X		-	-	-	-
		Pointer Pond					-	-	-	P
		Pointer Lake	X	X	X	X	F	U, F	F	-
		Sik Sik Lake					F	F	W[(a)], U, F	-
		Rock Lake					-	U, F	W[(a)], U, F	-
		Willow Lake					F	F	W[(a)], U, F	-
	Lower Lake	Mushroom Lake				X	-	U, F	W	-
		Pond 1 to Pond 8					-	-	-	P
		End Grid Lake					F	U, F	-	-
		Cigar Lake				X	-	U, F	-	-
		Knee Lake					-	U, F	-	-
		Lunch Lake					-	U, F	-	-
		Andrew Lake					F	U, F	W[(a)], F	-
		Shack Lake					F	U, F	-	-
		Lower Lake					F	U, F	-	-
	Caribou Lake	Ridge Lake				X	F	U, F	-	-
		Cirque Lake					F	F	-	-
		Crash Lake					F	F	-	-
		Fox Lake					F	U, F	-	-
		Caribou Lake					-	U, F	-	-
		Calf Lake					-	U, F	-	-
	Judge Sissons Lake	Judge Sissons Lake	X	X		X	-	U, F	W, U, F	-
	Siamese Lake	Siamese Lake					-	U, F	W	-
		L2					-	-	W	-
	Skinny Lake	Skinny Lake			X		F	F	-	-
	Kavisilik Lake	Kavisilik Lake		X			-	-	-	-
	Long Lake	Long Lake					-	-	W	-
	Audra Lake	Audra Lake					-	-	W	-
Thelon River	Squiggly Lake	Squiggly Lake		X			-	F	-	-
Baker Lake	Baker Lake	Qinguq Bay					-	-	W	-
		Baker Lake					-	F	W, U, F	-

Source: Modified from Appendix 5C, Table 6.0-1.

(a) Waterbody was frozen to the bottom.

X = no season of sampling specified; F = fall, U = summer, W = winter, P = spring, - = no data.

Table 5.5-3 Summary of Limnology Data Collected from Streams in the Kiggavik Project Area, 2007 to 2010

Watershed	Sub-Basin	Watercourse	2007	2008	2009	2010
Aniguq River	Willow Lake	Northeast Inflow of Pointer Lake	-	P, F	P, F	P
		Upper Tributary to the Northeast Inflow of Pointer Lake	-	-	-	P
		Upper Northwest Inflow of Pointer Lake	-	-	-	P
		Northwest Inflow of Pointer Lake	-	P, F	P	-
		Pointer/Rock Stream	F	P, F	P	-
		Sik Sik/Rock Stream	-	P, F	P, F	-
		Rock/Willow Stream	-	P, F	P, F	-
		Willow/Judge Sissons Stream	-	P, F	P, F	-
	Lower Lake	Mushroom/End Grid Stream	-	P, F	-	-
		End Grid/Shack Stream	-	P, F	-	-
		Cigar/Lunch Stream	-	P, F	-	-
		Knee/Lunch Stream	-	P, F	-	-
		Lunch/Andrew Stream	-	P, F	P	-
		Andrew/Shack Stream	-	P, F	P	-
		Shack/Lower Stream	F	P, F	-	-
		Lower/Judge Sissons Stream	-	P, F	-	-
	Caribou Lake	Ridge/Crash Stream	-	P, F	-	-
		Cirque/Crash Stream	-	P, F	-	-
		Crash/Fox Stream	F	P, F	-	-
		Fox/Caribou Stream	F	P, F	-	-
		Caribou/Calf Stream	-	P, F	-	-
		Calf/Judge Sissons Stream	-	P, F	-	-
	Aniguq River	Aniguq River	-	-	F	-
Access Local Study Area		several stream crossings	-	F	U, F	-

Source: Modified from Appendix 5C, Table 6.0-2.
F = fall, U = summer, P = spring, - = no data.

Lakes in the mine site LSA where maximum depth recorded was greater than or equal to 3 m are:

- Felsenmeer (6. 0 m), Escarpment (8.0 m), Scotch (6.0 m), Jaegar (4.0 m), Pointer (3.0 m) lakes, and Pointer Pond (4.5 m) in the Willow Lake sub-basin;
- Mushroom (8.9 m) and Cigar (3.6 m) lakes in the Lower Lake sub-basin;
- Ridge (7.1 m) and Cirque (5.2 m) lakes in the Caribou Lake sub-basin;
- Judge Sissons Lake (20.6 m) in the Judge Sissons Lake sub-basin;
- Siamese Lake (12.0 m) in the Siamese Lake sub-basin;
- Skinny Lake (12.8 m) in the Skinny Lake sub-basin; and
- Kavisilik Lake (12.0 m) in the Kavisilik Lake sub-basin.

Judge Sissons Lake is the largest (9,550 hectare [ha]) and deepest (20.6 m) lake in the mine site LSA. In winter 2008, DO concentration measured at the bottom of Judge Sissons Lake was 0.3 mg/L, considerably less than the Canadian Water Quality Guidelines (CWQG) of 9.5 mg/L for the protection of early life stages of cold water biota. However, DO levels at depths of 2.0 to 7.0 m were higher than the CWQG; this is the depth where most fall spawning species (e.g., lake trout and lake whitefish) would deposit their eggs. Generally, DO was above the CWQG for the protection of early life stages of cold water biota (9.5 mg/L) in most lakes. On occasion, in some lakes DO was below the early life stages guideline, but still above the guideline for other life stages (6.5 mg/L).

Although lake pH values in the mine site LSA varied among lakes and within an individual lake over time, values generally fell within the CWQG range of 6.5 to 9.0. Exceptions were Cigar Lake and Siamese Lake where pH levels were below 6.5 on occasion. Pointer Lake pH was especially variable, ranging from 9.9 in 2007 to 6.7 in 2009 (Technical Appendix 5C, Section 6.2).

Streams in the mine site LSA had similar limnology characteristics as the lakes and were generally shallow (less than 1.5 m).

5.5.2 Benthic Invertebrate Communities

This section presents the historical and current information available on benthic invertebrate communities within the local study area (LSA). Detailed methods and results can be found in Technical Appendix 5C (Section 7.0).

Benthic invertebrate community surveys were conducted between 1979 and 2009 in lakes and between 1989 and 2009 in streams of the mine site LSA. Table 5.5-4 summarizes the locations of benthic invertebrate community sampling in lakes by year. Table 5.5-5 summarizes the locations of benthic invertebrate community sampling in streams by year.

Overall, benthic invertebrate communities in lakes in the LSA were characterized by low to moderate density and diversity. Taxa richness varied from 5 taxa to 26 taxa per lake in the LSA (including Baker Lake). Chironomids were the dominant taxa, followed by fingernail clams in all lakes except Lunch Lake, Fox Lake, Crash Lake, and Calf Lake. Lakes with very high proportions of sandy or coarse substrate also tended towards high proportions of chironomids and decreased taxa richness. A previously unidentified species of orthoclads was documented in Willow Lake in 2007 (Technical Appendix 5C, Section 7.2). None of the taxa present are federally listed as being endangered or at risk species.

Table 5.5-4 Summary of Benthic Invertebrate Community Sampling Collected from Lakes in the Kiggavik Project Area, 1979 to 2009

Watershed	Sub-Basin	Waterbody	1979	1980	1990	1991	2007	2008	2009
Aniguq River	Willow Lake	Scotch Lake	X	X	-	-	-	-	-
		Pointer Lake	X	X	-	-	X	X	-
		Sik Sik Lake	-	-	-	-	X	X	X
		Rock Lake	-	-	-	-	-	X	X
		Willow Lake	-	-	-	-	X	X	X
	Lower Lake	Mushroom Lake	-	-	-	X	-	X	-
		End Grid Lake	-	-	-	-	X	X	-
		Cigar Lake	-	-	-	X	-	X	-
		Knee Lake	-	-	X	-	-	-	-
		Lunch Lake	-	-	X	-	-	X	-
		Andrew Lake	-	-	-	-	X	X	X
		Shack Lake	-	-	X	-	X	X	-
		Lower Lake	-	-	-	-	X	X	-
	Caribou Lake	Ridge Lake	-	-	-	-	X	X	-
		Cirque Lake	-	-	-	-	X	X	-
		Crash Lake	-	-	-	-	X	X	-
		Fox Lake	-	-	-	-	X	X	-
		Caribou Lake	-	-	-	-	-	X	-
		Calf Lake	-	-	-	-	-	X	-
	Judge Sissons Lake	Judge Sissons Lake	X	X	-	-	-	X	X
	Siamese Lake	Siamese Lake	-	-	-	-	-	X	-
	Kavisilik Lake	Kavisilik Lake	-	X	-	-	-	-	-
Thelon River	Squiggly Lake	Squiggly Lake	-	X	-	-	-	-	-
Baker Lake	Baker Lake	Baker Lake	-	-	-	-	-	X	-

Source: Modified from Appendix 5C, Table 7.0-1.
X = data collected, - = data not collected.

Judge Sissons Lake had variable taxa richness and density, likely a reflection of its large size relative to other lakes in the LSA. However, similar to most other lakes in the LSA, chironomids followed by fingernail clams were the dominant taxa (Appendix 5C, Section 7.2).

Stream benthic invertebrate communities generally had higher taxa richness than the lakes of the LSA. As in the lakes, chironomids were generally the dominant taxa. When the proportion of chironomids decreased, the proportion of seed shrimp and hydridae generally increased. A few streams were dominated by oligochaete worms or hydridae.

Table 5.5-5 Summary of Benthic Invertebrate Community Sampling Collected from Streams on the Kiggavik Project Area, 1989 to 2009

Watershed	Sub-Basin	Watercourse	1989	1990	1991	2008	2009
Aniguq River	Willow Lake	Northeast Inflow of Pointer Lake	-	-	-	X	X
		Northwest Inflow of Pointer Lake	-	-	-	X	-
		Jaeger Lake outlet	X	-	-	-	-
		Pointer/Rock Stream	X	-	X	X	-
		Rock/Willow Stream	-	-	-	X	X
		Willow/Judge Sissons Stream	-	-	-	X	X
	Lower Lake	Mushroom/End Grid Stream	-	-	-	X	-
		End Grid/Shack Stream	-	-	-	X	-
		Shack Lake Inlet Stream	-	X	-	-	-
		Cigar/Lunch Stream	-	-	-	X	-
		Lunch Lake Inlet Stream	-	X	-	-	-
		Knee Lake Inlet Stream	-	X	-	-	-
		Knee/Lunch Stream	-	-	-	X	-
		Lunch/Andrew Stream	-	-	-	X	-
		Andrew/Shack Stream	-	-	-	X	-
		Andrew Lake Study Area outflow	-	-	X	-	-
		Shack/Lower Stream	-	X	-	X	-
		Lower/Judge Sissons Stream	-	-	-	X	-
	Caribou Lake	Ridge/Crash Stream	X	-	-	X	-
		Cirque/Crash Stream	-	-	-	X	-
		Crash/Fox Stream	-	-	-	X	-
		Fox/Caribou Stream	-	-	-	X	-
		Caribou/Calf Stream	-	-	-	X	-
		Calf/Judge Sissons Stream	-	-	-	X	-
	Skinny Lake	Skinny Lake outlet	X	-	-	-	-
	Aniguq River	Judge Sissons Lake outlet	-	-	X	-	-
		Aniguq River	-	-	-	-	X

Source: Modified from Appendix 5C, Table 7.0-2.
X =data collected, - = data not collected.

5.5.3 Aquatic Macrophytes

Aquatic macrophytes are an important component of aquatic systems, providing habitat for both fish and invertebrates. They also offer fish and invertebrates protection against currents and predators, and a substrate for the deposition of eggs. Aquatic macrophytes can also be used as an indicator of the health of the aquatic ecosystem.

Macrophytes can be used in the monitoring of metals in the aquatic environment (Prasad 2009). Prasad (2009) identified Carex juncell and C. rostrata for use in the biomonitoring of trace elements of chromium, cobalt, copper, lead, molybdenum, nickel, uranium, and zinc. Carex sp.

have been used for monitoring metals such as cadmium, iron, lead, and manganese (Prasad 2009).

This section presents the current information available on macrophyte chemistry within the mine site LSA. Detailed methods and results can be found in Technical Appendix 5C (Section 8.0).

Baseline macrophyte data (i.e., roots and shoots of Carex ssp.) were collected in five lakes during fall 2009, including Pointer, Sik Sik, Rock, and Willow lakes in the Willow Lake sub-basin, and Judge Sissons Lake (Figures 5.2-1, 5.2-2, and 5.2-3). The following parameters were measured:

- physical properties (i.e., percent moisture);
- total metals by ICP-MS Scan (i.e., aluminium, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, strontium, thallium, tin, titanium, uranium, vanadium, and zinc); and
- radionuclides including lead-210, polonium-210, radium-226, thorium-228, thorium-230, and thorium-232.

All results were reported on a dry weight basis. Macrophyte chemistry for roots and shoots was compared between roots and shoots in the same lake, among sampling stations in the same lake, and among lakes from upstream to downstream.

Carex spp. were used to assess metal and radionuclide background concentrations in macrophytes, as these plants have been successfully used in the past to monitor various metals. Macrophytes were only sampled in 2009. In general, concentrations in roots and shoots differed, with percent moisture and concentrations of most metals and radionuclides higher in roots than shoots. Concentrations in shoots were near or below detection limits for most metals and radionuclides (Table 5.5-6).

Baseline macrophyte chemistry parameters for Judge Sissons Lake were within the range observed in lakes from the Willow Lake sub-basin (i.e., Pointer, Sik Sik, Rock, and Willow lakes) for roots and for shoots with the exception of a few parameters (i.e., barium, boron, uranium, and radium-226 for the roots, and moisture, cadmium, cobalt, copper, and manganese for the shoots). The range of manganese concentration in the shoots from Judge Sissons Lake (i.e., 390 to 650 µg/g dw) was higher than for lakes from the Willow Lake sub-basin (i.e., 90 to 350 µg/g dw) (Table 5.5-6).

Table 5.5-6 Summary of Macrophyte Chemistry for Roots and Shoots of Carex ssp Collected in the Kiggavik Project Area, 2009

Parameter	Unit	Willow Lake Sub-Basin		Judge Sissons Lake Sub-Basin	
		All Lakes		Judge Sissons Lake	
		Roots (n = 12)	Shoots (n = 12)	Roots (n = 3)	Shoots (n = 3)
Physical Properties					
Moisture	%	76.75 - 84.98	66.80 - 75.87	78.97 - 82.04	65.79 - 77.24
Metals					
Aluminum	µg/g dw	87 - 2,900	3.8 - 160	310 - 2,000	5.0 - 31
Antimony	µg/g dw	<0.1 (12 < DL)	<0.1 (12 < DL)	<0.1 - 0.1 (2 < DL)	<0.1 (3 < DL)
Arsenic	µg/g dw	0.64 - 31	<0.05 - 0.24 (1 < DL)	5.0 - 9.4	<0.05 - 0.11 (1 < DL)
Barium	µg/g dw	63 - 180	45 - 110	50 - 230	63 - 80
Beryllium	µg/g dw	0.02 - 0.25	<0.01 - 0.01 (11 < DL)	0.06 - 0.22	<0.01 - 0.01 (2 < DL)
Boron	µg/g dw	2 - 4	3 - 5	3 - 8	4 - 5
Cadmium	µg/g dw	0.06 - 0.71	<0.01 - 0.03 (2 < DL)	0.10 - 0.29	0.02 - 0.05
Chromium	µg/g dw	<0.5 - 5.3 (6 < DL)	<0.5 - 0.6 (11 < DL)	0.8 - 5.3	<0.5 (3 < DL)
Cobalt	µg/g dw	0.38 - 5.0	<0.01 - 0.17 (1 < DL)	0.84 - 2.2	0.10 - 0.23
Copper	µg/g dw	2.2 - 27	2.2 - 4.9	5.1 - 20	3.3 - 5.9
Iron	µg/g dw	3,200 - 17,300	70 - 900	5,100 - 11,400	150 - 250
Lead	µg/g dw	0.44 - 7.2	0.03 - 0.25	0.99 - 2.3	0.01 - 0.04
Manganese	µg/g dw	70 - 340	90 - 350	80 - 160	390 - 650
Molybdenum	µg/g dw	0.1 - 1.5	0.2 - 1.7	0.2 - 0.6	0.7 - 2.3
Nickel	µg/g dw	0.93 - 5.7	0.2 - 1.8	0.95 - 5.2	1.0 - 2.1
Selenium	µg/g dw	<0.05 - 0.18 (7 < DL)	<0.05 (12 < DL)	0.07 - 0.19	<0.05 (3 < DL)
Silver	µg/g dw	<0.01 - 0.03 (8 < DL)	<0.01 (12 < DL)	<0.01 - 0.02 (1 < DL)	<0.01 (3 < DL)
Strontium	µg/g dw	5.9 - 22	13 - 27	6.6 - 15	15 - 19
Thallium	µg/g dw	<0.05 - 0.19 (2 < DL)	<0.05 (12 < DL)	<0.05 (3 < DL)	<0.05 (3 < DL)
Tin	µg/g dw	<0.05 - 0.10 (10 < DL)	<0.05 - 0.08 (9 < DL)	<0.05 (3 < DL)	<0.05 (3 < DL)
Titanium	µg/g dw	2.2 - 97	0.08 - 4.9	6.2 - 45	0.16 - 0.57
Uranium	µg/g dw	0.02 - 0.61	<0.01 - 0.05 (8 < DL)	0.24 - 0.86	<0.01 (3 < DL)
Vanadium	µg/g dw	0.5 - 8.8	<0.1 - 0.4 (10 < DL)	3.0 - 7.0	<0.1 (3 < DL)
Zinc	µg/g dw	13 - 44	11 - 35	19 - 27	37 - 50
Radionuclides					
Lead-210	Bq/g dw	0.038 - 0.30	0.018 - 0.059	0.068 - 0.17	0.013 - 0.034
Polonium-210	Bq/g dw	0.028 - 0.16	0.012 - 0.035	0.052 - 0.097	0.012 - 0.027

Parameter	Unit	Willow Lake Sub-Basin		Judge Sissons Lake Sub-Basin	
		All Lakes		Judge Sissons Lake	
		Roots (n = 12)	Shoots (n = 12)	Roots (n = 3)	Shoots (n = 3)
Radium-226	Bq/g dw	0.004 - 0.017	0.001 - 0.004	0.006 - 0.047	0.002 - 0.004
Thorium-228	Bq/g dw	0.005 - 0.041	0.001 - 0.005	0.02 - 0.024	<0.001 - 0.002 (2 < DL)
Thorium-230	Bq/g dw	<0.001 - 0.008 (1 < DL)	<0.0009 - 0.001 (10 < DL)	0.003 - 0.006	<0.001 - 0.002 (1 < DL)
Thorium-232	Bq/g dw	0.001 - 0.01	<0.0009 - 0.001 (11 < DL)	0.002 - <0.006 (1 < DL)	<0.001 (3 < DL)

Source: Modified from Appendix 5C, Tables X.VI-1 and X.VI-2.

Moisture = moisture content by percent weight; µg/g dw = microgram per gram dry weight; Bq/g dw = Becquerels per gram dry weight; % = percent; n = number of samples.

5.5.4 Plankton and Periphyton Communities

The term “plankton” is a general term referring to small, usually microscopic, organisms that live suspended in open water. For the purpose of the Project, the term “phytoplankton” refers to the open-water, algal component (i.e., non-vascular, photosynthetic plants). Chlorophyll a is the primary photosynthetic pigment contained in phytoplankton (Wetzel 2001). The term “zooplankton” refers to microscopic animals that float, drift or swim weakly, and includes crustaceans (i.e., Cladocera [cladocerans], Calanoida and Cyclopoida [copepods]) and rotifers. For the purpose of the Project, the term “periphyton” refers only to the algal component as opposed to the entire biofilm. Periphyton is the term used to describe the algal community that grows attached to the substrate (generally rocks) in streams and lakes. They are a primary producer, similar to phytoplankton; however, periphyton is attached to the substrate where as phytoplankton is suspended in the water column.

This section presents the historical and current information available on plankton (i.e., phytoplankton and zooplankton) and periphyton within the local study area (LSA). Detailed methods and results can be found in Appendix 5C (Section 9.0).

Plankton community surveys were carried out between 1979 and 2009 in lakes and streams of the mine site LSA. Table 5.5-7 provides a summary of the plankton sampling locations by year. Periphyton community surveys were completed between 2008 and 2009. Table 5.5-8 provides a summary of the periphyton sampling locations in streams by year.

Table 5.5-7 Summary of Phytoplankton and Zooplankton Sampling in Lakes and Streams in the Kiggavik Project Area, 1979 to 2009

Watershed	Sub-Basin	Waterbody	1979	1989	1990	1991	2008	2009
Aniguq River	Willow Lake	Scotch Lake	ZP	-	-	-	-	-
		Jaeger Lake	ZP	PP, ZP	-	-	-	-
		Pointer Lake	ZP	PP, ZP	-	ZP	PP, ZP	-
		Pointer Lake Outfall	-	-	-	PP	-	-
		Sik Sik Lake	-	-	-	-	-	PP, ZP
		Rock Lake	-	-	-	-	-	PP, ZP
		Willow Lake	-	-	-	-	-	PP, ZP
	Lower Lake	Mushroom Lake	-	-	PP, ZP	PP, ZP	PP, ZP	-
		Cigar Lake	-	-	PP, ZP	PP, ZP	-	-
		Andrew Lake	-	-	-		-	PP, ZP
		Andrew Lake Outfall	-	-	PP	PP	-	-
		Shack Lake	-	-	ZP	-	-	-
		Bear Island Lake	-	-	ZP	-	-	-
		Bear Island Lake Outfall	-	-	PP	-	-	-
		Lower Lake	-	-	ZP	-	PP, ZP	-
		Lower Lake Outfall	-	-	PP	-	-	-
	Caribou Lake	Ridge Lake	-	PP, ZP	-	PP	-	-
		Cirque Lake	-	PP, ZP	-	-	-	-
		Fox Lake	-	-	-	-	PP, ZP	-
		Caribou Lake	-	-	-	-	PP, ZP	-
	Judge Sissons Lake	Judge Sissons Lake	ZP	PP, ZP	-	PP, ZP	PP, ZP	PP, ZP
		Judge Sissons Outfall	-	-	-	PP	-	-
Baker Lake	Baker Lake	Baker Lake	-	-	-	-	ZP	-

Source: Modified from Appendix 5C, Table 9.0-1.

- = not collected; PP = phytoplankton; ZP = zooplankton.

Table 5.5-8 Summary of Periphyton Sampling in Streams in the Kiggavik Project Area, 2008 to 2009

Watershed	Sub-Basin	Watercourse	2008	2009
Aniguq River	Willow Lake	Northeast Inflow of Pointer Lake	X	X
		Northwest Inflow of Pointer Lake	X	-
		Pointer/Rock Stream	X	-
		Sik Sik/Rock Stream	(a)	(a)
		Rock/Willow Stream	X	X
		Willow/Judge Sissons Stream	X	X
	Lower Lake	Mushroom/End Grid Stream	X	-
		End Grid/Shack Stream	X	-
		Cigar/Lunch Stream	X	-
		Knee/Lunch Stream	X	-
		Lunch/Andrew Stream	X	-
		Andrew/Shack Stream	X	-
		Shack/Lower Stream	X	-
		Lower/Judge Sissons Stream	X	-
	Caribou Lake	Ridge/Crash Stream	X	-
		Cirque/Crash Stream	X	-
		Crash/Fox Stream	X	-
		Fox/Caribou Stream	X	-
		Caribou/Calf Stream	X	-
		Calf/Judge Sissons Stream	X	-
	Aniguq River	Aniguq River	-	X

Source: Modified from Appendix 5C, Table 9.0-2.
(a) Sampling was not completed at this station due to inappropriate substrate type.
- = not collected.

5.5.4.1 Phytoplankton

Historical phytoplankton data from 1989 to 1991 are limited. The historical phytoplankton community data indicated some inter-lake variability in phytoplankton biomass, particularly in August 1990. Chrysophytes tended to be the dominant taxonomic group; however, cyanobacteria and diatoms were also identified as dominant taxonomic groups, but this may be related to variation in the timing of sample collection (i.e., under ice versus summer open water conditions). Overall, the historical phytoplankton community data indicated lakes within the Project area exhibited characteristics typical of unproductive Canadian Shield lakes.

In general, chrysophytes were the most abundant taxonomic group in the phytoplankton communities of lakes sampled within the Project area in both 2008 and 2009. In 2008, phytoplankton community biomass was more variable both across lakes and between the two sampling seasons. With the exception of Fox Lake (2008), Andrew Lake (2009), and Sik Sik Lake (2009), cyanobacteria biomass was consistently low in lakes sampled within the Project area. Diatoms and “Other Taxa” were consistently low in abundance and biomass in all lakes. Species richness varied across lakes, with chlorophytes and chrysophytes exhibiting the greatest diversity. Several unique phytoplankton taxa were identified within various waterbodies in both 2008 and 2009; however, none of these are federally or territorially listed as endangered or ‘at risk’ taxa.

In 2008 and 2009, chlorophyll a concentrations were within the range specified for oligotrophic lakes. In general, higher chlorophyll a concentrations in 2008 were observed in the summer and decreased in the fall, which is inconsistent with the pattern observed for phytoplankton biomass. This suggests that seasonal and taxonomical variation may be affecting overall chlorophyll a concentrations.

5.5.4.2 Zooplankton

Historical zooplankton data from 1979 to 1991 are limited. Biomass data are absent for this period, and while rotifers were identified in 1989, 1990 and 1991 samples, they were not enumerated. This group is ecologically important, but is often overlooked because of their small size. In general, the zooplankton communities were either dominated by cladocerans or calanoid copepods. However, variation in crustacean species richness is likely a reflection of differences in sampling methods (i.e., vertical tows versus stationary sampling) and locations (i.e., deep basin versus outflow areas).

In both 2008 and 2009, rotifers consistently exhibited the highest relative density in all lakes sampled within the Project area. Rotifers also accounted for the majority of the zooplankton biomass, with the exception of Fox Lake (2008) and Sik Sik Lake (2009). In both summer and fall 2008, the zooplankton community within Fox Lake was dominated by cladocerans, specifically by the large sized Daphnia middendorffiana. The presence of this species suggests fish predation in this lake is limited. In 2009, the zooplankton community biomass in Sik Sik Lake was co-dominated by calanoids and cladocerans. Leptodiaptomus sicilis (calanoid) and D. middendorffiana were the predominant species, suggesting that fish predation in this lake is also limited. Several unique zooplankton taxa were identified within various waterbodies in both 2008 and 2009; however, none of these are federally or territorially listed as endangered or ‘at risk’ species.

5.5.4.3 Periphyton

In both 2008 and 2009, chlorophytes had the highest density in the majority of stream periphyton communities within the Project area, although a number of streams within the Lower Lake sub-basin had high densities of diatoms. Cyanobacteria were present in variable numbers within all streams within the Project area. Chlorophytes and cyanobacteria dominated the periphyton community biomass in many of the streams; however, diatom biomass was greater in several streams within the Lower Lake sub-basin. Overall, lowest level taxonomic richness in periphytic communities was similar between sub-basins, with diatoms being the most taxonomically rich group within streams in the Project area, followed by chlorophytes and cyanobacteria. Chrysophytes and cryptophytes, as well as dinoflagellates, were represented by a small number of taxa and were absent from several of the Project area streams. These three taxonomic groups also contributed a low proportion to the density and biomass of the periphyton community in all streams sampled within the Project area. Several unique periphyton taxa were identified within various waterbodies in both 2008 and 2009; however, none of these are federally or territorially listed as endangered or 'at risk' species.

5.5.5 Freshwater Habitats

This section presents the historical and current information available on freshwater habitats (i.e., lakes and streams) within the local study area (LSA). Detailed methods and results can be found in Technical Appendix 5C (Section 10.0).

Bathymetric maps were produced between 1979 and 2010. Habitat maps were produced between 1979 and 2010 for lakes of the mine site LSA; and between 2008 and 2010 for all streams in the mine site and site access LSAs. Table 5.5-9 provides a summary of the lakes and ponds assessed for bathymetry and aquatic habitat. Table 5.5-10 provides a summary of the streams assessed for aquatic habitat. Table 5.5-11 provides a summary of stream crossings assessed along the proposed Kiggavik Access Road alignments between 2008 and 2010.

Table 5.5-9 Summary of the Lakes and Ponds Assessed for Bathymetry and Aquatic Habitat, Kiggavik Project Area, 1979 to 2010

Watershed	Sub-Basin	Waterbody	Bathymetry Map	Aquatic Habitat Map
Aniguq River	Willow Lake	Meadow Lake	1979-1986	-
		Felsenmeer Lake	1979-1986	-
		Escarpment Lake	1979-1986	-
		Drum Lake	1979-1986	-
		Lin Lake	1979-1986	-
		Scotch Lake	1979-1986	-
		Jaeger Lake	1979-1986	-
		Pointer Pond	2010	2010
		Pointer Lake	1979-1986, 2007	2007
		Sik Sik Lake	1979-1986, 2009	2007, 2009
		Rock Lake	1979-1986, 2008	2008
		Willow Lake	1979-1986	2007
	Lower Lake	Mushroom Lake	1990, 2009	2008
		Pond 1 to Pond 8	2010	2010
		End Grid Lake	2008	2007
		Smoke Lake	1990	-
		Cigar Lake	1990	2008
		Knee Lake	1990	2008
		Lunch Lake	1990	2008
		Andrew Lake	1990, 2009	2007, 2009
		Shack Lake	1990	2007
		Bear Island Lake	1990	-
		Lower Lake	1990-1991	2007
	Caribou Lake	Ridge Lake	1979-1986	2007
		Cirque Lake	1979-1986	2007
		Crash Lake	1979-1986	2007
		Fox Lake	1979-1986	2007
		Caribou Lake	1979-1986	2008
		Calf Lake	2008	2008
	Judge Sissons Lake	Judge Sissons Lake	1979-1986, 2009 (north)	2008 (north)
	Siamese Lake	Siamese Lake	2008	2008
	Skinny Lake	Skinny Lake	1979-1986	1979-1986
	Kavisilik Lake	Kavisilik Lake	1979-1986	-
Thelon River	Squiggly Lake	Squiggly Lake	1979-1986	-
Baker Lake	Baker Lake	Baker Lake	2008, 2009	2008, 2009

Source: Technical Appendix 5C, Table 10.0-1.

- = no data.

Table 5.5-10 Summary of the Streams Assessed for Aquatic Habitat, Kiggavik Project Area, 2008 to 2010

Watershed	Sub-Basin	Watercourse	Aquatic Habitat
Aniguq River	Willow Lake	Northeast Inflow of Pointer Lake	2008
		Upper Tributary to the Northeast Inflow of Pointer Lake	2010
		Upper Northwest Inflow of Pointer Lake	2010
		Northwest Inflow of Pointer Lake	2008
		Pointer/Rock Stream	2008
		Sik Sik/Rock Stream	2008
		Rock/Willow Stream	2008
		Willow/Judge Sissons Stream	2008
	Lower Lake	Mushroom/End Grid Lake	2008
		End Grid/Shack Stream	2008
		Cigar/Lunch Stream	2008
		Knee/Lunch Stream	2008
		Lunch/Andrew Stream	2008
		Andrew/Shack Stream	2008
		Shack/Lower Stream	2008
		Lower/Judge Sissons Stream	2008
	Caribou Lake	Ridge/Crash Stream	Flight overview only
		Cirque/Crash Stream	Flight overview only
		Crash/Fox Stream	Flight overview only
		Fox/Caribou Stream	2008
		Caribou/Calf Stream	2008
		Calf/Judge Sissons Stream	2008
	Aniguq River	Aniguq River	Flight overview only

Source: Technical Appendix 5C, Table 10.0-2.

Table 5.5-11 Summary of Stream Crossings Assessed Along the Proposed Kiggavik Access Road Alignments Between 2008 and 2010

Crossing Identification	Habitat Mapping	Fish Community
Km 2.0 (Mushroom/End Grid Stream)	2008, 2009	2008, 2009
Km 2.9	2009 (no map)	-
Km 6.7	2009	2009
Km 11.3	2009	2009
Km 14.1	2009 (no map)	-
Km 15.6	2009	2009
Km 17.2	2009	2009
Km 19.6	2009 (no map)	-
Km 100.2	2009	2009
Km 103.4	2009 (no map)	-
Km 107.8	2009	2009
Km 108.8	2009	2009
Km 109.8	2009	2009
Alternate NC22	2009 (no map)	2009
Alternate NC21	2009 (no map)	2009
Alternate NC20	2009 (no map)	2009
Km 112.9	2009 (no map)	-
Alternate NC18	2009	-
Alternate NC17	2009	2009
Km 127.5	2009	2009
Km 129.2	2009	2009
Alternate X33 (4 km downstream of Km 129.2)	2008	2008
Km 130.1	2009	-
Km 131.3	2009	-
Km 145.3	2009	2009
Km 147.1	2009	2009
Km 147.6	2009	2009
Km 154.8	2009 (no map)	-
Alternate X28 (0.5 km upstream of Km 157.3)	2008	2008
Km 157.3	2009	2009
Km 157.7	2009	2009
Km 159.5	2009 (no map)	-
Km 161.5	2009 (no map)	-
Km 163.2	2009 (no map)	-
Km 168.0	2009 (no map)	-
Km 171.2	2009 (no map)	-
Km 172.2	2009	2009
Km 174.3	2009	-

Crossing Identification	Habitat Mapping	Fish Community
Km 174.8 (Thelon River)	2008, 2009, 2010	2008, 2009
Alternate EC30	-	2009
Alternate EC22	2009	2009
Km 193.3	-	2009
Km 195.1	-	2009
Km 197.5	-	2009
Km 203.0	2009	2009
Km 209.4	2009	2009
Km 212.2	2009	2009
Km 213.1	2009	2009
Alternate W1	2009	2009
Alternate W2	2009	2009
Alternate W3	2009	2009
Alternate W4	2009	-
Alternate W5	2009	2009
Alternate W6	2009	2009
S13 (Long/Audra stream)	2009	2009
S14	2009	2009
S5 (Aniguq River)	2009	2009

Source: Modified from March 18, 2011 Golder Technical Memo to Nicola Banton, AREVA titled "Summary of Aquatics Studies for the Kiggavik Uranium Project".

- = no data ; km = kilometres; no map = no habitat mapping produced because section of stream had no visible channel or stream was dry at the time of survey.

5.5.5.1 Mine Site Local Study Area

A brief summary of the lake and stream habitat characteristics is provided in the following sections.

5.5.5.1.1 Willow Lake Sub-Basin (Surrounding the Proposed Kiggavik Mine Site)

Habitat assessment of lakes (i.e., Pointer Pond, Pointer Lake, Sik Sik Lake, Rock Lake, and Willow Lake) in the Willow Lake sub-basin was completed between 2007 and 2010 (Table 5.5-9). Surface area ranged from 3 ha for Pointer Pond to 393 ha for Pointer Lake. Maximum depth ranged from 1.5 m in Rock Lake to 4.5 m in Pointer Pond. The shoreline development index ranged from 1.3 for Pointer Pond to 1.8 for Rock Lake due to its more complex shoreline that includes several bays (Table 5.5-12).

Shoreline substrate in all lakes consisted primarily of boulder and cobble (n = 3) or cobble and boulder (n = 2) substrates. The shoreline slope was predominantly flat (n = 4) or varied from flat to moderately steep (n = 1). Shoreline vegetation was primarily grasses and low shrubs. In-lake habitat consisted of inundated vegetation, and/or interstitial spaces in the coarse cobble and boulder substrate, as well as some lakes containing areas of emergent and/or submergent aquatic vegetation (Table 5.5-12).

Habitat assessment of streams (i.e., Northeast Inflow of Pointer Lake Stream, Upper Tributary to the Northeast Inflow of Pointer Lake Stream, Upper Northwest Inflow of Pointer Lake Stream, Northwest Inflow of Pointer Lake Stream, Pointer/Rock Stream, Sik Sik/Rock Stream, Rock/Willow Stream, and Willow/Judge Sissons Stream) in the Willow Lake sub-basin was completed between 2008 and 2010 (Table 5.5-10). The stream lengths assessed for habitat ranged from 420 m for Rock/Willow Stream to 5,575 m for the Northeast Inflow of Pointer Lake Stream. Maximum depth recorded ranged from 0.8 m in Upper Northwest Inflow of Pointer Lake Stream to deeper than 2 m in Willow/Judge Sissons Stream. Wetted width ranged from 0.1 m in Upper Northwest Inflow of Pointer Lake Stream to 1,000 m in an area of unconfined flow during high water conditions in the Northeast Inflow of Pointer Lake Stream. Bankfull width ranged from 0.1 m in Upper Northwest Inflow of Pointer Lake Stream to wider than 100 m in a pond area on the lower section of the same stream (Table 5.5-13).

Dominant habitat types recorded were run (n = 8, for a total of 8,212 m) and riffle (n = 7, for a total of 2,318 m) habitats, with flats (n = 6, for a total of 2,260.5 m) also being common (Table 5.5-13). Pool (n = 4, for a total of 412.5 m), pond (n = 2, for a total of 396 m), rapid (n = 1, for a total of 350.5 m), and cascade (n = 1, for a total of 108 m) habitat types were observed less frequently. Some sections of boulder garden (n = 3, for a total of 608 m), no defined/visible channel (n = 2, for a total of 429 m), and falls (n = 1, for a total of 172 m) were also observed.

Organic material was observed as the dominant substrate in three streams. Cobble, gravel, and boulders were observed as the dominant substrate types in two, two, and one stream, respectively (Table 5.5-13). The shoreline slope was predominantly flat (n = 6) or varied from flat to moderate or steep slope (n = 2). Shoreline vegetation was primarily grasses and low shrubs. Overhead cover was limited and consisted of undercut banks. In-stream cover generally consisted of inundated vegetation, and/or interstitial spaces between the coarse substrate. In addition, some streams contained in-stream cover in the form of areas of emergent and/or submergent vegetation, deeper sections or areas of water turbulence, and woody debris (Technical Appendix 5C, Table 10A-1).

Table 5.5-12 Summary of Lake Habitat Characteristics in the Kiggavik Project Area

Sub-Basin	Waterbody	Survey Year or Reference	Surface Area (ha)[(a)]	Maximum Depth (m)[(b)]	Mean Depth (m)[(c)]	Shoreline Development[(d)]	Fish Observed/Captured (BEAK; 2007 to 2010)	Substrate	Habitat Assessment
Willow Lake	Pointer Pond	2010	3.09	4.5	1.5	1.3	no fish observed or captured in pond; slimy sculpin captured in the stream immediately upstream of pond	boulder/cobble	shoreline vegetation was predominantly grasses and low shrubs with areas bare or with moss, backed by tundra; shoreline slope varied from flat to moderately steep; cover consisted primarily of interstitial spaces in coarse substrate and inundated vegetation, with emergent and submergent vegetation also present .
	Pointer Lake	2007	393	3.0	1.4	1.7	Arctic grayling; cisco; lake trout; ninespine stickleback	cobble/boulder	shoreline vegetation was predominantly grasses and low shrubs, backed by tundra; predominantly a flat slope; exposed boulders present; shoreline cover consisted primarily of interstitial spaces in the coarse substrate and some areas with emergent vegetation.
	Sik Sik Lake	2009	17.5	1.7	0.9	1.5	ninespine stickleback	boulder/cobble	shoreline vegetation was predominantly grasses and low shrubs, backed by tundra; predominantly a flat slope; exposed boulders present; shoreline cover consisted primarily of interstitial spaces between coarse substrate with some inundated vegetation.
	Rock Lake	2008	32.4	1.5	0.7	1.8	Arctic grayling; lake trout	cobble/boulder	shoreline slope was predominantly flat; shoreline cover consisted primarily of interstitial spaces between coarse substrate and submergent vegetation; shoreline vegetation was dominated by grass, backed with tundra; secondary shoreline vegetation consisted of low shrubs; areas with boulder fields.
	Willow Lake	BEAK 1990	54.9	2.0	1.4	1.6	Arctic grayling; lake trout; ninespine stickleback	boulder/cobble	shoreline vegetation was predominantly grasses and low shrubs, backed by tundra; predominantly a flat slope; exposed boulders present; shoreline cover consisted primarily of interstitial spaces in the coarse substrate and inundated vegetation.
Lower Lake	Mushroom Lake	2009	32.0	8.9	1.9	1.7	Arctic grayling; cisco; lake trout; round whitefish	cobble/boulder	shoreline slope was predominantly flat with an area of moderate to moderately steep slope; shoreline cover consisted primarily of interstitial space between coarse substrate; shoreline vegetation was dominated by grass, backed with tundra; areas of exposed boulders and sand beach present.
	Pond 1	2010	9.94	1.5	0.7	1.7	no fish observed or captured	sand/boulder	shoreline vegetation was predominantly grasses and low shrubs, backed by tundra; flat shoreline slope; cover consisted of interstitial spaces between coarse substrate and emergent vegetation.
	Pond 2	2010	6.56	1.2	0.6	1.5	no fish observed or captured	sand/boulder	shoreline vegetation was predominantly grasses and low shrubs, backed by tundra; flat shoreline slope; exposed boulders present; cover consisted of inundated vegetation, emergent vegetation, and interstitial spaces between coarse substrate.
	Pond 3	2010	0.26	0.5	0.3	1.3	no fish observed or captured	silt/sand (permafrost at 0.5 m)	shoreline vegetation was predominantly grasses and low shrubs, backed by tundra; flat shoreline slope; cover consisted of emergent vegetation and interstitial spaces between coarse substrate.
	Pond 4	2010	0.67	0.7	0.3	1.2	no fish observed or captured	silt/cobble	shoreline vegetation was predominantly grasses and low shrubs, backed by tundra; flat shoreline slope; cover consisted primarily of interstitial spaces between coarse substrate, and emergent vegetation.
	Pond 5	2010	1.62	1.0	0.4	1.4	no fish observed or captured	silt/sand	shoreline vegetation was predominantly grasses and low shrubs, backed by tundra; flat shoreline slope; cover consisted of inundated vegetation, emergent vegetation, and interstitial spaces between coarse substrate.
	Pond 6	2010	1.76	1.2	0.7	1.4	no fish observed or captured	silt/sand	shoreline vegetation was predominantly grasses and low shrubs, backed with tundra; flat shoreline slope; cover consisted of inundated vegetation, emergent vegetation, and interstitial spaces between coarse substrate.
	Pond 7	2010	6.53	1.2	0.6	1.2	no fish observed or captured	sand/boulder	shoreline vegetation was predominantly grasses and low shrubs, backed with tundra; flat shoreline slope; cover consisted primarily of inundated vegetation, emergent vegetation, and interstitial spaces between coarse substrate.
	Pond 8	2010	0.44	0.7	0.4	1.1	no fish observed or captured	sand/silt	shoreline vegetation was predominantly grasses and low shrubs, backed with tundra; flat shoreline slope; cover consisted primarily of emergent vegetation and inundated vegetation.
	End Grid Lake	2008	13.2	1.4	0.8	1.2	Arctic grayling	sand/organic material/ cobble	shoreline vegetation was predominantly grasses, backed by tundra; predominantly a flat slope; exposed boulders present; inundated vegetation present
	Cigar Lake	BEAK 1992a	113	3.6	1.5	2.0	Arctic grayling; burbot; cisco; lake trout; round whitefish	cobble/boulder	shoreline slope was predominantly flat with an area of moderate to moderately steep slope; shoreline cover consisted primarily of interstitial spaces between coarse substrate; shoreline vegetation was dominated by grass, backed with tundra; areas of exposed boulders and boulder fields present.

Sub-Basin	Waterbody	Survey Year or Reference	Surface Area (ha)[(a)]	Maximum Depth (m)[(b)]	Mean Depth (m)[(c)]	Shoreline Development[(d)]	Fish Observed/Captured (BEAK; 2007 to 2010)	Substrate	Habitat Assessment
	Knee Lake	BEAK 1992a	34.9	0.8	0.2	1.6	Arctic grayling	sand/gravel	shoreline slope was predominantly flat with an area of moderate slope; shoreline cover consisted primarily of interstitial spaces between coarse substrate and inundated vegetation; shoreline vegetation was dominated by grass, backed with tundra; areas of boulder fields and boulder gardens present.
	Lunch Lake	BEAK 1992a	77.8	1.6	0.6	1.4	Arctic grayling; lake trout; round whitefish	boulder/silt	shoreline slope was predominantly flat; shoreline cover consisted primarily of interstitial spaces between coarse substrate; shoreline vegetation was dominated by grass, backed with tundra; areas of boulder gardens present.
	Andrew Lake	2009	54.3	1.0	0.2	1.9	Arctic grayling; burbot; cisco; round whitefish	sand/cobble	shoreline vegetation was predominantly grasses and low shrubs, backed by tundra; predominantly a flat slope; exposed boulders present; shoreline cover consisted primarily of interstitial spaces between coarse substrate, with some areas of inundated vegetation.
	Shack Lake	BEAK 1992a	60.0	1.6	0.6	1.8	Arctic grayling	sand/boulder/ cobble	shoreline vegetation was predominantly grasses and low shrubs, backed by tundra; predominantly a flat slope; exposed boulders present; shoreline cover consisted primarily of interstitial spaces between coarse substrate, with inundated vegetation.
	Lower Lake	BEAK 1992a	49.0	1.4	0.4	1.9	Arctic grayling; burbot; cisco; ninespine stickleback; round whitefish	cobble/boulder	shoreline vegetation was predominantly grasses, backed by tundra; predominantly a flat slope; exposed boulders present; shoreline cover consisted primarily of interstitial spaces between coarse substrate, and areas with inundated vegetation.; channel connecting north and south ends of lake had run and riffle habitat.
Caribou Lake	Ridge Lake	BEAK 1990	16.7	7.1	2.3	1.8	lake trout	cobble/boulder	shoreline vegetation was minimal, predominantly cobble/boulder, backed by tundra; predominantly had a flat slope; exposed boulders present; shoreline cover consisted primarily of interstitial spaces between coarse substrate.
	Cirque Lake	BEAK 1990	5.6	5.2	2.6	1.1	Arctic grayling; ninespine stickleback	cobble/boulder	shoreline vegetation was predominantly grasses backed by tundra; predominantly a flat slope; exposed boulders present, shoreline cover consisted primarily of interstitial spaces between coarse substrate with some inundated vegetation.
	Crash Lake	BEAK 1990	8.1	2.0	1.1	1.1	Arctic grayling	silt/sand/boulder	shoreline vegetation was predominantly grasses and low shrubs, backed by tundra; predominantly a flat slope; exposed boulders present; shoreline cover consisted primarily of interstitial spaces between the coarse substrates.
	Fox Lake	BEAK 1990	128	2.7	1.7	1.3	Arctic grayling; cisco; lake trout; ninespine stickleback	cobble/boulder	shoreline vegetation was predominantly grasses, backed by tundra; predominantly a flat slope; exposed boulders present; shoreline cover consisted of interstitial spaces between the coarse substrate.
	Caribou Lake	BEAK 1990	341	2.7	1.4	2.2	Arctic grayling; burbot; cisco; lake trout; ninespine stickleback; round whitefish	cobble/boulder	Shoreline slope was predominantly flat; shoreline cover consisted primarily of interstitial spaces between coarse substrate; shoreline vegetation was dominated by grass, backed with tundra; areas of exposed boulders and boulder fields present.
	Calf Lake	2008	35.8	1.2	0.6	1.3	burbot; cisco; ninespine stickleback	cobble/boulder	Shoreline slope was predominantly flat with an area of moderately steep slope; shoreline cover consisted primarily of interstitial spaces between coarse substrate; shoreline vegetation was dominated by grass and low shrubs, backed with tundra; areas of submergent vegetation and some inundated vegetation also present.
Judge Sissons Lake	Judge Sissons Lake	BEAK 1990, 2009	9,550	20.6	4.6	3.4	Arctic grayling; burbot; cisco; lake trout; ninespine stickleback; round whitefish; slimy sculpin	sand/gravel	Shoreline slope was predominantly flat; shoreline cover consisted primarily of interstitial spaces between coarse substrate, emergent and submergent vegetation, and inundated vegetation; shoreline vegetation was dominated by grass, backed with tundra; areas of exposed boulders and boulder fields present.
Siamese Lake	Siamese Lake	2008	2,792	12.0	4.1	2.4	lake trout	boulder/cobble	Shoreline slope was predominantly flat with an area of moderate to moderately steep slope; shoreline cover consisted primarily of interstitial spaces between coarse substrate, and inundated vegetation; shoreline vegetation was dominated by grass and low shrubs, backed with tundra.

Source: Modified from Appendix 5C, Table X.VIII-1.

(a) Based on bathymetric data as presented in BEAK (1990; 1992a) unless recent bathymetric information was available. If no bathymetry was available at all, value was estimated from digital NTS coverage.

(b) Maximum depth is the maximum depth either collected at sampling stations, noted on recent bathymetry, or shown on bathymetric maps from BEAK (1990; 1992a).

(c) Based on bathymetric data as presented in BEAK (1990; 1992a) unless recent bathymetric information was available.

(d) Calculated from available data.

km^2 = square kilometres; ha = hectares; m = metres; NTS = National Topogoraphic System; - = not applicable.

Table 5.5-13 Summary of Stream Habitat Characteristics in the Kiggavik Project Area, 2008 to 2010

Sub-Basin	Watercourse	Total Stream Length (m)	Habitat Classification and Total Habitat Unit Length (m)										Maximum Depth (m)	Wetted Width (m)	Bankfull Width (m)	Substrate (dominant/ subdominant)	Fish Observed/Captured
			Falls	Cascade	Rapids	Riffle	Run	Flat	Pool	Pond	Boulder Garden	No Defined/ Visible Channel					
Willow Lake	Northeast Inflow of Pointer Lake Stream	5,575	172[a]	108	-	410	4,789	211	57	-	280[b]	-	>1.0	0.2 – 1,000	0.2 - 43.9	cobble/organic material	ninespine stickleback
	Upper Tributary to the Northeast Inflow of Pointer Lake Stream	1,660	-	-	-	173	419	336	164	174	-	395	0.9	channel: 0.4-15; pond: 20-100; NDC: 20-120	channel: 0.4-15; pond: 20-100	organic material/ boulder	no fish observed or captured
	Upper Northwest Inflow of Pointer Lake Stream	1,815	-	-	-	283	192	962	122	222	included in other	34	0.8	channel: 0.1-10; pond: 30-100	channel: 0.1- 6; pond: 30-100	organic material/ boulder	slimy sculpin
	Northwest Inflow of Pointer Lake Stream	2,426	-	-	-	530[c]	1,542[c]	284	70	-	-	-	>1.0	1.0 - 75	0.6 - >100	gravel/cobble	Arctic grayling; lake trout
	Pointer/Rock Stream	1,071	-	-	350.5[d]	374.5[d]	346	-	-	-	156[b]	-	>1.5	-	-	boulder/cobble	Arctic grayling; burbot; ninespine stickleback; round whitefish
	Sik Sik/Rock Stream	925	-	-	-	-	547	378	-	-	-	-	0.9	2.5 - 100	-	organic material/ boulder	ninespine stickleback
	Rock/Willow Stream	420	-	-	-	329	91	-	-	-	172[b]	-	2	24.7 - 47.6	17.8 - 50.7	gravel/cobble	Arctic grayling; cisco; lake trout; ninespine stickleback; round whitefish
	Willow/Judge Sissons Stream	595	-	-	-	218.5	286[e]	90[e]	-	-	-	-	>2.0	60 - 110	-	cobble/organic material	Arctic grayling; lake trout; ninespine stickleback; slimy sculpin
Lower Lake	Mushroom/End Grid Stream	1,313	-	-	-	-	1,313	-	-	-	-	-	0.3	5.2 - 18.6	1.0 - 6.2	cobble/gravel	Arctic grayling; lake trout
	End Grid/Shack Stream	1,431	-	-	-	-	110	736	585	-	-	-	>1.0	30 - 500	1.9 - 25	organic material/ silt	Arctic grayling
	Cigar/Lunch Stream	1,190	-	-	-	120	840	230	-	-	-	-	0.8	12 - 200	2.5 - 6.5	cobble/boulder	no fish observed or captured
	Knee/Lunch Stream	258	-	-	-	106	152	-	-	-	-	-	0.8	4.5 - 19.1	0.8 - 3.8	sand/cobble	lake trout
	Lunch/Andrew Stream	763	-	-	-	-	288	475	-	-	-	-	1.2	10 - 34.5	8.6 - 27.5	silt/cobble	Arctic grayling
	Andrew/Shack Stream	1,014	-	-	-	320	694	-	-	-	-	-	1.1	12.0 - 60	7.5 - 15.4	cobble/boulder	Arctic grayling
	Shack/Lower Stream	6,002	-	-	1,227.7	232	2,325	1,244	974	-	-	-	>1.3	7.0 - 100	2.0 - 25	boulder/cobble	lake trout
	Lower/Judge Sissons Stream	976	-	-	-	92.5	743	140	-	-	-	-	0.89	23.5 - 75	4.0 - 5.0	cobble/organic material	lake trout; ninespine stickleback
Caribou Lake	Fox/Caribou Stream	650	-	-	-	540	110	-	-	-	-	-	0.5	14.5 - 40	7.5 - 20	cobble/boulder	no fish observed or captured
	Caribou/Calf Stream	251	-	-	-	180	71	-	-	-	-	-	0.5	18.4 - 18.5	20.4 - 21.6	boulder/cobble	no fish observed or captured
	Calf/Judge Sissons Stream	1,765	-	-	-	-	1,325	440	-	-	-	-	0.8	60 - 150	7.0 - 49.4	gravel/cobble	Arctic grayling; lake trout

Source: Modified from Appendix 5C, Table 10A-1.

Note:

Wetted and bankfull widths collected from transect data are the minimum and maximum widths recorded.

Habitat mapping and fish community survey were not completed for Ridge/Crash, Cirque/Crash, and Crash/Fox streams in the Caribou Lake sub-basin, but an overview flight was conducted. No obstacles were observed and fish habitat observed was similar to other streams in the area.

(a) falls present on a small section of a primary habitat classification, total habitat classification length is representative of two habitat classifications.

(b) boulder gardens accompanied a primary habitat classification, total habitat classification length is representative of two habitat classifications.

(c) 126 m of stream section was riffle/run; length of stream was separated half for riffle (63 m) and the other half for run (63 m).

(d) 325 m of stream section was riffle/rapids; length of stream was separated half for riffle (162.5 m) and the other half for rapids (162.5 m).

(e) 180 m of stream section was flat/run; length of stream was separated half for flat (90 m) and the other half for run (90 m).

m = metre; > = greater than; NDC = no defined channel; - = not available or not applicable.

5.5.5.1.2 Lower Lake Sub-Basin (Surrounding the Proposed Sissons Mine Site)

Habitat assessment of lakes (i.e., Mushroom Lake, Pond 1 to Pond 8, End Grid Lake, Cigar Lake, Knee Lake, Lunch Lake, Andrew Lake, Shack Lake, and Lower Lake) in the Lower Lake sub-basin was completed between 2007 and 2010 (Table 5.5-9). Surface area ranged from 0.26 ha for Pond 3 to 113 ha for Cigar Lake. Maximum depth ranged from 0.5 m in Pond 3 (with permafrost at 0.5 m) to 8.9 m in Mushroom Lake. The shoreline development index ranged from 1.1 for Pond 8 to 2.0 for Cigar Lake due to the elongated shape of the lake (Table 5.5-12).

Shoreline substrate in all lakes consisted primarily of sand (n = 8), silt (n = 4), cobble (n = 3), and boulder (n = 1). The shoreline slope was predominantly flat (n = 13) or varied from flat to moderately steep (n = 3). Shoreline vegetation was primarily grasses and low shrubs. In-lake habitat consisted of inundated vegetation, and/or interstitial spaces between the coarse cobble and boulder substrate. Some lakes contained areas of emergent vegetation as well (Table 5.5-12).

Habitat assessment of streams (i.e., Mushroom/End Grid, End Grid/Shack, Cigar/Lunch, Knee/Lunch, Lunch/Andrew, Andrew/Shack, Shack/Lower, and Lower/Judge Sissons streams) in the Lower Lake sub-basin was completed in 2008 (Table 5.5-10). The stream lengths assessed for habitat ranged from 258 m for Knee/Lunch Stream to 6,002 m for Shack/Lower Stream. Maximum depth recorded ranged from 0.3 m in Mushroom/End Grid Stream to deeper than 1.3 m in Shack/Lower Stream. Wetted width ranged from 4.5 m in Knee/Lunch Stream to 500 m in an area of unconfined flow during high water conditions in End Grid/Shack Stream. Bankfull width ranged from 0.8 m in Knee/Lunch Stream to 27.5 m in Lunch/Andrew Stream (Table 5.5-13).

Dominant habitat types recorded were run (n = 8, for a total of 6,464.5 m) and flats (n = 5, for a total of 2,825 m) habitats, with riffle (n = 5, for a total of 870.5 m) also being common (Table 5.5-13). Pool (n = 2, for a total of 1,559 m) and rapid (n = 1, for a total of 1,227.7 m) habitat types were observed less frequently.

Cobble was observed as the dominant substrate in four streams. Organic material, sand, silt, and boulder were observed as the dominant substrate types in one stream each (Table 5.5-13). The shoreline slope was predominantly flat (n = 4) or varied from flat to moderate or steep slopes (n = 4). Shoreline vegetation was primarily grasses and low shrubs. Overhead cover habitat was limited and consisted of undercut banks. In-stream cover consisted of inundated vegetation and interstitial spaces between the coarse substrate. Some streams contained in-stream cover in the form of areas of emergent and/or submergent vegetation, deeper sections or areas of water turbulence, and/or turbidity (Technical Appendix 5C, Table 10A-1).

5.5.5.1.3 Caribou Lake Sub-Basin (Traversed by the Proposed Haul Road)

Habitat assessment of lakes (i.e., Ridge, Cirque, Crash, Fox, Caribou, and Calf lakes) in the Caribou Lake sub-basin was completed between 2007 and 2008 (Table 5.5-9). Surface area ranged from 5.6 ha for Cirque Lake to 341 ha for Caribou Lake. Maximum depth ranged from 1.2 m in Calf Lake to 7.1 m in Ridge Lake. The shoreline development index ranged from 1.1 for Cirque and Crash lakes to 2.2 for Caribou Lake due to its elongated shape (Table 5.5-12).

Shoreline substrate in all lakes consisted primarily of cobble and boulder (n = 5) or silt, sand, and boulder (n = 1). The shoreline slope was predominantly flat (n = 5) or varied from flat to moderately steep (n = 1). Shoreline vegetation was primarily grasses and low shrubs. In-lake habitat consisted of interstitial spaces between the coarse cobble and boulder substrate and/or inundated vegetation, or submergent vegetation (Table 5.5-12).

Habitat assessment of streams (i.e., Fox/Caribou, Caribou/Calf, and Calf/Judge Sissons streams) in the Caribou Lake sub-basin was completed in 2008 (Table 5.5-10). The stream lengths assessed for habitat ranged from 251 m for Caribou/Calf Stream to 1,765 m for Calf/Judge Sissons Stream. Maximum depth recorded ranged from 0.5 m in Fox/Caribou and Caribou/Calf streams to 0.8 m in Calf/Judge Sissons Stream. Wetted width ranged from 14.5 m in Fox/Caribou Stream to 150 m in an area of unconfined flow during high water conditions in the Calf/Judge Sissons Stream. Bankfull width ranged from 7.0 to 49.4 m in Calf/Judge Sissons Stream (Table 5.5-13).

Dominant habitat types recorded were run (n = 3, for a total of 1,506 m) and riffle (n = 2, for a total of 720 m) habitats (Table 5.5-13). The flats (n = 1, for a total of 440 m) habitat type was observed less frequently.

Cobble, gravel, and boulder were observed as the dominant substrate types in one stream each (Table 5.5-13). The shoreline slope was predominantly flat (n = 3). Shoreline vegetation was primarily grasses and low shrubs. In-stream cover consisted of inundated vegetation, and/or interstitial spaces between the coarse substrate, with some streams containing areas of deeper flow and areas of concealing turbulence (Technical Appendix 5C, Table 10A-1).

5.5.5.1.4 Judge Sissons Lake (Proposed Treated Effluent Discharge)

Habitat assessment of the northern section of Judge Sissons Lake was completed in 2008 (Table 5.5-9). The surface area was 9,550 ha; maximum depth was 20.6 m; and the shoreline development index was 3.4 due to its more complex shoreline that includes several large bays (Table 5.5-12).

The shoreline substrate consisted primarily of sand mixed with coarse substrate on the west shoreline. Gravel mixed with coarse substrates was the dominate substrate along the northwest and east shorelines, with several areas of cobble and boulder substrate. The shoreline slope was predominantly flat in the northwest section of Judge Sissons Lake, and ranged from low to high slopes in the northeast section of the lake. Shoreline vegetation was grass with some patches of low shrubs, and several areas of exposed cobble, boulder, gravel, or sand. Shoreline cover consisted primarily of interstitial spaces between coarse substrates, with small areas of emergent and submergent vegetation, and inundated terrestrial vegetation (Table 5.5-12).

5.5.5.1.5 *Siamese Lake (Proposed Water Supply Lake, Traversed by Proposed Winter Access Road, and Near Proposed North All-Season Access Road)*

Habitat assessment of Siamese Lake was completed in 2008 (Table 5.5-9). The surface area was 2,792 ha; maximum depth was 12.0 m; and the shoreline development index was 2.4 due to a complex shoreline that includes two distinct basins as well as several bays (Table 5.5-12).

The shoreline substrate consisted primarily of boulder and cobble, but also contained some large areas of exposed sand or gravel mixed with the larger substrate. The shoreline slope was predominantly flat, ranging from flat to moderately steep slopes in the southwest and northeast sections of the lake. Shoreline vegetation was dominated by grass with some patches of low shrubs. Shoreline cover consisted primarily of interstitial space between coarse substrates, and small areas of inundated terrestrial vegetation (Table 5.5-12).

5.5.5.1.6 *Skinny Lake*

Habitat assessment of Skinny Lake was completed before 1992. Surface area was 197 ha; the maximum depth was 12.8 m; and the shoreline development index was 2.5 due to its elongated shape (Appendix 5C, Figure X.III-30a).

The shoreline substrate consisted primarily of cobble and boulder, but also contained some areas of sand. Sand is also present in the deep section of the lake. Shoreline cover consisted primarily of interstitial spaces between coarse substrates (Appendix 5C, Figure X.III-30a).

5.5.5.1.7 *Proposed Kiggavik Sissons Access Road*

The proposed Kiggavik Sissons access road crosses eight streams; three are first category streams (i.e. no defined or no visible channel), four are small to intermediate in size (i.e. channel widths less than 5 m) and one is classified as a large stream (i.e. channel width greater than 5 m).

Habitat assessment of eight stream crossings (i.e., Kms 2.0, 2.9, 6.7, 11.3, 14.1, 15.6, 17.2, and 19.6) located on the proposed Haul Road was completed between 2008 and 2009 (Table 5.5-11). The stream lengths assessed for habitat ranged from 77 m at Km 2.9 to 1,313 m at Km 2.0 (Mushroom/End Grid Stream). Maximum depth recorded ranged from 0.3 m at Km 2.0 (Mushroom/End Grid Stream) and Km 11.3 (Sleek/Caribou Stream) to 1.1 m at Km 6.7 (West Inflow of Boulder Lake). Wetted width ranged from 0.3 m at Km 15.6 (Rhyolite/Fox Stream) to 45 m in a backwater area at Km 2.9. Bankfull width ranged from 0.3 m at Km 15.6 (Rhyolite/Fox Stream) to 95 m in a backwater area at Km 2.9 (Table 5.5-14).

Dominant habitat types recorded were run (n = 4, for a total of 1,632 m), riffle (n = 4, for a total of 867 m), and flats (n = 3, for a total of 807 m) habitats (Table 5.5-14). Ponds (n = 2, for a total of 115 m) and backwater (n = 1, for a total of 75 m) habitat types were observed less frequently. Some sections of boulder garden (n = 2, for a total of 167 m), and no visible channel/dry channel (n = 3) were also observed.

Gravel was observed as the dominant substrate in three streams. Silt and boulder were observed as the dominant substrate types in two and one stream, respectively (Table 5.5-14). Overhead cover was limited and consisted of undercut banks, overhanging vegetation, and ledges. In-stream cover consisted of inundated vegetation and interstitial spaces between coarse substrates, with some streams containing areas of emergent and/or submergent vegetation, and cover associated with areas of depth, turbulence, and/or turbidity (Technical Appendix 5C, Table 10A-2).

5.5.5.1.8 Proposed Water Intake - Kiggavik

The proposed road for the water intake pipeline at the Kiggavik site crosses four streams; one is a first category stream (i.e. no defined or no visible channel), two are small to intermediate in size (i.e. channel widths less than 5 m), and one is classified as a large stream (i.e. channel width greater than 5 m).

Habitat assessment of four stream crossings (i.e., Km 100.2, alternate W1, alternate W2, and alternate W3) located on the proposed road for the water intake pipeline at the Kiggavik site was completed in 2009 (Table 5.5-11). The stream lengths assessed for habitat ranged from 320 m for alternate W1 (Meadow/Jaegar Stream) to 630 m for alternate W3 (North Inflow of Drum Lake). Maximum depth recorded ranged from 0.3 m in Km 100.2 (Northeast Inflow of Pointer Lake) to 0.5 m in alternate W2 (Escarpment/Jaegar Stream). Wetted and bankfull widths ranged from 0.4 m in alternate W2 (Escarpment/Jaegar Stream) to 75 m in alternate W3 (North Inflow of Drum Lake). The bankfull width of alternate W3 was 1 to 3 m for most of its length; however, there were also several ponds that were 40 to 75 m wide (Table 5.5-14).

Dominant habitat types recorded were flats (n = 3, for a total of 600 m) and run (n = 2, for a total of 550 m) habitats (Table 5.5-14). Ponds (n = 2, for a total of 280 m), pools (n = 1, for a total of 139 m), and riffle (n = 2, for a total of 45 m) habitat types were observed less frequently. Some sections of no visible channel/dry channel (n = 2) were also observed.

Cobble and organic material were observed as the dominant substrate in two streams each (Table 5.5-14). In-stream cover consisted of inundated vegetation, with some streams containing areas of emergent vegetation, as well as deeper sections and areas of concealing water turbulence (Technical Appendix 5C, Table 10A-2).

Table 5.5-14 Summary of Characteristics of Stream Crossings Along the Proposed Kiggavik Road Alignments, 2008 to 2010

Access Road	Crossing Identification	Total Stream Length Assessed (m)	Habitat Classification and Total Habitat Unit Length (m)										Maximum Depth (m)	Wetted Width (m)	Bankfull Width (m)	Substrate (dominant/ subdominant)	Fish Observed /Captured
			Cascade	Rapids	Riffle	Run	Flat	Pool	Pond/ Lake/ Wetland	Backwater /Snye	Boulder Garden/ Exposed Boulder	No Defined / Visible Channel or Dry or Underground Flow					
Haul	Km 2.0 (Mushroom/ End Grid Stream)	1,313	-	-	-	1,313	-	-	-	-	-	-	0.3	5.2 - 18.6	1.0 - 6.2	silt/cobble	Arctic grayling; lake trout(a)
	Km 2.9(b)	77	-	-	-	-	-	-	2	75	-	no visible channel	0.5	30 - 45	30 - 95	silt/sand	no fish sampling
	Km 6.7 (West Inflow of Boulder Lake)	124	-	-	8	94	22	-	-	-	-	-	1.1	0.5 - 7.0	1.0 - 8.0	gravel/cobble	Arctic grayling
	Km 11.3(Sleek/ Caribou Stream)	600	-	-	174	55	256	-	-	-	115	-	0.3	7.0 - 23	7.0 - 23	gravel/cobble	Arctic grayling; slimy sculpin
	Km 14.1(b)	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish sampling
	Km 15.6 (Rhyolite/Fox Stream)	588	-	-	31	-	529	28	-	-	-	-	0.5	0.3 - 15	0.3 - 15	boulder/cobble	ninespine stickleback
	Km 17.2 (Crash/Fox Stream)	989	-	-	654	170	-	-	113	-	52	-	> 1	0.8 - 4	1.0 - 10	gravel/cobble	Arctic grayling; ninespine stickleback; slimy sculpin
	Km 19.6(b)	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish sampling
Water Intake - Kiggavik	Km 100.2 (Northeast Inflow of Pointer Lake)	475	-	-	-	-	130	139	-	-	-	206 m dry	0.3	0 - 3.0	0 - 3.0	organic material/gravel	ninespine stickleback near mouth(c)
	alternate W1 (Meadow/Jaegar Stream)	320	-	-	-	-	-	-	120	-	-	no visible channel present and 200 m dry	-	0	2.0	organic material/silt	ninespine stickleback
	alternate W2 (Escarpment/Jaegar Stream)	595	-	-	15	245	335	-	-	-	-	-	0.5	0.4 - 1.2	0.4 - 1.2	cobble/gravel	ninespine stickleback; slimy sculpin
	alternate W3 (North Inflow of Drum Lake)	630	-	-	30	305	135	-	160	-	-	-	0.4	0.7 - 75	0.7 - 75	cobble/boulder	ninespine stickleback
Winter	alternate W4	670	-	-	30	75	345	-	135	-	-	85 m dry	0.1	0.2 - 0.5	0.2 - 0.5	cobble/boulder	no fish sampling
	alternate W5	275	-	-	-	20	255	-	-	-	-	-	0.7	0.3 - 7.0	0.3 - 7.0	organic material/cobble	no fish observed or captured
	alternate W6	885	-	-	15	610	260	-	-	-	-	-	0.3	0.2 - 10	0.2 - 6.0	organic material/gravel	no fish observed or captured
	S13 (Long/Audra Stream)	632	-	-	-	542	90	-	-	-	-	-	0.8	10 - 69	3.0 - 72	gravel/silt	Arctic grayling; ninespine stickleback; slimy sculpin
	S14	247	-	-	-	35	113	60	-	-	-	39 m no defined channel	0.65	0.3 - 30	0.3 - 20	organic material/silt	Arctic grayling; ninespine stickleback
North All-Season	Km 103.4(b)	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish sampling
	Km 107.8 (West Inflow of Skinny Lake)	953	-	-	227.5	172.5	463	10	70	-	-	10 m underground flow	> 1	0.2 - 50	0.2 - 50	organic material/cobble	no fish observed or captured
	Km 108.8	360	-	-	43	-	26	-	-	-	-	291 m dry	0.3	0.5	0.5 - 1.0	gravel/cobble	no fish observed

Access Road	Crossing Identification	Total Stream Length Assessed (m)	Habitat Classification and Total Habitat Unit Length (m)										Maximum Depth (m)	Wetted Width (m)	Bankfull Width (m)	Substrate (dominant/ subdominant)	Fish Observed /Captured
			Cascade	Rapids	Riffle	Run	Flat	Pool	Pond/ Lake/ Wetland	Backwater /Snye	Boulder Garden/ Exposed Boulder	No Defined / Visible Channel or Dry or Underground Flow					
	Km 109.8 (South Inflow of Skinny Lake)	578	-	-	-	135	93	-	350	-	-	-	0.4	0.5 - 75	1.0 - 75	gravel/cobble	Arctic grayling; ninespine stickleback; slimy sculpin
	alternate NC22[b]	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish observed
	alternate NC21[b]	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish observed
	alternate NC20[b]	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish observed
	Km 112.9[b]	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish sampling
	alternate NC18	490	-	-	-	-	80	-	100	-	-	150 m no visible channel and 160 m dry	0.2	1.5 - 100	1.5 - 100	cobble/gravel	no fish sampling
	alternate NC17	685	-	-	41	395	238	11	-	-	-	-	0.7	0.2 - 2.0	0.2 - 2.0	gravel/organic material	no fish observed or captured
	Km 127.5	957	-	-	-	477	478	-	-	2	-	-	1.0	0.5 - 20	1.0 - 21	gravel/silt	Arctic grayling; ninespine stickleback; slimy sculpin
	Km 129.2	1,141	-	-	511	624	-	4	-	2	-	-	1.1	8.0 - 26	15 - 40	cobble/boulder	Arctic grayling; burbot; slimy sculpin
	alternate X33 (4 km downstream of Km 129.2)	840	-	-	510	330	-	-	-	-	-	-	> 1.1	22 – 46	39 – 54	gravel/boulder	lake trout
	Km 130.1	700	-	-	-	-	-	210	-	-	-	400 m no visible channel and 90 m dry	0.75	35 - 140	35 - 140	organic material/sand	no fish sampling
	Km 131.3	122	-	-	-	-	122	-	-	-	-	-	0.1	0.25	0.25	organic material/sand	no fish sampling
	Km 145.3	541	-	-	61	347	133	-	-	-	-	-	0.6	2.0 - 6	2.0 - 6.5	sand/gravel	Arctic grayling; ninespine stickleback; round whitefish; slimy sculpin
	Km 147.1	1,045	-	-	-	983	60	2	-	-	-	-	1.0	0.5 - 8	0.5 - 8	sand/gravel	ninespine stickleback; slimy sculpin
	Km 147.6	861	-	-	-	-	614	243	4	-	-	-	~ 1.0	1.0 - 120	3.0 - 125	organic material/sand	no fish observed or captured
	Km 154.8[b]	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish sampling
	alternate X28 (0.5 km upstream of Km 157.3)	572	-	-	111	377	43	41	-	-	-	-	>1.2	45 – 45	1.2 – 30	cobble/boulder	lake trout
	Km 157.3 (North Inflow of Qikittalik Lake)	300	-	-	-	300	-	-	-	-	-	-	0.75	100	105	sand/gravel	ninespine stickleback
	Km 157.7 (Northeast Inflow of Qikittalik Lake)	351	-	-	-	-	32	142	6	96	-	75 m dry	0.5	0.5 - 12	1.0 - 40	cobble/gravel	Arctic grayling; longnose sucker; ninespine stickleback
	Km 159.5[b]	-	-	-	-	-	-	-	2	-	-	dry	-	-	-	-	no fish sampling

Access Road	Crossing Identification	Total Stream Length Assessed (m)	Habitat Classification and Total Habitat Unit Length (m)										Maximum Depth (m)	Wetted Width (m)	Bankfull Width (m)	Substrate (dominant/ subdominant)	Fish Observed /Captured
			Cascade	Rapids	Riffle	Run	Flat	Pool	Pond/ Lake/ Wetland	Backwater /Snye	Boulder Garden/ Exposed Boulder	No Defined / Visible Channel or Dry or Underground Flow					
	Km 161.5[(b)]	-	-	-	-	-	-	-	2	-	-	dry	-	-	-	-	no fish sampling
	Km 163.2[(b)]	-	-	-	-	-	-	-	2	-	-	dry	-	-	-	-	no fish sampling
	Km 168.0[(b)]	-	-	-	-	-	-	-	-	-	-	dry	-	-	-	-	no fish sampling
	Km 171.2[(b)]	-	-	-	-	-	-	-	-	-	-	dry	-	-	200	-	no fish sampling
	Km 172.2	700	-	-	-	-	640	60	-	-	-	-	1.0	1.0 - 5.0	1.0 - 5.0	organic material/cobble	no fish observed or captured
	KM 174.3	364	-	-	-	-	-	-	-	-	-	364 m dry	-	-	0.3 - 4.0	cobble/boulder	no fish sampling
	Km 174.8 (Thelon River around proposed bridge/ferry locations)	3,205	-	85	-	3,205	-	-	-	-	-	-	7.5	300 - 520	330 - 550	cobble/boulder and gravel	Arctic grayling; lake trout; slimy sculpin
	Km 174.8 (Thelon River around proposed Nuna ice bridge locations)	560	-	-	-	560	-	-	-	-	-	-	4.7	460	520	cobble/gravel	no fish sampling at this location
	alternate EC22	261	-	-	7	201	-	6	47	-	-	-	0.4	0.4 - 40	0.4 - 40	sand/gravel	ninespine stickleback
	Km 203.0	266	-	-	-	134	-	-	132	-	-	-	0.5	1.5 - 20	1.5 - 15	organic material/cobble	ninespine stickleback
	Km 209.4	313	-	-	-	172	5	55	70	-	-	11 m no defined channel	0.25	0.20 - 10	0.2 - 37	gravel/boulder	no fish observed
	Km 212.2	357	75	-	-	77	-	71	-	-	22	112 m dry	0.3	0.15 - 20	0.15 - 20	boulder garden/cobble	no fish observed
	Km 213.1	426	360	-	34	32	-	-	-	-	-	-	0.5	0.5 - 9.0	0.5 - 20	boulder garden/cobble	Arctic grayling
Aniguq River	S5 (Aniguq River)	290	-	-	-	203	-	-	-	87	-	-	>2	13 – 98	15 – 100	silt/cobble	Arctic grayling; burbot; lake trout; ninespine stickleback[(d)]

(a) Arctic grayling was observed in spring 2009 near the proposed road location; lake trout was captured and Arctic grayling was observed during 2008 Arctic grayling spring spawning survey.

(b) No habitat map available.

(c) No fish were captured or observed during the summer 2009 field sampling at the proposed road crossing located in the upper section of this stream, but ninespine sticklebacks were captured near the mouth of this stream during 2008 and 2009 Arctic grayling spring spawning surveys.

(d) Burbot and ninespine stickleback were captured in fall 2009 near the proposed road location; Arctic grayling and lake trout were captured further upstream during 2009 fall fish community survey.

m =metres; Km = kilometres; > = greater than; - = not available or not applicable.

5.5.5.1.9 Proposed Water Intake - Sissons

The proposed road for the water intake pipeline at the Sissons site crossed one potential stream likely classified as first category streams (i.e. no defined or no visible channel). Although NTS coverage show a stream at this location, Lidar imagery indicates that this stream does not exist.

5.5.5.1.10 Proposed Treated Effluent Discharge - Kiggavik and Road to Airstrip

The proposed road along the treated effluent discharge pipeline at the Kiggavik site (also accessing the airstrip) does not appear to cross any stream, since it is located on the divide between the Willow and Caribou lake sub-basins.

5.5.5.1.11 Proposed Treated Effluent Discharge - Sissons

The proposed road for the treated effluent discharge at the Sissons site crosses two streams classified as large streams (i.e., channel width greater than 5 m).

Habitat assessment of one stream crossing (i.e., End Grid/Shack Stream) located on the proposed road for the water intake pipeline at the Sissons site was completed in 2008 (Table 5.5-10), while the second stream crossing (i.e., Boulder/Judge Sissons Stream) was not assessed in the field. The stream length assessed for habitat was 1,431 m for End Grid/Shack Stream. Maximum depth recorded was greater than 1 m. Wetted width ranged from 30 m to 500 m in an area of unconfined flow during high water conditions in End Grid/Shack Stream. Bankfull width ranged from 1.9 m to 25 m in End Grid/Shack Stream (Table 5.5-13).

Dominant habitat types recorded for End Grid/Shack Stream were flats (736 m) and pools (585 m) habitats (Table 5.5-13). Run (110 m) habitat type was observed less frequently.

Organic material was observed as the dominant substrate in End Grid/Shack Stream (Table 5.5-14). The shoreline slope was predominantly flat. Shoreline vegetation was primarily grasses. In-stream cover consisted of inundated vegetation and interstitial spaces between the coarse substrate, with some streams containing areas of emergent and submergent vegetation (Technical Appendix 5C, Table 10A-1).

5.5.5.2 Site Access Local Study Area

A brief summary of the stream and lake habitat characteristics is provided in the following sections.

5.5.5.2.1 Proposed South Winter Access Road

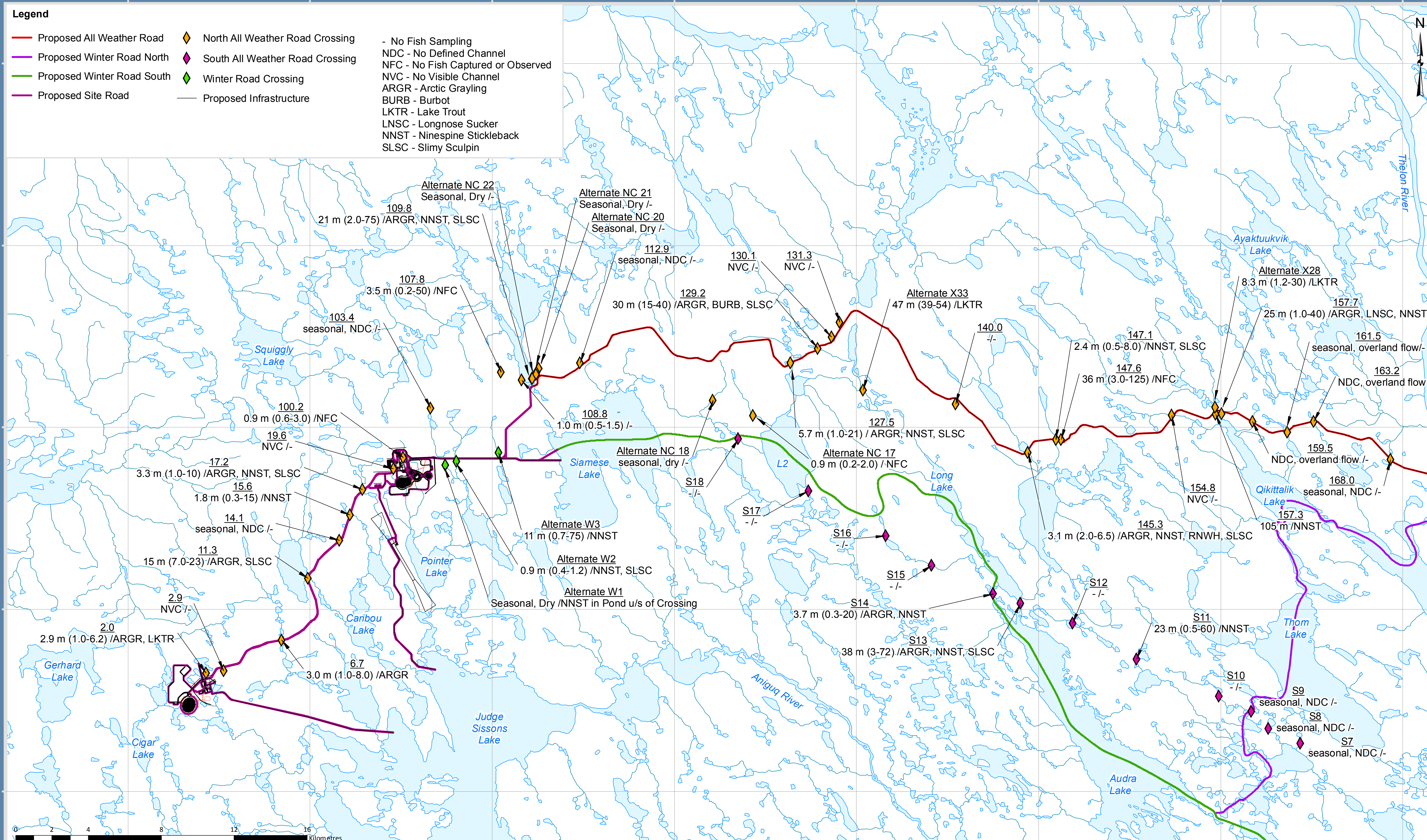
Five potential stream crossing locations were assessed along the route of the proposed South Winter Access Road in 2009. Four of the assessed watercourses (i.e., S14, alternate W4, alternate W5, and alternate W6) were small to intermediate in size with channel widths less than 5 m (Figures 5.5-1, part A and part B). One watercourse was classed as a large stream (i.e., crossing Km S13 [Long/Audra Stream]. One of the streams (i.e., alternate W4) had localized ponding where the channel width in the area sampled was substantially wider that the channel width of the majority of the stream (Table 5.5-14; Figures 5.5-1a and 5.5-1b).

Habitat assessment at the five stream crossings was also completed in 2009 (Tables 5.5-11 and 5.5-14). The stream lengths assessed for habitat ranged from 247 m for S14 to 885 m for alternate W6. Maximum depth recorded ranged from 0.1 m in alternate W4 to 0.8 m in S13 (Long/Audra Stream). Wetted width ranged from 0.2 m in alternate W4 and alternate W6 to 69 m in S13 (Long/Audra Stream). Bankfull width ranged from 0.2 m in alternate W4 and alternate W6 to 72 m in S13 (Long/Audra Stream) (Table 5.5-14).

Dominant habitat types recorded were run (n = 5, for a total of 1,282 m) and flats (n = 5, for a total of 1,063 m) habitats (Table 5.5-14). Riffle (n = 2, for a total of 45 m), ponds (n = 1, for a total of 135 m), and pools (n = 1, for a total of 60 m) habitat types were observed less frequently. No visible channel/dry channel (n = 2, for a total of 124 m) were also observed.

Organic material was observed as the dominant substrate in three streams. Cobble and gravel were observed as the dominant substrate in one stream each (Table 5.5-14). Overhead cover was limited and consisted of undercut banks and overhanging vegetation. In-stream cover consisted of inundated vegetation and interstitial spaces between the coarse substrates, with some streams containing areas of emergent and/or submergent vegetation, and areas of deeper water and concealing turbulence (Technical Appendix 5C, Table 10A-2).

Several lakes were also present along the proposed South Winter Access Road. From west to east, the proposed road crosses the following large waterbodies: Siamese Lake, an unnamed lake (Lake 2), Long Lake, Audra Lake, and Quinguq Bay of Baker Lake. No habitat assessment of lakes was completed; as lakes were ice-covered during the 2009 (winter) assessment (Table 5.3-1). Surface area of lakes along the proposed South Winter Access Road ranges from 614.4 ha for Long Lake to 9,520 ha for Audra Lake. Maximum depths range from 2.5 m in Long Lake to 8.0 m in Lake 2. The shoreline development index ranges from 1.3 for Lake 2 to 2.7 for Long Lake due to its elongated shape (Table 5.3-1).



Projection: NAD 1983 UTM Zone 14N
Creator: JRC
Date: 12/07/2011 Scale: 1:200,000
KIO8C347
Data Sources: *NTS Mapsheet 56D, 66A, 66B, AREVA Resources Canada Inc.*

FIGURE 5.5-1A

SUMMARY OF AQUATIC HABITAT AND FISH DISTRIBUTION AT PROPOSED ROAD CROSSINGS

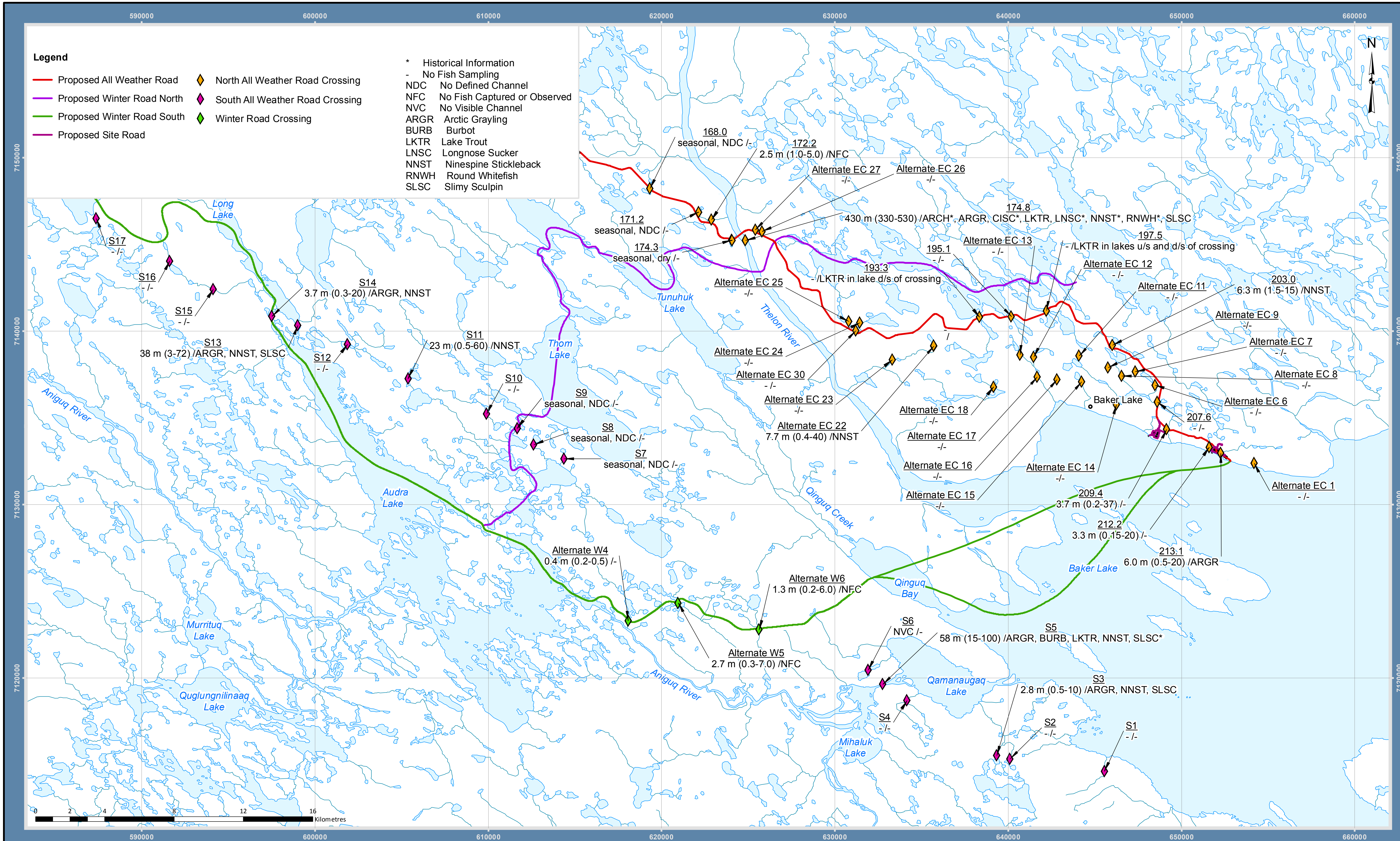
KIGGAVIK PROJECT - EIS

120.0	Stream Crossing ID (Kilometre Marker)
Bankfull Width — 2.5m(1.0 - 5.0)/NFC	Fish Species

Golder Associates

AREVA

AREVA Resources Canada Inc - P.O. Box 9204 - 817 - 45th Street West - Saskatoon, SK - S7K 3X5



Projection: NAD 1983 UTM Zone 14N
Creator: JRC
Date: 12/07/2011 Scale: 1:200,000
KIO8C348
Data Sources: NTS Mapsheet 56D, 66A, 66B, AREVA Resources Canada Inc.

FIGURE 5.5-1B
SUMMARY OF AQUATIC HABITAT AND FISH DISTRIBUTION AT PROPOSED ROAD CROSSINGS

KIGGAVIK PROJECT - EIS

Golder Associates
AREVA

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5.5.5.2.2 Proposed North Winter Access Road

Only one potential stream crossing location was assessed along the route of the proposed North Winter Access Road. This watercourse was classed as a large stream (i.e., crossing Km 174.8 [Thelon River, around the Nuna ice bridge location] (Table 5.5-14; Figure 5.5-1b).

Habitat assessment of this section of the Thelon River (Km 174.8 around the Nuna ice bridge proposed location) was completed in 2010 (Tables 5.5-11 and 5.5-14). Stream length assessed for habitat was 560 m. Maximum depth recorded was 4.7 m. Wetted and bankfull widths were 460 m and 520 m, respectively (Table 5.5-14).

This section of the Thelon River (i.e., Km 174.8 around the Nuna ice bridge location) is a fast flowing run. The Thelon is a fish bearing stream with good overwintering habitat, and year round cover and spawning habitats in the assessed river section. Cobble was observed as the dominant substrate type, followed by gravel (Table 5.5-14). In-stream cover consisted of interstitial spaces between the coarse substrates, and areas of deeper water and concealing turbulence (Technical Appendix 5C, Table 10A-2).

Several lakes were also present along the proposed North Winter Access Road. From west to east, the proposed road crosses the following large waterbodies: many unnamed lakes, Thom Lake, three more unnamed lakes, Qikittalik Lake, Tunuhuk Lake, and many more unnamed lakes east of the Thelon River. No habitat assessment of lakes was completed; as this proposed North Winter Access Road was not identified when the winter road assessment was completed in 2009.

5.5.5.2.3 Proposed North All-Season Access Road

The majority of the watercourses crossed along the North All-Season Access Road (west of the Thelon River) were first category streams. Seven were classified as large streams or rivers (i.e., crossings Km 109.8 [South Inflow of Skinny Lake], Km 127.5, Km 129.2, Km 147.6, Km 157.3 [North Inflow of Qikittalik Lake], Km 157.7 [Northeast Inflow of Qikittalik Lake], and Km 174.8 [Thelon River]). Six streams (i.e., 107.8 [West Inflow of Skinny Lake], Km 108.8, alternate NC 17, Km 145.3, Km 147.1, and Km 172.2) were small to intermediate in size with channel widths less than 5 m (Tables 5.5-11 and 5.5-14; Figures 5.5-1a and 5.5-1b).

The portion of the Thelon River (i.e., Km 174.8) in the site access LSA is generally fast flowing with run sections most common and a rapid section further upstream. The Thelon River is a fish bearing stream with good overwintering habitat, and year round cover and spawning habitats in the assessed river section. Interstitial spaces in the coarse substrate, depth, and water turbulence provide good cover for all sizes of fish.

A majority of the watercourses crossed along the section of North All-Season Access Road located east of the Thelon River were classed as first category streams, or were not assessed for habitat and fish presence. Two streams were second category streams (i.e., crossings Km 209.4, and Km 212.2). As well, three additional streams are expected to be fish bearing due to their proximity to fish bearing lakes (i.e., crossings Km 193.3, Km 195.1, and Km 197.5). Two large watercourses had average channel widths ranging from 6.0 m (crossing Km 213.1) to

6.3 m (crossing Km 203.0); an additional large watercourse (crossing alternate EC22) was located on an alternate road location (Tables 5.5-11 and 5.5-14; Figure 5.5-1b). Detailed habitat assessments were completed only on specific streams.

Habitat assessment of 34 stream crossings located on the North All-Season Access Road (i.e., twenty-six with specific kilometre numbers and eight alternate stream crossings) was completed between 2008 and 2009 (Tables 5.5-11 and 5.5-14). The stream lengths assessed for habitat ranged from 122 m for Km 131.3 to 3,205 m for Km 174.8 (Thelon River around the proposed bridge/ferry locations). Maximum depth recorded ranged from 0.1 m at Km 131.3 to 7.5 m at Km 174.8 (Thelon River around the proposed bridge/ferry locations). Wetted width ranged from 0.15 m at Km 212.2 to 520 m at Km 174.8 (Thelon River around the proposed bridge/ferry locations). Bankfull width ranged from 0.15 m at Km 212.2 to 550 m at Km 174.8 (Thelon River around the proposed bridge/ferry locations) (Table 5.5-14).

Dominant habitat types recorded were run (n = 16, for a total of 8,521.5 m), flats (n = 13, for a total of 2,897 m), no visible channel/dry channel/underground channel (n = 18, for a total of 1,457 m), riffle (n = 9, for a total of 1,545.5 m), and pools (n = 11, for a total of 716 m) habitats (Table 5.5-14). Ponds/lakes/wetlands (n = 11, for a total of 785 m) and backwater/snye (n = 3, for a total of 100 m) habitat types were observed less frequently. Some sections of boulder garden (n = 1, for a total of 22 m) were also observed.

Cobble was observed as the dominant substrate in seven streams. Gravel was observed as the dominant substrate type in six streams. Organic material was observed as the dominant substrate type in five streams. Sand and boulder were observed as the dominant substrate types in four and two streams, respectively (Table 5.5-14). Overhead cover was limited and consisted of undercut banks, overhanging vegetation, and ledges. In-stream cover consisted of inundated vegetation and interstitial spaces between the coarse substrates, with some streams containing areas of emergent and/or submergent vegetation, and areas of deeper flows and concealing water turbulence (Technical Appendix 5C, Table 10A-2).

5.5.5.2.4 Aniguq River (Proposed Treated Effluent Path to Baker Lake)

The Aniguq River (i.e., S5) is classified as a large river. A flight overview of the entire river was completed in 2008. Otherwise, habitat assessment of a 290 m long section of the river was completed in 2009. Maximum depth recorded was greater than 2 m. Wetted width was 98 m; bankfull width was 100 m (Table 5.5-14).

Dominant habitat types recorded in the surveyed section consisted of run (for a total of 203 m) and a backwater/snye (for a total of 87 m). Silt was observed as the dominant substrate, and cobble as sub-dominant substrate. Overhead cover was limited and consisted of overhanging vegetation. In-stream cover consisted of interstitial spaces between the coarse substrates, with some areas of emergent and/or submergent vegetation, and areas of deeper flows and concealing water turbulence (Technical Appendix 5C, Table 10A-2).

5.5.5.2.5 Baker Lake (Proposed Baker Lake Facility)

Five sites in Baker Lake were assessed for fish habitat between 2008 and 2009. Site 2 was deepest (up to 14.4 m) and had the most uniform lake bottom. Site 2 had a slope steep close to the shore making it well suited for docking facilities and vessel traffic.

5.6 FISH

5.6.1 Fish Distribution

The majority of the lakes examined (37 of 39 lakes) are situated within the Aniguq River watershed. Squiggly Lake (Thelon Lake watershed) and Baker Lake (Baker Lake watershed) are outside the Aniguq watershed (Figures 5.3-1, 5.3-2, and 5.3-3). This section presents the current information available on fish distribution within the mine site LSA, as well as information collected for selected streams along the potential North All-Season Access Road. Detailed methods and results can be found in Technical Appendix 5C (Section 11.0).

Previous studies, by McLeod et al. (1976), BEAK (1987, 1990, 1992a,b) as well as the most recent studies by Golder and Nunami Stantec presented in Technical Appendix 5C (Section 11.0), reported the following 7 fish species in lakes within the mine site LSA:

- Arctic grayling (Thymallus arcticus);
- burbot (Lota lota);
- cisco (Coregonus artedi);
- lake trout (Salvelinus namaycush);
- ninespine stickleback (Pungitius pungitius);
- round whitefish (Prosopium cylindraceum); and
- slimy sculpin (Cottus cognatus).

Four additional species of fish have been documented as occurring in Baker Lake:

- Arctic char (Salvelinus alpinus alpinus);
- fourhorn sculpin (Myoxocephalus quadricornis);
- lake whitefish (Coregonus clupeaformis); and
- longnose sucker (Catostomus catostomus).

Arctic grayling were the most widely distributed species in lakes and streams in the LSA, followed by lake trout (Tables 5.6-1 and 5.6-2).

Twenty-four rivers and stream segments associated with the assessed lakes in the LSA (referred to as “streams”), were recently assessed by Golder between 2008 to 2010, and the

Aniguq River was historically assessed in 1975 by McLeod et al. (1976). Twenty-three of these streams are situated in the Aniguq River watershed, with one (Thelon River) in the Thelon River watershed. Two fish species found in the LSA lakes were not found in streams sampled between 1975 and 2010 (i.e., fourhorn sculpin and lake whitefish).

5.6.1.1 Mine Site Local Study Area

5.6.1.1.1 Willow Lake Sub-Basin (Surrounding the Proposed Kiggavik Mine Site)

Twelve lakes and eight stream segments (streams) in the Willow Lake sub-basin of the Aniguq River watershed were assessed for fish species distribution. Arctic grayling were most widely distributed and were present in all lakes except Meadow Lake, Scotch Lake, Pointer Pond, and Sik Sik Lake. Meadow Lake was the only lake with no fish documented. Slimy sculpin were the only species reported in Pointer Pond; ninespine stickleback were the only species reported from Sik Sik Lake (Table 5.6-1).

Fish were not found in the upper tributary to the northeast Inflow of Pointer Lake, however it was only surveyed in one season. The remaining seven streams in the sub-basin contained fish, with ninespine stickleback being most widely distributed (found in five streams), followed by Arctic grayling (found in four streams; Table 5.6-2).

Table 5.6-1 Summary of Fish Species Distribution in Lakes of the Kiggavik Project Area, 1975 to 2010

Watershed	Sub-Basin	Waterbody	Fish Species										
			Arctic Char	Arctic Grayling	Burbot	Cisco	Fourhorn Sculpin	Lake Trout	Lake Whitefish	Longnose Sucker	Ninespine Stickleback	Round Whitefish	Slimy Sculpin
Aniguq River	Willow Lake	Meadow Lake[(a)]	-	-	-	-	-	-	-	-	-	-	-
		Felsenmeer Lake	-	X	-	-	-	X	-	-	-	X	-
		Escarpment Lake	-	X	-	-	-	X	-	-	-	X	-
		Drum Lake	-	X	-	-	-	-	-	-	-	-	-
		Lin Lake	-	X	-	-	-	-	-	-	-	-	-
		Scotch Lake	-	-	-	-	-	X	-	-	X	X	X
		Jaegar Lake	-	X	-	-	-	-	-	-	-	-	-
		Pointer Pond	-	-	-	-	-	-	-	-	-	-	X
		Pointer Lake	-	X	-	X	-	X	-	-	X	-	-
		Sik Sik Lake	-	-	-	-	-	-	-	-	X	-	-
		Rock Lake	-	X	-	-	-	X	-	-	-	-	-
		Willow Lake	-	X	-	-	-	X	-	-	X	-	-
	Lower Lake	Mushroom Lake	-	X	-	X	-	X	-	-	-	X	-
		Ponds 1 to 8[(b)]	-	-	-	-	-	-	-	-	-	-	-
		End Grid Lake	-	X	-	-	-	-	-	-	-	-	-
		Smoke Lake	-	X	-	X	-	-	-	-	-	-	-
		Cigar Lake	-	X	X	X	-	X	-	-	-	X	-
		Knee Lake	-	X	-	-	-	-	-	-	-	-	-
		Lunch Lake	-	X	-	-	-	X	-	-	-	X	-
		Andrew Lake	-	X	X	X	-	-	-	-	-	X	-
		Shack Lake	-	X	-	-	-	-	-	-	-	-	-
		Bear Island Lake	-	X	-	-	-	-	-	-	-	-	-
		Lower Lake	-	X	X	X	-	-	-	-	X	X	-
	Caribou Lake	Ridge Lake	-	-	-	-	-	X	-	-	-	-	-
		Cirque Lake	-	X	-	-	-	-	-	-	X	-	-
		Crash Lake	-	X	-	-	-	-	-	-	-	-	-
		Fox Lake	-	X	-	X	-	X	-	-	X	-	-
		Caribou Lake	-	X	X	X	-	X	-	-	X	X	-
		Calf Lake	-	-	X	X	-	-	-	-	X	-	-
	Judge Sissons Lake	Judge Sissons Lake	-	X	X	X	-	X	-	-	X	X	X
	Siamese Lake	Siamese Lake	-	-	-	-	-	X	-	-	-	-	-
	Skinny Lake	Skinny Lake	-	X	-	X	-	X	-	-	-	X	-
	Kavisilik Lake	Kavisilik Lake	-	X	-	X	-	X	-	-	-	X	-
Thelon River	Squiggly Lake	Squiggly Lake	X	X	X	-	-	X	-	-	-	X	-
Baker Lake	Baker Lake	Baker Lake	X	X	X	X	X	X	X	X	X	X	X

Source: Modified from Appendix 5C, Table 11A-1.
(a) No fish captured as per BEAK 1987; 1990; 1992b.
(b) No fish captured during spring 2010.
- = no fish captured.

Table 5.6-2 Summary of Fish Species Distribution in Streams of the Kiggavik Project Area, 1975 to 2010

Watershed	Sub-Basin	Watercourse	Fish Species								
			Arctic Char	Arctic Grayling	Burbot	Cisco	Lake Trout	Longnose Sucker	Ninespine Stickleback	Round Whitefish	Slimy Sculpin
Aniguq River	Willow Lake	Northeast Inflow of Pointer Lake	-	-	-	-	-	-	X	-	-
		Upper Tributary to the Northeast Inflow of Pointer Lake[(a)]	-	-	-	-	-	-	-	-	-
		Upper Northwest Inflow of Pointer Lake	-	-	-	-	-	-	-	-	X
		Northwest Inflow of Pointer Lake	-	X	-	-	X	-	-	-	-
		Pointer/Rock Stream	-	X	X	-	-	-	X	X	-
		Sik Sik/Rock Stream	-	-	-	-	-	-	X	-	-
		Rock/Willow Stream	-	X	-	X	X	-	X	X	-
		Willow/Judge Sissons Stream	-	X	-	-	X	-	X	-	X
	Lower Lake	Mushroom/End Grid Stream	-	X	-	-	X	-	-	-	-
		End Grid/Shack Stream	-	X	-	-	-	-	-	-	-
		Cigar/Lunch Stream[(b)]	-	-	-	-	-	-	-	-	-
		Knee/Lunch Stream	-	-	-	-	X	-	-	-	-
		Lunch/Andrew Stream	-	X	-	-	-	-	-	-	-
		Andrew/Shack Stream	-	X	-	-	-	-	-	-	-
		Shack/Lower Stream	-	-	-	-	X	-	-	-	-
		Lower/Judge Sissons Stream	-	-	-	-	X	-	X	-	-
	Caribou Lake	Fox/Caribou Stream[(b)]	-	-	-	-	-	-	-	-	-
		Caribou/Calf Stream[(b)]	-	-	-	-	-	-	-	-	-
		Calf/Judge Sissons Stream	-	X	-	-	X	-	-	-	-
	Aniguq River	Aniguq River[(c)]	-	X	X	-	X	-	X	-	X
Thelon River	Thelon River	Thelon River	X	X	-	X	X	X	X	X	X

Source: Modified from Appendix 5C, Table 11A-2.
(a) No fish captured during the spring 2010 field sampling.
(b) No fish captured during the Arctic grayling spring spawning survey in 2008.
(c) Data came from the “Bunker River” between Audra Lake and Baker Lake (Mcleod et al. 1976), which is a section of the Aniguq River.
- = No fish captured.

5.6.1.1.2 Lower Lake Sub-basin (Surrounding the Proposed Sissons Mine Site)

Ten lakes, eight ponds, and eight stream segments (streams) in the Lower Lake sub-basin were assessed for fish species distribution. Arctic grayling were present in all ten lakes with cisco and round whitefish documented in five lakes each. No fish were found in the eight shallow (less than or equal to 1.5 m deep) ponds that were not connected by visible outflow watercourses to nearby fish-bearing streams or lakes (Table 5.6-1).

Cigar/Lunch Stream was the only stream in which no fish were captured or observed out of the eight streams that were assessed for fish in the Lower Lake sub-basin. Only three fish species were found in streams in the Lower Lake sub-basin (Arctic grayling, lake trout, and ninespine stickleback; Table 5.6-2).

5.6.1.1.3 Caribou Lake Sub-basin (Traversed by the Proposed Mine Haul Road)

Six lakes were assessed for fish distribution in the Caribou Lake sub-basin. Arctic grayling and ninespine stickleback were most widely distributed (four lakes each), followed by cisco and lake trout (three lakes each). Fish were found in every lake assessed (Table 5.6-1).

Three streams of interest in the Caribou Lake sub-basin were not surveyed for the presence of fish (Ridge/Crash Stream, Cirque/Crash Stream, and Crash/Fox Stream) but these stream segments connect lakes known to contain Arctic grayling or lake trout, with ninespine stickleback in Cirque Lake (Table 5.6-1). Three streams were assessed for fish distribution in the Caribou Lake sub-basin. Fox/Caribou stream and Caribou/Calf Stream were visited in one field season and no fish were captured, but also connect lakes known to contain Arctic grayling, cisco, lake trout, and ninespine stickleback, with the addition of burbot and round whitefish in Caribou Lake (Table 5.6-2). Arctic grayling and lake trout were found in Calf/Judge Sissons Stream (Table 5.6-2).

5.6.1.1.4 Judge Sissons Lake (Proposed Treated Effluent Discharge)

Seven fish species were documented in Judge Sissons Lake (Arctic grayling, burbot, cisco, lake trout, ninespine stickleback, round whitefish, and slimy sculpin; Table 5.6-1).

5.6.1.1.5 Siamese Lake (Proposed Water Supply Lake, Traversed by Proposed Winter Access Road, and Near Proposed North All-Season Access Road)

Only lake trout have been documented in Siamese Lake (Table 5.6-1), although a number of other species are also expected to inhabit the lake.

5.6.1.1.6 Skinny Lake and Kavisilik lake

Arctic grayling, cisco, lake trout, and round whitefish have been documented in both Skinny and Kavisilik lakes (Table 5.6-1).

5.6.1.1.7 Proposed Haul Road

Fish are widely distributed in the streams crossed by the proposed haul road. Ninespine stickleback and slimy sculpin were present in streams greater than 2 m wide. Large-bodied fish species including Arctic grayling and lake trout were found in streams with bankfull widths of approximately 3 m or more.

5.6.1.1.8 Proposed Water Intake - Kiggavik

Fish are widely distributed in the streams crossed by the proposed road for the water intake pipeline at the Kiggavik site. Ninespine stickleback and/or slimy sculpin were present in all four streams (Table 5.6-3).

5.6.1.1.9 Proposed Water Intake - Sissons

The proposed road for the water intake pipeline at the Sissons site crossed one potential stream likely classified as first category streams (i.e. no defined or no visible channel). Although NTS coverage shows a stream at this location, Lidar imagery indicates that this stream does not exist.

5.6.1.1.10 Proposed Treated Effluent Discharge - Kiggavik and Road to Airstrip

The proposed road to the treated effluent discharge point in Judge Sissons Lake from the Kiggavik site also provides airstrip access. This road does not cross any stream, since it is located on the divide between the Willow and Caribou lake sub-basins.

5.6.1.1.11 Proposed Treated Effluent Discharge - Sissons

Fish are widely distributed in the two streams crossed by the proposed road for the treated effluent discharge at the Sissons site. Arctic grayling are present in End Grid/Shack Stream (Table 5.6-2), while most local fish species are expected to be present in Boulder/Judge Sissons Stream due to its proximity to Judge Sissons Lake, its width, and the expected potential for fish overwintering in Boulder Lake.

5.6.1.2 Site Access Local Study Area

Nine species of fish are present in the streams from the Site Access LSA; with an additional two species of fish only being found in Baker Lake (Table 5.6-3). None of these species are considered regionally or locally rare. Fish communities in the Site Access LSA streams are dominated by ninespine stickleback, Arctic grayling, and slimy sculpin. Lake trout, round whitefish, burbot, cisco, and longnose sucker were present in larger streams and rivers of the Site Access LSA. Arctic char were only present in the Thelon River and in Baker Lake. All fish species present in the Site Access LSA were also present in Baker Lake. Fourhorn sculpin and lake whitefish were only present in Baker Lake (Table 5.6-3).

5.6.1.2.1 Proposed South Winter Access Road

Four stream crossing locations were checked for fish presence along the proposed South Winter Access Road. Fish species present were limited to Arctic grayling and ninespine stickleback at two locations (i.e., S13 [Long/Audra Stream] and S14), and slimy sculpin at one location (i.e., S14) (Table 5.6-3; Figure 5.5-1a). Fish were not observed or captured at the two stream crossing locations near the downstream section of the Aniguq River watershed (Figure 5.5-1b).

Several lakes were also present along the proposed South Winter Access Road. From west to east, the proposed road crosses the following large waterbodies: Siamese Lake, an unnamed lake (Lake 2), Long Lake, Audra Lake, and Quinguq Bay of Baker Lake. No fishing was completed in any of these lakes, except for Siamese Lake which had lake trout (Table 5.6-1).

5.6.1.2.2 Proposed North Winter Access Road

No stream crossing locations were checked for fish presence along the proposed North Winter Access Road. All available fish information comes from fish sampling that occurred in proximity to the proposed winter road location. Fish species present at stream crossing locations along the proposed North Winter Access Road were limited to eight fish species (i.e., Arctic char, Arctic grayling, cisco, lake trout, lake whitefish, ninespine stickleback, round whitefish, and slimy sculpin) present in the Thelon River (i.e., Km 174.8) (Table 5.6-3; Figure 5.5-1b).

Several lakes were also present along the proposed North Winter Access Road. From west to east, the proposed road crosses the following large waterbodies: many unnamed lakes, Thom Lake, three more unnamed lakes, Qikittalik Lake, Tunuhuk Lake, and many more unnamed lakes east of the Thelon River. No fishing was completed in these lakes in relation to this proposed road location. However, Arctic grayling, lake trout, longnose sucker, and ninespine stickleback are expected to be present in Qikittalik Lake since they were present in its northern inflows (i.e., Km 157.3, Km 157.7, and alternate X28; Table 5.6-3). Lake trout were captured in lakes near Km 193.3 and Km 197.5, which are connected to an unnamed lake located east from the Thelon River (Table 5.6-3).

5.6.1.2.3 Proposed North All-Season Access Road

Fish are widely distributed in the streams crossed by the North All-Season Access Road (Table 5.6-3, Figures 5.5-1a and 5.5-1b). A general observation was that fish appeared to be present if the stream was flowing in late July and there was a large pond or lake upstream of the sampling location. Channel width also appears to influence fish presence. Ninespine stickleback and slimy sculpin were usually present if the stream was greater that 2 m wide (e.g., crossing Km 147.1). Large-bodied fish species, such as lake trout and Arctic grayling, were found in streams with bankfull widths of about 3 m or more (e.g., crossing Km 157.7). Eight fish species were historically and/or more recently captured in the Thelon River (crossing Km 174.8) included Arctic char, Arctic grayling, cisco, lake trout, longnose sucker, ninespine stickleback, round whitefish, and slimy sculpin (Table 5.6-3; Figures 5.5-1b).

5.6.1.2.4 Aniguq River (Proposed Treated Effluent Path to Baker Lake)

Arctic grayling, burbot, lake trout, ninespine stickleback, and slimy sculpin were all found in the Aniguq River (Table 5.6-2).

5.6.1.2.5 Baker Lake (Proposed Baker Lake Facility)

Baker Lake had the most diverse fish population of all the lakes assessed. Eleven species including Arctic char, Arctic grayling, burbot, cisco, fourhorn sculpin, lake trout, lake whitefish, longnose sucker, ninespine stickleback, round whitefish and slimy sculpin have all been found there (Tables 5.6-1 and 5.6-3).

Table 5.6-3 Summary of Fish Species Distribution in Stream Crossings of the Site Access Local Study Area, 1979 to 2010

Access Road	Crossing Identification	No Fish Captured / Observed	Fish Species										
			Arctic Char	Arctic Grayling	Burbot	Cisco	Fourhorn Sculpin	Lake Trout	Lake Whitefish	Longnose Sucker	Ninespine Stickleback	Round Whitefish	Slimy Sculpin
Haul	Km 2.0 (Mushroom/End Grid Stream)	-	-	X	-	-	-	X	-	-	-	-	-
	Km 6.7 (West Inflow of Boulder Lake)	-	-	X	-	-	-	-	-	-	-	-	-
	Km 11.3 (Sleek/Caribou Stream)	-	-	X	-	-	-	-	-	-	-	-	X
	Km 15.6 (Rhyolite/Fox Stream)	-	-	-	-	-	-	-	-	-	X	-	-
	Km 17.2 (Crash/Fox Stream)	-	-	X	-	-	-	-	-	-	X	-	X
Water Intake - Kiggavik	Km 100.2 (Northeast Inflow of Pointer Lake)	X[a]	-	-	-	-	-	-	-	-	X[a]	-	-
	alternate W1 (Meadow/Jaegar Stream)	-	-	-	-	-	-	-	-	-	X	-	-
	alternate W2 (Escarpment/Jaegar Stream)	-	-	-	-	-	-	-	-	-	X	-	X
	alternate W3 (North Inflow of Drum Lake)	-	-	-	-	-	-	-	-	-	X	-	-
Winter	alternates W5 and W6	X	-	-	-	-	-	-	-	-	-	-	-
	S13 (Long/Audra Stream)	-	-	X	-	-	-	-	-	-	X	-	X
	S14	-	-	X	-	-	-	-	-	-	X	-	-
North All-Season	Km 107.8 (West Inflow of Skinny Lake)	X	-	-	-	-	-	-	-	-	-	-	-
	Km 108.8	X	-	-	-	-	-	-	-	-	-	-	-
	Km 109.8 (South Inflow of Skinny Lake)	-	-	X	-	-	-	-	-	-	X	-	X
	alternates NC22, NC21, NC20, and NC17	X	-	-	-	-	-	-	-	-	-	-	-
	Km 127.5	-	-	X	-	-	-	-	-	-	X	-	X
	Km 129.2	-	-	X	X	-	-	-	-	-	-	-	X
	alternate X33 (4 km downstream of Km 129.2)	-	-	-	-	-	-	X	-	-	-	-	-
	Km 145.3	-	-	X	-	-	-	-	-	-	X	X	X
	Km 147.1	-	-	-	-	-	-	-	-	-	X	-	X
	Km 147.6	X	-	-	-	-	-	-	-	-	-	-	-
	alternate X28 (0.5 km upstream of Km 157.3)	-	-	-	-	-	-	X	-	-	-	-	-
	Km 157.3 (North Inflow of Qikittalik Lake)	-	-	-	-	-	-	-	-	-	X	-	-
	Km 157.7 (Northeast Inflow of Qikittalik Lake)	-	-	X	-	X	-	-	X	-	X	-	-
	Km 172.2	X	-	-	-	-	-	-	-	-	-	-	-
	Km 174.8 (Thelon River)	-	X	X	-	X	-	X	X	-	X	X	X
	alternate EC30	X	-	-	-	-	-	-	-	-	-	-	-
	alternate EC22	-	-	-	-	-	-	-	-	-	X	-	-
	Km 193.3	X[b]	-	-	-	-	-	X[b]	-	-	-	-	-
	Km 195.1	X[c]	-	-	-	-	-	-	-	-	-	-	-
	Km 197.5	X[d]	-	-	-	-	-	X[d]	-	-	-	-	-
	Km 203.0	-	-	-	-	-	-	-	-	-	X	-	-
	Km 209.4	X	-	-	-	-	-	-	-	-	-	-	-

Access Road	Crossing Identification	No Fish Captured / Observed	Fish Species										
			Arctic Char	Arctic Grayling	Burbot	Cisco	Fourhorn Sculpin	Lake Trout	Lake Whitefish	Longnose Sucker	Ninespine Stickleback	Round Whitefish	Slimy Sculpin
	Km 212.2	X	-	-	-	-	-	-	-	-	-	-	-
	Km 213.1	-	-	X	-	-	-	-	-	-	-	-	-
Baker Lake Facility	Baker Lake	-	X	X	X	-	X	X	X	X	X	X	X

Source: Modified from March 18, 2011 Golder Technical Memo to Nicola Banton, AREVA titled “Summary of Aquatics Studies for the Kiggavik Uranium Project”.

(a) No fish were captured or observed during the summer 2009 field sampling at the proposed road crossing located in the upper section of this stream, but ninespine sticklebacks were captured near the mouth of this stream during 2008 and 2009 Arctic grayling spring spawning surveys.

(b) No fish sampling or habitat mapping was conducted at this crossing. No fish observed during the fall 2009 hydrology field work at the proposed road crossing. However, fish are expected in this location due to stream location between two lakes and lake trout captured in the downstream lake.

(c) No fish sampling or habitat mapping was conducted at this crossing. No fish observed during the fall 2009 hydrology field work at the proposed road crossing. However, fish are expected in this location due to stream location between two lakes.

(d) No fish sampling or habitat mapping was conducted at this crossing. No fish observed during the fall 2009 hydrology field work at the proposed road crossing. However, fish are expected in this location due to stream location between two lakes and lake trout captured in both lakes.

- = No data.

5.6.2 Fish Habitat Requirements and Uses

This section presents information for all fish species known to occur in the mine site and site access LSAs. The habitat requirements for each species were obtained from a review of fish habitat literature describing rearing, feeding, overwintering, spawning, and other habitat requirements for each species. A short summary of observed fish use is also included for each species. More detailed life-history and a habitat requirement summary can be found in Technical Appendix 5C (Section 11.2.1).

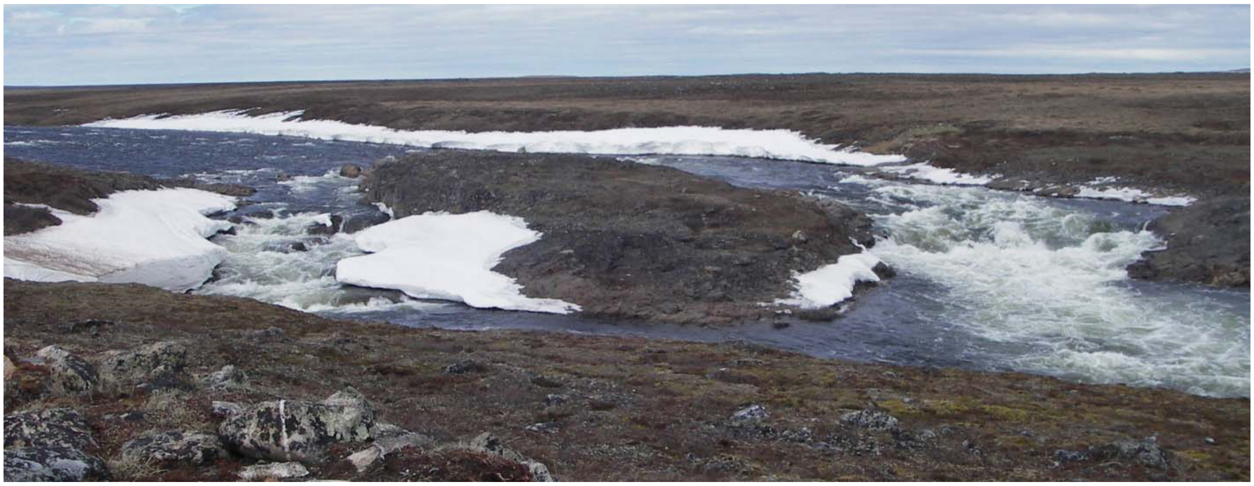
5.6.2.1 Arctic Char

Arctic char may be anadromous (living in salt water, but spawning in fresh water) or freshwater only residents. They can be found in rivers, lakes, estuaries and marine environments at different stages of their lifecycle (Johnson 1989; Lee et al. 1980; Scott and Crossman 1998). In lakes, adult Arctic char migrate seasonally between the open water zone in summer and the shoreline areas in the fall and winter. Arctic char are most commonly found in less than 5 m of water over boulder, rubble and cobble substrates (Bjoru and Sandlund 1995; Jamet 1995). Diet is widely variable according to size and availability, and may include a variety of algae, insects, invertebrates, fish, and plankton while residing in freshwater habitats (Hunter 1970; McPhail and Lindsey 1970; Scott and Crossman 1998). Resident Arctic char overwinter in deeper lakes, or sometimes in rivers deep enough that they don't freeze to the bottom during winter months (Scott and Crossman 1998; Stewart and Watkinson 2007).

Spawning occurs in rivers or deep lakes for both anadromous and fresh water resident forms of Arctic char in water less than 6 m deep over gravel and cobble substrates from September through October (Gyselman 1984; Johnson 1980, 1989; Scott and Crossman 1998). Fry hatch in late March to April, emerge around the time of ice breakup, and remain on the spawning grounds (Johnson 1980; Scott and Crossman 1998). Later in the summer, young-of-the-year char move to the shallow, near shore zone, and reside in rocky or cobble areas for protection from predators (Johnson 1980; Scott and Crossman 1998). Dwarf forms of Arctic char have also been documented to spawn and reside in deeper water than normal forms, and also to mature earlier (Parker and Johnson 1991).

Arctic char were not captured in any lakes or rivers in the upper Aniguq River watershed near the mine site LSA. However, they have been caught in Squiggly Lake, which is part of the Thelon River watershed, as well as in the Thelon River, and Baker Lake (Tables 5.6-1 and 5.6-2). It appears that Arctic char may not be able to access the upper Aniguq River watershed and the sub-basins of the mine site LSA. Movements upstream from Baker Lake appear to be blocked by two sets of cascades in the Aniguq River. The first barrier is a single cascade that may be passable under some flow conditions. However, the second barrier is a double cascade that appears to completely obstruct upstream fish migration (Photo 5.6-1). As a result, Judge Sissons Lake and its contributing watersheds are not used by Arctic char for spawning or rearing.

Photo 5.6-1 Second set of cascades in the Aniguq River.



5.6.2.2 Arctic Grayling

Arctic grayling occur in clear, cold rivers, streams and lakes and generally avoid turbid areas (Scott and Crossman 1998). The diet of young Arctic grayling consists of zooplankton, shifting to immature and mature insects, various invertebrates, and fish as they attain adult size (Schmidt and O'Brien 1982; Scott and Crossman 1998). Arctic grayling are assumed to overwinter in deep pools of rivers, and in deeper portions of lakes (Ford et al. 1995).

As the ice begins to break up, adult Arctic grayling migrate from lakes and larger rivers to smaller streams or tributaries with areas of small gravel and rock to spawn before returning to the lakes or rivers from which they came (Scott and Crossman 1998). The timing of spawning may vary from April to June depending on the particular Arctic habitat (Scott and Crossman 1998). Eggs hatch after about 13 to 18 days, with alevin starting to eat after another eight or more days during which the alevin absorbs the egg sac (Scott and Crossman 1998). Lakes tend to provide warmer summer water temperatures, and young-of-the-year Arctic grayling from watersheds with more lakes tend to exhibit increased growth rates (Luecke and MacKinnon 2008).

Arctic grayling were present in most lakes and streams throughout all sub-basins sampled (Tables 5.6-1 and 5.6-2). After overwintering in the deeper lakes (i.e., Pointer, Mushroom, Cigar, Cirque, Fox, Caribou, and Judge Sissons lakes), Arctic grayling migrate to tributaries in the early spring to spawn. Spawning was confirmed in four streams of the Willow Lake and Lower Lake sub-basins. Rearing and feeding activities may occur throughout all the sub-basins, in both shallow and deep lakes. Shallow lakes freeze to the bottom in winter and thus do not support overwintering fish populations. However, the presence of larger inlet and outlet streams allows re-population of the shallow lakes from nearby overwintering lakes each spring. Deeper lakes like Cirque Lake near the head waters of the Caribou Lake sub-basin may support an isolated Arctic grayling population. Its outlet stream channel contains obstructions that would prevent upstream fish movement from the downstream lakes.

In 2009, spawning was confirmed in Pointer/Rock Stream and Rock/Willow Stream in the Willow Lake sub-basin, and in Lunch/Andrew Stream and Andrew/Shack Stream in the Lower Lake sub-basin. The eggs were collected in 0.1 to 0.7 m water depth, with velocities between 0.2 and 1.0 m/s. The spawning substrate consisted of primarily gravel or cobble, with some sand in the Willow Lake sub-basin, and varied greatly but generally consisted of cobble, with some sand, gravel, or boulder, in the Lower Lake sub-basin (Technical Appendix 5C, Section 11.2.5.5).

Eggs were more abundant in the streams of the Lower Lake sub-basin compared to the streams of the Willow Lake sub-basin. By comparing fish habitat, limnology, daily stream temperature, and stream hydrology at the time of sampling, Arctic grayling eggs appeared to be most abundant in streams characterized by the following:

- The smallest drainage area;
- The smallest number of lakes deeper than 2 m located upstream;
- The smallest volume ratio between deep lakes and shallow lakes;
- The lowest stream discharge;
- The quickest flushing rate; and
- The largest number of Arctic grayling captured.

The scarcity of lakes deeper than 2 m, and the abundance of large lakes shallower than 2 m in depth, in the Lower Lake sub-basin appears to allow streams to warm up faster in the spring. This may favour an earlier spawning event and faster embryonic development of Arctic grayling.

5.6.2.3 Burbot

Burbot may complete their life history as residents of lakes or rivers, or both; burbot spawning has been documented in lakes, rivers and streams (McPhail and Lindsey 1970; Scott and Crossman 1998). Burbot are nocturnal predators, young feed on aquatic insects, crayfish, molluscs and invertebrates, while adults feed on fish eggs, invertebrates, and fish (Scott and Crossman 1998). Juvenile habitat includes rock and gravel substrate along rocky shorelines with the presence of daytime shelter (i.e., boulders, cobbles, logs, or within submergent vegetation), while adults prefer cooler deeper waters in the summer and move in to shallower water to feed. Both juvenile and adult burbot are found over boulders, cobble, sand substrates or in turbid water (Ford et al. 1995; Scott and Crossman 1998).

Burbot spawn in winter (January to April), under the ice in water temperatures usually between 0.6 and 1.7 degrees Celsius (oC), typically over gravel or rubble in 0.5 to 3.0 m of water (Ford et al. 1995; Scott and Crossman 1998). Eggs hatch after three weeks to three months depending on water temperature (Goodyear et al. 1982; Scott and Crossman 1998). Sac-fry (active at twilight) are found in the open water zone over sand and rubble, while young-of-the-year and juvenile burbot are mainly nocturnal shoreline zone, bottom feeders (Ford et al. 1995; McPhail 1997; Ryder and Pisendorfer 1992).

Burbot were found in eight lakes throughout the Lower (Cigar, Andrew, and Lower lakes), Caribou (Caribou and Calf lakes), Judge Sissons, Squiggly, and Baker lakes sub-basins, and in two streams in the Willow Lake (Pointer/Rock Stream) and Aniguq River sub-basins (Tables 5.6-1 and 5.6-2). It is expected that burbot are able to migrate freely between Pointer and Judge Sissons lakes, Cigar and Judge Sissons lakes, and Caribou and Judge Sissons lakes. Spawning and overwintering habitat may be limited to Pointer, Cigar, Caribou, and Judge Sissons lakes; while rearing and foraging habitats are abundant in lakes and streams where burbot can migrate.

5.6.2.4 Cisco

Cisco are primarily a lake species but may be found in larger rivers in the NT and NU. A dwarf form of cisco also exists in the same habitat as the normal form. The diet of cisco is varied, with the young reported to feed on algae, copepods and cladocera (Pritchard 1930). As adults they feed on copepods, small minnows, crustaceans, aquatic insects (mayflies and caddisflies), water mites, zooplankton, their own eggs and those of other fish species (Scott and Crossman 1998). Cisco are a significant part of the diet of many fish species, including being a preferred food source of lake trout (Scott and Crossman 1998).

Lake spawning occurs in the fall over a variety of substrates (Scott and Crossman 1998; Stewart and Watkinson 2007). In small inland lakes, spawning is usually underway when ice begins to form around the shores (Scott and Crossman 1998). Although cisco are primarily a lake species, large numbers have been reported at the mouth of the Thelon River during mid-November, where suitable spawning habitat (i.e., coarser sand, gravel, and cobble) exists, as well as in a pooled area of the same river above a section of rapids (McLeod et al. 1976). River spawning runs have also been reported in the Hudson Bay Region; however, rivers are not normally considered as cisco habitat (Scott and Crossman 1998). Hatching of eggs does not occur until after the spring breakup (Scott and Crossman 1998).

Cisco were found in 13 lakes throughout the Willow (Pointer Lake), Lower (Mushroom, Smoke, Cigar, Andrew, and Lower lakes), Caribou (Fox, Caribou and Calf lakes), Judge Sissons, Skinny, Kavisilik, and Baker lakes sub-basins, and in two streams in the Willow Lake (Rock/Willow Stream) and Thelon River sub-basins (Tables 5.6-1 and 5.6-2). It is expected that cisco can migrate freely between Pointer and Judge Sissons lakes, Cigar and Judge Sissons lakes, and Fox and Judge Sissons lakes. Spawning and overwintering habitats may be limited to Pointer, Cigar, Mushroom (cisco were present in this lake according to historical data), Fox, Caribou, and Judge Sissons lakes; while rearing and feeding habitat are present in all lakes and streams where cisco can migrate.

5.6.2.5 Fourhorn Sculpin

The fourhorn sculpin (freshwater form) is a land locked relic, found in cold, deep freshwater lakes. Preference for cold water (less than 10oC) seems to influence depth distribution in summer (especially the marine form; Hammar et al. 1996). Fourhorn sculpin are usually found near the lake bottom at temperatures below 5oC; although, the freshwater form may have a higher tolerance for warmer temperatures, with some specimens being caught near the surface at 17oC (Hammar et al. 1996). Fourhorn sculpin are largely nocturnal but may also be diurnal through the winter, consuming invertebrates, small fish and fish eggs (COSEWIC 2003). Little is known about reproductive habits and requirements of the fourhorn sculpin, especially the freshwater form (COSEWIC 2003).

In 1975, fourhorn sculpin were found in Baker Lake (Table 5.6-1). No fourhorn sculpin were captured during recent fish sampling of Baker Lake. Spawning, overwintering, rearing, and feeding habitats are expected to occur in Baker Lake.

5.6.2.6 Lake Trout

Lake trout are mainly found in deeper lakes, but may also be found in large, clear rivers (Ford et al. 1995; Scott and Crossman 1998). Cobble, boulder, rubble and woody debris provide juvenile lake trout with cover (Ford et al. 1995). Adult lake trout are commonly found at depths of 10 m or greater, in cooler (about 10oC) waters, while juveniles move to shallower waters at night for foraging (Scott and Crossman 1998). Lake trout are predatory fish with a varied diet consisting of plankton, aquatic and terrestrial insects, crustaceans, small mammals and fish (Scott and Crossman 1998).

In lakes, spawning occurs in late summer or early fall over the shallow, inshore areas of lakes on cobble, rubble and large gravel substrates, interspersed with boulders (Ford et al. 1995; McPhail and Lindsey 1970). The lake spawning ground is often associated with currents or wave action and may occur at a variety of depths (Ford et al. 1995; McPhail and Lindsey 1970; Scott and Crossman 1998; Stewart and Watkinson 2007). Spawning may also occur over similar substrate in slower moving sections of streams and rivers (Evans et al. 2002). The eggs usually hatch from March to April, and even June in northern lakes such as Great Bear Lake (Scott and Crossman 1998). The young-of-the-year may remain at the spawning area for several weeks or several months, before moving to deeper cooler waters (Goodyear et al. 1982; Martin and Oliver 1980; Morrow 1980; Peck 1982; Scott and Crossman 1998).

Lake trout were found in 18 lakes throughout the Willow (Felsenmeer, Escarpment, Scotch, Pointer, Rock, and Willow lakes), Lower (Mushroom, Cigar, and Lunch lakes), Caribou (Ridge, Fox, and Caribou lakes), Judge Sissons, Siamese, Skinny, Kavisilik, Squiggly, and Baker lakes sub-basins, and in ten streams throughout the Willow Lake (Northwest Inflow of Pointer Lake, Rock/Willow Stream, and Willow/Judge Sissons Stream), Lower Lake (Mushroom/End Grid Stream, Knee/Lunch Stream, Shack/Lower Stream, and Lower/Judge Sissons Stream), Caribou Lake (Calf/Judge Sissons Stream), Aniguq River, and Thelon River sub-basins (Tables 5.6-1 and 5.6-2).

In the Willow Lake, Lower Lake and Caribou Lake sub-basins, there is potential for migration of lake trout throughout the sub-basin and towards Judge Sissons Lake, as evidenced by their relatively widespread distribution, except for the inaccessibility of Sik Sik Lake. Lake trout overwintering habitat may be limited to Mushroom, Cigar, Ridge, Judge Sissons, Siamese, Skinny, Kavisilik. Squiggly, and Baker lakes (Table 5.3-1). Potential overwintering habitat maybe available in the deeper portions of Pointer, Fox, and Caribou lakes, but the absence of lake trout during the fall spawning surveys suggests that the lake trout population of these lakes is transient. The maximum depth of these three lakes ranged from 2.7 to 3.0 m, therefore use by spawning lake trout is unlikely. After overwintering, lake trout may remain in the same lake for rearing, feeding and spawning. However, based on observations and fish captured in the spring surveys, it is thought that some lake trout may migrate into nearby shallow lakes and tributaries to feed. As these shallow lakes likely freeze to the bottom during winter, the lake trout sampled in them appear to be transient, using the lakes during the open water period as foraging areas, before returning to larger, deeper lakes for overwintering.

Lake trout spawning was confirmed in Mushroom, Cigar, Ridge, Judge Sissons, and Siamese lakes. The habitats and site characteristics where lake trout in spawning condition were captured were:

- Depths between 1.5 and 3.9 m;
- Substrate contained a majority of cobble with either boulder, gravel, or sand; and
- Surface water temperatures ranging between 6.6ºC and 10.7ºC.

5.6.2.7 Lake Whitefish

Lake whitefish are usually found in lakes and large rivers (McPhail and Lindsey 1970; Richardson et al. 2001). Adult resident lake whitefish prefer deep water habitat (depths greater than 10 m) for most of the year (i.e., rearing and overwintering; McPhail and Lindsey 1970). Despite being primarily bottom dwelling, they may be found in the open water zone of lakes as well (Ford et al. 1995). Lake whitefish move into shallow water habitats at night to feed (McPhail and Lindsey 1970). Their diet includes: snails, clams, terrestrial insects, aquatic insects, plankton, and small fishes (Scott and Crossman 1998). Lake whitefish are preyed upon by lake trout, burbot and other lake whitefish, in both the egg and adult life-stages (Scott and Crossman 1998). Resident lake whitefish are a valuable commercial freshwater fish species in Canada (Scott and Crossman 1998).

Spawning of resident lake whitefish usually occurs in lake and river systems from mid-September to mid-October in northern regions (Richardson et al. 2001). Individual fish may only spawn every two or three years (Scott and Crossman 1998). Spawning usually takes place in shallow water areas at depths less than 8 m (Scott and Crossman 1998). Eggs are released randomly over substrates that range from large boulders to gravel and occasionally sand (Richardson et al. 2001; Scott and Crossman 1998). The eggs settle into crevices, incubate, and hatch between March and May (Richardson et al. 2001). Juveniles are often found close to spawning areas in association with boulder, cobble or sand substrate and emergent vegetation and woody debris (Ford et al. 1995).

Lake whitefish were not captured in any lakes or rivers in the upper Aniguq River watershed near the mine site LSA, however they are known to occur in Baker Lake (Table 5.6-1). Spawning, overwintering, rearing, and feeding habitats are also expected to exist in Baker Lake.

5.6.2.8 Longnose Sucker

Longnose suckers are found in lakes, rivers and streams. The diet of longnose sucker consists mostly of amphipods, chironomids, midge larvae, caddisfly larvae and sphaeriid clams (Richardson et al. 2001). Their down facing mouth and large lips aid in suction as they primarily feed on invertebrates from stream and lake beds (Mecklenburg et al. 2002). Juveniles occupy shallow areas of lakes, in association with vegetation and sandy substrates, as well as shallow weedy areas (Richardson et al. 2001).

Longnose suckers spawn in the spring, between April and June, shortly after ice breakup. Spawning occurs in streams and rivers but may also occur in shallow lakes over gravel and sand substrates. Eggs hatch after 11 to 15 days of incubation and young-of-the-year remain in the gravel substrate for an additional 7 to 14 days (depending upon water temperature). Emergent young occupy shallow areas in association with vegetation and sandy substrate (Richardson et al. 2001).

Longnose suckers were not captured in any lakes or rivers in the upper Aniguq River watershed near the mine site LSA. However, they have been caught in the Thelon River and Baker Lake (Tables 5.6-1 and 5.6-2). Spawning, overwintering, rearing, and feeding habitats are expected to occur in both the Thelon River and Baker Lake.

5.6.2.9 Ninespine Stickleback

In fresh water, ninespine stickleback are found in densely vegetated areas, as well as sand and gravel beaches with sparse vegetation, in shallow bays of lakes, tundra ponds and slow streams (Lee et al. 1980; McPhail and Lindsey 1970; Scott and Crossman 1998). Ninespine sticklebacks become mature in their first year, and live for up to three and a half years (Scott and Crossman 1998; Wootton 1984). Diet consists of aquatic insects, chronomid larvae, small crustaceans, molluscs, cladocerans and other zooplankton (McPhail and Lindsey 1970; Scott and Crossman 1998). Ninespine sticklebacks are part of the diet of larger fish species (Scott and Crossman 1998). Ninespine sticklebacks are tolerant of low dissolved oxygen levels (Morrow 1980).

Spawning occurs in shallow, weedy areas between May and July (i.e., spring and summer; McPhail and Lindsey 1970; Scott and Crossman 1998; Wootton 1976); nests are built by males, amongst weeds in densely vegetated areas. Eggs hatch after four to seven days and the young-of-the-year are then moved into a nursery area constructed by the male from nest building material immediately above the nest (McPhail and Lindsey 1970; Morrow 1980; Wootton 1976). Once free swimming, the emergent young disperse into shallow weedy areas, before dispersing again into deeper waters in the fall to overwinter (Goodyear et al. 1982; McPhail and Lindsey 1970).

Ninespine sticklebacks were found during the open water season in 11 lakes distributed throughout the Willow (Scotch, Pointer, Sik Sik, and Willow lakes), Lower (Lower Lake), Caribou (Cirque, Fox, Caribou and Calf lakes), Judge Sissons, and Baker lakes sub-basins, and in eight streams in the Willow Lake (Northeast Inflow of Pointer Lake, Pointer/Rock Stream, SikSik/Rock Stream, Rock/Willow Stream, and Willow/Judge Sissons Stream), Lower Lake (Lower/Judge

Sissons Stream), the Aniguq River, and the Thelon River sub-basins (Tables 5.6-1 and 5.6-2). Ninespine sticklebacks are thought to return to Pointer, Cirque, Fox, Caribou, Judge Sissons, and Baker lakes, and into the Aniguq and Thelon rivers to overwinter.

5.6.2.10 Round Whitefish

Adult round whitefish are commonly found in areas with rocky and boulder substrates, often in the shallows of lakes or slow flowing rivers and streams (McPhail and Lindsey 1970; Scott and Crossman 1998). Round whitefish feed on benthic invertebrates, mayfly, caddisfly and chironomids larvae, as well as small crustaceans, fishes and fish eggs, and molluscs (Scott and Crossman 1998; Stewart and Watkinson 2007). Round whitefish are preyed upon by lake trout, while round whitefish eggs are preyed on by lake trout, burbot, and round whitefish (Scott and Crossman 1998).

Round whitefish spawn from fall to early winter, usually in lakes and occasionally in streams and rivers; they prefer gravel and cobble substrate for spawning (Normandeau 1969; Richardson et al. 2001). Round whitefish broadcast spawn their eggs over the chosen substrate, in 15 to 200 cm of water (Normandeau 1969). Hatching generally occurs between March and May (Goodyear et al. 1982). After emerging from the eggs the young are generally found near the bottom, in association with rock, sand and gravel substrates (Goodyear et al. 1982).

During the open water season round whitefish were found in 14 lakes distributed throughout the Willow (Felsenmeer, Escarpment, and Scotch lakes), Lower (Mushroom, Cigar, Lunch, Andrew, and Lower lakes), Caribou (Caribou Lake), Judge Sissons, Skinny, Kavisilik, Squiggly, and Baker lakes sub-basins, and in three streams in the Willow Lake (Pointer/Rock Stream and Rock/Willow Stream) and the Thelon River sub-basins (Tables 5.6-1 and 5.6-2). In similar manner to ninespine stickleback, it is thought that round whitefish return to deeper lakes during the winter. After overwintering in these large lakes and rivers, round whitefish may rear, feed, and spawn in these lakes and rivers, or they may migrate to the tributaries.

5.6.2.11 Slimy Sculpin

Slimy sculpin may live in either lakes or rivers; they are found in cool, clear or muddy waters of rivers in streams with rocky or gravelly bottoms, as well as in lacustrine habitats (Craig and Wells 1976; Lee et al. 1980; McPhail and Lindsey 1970; Scott and Crossman 1998). Adult slimy sculpin can be found at depths from 0.5 m to 210 m, on gravel and rocky substrates in lakes (Mohr 1984, 1985; Scott and Crossman 1998). In the NT, slimy sculpin were found in areas with both current and wind action, in waters less than 10 m deep (McPhail and Lindsey 1970). When living in small and shallow lakes, slimy sculpin show seasonal and diurnal changes due to variation in water temperature and/or oxygen concentrations (Mohr 1984, 1985). Diet of the slimy sculpin consists of aquatic insects, crustaceans, juvenile fish and aquatic vegetation (McPhail and Lindsey 1970; Mohr 1984).

Slimy sculpin spawn in May over sand, gravel or rock substrate in shallow water (McPhail and Lindsey 1970; Scott and Crossman 1998). Emergent young are found over shallow gravel and sand and move to deeper water as they mature (Mohr 1984). As they mature the young slimy sculpin gradually move to deepwater habitat (Mohr 1985).

During the open water season slimy sculpins were found in four lakes distributed throughout the Willow (Scotch Lake and Pointer Pond), Lower (Lower Lake), Judge Sissons, and Baker lakes sub-basins, and in four streams in the Willow Lake (Upper Northwest Inflow of Pointer Lake and Willow/Judge Sissons Stream), the Aniguq River, and the Thelon River sub-basins (Tables 5.6-1 and 5.6-2). After overwintering in these large lakes and river, slimy sculpin may rear, feed, and spawn in these lakes and river, or they may migrate short distances up their small tributaries.

5.6.3 Fish Health and Fish Tissue Chemistry

During fish sampling completed between 2007 and 2010, a total of 995 fish from eight species were processed (Table 5.6-4). Fish health assessment (external only, or full) were completed on 28 fish in 2007, 336 fish in 2008, 366 fish in 2009, and 8 fish in 2010.

Table 5.6-4 Summary of the Fish Processed and the Fiah Health Assessment Conducted Between 2007 and 2010

Fish Species	2007			2008			2009			2010	Total
	None	External	Full[(a)]	None	External	Full[(a)]	None	External	Full[(a)]	External	
Arctic grayling	0	9	1	0	40	52	5	102	10	0	**219**
Burbot	0	1	0	1	2	2	2	1	0	0	**9**
Cisco	0	1	0	5	3	67	20	17	0	0	**113**
Lake trout	0	1	0	10	66	54	1	15	5	0	**152**
Longnose sucker	0	0	0	0	0	0	4	0	0	0	**4**
Ninespine stickleback	0	15	0	2	6	0	199	120	0	0	**342**
Round whitefish	0	0	0	4	1	43	0	7	0	0	**55**
Slimy sculpin	0	0	0	0	0	0	4	89	0	8	**101**
Total	**0**	**27**	**1**	**22**	**118**	**218**	**235**	**351**	**15**	**8**	**995**

(a) Full assessment includes external and internal health assessment.

Based on the fish health assessments, all species sampled appeared to be in good health. Observations of external or internal abnormalities, or parasites were generally low.

Flesh and bone from Arctic char, Arctic grayling, cisco, lake trout, and round whitefish captured between 1980 and 2009 were analyzed for trace metals and radionuclides (Table 5.6-5). Historical chemistry data (1980 to 1990) came from composite flesh samples, while the recent analyses (2008 to 2009) used individual fish separated into flesh and bone. Liver tissue was analyzed for Arctic char and lake trout captured in Baker Lake. In recent sampling, one to 12 fish were analyzed per fish species per lake for Pointer, Mushroom, Lower, Caribou, Judge Sissons, and Baker lakes (Table 5.6-5).

Fish tissue chemistry results indicate that most metals and radionuclides were at or below detection limits. There were few individual exceedances of consumption guidelines for arsenic, cadmium, mercury, and lead. Selenium appeared to be present at higher concentrations in fish captured in Mushroom Lake.

Table 5.6-5 Summary of Waterbodies and Fish Species Sampled for Tissue Chemistry, Between 1980 and 2009

Sub-Basin	Waterbody	Arctic Char	Arctic Grayling	Cisco	Lake Trout	Round Whitefish
Willow Lake	Felsenmeer Lake	-	1986 (C)	-	1986 (C)	-
	Escarpment Lake	-	-	-	1986 (C)	-
	Lin Lake	-	1986 (C)	-	-	-
	Pointer Lake	-	1988 (10); 2008 (5)	2009 (5)	1989 (3); 2008 (4)	
	Willow Lake	-	1986 (C)		1986 (C)	-
Lower Lake	Mushroom Lake		2008 (5)	-	1990 (C); 2008 (5)	2008 (5)
	Cigar Lake	-	-	-	1990 (C)	-
	Andrew Lake	-	1990 (C)	-	-	-
	Lower Lake	-	1990 (C)	-	-	2008 (1)
Caribou Lake	Ridge Lake	-	-	-	1986 (C)	-
	Caribou Lake	-	1986 (C); 2008 (3)	-	1986 (C); 2008 (1)	2008 (4)
Judge Sissons Lake	Judge Sissons Lake	-	2008 (2), 2009 (5)	-	1980 (?); 2008 (5), 2009 (5)	2008 (1)
Baker Lake	Baker Lake	1989 (C), 2009 (3)	-	-	2009 (12)	-

Source: Modified from Appendix 5C, Table 11.2-21.

(number) = number of samples; (C) = composite sample, number of samples in the composite sample is not available; (?) = number of samples not available.

5.6.3.1 Arctic Char

Three Arctic char were captured in Baker Lake in 2009. The fork lengths of Arctic char ranged from 445 to 490 mm; the total body weight ranged from 875 to 1,200 g. The age of Arctic char sampled ranged from 7 to 8 years.

Historical concentrations of trace metals in Arctic char from Baker Lake were low, with the exceptions of arsenic, mercury and selenium in 1989.

Flesh and liver samples from three Arctic char were analyzed from Baker Lake in 2009. Some of the concentrations of iron, zinc, selenium, and molybdenum in Arctic char liver tissue exceeded the various corresponding guidelines (i.e., Rieberger average for uncontaminated lakes, British Columbia [BC] tissue quality guidelines, and Environmental Residue Effects Database [ERED] toxicity values specified for sockeye salmon). Mean concentrations of aluminum, copper, iron, and zinc were highest for Arctic char liver samples collected at Site 1. Mean mercury concentrations in Arctic char muscle tissue at Station 1 did not exceed Rieberger averages (Rieberger 1992) and were below BC MoE recommended levels for human consumption (0.1 to 0.5 mg/kg) (MoE 2006). Radionuclide values of flesh and bone samples from Baker Lake Arctic char were near or below detection limits.

5.6.3.2 Arctic Grayling

External (n = 214) and internal (n = 63) fish health assessments were conducted on Arctic grayling captured in 2007, 2008 and 2009, excluding Arctic grayling captured in Baker Lake (Table 5.6-4). The fork lengths of Arctic grayling ranged from 57 to 362 mm; the total body weights ranged from 2.5 to 680 g. The age of Arctic grayling sampled ranged from 1 to 10 years. Younger fish (i.e., Age 1 to 3) were captured in lakes 3 m deep or less, suggesting that smaller fish were rearing in the shallow lakes in the local study area. The older fish (i.e., Age 9 and 10) were captured in the deeper lakes in the local study area. The Arctic grayling captured in Baker Lake in 2009 had a fork length of 315 mm and a total body weight of 400 g.

Overall, the majority of the Arctic grayling processed were in good health and abnormalities or incidents of parasites were low, including nine fish with minor to severe fin erosion, one fish with moderate skin aberrations; and eight fish with minor to severe parasite infestations, all of which were copepods on gills. Internal health assessments were conducted in 2008 and the incidents of internal abnormalities were low, including one fish with hemorrhaged gonads, one fish with a fatty liver; and one fish with a pale discoloured liver.

Historical concentrations of trace metals in Arctic grayling were low and close to the detection limit or below the consumption guideline, with the exception of arsenic in Arctic grayling from Felsenmeer, Lin, Willow, and Caribou lakes in 1986; cadmium and lead in Arctic grayling from Pointer Lake in 1988; and mercury in Arctic grayling from Andrew and Lower lakes in 1990. Historical concentrations of radionuclides were below detection limits for all parameters with the exception of Po-210 in Arctic grayling flesh from Andrew and Lower lakes in 1990, and Ra-226 in Arctic grayling bone from Pointer Lake in 1988.

In general, concentrations of trace metals in flesh and bone samples of Arctic grayling in 2008 were similar between lakes. Many of the chemistry parameters were near or below detection limits. In 2009, chemistry analysis was completed on Arctic grayling flesh and bone samples from Judge Sissons Lake only. The concentration of arsenic, cadmium, and lead in flesh samples of Arctic grayling were below guidelines. Variation between flesh and bone samples was limited. Many of the chemistry parameters were near or below detection limits.

Concentrations of radionuclides were near or below detection limits in flesh and bone samples from Arctic grayling captured in 2008 and 2009 for all parameters, with the exception of Pb-210 in flesh samples from Pointer Lake (2008) and in bone samples from Judge Sissons Lake (2008 and 2009); and Po-210 and Ra-226 in flesh and bone samples from at least one fish from Pointer (2008), Mushroom (2008), Caribou (2008), and Judge Sissons (2008 and 2009) lakes.

5.6.3.3 Burbot

External (n = 6) and internal (n = 2) fish health assessments were conducted on burbot captured in 2007, 2008, and 2009 (Table 5.6-4). Total lengths of burbot ranged from 70 to 219 mm; total body weights ranged from 4 to 70 g.

Overall, all burbot processed were in good health with no abnormalities or incidents of parasites observed. Internal health assessments were conducted in 2008; no internal abnormalities were observed.

5.6.3.4 Cisco

External (n = 88) and internal (n = 67) fish health assessments were conducted on cisco captured in 2007, 2008, and 2009, excluding cisco captured in Baker Lake (Table 5.6-4). Cisco ranged from 80 to 342 mm fork length and from 30 to 600 g total body weight. Fish with total body weights less than 100 g were captured in Pointer, Cigar, Caribou, and Calf lakes, suggesting that these are rearing lakes for juvenile cisco. Larger fish, with total body weights greater than 500 g, were captured in Pointer and Caribou lakes. Five cisco were captured in Baker Lake in 2009. The fork lengths of cisco ranged from 223 to 295 mm. The ages of cisco sampled ranged from 5 to 10 years.

Overall, the majority of the cisco processed were in good physical health and abnormalities or incidents of parasites were low, including nine fish with minor to severe fin erosion; and one fish with hemorrhaging on its fins. Internal health assessments were conducted in 2008; the incidents of internal abnormalities were low, including one fish with a fatty liver; and two fish with discoloured livers.

In 2009, chemistry analysis was completed on cisco flesh and bone samples from Pointer Lake only. Many of the chemistry parameters were near or below detection limits. The concentrations of arsenic, cadmium, and lead in flesh samples of cisco were below guidelines. Variation between flesh and bone samples was limited, with the exception of nickel detected in bone samples and higher concentrations of aluminum, arsenic, barium, iron, manganese, strontium, titanium, and zinc in bone samples. Concentrations of all radionuclides were near or below detection limits in flesh and bone samples from cisco, except for Pb-210 (lower in flesh samples than bone samples) and Po-210 (low and similar between flesh and bone samples).

5.6.3.5 Lake Trout

External (n = 141) and internal (n = 59) fish health assessments were conducted on lake trout captured in 2007, 2008, and 2009, excluding lake trout captured in Baker Lake (Table 5.6-4). The fork lengths of lake trout ranged from 174 to 810 mm; total body weights ranged from 60 to 5,450 g. The ages of lake trout sampled ranged from 6 to 35 years.

Twenty-four lake trout were captured in Baker Lake in 2009; fork lengths ranged from 340 to 685 mm, and total body weights ranged from 500 to 2,250 g. The age of lake trout sampled ranged from 7 to 17 years. The absence of young age classes and small fish lengths of lake trout captured in Baker Lake in 2009 is likely a product of the selected sampling method and location.

Overall, the majority of the lake trout processed were in relatively good physical health and abnormalities or incidents of parasites were moderate, including three fish with body deformities, such as clubbed dorsal fin, bump on caudal fin, or lump on jaw; eleven fish were blind in one or both eyes; four fish had eroded gills, gill raker detached, or frayed gills; thirty-seven fish had minor to severe fin erosion, or hemorrhaged fins; three fish had minor to moderate shortening of the opercle, or the top of the opercle was cut; nine fish had minor skin aberrations, pale skin, or scars on the body; two fish had minor hindgut inflammation or reddening; and thirty-six fish had minor to moderate parasite infestation (e.g., copepods on gills, leaches on gills, and leaches on the skin). Internal health assessments were conducted in 2008 and the incidents of internal abnormalities were low, including two fish with minor to moderate parasite infestation, which were either segmented worms or nematodes; two fish had hemorrhaged or atretic gonads; one fish had a cyst on the kidney; one fish had an enlarged gall bladder; four fish had fatty livers; and four fish had discoloured livers.

In general, historical concentrations of trace metals in lake trout were low and close to the detection limit or below the consumption guideline, with the exception of arsenic in lake trout from Escarpment Lake (1986); cadmium in lake trout from Judge Sissons Lake (1980); and mercury in lake trout from Pointer Lake in 1989, Mushroom and Cigar lakes in 1990, Caribou Lake in 1986, and Judge Sissons Lake in 1980. Concentrations of radionuclides were below detection limits in most of the lake trout sampled between 1980 and 1990 with the exception of Pb-210 in lake trout flesh from Judge Sissons Lake (1980), and from Mushroom and Cigar lakes (1990); and Th-230 in lake trout flesh from Cigar Lake (1990).

In general, concentrations of trace metals in flesh and bone samples of lake trout in 2008 were similar between lakes, with the exception of barium, selenium, and uranium in the flesh sample of lake trout; and aluminum and boron in the bone sample. Many of the trace metals were near or below detection limits, or below guidelines concentrations. Higher concentrations were found in Pointer Lake (barium, selenium, and uranium in flesh sample), Mushroom Lake (selenium in flesh sample), Caribou Lake (selenium in flesh sample), and Judge Sissons Lake (barium and selenium in flesh sample). In 2009, chemistry analysis was completed on lake trout flesh and bone samples from Judge Sissons Lake only. Many of the trace metals were near or below detection limits or below guidelines, with the exception of mercury in the flesh sample of lake trout. Concentrations of all metals for lake trout captured in Baker Lake in 2009 were below Rieberger averages plus one standard deviation for uncontaminated lakes (Rieberger 1992). Mean concentrations of aluminum, copper, iron, and zinc were highest for lake trout liver samples. Mean mercury concentrations in lake trout muscle tissue at Station 1 did not exceed Rieberger averages (Rieberger 1992) and were below maximum BC MoE recommended levels for human consumption (0.1 to 0.5 mg/kg) (MoE 2006).

Concentrations of radionuclides were near of below detection limits in flesh and bone samples from lake trout captured in 2008 and 2009 for all parameters, with the exception of Po-210 in bone samples from Mushroom Lake (2008) and Judge Sissons Lake (2008 and 2009); and Ra-226 in bone samples from Pointer Lake (2008) and in flesh and bone samples from Judge Sissons Lake (2009). Concentrations of radionuclides were near or below detection limits in flesh and bone samples from lake trout captured in Baker Lake in 2009 for a few parameters (i.e., Th-228 and Th-230). However, Pb-210, Po-210, and Ra-226 were detected in flesh and bone samples from several lake trout captured in Baker Lake.

5.6.3.6 Lake Whitefish

Twenty-three lake whitefish were captured in Baker Lake in 2009. The fork lengths of lake whitefish ranged from 115 to 359 mm. The ages of lake whitefish ranged from 0 to 8 years, with all fish captured between 0 and 3 years, except for one 8 years old fish.

5.6.3.7 Ninespine Stickleback

External (n = 141) fish health assessments were conducted on ninespine sticklebacks captured in 2007, 2008, and 2009 (Table 5.6-4). The fork lengths of ninespine sticklebacks ranged from 27 to 67 mm; total body weights ranged from 1 to 4 g.

Overall, the majority of the ninespine sticklebacks processed were in good physical health and no abnormalities or incidents of parasites were observed.

5.6.3.8 Round Whitefish

External (n = 51) and internal (n = 43) fish health assessments were conducted on round whitefish captured in 2008 and 2009 (Table 5.6-4). The fork lengths of round whitefish ranged from 95 to 387 mm; the total body weights ranged from 6.75 to 640 g. The ages of round whitefish ranged from 2 to 17 years.

Overall, the majority of the round whitefish processed were in good physical health and abnormalities or incidents of parasites were low, but included two fish with cataracts in both eyes; two fish with a section of the gill missing; fourteen fish with minor to moderate fin erosion or fin haemorrhaging; one fish with minor skin aberrations; and eight fish with minor to moderate parasite infestations, all of which were copepods on gills. Internal health assessments were conducted in 2008 and the incidents of internal abnormalities were low, including three fish with shrunken or incomplete gonads; two fish with granular kidney or discoloured kidney; one fish with a fatty liver; and two fish with discoloured livers.

In general, concentrations of trace metals in flesh and bone samples of round whitefish captured in 2008 were similar between lakes. Many of the trace metals were near or below detection limits or below guidelines concentrations. Higher concentrations were found in Caribou Lake (aluminum, barium, copper, lead, silver, strontium, uranium, and zinc in flesh sample, and uranium in bone samples), Mushroom Lake (selenium in flesh and bone samples; and manganese, strontium, and uranium in bone samples), and Lower Lake (boron and zinc in bone samples).

Concentrations of radionuclides were near of below detection limits in flesh and bone samples from round whitefish captured in 2008 for all parameters, with the exception of Po-210 which was detected in flesh and bone samples from at least one fish from all four lakes sampled in 2008.

5.6.3.9 Slimy Sculpin

External (n = 97) fish health assessments were conducted on slimy sculpins captured in 2009 and 2010. The total lengths of slimy sculpins ranged from 34 to 110 mm; the total body weights ranged from 0.5 to 13 g.

Overall, the majority of the slimy sculpins processed were in good physical health and no abnormalities or incidents of parasites were observed.

5.7 SPECIES AT RISK

There are no SARA or COSEWIC listed aquatic species within the mine site or mine access LAAs.

6 EFFECTS ASSESSMENT FOR SURFACE HYDROLOGY

6.1 SURFACE HYDROLOGY

The scope of the assessment for surface hydrology focuses on the water quantity aspect of the aquatic environment. As outlined in Section 4, surface hydrology has been identified as a valued ecosystem component (VEC), which is a component of the environment that is considered to be important by society. While VECs have measureable parameter(s) and changes in these can be quantified, their residual effect and significance is relative to a defined assessment endpoint. Assessment endpoints represent key properties of the VEC that should be protected. Through stakeholder and public consultations, regulatory requirements, and professional scientific judgement, no assessment endpoint(s) are identified within the discipline of surface hydrology; surface hydrology is primarily valued and regulated as a pathway to other valued components, such as water quality, fish, and fish habitat. For example, while the collection, storage, treatment, and disposal methods of contaminated snow, ice, and surface runoff may result in changes in hydrological measurable parameters, the significance of these changes in baseline conditions is ultimately determined in the context of environmental effects to water quality and fish. Therefore, the assessment for surface hydrology identifies key environment-project interactions and quantifies their respective effects, but does not classify residual effects or determine the significance of effects. The hydrological assessments provide an appropriate hydrological context that can be linked to other VECs and assessment endpoints for which thresholds and significance are directly defined (e.g., fish and fish habitat).

6.1.1 Project–Environment Interactions and Effects

Information was gathered from the environmental and engineering teams for the Kiggavik Project, through public engagement, and by NIRB to identify project activities that have potential to interact with surface hydrology by affecting its spatial and/or temporal distribution. The relevant project activities and the associated environmental interactions for each Project phase are presented in Table 6.1-1

Table 6.1-1 Project-Environmental Interactions and Effects – Surface Hydrology

	Project Activities/Physical Works	Change in Water Quantity
Construction:		
In-Water Construction	Construct freshwater diversions and site drainage containment systems (dykes, berms, and collection ponds)	1
	Construct in-water/shoreline structures	1
On-Land Construction	Site clearing and pad construction (blasting, earth moving, loading, hauling, dumping, crushing	2
Operation:		
Mining	Mine dewatering	2
Water Management	Freshwater withdrawal	2
	Collection of site and stockpile drainage	2
	Discharge of treated effluents (including greywater)	2
Ongoing exploration	Drilling	1
Final Closure:		
General	Ongoing withdrawal, treatment and release of water, including domestic wastewater	2
In-water Decommissioning	Remove freshwater diversions; re-establish natural drainage	1
	Remove in-water/shoreline structures	1
	Construct fish habitat as per FHCP	1

Category 1 activities are those having an interaction with the aquatic environment; however, based on past experience and professional judgment, the resulting effect can be managed to acceptable levels through standard operating practices and/or through the application of best management or codified practices. No further assessment is warranted.

Category 2 activities are those activities that do interact with the aquatic environment and the resulting effect may exceed acceptable levels without implementation of specified mitigation. Further assessment of the effects of these interactions on the aquatic environment is warranted and is presented in this environmental assessment report.

The construction and decommissioning of in-water/shoreline structures, freshwater diversions, and site drainage containment systems includes the installation of water crossing structures, and the construction of dykes, berms, collection ponds, and diversion channels. These Project activities have been ranked as "1" with respect to surface hydrology. The installation and removal of structures may interrupt or constrict local and/or downstream water quantity. However, effects will be mitigated by following standard construction practices that will help to maintain the spatial and temporal distribution of water. For example, in-water works will take place "in the dry", with a temporary channel or pumping system to maintain downstream flow. If this is not possible, work will be restricted to low flow periods and flow constriction will be minimized. Mitigation and best management practices are expected to effectively reduce effects of in-water works on water quantity and therefore no further assessment is warranted.

Ongoing exploration in the vicinity of the site may require additional water sources. A drill rig typically requires intermittent water withdrawal at a rate of less than 10 m^3/day, for a period of several days. This small volume of water is likely to be withdrawn from a proximal waterbody sufficient in size such that effects to surface hydrology are not measureable.

During final closure, the construction of fish habitat has potential to affect surface hydrology. However, an approved Fish Habitat Compensation Plan will be followed such that the effects to water quantity do not significantly and negatively affect environmental receptors that are influenced by the changes in surface hydrology.

6.1.2 Indicators and Measurable Parameters

In the Guidelines for the Preparation of an Environmental Impact Statement issued in May 2011, NIRB identified hydrology as a VEC. A number of Project activities have the potential to affect surface water quantity and therefore other environmental receptors; surface water quantity is a key pathway to other components of the natural ecosystem due to its fundamental role in sustaining life, including that of fish, vegetation, wildlife, and people.

In assessing Project effects on surface water quantity, four measureable parameters were selected: water level, waterbody volume, stream flow rates, and effective drainage areas (Table 6.1-2). Water level, waterbody volume, and stream flow rates directly capture the spatial and temporal characteristics of surface water and provide a means of quantifying changes. Effective drainage area is an indirect measure of water quantity as it largely controls the amount of runoff generated from a watershed. Sufficient water level, volume, stream flow, and geospatial data are available to confidently estimate potential effects through these measurable parameters.

Table 6.1-2 Measurable Parameters for Surface Water Quantity

Environmental Effect	Measurable Parameter(s)	Notes or Rationale for Selection of the Measureable Parameter
Change in water quantity	• Stream flow rates • Water level • Waterbody volumes • Effective drainage area	• Stream flow rates, water levels, and waterbody volumes allow quantification of changes in the spatial and temporal distribution of water and provide information on water availability and storage capacities. • Effective drainage areas affect the quantity of water in a watershed and the respective drainage characteristics • Community, government, stakeholder engagement and professional judgement

6.2 EFFECTS ASSESSMENT FOR SURFACE HYDROLOGY

6.2.1 Assessment for Changes in Surface Hydrology

Stream flow rate, water level, water body volume, and effective drainage areas typically capture changes in water quantity which in turn can be associated with changes in fish, aquatic organisms and fish habitat, sediment quality, and water quality.

Project activities that are expected to have a substantive effect on surface hydrology are:

- Construction- On-Land Construction: Site clearing and pad construction;
- Operation - Mining: Mine dewatering;
- Operation - Water Management: Freshwater withdrawal;
- Operation - Water Management: Collection of site and stockpile drainage;
- Operation - Water Management: Discharge of treated effluents (including greywater); and
- Final Closure – General: Ongoing withdrawal, treatment and release of water, including domestic wastewater.

6.2.1.1 Analytical Methods for Changes in Surface Hydrology

6.2.1.1.1 Flow Rate

Mean natural flow conditions are calculated by averaging the 3 to 4 year record for streamflow at each site of concern (Andrew Lake Outflow, Judge Sissons Lake Outflow, and Siamese Lake Outflow) and the peak flow is compared to estimated flood flow values as reported in the baseline report. In cases where measured streamflow records are not available (i.e., Mushroom Lake Outflow), a hypothetical hydrograph is created using regional hydrological characteristics and estimated flood flows (1 in 2 year flood flow) and annual basin yields. Conservative assumptions are incorporated when creating hypothetical hydrographs such that effects are overestimated rather than underestimated (Technical Appendix 5N).

To estimate the effects of water withdrawal or discharge to/from source waterbodies and their outflow channels, withdrawal or discharge rates are superimposed on baseline flow conditions to determine relative change.

6.2.1.1.2 Water Level

Lake water levels respond to inflow and outflow characteristics, which are active during the open water season and inactive during the winter. Therefore, water levels during ‘open-system’ conditions (i.e., the active flow season) and ‘closed-system’ (i.e., the inactive flow season) are analyzed separately.

Open-system conditions are applied to lakes when the outflow channel is actively flowing according to the baseline hydrograph; this ranges from mid-June through mid-July for Mushroom Lake to mid-June through mid-September for Judge Sissons Lake. Changes in lake water level during open-system conditions is estimated by using the outflow stage-discharge curve developed during baseline studies (Technical Appendix 5A) and baseline flow rates (Section 6.3.1.2). These data are also used to estimate the intra-annual fluctuation in lake level.

Closed-system conditions are applied to lakes when the outflow channel is inactive according to the baseline hydrograph; this ranges from mid-July for Mushroom Lake or mid-September for Judge Sissons Lake until the following spring freshet. During this period, when inflows and outflow effectively cease, the lake is considered to be a close system, and thus effects from withdrawal or discharge are isolated to the lake. This is a conservative approach because if the system remains open, effects to water levels will be attenuated by the inflow and outflow conditions.

Changes in lake levels during closed-system conditions are estimated using bathymetric data and resultant stage-storage curves. For instances where water levels must be estimated beyond the observed water level, the slope of the upper-most contour is extrapolated. For lakes in which bathymetric data are not available, changes in lake volumes are estimated by applying the observed basin slopes from ground penetrating radar (GPR) transects to the entire lake. If bathymetric data and estimated ice thicknesses (Technical Appendix 5A) suggest that specific basins of the lake become hydrologically separated for a portion of the winter season, effects are examined in the affected basin exclusively for the period of separation.

6.2.1.1.3 Waterbody Volume

Natural waterbody volumes are calculated from bathymetric surveys. For lakes in which detailed bathymetry is not available, lake volumes are estimated using ground penetrating radar (GPR) transects that were completed along lake crossing segments of the proposed winter road. From these data, bathymetric information is synthesized for each lake by applying the observed basin slopes to the entire lake.

When appropriate, a range of lake volumes are calculated for the open water season; the high value is associated with spring freshet and the low value is associated with low water levels prior to freeze-up in the fall. As lake ice thickness near Kiggavik is estimated to reach approximately 2 m to 2.5 m near the end of the winter (Technical Appendix 5A), minimum under-ice volumes were calculated as the volume under the 2 m or 2.5 m contour.

6.2.1.1.4 Effective Drainage Area

Effective drainage areas are delineated using ArcHydro software and a digital elevation model using LiDAR topographic data.

6.2.1.2 Baseline Conditions for Changes in Surface Hydrology

6.2.1.2.1 Streams

Streams in the LSA and RSA are typically characterized by an arctic nival regime. Their hydrographs reflect a steep rising limb, peaking in approximately mid-June due to the onset of spring snowmelt, followed by receding flows for the remainder of the open water period. Rainfall events throughout the summer may temporarily reactivate the channels or cause secondary peaks. Streamflow typically ceases during winter months.

Flood magnitude and frequency predictions for Andrew Lake Outflow, Judge Sissons Lake Outflow, Mushroom Lake, and Siamese Lake Outflow (Technical Appendix 5A) and mean baseline hydrographs are presented in Figure 6.2-1 to 6.2-4. Sharp fluctuations observed in the average hydrographs at the beginning and end of the open water period are due to differences in the time period associated with the datasets. For example, the flow on August 24 according to the Judge Sissons Outlfow hydrograph is derived from all four years of data, while flow on September 2 is derived from 2007 data exclusively.

The magnitude of each baseline hydrograph peak can be compared to the flood magnitude and frequency values (Table 6.2-1) to confirm that conservatism is incorporated into the specific assessments.

Table 6.2-1 Flood Magnitude (m^3/s) and Frequency Predictions for Streams Potentially Affected By the Project

Stream Name	Return Interval (year)						
	1.01	2	5	10	20	50	100
Outflow of Andrew Lake	1.19	6.12	8.91	10.4	11.7	13.0	13.8
Outflow of Mushroom Lake	0.21	1.10	1.60	1.87	2.09	2.33	2.48
Outflow of Siamese Lake	2.54	13.1	19.0	22.3	24.9	27.8	29.5
Outflow of Judge Sissons Lake	13.2	67.7	98.5	115	129	144	153

Figure 6.2-1 Baseline Hydrograph for Mushroom Lake Outflow

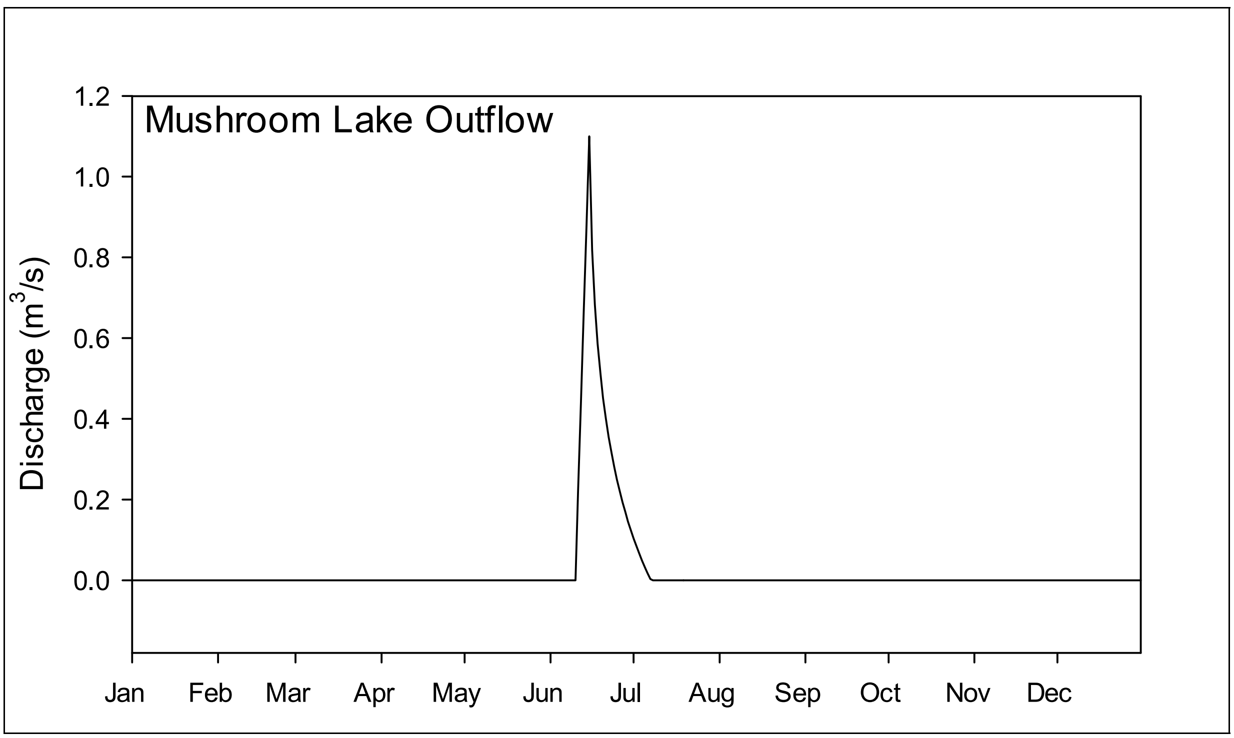


Figure 6.2-2 Baseline Hydrograph for Siamese Lake Outflow

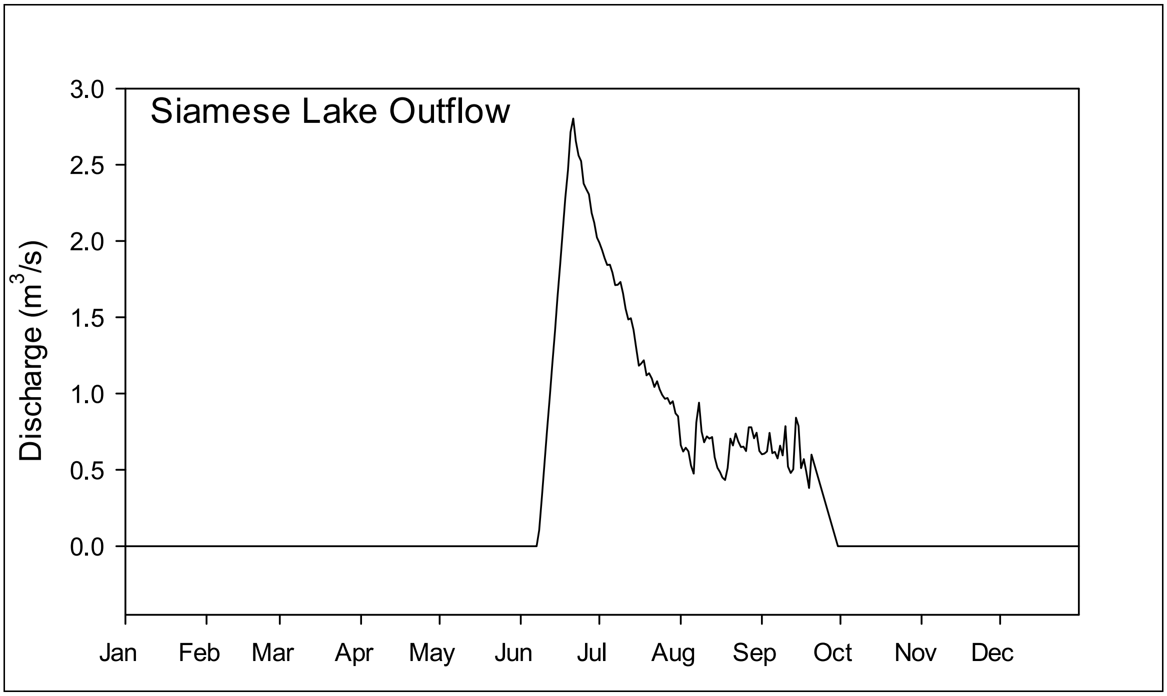


Figure 6.2-3 Baseline Hydrograph for Andrew Lake Outflow

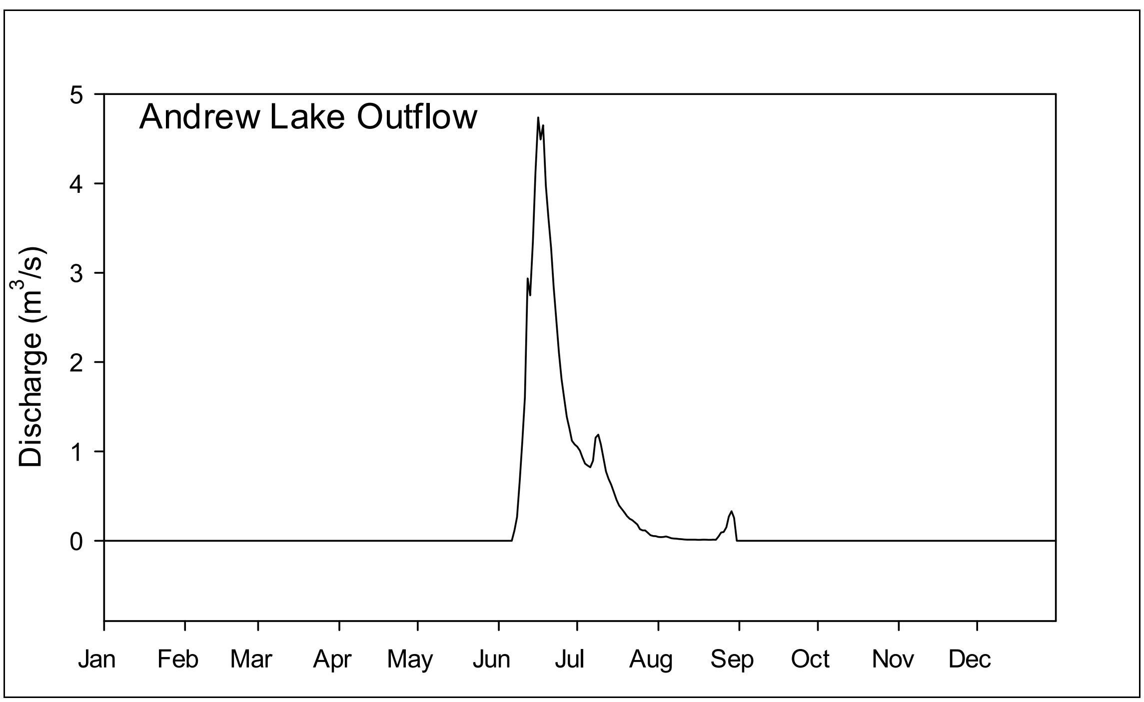
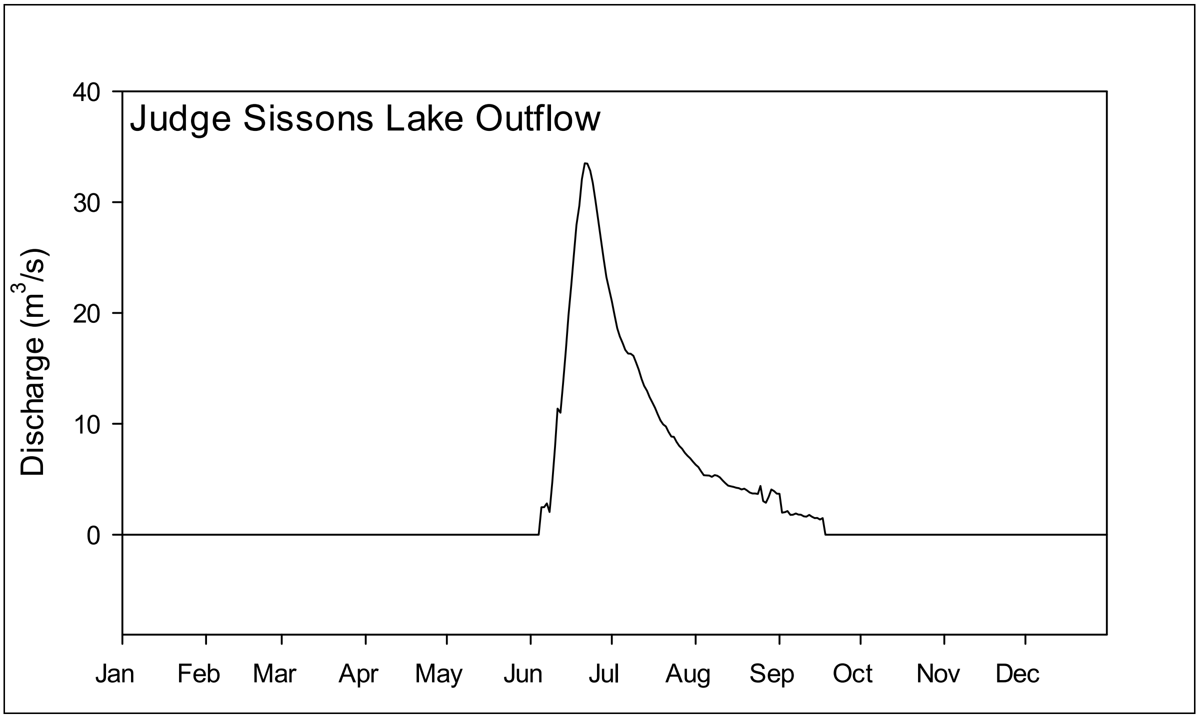


Figure 6.2-4 Baseline Hydrograph for Judge Sissons Lake Outflow



6.2.1.2.2 Lakes

Lakes in the LSA and RSA are typically ice covered from approximately October through June, with mean maximum thickness near 2 m. Lake levels and volumes reflect inflow and outflow characteristics and thus reach their peaks during the spring freshet in mid-June with levels and volumes typically decreasing throughout the remainder of the open-water season. Lake volumes and changes in levels for Andrew Lake, Pointer Lake, Judge Sissons Lake, Mushroom Lake, Siamese Lake, 20 km Lake, Long Lake, Audra Lake, Unnamed Ponds, and Qinguq Bay are presented in Table 6.2-2.

Table 6.2-2 Depths and Volumes for Lakes Potentially Affected by the Project

Lake		Volume (m^3)	Under-Ice Volume (m^3)	Change in Water Level During the Open Water Period (cm)
Andrew Lake	Pit Area	41,000-91,000[a]	NA	60
	Remaining Area	54,800	NA	
	Total	95,800	NA	
Pointer Lake		5,470,000	118,000	NA
Mushroom Lake		587,000	284,000	20
Siamese Lake	East	NA	38,000,000	30
	West	NA	27,800,000	
	Total	115,000,000	65,800,000	
Judge Sissons Lake	East Basin	NA	271,469,000	30
	Northwest Basin	NA	771,000	
	Southwest Basin	NA	9,579,000	
	Total	439,000,000	281,819,000	
"20 km Lake"	NA	NA	21,215,910	NA
Long Lake	NA	NA	1,573,164	NA
Audra Lake	NA	NA	30,409,439	NA
Unnamed Ponds	NA	NA	1,990,323	NA
Qinguq Bay	NA	NA	1,389,562	NA

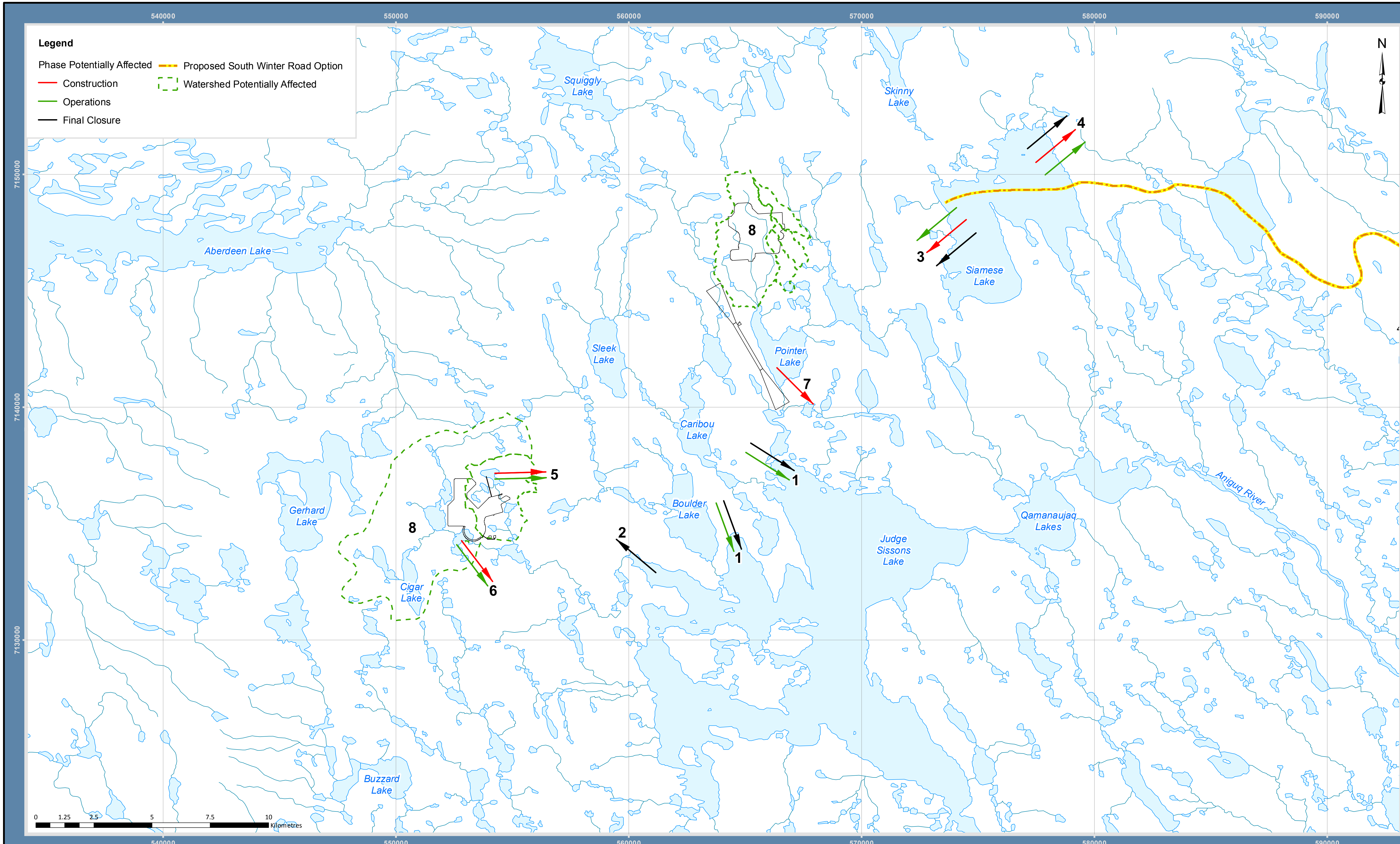
Note:
[a] Peak volume associated with the spring freshet.
N/A: Not applicable.

6.2.1.2.3 Effective Drainage Areas

Effective drainage areas potentially affected by the project are included in Table 6.2-3 and Figure 6.2-5.

Table 6.2-3 Effective Drainage Areas Potentially Affected by the Project

Site	Watershed	Baseline Effective Drainage Area (km^2)
Kiggavik Site	Watershed 1	10.9
	Watershed 2	1.6
	Watershed 3	1.2
	Watershed 4	1.5
	Pointer Lake Outflow	79.1
Sissons Site	Watershed 1	8.2
	Andrew Lake Outflow	33.7



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Creator: JRC
Date: 12/05/2011 Scale: 1:150,000
File: KI09C345
Data Sources: *Natural Resources Canada, Geobase®, National Topographic Database, Areva Resources Canada Inc.*

FIGURE 6.2-5A
POTENTIAL PROJECT EFFECTS ON SURFACE HYDROLOGY NEAR THE KIGGAVIK AND SISSONS SITES

KIGGAVIK PROJECT - EIS

Note:
1. Treated effluent and greywater discharge
2. Withdrawal for flooding the Andrew Lake Pit
3. Freshwater withdrawal for Kiggavik Site
4. Freshwater withdrawal for ice road flooding
5. Freshwater withdrawal for Sissons Site
6. Discharge from dewatering the Andrew Lake Pit Area
7. Withdrawal for flooding temporary airstrip
8. Sissons Site watershed

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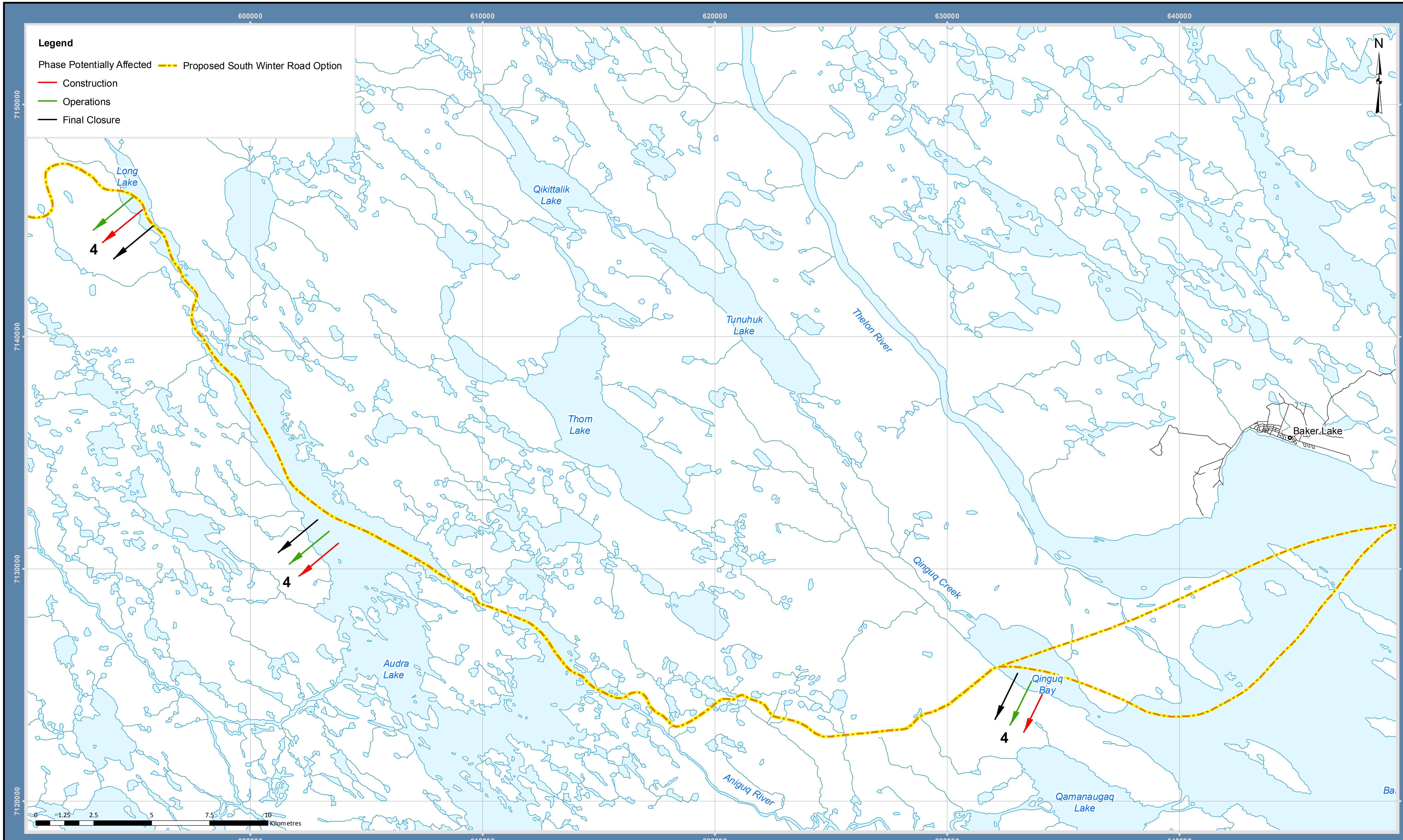

Projecton: NAD 1983 UTM Zone 14N
Creator: JRC
Date: 12/05/2011 Scale: 1:150,000
File: KI09C346
Data Sources: *Natural Resources Canada, Geobase®, Naton Topographic Database, Areva Resources Canada Inc.*

FIGURE 6.2-5B
POTENTIAL PROJECT EFFECTS ON SURFACE HYDROLOGY ALONG THE SITE ACCESS ROAD

KIGGAVIK PROJECT - EIS

Note:
4. Freshwater withdrawal for ice road flooding

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6.2.1.3 Effect Mechanism and Linkages for Changes in Surface Hydrology

The effect mechanisms and linkages for changes in surface hydrology include site clearing and pad construction, mine dewatering, freshwater withdrawal, the collection of site and stockpile drainage, the discharge of treated effluents, and the ongoing withdrawal, treatment and release of water (Table 6.2-1). These activities have potential to affect a number of waterbodies, both at the location of the activity, and in the downstream environment. Figure 6.2-5 indicates the location for each activity and the corresponding waterbodies directly affected. The following describe the effect mechanisms and linkages associated with each activity.

Construction - On-Land Construction: Site clearing and pad construction: General construction activities at the Kiggavik and Sissons Sites will require the dewatering of minor ponds and standing water, which can affect surface hydrology (including water volumes, levels, and flow rates) locally and downstream. A total of about 25,000 m^3 of ponded water will require dewatering at the Kiggavik Site while about 15,000 m^3 of ponded water will require dewatering at the Sissons site.

Operation - Mining: Mine dewatering: The construction of the Andrew Lake Pit requires that a dyke be constructed and a section of Andrew Lake dewatered. The water will be pumped out of the future pit area into the main body of Andrew Lake. The additional water to the main body of Andrew Lake may increase water quantities in the lake and the downstream environment and therefore water volumes, levels, and flow rates.

Operation - Water Management: Freshwater withdrawal: Water withdrawal is required during the operational phase to support activities at the Sissons and Kiggavik sites, as well as for flooding of the winter roads and temporary airstrip. Water will be sourced from local waterbodies, which, depending on the flow-through characteristics and size, may reduce water levels, volumes, and flow rates in the lake and downstream environment.

Operation - Water Management: Collection of site and stockpile drainage: To avoid effects to water quality, runoff from site during operation, including that from the core facilities, the ore, permanent and temporary mine rock piles and the Andrew Lake Pit, will require treatment or passage through sedimentation ponds prior to release. As water is treated or passed through sedimentation ponds and released at a controlled rate, there is potential for effects to the temporal distribution of water quantity and therefore water levels, volumes, and flow rates. Effective drainage boundaries may also be altered as the runoff requiring treatment will ultimately be discharged with effluent and wastewater at Judge Sissons Outflow. In effect, some site runoff will bypass its natural drainage pathway between the Kiggavik or Sissons sites and Judge Sissons Outflow and will therefore no longer contribute runoff to waterbodies between the two locations. As a consequence, water quantity will be reduced in the connecting waterbodies.

Operation - Water Management: Discharge of treated effluents (including greywater): Discharge of wastewater and treated effluent will occur during the construction, operation and decommissioning phases of the Project. The additional source of water to the receiving environment may increase local and downstream water levels, volumes, and flow rates.

Final Closure – General: Ongoing withdrawal, treatment and release of water, including domestic wastewater: Water withdrawal is required during the final closure phase of the Project, for industrial and domestic purposes, including the flooding of winter roads and the temporary airstrip and the flooding of the Andrew Lake Pit. Water will be sourced from local waterbodies for these activities, which, depending on the flow-through characteristics and size, may reduce water levels, volumes and flow rates in the lake and downstream environment. Final closure activities will also result in the discharge of treated effluent and greywater into a local waterbody, which also has potential to affect water levels, volumes, and flow rates.

6.2.1.4 Mitigation Measures and Project Design for Changes in Surface Hydrology

A number of mitigation measures and project designs will be implemented to limit changes to surface hydrology:

- Site footprint will be minimized and situated such that natural drainage areas and watershed boundaries are maintained;
- The site water management system will be designed to recycle water where applicable and water use will be minimized to limit withdrawal requirements and discharge quantities;
- Diversion channels will be designed to intercept freshwater from upslope, divert it around development areas, and reintroduce it to natural stream channels downstream;
- Sedimentation ponds will be designed with a control structure so that evaporative losses can be minimized;
- In-water construction will follow standard protocols and best management practices;
- Snow fences will be constructed to limit snow drifting on site;
- Andrew Lake pit will be pumped and refilled at a rate such that effects to surface hydrology are minimized.
- DFO procedures for water withdrawal from ice-covered waterbodies in the Northwest Territories and Nunavut will be followed. Specifically, no more than 10% of the under-ice volume will be withdrawn from a lake during one ice covered season.
- Water will be sourced and discharged into large waterbodies to reduce effects to surface hydrology;
- During decommissioning, the ground surface will be recontoured and natural flow patterns will be restored; and

- Andrew Lake Pit area will be dewatered after the spring freshet and before freeze-up (July/August).

6.2.1.5 Residual Effects for Changes in Surface Hydrology

Residual effects for changes in surface hydrology have potential to occur at the waterbodies and drainage areas directly affected by Project activities as well as their downstream environments. Project activities are predicted to occur at Judge Sissons Lake, Siamese Lake, Andrew Lake, Mushroom Lake, waterbodies along the site access road, and watersheds associated with the Project Footprint.

6.2.1.5.1 Judge Sissons Lake and Outflow

Hydrological effects at Judge Sissons Lake and its outflow are largely a result of the discharge of treated effluent and greywater during operations and potentially final closure, and water withdrawal during final closure. AREVA proposes to release treated effluent and greywater at either one or two locations in the east basin of Judge Sissons Lake. Although Judge Sissons Lake and its outflow will additionally be affected by upstream activities, such as pit dewatering, site runoff, and water withdrawal at Mushroom Lake, these activities are expected to be sufficiently attenuated downstream such that incremental effects at Judge Sissons Lake and its outflow are not measureable (Section 6.3.1.5.7). Therefore, potential effects at Judge Sissons Lake and its outflow during operations is exclusively associated with the discharge of treated effluent and greywater in Judge Sissons Lake. During final closure, Judge Sissons may continue to be affected by the discharge of treated effluent and greywater, as well as water withdrawal from Judge Sissons Lake for the purposes of refilling the Andrew Lake Pit.

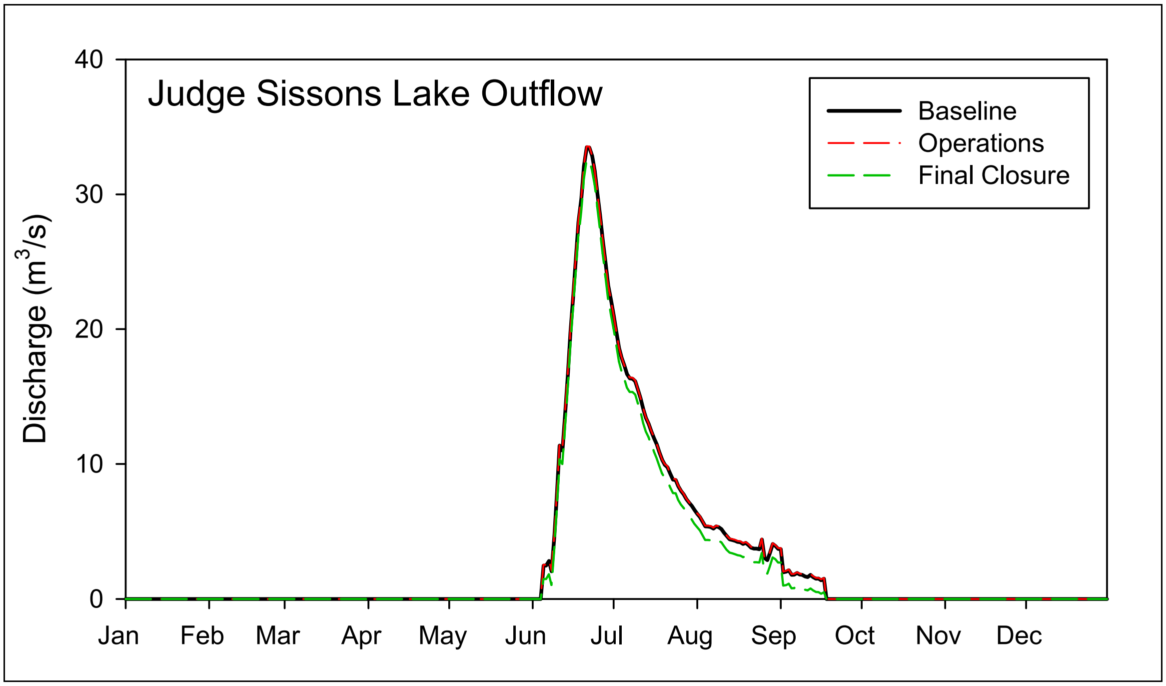
Operations

AREVA has estimated treated effluent and greywater discharge at a base case of 4,407 m^3/day for Sissons and Kiggavik sites combined; however, to incorporate environmental conservatism and potential variability in discharge, 0.054 m^3/s (4,700 m^3/day) has been assessed; 0.035 m^3/s (3,000 m^3/day) from the Kiggavik Site and 0.012 m^3/s (1,700 m^3/day) from the Sissons Site.

Currently, Judge Sissons Lake is the preferred location for treated effluent and greywater discharge from both the Kiggavik and Sissons sites. Treated effluent and greywater from both sites may be discharged into the Judge Sissons Lake at one location in the east basin, or at two separate locations in the east basin. As both discharge locations remain hydraulically connected throughout the year, resultant effects to flow rates, water levels, and water volumes will be equivalent under both scenarios.

During the open water period, the discharge of treated effluent and greywater may cause an increase in streamflow from Judge Sissons Lake by up to 0.054 m^3/s, which is indistinguishable from baseline conditions (Figure 6.2-6). This increase in discharge consistently accounts for less than 4% of natural discharge from Judge Sissons Lake and is therefore unlikely to be measureable, particularly during spring freshet when treated effluent and greywater consists of less than 0.5% of the natural discharge. Treated effluent and greywater discharge results in a predicted increase in stream level of less than 3 mm at Judge Sissons Outflow. As natural inter and intra-annual stream level fluctuations are of the magnitude of 10s of centimeters, this increase is well within natural variability, and not likely measurable.

Figure 6.2-6 Discharge at Judge Sissons Lake Outflow During Operations and Final Closure



During natural conditions and mean discharge under conditions of treated effluent and greywater release, Judge Sissons lake level is predicted to increase 0.5 mm due to effluent and greywater discharge during open system conditions. The predicted increase in lake level is considerably lower than the approximately 30 cm mean natural intra-annual fluctuation, and is not likely to be measurable.

During winter, the under ice water level increase due to treated effluent and greywater discharge is estimated at 2.18 cm; this is considerably lower than the approximately 30 cm intra-annual natural fluctuations in lake level. The cumulative discharge over the nine winter months accounts for an increase in under ice volume of approximate 0.46% in the east basin.

Further details regarding the hydrological assessment of effluent discharge into Judge Sissons Lake are included in Technical Appendix 5N.

Final Closure

During final closure, Judge Sissons Lake and its outflow may be potentially affected by continued discharge of treated effluent and greywater and the withdrawal of water to fill the Andrew Lake Pit. If treated effluent and greywater are discharged into Judge Sissons Lake during Final Closure, they are not predicted to exceed effects observed during operations (i.e. increase in discharge of 0.054 m^3/s). Withdrawal rates predicted for the flooding of the Andrew

Lake Pit is predicted to be less than 1 m^3/s. Therefore, the greatest effects on Judge Sissons Lake will occur if no water is discharged, but water is withdrawn at a rate of 1 m^3/s. Therefore, potential hydrological effects to Judge Sissons Lake will be less than those due to withdrawal exclusively.

If water withdrawal occurs from Judge Sissons Lake from mid June through mid September (122 days), at a rate of 1 m^3/s (86,400 m^3/day), 10,540,800 m^3 of the pit can be filled annually and withdrawal will occur for approximately 4 seasons. During this period, effects to flow rates at Judge Sissons Outflow will be a maximum of 1 m^3/s; 1 m^3/s is less than 3% of the average peak flow. Water levels at Judge Sissons Lake are predicted to decrease approximately 8 cm during the period of water withdrawal.

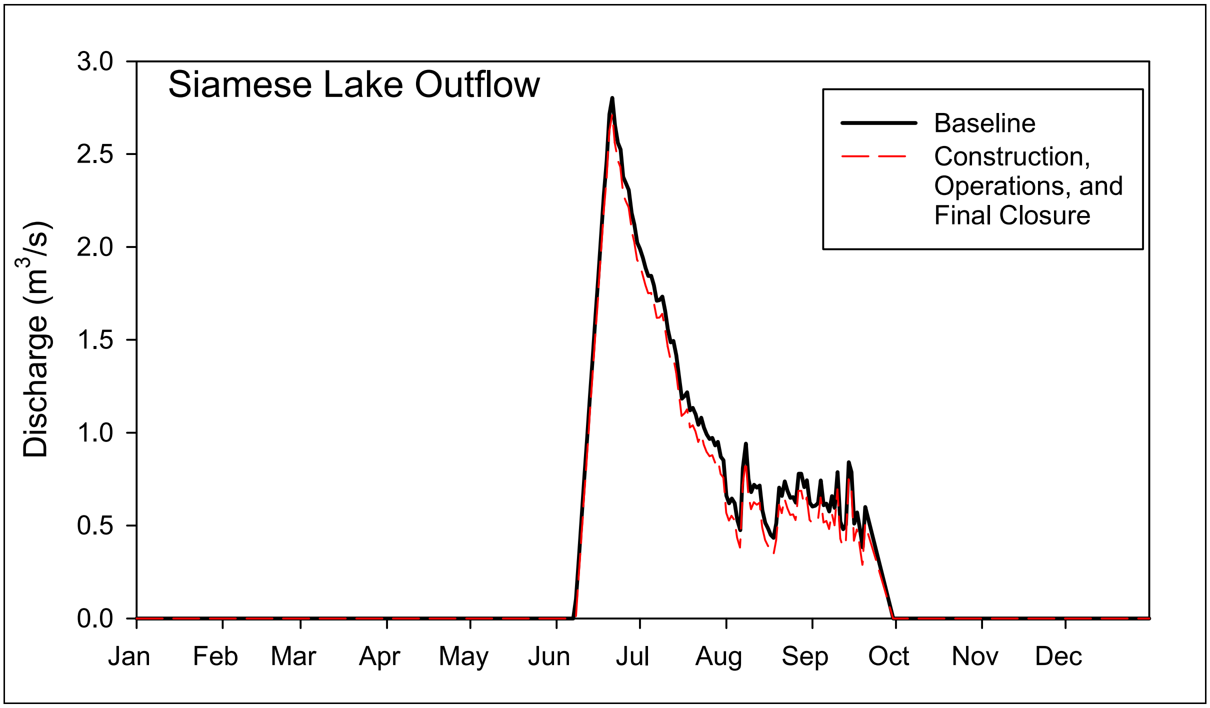
The effects predicted for Judge Sissons Lake and Outlflow are predicted to diminish downstream as drainage areas and basin yields increase.

6.2.1.5.2 Siamese Lake and Outflow

No Project activities will occur upstream of Siamese Lake and thus Project activities with potential to affect hydrological conditions at Siamese Lake and its outflow include freshwater water withdrawal for industrial and domestic purposes, and water withdrawal for flooding the ice road. These activities have potential to occur throughout construction, operations, and final closure phases of the Project, with peak effects occurring during operations when withdrawal requirements are greatest.

AREVA has estimated water withdrawal rates for the Kiggavik site at 0.0926 m^3/s (8,000 m^3/day). Withdrawal at this rate is predicted to cause a maximum decrease in discharge of 0.0926 m^3/s (Figure 6.2-7). During the period June through September, withdrawal rates may result in a decrease of approximately 3% in peak discharge rates and approximately 20% during low discharge rates in the fall.

Figure 6.2-7 Discharge at Siamese Lake Outflow During Construction, Operations, and Final Closure



During summer while Siamese Lake inflows and outflow are active, lake levels will be moderated by through-flow. During this time, changes in lake level due to water withdrawal are estimated to reach 2 cm. During winter, when Siamese Lake is effectively a closed system, cumulative water withdrawal is predicted to reach a maximum of 3% of the under ice volume over the entire lake immediately prior to spring melt. If the east and west basins of Siamese Lake become disconnected during the winter and withdrawal occurs from the west basin exclusively during April and May, withdrawal reaches a maximum of 4% of the under ice volume in the west basin.

Water withdrawal during winter is typically permitted to be 10% of under-ice volume for lakes that have a depth of at least 1.5 m during maximum ice thickness (DFO, 2005). Therefore, for winter conditions, cumulative water withdrawal from Siamese Lake is limited to 10% of the under-ice volume. Water withdrawal requirements for the winter road are predicted to be 75,000 m^3 annually. Although other waterbodies suitable for freshwater withdrawal are available along the road alignment (Section 6.3.1.5.6), if all the required water is withdrawn from Siamese lake, this would account for 0.1% of its under-ice volume. As up to 1,960,000 m^3 (3% to 4% of the under-ice volume) is required for domestic and industrial purposes, cumulative withdrawal at Siamese Lake should remain below 3.1 to 4.1% of the under ice volume; corresponding to a decrease in lake level in the west basin of approximately 12 cm to 16.5 cm

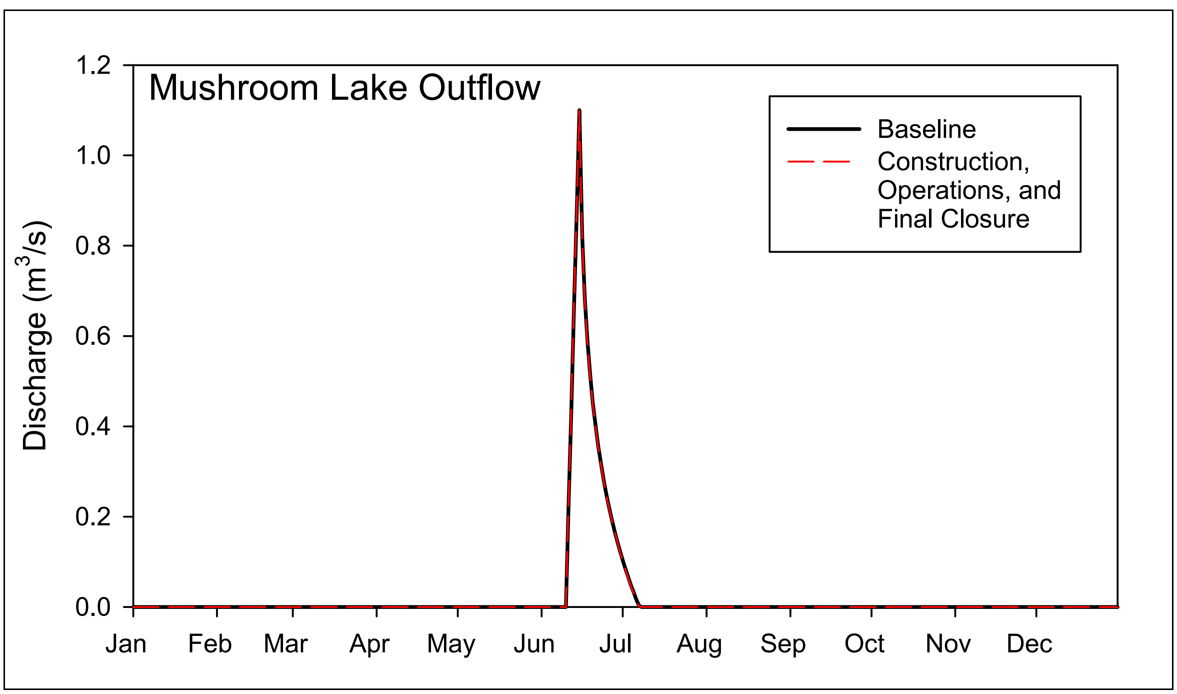
The effects predicted for Siamese Lake and its Outlflow are predicted to diminish downstream as drainage areas and basin yields increase. Further details regarding the hydrological assessment of water withdrawal at Siamese Lake are included in Technical Appendix 5N.

6.2.1.5.3 Mushroom Lake and Outflow

No Project activities will occur upstream of Mushroom Lake and thus hydrological effects at Mushroom Lake and its outflow stream will result from water withdrawal for industrial and domestic purposes at the Sissons Site exclusively. Water withdrawal requirements are estimated to be 0.000868 m^3/s (75 m^3/day) for the Sissons Site; therefore, water will be withdrawn from Mushroom Lake at a continuous rate of 0.000868 m^3/s throughout construction, operations, and final closure phases of the Project, with peak effects occurring during operations when withdrawal requirements are greatest.

If steady state conditions are reached in Mushroom Lake, natural discharge will decrease by a maximum of 0.000868 m^3/s, which is indistinguishable from baseline conditions (Figure 6.2-8). A withdrawal rate of 0.00868 m^3/s is approximately 0.08% of the peak discharge at Mushroom Lake Outflow. While inflows and outflows are active, withdrawal is predicted to result in a 2 mm change in lake level from natural levels.

Figure 6.2-8 Discharge at Mushroom Lake During Construction, Operations, and Final Closure



For July though May, Mushroom Lake is effectively a closed system as little outflow occurs after the spring freshet. Cumulative water withdrawal is 35,125 m^3, which is 4% of the total volume and 9% of the approximate late-winter under-ice volume. The decrease in water level during closed system conditions is predicted to be 34.2 cm.

The effects predicted for Mushroom Lake and its Outlflow are expected to diminish downstream as drainage areas and basin yields increase. Further details regarding the hydrological assessment of water withdrawal at Siamese Lake are included in Technical Appendix 5A.

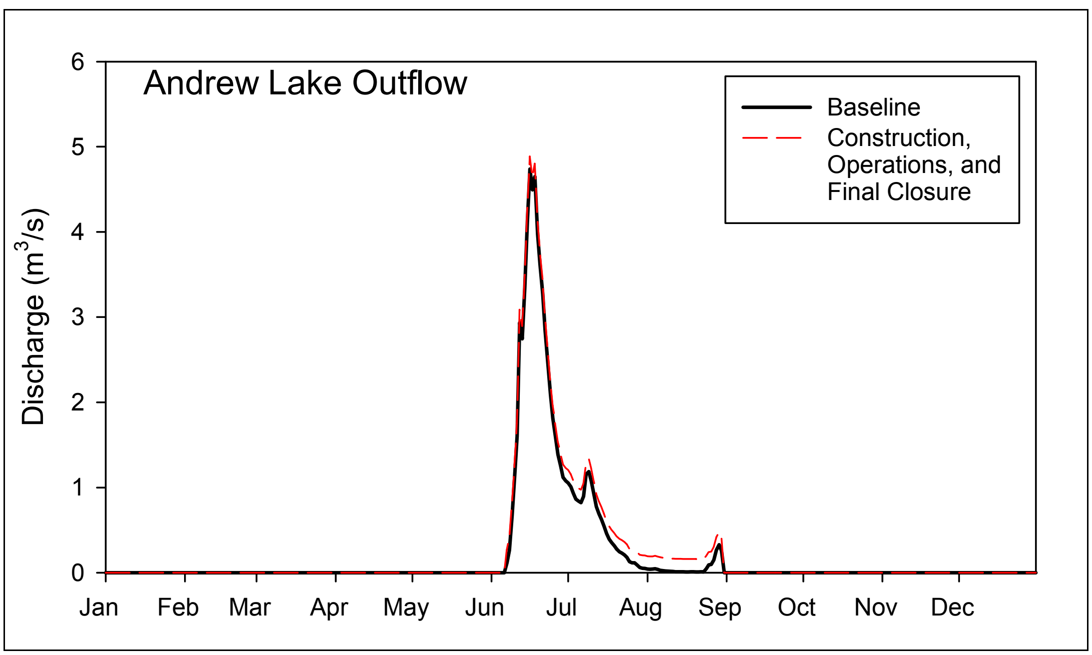
6.2.1.5.4 Andrew Lake and Outflow

Construction

During construction, no Project activities will occur upstream of Andrew Lake and thus hydrological effects at Andrew Lake and its outflow will result from the dewatering of the Andrew Lake pit exclusively. The dewatering area of Andrew Lake has an estimated volume of 41,000 m^3 during late summer when water levels are low. During the spring freshet, when water levels are at their maximum, the volume of this area increases to approximately 91,000 m^3. At a continuous pumping rate of 0.15 m^3/s, the dewatering process would occur over a period of 3-7 days, depending on lake water levels when dewatering is initiated.

To avoid potential erosion and inundation of shoreline, Andrew Lake Pit area will not be dewatered during the spring freshet. The elevated discharge resulting from dewatering at 0.15 m^3/s for 3-7 days in July or August will not cause flows to reach spring flood rates or levels (Figure 6.2-9). If the area is dewatered during this time, lake water levels would recede more slowly than usual until pumping is completed. Lake level may reach 24 cm higher than normal, though both lake elevation and stream discharge would be well below early summer levels and the effect would be limited to seven days.

Figure 6.2-9 Discharge at Andrew Lake During Construction



Operations

During operations, when diversion channels, sedimentation ponds, and water treatment plant processes are active at the Sissons Site, the effective drainage area of Andrew Lake Outflow is predicted to decrease by 3% (Technical Appendix 5N). This 3% change in effective drainage area may result in a 3% change in the annual basin yield at Andrew Lake Outflow.

The effects for Andrew Lake and its outlflow are predicted to diminish downstream as drainage areas and basin yields increase.

6.2.1.5.5 Pointer Lake

During construction, until the airstrip is built, a temporary airstrip will be maintained west of Pointer Lake. This temporary airstrip will be flooded, requiring 450 m^3 of water annually. Due to its proximity, this water will be withdrawn from Pointer Lake, which has a total volume of 5,470,000 m^3, and an under-ice volume of 118,000 m^3. Therefore, the water requirements from Pointer Lake consist of 0.4% of the under-ice volume.

During operations, when diversion channels, sedimentation ponds, and water treatment plant processes are active at the Kiggavik Site, the effective drainage area of Pointer Lake Outflow is predicted to decrease by 1% (Technical Appendix 5N). This 1% change in effective drainage area may result in a 1% change in the annual basin yield at Pointer Lake outflow.

6.2.1.5.6 Site Access Road Waterbodies

AREVA has proposed options for a site access road from Baker Lake: two winter road options and an all-season road option (Figure 6.2-5b). The South Winter Road is currently the preferred option for early stages of the project, with the North Winter Road as an alternative option. In the event that traffic requirements, climatic conditions, or surface conditions become unmanageable for a winter road, an all-season road option may be explored further.

The proposed South Winter Road crosses 6 major waterbodies. It is recommended that over-land portions of the winter road be flooded to maintain sufficient bearing capacity and estimate that 75,000 m^3 of water will be required annually (see Technical Appendix 2K).

DFO protocol indicates that, for the protection of aquatic species, water withdrawal from lakes in Nunavut during one ice covered season should not exceed 10% of the under ice volume (DFO, 2005). Ten percent of the estimated under-ice volume is calculated for each lake crossing and is presented as the maximum withdrawal volume (Table 6.2-4).

Table 6.2-4 Maximum Water Withdrawal Volumes for the Kiggavik South Winter Road

Waterbody	Under-ice volume (m^3)	Maximum available withdrawal volume (m^3)
Siamese Lake	65,800,000	4,620,000[a]
“20 km Lake”	21,200,000	2,120,000
Long Lake	1,600,000	160,000
Audra Lake	30,400,000	3,040,000
Unnamed Ponds	2,000,000	200,000
Qinguq Bay	1,400,000	140,000
Total	*160,400,000*	*10,280,000*

Note: [a] 1,960,000 m^3 of water may be withdrawn from Siamese Lake for freshwater at the Kiggavik Site leaving 4,620,000 m^3 available for withdrawal for the winter road.

According to Table 6.2-4, approximately 10,280,000 m^3 of water is available from the proposed winter road lake crossings. EBA estimates that 75,000 m^3 will be required during the winter and therefore sufficient supply from any of the listed sources in Table 6.2-4. In practice, water would be withdrawn from the nearest source to where water is needed for the ice road, thus the required volume would be pumped from multiple sources over the length of the winter road. Therefore, hydrological effects due to the South Winter Road are predicted to remain far below a reduction of 10% in under ice volume annually.

The North Winter Road option covers a smaller over-land distance (see Technical Appendix 2K) than the south option; 26% of the north winter road crosses land while 40% - 48% of the south winter road crosses land (depending on the route from Baker Lake to Qinguq Bay). Therefore, the north winter road option is predicted to have smaller water demands for flooding.

Although lake volumes for the north winter road option are unknown, the higher percentage of lake crossings on the North Winter Road option provides good potential for withdrawal options. The North Winter Road option crosses several large waterbodies that may provide water source for flooding. The surface areas of Thom Lake, Qikittlalik Lake, and Tunuhuk Lake are comparable to that of other lakes in the area with sufficient estimated under-ice volume for water supply (e.g. Siamese Lake, 20 km Lake, and Long Lake). In addition, the Thelon River typically maintains winter discharge in excess of 100 m^3/s and therefore may also provide a continuous water source for the north winter road option.

Regardless of which winter road option is selected, bathymetric data will be collected such that 10% of the under-ice volume will not be exceeded during one winter season of water withdrawal.

The all-season road option is not predicted to pose effects to surface hydrology; mitigation measures will be applied (e.g. the installation of cross drainage structures) such that natural drainage pathway will be maintained, and flow rates, water levels, and water body volumes will not be affected.

6.2.1.5.7 *Footprint Waterbodies*

Waterbodies associated with the project footprint and immediately downstream have potential to be affected by site clearing and pad construction, and the collection of stockpile and site drainage. During construction, ponds and standing water will be dewatered and diversion channels be built, thereby potentially affecting the hydrology of receiving waterbodies. Additionally, the presence of diversion channels and the collection of stockpile and site drainage have potential to alter effective drainage areas.

During site clearing and pad construction activities, ponds and standing water will be dewatered according to the Pond Dewatering Plan for the Kiggavik and Sissons Sites (Technical Appendix 5N). If ponds are dewatered at 0.15 m^3/s in sequence at the Kiggavik and Sissons sites, and this occurs outside the period associated with the spring freshet, effects to streamflows and lake levels and volumes should remain within their intra-annual variation. All receiving waterbodies identified in the Pond Dewatering Plan for the Kiggavik and Sissons Sites experience natural inflows greater than 0.15 m^3/s.

The waterbodies potentially affected by the collection of stockpile and site drainage are indicated in Figure 6.2-5. The Hydrological Assessment on the Downstream Effects of Site Runoff and Diversions (Technical Appendix 5N) estimate changes in basin yields as indicated in Table 6.2-5. For example, the basin yield in Watershed 1 at the Kiggavik site is predicted to decrease by 2%, while 14% of the basin yield in this watershed may either be attenuated or subject to small increases in evaporative losses as it passes through the sedimentation ponds.

Table 6.2-5 Changes in Watersheds Associated with the Kiggavik and Sissons Sites

		Potential change in basin yield (%)	Percent of modified basin yield subject to attenuation or small increases in evaporative losses
Kiggavik Site	Watershed 1	-2	14
	Watershed 2	-44	0
	Watershed 3	-33	0
	Watershed 4	-27	0
Sissons Site	Watershed 1	-10	0

6.2.1.6 Compliance and Environmental Monitoring for Changes in Surface Hydrology

Monitoring of hydrological effects can be completed through the collection of specific data at the waterbodies potentially affected by project activities. These data are sufficient for measuring or estimating flow rates, water levels, and waterbody volumes and can be obtained by the following methods.

- **Water levels:** Staff gauges can be installed on Andrew Lake, Siamese Lake, Mushroom Lake, Judge Sissons Lake, and their outflow channels and levels can be manually recorded on a regular basis during periods in which effects may occur. Continuous water levels sensors can also be installed in these lakes and streams during the open water season to obtain detailed water level data.
- **Flow rates:** Instantaneous discharge measurements can be measured at Andrew Lake Outflow, Siamese Lake Outflow, Mushroom Lake Outflow, and Judge Sissons Lake Outflow while effects are predicted to occur. These flow rates can be used to develop and maintain stage-discharge rating curves so that water level data can be used to estimate continuous discharge. In addition, water withdrawal and treated effluent and greywater discharge rates can be continually documented;
- **Waterbody volumes:** Lake level data can be applied to bathymetric data to estimate waterbody volumes at waterbodies potentially affected by the project. Under-ice volumes can be confirmed by annual ice thickness measurements at Siamese Lake, Mushroom Lake, and ice road lakes.

6.3 CUMULATIVE EFFECTS ANALYSIS FOR SURFACE HYDROLOGY

6.3.1 Screening for Cumulative Environmental Effects

Project-related residual effects to surface hydrology occur within the LAA and are expected to diminish to immeasurable levels downstream at the Anigaq River. Residual effects in these areas have potential to overlap with other projects and activities that occur or may occur in the future and therefore act cumulatively on surface hydrology.

The screening for cumulative effects to surface hydrology is conducted to determine if there is potential for cumulative environmental effects. Potential cumulative effects exist if project-related effects to surface hydrology overlap spatially and temporally with those of other past, present and future projects, and activities. Projects considered for cumulative environmental effects are described in Section 6. Of these projects, no local, Nunavut, or Far Future Scenario projects from the Project Inclusion List affect surface hydrology and overlap spatially and temporally with those associated with the Project. Therefore, no cumulative effects to surface hydrology are predicted for this project.

6.4 SUMMARY OF RESIDUAL EFFECTS ON SURFACE HYDROLOGY

6.4.1 Project Effects

Project activities have potential to directly affect Judge Sissons Lake, Siamese Lake, Mushroom Lake, Andrew Lake, Pointer Lake and their outflow streams, site access lakes (20 km Lake, Long Lake, Audra Lake, Unnamed Ponds, and Qinguq Bay), and watersheds associated with the project footprint. A summary of potential effects is included in Table 6.4-1 as well as a reference to the sections of this document for which significance is determined.

Table 6.4-1 Summary of Project Effects on Surface Hydrology

	Phase			Magnitude of Effects to Surface Hydrology					Duration/Frequency of Effect to Surface Hydrology
					Lake Level (cm)				
	Construction	Operations	Final Closure	Outflow Flow Rate (m^3/s)	During the active flow season	During the inactive flow season	Under-ice Volume (%)	Effective Drainage Area (%)	
Judge Sissons Lake		X		0.054	0.05	2.18	0.46	-	Continuously
			X	-1.000	-8	-	-	-	Occurs continuously during June through September for 4 seasons
Siamese Lake	X	X	X	-0.0926	-2	-12 or 16.5	3.1 or 4.1	-	Continuously
Mushroom Lake	X	X	X	-0.000868	-0.2	-34.2	9	-	Continuously
Andrew Lake	X			0.15	24	-	-	-	Continuously for 3-7 days after the spring freshet
		X		-	-	-	-	3	Continuously
Pointer Lake	X			-	-	-	0.4	-	Seasonally until airstrip is built
		x		-	-	-	-	1	Continuously
20 km Lake		X	X	-	-	-	<10	-	Seasonally
Long Lake		X	X	-	-	-	<10	-	Seasonally
Audra Lake		X	X	-	-	-	<10	-	Seasonally
Unnamed Ponds		X	X	-	-	-	<10	-	Seasonally
Qinguq Bay		X	X	-	-	-	<10	-	Seasonally
Kiggavik site – watershed 1		X		-	-	-	-	5	Continuously
Kiggavik site – watershed 2		X		-	-	-	-	-44	Continuously
Kiggavik site – watershed 3		X		-	-	-	-	-39	Continuously
Kiggavik site – watershed 4		X		-	-	-	-	-30	Continuously
Sissons site – watershed 1		X		-	-	-	-	-10	Continuously

6.4.2 Effects of Climate Change on Project and Cumulative Effects on Surface Hydrology

To estimate the effects of climate change on the Project and cumulative effects on surface hydrology, climate change data were used to estimate five components of the water balance at Pointer Lake Outflow and Judge Sissons Lake Outflow: precipitation, evaporation, evapotranspiration, sublimation, and runoff, as discussed in Technical Appendix 5K.

Twenty three climate change scenarios were explored, of which twenty predict an increase in annual precipitation for the period 2071-2099. The greatest increase in precipitation was 78% greater than historical rates. On average, the models predict a 34% increase in precipitation; this increase is typically distributed throughout the year, however most dramatic increases occur in the autumn.

As summers become warmer and wetter, lake evaporation and evapotranspiration conditions are typically predicted to increase, however under nine ensembles lake evaporation is predicted to decrease and seven ensembles evapotranspiration is predicted to decrease. Fifteen ensembles result in a predicted decrease in sublimation while eight result in a predicted increase. Although water losses typically increase, under many ensembles, the magnitude does not compensate for the dramatic increases in precipitation. Twenty of the twenty three climate change ensembles predict an increase in runoff at Judge Sisson and Pointer Lake outflows. On average, runoff is estimated to increase 67% and 74% for Pointer Lake and Judge Sissons Lake watersheds, respectively. The maximum increase in runoff is observed at 177% and 200% of historical discharge for the two watersheds. The hydrological effects resulting from climatic changes are orders of magnitude greater than those generated from Project activities.

Although runoff volumes are predicted to increase by 2071-2099, potential changes in the intensity of precipitation events is unknown. Most site designs, particularly those of high hydrological importance such as diversion channels, are designed based on a probable maximum precipitation (PMP) event. This design criterion is not sensitive to annual runoff rates, but rather the intensity of specific rainfall events. Therefore, if the intensity of rainfall events remains consistent with historical conditions, climate change will not affect the effectiveness of Project designs based on a PMP event.

6.5 COMPLIANCE AND ENVIRONMENTAL MONITORING FOR SURFACE HYDROLOGY

Monitoring of hydrological effects can be completed through the collection of specific data at the waterbodies potentially affected by project activities. These data are sufficient for measuring or estimating flow rates, water levels, and waterbody volumes and can be obtained by the following methods.

- **Water levels:** Staff gauges and continuous water level sensors will be installed on Andrew Lake, Siamese Lake, Mushroom Lake, Judge Sissons Lake, and their outflow channels and levels will be manually recorded during periods in which effects may occur;

- **Flow rates:** Instantaneous discharge measurements will be taken at Andrew Lake Outflow, Siamese Lake Outflow, Mushroom Lake Outflow, and Judge Sissons Lake Outflow while effects are predicted to occur. These flow rates can be used to develop and maintain stage-discharge rating curves so that water level data can be used to estimate continuous discharge. In addition, water withdrawal and treated effluent and greywater discharge rates will be continually documented;
- **Waterbody volumes:** Under-ice volumes will be confirmed by annual ice thickness measurements at Siamese Lake, Mushroom Lake, and ice road lakes.

7 EFFECTS ASSESSMENT FOR HYDROGEOLOGY

7.1 SCOPE OF THE ASSESSMENT FOR HYDROGEOLOGY

In the context of the proposed Kiggavik Project the scope of the assessment for groundwater and hydrogeology focuses on the groundwater quantity and groundwater quality aspects of the aquatic environment. However as there is no current and foreseeable usage of groundwater in the Project area groundwater is primarily valued as a pathway to other valued components, such as surface water quality and aquatics organisms. For example, while the mining, mine rock and tailings management activities may result in changes in hydrogeological measurable parameters, the significance of these changes on baseline conditions is ultimately determined in the context of environmental effects to surface water quality.

7.1.1 Project–Environment Interactions and Effects

The environmental effects of the Project on hydrogeology are changes to groundwater quantity and surface water receptor quality. The relevant project activities and the associated environmental interactions for each Project phase are presented in Table 7.1-1.

Table 7.1-1 Project-Environmental Interactions and Effects – Groundwater

	Project Activities/Physical Works	Change in groundwater quantity	Change in surface water receptor quality
On-Land Construction	Construct foundations	1	0
Mining	Mine dewatering	2	0
Mine rock management	Stockpiling activities	0	2
Tailings Management	Pumping and placement of tailings slurry	0	2
Water Management	Freshwater withdrawal	1	0
	Discharge of treated effluents (including greywater)	0	1
Ongoing exploration	Drilling	1	1

Category 1 activities are those having an interaction with the aquatic environment; however, based on past experience and professional judgment, the resulting effect can be managed to acceptable levels through standard operating practices and/or through the application of best management or codified practices. No further assessment is warranted.

Category 2 activities are those activities that do interact with the aquatic environment and the resulting effect may exceed acceptable levels without implementation of specified mitigation. Further assessment of the effects of these interactions on the aquatic environment is warranted and is presented in this environmental assessment report.

7.1.2 Indicators and Measurable Parameters

In assessing Project effects on groundwater, two measureable parameters were selected.

- The first indicator is the elevation of lakes potentially affected by the dewatering of mines extending beneath the permafrost. This is considered to be an indicator of groundwater quantity because dewatering activities of open pit and underground mines commonly result in depressed groundwater levels in the vicinity of the mines and have the potential to impact lake levels in the study area.
- The second indicator is the quality of the receiving surface water bodies potentially connected hydraulically to the deep groundwater system. Groundwater represents a pathway for potential interactions between dissolved constituents in water originating from the mining activities and the surface water where the groundwater discharges. Because groundwater is not used in the Kiggavik Project area this indicator is considered to be the main measurable parameter of the potential long-term effects of the Project on the aquatic environment.

It is considered that sufficient geological, hydrogeological and hydrological data as well as modelling results are available to confidently estimate potential effects through these measurable parameters.

Table 7.1-2 Measurable Parameters for Groundwater

Environmental Effect	Measurable Parameter(s)	Notes or Rationale for Selection of the Measureable Parameter
Change in groundwater quantity	• Hydraulic head • Lake water level	• Hydraulic heads measured from piezometers and lake water levels measurements allow quantification of potential changes in the spatial and temporal distribution of groundwater as a result of Project activities
Change in surface water receptor quality	• Major ions, trace metals and radionuclides in groundwater and surface water samples	• The chemical composition of groundwater and surface water allow quantification of potential migration of constituents of concern in groundwater as a result of Project activities

7.1.3 Residual Environmental Effects Criteria

Residual environmental effects criteria specific to hydrogeology and groundwater that differ from the description in Section 4.6 are:

- The magnitude of residual environmental effects for groundwater describes the overall effect of project activities on the surface water where groundwater discharges. For hydrogeology, magnitude is defined as:
  - Negligible: Very minor changes to groundwater quantity or surface water receptor quality that are imperceptible in their effect in the LAA or RAA
  - Low: Minor changes to groundwater quantity or surface water receptor quality that can be detected in the LAA or RAA but do not exceed surface water water quality standards or affect water users
  - High: Large changes to groundwater quantity or surface water receptor quality that exceed water quality standards or affect water users in the LAA or RAA.
- The geographic extent of environmental effects to hydrogeology refers to the area within which the environmental effect occurs and is described either as the number of square kilometres affected or the number of kilometres affected downstream of the activity location. The geographic extent is described as local if the predicted effect does not extend beyond the LSA and Regional if it extends into the RSA.
- The frequency of an environmental effect to hydrogeology refers to the number of times the effect occurs during the project or during a specific phase of the project. Frequency is described as isolated, periodic, or continuous. An environmental effect has an isolated frequency if the effect is confined to a specific discrete period; an environmental effect

has a periodic frequency if the effect occurs intermittently or may repeat over the assessment period, while an environmental effect is continuous if the effect occurs continually over the assessment period.

7.1.4 Standards or Thresholds for Determining Significance

The significance of Project environmental effects on hydrogeology is determined by the extent of change in lake levels and the quality of the surface water where groundwater discharges in comparison to CCME guidelines for aquatic life and Health Canada guidelines for drinking water. A significant environmental effect on hydrogeology occurs if there is a greater than 10-cm change in a lake level as a result of mine dewatering or if the CCME and Health Canada guidelines, as presented in Table 7.1-3 are exceeded. The effects are not significant if these conditions do not occur.

Table 7.1-3 CCME and Health Canada Guidelines for Determination of Significance on Surface Water Receptor Quality

Analyte	Units	CCME guidelines	Health Canada Drinking water Guidelines	
pH (laboratory)	pH units	6.5 to 9.0	6.5 - 8.5	AO or OG
Aluminum	mg/L	0.005-0.1	0.1 / 0.2	AO or OG
Antimony	mg/L		0.006	MAC
Arsenic	ug/L	5	10	MAC
Barium	mg/L		1	MAC
Boron	mg/L		5	MAC
Cadmium	mg/L	0.000017	0.005	MAC
Chromium	mg/L	0.001 (Cr(VI)) 0.0089 (Cr(III))	0.05	MAC
Copper	mg/L	0.002-0.004	1	AO or OG
Iron	mg/L	0.3	0.3	AO or OG
Lead	mg/L	0.001-0.007	0.01	MAC
Manganese	mg/L		0.05	AO or OG
Molybdenum	mg/L	0.073		
Nickel	mg/L	0.025-0.150		
Selenium	mg/L	0.001	0.01	MAC
Silver	mg/L	0.0001		
Thallium	mg/L	0.0008		
Uranium	ug/L	15 (long-term)	20	MAC
Vanadium	mg/L			
Zinc	mg/L	0.03	5	AO or OG
Radium-226	Bq/L		0.5	MAC
Chloride	mg/L		250	AO or OG
Sodium	mg/L		200	AO or OG
Sulfate	mg/L		500	AO or OG
Nitrate	mg/L	13	45	MAC

CCME – Canadian Water Quality Guidelines for the Protection of Aquatic Life (2011)
Health Canada – Guidelines for Canadian Drinking Water Quality (December 2010)
MAC – Maximum Acceptable Concentration
AO – Aesthetic Objectives or Operationnal Guidance Values)OG)

7.2 EFFECTS ASSESSMENT FOR HYDROGEOLOGY

7.2.1 Assessment of Changes in Groundwater Quantity

7.2.1.1 Analytical Methods for Changes in Groundwater Quantity

A three-dimensional regional groundwater flow model of the LSA was developed in support of the effects assessment for hydrogeology. This regional flow model encompasses a large area, including the Kiggavik and Sissons Mine Sites, considering as far as practical natural boundary conditions with limited artificial control of the calculated flow regime. The groundwater flow model was based on historical and recent geological and hydrogeological information, including ground temperature measurements, hydraulic conductivity test results and water levels.

Details of the conceptual and numerical models can be found in Technical Appendix 5D. The groundwater flow model was used to simulate progressive mining of the open pit and underground workings below the permafrost zone (see Technical Appendix 5E). Steady state and transient mine dewatering rates were predicted and natural reflooding rates were estimated for the End Grid underground mine and the Andrew Lake open pit. The flow model was also used as part of the assessment of the long-terms effects related to tailings management (see Technical Appendix 5J).

7.2.1.2 Baseline Conditions for Changes in Groundwater Quantity

Baseline conditions for changes in groundwater quality are summarized by the current hydraulic distribution in the sub-permafrost aquifer. Figure 5.2-6 shows the simulated steady-state hydraulic head distribution in the sub-permafrost aquifer under pre-mining conditions. The figure also shows the areas where groundwater is predicted to be flowing artesian.

7.2.1.3 Effect Mechanism and Linkages for Changes in Groundwater Quantity

Dewatering activities of the Kiggavik open pits, Andrew Lake open pit and End Grid will result in depressed groundwater levels in the vicinity of the mine and have the potential to affect waterbodies by decreasing water quantities in the lakes in the vicinity of the mines.

7.2.1.4 Residual Effects for Changes in Groundwater Quantity

Mine dewatering activities are predicted to result in depressed groundwater levels beyond the upper limits of natural variation in the immediate vicinity of the Kiggavik open pits, Andrew Lake open pit and End Grid underground mine. The potential effects are anticipated to last throughout the active mining period, following which dewatering activities will cease, and the groundwater system will recover to conditions similar to natural pre-mining conditions. Groundwater quantities extracted from dewatering activities are predicted to be low and will not affect lake leveks.

Model results presented in Technical Appendix 5E suggest that the groundwater inflow to the proposed open pits would be low due to low hydraulic conductivity of the rock mass in which the pits would be excavated. Mining of the Andrew Lake and Main Zone pits is expected to take place over several years. During most of this time, the pits will be excavated in permafrost and groundwater inflows are expected to be negligible. In the final years of mining the pits are expected to extend below the bottom of permafrost; the results of the model simulations predict that groundwater inflow to the Andrew Lake and Main Zone pits will be lower than 100 m3/year for the ultimate pit depth.

Predicted groundwater flow to the End Grid underground mine is approximately 160 m3/day for the ultimate configuration of the mine. Most of this flow originates from the enhanced permeability zones assumed to be associated with the sub-vertical faults passing through the mine. If these faults are either not present or have a lower hydraulic conductivity than assumed then inflow to the mine would be lower than 100 m3/day.

7.2.1.5 Determination of Significance for Changes in Groundwater Quantity

Effects of mine dewatering activities on groundwater levels are predicted to be localized within the site assessment boundary. The effects will be continuous during the mining period, but reversible in the medium-term, and are anticipated to have negligible ecological and socio-economic implications. The low hydraulic conductivity of the rock mass and the permafrost conditions will result in limited groundwater inflows to the proposed mines and lake levels will not be affected by mine dewatering activities. Therefore, the residual adverse effects from the Project on groundwater quantity are considered not significant.

7.2.2 Assessment of Changes in Surface Water Receptor Quality

7.2.2.1 Analytical Methods for Changes in Surface Water Receptor Quality

The post-decommissioning flow regime of the Kiggavik area was modelled based on the groundwater flow model presented in Technical Appendix 5D. Groundwater flow simulations were performed under steady state conditions, as would exist following decommissioning.

As presented in Table 7.2-1, field data acquisition, laboratory testing and modelling programs were developed to assess the potential long-term effects of tailings and mine rock management activities. These programs are summarized in Technical Appendix 5F for mine rock and in Technical Appendix 5J for tailings.

Hydrogeological and geochemical models were first calibrated on field data and laboratory experiments. The models were then used to predict the potential loadings over time of key COPC at receptors. This included Pointer Lake and the flooded Andrew Lake pit. For simplicity and conservatism, maximum predicted loadings were used, regardless of the peak arrival time, and all maximum loadings were assumed to reach the waterbodies at the same time. The maximum loadings were transformed to peak incremental surface water concentrations at the receptors using average flow conditions at the receptors and neglecting removal processes in waterbodies.

Sensitivity analyses were performed to account for uncertainties in the hydrogeological and geochemical parameters. This included the assessment of combined effects of varying several key parameters simultaneously in the direction that increases the COPC concentrations in receiving surface water bodies.

Calculated long-term surface water concentrations were compared to currently applicable water quality objectives. Long-term peak incremental concentrations were found to differ negligibly from baseline conditions. As a result, a human health and ecological risk assessment was not deemed necessary for the long-term effects, as the predicted water and sediment quality are only marginally above natural background levels and are well below benchmark values. Additional information can be found in Technical Appendix 5J.

Table 7.2-1 Methodology for the Assessment of Long-Term Effects on Surface Water Receptor Quality

Topic	Summary Of Work Done To Date
Flow	Pre-mining and mine-dewatering groundwater flow conditions • Review of geological, hydrological and hydrogeological data • In-situ determination of ground temperatures, hydraulic conductivity and sub-permafrost hydraulic heads • Development of a steady-state regional three-dimensional (3D) flow model (Feflow and Modflow softwares) for pre-mining conditions • Development of a transient 3D flow model (Feflow) for mine-dewatering conditions Post closure groundwater flow conditions • Laboratory determination of tailings hydraulic conductivity and geotechnical parameters • Modelling of post-consolidation tailings hydraulic conductivity • Modelling of thermal conditions of the min rock piles • Literature review on hydrology of mine rock piles in cold climates • Evaluation of the water balance for mine rock piles and covered TMFs • Modelling of the impact of climate warming trends on permafrost • Modelling of groundwater flow through the decommissioned TMFs for both current permafrost and no-permafrost cases
Source Term	Tailings geochemical behaviour • Laboratory determination of tailings neutralization conditions and long-term tailings behaviour using aging tests • Thermodynamic modelling (PhreeqC) of minerals-solution equilibrium • Determination of constant concentration-type boundary condition values for the contaminant transport model Mine rock geochemical behaviour • Determination of solid inventory from drill core samples • Determination of mine rock pore water and leachable fractions from sequential leach tests, humidity cell tests and column tests • Determination of source term functions for the contaminant transport model
Contaminant Transport	Contaminant transport and loadings to receiving surface water bodies • Literature review on effective porosity values in crystalline fractured environment • Laboratory determination of total porosity and Kd for sub-permafrost granite samples • Partical path analysis (Modpath), from the decommissioned TMFs to the receiving surface water bodies for both current permafrost and no-permafrost cases • Analytical modelling of contaminant transport along each particle path
Consequence Of Predictions	Consequence of predicted long-term concentrations • Sensitivity analysis to account for hydrological, hydrogeological and geochemical uncertainties • Comparison of predicted surface water concentrations with guidelines

7.2.2.2 Baseline Conditions for Changes in Surface Water Receptor Quality

The surface water receptors potentially affected by groundwater discharge in relation to project activities are Pointer Lake and Andrew Lake. Baseline water quality for these two lakes is good, characterized by low-hardness water. Section 5.3 provides a summary of the data collected from the baseline monitoring program. Compared to available guidelines, all samples were below the water quality guidelines for arsenic, nickel, selenium, uranium, and zinc. The majority of the data for copper and lead were below the water quality objectives as the upper 95th percentile concentration was at or below the applicable guideline. The assessment of baseline water quality for cadmium is complicated as the analytical detection limit reported by the laboratory is generally above the water quality guideline, although it is noted that cadmium had been detected a number of times at a concentration of 0.1 µg/L which is above the water quality guideline.

7.2.2.3 Effect Mechanism and Linkages for Changes in Surface Water Receptor Quality

Tailings management activities at the Kiggavik Project are identified as the main Project component for potential interaction with the groundwater regime during the post-decommissioning period. Groundwater is not used in the Kiggavik Project area. However groundwater represents a pathway for potential interactions between dissolved constituents in water originating from the TMFs and the surface water where the groundwater discharges. The linkage between tailings and surface water receptor quality involves a series of hydrological, hydrogeological and geochemical mechanisms, including, but not limited to, the following parameters:

- The tailings pore water long-term concentrations and the inventory of soluble constituents in the tailings, which constitute the source term for potential release of COPC into the groundwater regime.
- The flow through the decommissioned TMFs, which when multiplied by the source term provides the flux of consituents potentially released into the groundwater regime. The loadings to the surface water receptors from the TMFs through the groundwater pathway cannot exceed this flux.
- The hydraulic conductivity and effective porosity of the rock mass between the TMFs and the surface water receptors and the distribution of hydraulic heads, which generate the groundwater velocity along the flowpath.
- Geochemical processes, such as mineral precipitation and adsorption, which attenuate the release and transport of constituents from the TMFs to surface water receptors.
- The flow through the surface water receptors, which transforms the flux of COPC originating from the TMFs into resulting surface water concentrations.

These processes are captured by the groundwater flow and contaminant transport models used to evaluate changes in surface water receptor quality.

7.2.2.4 Mitigation Measures and Project Design for Changes in Surface Water Receptor Quality

The proposed tailings management plan for the Kiggavik Project has been designed to avoid interaction between tailings and natural water bodies, to maximize the use of mine workings for long-term management of tailings and to ensure the long-term protection of terrestrial, aquatic and human environments.

The tailings treatment system in the mill and the TMFs are designed to minimize the release of COPC into the aquatic environment.

7.2.2.5 Residual Effects for Changes in Surface Water Receptor Quality

7.2.2.5.1 Kiggavik TMFs area

In the current permafrost case the predicted flow through the tailings is very limited, approximately 0.01 m^3/day. Subsequently there is a very small flux to Pointer Lake for all constituents resulting in negligible incremental concentration in relation to baseline concentrations.

Figure 7.2-1 shows the simulated hydraulic head distribution and results of the particle path analysis in the sub-permafrost aquifer for the post-decommissioning scenario with an expected tailings hydraulic conductivity of $5x10^{-8}$ m/s. This simulation is considered to be the base case representative of the current atmospheric and permafrost conditions.

The hydraulic head distributions in the Kiggavik area for the baseline and post-decommissioning cases are relatively similar. Differences, due to the presence of the tailings (i.e, tailings with slightly higher permeability than the surrounding rock mass) in the post-decommissioning case, are only apparent in close proximity of the Main Zone TMF, which extents below the permafrost.

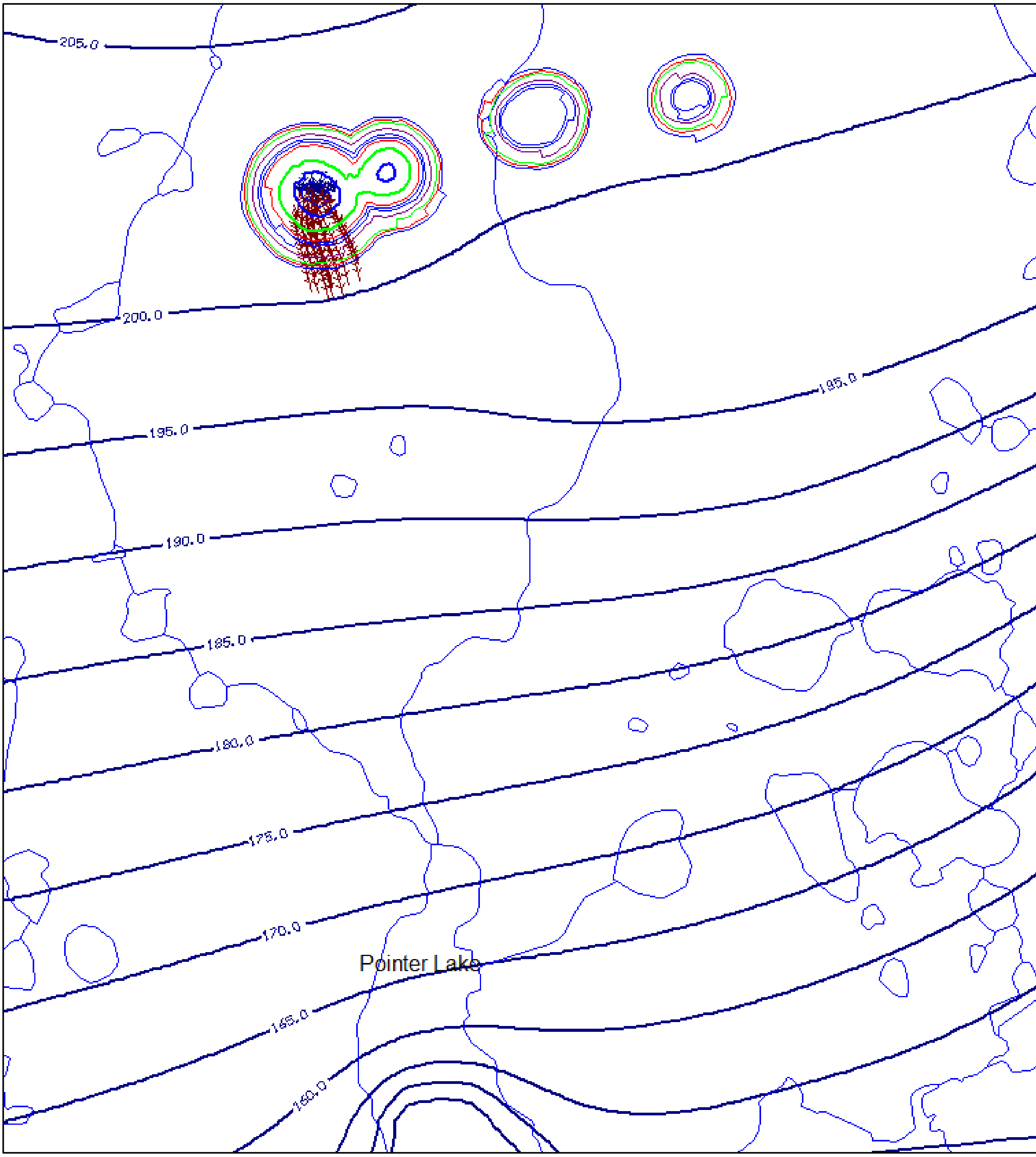


Figure 7.2-1
Pathlines from tailings for current permafrost conditions (pathlines for 10000 years, ticks every 1000 years)

Particles were released in the model throughout the Kiggavik TMFs to track the advective groundwater flow paths to discharge locations. Because of the low hydraulic conductivity of the rock mass the travel time is extremely long. For instance Figure 7.2-2 shows that after 10,000 years particles remain in the immediate vicinity of the TMFs and do not discharge to a receiving surface water bodies.

Under steady state conditions the particles discharge to Pointer Lake. However the breakthrough time is long, in the order of million years. Predicted long-term water concentrations of solutes in Pointer Lake were compared to baseline and to the applicable surface water quality objectives. Table 7.2-2 shows that all predicted concentrations are well below applicable water quality objectives and for most constituents incremental concentrations are negligible in relation to baseline concentrations. Groundwater flow and solute transport models confirm the performance of the tailings containment system and the limited interaction between tailings and natural surface water bodies.

Table 7.2-2 Predicted Peak Incremental Loadings to Pointer Lake and Resulting Surface Water Concentrations – Current Permafrost Conditions

COPC	Reference values		Flux and resulting surface water concentrations	
	Baseline (µg/L)	Guideline (µg/L)	Mass Flux (kg/year)	Concentration (µg/L
Al	21	5 to 100	1.53E-03	1.01E-04
As	0.2	5	6.10E-05	4.04E-06
Cd	<0.1	0.017	9.15E-06	6.06E-07
Cr	<0.5	1 to 8.9	1.07E-03	7.07E-05
Co	<0.1		3.05E-04	2.02E-05
Cu	0.8	2	1.22E-03	8.08E-05
Fe	45	300	1.53E-02	1.01E-03
Pb	0.1	1 to 7	1.22E-04	8.08E-06
Mn	2.4		3.05E-03	2.02E-04
Mo	<0.1	73	6.10E-04	4.04E-05
Ni	0.4	25 to 150	1.22E-03	8.08E-05
Se	<0.1	1	1.53E-04	1.01E-05
U	<0.1	15	4.27E-04	2.83E-05
V	0.1		2.14E-03	1.41E-04
Zn	5.8	30	9.15E-03	6.06E-04
	Baseline (Bq/L)	**Guideline (Bq/L)**	**Mass Flux (Bq/year)**	**Concentration (Bq/L)**
^{226}Ra	<0.005	0.5	2.06E+04	1.36E-06

a = Baseline, September 2008 (See Technical Appendix 5C)

b = Guideline, Canadian Council of Mininters of the Environmen's (CCME) Canadian Water Quality Guidelines (CWQG) for the protection of aquatic life (2011)

c = Guideline, Health Canada Guidelines for Canadian Driking Wate Quality(2010)

7.2.2.5.2 Andrew Lake Flooded Pit

The Andrew Lake open pit will be flooded after operation to permanently store, underwater, the Type 3 Andrew Lake rock material that will be temporarily stored near the pit during operation. There are two possible scenarios for flooding after closure. One scenario is to allow flooding that will occur naturally as a result of the accumulation of rain and snow melt and the small amount of seepage that may be expected to occur in the active layer near ground surface. At the expected natural filling rate, complete flooding will require approximately 480 years.

Alternatively, the natural filling of the pit can be complemented by flow from a larger water body, such as Judge Sissons Lake, during periods of high flow in order to shorten the flooding period. Experience has shown that while leaching of metals and other COPC can occur while rock, including pit walls, is exposed to the atmosphere and natural weathering processes, such leaching tends to be insignificant to non-measurable when the same rock is submerged below water. This difference in behaviour suggests that rapid flooding may have some advantages for maintaining good water quality at some sites. However, water quality will depend on site-specific conditions, including expected leaching rates for pit rock. Therefore, the water quality in the flooded Andrew Lake pit was evaluated at a conservative screening level in order to determine whether or not natural filling would result in acceptable water quality after flooding was complete.

The Andrew Lake pit water quality was assessed by evaluating constituent loadings originating from the pit walls, rock rubble on pit floor, and benches, pore water concentrations from the temporarily stored material, and the leaching of the relocated material as the pit fills under natural conditions, as well as under accelerated pit filling conditions. These loadings were assessed to estimate the concentrations of COPC in the pit water after the pit is filled. Although all sources of constituent loadings to the Andrew Lake pit will be eliminated as the pit fills and covers the various sources of loads with water, the pit walls above the final water level will continue to be a potential source of loadings to the pit as it remains exposed to the atmosphere and weathering conditions. Therefore, the influence of the unflooded pit walls was assessed to estimate maximum concentrations of COPC when flow out of the pit occurs and over the long term. These results provided a screening level estimate of the Andrew Lake pit water quality that will potentially exist immediately after flooding is complete and into the future after the pit overflows.

The Andrew Lake pit water quality evaluation was conducted using constituent loading rates calculated from the steady-state conditions exhibited by the humidity cell tests on the Type 3 Andrew Lake rock material. The calculated field loading rate terms for the rubble, pit walls, and mine rock material were derived from the laboratory loading rates by making adjustments for expected grain size, surface area, and/or temperature. The field loading rates for the mine rock materials were also used to estimate the pore water concentration of the temporarily stored Type 3 Andrew Lake Rock material in order to account for the loadings from the pore water or resident moisture in the material when it is relocated to the open pit. The pit water quality was then determined assuming a well-mixed waterbody for a natural filling rate, which would require approximately 480 years, and two accelerated rates, which would hypothetically require 10 and

100 years. The natural filling rate was then used to calculate the water elevation as a function of time. The unflooded area of the pit floor was calculated as a function of filling time. The results are presented graphically in Technical Appendix 5F (Mine Rock Characterization and Management).

The calculated Andrew Lake concentrations of COPC under the natural filling rate condition were compared to CCME guidelines for the protection of freshwater aquatic life. The calculated pit water concentrations will be less than the guideline values for all COPC, except for aluminum and cadmium. The estimated concentration of aluminum in pit water was 0.069 mg/L, which is greater than the 0.005 mg/L CCME guideline value. The calculated aluminum concentration is considered to be very conservative as aluminum is pH sensitive, such that the expected pit water pH will likely result in lower aluminum concentrations. The estimated cadmium pit water concentration was 0.000017 mg/L, which is equal to the 0.000017 mg/L CCME guideline value. The calculated cadmium concentration is also extremely conservative as the detection limit was used in the loading rate estimate because the cadmium concentration in the leachate samples from the humidity cells were almost always less than the detection limit.

The pit water quality may also be improved with accelerated pit filling. The enhanced pit filling would produce water quality better than that for the natural filling scenario because more rapid filling would result in shorter exposure times for the same rock mass or surface area creating less cumulative loadings of COPC that will mix with the same total volume of water (see Technical Appendix 5F). If natural long-term filling results produce unacceptable water quality for only two constituents, more rapid filling can produce acceptable water quality.

The calculated initial COPC concentrations will slowly decrease in time to the steady-state concentrations associated only with the loadings from the exposed pit walls, while the net inflow, and thus discharge, remains constant. If necessary, the pit water can be treated in-situ by pH adjustment to reduce metal concentrations to levels below guideline values. Once the pit water quality is below the guideline values the concentrations will continue to decrease to the steady-state concentrations, which are well below the CCME guidelines, thus assuring the long-term management strategy. This evaluation therefore suggests that the pit water will not represent a risk to aquatic life and can be discharged to surrounding surface water bodies without concern after closure.

7.2.2.6 Determination of Significance for Changes in Surface Water Receptor Quality

As outlined in the previous sections the assessment of potential long-term effects of groundwater and contaminant flux to surface waters from the Kiggavik TMFs and the Sissons mining area indicated minimal effects on background concentrations of constituents of concern in local lakes. As such, potential effects to surface waters are expected to fall within the range of background concentrations (i.e., low magnitude). The long-term effects are considered reversible and have negligible ecological and socio-economic implications. The potential long-term effects are, therefore, considered not significant.

7.3 CUMULATIVE EFFECTS ANALYSIS FOR HYDROGEOLOGY

7.3.1 Screening for Cumulative Environmental Effects

Project-related residual effects to groundwater occur only within the LAA and as outlined in the previous sections are expected to translate to non significant levels.

The screening for cumulative effects to groundwater is conducted to determine if there is potential for cumulative environmental effects. Potential cumulative effects exist if project-related effects to groundwater overlap spatially and temporally with those of other past, present and future projects, and activities. No local, Nunavut, or Far Future Scenario projects from the Project Inclusion List affect groundwater and overlap spatially and temporally with those associated with the Project. Therefore, no cumulative effects to groundwater are predicted for this project.

7.4 EFFECTS OF CLIMATE CHANGE ON PROJECT AND HYDROGEOLOGY

7.4.1.1 Scenarios

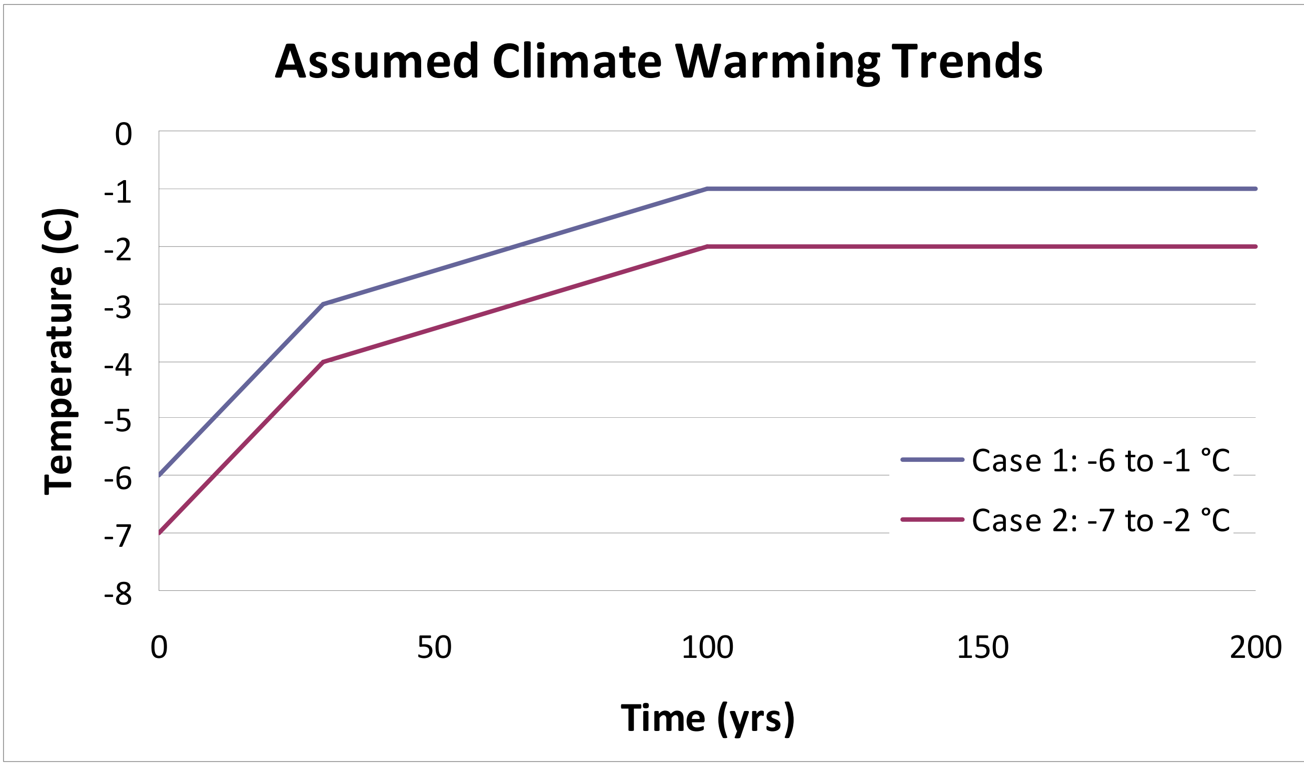
The effects of climate change on the project in the short and long term will depend on the degree and rate of warming. To assess the worst case potential for the transport of COPC, a conservative approach is to consider the warming trend because of its impacts on permafrost extent. Cooling of climate is not considered here because it would not have a negative impact on the permafrost extent and only enforce the containment of material stored in the TMFs.

Two successive scenarios were considered to assess the potential effects of climate change on hydrogeology:

- The first scenario considered a warming trend over 100 years from a mean annual surface temperature of -7 °C to -2 °C (i.e. 5 degree rise in temperature). The objective of this scenario was to assess the effect of a significant warming trend on the extent of permafrost in the TMFs area.
- The second scenario simply assumed no permafrost. The objective of this scenario was to predict groundwater flow conditions in a very long term scenario, with the assumption that the hydrogeological system has stabilized to a new pseudo-equilibrium state, and where warming global temperatures have melted the permafrost completely (worst case scenario). The objectives of this model were to predict the changes in transport of solutes from tailings and mine rock in the Main, Centre, and East Pits to potential receptors.

7.4.1.2 Effect of a Warming Trend on the Local Permafrost Regime

Figure 7.4-1 shows the computed change in permafrost depth for the 5 degree warming trend. Model results (see Technical Appendix 5J) show that if the mean annual surface temperature rises the change is manifested as a reduction in depth of permafrost at the base, and not at the surface. Figure 7.4-1 suggests that the warming trend may result in long term permafrost depths of about 90 m from surface. Therefore it is conservative to conclude that the base of all the TMF's may be exposed to a thawed state over the long term.



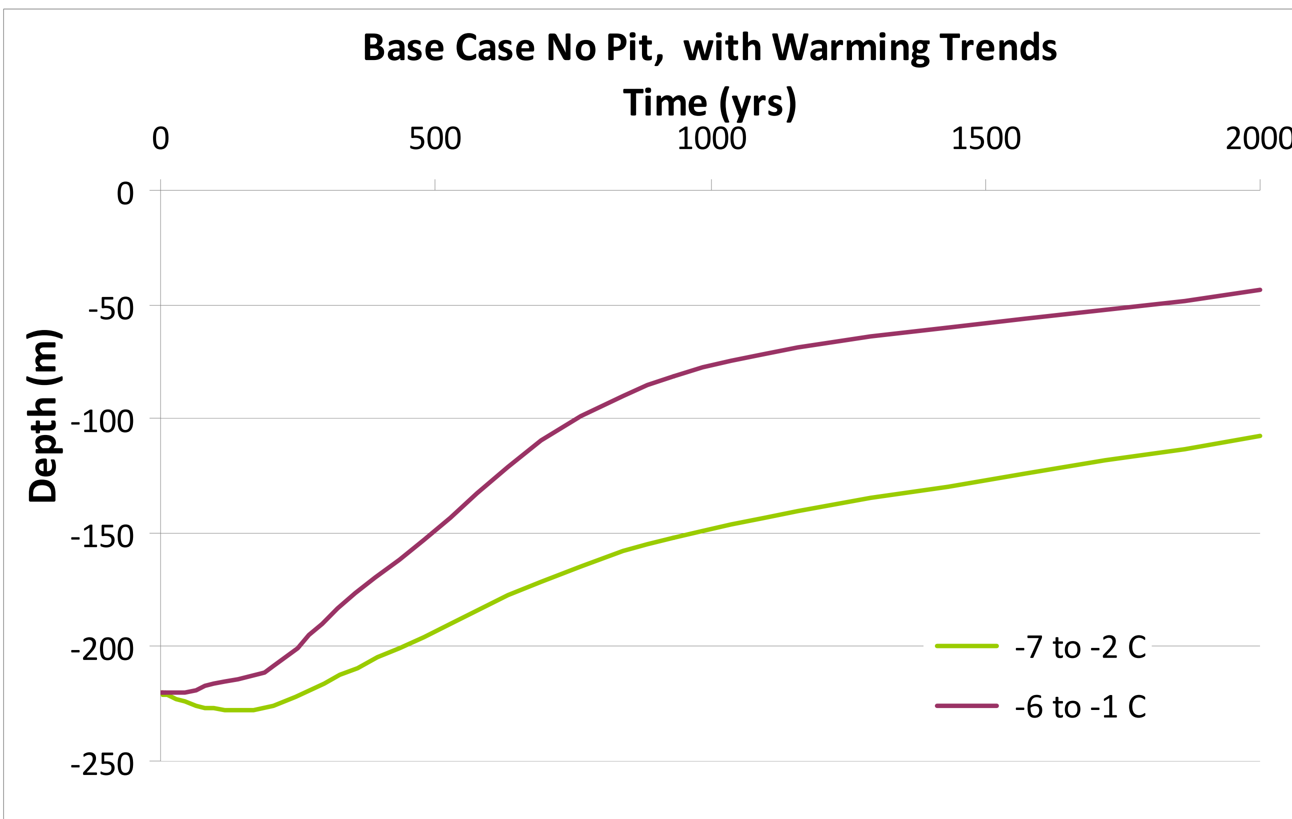


Figure 7.4-1
Natural ground permafrost degradation with climate warming

7.4.1.3 No-Permafrost Case

This scenario assumes complete melting of permafrost. With removal of the confining permafrost layer (aquitard), piezometric levels would likely equilibrate to near ground surface levels, except in low topographical locations, which would act as discharge zones for the groundwater system.

The absence of permafrost would be a fundamental change to the groundwater flow system. Surface components of the hydrological system would be in direct connection with the underlying hydrogeological flow system across the region, and not just through the open taliks. This would have a significant effect on the pressure distribution and hydraulic heads, such that flow would not be pushed in and out of taliks, but would begin to move laterally.

7.4.1.3.1 Hydraulic Conductivty

Under no-permafrost conditions the hydraulic conductivity distribution would change for units that were previously located in the permafrost layer.

7.4.1.3.2 Recharge

As summers become warmer and wetter, lake evaporation and evapotranspiration conditions are typically predicted to increase. Although water losses typically increase the magnitude is not expected to compensate for the increases in precipitation. Therefore both runoff and recharge are expected to increase relative to the current permafrost conditions. However recharge is not expected to increase as much as precipitation because the thin soils and weathering profile and the underlying low permeability bedrocks will limit the infiltration rate.

To account for the expected change in hydrology groundwater recharge from precipitation was included as a boundary condition in the no-permafrost groundwater flow model. A maximum "reasonable" recharge rate was estimated by increasing the recharge rate in the model until the simulated hydraulic heads be equal or higher than ground surface in areas of the model located at sufficient distance from boundary conditions such as drains and lakes. This iterative process resulted in a recharge value of 15 mm/year. Any additional recharge above this value was found to cause unrealistic mounding of groundwater above ground surface.

7.4.1.3.3 Lakes

The location of the lakes was not changed in the no-permafrost model, assuming no geomorphic changes to ground surface. The following four lakes however were removed from the model: Ridge Lake, Felsenmeer Lake, Escarpment Lake, and Mushroom Lake. These lakes were removed considering that, with thawing of the permafrost, they would likely drain into the underlying rock and become dry depressions rather than annual lake bodies. This assumption was based on the observation that the lake elevations are much higher than the surrounding groundwater head. Therefore it is reasonable to assume that these lakes may be "perched" on frozen ground.

7.4.1.3.4 Stream Channels

Drain boundary conditions were added along stream channels at the top surface of the no-permafrost model in order to prevent excessive mounding of the water table as a result of the applied recharge flux, particularly in areas away from lakes. The stream channels were simulated as drains allowing groundwater to exit the model but not recharge the model. This assumption is considered to be reasonable because the water table is close to ground surface and the drainage channels are the lowest points along topography. The drains added to the model were selected to match topographical depressions and existing channels.

7.4.1.3.5 Contaminant Transport Calculation

As detailed in Technical Appendix 5J, analyses for the Main Zone TMF were conducted considering the Main Zone TMF full to capacity with tailings

Under the current permafrost conditions, the flow through the tailings mass in Main Zone TMF was simulated to be 0.01 m^3/day. Flow through the tailings in Main Zone increases to 0.88 m^3/day for the no permafrost scenario. The increase is due in part to the increased hydraulic conductivity of the surrounding unfrozen rock mass. The increase is also attributable to the increased amount of surface recharge that reaches the tailings through the unfrozen cover. Under the current permafrost conditions Centre Zone and East Zone TMFs are located entirely within permafrost and there is virtually no groundwater flow through the tailings mass. In the no permafrost case the calculated flow through the tailings in Centre Zone and East Zone increases to 0.32 m^3/day and 0.23 m^3/day, respectively.

Under the no-permafrost case the pathlines originating from the TMFs also discharge in Pointer Lake. Relative to the current permafrost conditions the breakthrough time is shorten, in the order of thousand years as opposed to million years. The key output of the contaminant transport modelling is the predicted loadings (mass flux) to surface water. Predicted long-term water concentrations of solutes in Pointer Lake were compared to baseline and to the applicable surface water quality objectives. Table 7.4-1 shows that all predicted concentrations are well below applicable water quality objectives and for most constituents incremental concentrations are negligible in relation to baseline concentrations. Groundwater flow and solute transport models confirm the performance of the tailings containment system and the limited interaction between tailings and natural surface water bodies, even in case of dramatic climatic change.

Table 7.4-1 Predicted Peak Incremental Loadings to Pointer Lake and Resulting Surface Water Concentrations – No Permafrost Scenario

COPC	Reference values		Flux and resulting surface water concentrations	
	Baseline (µg/L)	Guideline (µg/L)	Mass Flux (kg/year)	Concentration (µg/L
Al	21	5 to 100	2.61E-01	1.72E-02
As	0.2	5	1.04E-02	6.90E-04
Cd	<0.1	0.017	1.57E-03	1.03E-04
Cr	<0.5	1 to 8.9	1.83E-01	1.21E-02
Co	<0.1		5.22E-02	3.45E-03
Cu	0.8	2	2.09E-01	1.38E-02
Fe	45	300	2.61E+00	1.72E-01
Pb	0.1	1 to 7	2.09E-02	1.38E-03
Mn	2.4		5.22E-01	3.45E-02
Mo	<0.1	73	1.04E-01	6.90E-03
Ni	0.4	25 to 150	2.09E-01	1.38E-02
Se	<0.1	1	2.61E-02	1.72E-03
U	<0.1	15	7.31E-02	4.83E-03
V	0.1		3.65E-01	2.41E-02
Zn	5.8	30	1.57E+00	1.03E-01
	Baseline (Bq/L)	**Guideline (Bq/L)**	**Mass Flux (Bq/year)**	**Concentration (Bq/L)**
^{226}Ra	<0.005	0.5	3.53E+06	2.33E-04

a = Baseline, September 2008 (See Technical Appendix 5C)

b = Guideline, Canadian Council of Mininters of the Environmen's (CCME) Canadian Water Quality Guidelines (CWQG) for the protection of aquatic life (2011)

c = Guideline, Health Canada Guidelines for Canadian Driking Wate Quality(2010)

7.5 SUMMARY OF RESIDUAL EFFECTS ON HYDROGEOLOGY

Effects on hydrogeology, groundwater and surface water receptors where groundwater discharges resulting from Project activities are expected to be low, for both current permafrost conditions and potential no-permafrost conditions that would result from dramatic warming conditions.

Given the project design features and the low hydraulic conductivty of the rock mass, all project effects on hydrogeology are predicted to be not significant.

7.6 CUMULATIVE EFFECTS

Activities associated with the Project are not expected to contribute to cumulative effects on hydrogeology and groundwater.

7.7 COMPLIANCE AND ENVIRONMENTAL MONITORING FOR HYDROGEOLOGY

Monitoring of hydrogeological effects can be completed through the collection of specific data at waterbodies potentially affected by project activities (i.e., End Grid Lake, Mushroom Lake and Pointer Lake) in a manner consistent with monitoring for changes in surface hydrology (see section 6.2.1.6).

Water quality in lakes and streams adjacent to and downstream of the the Kiggavik and Sissons areas will be monitored during the spring freshet each year during the operational life of the Project to confirm that COPC do not increase as a result of tailings management of mine rock management activities.

In addition a groundwater monitoring program will be implemented. The program will consist of an array of monitoring points to track changes in ground temperature, pressure gradients (flow direction) and water quality in the deep, sub-permafrost, groundwater flow regime. The proposed monitoring system will be phased in as the project moves from planning and design, through operations, and finally into closure. Groundwater pressures and chemistry will be established in the rock mass surrounding the proposed TMF prior to excavation of the pits, and then monitored as the excavation base penetrates the permafrost base and as the pit is filled with tailings material. This will require an increasing array of monitoring points in order to detect changes brought about by the mining activities.

Contingency plans are intended to address unforeseen circumstances which could result in a significant increase in the mass flux of solutes to the receptors. Extensive investigations into the chemical and physical properties of tailings has been undertaken at Kiggavik and will continue to be undertaken as part of a Tailings Optimization and Validation Program (TOVP), similar to the program that was initiated at McClean Lake Operation and has been a successful audit program for the behaviour of the tailing produced at that site in Northern Saskatchewan.

8 ASSESSMENT OF PROJECT EFFECTS ON WATER QUALITY

8.1 SCOPE OF THE ASSESSMENT FOR WATER QUALITY

The NIRB Guidelines for the Kiggavik Project (NIRB, 2011) identify water quality as a Valued Ecosystem Component (VEC). The scope of the assessment for water quality focuses on the physical and chemical characteristics of water quality, as well as its value as a critical component in the maintenance of healthy aquatic ecosystems. Thus, water quality is a valued ecosystem component in its own right, as well as being crucial to the functioning and maintenance of other valued aquatic ecosystem components such as aquatic organisms and plants, fish habitat, and fish populations. Water quality is also an important attribute of waters that may be used as a supply of drinking water for humans and Arctic wildlife.

8.1.1 Project–Environment Interactions and Effects

Information was gathered from the environmental and engineering teams for the Kiggavik Project, through public engagement, and by NIRB to identify project activities that have potential to interact with surface water quality by affecting its physical or chemical makeup. Relevant project activities and the associated environmental interactions for each Project phase are summarized in Table 8.1-1 for project-environment interactions that were ranked 1 or 2.

The rationale for ranking interactions as Category 1 is presented below. Those interactions ranked as Category 2 are discussed in more detail in the following sections.

Table 8.1-1 Project – Environment Interactions and Effects – Water Quality

Project Phase	Project Activities/Physical Works	Change in Water Quality
Construction:		
In-Water Construction	Construct freshwater diversions and site drainage containment systems (dykes, berms, collection ponds)	1
	Construct in-water/shoreline structures	1
	Water transfers and discharge	1
	Freshwater withdrawal	0
On-Land Construction	Site clearing and pad construction (blasting, earth moving, loading, hauling, dumping, crushing	1
Operation:		
Mining	Mining ore (blasting, loading, hauling)	2
	Mining special waste (blasting, loading, hauling)	2
	Mining clean waste (blasting, loading, hauling)	2
	Mine dewatering	1
Water Management	Create and maintain water levels	0
	Freshwater withdrawal	0
	Collection of site and stockpile drainage	1
	Water and sewage treatment	1
	Discharge of treated effluents (including greywater)	2
	Disposal of sewage sludge	1
Transportation	Truck transportation	2
	General traffic (project-related)	2
Ongoing exploration	Ground surveys	0
	Drilling	0
Final Closure:		
General	Ongoing withdrawal, treatment and release of water, including domestic wastewater	2
In-water Decommissioning	Remove freshwater diversions; re-establish natural drainage	1
	Remove surface drainage containment	1
	Remove in-water/shoreline structures	1
	Water transfers and discharge	1
	Construct fish habitat as per Fish Habitat Compensation Plan	1
On-land Decommissioning	Remove site pads (blasting, earth moving, loading, hauling, dumping)	1
Post Closure:		
On-land Decommissioning	Management of restored site	0

Category 1 activities are those having an interaction with the aquatic environment; however, based on past experience and professional judgment, the resulting effect can be managed to acceptable levels through standard operating practices and/or through the application of best management or codified practices. No further assessment is warranted.

Category 2 activities are those activities that do interact with the aquatic environment and the resulting effect may exceed acceptable levels without implementation of specified mitigation. Further assessment of the effects of these interactions on the aquatic environment is warranted and is presented in this environmental assessment report.

CONSTRUCTION:

Construction of Freshwater Diversions and Site Drainage Containment Systems; Site Clearing and Pad Construction

During the Project construction phase, land clearing and earth moving will be carried out to prepare areas for mine and mill site infrastructure development. This work will include diverting existing surface drainage systems, as well as excavating mine pits and pads for storage of mine rock and ore. Soil disturbance will also occur as a component of developing other mine infrastructure such as the ore haul road between the Kiggavik and Sissons Mine Sites, the access roads to the water intake locations and effluent discharge point, and the airstrip. All Project activities involving land clearing or earth movement have the potential to increase surface water runoff and cause soil erosion into adjacent waterbodies. To reduce these effects, best management practices have been incorporated into the Project design to control surface water runoff and minimize the potential for erosion. For example, watercourses diverted away from the mine site development areas are reconnected to the same drainage system, but at a location downstream of the mine site. Diversion channels will also incorporate sedimentation ponds to settle any suspended sediments prior to release back into the environment.

No long term or large-scale changes to surface water quality are anticipated; therefore, this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects.

FINAL-CLOSURE:

Removal of Freshwater Diversions and Site Drainage Containment Systems; Pad Removal

Surface water runoff and erosion effects at Project closure are expected to be similar to those described for the Project construction period. No long term or large-scale changes to surface water quality are anticipated; therefore, this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects.

CONSTRUCTION:

Construction of In-Water/Shoreline Structures

Installation of water intake structures and connecting water intake lines in Mushroom and Siamese Lakes, and the effluent diffuser structure(s) and effluent discharge line(s) in Judge Sissons Lake are likely to result in some disturbance to the lake bottom sediments with accompanying increases in turbidity and total suspended solids (TSS) levels in the water. Similar, but reduced effects are also expected during the Project final-closure phase when the water intake and effluent diffuser structures are removed.

The increases in turbidity/TSS released during the installation of the water intake structures and connecting water intake lines, and the effluent diffuser structure(s) and effluent discharge line(s), will be kept to acceptable levels by using a turbidity curtain to separate the installation/construction activities from the surrounding lake environment. Water quality in the vicinity of the construction activity will be monitored during installation of the water intake and effluent diffuser structures, and preventative actions taken if turbidity/TSS levels approach a pre-determined threshold. If turbidity readings were to exceed the threshold level, all construction activities would stop until a more effective construction method could be instituted. Because these interactions are limited in areal extent, are of short duration, can be mitigated by use of a turbidity curtain, and will be monitored closely, they are ranked as Category 1 interactions and are not carried forward to the detailed analysis of residual effects.

FINAL-CLOSURE:

Removal of In-Water/Shoreline Structures

Removal of water intake structures and connecting water intake lines, and effluent diffuser structure(s) and effluent discharge line(s) will result in similar disturbances to lake bottom sediments and surrounding water quality as resulted during construction and installation of the in-water structures. However, the disturbance effects are likely to be of smaller magnitude and shorter duration than those associated with the construction and installation of the in-water/shoreline structures. The anticipated project-environment interactions will be limited in areal extent and will be of short duration. Because in-water structure removal can be effectively mitigated using turbidity curtains and turbidity monitoring during the removal process, this activity is ranked as a Category 1 interaction and is not carried forward to the detailed analysis of residual effects.

CONSTRUCTION:

Water Transfers and Discharge

In order to begin development of the Andrew Lake Pit, a dyke will be constructed across the east end of Andrew Lake and that portion of Andrew Lake dewatered. Construction of the dyke and dewatering the east section of Andrew Lake will result in increased turbidity and TSS levels in the water. The increases in turbidity/TSS released to the downstream environment will be kept to acceptable levels by using a turbidity curtain to separate the dyke construction activity from the larger western portion of Andrew Lake. Water quality will be monitored during dyke construction and actions taken if turbidity/TSS levels approach an unacceptable, pre-determined threshold. If turbidity readings exceed the threshold level, all construction activities will stop until a more effective construction method can be instituted.

Following dyke construction, the east portion of Andrew Lake will be dewatered by pumping it into the larger, remaining portion of Andrew Lake. Pumping will only take place once turbidity levels in that portion of the lake have fallen below the established threshold level. If turbidity levels are too high to allow discharge into the downstream environment, the water will be treated as part of mine water effluent treatment. Because water quality effects on the downstream environment will be small in magnitude and short lived in duration, this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects on water quality.

FINAL CLOSURE:

Water Transfers and Discharge

During the final closure phase, water will be pumped from Judge Sissons Lake to flood the Andrew Lake Pit. Pumping is expected to completely fill the pit in four years if pumping takes place at a rate of 1 m^3/second during the open water period each year (mid-June through mid-September). This rate of pumping (1 m^3/sec) represents less than 3% of the average annual peak flow. Once the Andrew Lake Pit is full, the water quality of the pit water will be assessed. If the water quality meets surface water quality objectives (SWQO) then the dyke separating the Andrew Lake Pit and Andrew Lake could be breached to reconnect the two water bodies. If Andrew Lake Pit water quality does not meet SWQO then the dyke separating the two waterbodies will be maintained. Because there will be no water quality effects on the downstream environment (the Andrew Lake drainage system), this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects on water quality.

OPERATION:

Mining Ore; Mining Mine Rock; Truck Transportation; General Project-Related Traffic

Air emissions and dust deposition from vehicle and heavy equipment operation, and from blasting, loading, and hauling mine ore and mine rock during the operations phase of the Project has the potential to affect surface water quality. Minor changes in Total Suspended Solids (TSS) are anticipated from the deposition of dust that settles on LAA vegetation in summer and fall, and snow in winter, being carried into lakes and streams along with spring snowmelt. Although increases in TSS are expected to be small in magnitude and short lived in duration, this project-environment interaction is being carried forward for more detailed analysis to confirm whether there will be residual effects on water quality. In addition, components in wind-borne dust and air emissions from mining have the potential to acidify poorly buffered Arctic surface waters. Because air emission and dust deposition may interact with the aquatic environment, and the resulting effect may exceed acceptable levels without implementation of specified mitigation, further assessment of the potential effects of these interactions on water quality is warranted. This environmental assessment is presented in this report.

OPERATION:

Mine Dewatering; Collection of Site and Stockpile Drainage; Water and Sewage Treatment

Water removed from the pits and underground mine workings, as well as water collected from site and stockpile drainage, will be used in the mill as process water, or sent to the Kiggavik or Sissons Water Treatment Plants (WTP) and processed to meet required standards before being released to the environment. Domestic sewage will also be treated to meet required standards before being released to the environment. Because no mine water, site and stockpile drainage waters, or sewage wastes will be released to the environment without having been treated in the WTP, this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects on water quality.

OPERATION:

Discharge of Treated Effluents

Treated effluent discharge from the Kiggavik and Sissons Water Treatment Plants (WTP) may affect surface water quality. The potential change in the concentrations of water quality constituents due to effluent release from the WTP will be examined. The particular focus is on treated effluent discharges to Judge Sissons Lake for the extended 25 year operating period. Because the treated effluent discharge may interact with the aquatic environment, and the resulting effect may exceed acceptable levels, further assessment of the potential effects of these interactions on water quality is warranted. This environmental assessment is presented in this report.

FINAL CLOSURE:

Discharge of Treated Effluents

During the final closure phase of the Project, there will be an ongoing requirement for water withdrawal, and effluent treatment and discharge (including domestic wastewater). The quality of site drainage and runoff waters will necessitate treatment before it can be discharged to the environment. Water treatment may be required for a number of years before the quality of untreated site drainage and runoff reaches a level where it can be allowed to flow directly into natural receiving waters. This environmental assessment is presented in this report.

8.1.2 Indicators and Measurable Parameters

In assessing Project effects on surface water quality, four measurable parameters were selected: (1) physical properties of water such as temperature and concentrations of total suspended solids; (2) major ions and nutrient concentrations; (3) total and dissolved metals concentrations; and (4) concentrations of radionuclides (Table 8.2-1). Changes in any of these measurable parameters provide a direct method of quantifying project effects on water quality. Sufficient baseline water quality information is available for lakes in the LAA to confidently estimate potential effects through these measurable parameters.

Table 8.1-2 Measurable Parameters for Water Quality

Environmental Effect	Measurable Parameter	Notes or Rationale for Selection of the Measurable Parameter
Change in Water Quality	• Physical properties (e.g., temperature, turbidity/total suspended solids) • Major ions and nutrients • Total and dissolved metals • Radionuclides	The physical properties of water (e.g., temperature, TSS/turbidity), and major ion, nutrient, total and dissolved metals, and radionuclide concentrations strongly influence the abundance and distribution of aquatic organisms and fish in the receiving environment.

8.1.3 Residual Environmental Effects Criteria

General descriptions of residual environmental effects criteria are presented in Section 4.6 and apply to effects on water quality. However, more specific descriptions apply to the magnitude of residual environmental effects for water quality.

For some water quality parameters, magnitude is defined as the amount of change in a parameter relative to the natural range of variability found in the undisturbed existing environment baseline (e.g., temperature, turbidity measurements). Thus, a high magnitude is defined as a change in water temperature relative to background levels, of more than 5 degrees Celsius. A medium magnitude change in water temperature would be in the order of 3 or 4 degrees C. Changes in water temperature less than 3 degrees C would be considered to be small in magnitude. Changes in water temperature greater than 5 degrees C can influence the timing of fish spawning migrations, and affect the vigour and health of juvenile fish populations and other aquatic biota.

For turbidity, total suspended solids (TSS) levels that exceed 150 mg/l would be considered to be of high magnitude. TSS levels less than 75 mg/l are considered to be small in magnitude. Medium magnitude levels of TSS are between 75 and 150 mg/l. A TSS value of 150mg/L is often used as the threshold beyond which in-water construction projects are stopped in order to find ways to complete the project with reduced levels of disturbance. For other water quality parameters (e.g., dissolved metals), magnitude is defined by whether measured values exceed a threshold value such as those contained in the Canadian Council of Ministers of the Environment's (CCME) Canadian Water Quality Guidelines (CWQG).

8.1.4 Standards or Thresholds for Determining Significance

Under the NIRB Project Specific Guidelines the environmental assessment must include a determination of the significance of environmental effects. Threshold criteria or standards for determining the significance of environmental effects were identified for each VEC, beyond which a residual environmental effect would be considered significant. Where available, these were selected in consideration of federal and territorial regulatory requirements, standards, objectives, or guidelines applicable to the VEC.

The significance of changes in water quality parameters is determined by the user of the water resource. Thus, the determination of significance of changes to water quality, should they occur, is included in the evaluation of effects on Vegetation, Wildlife, Aquatic Resources, Human and Ecological Health, Land Use and Traditional Land Use. The effects of the Project on water quality are assessed in terms of their consequence, evaluated by comparing measured values with established water quality guidelines. Table 8.1-3 provides a summary of the water quality guidelines used in the assessment. These values were obtained from the CCME and are based on the protection of aquatic life; the impact of water quality on human health (i.e. via drinking water) is assessed in Volume 8. A low consequence is one in which the changes to water quality are not expected to affect water users. A high consequence is one in which the changes are expected to affect users.

Table 8.1-3 Summary of Water Quality Guidelines Used in Assessment

Constituent	Units	Value	Source
Arsenic	µg/L	5	CWQG
Cadmium	µg/L	0.017	CWQG – The guideline is hardness dependent, the value provided is the historical CCME guideline for low hardness conditions and is based on a hardness of 48.5 mg/L
Cobalt	µg/L	-	
Copper	µg/L	2	CWQG – The guideline is hardness dependent, the value provided is the historical CCME guideline for low hardness conditions and is valid for hardness range of 0 to 100 mg/L
Lead	µg/L	1	CWQG – The guideline is hardness dependent, the value provided is the historical CCME guideline for low hardness conditions and is valid for hardness range of 0 to 50 mg/L
Molybdenum	µg/L	73	CWQG
Nickel	µg/L	25	CWQG – The guideline is hardness dependent, the value provided is the historical CCME guideline for low hardness conditions and is valid for hardness range of 0 to 20 mg/L
Selenium	µg/L	1	CWQG
Uranium	µg/L	15	CWQG
Zinc	µg/L	30	CWQG
Ammonia (un-ionized)	mg/L	0.019	CWQG
Chloride	mg/L	-	
Sulphate	mg/L	-	
TDS	mg/L	-	
Hardness	mg/L	-	
Thorium-230	Bq/L	-	
Radium-226	Bq/L	-	
Lead-210	Bq/L	-	
Polonium-210	Bq/L	-	

Note:

For those constituents of potential concern (COPC) with no water quality objective, an assessment of the potential effect is made based on the change from baseline as well as comparison to values that are protective of aquatic biota (see Sections 10 and 11).

CWQG Canadian Water Quality Guideline for the Protection of Aquatic Life (CCME 2011)

µg/L = micrograms per litre; Bq/L = Bequerels per litre; mg/L – milligrams per litre

8.2 EFFECTS ASSESSMENT FOR WATER QUALITY

The effect of the Project on the Water Quality VEC is the initiation of changes in water quality. This effect is assessed in the following section.

8.2.1 Assessment of Changes in Water Quality Due to Effluent Discharge

The potential change in water concentrations due to effluent release from the WTP will be examined. The particular focus is on Judge Sissons Lake.

8.2.1.1 Analytical Methods for Changes in Water Quality Due to Effluent Discharge

Treated effluent discharge from the Kiggavik and Sissons Water Treatment Plants (WTP) may affect surface water quality. Parameters in water that were identified as constituents of potential concern (COPC) include: ammonia, chloride, sulphate, radionuclides (U-238, Th-230, Ra-226, Pb-210, and Po-210), and select metals (arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, and zinc). Detailed modelling of concentration of these COPC in the receiving environment, Judge Sissons Lake (JSL), was completed using the LAKEVIEW model. The LAKEVIEW dispersion model has been applied to several other uranium mining projects in northern Saskatchewan to simulate constituent transport and concentrations in the aquatic environment. For this application, the LAKEVIEW model was modified to simulate the effects of extensive ice cover on Judge Sissons Lake (on the order of 2m thick) as well as the effects of prolonged periods (up to 8 months in any year) with no flow. Important processes incorporated into the LAKEVIEW model include horizontal (lateral) and vertical transport of dissolved species, chemical and biochemical reactions in the sediment and in the water column, settling of particulate matter, and sediment exchange processes. LAKEVIEW incorporates a detailed computational protocol for estimating the flux of dissolved chemical species in and out of the sediment together with chemical reactions (reduction or oxidation) and solid phase and solid solution partitioning along with conventional sorption equilibrium. A detailed description of the LAKEVIEW module and its application to this project is provided in Appendix 8A.

Where possible, site-specific data or data reported for similar environments (e.g. northern Saskatchewan) were used to characterize inputs to the LAKEVIEW model. These inputs include baseline water and sediment quality in the Kiggavik Project area and water-to-sediment distribution coefficients for estimation of constituent concentrations in sediment resulting from changes in concentrations in the water column of affected waterbodies.

Although different discharge locations and duration of release were examined, the bounding scenario carried through the assessment was based on separate discharges from the Kiggavik water treatment plant and Sissons water treatment plant, an extended operating period (25 years) followed by a 22-year period of consolidation where water treatment would be required. The assessment accounted for the uncertainty and variability in the emissions and the behaviour in the environment.

Tables 8.2-1 through 8.2-3 summarize the water quality distributions assumed to characterize the Kiggavik WTP, Sissons WTP, and Kiggavik Reverse Osmosis (RO) effluent, respectively. Figures 8.2-1 through 8.2-3 present the assumed monthly flows for the selected bounding scenario.

Table 8.2-1 Effluent Concentration Distributions for Kiggavik WTP Discharge

COPC	Lognormal Distribution Descriptors (mg/L or Bq/L)			
	Geometric Mean (GM)[a]	Geometric Standard Deviation (GSD)[b]	Minimum (-3 GSD)	Maximum (+3 GSD)
Uranium	0.002	2.24	0.0002	0.02
Thorium-230	0.011	2.05	0.0013	0.10
Lead-210	0.052	1.54	0.014	0.19
Radium-226	0.008	2.53	0.0005	0.13
Polonium-210	0.007	2.10	0.0007	0.06
Arsenic	0.021	1.76	0.004	0.11
Cadmium	0.007	1.44	0.0023	0.02
Cobalt	0.007	2.12	0.0007	0.07
Copper	0.002	2.41	0.0001	0.02
Lead	0.002	2.63	0.0001	0.04
Molybdenum	0.2	1.75	0.038	1.1
Nickel	0.02	1.57	0.005	0.08
Selenium	0.01	1.28	0.0047	0.02
Zinc	0.003	2.06	0.0003	0.03
Ammonia	17.3	1.36	6.9	44
Calcium	470	1.29	219	1010
Chloride	237	1.49	71	792
Sulphate	2199	1.29	1027	4708
TDS[c]	3115	1.31	1373	7068

Note: a - GM from predicted Kiggavik WTP data, if not specified. Kiggavik WTP values provided by AREVA were assumed to be geometric mean values for the distributions.

b – GSDs preferentially selected from Key Lake data (4/2009-9/2010) for uranium, radium-226, arsenic, copper, molybdenum, nickel, selenium, and ammonia. GSDs from McClean (2011) for the JEB WTP (future quality) were used in the absence of other data for thorium-230, lead-210, polonium-210, cadmium, cobalt, lead, zinc, chloride, sulphate, and TDS.

c – TDS calculated as the sum of the anions and cations (as available).

Table 8.2-2 Effluent Concentration Distributions for Sissons WTP Discharge

COPC	Lognormal Distribution Descriptors (mg/L or Bq/L)			
	Geometric Mean (GM)[a]	Geometric Standard Deviation (GSD)[b]	Minimum (-3 GSD)	Maximum (+3 GSD)
Uranium	0.034	2.24	0.003	0.38
Thorium-230	0.19	2.05	0.022	1.64
Lead-210	0.59	1.54	0.16	2.17
Radium-226	0.10	2.53	0.006	1.62
Polonium-210	0.17	2.10	0.018	1.58
Arsenic	0.018	1.76	0.003	0.10
Cadmium	0.0001	1.44	0.00004	0.0004
Cobalt	0.0003	2.12	0.00003	0.003
Copper	0.001	2.41	0.00007	0.014
Lead	0.0005	2.63	0.00003	0.009
Molybdenum	0.085	1.75	0.016	0.46
Nickel	0.001	1.57	0.0003	0.005
Selenium	0.004	1.28	0.002	0.008
Zinc	0.014	2.06	0.002	0.12
Ammonia	3.1	1.36	1.24	7.86
Calcium	336	1.29	157	721
Chloride	846.6	1.49	254	2825
Sulphate	167.0	1.29	78	357
TDS[c]	1528	1.31	673	3466

Note: a - GM from predicted Kiggavik WTP data, if not specified. Kiggavik WTP values provided by AREVA were assumed to be geometric mean values for the distributions.

b – GSDs preferentially selected from Key Lake data (4/2009-9/2010) for uranium, radium-226, arsenic, copper, molybdenum, nickel, selenium, and ammonia. GSDs from McClean (2011) for the JEB WTP (future quality) were used in the absence of other data for thorium-230, lead-210, polonium-210, cadmium, cobalt, lead, zinc, chloride, sulphate, and TDS.

c – TDS calculated as the sum of the anions and cations (as available).

Table 8.2-3 Effluent Concentration Distributions for Kiggavik RO Discharge

COPC	Lognormal Distribution Descriptors (mg/L or Bq/L)			
	Geometric Mean (GM)[a]	Geometric Standard Deviation (GSD)[b]	Minimum (-3 GSD)	Maximum (+3 GSD)
Uranium	0.0003	2.25	0.00003	0.003
Thorium-230	0.002	2.05	0.0002	0.02
Lead-210	0.005	1.54	0.001	0.02
Radium-226	0.013	2.42	0.0009	0.19
Polonium-210	0.002	2.10	0.0002	0.02
Arsenic	0.001	1.60	0.00025	0.00
Cadmium	0.0003	1.44	0.0001	0.001
Cobalt	0.0003	2.12	0.0000	0.003
Copper	0.0004	2.04	0.00005	0.003
Lead	0.0002	2.63	0.00001	0.004
Molybdenum	0.03	1.69	0.006	0.13
Nickel	0.001	2.31	0.0001	0.01
Selenium	0.001	2.42	0.000071	0.0142
Zinc	0.0001	2.28	0.00001	0.001
Ammonia	1.11	1.63	0.254	4.84
Calcium	1.06	1.29	0.494	2.28
Chloride	1.0	1.49	0.300	3.34
Sulphate	5.2	1.29	2.4	11.2
TDS[c]	11	1.31	4.7	24.0

Note: a - Kiggavik RO values provided by AREVA were assumed to be geometric mean values for the distributions. The ammonia GM value from the Midwest RO.

b – GSDs from McClean (2011) for the JEB WTP (future quality) for all but nickel. The GSD for nickel was based on the Midwest RO GSD due to high variability in the JEB WTP.

c – TDS calculated as the sum of the anions and cations (as available).

Figure 8.2-1 Assumed Flow Distributions for the Kiggavik WTP

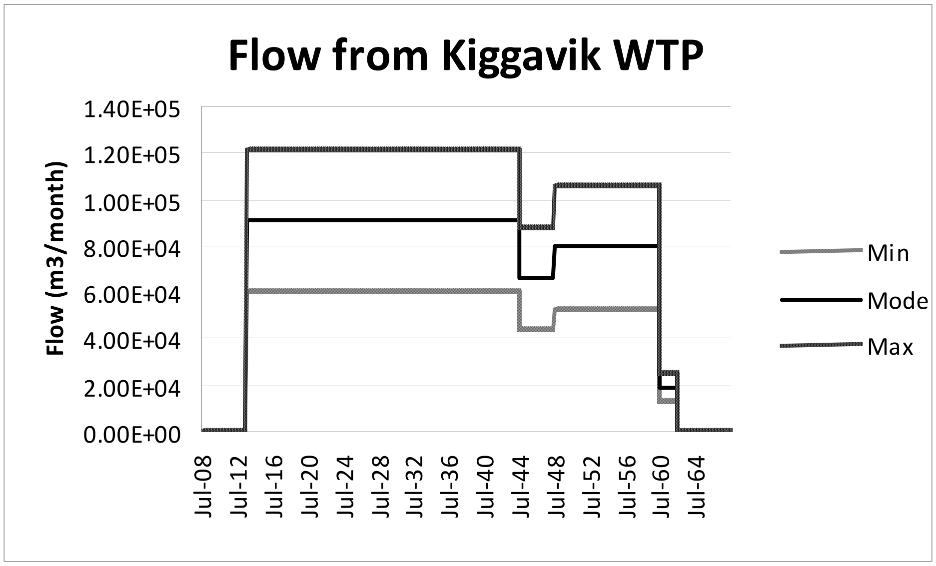


Figure 8.2-2 Assumed Flow Distributions for the Sissons WTP

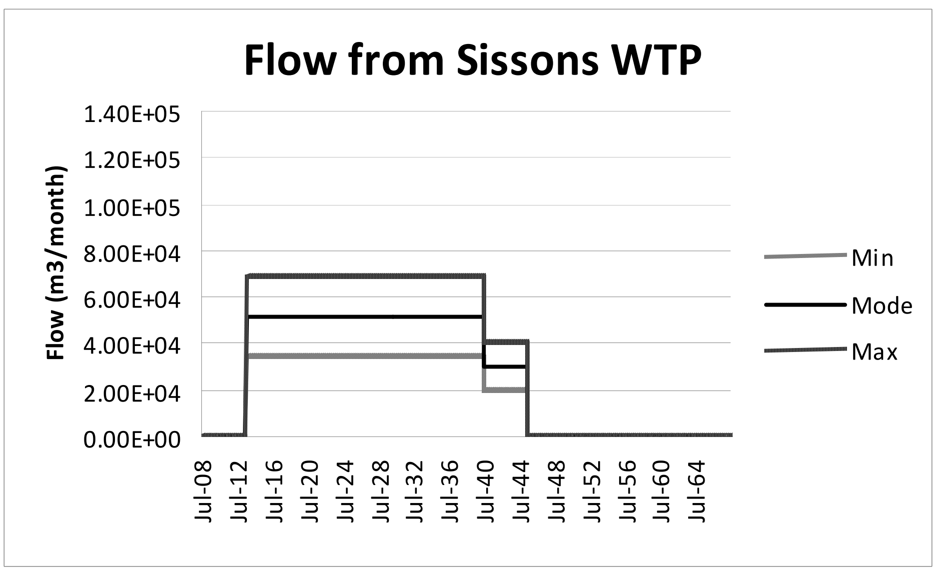
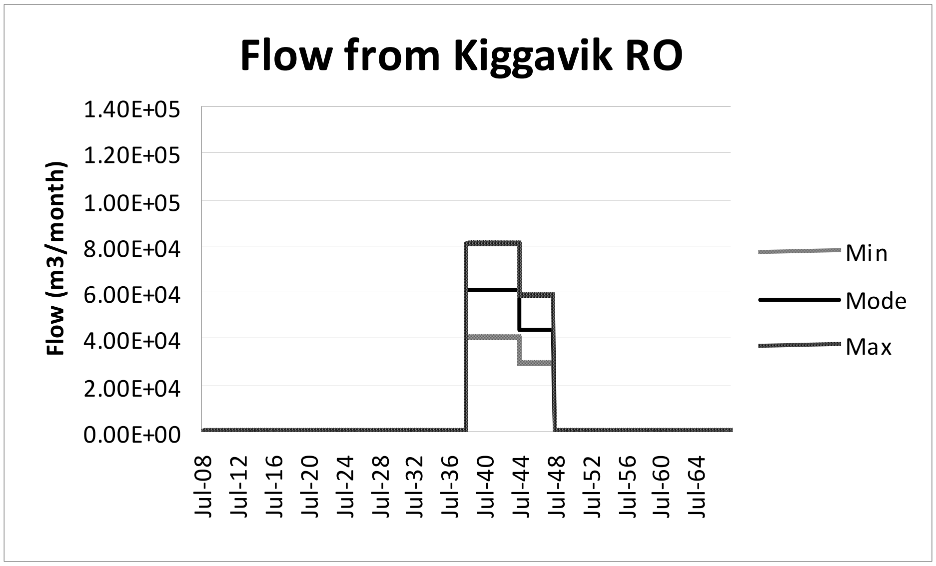


Figure 8.2-3 Assumed Flow Distributions for the Kiggavik RO



Treated effluent discharge from the Kiggavik and Sissons Water Treatment Plants (WTP) may affect surface water quality. Changes in surface water affect the sediment through processes such as deposition of settling solids, adsorption and diffusion.

The potential effects of the Project on water and sediment quality were assessed using the LAKEVIEW dispersion model. This is described in detail in Volume 8.

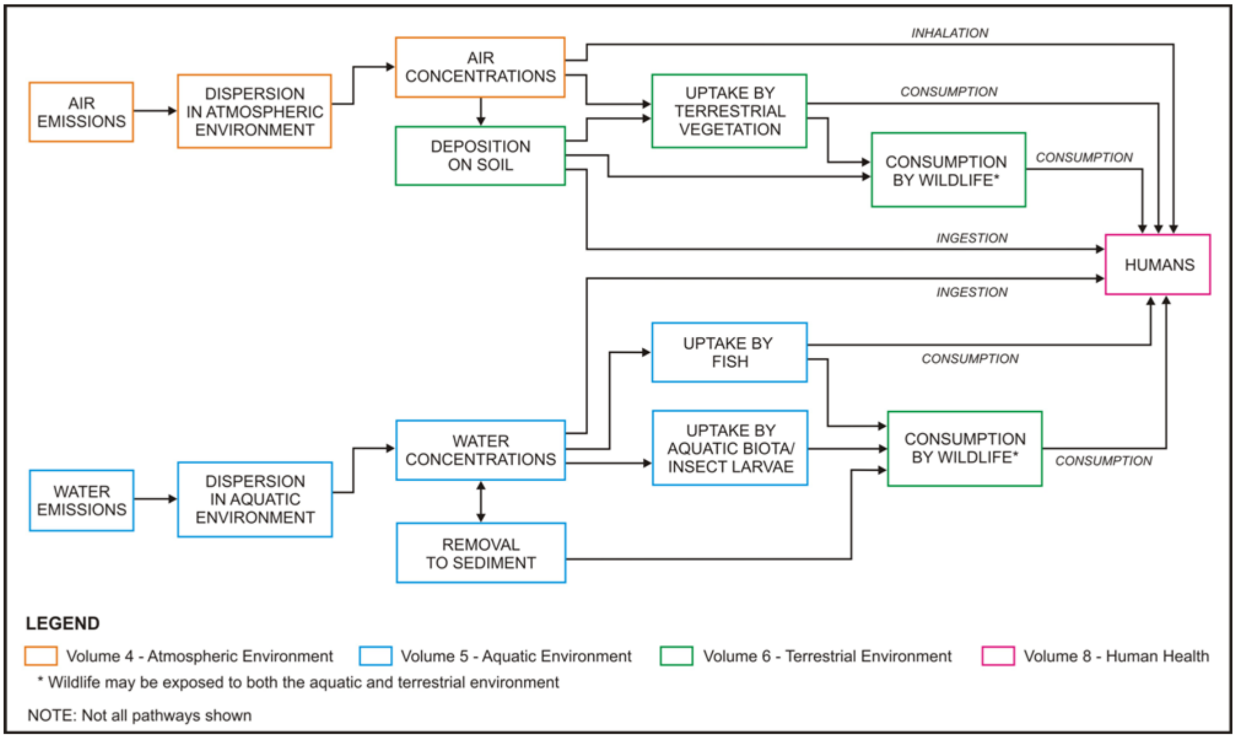
8.2.1.2 Baseline Conditions for Changes in Water Quality Due to Effluent Discharge

Baseline water quality in the area is good, characterized by low-hardness water. Section 5.3 provides a summary of the data collected from the baseline monitoring program. Compared to available guidelines, all samples were below the water quality guidelines for arsenic, nickel, selenium, uranium, and zinc. The majority of the data for copper and lead were below the water quality objectives as the upper 95th percentile concentration was at or below the applicable guideline. The assessment of baseline water quality for cadmium is complicated as the analytical detection limit reported by the laboratory is generally above the water quality guideline, although it is noted that cadmium had been detected a number of times at a concentration of 0.1 µg/L which is above the water quality guideline.

8.2.1.3 Effect Mechanism and Linkages for Changes in Water Quality Due to Effluent Discharge

The release of COPC from the WTP can affect water quality in the receiving environment. Changes in water quality can affect the concentration of COPC in sediment. The quality of the water is critical for evaluating the potential effect on aquatic biota. The linkages between water quality and other environmental compartments are illustrated in Figure 8.2-4. The effect on water quality will change with different phases of the project (e.g., operational period, closure). In the post-decommissioning period the recovery of the system can be predicted.

Figure 8.2-4 Linkages Between Water Quality and Other Environmental Components



8.2.1.4 Mitigation Measures and Project Design for Changes in Water Quality Due to Effluent Discharge

The Kiggavik water treatment plant has two effluent streams; RO permeate and chemical water treatment plant effluent. During operation, it is expected that the RO permeate will be recycled to the mill for use in mill process. The preferred water treatment option at Sissons is a 3-stage chemical water treatment plant. The design of the WTP was such to provide an effluent that met or exceeded all appropriate regulations such as the Metal Mining Effluent Regulation (MMER) as well as site-specific discharge limits. Environmental considerations were paramount in the selection of the appropriate technology for the WTP. Further detail on the design of the water treatment plant can be found in Volume 2.

8.2.1.5 Residual Effects for Changes in Water Quality Due to Effluent Discharge

To examine the implication of the two discharge locations on Judge Sissons Lake, the lake was divided into eight segments (Figure 8.2-5). The model takes into account the effects of ice formation on the concentrations of the COPC in both the water column and in sediments. Ice thickness of 2 m is typical in the study area and ice cover typically lasts 8 to 9 months per year. JSL-1 is shallow (average depth of 1.4 m) and therefore, there is very little free-flowing water in the winter months below the ice cover. The deepest segment is JSL-4 with an average depth of 8 metres.

Figure 8.2-5 Judge Sissons Lake

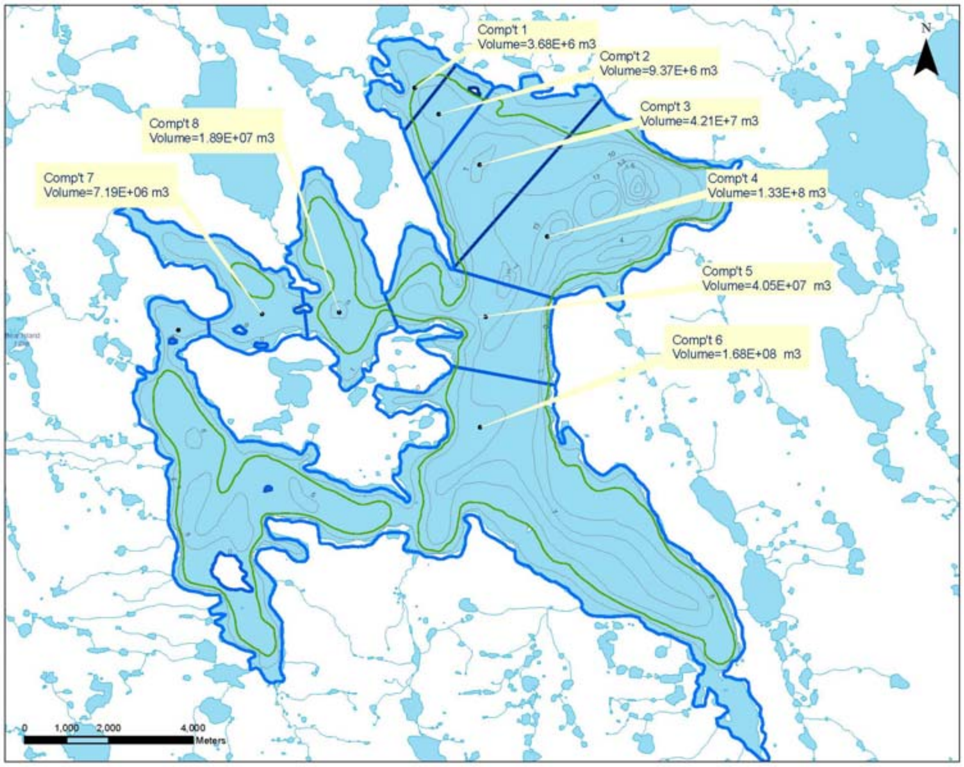


Figure 8.2-5 presents the monthly predicted water concentrations in the eight segments of Judge Sissons Lake for the bounding effluent release scenario. The four phases of effluent release are indicated on the figures: baseline conditions (pre-operation), operation phase, final closure phase, and post-closure phase.

The baseline results provide the water quality in each segment under natural conditions and the impact of the winter ice cover is evident in this phase of the simulation. Comparison of the range of concentrations in the baseline phase among the various Judge Sissons Lake segments illustrates the effect of the ice cover on the different segments. For example, JSL-1 is shallow compared with JSL-4 and, therefore, there is much fluctuation between the summer and winter concentrations in JSL-1 (for uranium, from 0.1 to 0.5 μg/L) compared with concentrations in JSL-4 (for uranium, from 0.1 to 0.12 μg/L).

The operation phase show the predicted water quality results under the assumed effluent release for the extended operation, which considers discharge of the Kiggavik WTP to JSL-2 and Sissons WTP to JSL-8. The effluent is distributed throughout Judge Sissons Lake by natural flow processes and horizontal dispersion. Figure 8.2-5 illustrates the range of predicted water concentrations in each of the Judge Sissons Lake segments during the operation phase. Comparison of the baseline phase with the operation phase gives an indication of which COPC in the effluent have more of an impact on the Judge Sissons Lake segments. For example, comparison between the baseline and operation phase concentrations of uranium at JSL-1 shows that uranium in the effluent discharge creates a noticeable difference, while concentrations of thorium-230 are essentially the same between the two phases.

The final closure phase represents the predicted water quality under the bounding case decommissioning scenario with 22-years of Main Zone consolidation. Figure 8.2-5 shows that water quality is predicted to return to slightly elevated levels above baseline as effluent releases are gradually decreased through this phase. The system responds quickly to changes in the effluent release scenario.

Finally, the post-closure phase shows the recovery of predicted water quality for Judge Sissons Lake after effluent releases have stopped. Again, the system responds quickly and returns to baseline/pre-operation conditions, and the water effluent scenario assessed for the Project does not have long-term impacts on the water quality of Judge Sissons Lake.

The associated water quality guidelines are indicated on the graphs. For arsenic, lead, molybdenum, nickel, selenium, zinc, and un-ionized ammonia, which have applicable with water quality guidelines, the predicted concentrations of were below the guidelines in all segments of Judge Sissons Lake. Copper concentrations in JSL-1 and JSL-7 are predicted to exceed the CWQG. However, this is predicted to occur during the winter in the shallow segments and the Project has no influence on the copper concentrations in Judge Sissons Lake.

For cadmium, predicted concentrations in water exceed the Canadian Water Quality Guideline (CWQG) of 0.017 µg/L at all points of the assessment. Effluent discharge does have an influence on cadmium concentrations in water; however the baseline cadmium concentrations were taken to be at half of the detection limit of 0.1 µg/L, which is already above the CWQG.

For those COPC with no applicable guideline, a comparison can be made between the timeframe of the Project release and baseline conditions. As seen from Figure 8.2-5, the levels of the radionuclides (thorium-230, radium-226, lead-210 and polonium-210) are not expected to be affected by the Project when compared to baseline levels. The only metal that does not have an applicable CWQG guideline is cobalt. The Project is not expected to have a large influence on the cobalt levels in Judge Sissons Lake and the concentrations remain below the objective set by the British Columbia Ministry of Environment based on protection of aquatic life in the freshwater environment of 4 µg/L (BC MOE 2011a). No CWQG are available for the other COPC that describe the general water quality, namely sulphate, chloride and TDS. It is noted that the chloride concentrations remain below the objective set by the British Columbia Ministry of Environment based on protection of aquatic life in the freshwater environment of 150 mg/L (BC MOE 2011b). There are no appropriate guidelines available to compare the concentrations of sulphate and TDS (BC MOE indicates that the current sulphate guideline is currently being updated) thus the assessment of residual and significant effect of these COPC will be completed with respect to effects on aquatic biota. Hardness is not a COPC but is carried through the assessment to be used in the interpretation of potential effects on aquatic biota. Based on the results above, a residual effect with respect to cadmium levels in water quality has been identified.

8.2.1.6 Determination of Significance for Changes in Water Quality Due to Effluent Discharge

A residual effect was identified with respect to cadmium water quality based on a comparison to CWQG. A more detailed assessment of this affect was therefore undertaken to determine its significance.

The CWQG for cadmium provided by CCME is consistent with that presented in previous documents (CCME 1996). A more recent assessment of the aquatic toxicity information was considered in the evaluation of a water quality criterion for cadmium by the US EPA (2001). The US EPA developed a hardness-dependent criteria based on an assessment of the complete database of information. As discussed previously, due to the presence of the ice cover in Judge Sissons Lake there is expected to be fluctuation concentrations during the year. This was examined for JSL-1 which is a shallow segment directly adjacent to the Kiggavik WTP discharge location and JSL-4 a larger segment that represents the outflow from the lake. Table 8.2-4 provides the estimated hardness; the calculated criterion following the EPA approach; and, the estimated cadmium concentration for JSL-1 and JSL-4 separately for the summer and winter periods.

Table 8.2-4 Summary of Cadmium Water Concentrations and Appropriate Criteria for the Summer and Winter Periods

	Estimated Hardness (mg/L)	Calculated Cadmium Water Quality Criterion[(a)] (µg/L)	Estimated Cadmium Concentration in Water[(b)] (µg/L)
JSL-1			
Summer	13	0.06	0.07
Winter	115	0.27	0.44
JSL-4			
Summer	20	0.08	0.086
Winter	176	0.36	0.25

Note:
Water quality criterion calculated following the approach adopted by the US EPA
Concentrations include baseline level of <0.1 µg/L (taken to be 0.05 µg/L during the summer)

Table 8.2-5 Application of Residual Effects Criteria for Water Quality

Attribute	Description	Rating	Comment
Direction	The ultimate long-term trend of the environmental effect	Adverse	Levels of COPC are expected in increase due to Project emissions
Magnitude	Amount of change in a measurable parameter relative to the baseline case or relative to a threshold	Medium	It is expected that cadmium concentrations in Judge Sissons Lake would be elevated compared to baseline and may exceed the appropriate threshold. Other COPC are not expected to be present at levels that exceed a threshold. Cadmium is expected to be within a factor of 2 compared to the appropriate criterion (see Table 8.2-4)
Geographic Extent	The geographic area within which an environmental effect occurs	Local	Effect confined to the select segments of Judge Sissons Lake.
Frequency	Number of times that an effect may occur over the life of the project	Continuous	Effect occurs continuously throughout the project.
Duration	Length of time over which the effect is measurable	Medium term	More than one year, but not beyond the end of project decommissioning.
Reversibility	Likelihood that a measurable parameter for a VEC will recover from an environmental effect to baseline conditions	Reversible	Will likely recover to baseline conditions in the post closure phase.

As discussed, for those COPC with a threshold, the concentrations are expected to be below the appropriate value with the exception of cadmium. For cadmium, the maximum concentrations within Judge Sissons Lake are expected to be within a factor of 2 of the appropriate threshold. It is noted that baseline levels of cadmium are below detection and depending on the exact level, the concentration change may not be measureable during a summer monitoring program. Other COPC (e.g. sulphate) is expected to change relative to baseline but no appropriate threshold is available. The changes in water quality are expected to occur during the operation and final closure stages of the project but return to baseline levels at post closure. Overall, no significant adverse effects on water quality are expected.

It is also important to note that the significance of changes in water quality parameters is determined by the user of the resource. Thus, the determination of significance of changes to water quality is also included in the evaluation of effects on aquatic biota (Section 10) and fish (Section 11).

8.2.1.7 Compliance and Environmental Monitoring for Changes in Water Quality Due to Effluent Discharge

Wastewater/effluent discharge quality will be analysed and documented regularly according to Nunavut regulatory requirements during mine operations, and during and after mine closure. In addition, water quality in each section of Judge Sissons Lake receiving treated effluent, as well as at the outlet of Judge Sissons Lake, will be monitored on a monthly basis during the operations and closure phases of the Kiggavik Project, and on an annual basis during the post-closure phase.

8.2.2 Assessment of Changes in Water Quality Due to Dust Deposition

The potential change in water quality due to dust deposition from mining ore, special waste and clean rock (blasting, loading and hauling), as well as truck transportation and general project-related traffic will be examined. The particular focus is on local waterbodies near the Kiggavik and Sissons Mine Sites, and along the main haul road between the Sissons Mine Site and the ore processing mill at the Kiggavik site.

8.2.2.1 Analytical Methods for Changes in Water Quality Due to Dust Deposition

A mass balance approach was used to assess the impacts of dust deposition on metal concentrations and total suspended solids (TSS) in waterbodies located in the Minesite LAA and Road LAA of the Kiggavik Project. Dust deposition data for the LAAs were supplied by SENES Consulting Limited. Point estimates of the deposited particulate (Total, PM_{10} and $PM_{2.5}$) and the metals (in the particulate) were provided on a one (1) km grid over most of the Mine LAA, and less frequently along the proposed road alignments in the Road LAA as $\mu g/m^2$/annum. The metals evaluated included arsenic, cadmium, chromium, cobalt, copper, lead, nickel, molybdenum, selenium, uranium and zinc. As well, annual deposition of lead-210 and polonium-210 (by calculation of decay only as Bq/m^2/annum) were provided.

Screening assessments following a mass balance approach were completed using conservative and simplifying assumptions (outlined in detail for each Scenario in Table 8.2-6). The Pointer Lake watershed was used for this preliminary screening as it was quite typical for the area. For determining possible lake concentrations of metals and radionuclides, 50% of the annual deposition in the upstream watershed (based on the maximum deposition rate observed anywhere in the complete data set was applied over the entire watershed of Pointer Lake) and was assumed to report instantaneously to Pointer Lake as the most downstream lake to obtain an instantaneous load (as a mass unit). This load was then conservatively divided by one lake volume of Pointer Lake (with an actual lake residence time of 0.36 years) to determine potential maximum increases above background concentrations. For determining possible maximum potential increases in stream concentrations above background, this same load was divided by 50% of the annual stream discharge at the outlet of Pointer Lake.

To assess possible increases in TSS concentrations in waterbodies in the Mine LAA and Road LAA, a similar approach was used with 50% of the annual dust deposition in the upstream watershed (based on the average deposition rate observed over that entire specific watershed) reporting instantaneously to the most downstream lake to obtain an instantaneous load (as a mass unit). The applicable average annual deposition rate (more realistic but less conservative assumption) in the specific watershed being assessed was applied over the entire watershed, as opposed to the maximum used to calculate the metal and radionuclides loads in a model watershed (i.e., Pointer Lake). As well, the lake residence time was used to calculate a more realistic lake volume available for dilution. For determining possible maximum increases in stream concentrations above background, this same load was divided by 50% of the annual stream discharge.

8.2.2.2 Baseline Conditions for Changes in Water Quality Due to Dust Deposition

For the metals assessed (arsenic, cadmium, chromium, cobalt, copper, lead, nickel, molybdenum, selenium, uranium and zinc), most metals were well below both provincial objectives and federal guidelines in the 2007-2008 sampling (Table 5.3-2). The only exception was lead (0.0026 mg/L on August 27, 2007) in Pointer Lake, however, other sample dates on Pointer Lake were well below the guidelines. The most conservative model applied (Table 8.2-6; Scenario 1), predicted maximum increases of lead to Pointer Lake of 0.00032 mg/L which is less than one third of the guideline of 0.001 mg/L. The more realistic model (Table 8.2-6; Scenario 2) predicted average increases of 0.00002 mg/L which is 50-fold lower than the guideline. Based on the conservative modeling, no changes in the water quality is predicted in the Minesite LAA and Road LAA of the Kiggavik Project beyond the natural variability noted in the area.

8.2.2.3 Effect Mechanism and Linkages for Changes in Water Quality Due to Dust Deposition

Increased dust generated during mine construction and operation could potentially increase particulate and metals deposition in the Minesite LAA and Road LAA of the Kiggavik Project. In turn, this increased atmospheric deposition can report directly and indirectly to the waterbodies and potentially change the water quality of those waterbodies. Changes in water quality have the potential to affect aquatic biota residing in that system.

8.2.2.4 Mitigation Measures and Project Design for Changes in Water Quality Due to Dust Deposition

No specific mitigation measures or Project design changes are required beyond using best management practices for dust control on roads and during the pit mining operation.

8.2.2.5 Residual Effects for Changes in Water Quality Due to Dust Deposition

This screening assessment indicates that metal and radionuclides concentrations in the waterbodies in the Mine LAA and Road LAA are unlikely to exceed any applicable water quality guidelines or objectives, as possible increases are generally ten-fold to 100 fold less than guidelines (Table 8.2-6; Scenario 1). Predicted maximum uranium concentrations were about 1/3 of the guideline level, but based on average values were 40-times lower than the guideline (Table 8.2-6). Based on this conservative assessment, metals and radionuclides are screened out from further assessment.

Predicted TSS concentrations were all generally well below 10 mg/L in the Mine LAA and well below 10 mg/L in the Road LSA (outside of the mine LAA; Table 8.2-6). These minimal increases in TSS would most likely happen during the freshet period (the time of highest background concentrations), and for a very short duration (freshet is from 1 to 2 weeks depending on watershed size).

Also presented are the maximum, average and minimum predicted concentrations for all parameters examined and for all models used. These verify that Scenario 1 is a very conservative approach for screening out the metals and radionuclides (Table 8.2-6).

Table 8.2-6 Screening Assessment Of Dust Deposition(TSP, Metals And Radionuclides) in the Kiggavic Mine And Road Lsas Using A Mass Balance Approach

Scenario 1 -Conservative Assumptions (using as Pointer Lake as the model system)

Assumptions:	Assume up to the Maximum-Predicted deposition rate anywhere in the study area (i.e., close to the mine) and apply it across all of the Pointer Lake watershed. Assume 50% of Lake Basin Annual Deposited Load reports instanaeously to Pointer Lake. Assume only 1 lake volume available for basin load calculated.

				Annual Average Deposition (µg/m²/s)															
				TSP	**PM10**	**PM2.5**	**Arsenic**	**Cobalt**	**Cadmium**	**Chromium**	**Copper**	**Molybdenum**	**Nickel**	**Lead**	**Selenium**	**Uranium**	**Zinc**	**Lead-210 (Bq/m²/s)**	**Polonium-210 (Bq/m²/s)**
			Average	**3.91E-02**	**2.52E-03**	**2.91E-05**	**1.38E-08**	**3.10E-08**	**4.59E-10**	**2.74E-07**	**5.04E-08**	**3.69E-08**	**1.18E-07**	**9.90E-08**	**5.50E-09**	**1.53E-06**	**9.63E-08**	**1.89E-08**	**1.89E-08**
			Maxium	**9.05E-01**	**4.06E-02**	**3.29E-04**	**2.77E-07**	**4.58E-07**	**5.83E-09**	**5.16E-06**	**6.54E-07**	**5.74E-07**	**1.74E-06**	**1.39E-06**	**8.20E-08**	**1.89E-05**	**1.40E-06**	**2.33E-07**	**2.33E-07**
			Minimum	**7.23E-05**	**1.57E-05**	**4.26E-07**	**1.02E-10**	**2.64E-10**	**3.51E-12**	**1.98E-09**	**4.14E-10**	**3.43E-10**	**9.13E-10**	**8.75E-10**	**4.20E-11**	**1.31E-08**	**8.13E-10**	**1.62E-10**	**1.62E-10**
Pointer Lake				(mg/L)	(mg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(Bq/L)	(Bq/L)
Lake Volume	m3	5.47E+06	**Maximum**	206	9.25	0.07	0.06	0.10	0.001	1.18	0.15	0.13	0.40	0.32	0.02	4.30	0.32	0.053	0.053
Basin Area	km2	7.90E+01	**Minimum**	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.037
Retenion Time is 0.36 years			**Average**	8.91	0.57	0.01	0.00	0.01	0.000	0.06	0.01	0.01	0.03	0.02	0.00	0.35	0.02	0.004	0.004
			WQOs CCME				**5**	**4 (BC)**	**0.017**	**8.9**	**2**	**73**	**25**	**1**	**1**	**15**	**30**	**0.2**	**0.2**
							AL	AL	AL	AL as Cr (III)	AL	AL	AL	AL	AL	AL	AL	DW	DW

Scenario 2 - Average Deposition by Lake Watershed for Lake Concentrations

Assumptions:	Assume the Annual Average-Predicted deposition rate for the watershed being examined (given non-linearity of TSP) to determine the annual waterhed load. Assume 50% of Lake Basin Annual Avearge Load reports to most d/s lake in the watershed of interest. Assume lake volumes available for basin load based on actual retention time

					Annual Average Deposition (µg/m²/s)																
Pointer Lake					**TSP**	**PM10**	**PM2.5**	**Arsenic**	**Cobalt**	**Cadmium**	**Chromium**	**Copper**	**Molybdenum**	**Nickel**	**Lead**	**Selenium**	**Uranium**	**Zinc**	**Lead-210 (Bq/m²/s)**	**Polonium-210 (Bq/m²/s)**	
				Average	**5.17E-02**	**3.79E-03**	**3.80E-05**	**8.40E-09**	**5.84E-08**	**5.71E-10**	**3.15E-07**	**8.62E-08**	**8.46E-08**	**1.67E-07**	**1.97E-07**	**7.53E-09**	**2.73E-06**	**1.78E-07**	**3.37E-08**	**3.37E-08**	**Annual Average Deposition (µg/m²/s)**
				Maximum	**4.76E-01**	**3.16E-02**	**1.63E-04**	**5.61E-08**	**4.58E-07**	**3.97E-09**	**2.37E-06**	**6.54E-07**	**5.74E-07**	**1.29E-06**	**1.39E-06**	**5.79E-08**	**1.89E-05**	**1.40E-06**	**2.33E-07**	**2.33E-07**	
				Minimum	**1.11E-02**	**9.38E-04**	**1.00E-05**	**3.03E-09**	**1.53E-08**	**1.67E-10**	**9.06E-08**	**2.36E-08**	**1.90E-08**	**4.68E-08**	**4.73E-08**	**2.12E-09**	**6.73E-07**	**4.67E-08**	**8.31E-09**	**8.31E-09**	
Pointer Lake					(mg/L)	(mg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(Bq/L)	(Bq/L)	
Lake Volume	m3	5.47E+06	1.52E+07	**Maximum**	39	2.59	0.01	0.005	0.04	0.00	0.19	0.05	0.05	0.11	0.11	0.00	1.55	0.11	0.019	0.019	
Basin Area	km2	7.90E+01	7.90E+01	**Minimum**	1	0.08	0.00	0.000	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.001	0.001	
Retention Time	year	0.36		**Average**	**4**	**0.31**	**0.00**	0.001	0.00	0.00	0.03	0.01	0.01	0.01	0.02	0.00	0.22	0.01	0.003	0.003	
				WQOs CCME				**5**	**4 (BC)**	**0.017**	**8.9**	**2**	**73**	**25**	**1**	**1**	**15**	**30**	**0.2**	**0.2**	
								AL	AL	AL	AL as Cr (III)	AL	AL	AL	AL	AL	AL	AL	DW	DW	

Annual Average Deposition (µg/m²/s)																					
Shack Lake					**TSP**	**PM10**	**PM2.5**	**Arsenic**	**Cobalt**	**Cadmium**	**Chromium**	**Copper**	**Molybdenum**	**Nickel**	**Lead**	**Selenium**	**Uranium**	**Zinc**	**Lead-210 (Bq/m²/s)**	**Polonium-210 (Bq/m²/s)**	
				Average	7.38E-02	4.25E-03	4.80E-05	3.89E-08	3.23E-08	8.74E-10	5.69E-07	6.06E-08	1.59E-08	2.02E-07	8.73E-08	9.44E-09	1.86E-06	1.07E-07	2.29E-08	2.29E-08	Annual Average Deposition (µg/m²/s)
				Maximum	9.05E-01	4.06E-02	3.29E-04	2.77E-07	2.49E-07	5.83E-09	5.16E-06	4.83E-07	7.20E-08	1.74E-06	5.80E-07	8.20E-08	1.22E-05	8.68E-07	1.51E-07	1.51E-07	
				Minimum	7.81E-03	6.16E-04	1.03E-05	4.95E-09	6.01E-09	1.32E-10	9.23E-08	1.09E-08	3.98E-09	3.35E-08	1.65E-08	1.58E-09	3.14E-07	1.98E-08	3.88E-09	3.88E-09	
Shack Lake					(mg/L)	(mg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(Bq/L)	(Bq/L)	
Lake Volume	m3	3.60E+05	9.00E+06	Maximum	75	3.36	0.03	0.023	0.02	0.000	0.43	0.04	0.01	0.14	0.05	0.01	1.01	0.07	0.012	0.012	
Basin Area	km2	4.72E+01	4.72E+01	Minimum	1	0.05	0.00	0.000	0.00	0.000	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.000	0.000	
Retention Time	year	0.04		Average	6	0.35	0.00	0.003	0.00	0.000	0.05	0.01	0.00	0.02	0.01	0.00	0.15	0.01	0.002	0.002	
				WQOs CCME				5	4 (BC)	0.017	8.9	2	73	25	1	1	15	30	0.2	0.2	
								AL	AL	AL	AL as Cr (III)	AL	AL	AL	AL	AL	AL	AL	DW	DW	
Annual Average Deposition (µg/m²/s)																					
Boulder Lake					**TSP**	**PM10**	**PM2.5**	**Arsenic**	**Cobalt**	**Cadmium**	**Chromium**	**Copper**	**Molybdenum**	**Nickel**	**Lead**	**Selenium**	**Uranium**	**Zinc**	**Lead-210 (Bq/m²/s)**	**Polonium-210 (Bq/m²/s)**	
				Average	**1.42E-02**	**9.93E-04**	**1.81E-05**	**8.39E-09**	**1.22E-08**	**2.39E-10**	**1.33E-07**	**2.36E-08**	**1.21E-08**	**5.29E-08**	**3.65E-08**	**2.70E-09**	**5.83E-07**	**3.73E-08**	**7.21E-09**	**7.21E-09**	**Annual Average Deposition (µg/m²/s)**
				Maximum	**4.72E-02**	**2.73E-03**	**4.74E-05**	**3.43E-08**	**2.70E-08**	**8.05E-10**	**3.78E-07**	**5.31E-08**	**2.24E-08**	**1.42E-07**	**8.97E-08**	**7.14E-09**	**1.76E-06**	**8.26E-08**	**2.18E-08**	**2.18E-08**	
				Minimum	**7.51E-03**	**6.55E-04**	**1.13E-05**	**3.93E-09**	**9.09E-09**	**1.49E-10**	**8.45E-08**	**1.62E-08**	**9.51E-09**	**3.61E-08**	**2.87E-08**	**1.76E-09**	**4.52E-07**	**2.79E-08**	**5.58E-09**	**5.58E-09**	
Boulder Lake (assume volume was equal to Pointer Lake which has smaller surface area so should be conservative)																					
					(mg/L)	(mg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(Bq/L)	(Bq/L)	
Lake Volume	m3 (?)	5.47E+06	1.52E+07	**Maximum**	3	0.19	0.00	0.002	0.00	0.000	0.03	0.00	0.00	0.01	0.01	0.00	0.12	0.01	0.002	0.002	
Basin Area	km2	6.68E+01	6.68E+01	**Minimum**	1	0.05	0.00	0.000	0.00	0.000	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.000	0.000	
Retention Time	year (?)	0.36		**Average**	**1**	**0.07**	**0.00**	0.001	0.00	0.000	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.000	0.000	
				WQOs CCME				**5**	**4 (BC)**	**0.017**	**8.9**	**2**	**73**	**25**	**1**	**1**	**15**	**30**	**0.2**	**0.2**	
								AL	AL	AL	AL as Cr (III)	AL	AL	AL	AL	AL	AL	AL	DW	DW	

Caribou Lake					TSP	PM10	PM2.5	Arsenic	Cobalt	Cadmium	Chromium	Copper	Molybdenum	Nickel	Lead	Selenium	Uranium	Zinc	Lead-210 (Bq/m^2/s)	Polonium-210 (Bq/m^2/s)	
					Annual Average Deposition (µg/m^2/s)																
				Average	4.60E-02	2.94E-03	3.17E-05	7.98E-09	4.67E-08	4.86E-10	2.68E-07	7.30E-08	6.71E-08	1.37E-07	1.57E-07	6.46E-09	2.14E-06	1.41E-07	2.64E-08	2.64E-08	Annual Average Deposition (µg/m^2/s)
				Maximum	4.76E-01	3.16E-02	1.63E-04	5.61E-08	4.58E-07	3.97E-09	2.37E-06	6.54E-07	5.74E-07	1.29E-06	1.39E-06	5.79E-08	1.89E-05	1.40E-06	2.33E-07	2.33E-07	
				Minimum	8.46E-03	6.84E-04	1.03E-05	3.58E-09	1.00E-08	1.49E-10	8.45E-08	1.79E-08	1.14E-08	3.70E-08	3.07E-08	1.83E-09	4.56E-07	3.05E-08	5.63E-09	5.63E-09	
Caribou Lake					(mg/L)	(mg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(Bq/L)	(Bq/L)	
Lake Volume	m3	4.77E+06	1.54E+07	Maximum	39	2.62	0.01	0.005	0.04	0.000	0.20	0.05	0.05	0.11	0.12	0.00	1.56	0.12	0.019	0.019	
Basin Area	km2	8.09E+01	8.09E+01	Minimum	1	0.06	0.00	0.000	0.00	0.000	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.000	0.000	
Retention Time	year	0.31		Average	4	0.24	0.00	0.001	0.00	0.000	0.02	0.01	0.01	0.01	0.01	0.00	0.18	0.01	0.002	0.002	
				WQOs CCME				5	4 (BC)	0.017	8.9	2	73	25	1	1	15	30	0.2	0.2	
								AL	AL	AL	AL as Cr (III)	AL	AL	AL	AL	AL	AL	AL	DW	DW	

Scenario 3 - Average Deposition by Lake Watershed for Lake Outlet Concentrations

Assuptions:	Assume the Annual Average-Predicted deposition rate determined for the basin being examined. Assume 50% of Lake Basin Annual Load reports to most d/s Lake per annum (and hence its outlet) Assume 50% annual creek volume available volume available diluting for basin load

Pointer Lake Outlet					TSP	PM10	PM2.5	Arsenic	Cobalt	Cadmium	Chromium	Copper	Molybdenum	Nickel	Lead	Selenium	Uranium	Zinc	Lead-210 (Bq/m^2/s)	Polonium-210 (Bq/m^2/s)	
					Annual Average Deposition (µg/m^2/s)																
				Average	5.17E-02	3.79E-03	3.80E-05	8.40E-09	5.84E-08	5.71E-10	3.15E-07	8.62E-08	8.46E-08	1.67E-07	1.97E-07	7.53E-09	2.73E-06	1.78E-07	3.37E-08	3.37E-08	Annual Average Deposition (µg/m^2/s)
				Maximum	4.76E-01	3.16E-02	1.63E-04	5.61E-08	4.58E-07	3.97E-09	2.37E-06	6.54E-07	5.74E-07	1.29E-06	1.39E-06	5.79E-08	1.89E-05	1.40E-06	2.33E-07	2.33E-07	
				Minimum	**1.11E-02**	**9.38E-04**	**1.00E-05**	**3.03E-09**	**1.53E-08**	**1.67E-10**	**9.06E-08**	**2.36E-08**	**1.90E-08**	**4.68E-08**	**4.73E-08**	**2.12E-09**	**6.73E-07**	**4.67E-08**	**8.31E-09**	**8.31E-09**	
Pointer Lake Outlet					(mg/L)	(mg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(Bq/L)	(Bq/L)	
Discharge/yr	m3		1.51E+07	**Maximum**	39.1	2.60	0.013	0.005	0.038	0.000	0.195	0.054	0.047	0.106	0.114	0.005	1.552	0.115	0.019	0.019	
Basin Area	km2		7.90E+01	**Minimum**	0.9	0.08	0.001	0.000	0.001	0.000	0.007	0.002	0.002	0.004	0.004	0.000	0.055	0.004	0.001	0.001	
Mean Annual	m3/s		0.48	**Average**	**4.3**	**0.31**	**0.003**	0.001	0.005	0.000	0.026	0.007	0.007	0.014	0.016	0.001	0.224	0.015	0.003	0.003	
				WQOs CCME				**5**	**4 (BC)**	**0.017**	**8.9**	**2**	**73**	**25**	**1**	**1**	**15**	**30**	**0.2**	**0.2**	
								AL	AL	AL	AL as Cr (III)	AL	AL	AL	AL	AL	AL	AL	DW	DW	

Annual Average Deposition (μg/m^2/s)																					
Shack Lake Outlet					**TSP**	**PM10**	**PM2.5**	**Arsenic**	**Cobalt**	**Cadmium**	**Chromium**	**Copper**	**Molybdenum**	**Nickel**	**Lead**	**Selenium**	**Uranium**	**Zinc**	**Lead-210 (Bq/m^2/s)**	**Polonium-210 (Bq/m^2/s)**	
				Average	7.38E-02	4.25E-03	4.80E-05	3.89E-08	3.23E-08	8.74E-10	5.69E-07	6.06E-08	1.59E-08	2.02E-07	8.73E-08	9.44E-09	1.86E-06	1.07E-07	2.29E-08	2.29E-08	Annual Average Deposition (μg/m^2/s)
				Maximum	9.05E-01	4.06E-02	3.29E-04	2.77E-07	2.49E-07	5.83E-09	5.16E-06	4.83E-07	7.20E-08	1.74E-06	5.80E-07	8.20E-08	1.22E-05	8.68E-07	1.51E-07	1.51E-07	
				Minimum	7.81E-03	6.16E-04	1.03E-05	4.95E-09	6.01E-09	1.32E-10	9.23E-08	1.09E-08	3.98E-09	3.35E-08	1.65E-08	1.58E-09	3.14E-07	1.98E-08	3.88E-09	3.88E-09	
Shack Lake Outlet					(mg/L)	(mg/L)	(mg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(Bq/L)	(Bq/L)	
Discharge/yr	m3		9.15E+06	Maximum	73.6	3.30	0.027	0.023	0.020	0.000	0.420	0.039	0.006	0.141	0.047	0.007	0.995	0.071	0.012	0.019	
Basin Area	km2		4.72E+01	Minimum	0.6	0.05	0.001	0.000	0.000	0.000	0.008	0.001	0.000	0.003	0.001	0.000	0.026	0.002	0.000	0.001	
Mean Annual	m3/s		0.29	Average	6.0	0.35	0.004	0.003	0.003	0.000	0.046	0.005	0.001	0.016	0.007	0.001	0.151	0.009	0.002	0.003	
				WQOs CCME				5	4 (BC)	0.017	8.9	2	73	25	1	1	15	30	0.2	0.2	
								AL	AL	AL	AL as Cr (III)	AL	AL	AL	AL	AL	AL	AL	DW	DW	
Annual Average Deposition (μg/m^2/s)																					
Boulder Lake Outlet					**TSP**	**PM10**	**PM2.5**	**Arsenic**	**Cobalt**	**Cadmium**	**Chromium**	**Copper**	**Molybdenum**	**Nickel**	**Lead**	**Selenium**	**Uranium**	**Zinc**	**Lead-210 (Bq/m^2/s)**	**Polonium-210 (Bq/m^2/s)**	
				Average	1.42E-02	9.93E-04	1.81E-05	8.39E-09	1.22E-08	2.39E-10	1.33E-07	2.36E-08	1.21E-08	5.29E-08	3.65E-08	2.70E-09	5.83E-07	3.73E-08	7.21E-09	7.21E-09	Annual Average Deposition (μg/m^2/s)
				Maximum	4.72E-02	2.73E-03	4.74E-05	3.43E-08	2.70E-08	8.05E-10	3.78E-07	5.31E-08	2.24E-08	1.42E-07	8.97E-08	7.14E-09	1.76E-06	8.26E-08	2.18E-08	2.18E-08	
				Minimum	7.51E-03	6.55E-04	1.13E-05	3.93E-09	9.09E-09	1.49E-10	8.45E-08	1.62E-08	9.51E-09	3.61E-08	2.87E-08	1.76E-09	4.52E-07	2.79E-08	5.58E-09	5.58E-09	
Boulder Lake Outlet																					
					(mg/L)	(mg/L)	(mg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(Bq/L)	(Bq/L)	
Discharge/yr	m3		1.70E+07	Maximum	2.9	0.17	0.003	0.002	0.002	0.000	0.023	0.003	0.001	0.009	0.006	0.000	0.109	0.005	0.001	0.019	
Basin Area	km2		6.68E+01	Minimum	0.5	0.04	0.001	0.000	0.001	0.000	0.005	0.001	0.001	0.002	0.002	0.000	0.028	0.002	0.000	0.001	
Mean Annual	m3/s		0.54	Average	0.9	0.06	0.001	0.001	0.001	0.000	0.008	0.001	0.001	0.003	0.002	0.000	0.036	0.002	0.000	0.003	
				WQOs CCME				5	4 (BC)	0.017	8.9	2	73	25	1	1	15	30	0.2	0.2	
								AL	AL	AL	AL as Cr (III)	AL	AL	AL	AL	AL	AL	AL	DW	DW	

Annual Average Deposition (µg/m²/s)																					
Caribou Lake Outlet					**TSP**	**PM10**	**PM2.5**	**Arsenic**	**Cobalt**	**Cadmium**	**Chromium**	**Copper**	**Molybdenum**	**Nickel**	**Lead**	**Selenium**	**Uranium**	**Zinc**	**Lead-210 (Bq/m²/s)**	**Polonium-210 (Bq/m²/s)**	
				Average	4.60E-02	2.94E-03	3.17E-05	7.98E-09	4.67E-08	4.86E-10	2.68E-07	7.30E-08	6.71E-08	1.37E-07	1.57E-07	6.46E-09	2.14E-06	1.41E-07	2.64E-08	2.64E-08	**Annual Average Deposition (µg/m²/s)**
				Maximum	4.76E-01	3.16E-02	1.63E-04	5.61E-08	4.58E-07	3.97E-09	2.37E-06	6.54E-07	5.74E-07	1.29E-06	1.39E-06	5.79E-08	1.89E-05	1.40E-06	2.33E-07	2.33E-07	
				Minimum	8.46E-03	6.84E-04	1.03E-05	3.58E-09	1.00E-08	1.49E-10	8.45E-08	1.79E-08	1.14E-08	3.70E-08	3.07E-08	1.83E-09	4.56E-07	3.05E-08	5.63E-09	5.63E-09	
Caribou Lake Outlet					(mg/L)	(mg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(Bq/L)	(Bq/L)	
Discharge/yr	m3		1.55E+07	Maximum	39.3	2.61	0.013	0.005	0.038	0.000	0.196	0.054	0.047	0.106	0.115	0.005	1.557	0.115	0.019	0.019	
Basin Area	km2		8.09E+01	Minimum	0.7	0.06	0.001	0.000	0.001	0.000	0.007	0.001	0.001	0.003	0.003	0.000	0.038	0.003	0.000	0.001	
Mean Annual	m3/s		0.49	Average	3.8	0.24	0.003	0.001	0.004	0.000	0.022	0.006	0.006	0.011	0.013	0.001	0.177	0.012	0.002	0.003	
				WQOs CCME				5	4 (BC)	0.017	8.9	2	73	25	1	1	15	30	0.2	0.2	
								AL	AL	AL	AL as Cr (III)	AL	AL	AL	AL	AL	AL	AL	DW	DW	

Scenario 4 - Road allowances - Average Deposition by Lake Watershed for Lakeand Outlet Concentrations (using Pointer Lake as a model system)

Pointer Lake Model

Assumptions:	Assume up to the Annual Average-Predicted deposition rate to Siamese Lake Watershed and along the road allowances and apply it across all of the model basin being examined Assume 50% of Lake Basin Annual Load reports to most d/s Lake per annum Assume only 1 lake volume available for basin load

Road Allowances - Annual Average Deposition (µg/m²/s)

					TSP	**PM10**	**PM2.5**	**Arsenic**	**Cobalt**	**Cadmium**	**Chromium**	**Copper**	**Molybdenum**	**Nickel**	**Lead**	**Selenium**	**Uranium**	**Zinc**	**Lead-210 (Bq/m²/s)**	**Polonium-210 (Bq/m²/s)**
				Average	3.54E-03	3.34E-04	6.00E-06	1.13E-09	5.59E-09	5.96E-11	3.28E-08	8.42E-09	8.02E-09	1.67E-08	1.90E-08	7.59E-10	2.72E-07	1.70E-08	3.35E-09	3.35E-09
				Maxium	1.95E-02	1.49E-03	2.41E-05	4.16E-09	2.44E-08	2.47E-10	1.36E-07	3.63E-08	3.50E-08	7.07E-08	8.21E-08	3.20E-09	1.16E-06	7.43E-08	1.44E-08	1.44E-08
				Minimum	7.23E-05	1.57E-05	4.26E-07	1.02E-10	2.64E-10	3.51E-12	1.98E-09	4.14E-10	3.43E-10	9.13E-10	8.75E-10	4.20E-11	1.31E-08	8.13E-10	1.62E-10	1.62E-10
Pointer Lake					(mg/L)	(mg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(Bq/L)	(Bq/L)
Lake Volume	m3	5.47E+06	1.52E+07	Maximum	2	0.12	0.00	0.000	0.00	0.000	0.01	0.00	0.00	0.01	0.01	0.00	0.10	0.01	0.001	0.001
Basin Area	km2	7.90E+01	7.90E+01	Minimum	0	0.00	0.00	0.000	0.00	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000
Retention Time	year	0.36		Average	0	0.03	0.00	0.000	0.00	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.000	0.000
				WQOs CCME				5	4 (BC)	0.017	8.9	2	73	25	1	1	15	30	0.2	0.2
								AL	AL	AL	AL as Cr (III)	AL	AL	AL	AL	AL	AL	AL	DW	DW

Pointer Lake Outlet Model	
Assumptions:	Assume up to the Annual Average-Predicted deposition rate to Siamese Lake Watershed and along the road allowances and apply it across all of the model basin being examined Assume 50% of Lake Basin Annual Load reports to most d/s Lake per annum (and hence its outlet) Assume 50% annual creek volume available volume available diluting for basin load

Road Allowances - Annual Average Deposition (µg/m²/s)

Pointer Lake Outlet					**TSP**	**PM10**	**PM2.5**	**Arsenic**	**Cobalt**	**Cadmium**	**Chromium**	**Copper**	**Molyb-denum**	**Nickel**	**Lead**	**Selenium**	**Uranium**	**Zinc**	**Lead-210 (Bq/m²/s)**	**Polonium-210 (Bq/m²/s)**	
				Average	3.54E-03	3.34E-04	6.00E-06	1.13E-09	5.59E-09	5.96E-11	3.28E-08	8.42E-09	8.02E-09	1.67E-08	1.90E-08	7.59E-10	2.72E-07	1.70E-08	3.35E-09	3.35E-09	Annual Average Deposition (µg/m²/s)
				Maximum	1.95E-02	1.49E-03	2.41E-05	4.16E-09	2.44E-08	2.47E-10	1.36E-07	3.63E-08	3.50E-08	7.07E-08	8.21E-08	3.20E-09	1.16E-06	7.43E-08	1.44E-08	1.44E-08	
				Minimum	7.23E-05	1.57E-05	4.26E-07	1.02E-10	2.64E-10	3.51E-12	1.98E-09	4.14E-10	3.43E-10	9.13E-10	8.75E-10	4.20E-11	1.31E-08	8.13E-10	1.62E-10	1.62E-10	
Pointer Lake Outlet					(mg/L)	(mg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(Bq/L)	(Bq/L)	
Discharge/yr	m3		1.51E+07	Maximum	1.6	0.12	0.002	0.000	0.002	0.000	0.011	0.003	0.003	0.006	0.007	0.000	0.096	0.006	0.001	0.019	
Basin Area	km2		7.90E+01	Minimum	0.0	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	
Mean Annual	m3/s		0.48	Average	0.3	0.03	0.000	0.000	0.000	0.000	0.003	0.001	0.001	0.001	0.002	0.000	0.022	0.001	0.000	0.003	
				WQOs CCME				5	4 (BC)	0.017	8.9	2	73	25	1	1	15	30	0.2	0.2	
								AL	AL	AL	AL as Cr (III)	AL	AL	AL	AL	AL	AL	AL	DW	DW	

8.2.2.6 Determination of Significance for Changes in Water Quality Due to Dust Deposition

Changes in water quality due to dust deposition are predicted to be minor and will occur primarily during the period of spring freshet flows. The annual minor increases in metals, radionuclides and TSS will occur over the operational life of the mine (about 25 years), but are not expected to exceed any applicable water quality guideline or objective, or be measurable above natural background variation. Overall, no significant adverse effects on water quality are expected due to dust deposition.

8.2.2.7 Compliance and Environmental Monitoring for Changes in Water Quality Due to Dust Deposition

Air and dust emission levels, and dust deposition should be monitored on a regular basis near both the Kiggavik and Sissons mining operations, and adjacent to the ore haul road between the two sites to determine whether actual levels are similar to predicted levels.

Water quality in lakes and streams adjacent to and downstream of the Mine LAA should be monitored during the spring freshet each year during the operational life of the mine to confirm that metal, radionuclide, and TSS concentrations do not increase above predicted levels.

8.2.3 Assessment of Changes in Water Quality Due to Acid Deposition and Lake Acidification

Mining activities have the potential to affect aquatic ecosystems through the release of air emissions that result in increased deposition rates of sulphate (SO_4^{2-}) and nitrate (NO_3^-). Deposition of SO_4^{2-} and NO_3^- can lead to a reduction in pH in acid-sensitive lakes, which in turn might alter other aspects of water chemistry, ultimately resulting in adverse effects on aquatic life.

The potential change in water quality due to acid deposition from mining ore, special waste and clean rock (blasting, loading and hauling), as well as truck transportation and general project-related traffic will be examined. The particular focus is on local waterbodies near the Kiggavik and Sissons Mine Sites, and along the main haul road between the Sissons Mine Site and the ore processing mill at the Kiggavik site.

8.2.3.1 Baseline Conditions for Changes in Water Quality Due to Acid Deposition and Lake Acidification

The only currently available information on the deposition of atmospheric acids for the Northwest Territories and Nunavut are the Canadian National Atmospheric Chemistry Database and Analysis System (NAtChem) measurements from Environment Canada's Snare Rapid station (63^{o} 31' N, 116^{o} 00' W). Data from Snare Rapids used in this analysis include the precipitation-weighted mean wet deposition, in kilograms per hectare per month (kg/ha/mo), for sulphate (SO_4^{2-}), nitrate (NO_3^-), and base cations (Ca^{2+}, Mg^{2+}, Na^+, K^+). The Snare Rapids site is located approximately 900 kilometres due West of the Kiggavik site (64° 22'N, 97° 44'W), so it is reasonable to assume that regional meteorological parameters, and thus wet deposition, may vary between these two locations.

Environment Canada's meteorology station at Baker Lake Airport is a World Meteorological Organization (WMO) class observation site and is located 80 km east of Kiggavik. The Snare Rapids site only records basic meteorological parameters (e.g., temperature and precipitation). The closest WMO class meteorological sites to Snare Rapids are at Fort Simpson Airport (325 km Southwest of Snare Rapids) and the Yellowknife Airport (150 km Southeast of Snare Rapids). In general the climatological averages show that Baker Lake is slightly cooler, windier and drier than Fort Simpson and Yellowknife. The long term average annual precipitation at Baker Lake (270 mm/y) is comparable to the long-term average at Yellowknife (281 mm/y), but lower than Fort Simpson (369 mm/y) and the five year average (2004-2008) at Snare Rapids (316 mm/y).

Thus, to compute precipitation-weighted annual average wet deposition at the Kiggavik site, the wet deposition values at Snare Rapids are normalized by the ratio of precipitation at Baker Lake compared to Snare Rapids, or a factor of 0.87 (i.e., 13% lower wet deposition).

The sensitivity of surface waters to acid deposition can be evaluated based on alkalinity or acid neutralizing capacity (ANC). Alkalinity is frequently expressed in units of milligrams per litre (mg/L) as calcium carbonate ($CaCO_3$), assuming that alkalinity results only from calcium carbonate and bicarbonate, which may or may not be applicable to a given lake. Therefore, the clearest expression of alkalinity is in terms of microequivalents per litre (µeq/L) or milliequivalents per litre (meq/L). For comparative purposes, alkalinity of 1 mg/L as $CaCO_3$ = 20 µeq/L, or 50 mg/L as $CaCO_3$ = 1 meq/L. Saffran and Trew (1996) presented a scale of lake sensitivity to acidification based on alkalinity/ANC (Table 8.2-7).

Table 8.2-7 Acid Sensitivity Scale for Lakes Based on Alkalinity/ANC

Acid Sensitivity	Alkalinity (mg/L as $CaCO_3$)	Alkalinity (as µeq/L)
High	0 to 10	0 to 200
Moderate	>10 to 20	>200 to 400
Low	>20 to 40	>400 to 800
Least	>40	>800

Source: Saffran and Trew (1996).
mg/L = milligrams per litre; $CaCO_3$ = calcium carbonate; µeq/L = microequivalents per litre; > = greater than.

Acid sensitive lakes are situated in areas where soils have little or no capacity to reduce the acidity of the atmospheric deposition. Physical properties of soils (e.g., particle size, texture), their chemistry (e.g. soil pH, cation exchange capacity), soil depth, drainage, vegetation cover and type, bedrock geology and topographic relief are all factors that determine the sensitivity of the drainage basin to acid deposition (Lucas and Cowell 1984; Holowaychuk and Fessenden

1987; Sullivan 2000). Surface waters that are sensitive to acidification usually have the following characteristics, as summarized by Sullivan (2000).

- They are dilute, with low concentrations of major ions (i.e., specific conductance is less than 25 microSiemens per centimetre (µS/cm).
- Alkalinity/ANC are low (i.e., less than 10 mg/L as $CaCO_3$ or less than 200 µeq/L).
- Base cation concentrations are low (i.e., the combined concentration of calcium, magnesium, potassium and sodium in sensitive waters is generally less than 50 to 100 µeq/L).
- Organic acid concentrations are low (i.e., dissolved organic carbon [DOC] concentration is generally less than 3 to 5 mg/L).
- The pH is low (i.e., less than 6).

Physical characteristics of these lakes may be described as:

- elevation is moderate to high;
- lakes are located in areas of high relief;
- lakes are subject to severe, short-term changes in hydrology;
- there is minimal contact between drainage waters and soils or geologic material that may contribute weathering products to solution; and
- sensitive lakes may have small drainage basins that derive much of their hydrologic input as direct precipitation to the lake surface.

Three lakes were selected for acid sensitivity analysis; Caribou Lake, Pointer Lake and Shack Lake. These are major lakes within each of the sub-basins found near the Kiggavik area. Table 8.2-8 summarizes lake pH, specific conductivity, total alkalinity, base cation concentrations, dissolved organic carbon concentration (DOC), and acid sensitivity based on Table 8.2-7. The analysis is paired to include ‘Minimum’ and ‘Maximum’ values based on water quality samples from the region between 1974 and 2009. However, ‘Minimum’ and ‘Maximum’ values for the parameters were not necessarily observed concurrently. Instead extreme values from all observations for each parameter were chosen to provide the most conservative estimate of acid sensitivity. As indicated, the lakes in the Kiggavik area exhibit High to Least sensitivity. High sensitivity is typical of summertime or open water conditions where the lakes are exposed to the atmosphere. Low and Least sensitivities are typical of winter conditions where the formation of ice leads to concentration of cations in the water column due to their exclusion from the ice (salting-out).

Table 8.2-8 Summary of Example Lake Characteristics for the Kiggavik Area

Basin	Lake	Estimate	pH	Specific Conductivity	Total Alkalinity	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	DOC	Lake Sensitivity
				µS/cm	(mg/L as CaCO3)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
Caribou Lake Sub-basin	Caribou Lake	Minimum	5.9	8	2	0.85	0.30	0.20	0.10	1.8	High
		Maximum	7.3	48	15	4.3	1.6	5.0	0.85	6.0	Moderate
Willow Lake Sub-basin	Pointer Lake	Minimum	5.6	14	1	0.85	0.30	0.20	0.10	2.5	High
		Maximum	7.6	116	50	16.8	5.2	2.5	2.1	26	Least
Lower Lake Sub-basin	Shack Lake	Minimum	6.4	13	2	0.10	0.05	0.30	0.40	3.4	High
		Maximum	7.5	53	25	6.2	1.7	0.8	0.9	10	Low

8.2.3.2 Analytical Methods for Changes in Water Quality Due to Acid Deposition and Lake Acidification

The assessment approach used is based on the application of critical loads. Critical loads of acidity can be used to evaluate the likelihood of lake acidification (Henriksen et al. 1992; Kämäri et al. 1992; Rihm 1995; RMCC 1990). The critical load has been defined in general terms as "a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" (Nilsson and Grennfelt 1988). For evaluating the effects of acid deposition, the critical load can be thought of as an estimate of the amount of acidic deposition below which no significant harmful effects occur to a specified component of a lake's ecosystem (e.g., a valued fish species) (Sullivan 2000).

The calculation of critical loads is based on a dose-response relationship between ANC and an aquatic organism considered important to the ecosystem. Many studies have shown that the effects of acidification on aquatic organisms are better correlated with ANC than with pH (as reviewed by Sullivan 2000) because pH measurements are sensitive to carbon dioxide (CO_2) effects (Stumm and Morgan 1981).

The following formula was used to calculate the critical load for each lake included in the analysis (Henriksen et al. 1992):

$$CL = ([BC^*]_0 – [ANC]_{lim}) \times Q$$

where:

- CL = critical load (keq/ha/y);
- $[BC^*]_0$ = pre-industrial non-marine base cation concentration (keq/L), assumed to correspond to the current values in lakes near the Project, because they are considered unaffected by acidification at the present;
- $[ANC]_{lim}$ = critical value for acid neutralizing capacity (20 µeq/L = 2 × 10-8 keq/L) based on observed effects to brown trout (*Salmo trutta*), a European species; and
- Q = mean annual runoff to the lake (L/ha/y).

Acid Input Rates: Background wet deposition of sulphate and nitrate were derived from the 5-year average deposition rates measured at Snare Rapids corrected by a factor of 0.87 to account for lower average annual precipitation at Kiggavik. Total wet deposition is estimated at 0.034 kilo-equivalents per hectare per year (keq/ha/y) from the sum of sulphate deposition (0.019 keq/ha/y) and nitrate deposition (0.015 keq/ha/y). Modelled dry deposition as a result of the mine site development at Kiggavik varies by sub-basin and lake location. For the three example lakes used in this analysis dry deposition varies between 0.014 and 0.016 keq/ha/y resulting in total acid deposition estimates between 0.048 and 0.050 keq/ha/y.

Gross versus Net Potential Acid Input: The effects of Project-related SO_4^{2-} and NO_3^- deposition on nearby surface waters were evaluated by comparing modelled acid deposition rates to lake-specific critical loads. Acid deposition is expressed as the Potential Acid Input (PAI). The critical load is an estimate of the amount of acidifying input above which a change in pH corresponding to adverse effects to aquatic life may occur. A PAI value above the critical load was considered an indication that a lake's buffering capacity may be exceeded, with a subsequent drop in pH below a specified threshold value.

The PAI is usually calculated as the sum of SO_4^{2-} and NO_3^- deposition minus base cation deposition. This calculation includes deposition from all sources (wet and dry) and is therefore referred to as the gross PAI. The gross PAI is commonly used to evaluate the effects of acid deposition on terrestrial ecosystems. Here gross PAI is compared to critical loads for the 'Maximum' cases to reflect the buildup of acids on snow and ice prior to its incorporation in surface waters during the spring freshet.

By incorporating retention of a portion of deposited nitrogen by the terrestrial ecosystem, a more refined estimate of the PAI was used in this assessment to evaluate aquatic effects. During open water conditions, when the short growing season occurs, plants completely assimilate NO_3^- deposition up to 5 to15 kg/ha/y (Gordon et al. 2001). Thus, the retained portion does not contribute to surface water acidification. Since the sum of wet and dry deposition of NO_3^- at Kiggavik is below 5 kg/ha/y for all Lakes, only the SO_4^{2-} deposition was included in the calculation of the PAI for open water conditions ('Minimum' alkalinity and base cation case). The resulting PAI is referred to as the net PAI.

Also note that the net PAI does not incorporate the mitigating effect of base cation deposition. In the Steady-State Water Chemistry (SSWC) model (Henriksen and Posch 2001) used to estimate critical loads, the base cation component of the critical load is assumed to represent the current base cation flux to the waterbody from all sources, including base cation deposition from the atmosphere. Therefore, accounting for the neutralizing effect of base cation deposition, as done when using the gross PAI, would result in double-counting of base cations.

8.2.3.3 Effect Mechanism and Linkages for Changes in Water Quality Due to Acid Deposition and Lake Acidification

Air and dust emissions from mining activities have the potential to affect aquatic ecosystems through the deposition of sulphate (SO_4^{2-}) and nitrate (NO_3^-). These compounds form acids which can lead to increasing acidity (lowering of pH) in acid-sensitive lakes. This in turn may alter other aspects of water chemistry, which can result in adverse effects on aquatic life. Mitigation Measures and Project Design for Changes in Water Quality Due to Acid Deposition and Lake Acidification

In order to mitigate the release of acid generating materials to the atmosphere, scrubbers should be installed on emissions from the sulphuric acid plant, and NOx control systems should be installed on the oil-fired power generators and/or product driers.

8.2.3.4 Residual Effects for Changes in Water Quality Due to Acid Deposition and Lake Acidification

Table 8.2-9 summarizes critical load (keq/ha/y), gross PAI (keq/ha/y) and net PAI (keq/ha/y) calculations for the three example lakes in the Kiggavik area. For both Caribou Lake and Pointer Lake the PAI values are more than a factor of five below the critical load indicating limited potential for activities at Kiggavik to contribute to acidification of these lakes. However, the 'Minimum' alkalinity and base cation case for Shack Lake indicates that net PAI during open water conditions (i.e., summer) could reach values up to 83% of the critical load. As previously discussed, the 'Minimum' values for alkalinity and base cation concentrations were chosen as extreme values and were not necessarily measured concurrently. A more precise estimate of the acid sensitivity of Shack Lake during summer, when it is most sensitive to acid deposition, was undertaken for five separate water quality measurements (August, 1990; August, 2007; June, August and September, 2008).

Table 8.2-9 indicates that Shack Lake has the lowest variability in pH among the three lakes and is near neutral pH. Due to its short residence time (0.04 years), it is likely that high, summertime acid sensitivity is due to physical effects (i.e., it is subject to severe, short-term changes in hydrology due to the controlling influence of precipitation). Lake sensitivity using actual water quality data varies from High to Low. However, the net PAI values are more than a factor of ten below the case-specific critical load values.

Table 8.2-9 Comparison of Critical Loads and Potential Acid Inputs for Example Lakes at Kiggavik

Basin	Lake	Estimate	pH	Total Alkalinity (mg/L as $CaCO_3$)	Lake Sensitivity	Critical Load (keq/ha/y)	Gross PAI (keq/ha/y)	Net PAI (keq/ha/y)
Caribou Lake Sub-basin	Caribou Lake	Minimum	5.9	2	High	0.111		0.020
		Maximum	7.3	15	Moderate	1.068	0.023	
Willow Lake Sub-basin	Pointer Lake	Minimum	5.6	1	High	0.112		0.020
		Maximum	7.6	50	Least	2.709	0.025	
Lower Lake Sub-basin	Shack Lake	Minimum	6.4	2	High	0.024		0.020
		1-Aug-90	7.0	9	High	0.508		0.020
		27-Aug-07	6.8	18	Moderate	0.704		0.020
		20-Jun-08	6.9	4	High	0.257		0.020
		29-Aug-08	7.3	14	Moderate	0.620		0.020
		3-Sep-08	7.1	12	Moderate	0.669		0.020
		Maximum	7.5	25	Low	0.929	0.024	

8.2.3.5 Determination of Significance for Changes in Water Quality Due to Acid Deposition and Lake Acidification

Inter-annual and seasonal variations in lake pH are expected to occur naturally over the operational life of the Kiggavik mine (about 25 years). These changes are in response to deposition of atmospheric acids by precipitation and the effects of seasonal freeze-thaw cycles on lake chemistry. Potential changes to lake pH due to increased atmospheric acid deposition as a result of the Project are predicted to occur primarily during the summer, open water, period. However, any potential changes would be small (i.e. below the critical load value) and likely brief, due to the short residence times of the lakes (0.04 to 0.36 years). In conclusion, no significant adverse effects on water quality are expected, and a long-term trend towards increasing lake acidification as a result the Project is not expected to occur.

8.2.3.6 Compliance and Environmental Monitoring for Changes in Water Quality Due to Acid Deposition and Lake Acidification

Over the operational life of the mine, water quality in lakes and streams adjacent to and downstream of the Mine LAA should be monitored each spring during freshet, and in the case of lakes, once again during autumn prior to freeze up, to confirm that acid deposition and lake acidification are not increasing above predicted or acceptable levels.

8.3 CUMULATIVE EFFECTS ANALYSIS FOR WATER QUALITY

8.3.1 Screening for Cumulative Environmental Effects

Project-related residual effects to water quality occur within the Mine Site LAA, but are expected to diminish to background levels downstream of the outlet of Judge Sissons Lake. Any remaining residual effects leaving Judge Sissons Lake would have potential to overlap with other projects and activities that occur or may occur in the future, and therefore act cumulatively on surface water quality.

The screening for cumulative effects to water quality is conducted in order to determine if there is potential for cumulative environmental effects to occur. Potential cumulative effects exist if project-related effects to surface water quality overlap spatially and temporally with those of other past, present and future projects and activities. Projects considered for cumulative environmental effects are described in Section 6. Of these projects, no local, Nunavut, or Far Future Scenario projects from the Project Inclusion List affect surface water quality and overlap spatially and temporally with effects associated with this Project. Therefore, no cumulative effects to surface water quality are predicted for this project.

8.4 SUMMARY OF RESIDUAL EFFECTS ON WATER QUALITY

8.4.1 Project Effects

In reviewing the potential effects on water quality from the Kiggavik Projects treated effluent discharges to Judge Sissons Lake, the concentration of constituents of potential concern (COPC), with established thresholds, are expected to be below the appropriate threshold value, with the exception of cadmium. For cadmium, the maximum concentrations within Judge Sissons Lake are expected to be within a factor of two of the appropriate threshold. It is noted that baseline levels of cadmium are below detection and depending on the exact level, the concentration change may not be measureable during a summer monitoring program. Other COPC (e.g. sulphate) is expected to change relative to baseline but no appropriate threshold is available. The changes in water quality are expected to occur during the operation and final closure stages of the project but return to baseline levels at post closure. Overall, no significant adverse effects on water quality are expected.

Changes in water quality due to dust deposition are predicted to be minor and will occur primarily during the period of spring freshet flows. The annual minor increases in metals, radionuclides and TSS will occur over the operational life of the mine (about 25 years), but are not expected to exceed any applicable water quality guideline or objective, or be measurable above natural background variation. Overall, no significant adverse effects on water quality are expected due to dust deposition.

Inter-annual and seasonal variations in lake acidity/alkalinity (pH) are expected to occur naturally over the operational life of the Kiggavik mine (about 25 years). These changes are in response to deposition of atmospheric acids by precipitation and the effects of seasonal freeze-thaw cycles on lake chemistry. Potential changes to lake pH due to increased atmospheric acid deposition as a result of the Project are predicted to occur primarily during the summer, open water, period. However, any potential changes would be small (i.e. below the critical load value) and likely brief, due to the short residence times of the lakes (0.04 to 0.36 years). In conclusion, no significant adverse effects on water quality are expected. No long-term trend towards increasing lake acidification as a result the Project is expected to occur.

No residual effects are expected for the various components of water quality assessed in this document. Because of this lack of residual water quality effects, it is not expected that the Project will result in any combined project effects on water quality. Table 8.4-1 summarizes Project residual environmental effects for water quality.

Table 8.4-1 Summary of Project Residual Environmental Effects and Significance Determinations for Water Quality

Project Phase	Mitigation/ Compensation Measures	Residual Environmental Effect (Y/N)	Direction	Residual Environmental Effects Characteristics						Significance	Likelihood	Prediction Confidence	Recommended Follow-up and Monitoring
				Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental Context				
Change in water quality: Treated effluent discharge from the Kiggavik and Sissons Water Treatment Plants (WTP) may affect surface water quality in the receiving environment. This potential alteration to surface water chemistry has the potential to affect aquatic organisms													
Construction		N	-	-	-	-	-	-	-	N	M	H	Wastewater and effluent quality monitoring; water quality monitoring in receiving environment.
Operation	Design of WTP.	Y	N	L	L	MT	C	I	U				
Decommissioning and Abandonment		Y	N	L	L	MT	C	I	U				
Residual environmental effects for all Phases		N	-	-	-	-	-	-	-				
Change in water quality: Increased dust generated during mine construction and operation could increase particulate and metals deposition in the Kiggavik Project area. Increased atmospheric deposition can report directly and indirectly to waterbodies and potentially change the water quality of those systems. Changes in water quality have the potential to affect aquatic biota.													
Construction		Y	N	L	L	ST	C	I	U	N	L	H	Dust emission levels and deposition monitoring; water quality monitoring in lakes for metals, radionuclide, and TSS concentrations.
Operation	Dust control on roads and during the pit mining.	Y	N	L	L	MT	C	I	U				
Decommissioning		Y	N	L	L	ST	C	I	U				
Residual environmental effects for all Phases		Y	N	L	L	MT	C	I	U				
Change in water quality: The release of air emissions that result in increased deposition rates of sulphate (SO_4^{2-}) and nitrate (NO_3^-). Deposition of SO_4^{2-} and NO_3^- can lead to a reduction in pH in acid-sensitive lakes, which in turn might alter other aspects of water chemistry, ultimately resulting in adverse effects on aquatic life.													
Construction		N	-	-	-	-	-	-	-	N	L	H	Lakes and streams monitored to confirm acid deposition and lake acidification are not increasing above acceptable levels.
Operation	Scrubbers on sulphuric acid plant; NOx control systems.	Y	N	L	L	MT	C	I	U				
Decommissioning		N	-	-	-	-	-	-	-				
Residual environmental effects for all Phases													

8.4.2 Cumulative Effects

No local, Nunavut, or Far Future Scenario projects from the Project Inclusion List affect surface water quality and overlap spatially and temporally with effects associated with this Project. Therefore, no cumulative effects to surface water quality are predicted for this project.

8.4.3 Effects of Climate Change on Project and Cumulative Effects on Water Quality

Twenty three climate change scenarios were explored, of which twenty predict an increase in annual precipitation for the period 2071-2099. The greatest increase in precipitation was 78% greater than historical rates. On average, the models predict a 34% increase in precipitation; this increase is typically distributed throughout the year, however most dramatic increases occur in the autumn.

As summers become warmer and wetter, lake evaporation and evapotranspiration conditions are typically predicted to increase. Although water losses typically increase, under many ensembles, the magnitude does not compensate for the dramatic increases in precipitation. Twenty of the twenty three climate change ensembles predict an increase in runoff at Judge Sisson and Pointer Lake outflows. On average, runoff is estimated to increase 67% and 74% for Pointer Lake and Judge Sissons Lake watersheds, respectively.

Increased precipitation and stream flows associated with climate change would result in reduced concentrations of COPCs in Judge Sissons Lake over those levels predicted in this EIA. This is due to the increased volumes of water flowing through the lake, effectively flushing COPCs out of the lake more quickly, giving them less time to build.

8.5 MITIGATION MEASURES FOR WATER QUALITY

A number of mitigation measures and project design modifications will be implemented to limit changes in water quality:

- Site footprint will be minimized and situated such that natural drainage areas and watershed boundaries are maintained;
- The site water system will be designed to recycle water where applicable and water use will be minimized to limit withdrawal requirements and discharge quantities;
- Diversion channels will be designed to keep water within its natural drainage path;
- In-water construction will follow standard protocols and best management practices;
- Andrew Lake pit will be de-watered at a rate such that effects to water quality are minimized;

- Andrew Lake Pit area will be dewatered after the spring spawning season and before freeze-up (July/August;
- Measures will be taken to minimize the amount of dust generated at the two mine sites and along the main haul road between the mine sites;
- Water will be sourced and discharged into large waterbodies to reduce effects to water quality; and
- During decommissioning, the ground surface will be recontoured and natural flow patterns will be restored.

8.6 COMPLIANCE AND ENVIRONMENTAL MONITORING FOR WATER QUALITY

- Water withdrawal and wastewater/effluent discharge rates will be continually documented during the construction, operations, and closure phases of the mine;
- Wastewater/effluent discharge quality will be analysed and documented regularly according to Nunavut regulatory requirements during mine operations, and during and after mine closure;
- Water quality in each section of Judge Sissons Lake receiving treated effluent, as well as at the outlet of Judge Sissons Lake, will be monitored on a monthly basis during the operations and closure phases of the Kiggavik Project, and on an annual basis during the post-closure phase;
- Air and dust emission levels, and dust deposition should be monitored on a regular basis near both the Kiggavik and Sissons mining operations, and adjacent to the ore haul road between the two sites to determine whether actual levels are similar to predicted levels; and
- Water quality in lakes and streams adjacent to and downstream of the Mine LAA will be monitored each spring during freshet, and in the case of lakes, once again during autumn prior to freezeup, to confirm that metals and radionuclide concentrations, TSS and acid deposition levels, and lake acidification are not increasing above predicted levels. This monitoring will occur during the operational and closure phases of the Project.
- Water quality monitoring of the reflooded Andrew Lake Pit should be carried out to determine if and when the dyke separating Andrew Lake from the reflooded mine pit should be breached and the two waterbodies connected. If water quality is high then the two water bodies could be connected. If water quality is poor or unsuitable for fish use, the waterbodies should remain unconnected.

9 EFFECTS ASSESSMENT FOR SEDIMENT QUALITY

9.1 SCOPE OF THE ASSESSMENT FOR SEDIMENT QUALITY

The NIRB Guidelines for the Kiggavik Project (NIRB, 2011) identify sediment quality as a Valued Ecosystem Component (VEC). The scope of the assessment for sediment quality focuses on the chemical characteristics of sediments as they relate to the maintenance of healthy aquatic ecosystems. Sediment quality is important to the proper functioning and maintenance of other valued aquatic ecosystem components such as water quality, aquatic organisms and plants, fish habitat, and fish populations.

9.1.1 Project–Environment Interactions and Effects

Information was gathered from the environmental and engineering teams for the Kiggavik Project, through public engagement, and by NIRB to identify project activities that have potential to result in changes to sediment quality by affecting its physical or chemical makeup. Relevant project activities and the associated environmental interactions for each Project phase are summarized in Table 9.1-1 for project-environment interactions that were ranked 1 or 2 in Table 4.3-1.

Table 9.1-1 Project – Environment Interactions and Effects – Sediment Quality

Project Phase	Project Activities/Physical Works	Change in Sediment Quality
Construction:		
In-Water Construction	Construct freshwater diversions and site drainage containment systems (dykes, berms, collection ponds)	1
	Construct in-water/shoreline structures	1
	Water transfers and discharge	1
	Freshwater withdrawal	0
On-Land Construction	Site clearing and pad construction (blasting, earth moving, loading, hauling, dumping, crushing	1
Operation:		
Mining	Mining ore (blasting, loading, hauling)	1
	Mining special waste (blasting, loading, hauling)	1
	Mining clean waste (blasting, loading, hauling)	1
	Mine dewatering	0
Water Management	Create and maintain water levels	0
	Freshwater withdrawal	0

Project Phase	Project Activities/Physical Works	Change in Sediment Quality
	Collection of site and stockpile drainage	0
	Water and sewage treatment	0
	Discharge of treated effluents (including greywater)	2
	Disposal of sewage sludge	0
Transportation	Truck transportation	1
	General traffic (project-related)	1
Ongoing exploration	Ground surveys	0
	Drilling	0
Final Closure:		
General	Ongoing withdrawal, treatment and release of water, including domestic wastewater	2
In-water Decommissioning	Remove freshwater diversions; re-establish natural drainage	1
	Remove surface drainage containment	1
	Remove in-water/shoreline structures	1
	Water transfers and discharge	1
	Construct fish habitat as per FHCP	1
On-land Decommissioning	Remove site pads (blasting, earth moving, loading, hauling, dumping)	1
Post Closure:		
On-land Decommissioning	Management of restored site	0

Category 1 activities are those having an interaction with the aquatic environment; however, based on past experience and professional judgment, the resulting effect can be managed to acceptable levels through standard operating practices and/or through the application of best management or codified practices. No further assessment is warranted.

Category 2 activities are those activities that do interact with the aquatic environment and the resulting effect may exceed acceptable levels without implementation of specified mitigation. Further assessment of the effects of these interactions on the aquatic environment is warranted and is presented in this environmental assessment report.

The rationale for ranking interactions as Category 1 is presented below. Those interactions ranked as Category 2 are discussed in more detail in the following sections.

CONSTRUCTION:

Construction of Freshwater Diversions and Site Drainage Containment Systems; Site Clearing and Pad Construction

During the Project construction phase, land clearing and earth moving will be carried out to prepare areas for mine and mill site infrastructure development. This work will include diverting existing surface drainage systems, as well as excavating mine pits and pads for storage of mine rock and ore. Soil disturbance will also occur as a component of developing other mine infrastructure such as the ore haul road between the Kiggavik and Sissons Mine Sites, the access roads to the water intake locations and effluent discharge point, and the airstrip. All Project activities involving land clearing or earth movement have the potential to increase surface water runoff and cause soil erosion into adjacent waterbodies. To reduce these effects, best management practices have been incorporated into the Project design to control surface water runoff and minimize the potential for erosion. For example, watercourses diverted away from the mine site development areas are reconnected to the same drainage system, but at a location downstream of the mine site. Diversion channels will also incorporate sedimentation ponds to settle any suspended sediments prior to release back into the environment.

No long term or large scale changes to sediment quality are anticipated; therefore this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects.

FINAL-CLOSURE:

Removal of Freshwater Diversions and Site Drainage Containment Systems; Pad Removal

Surface water runoff and erosion effects at Project closure are expected to be similar to those described for the Project construction period. No long term or large-scale changes to sediment quality are anticipated; therefore, this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects.

CONSTRUCTION:

Construction of In-Water/Shoreline Structures

Installation of water intake structures and connecting water intake lines in Mushroom and Siamese Lakes, and the effluent diffuser structure(s) and effluent discharge line(s) in Judge Sissons Lake will result in some disturbance to the lake bottom sediments with accompanying increases in turbidity and total suspended solids (TSS) levels in the water. Similar, but reduced effects are also expected during the Project final-closure phase when the water intake and effluent diffuser structures are removed. Because these interactions are limited in areal extent and are of short duration, they are ranked as Category 1 interactions and are not carried forward to the detailed analysis of residual effects.

FINAL-CLOSURE:

Removal of In-Water/Shoreline Structures

Removal of water intake structures and connecting water intake lines, and effluent diffuser structure(s) and effluent discharge line(s) will result in similar disturbances to lake bottom sediments and surrounding sediment quality as resulted during construction and installation of the in-water structures. However, the disturbance effects are likely to be of smaller magnitude and shorter duration than those associated with the construction and installation of the in-water/shoreline structures. Because these project-environment interactions are limited in areal extent and are of short duration, they are ranked as Category 1 and are not carried forward to the detailed analysis of residual effects on sediment quality.

CONSTRUCTION:

Water Transfers and Discharge

In order to begin development of the Andrew Lake Pit, a dyke will be constructed across the east end of Andrew Lake, and that portion of Andrew Lake dewatered. Construction of the dyke and dewatering the east section of Andrew Lake will result in increased turbidity and TSS levels in the water. The increases in turbidity/TSS released to the downstream environment will be kept to acceptable levels by using a turbidity curtain to separate the dyke construction activity from the larger western portion of Andrew Lake. Water quality will be monitored during dyke construction and actions taken if turbidity/TSS levels approach an unacceptable, pre-determined threshold. If turbidity readings exceed the threshold level, all construction activities will stop until a more effective construction method can be instituted.

Following dyke construction, the east portion of Andrew Lake will be dewatered by pumping it into the larger, remaining portion of Andrew Lake. Pumping will only take place once turbidity levels in the portion of Andrew Lake being drained have fallen below the established threshold level. If turbidity levels are too high to allow discharge into the downstream environment, the water will be treated as part of mine water effluent treatment. Because water quality and thus sediment quality, effects on the downstream environment will be small in magnitude and short lived in duration, this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects on sediment quality.

OPERATION:

Mining Ore; Mining Special Waste; Mining Clean Waste; Truck Transportation; General Project-Related Traffic

Air emissions and dust deposition from vehicle and heavy equipment operation, and from blasting, loading, and hauling mine ore and mine rock during the operations phase of the Project may affect sediment quality in nearby LAA lakes. Minor changes in total suspended solids (TSS) are anticipated from the deposition of dust that settles on LAA vegetation in summer and fall and snow in winter, being carried into lakes and streams along with spring snowmelt. As described in Section 8.2.2, increases in TSS are expected to be small in magnitude and short lived in duration. Therefore, this interaction is ranked as a Category 1 and is not carried forward to the detailed analysis of residual effects on sediment quality.

OPERATION:

Mine Dewatering; Collection of Site and Stockpile Drainage; Water and Sewage Treatment

Water removed from the pits and underground mine workings, as well as water collected from site and stockpile drainage, will be used in the mill as process water, or sent to the Kiggavik or Sissons Water Treatment Plants (WTP) and processed to meet required standards before being released to the environment. Domestic sewage will also be treated to meet required standards before being released to the environment. Because no mine water, site and stockpile drainage waters, or sewage wastes will be released to the environment without having been treated in the WTP, this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects on water quality.

OPERATION:

Discharge of Treated Effluents

Treated effluent discharge from the Kiggavik and Sissons Water Treatment Plants (WTP) may affect surface water quality and sediment quality. The potential change in the concentrations of sediment quality constituents due to effluent release from the WTP will be examined. The particular focus is on Judge Sissons Lake. Because the treated effluent discharge may interact with the aquatic environment, and the resulting effect may exceed acceptable levels, further assessment of the potential effects of these interactions on sediment quality is warranted. This environmental assessment is presented in this report.

FINAL CLOSURE:

Discharge of Treated Effluents

During the final closure phase of the Project, there will be an ongoing requirement for water withdrawal, and effluent treatment and discharge (including domestic wastewater). The quality of site drainage and runoff waters will necessitate treatment before it can be discharged to the environment. Water treatment may be required for a number of years before the quality of untreated site drainage and runoff reaches a level where it can be allowed to flow directly into natural receiving waters. Because the treated effluent discharge may interact with the aquatic environment, and the resulting effect may exceed acceptable levels, further assessment of the potential effects of these interactions on sediment quality is warranted. This environmental assessment is presented in this report.

9.1.2 Indicators and Measurable Parameters

Assessment indicators represent the key aspects of the VEC that should be protected to maintain the continued health of all aspects of the aquatic environment in the LAA, and to protect its value for use by future generations of Nunavut residents and the general public. Measurable parameters refer to quantifiable and measurable aspects of each assessment indicator that can be used to determine the magnitude and direction of environmental change associated with Project activities. Changes to the measurement parameters will be assessed to determine the significance of Project activities on assessment indicators and ultimately, on VECs. Valued environmental components, assessment indicators, and measurable parameters used in assessing effects of Project activities on the sediment quality are presented in Table 9.1-2.

Table 9.1-2 Measureable Parameters for Sediment Quality

Environmental Effect	Measurable Parameter(s)	Notes or Rationale for Selection of the Measurable Parameter
Change in Sediment Quality	• Physical properties (e.g., particle size) • Total and dissolved metals • Radionuclides	• The physical and chemical makeup of sediment influences the abundance and distribution of aquatic organisms and fish life in the receiving environment.

9.1.3 Residual Environmental Effects Criteria

General descriptions of residual environmental effects criteria are presented in Section 4.6 and apply to effects on sediment quality. However, more specific descriptions apply to the magnitude of residual environmental effects for sediment quality.

For sediment quality magnitude is defined by whether measured values exceed a threshold value such as those contained in the Canadian Council of Ministers of the Environment's (CCME) Freshwater Interim Sediment Quality Guidelines (ISQG) and probable effects levels (PEL) (CCME 2002). Specific definitions for the magnitude of effects on the Sediment Quality VEC are:

- Negligible: no discernible effect on sediment quality.
- Low: Project will measurably affect sediment quality but these changes will be within the range of natural variability.
- Medium: Project will affect sediment quality to the extent that some parameters are not compliant with established water quality guidelines within the LAA.
- High: Project will affect sediment quality to the extent that several parameters are not compliant with established water quality guidelines within the LAA.

9.1.4 Standards or Thresholds for Determining Significance

Under the NIRB Project Specific Guidelines the environmental assessment must include a determination of the significance of environmental effects. Threshold criteria or standards for determining the significance of environmental effects were identified for each VEC, beyond which a residual environmental effect would be considered significant. CNSC (Thompson et al. 2005) has developed sediment quality guidelines for a number of radionuclides and metals which are used in the assessment. These are augmented with the values provided by the CCME. These guidelines are summarized in Table 9.1-3.

Table 9.1-3 Summary of Sediment Quality Guidelines Used in Assessment

Constituent	Units	ISQG / LEL	PEL / SEL	Source
Arsenic	µg/g	9.8	346	Thompson et al. 2005
Cadmium	µg/g	0.6	3.5	CSQG
Cobalt	µg/g			
Copper	µg/g	22	269	Thompson et al. 2005
Lead	µg/g	36.7	412	Thompson et al. 2005
Molybdenum	µg/g	13.8	1239	Thompson et al. 2005
Nickel	µg/g	23.4	484	Thompson et al. 2005
Selenium	µg/g	1.9	16	Thompson et al. 2005
Uranium	µg/g	104.4	5874	Thompson et al. 2005
Zinc	µg/g	123	315	CSQG
Thorium-230	Bq/g	-	-	
Radium-226	Bq/g	0.6	14.4-	Thompson et al. 2005
Lead-210	Bq/g	0.9	21	Thompson et al. 2005
Polonium-210	Bq/g	0.8	12.1	Thompson et al. 2005

ISQG Interim Sediment Quality Guideline
LEL Lowest Effects Level
PEL Probable Effect Level
SEL Severe Effects Level
CSQG Canadian Sediment Quality Guideline (CCME 2011)
µg/g = micrograms per gram; Bq/g = Bequerels per gram
For those COPC with no objective, an assessment of the potential effect is made based on the change from baseline as well as comparison to values that are protective of aquatic biota (see Sections 10 and 11).

The significance of changes in sediment quality parameters is determined by the user of the resource. Thus, the determination of significance of changes to sediment quality, should they occur, is included in the evaluation of effects on Vegetation, Wildlife, Aquatic Resources, Human and Ecological Health, Land Use and Traditional Land Use. The effects of the Project on sediment quality are assessed in terms of their consequence, evaluated by comparing measured values with established sediment quality guidelines (see Table 9.1-3). A low consequence is one in which the changes to sediment quality are not expected to affect water users. A high consequence is one in which the changes are expected to affect users.

9.2 EFFECTS ASSESSMENT FOR SEDIMENT QUALITY

The effect of the Project on the Sediment Quality VEC is the initiation of changes in sediment quality. This effect is assessed in the following section.

9.2.1 Assessment of Changes in Sediment Quality

The potential change in sediment concentrations due to effluent release from the WTP will be examined. The particular focus is on Judge Sissons Lake.

9.2.1.1 Analytical Methods for Changes in Sediment Quality

Treated effluent discharge from the Kiggavik and Sissons Water Treatment Plants (WTP) may affect surface water quality. Changes in surface water affect the sediment through processes such as deposition of settling solids, adsorption, and diffusion. Parameters in water that were identified as COPC for sediment include: radionuclides (U-238, Th-230, Ra-226, Pb-210, Po-210) and select metals (arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, and zinc). Detailed modelling of concentration of these COPC in the receiving environment, Judge Sissons Lake (JSL), was completed using the LAKEVIEW model. The LAKEVIEW dispersion model has been applied to several other uranium mining projects in northern Saskatchewan to simulate constituent transport and concentrations in the aquatic environment. Important processes incorporated into the LAKEVIEW model include horizontal (lateral) and vertical transport of dissolved species, chemical and biochemical reactions in the sediment and in the water column, settling of particulate matter, and sediment exchange processes. LAKEVIEW incorporates a detailed computational protocol for estimating the flux of dissolved chemical species in and out of the sediment together with chemical reactions (reduction or oxidation) and solid phase and solid solution partitioning along with conventional sorption equilibrium. A detailed description of the LAKEVIEW module and its application to this project is provided in Appendix 8A.

Where possible, site-specific data or data reported for similar environments (e.g. northern Saskatchewan) were used to characterize inputs to the LAKEVIEW model. For this assessment, sediment samples in the Kiggavik study area were collected and Tessier sequential extraction tests were performed to provide an estimate of the amount of metal and radionuclide present in the sediment that is available for exchange with the water column. Although different discharge locations and duration of release were examined, there was found to be little difference on the sediment quality and thus the scenario carried through the assessment was based on separate discharges from the Kiggavik water treatment plant and Sissons water treatment plant, an extended operating period (25 years) followed by a 22-year period of consolidation where water treatment would be required. The assessment accounted for the uncertainty and variability in the emissions and the behaviour in the environment.

9.2.1.2 Baseline Conditions for Changes in Sediment Quality

Section 5.4 provides a summary of the data collected from the baseline monitoring program. Compared to available guidelines, the mean and median of the sediment samples are below the appropriate ISQG or LEL level. Due to the variability in sediment from discrete samples the comparison of the average concentration to the guideline is the most appropriate point of comparison. It is noted however, that with the exception of zinc, the upper 95th percentile and maximum measured concentration is below the PEL/SEL for all COPC. The maximum measured zinc concentration in sediment was 440 mg/kg which is above the SEL of 315 mg/kg. This indicates that zinc can be naturally elevated in the sediment in the area.

9.2.1.3 Effect Mechanism and Linkages for Changes in Sediment Quality

The release of COPC from the WTP can affect water quality in the receiving environment. Changes in water quality can affect the concentration of COPC in sediment. COPC levels in sediment will have an effect on biota that reside in sediment (e.g. benthic invertebrates) as well as wildlife that may have incidental ingestion of sediment while feeding on other aquatic biota.

9.2.1.4 Mitigation Measures and Project Design for Changes in Sediment Quality

The design of the WTP was such to provide an effluent that met or exceeded all appropriate regulations. Environmental considerations were paramount in the selection of the appropriate technology for the WTP. Further detail on the design of the water treatment plant can be found in Volume 2.

9.2.1.5 Residual Effects for Changes in Sediment Quality

Table 9.2-1 presents a summary of the maximum predicted mean and 95th percentile sediment concentrations over the duration of the assessment (i.e., all four phases of the effluent release scenario). Although the lake was sub-divided into several segments, the sediment concentrations were not found to vary significantly between the segments so the overall maximum is presented. Also shown in Table 9.2-1 are the associated sediment quality guidelines. For the COPC with sediment quality guidelines available, predicted sediment concentrations of all COPC were below the guidelines in all segments of Judge Sissons Lake, with the exception of nickel. The 95th percentile predicted concentration of nickel in sediment is slightly elevated compared to the Thompson et al. (2005) lowest effects level (LEL) during all phases of the assessment, including baseline. Baseline nickel levels were taken to be 22.4 µg/g and therefore the upper 95th percentile sediment concentration of 23.6 µg/g indicates that the Project is not expected to have a substantial effect on the levels of nickel in sediment. Predicted nickel concentrations in sediment are well below the severe effects level (SEL) of 484 µg/g.

Table 9.2-1 Maximum Predicted Mean and 95th Percentile Sediment Concentrations

COPC	Units	SQG		Maximum Predicted Sediment Concentration	
		LEL/ ISQG	SEL/ PEL	Mean	95th Percentile
U	µg/g	104.4	5874	2.8	3.1
Th-230	Bq/g	-	-	0.05	0.05
Pb-210	Bq/g	0.9	21	0.12	0.14
Ra-226	Bq/g	0.6	14.4	0.05	0.06
Po-210	Bq/g	0.8	12	0.11	0.13
As	µg/g	9.8	346	8.5	9.3
Cd	µg/g	0.6	3.5	0.2	0.2
Co	µg/g	-	-	9.9	12.5
Cu	µg/g	22	269	21.3	21.7
Pb	µg/g	37	412	10.1	10.2
Mo	µg/g	13.8	1238	2.3	3.3
Ni	µg/g	23	484	22.7	**23.6**
Se	µg/g	1.9	16.1	0.7	0.9
Zn	µg/g	123	315	71.8	74.4

Note: **BOLD SHADED** values exceed the LEL/ISQG sediment guidelines

For those COPC with no applicable guideline, a comparison can be made between the timeframe of the Project release and baseline conditions. The baseline levels of thorium-230 in sediment were taken to be 0.04 Bq/g. The baseline cobalt level in sediment within Judge Sissons Lake is taken to be 8.9 µg/g. As seen from Table 9.2-1, the Project emissions are not have a large influence on the sediment concentrations.

Based on the results above, no residual effects with respect to changes in sediment quality have been identified.

9.2.1.6 Compliance and Environmental Monitoring for Changes in Sediment Quality

Sediment quality in each section of Judge Sissons Lake receiving treated effluent, as well as at the outlet of Judge Sissons Lake, will be monitored every three years during the operations and closure phases of the Kiggavik Project as part of the Environmental Effects Monitoring (EEM) Program.

9.3 CUMULATIVE EFFECTS ANALYSIS FOR SEDIMENT QUALITY

9.3.1 Screening for Cumulative Environmental Effects

Project-related residual effects to sediment quality will occur within the Mine Site LAA, but will diminish to background levels before reaching the outlet of Judge Sissons Lake. Should any residual effects to sediment quality leave Judge Sissons Lake, they would have potential to overlap with other projects and activities that occur or may occur in the future, and therefore act cumulatively on surface water quality.

The screening for cumulative effects to sediment quality is conducted in order to determine if there is potential for cumulative environmental effects to occur. Potential cumulative effects exist if project-related effects to sediment quality overlap spatially and temporally with those of other past, present and future projects, and activities. Projects considered for cumulative environmental effects are described in Section 6. Of these projects, no local, Nunavut, or Far Future Scenario projects from the Project Inclusion List affect sediment quality and overlap spatially and temporally with effects associated with this Project. Therefore, no cumulative effects to sediment quality are predicted for this project.

9.4 SUMMARY OF RESIDUAL EFFECTS ON SEDIMENT QUALITY

9.4.1 Project Effects

Predicted sediment concentrations for all constituents of potential concern (COPC) with sediment quality guidelines available, were below the guideline levels in all segments of Judge Sissons Lake, with the exception of nickel. The 95^{th} percentile predicted concentration of nickel in sediment is slightly elevated compared to the Thompson et al. (2005) lowest effects level (LEL) during all phases of the assessment, including baseline. Baseline nickel levels were taken to be 22.4 µg/g. Therefore, the upper 95^{th} percentile sediment concentration of 23.6 µg/g indicates that the Project is not expected to have a substantial effect on the levels of nickel in sediment. Predicted nickel concentrations in sediment are well below the severe effects level (SEL) of 484 µg/g. In summary, minor Project-related residual effects to sediment quality will occur within the Mine Site LAA, but will diminish to background levels before reaching the outlet of Judge Sissons Lake. Overall, no significant adverse effects on sediment quality are expected. Table 9.4-1 summarizes Project residual environmental effects for water quality.

Table 9.4-1 Summary of Project Residual Environmental Effects and Significance Determinations for Sediment Quality

Project Phase	Mitigation/ Compensation Measures	Residual Environmental Effect (Y/N)	Direction	Residual Environmental Effects Characteristics: Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental Context	Significance	Likelihood	Prediction Confidence	Recommended Follow-up and Monitoring
Change in sediment quality: The release of treated effluent from the Kiggavik and Sissons Water Treatment Plants can affect water quality in the receiving environment. Changes in surface water can subsequently affect the sediment through processes such as deposition of settling solids, adsorption, and diffusion. Contaminant levels in sediment can have an effect on biota that reside in sediment (e.g., benthic invertebrates) as well as wildlife that may have incidental ingestion of sediment while feeding on other aquatic biota.													
Construction		N	-	-	-	-	-	-	-	N	L	H	Monitoring to confirm metals and radionuclide concentrations in sediment; and lake sedimentation rates are not increasing above predicted levels.
Operation	Design of WTP.	Y	N	L	L	MT	C	I	U				
Decommissioning and Abandonment		N	-	-	-	-	-	-	-				
Residual environmental effects for all Phases													

9.4.2 Cumulative Effects

No local, Nunavut, or Far Future Scenario projects from the Project Inclusion List affect sediment quality and overlap spatially and temporally with effects associated with this Project. Therefore, no cumulative effects to sediment quality are predicted for this project.

9.4.3 Effects of Climate Change on Project and Cumulative Effects on Sediment Quality

Twenty three climate change scenarios were explored, of which twenty predict an increase in annual precipitation for the period 2071-2099. The greatest increase in precipitation was 78% greater than historical rates. On average, the models predict a 34% increase in precipitation; this increase is typically distributed throughout the year, however most dramatic increases occur in the autumn.

As summers become warmer and wetter, lake evaporation and evapotranspiration conditions are typically predicted to increase. Although water losses typically increase, under many ensembles, the magnitude does not compensate for the dramatic increases in precipitation. Twenty of the twenty three climate change ensembles predict an increase in runoff at Judge

Sisson and Pointer Lake outflows. On average, runoff is estimated to increase 67% and 74% for Pointer Lake and Judge Sissons Lake watersheds, respectively.

Increased precipitation and stream flows associated with climate change would result in reduced buildup of metals and other COPCs in Judge Sissons Lake sediments over those levels predicted in this EIA. This is due to the increased volumes of water flowing through the lake, effectively flushing COPCs out of the lake more quickly, giving them less time to build up.

9.5 MITIGATION MEASURES FOR SEDIMENT QUALITY

This is a summary of the project effects considered for sediment quality. A number of mitigation measures and project design modifications will be implemented to limit changes to sediment quality:

- The site footprint will be minimized and situated such that natural drainage areas and watershed boundaries are maintained.
- The site water system will be designed to recycle water where applicable and water use will be minimized to limit withdrawal requirements and discharge quantities.
- Diversion channels will be designed to keep water within its natural drainage path.
- In-water construction will follow standard protocols and best management practices.
- Andrew Lake pit will be dewatered at a rate such that effects to sediment quality in Andrew Lake and downstream areas are minimized.
- Andrew Lake Pit area will be dewatered after the spring freshet and before freeze-up (July/August).
- Water will be discharged into large waterbodies to reduce effects to sediment quality.
- During decommissioning, the ground surface will be recontoured and natural flow patterns will be restored.

9.6 COMPLIANCE AND ENVIRONMENTAL MONITORING FOR SEDIMENT QUALITY

- Sediment quality in lakes adjacent to and downstream of the Mine LAA will be monitored every three years to confirm that metals and radionuclide concentrations, and lake sedimentation rates are not increasing above predicted levels. Sediment monitoring will occur during the operational and closure phases of the Project.
- Sediment quality will be monitored in the two receiving basins, and in the main body of Judge Sissons Lake every three years as part of the Environmental Effects Monitoring Plan.

10 EFFECTS ASSESSMENT FOR AQUATIC ORGANISMS AND FISH HABITAT

10.1 SCOPE OF THE ASSESSMENT FOR AQUATIC ORGANISMS AND FISH HABITAT

The NIRB Guidelines for the Kiggavik Project (NIRB, 2011) identify the freshwater aquatic environment, including aquatic ecology, aquatic biota (including fish, aquatic macrophytes, benthic invertebrates, and other aquatic organisms), and habitat as a single Valued Ecosystem Component (VEC). For the purposes of this assessment, aquatic organisms and fish habitat have been combined into a single Valued Ecosystem Component (VEC), as they are supporting ecosystem components for maintaining a healthy fish population. Aquatic organism populations and distributions must be healthy and productive, as does fish habitat, if fish populations are to remain healthy and resilient, and available for human consumption. In turn, healthy aquatic organism populations and fish habitat are supported by good quality water and sediments. Fish populations and distributions and fish flesh chemistry will be considered as a separate VEC; they are described in Section 11.

10.1.1 Project–Environment Interactions and Effects

Information was gathered from the environmental and engineering teams for the Kiggavik Project, through public engagement, and by NIRB to identify project activities that have potential to result in changes to the abundance or distributions of aquatic organisms, or to the quality or distribution of fish habitat. Relevant project activities and the associated environmental interactions for each Project phase are summarized in Table 10.1-1 for project-environment interactions that were ranked Category 1 or 2 in Table 4.3-1.

Table 10.1-1 Project – Environment Interactions and Effects – Aquatic Organisms and Fish Habitat

Project Phase	Project Activities/Physical Works	Change in Aquatic Organism Abundance or Distribution	Change in Quality or Distribution of Fish Habitat
Construction:			
In-Water Construction	Construct freshwater diversions and site drainage containment systems (dykes, berms, collection ponds)	0	2
	Construct in-water/shoreline structures	0	2
	Water transfers and discharge	0	2
	Freshwater withdrawal	0	1
On-Land Construction	Site clearing and pad construction (blasting, earth moving, loading, hauling, dumping, crushing	0	2
Operation:			
Mining	Mining ore (blasting, loading, hauling)	0	0
	Mining special waste (blasting, loading, hauling)	0	0
	Mining clean waste (blasting, loading, hauling)	0	0
	Mine dewatering	0	0
Water Management	Create and maintain water levels	0	0
	Freshwater withdrawal	0	1
	Collection of site and stockpile drainage	1	0
	Water and sewage treatment	1	0
	Discharge of treated effluents (including greywater)	2	0
	Disposal of sewage sludge	0	0
Transportation	Truck transportation	1	2
	General traffic (project-related)	0	0
Ongoing exploration	Ground surveys	0	0
	Drilling	0	0
Final Closure:			
General	Ongoing withdrawal, treatment and release of water, including domestic wastewater	2	0
In-water Decommissioning	Remove freshwater diversions; re-establish natural drainage	0	2
	Remove surface drainage containment	0	2
	Remove in-water/shoreline structures	0	2
	Water transfers and discharge	0	0
	Construct fish habitat as per FHCP	0	2
On-land Decommissioning	Remove site pads (blasting, earth moving, loading, hauling, dumping)	0	2
Post Closure:			
On-land Decommissioning	Management of restored site	0	0

Category 1 activities are those having an interaction with the aquatic environment; however, based on past experience and professional judgment, the resulting effect can be managed to acceptable levels through standard operating practices and/or through the application of best management or codified practices. No further assessment is warranted.

Category 2 activities are those activities that do interact with the aquatic environment and the resulting effect may exceed acceptable levels without implementation of specified mitigation. Further assessment of the effects of these interactions on the aquatic environment is warranted and is presented in this environmental assessment report.

The rationale for ranking interactions as Category 1 is presented below. Those interactions ranked as Category 2 are discussed in more detail in the following sections.

CONSTRUCTION:

Construction of Freshwater Diversions and Site Drainage Containment Systems; Water Transfers and Discharge; Site Clearing and Site Pad Construction; Truck Transportation (hauling ore from Sissons to Kiggavik Mine Site)

During the Project construction phase, land clearing and earth moving will be carried out to prepare areas for mine and mill site infrastructure development. Stream and watercourse crossings will be required as a component of developing mine infrastructure such as the ore haul road between the Kiggavik and Sissons Mine Sites, the access roads to the water intake locations and effluent discharge point, and the airstrip. As most medium- to large-sized streams support fish during the summer months, installation of stream crossing structures will result in the alteration, and possibly loss, of fish habitat. To reduce and mitigate these effects, best management practices will be incorporated into stream crossing design to minimize the amount of fish habitat lost or altered at each crossing.

As part of developing the mine site and infrastructure at the Kiggavik site, the stream between Mushroom Lake and End Grid Lake will have to be diverted around the mine workings. Portions of this stream are known to contain fish during the open water season.

During the mine development process, a portion of Andrew Lake will be dyked off and dewatered in order to construct the Andrew Lake mine pit at the Sissons site. This work will result in the loss of 13.5 hectares of seasonal use fish habitat in the east end of Andrew Lake. Although Andrew Lake has a maximum depth of only 1.0 metre, it represents rearing and foraging habitat for a number of fish species during the open water season. A Fish Habitat Compensation Plan (FHCP) will address this loss of seasonal fish habitat with the replacement of an equal amount of similar quality habitat.

A FHCP will be developed for submission to Fisheries and Oceans Canada (DFO). All known alterations, disruptions, and losses of fish habitat will be identified, and acceptable fish habitat compensation and mitigation efforts will be identified and put forward. Although no-net-loss of fish habitat will occur as a result of the Project, this effect is carried forward to the analysis of residual effects, because the final Fish Habitat Compensation Plan is still being developed, and has not yet been approved by DFO.

FINAL-CLOSURE:

Removal of Freshwater Diversions and Site Drainage Containment Systems; Site Pad Removal; Construct Fish Habitat as per FHCP

All water course diversions and stream crossing structures will be removed during the final closure phase, and stream substrates restored to similar conditions to those found in the pre-development stream. Although no long term or large scale changes to fish habitat associated with road construction are anticipated, this Project effect is carried forward to the detailed analysis of residual effects because the final FHCP is still being developed.

CONSTRUCTION:

Construction of In-Water/Shoreline Structures

Installation of water intake structures and connecting water intake lines in Mushroom and Siamese Lakes, and the effluent diffuser structure and effluent line in Judge Sissons Lake is expected to result in the alteration or temporary loss of fish habitat. Any alterations or losses of fish habitat will be identified in the FHCP for the Project. The FHCP will identify fish habitat compensation and mitigation efforts required to achieve “no-net-loss” of fish habitat. Because the FHCP is still being developed, and has not yet received the approval of DFO or the government of Nunavut, this project-environment interaction is carried forward to the analysis of residual effects.

FINAL-CLOSURE:

Removal of In-Water/Shoreline Structures

Removal of water intake structures and connecting water intake lines in Mushroom and Siamese Lakes, and the effluent diffuser structure and effluent line in Judge Sissons Lake is also expected to result in alterations to fish habitat. However, the effect is expected to be reduced from that incurred during the initial structure construction/installation. Any alterations or losses of fish habitat will be identified in the FHCP for the Project; the FHCP will also identify fish habitat compensation and mitigation efforts required to achieve “no-net-loss” of fish habitat. The FHCP is in the process of being developed, but has not yet received the approval of DFO or the government of Nunavut. This project-environment interaction has been carried forward to the analysis of residual effects.

CONSTRUCTION and OPERATION:

Freshwater Withdrawal

Water will be withdrawn from Mushroom and Siamese lakes for use as potable and mill process water supplies. Water balance calculations have been completed for both lakes to ensure that they are capable of supplying the required water volumes with minimal lake level drawdown over the winter ice-covered season. Water levels in both lakes recover during the spring snowmelt freshet. Water volumes proposed for withdrawal during the winter ice-covered period represent 3.0% to 4.0% of the under-ice volumes of Siamese Lake and 8.8% of the under-ice volume of Mushroom Lake; less than the 10% of under-ice volume maximum acceptable withdrawal limit set by DFO for Arctic waters (DFO 2005) (Table 10.1-2). Winter draw downs are expected to be about 34.2 cm for Mushroom Lake, and between 9.4 cm and 16.5 cm in Siamese Lake, depending on several water availability scenarios (Table 10.1-3).

Table 10.1-2 Estimated Maximum Annual Water Withdrawal Volumes for Selected Waterbodies

Waterbody	Under-Ice Volume (m^3)	Maximum Annual Water Withdrawal Volume		
		Maximum of 10% Allowed by DFO (m^3)	Required Volume (m^3)	Required portion of Lake Under-Ice Volume (%)
Siamese Lake: both basins together	65,800,000	6,580,000	1,960,000	3.0 (equivalent of 9.4 cm)
Siamese Lake: both basins (October-March) and West Basin only (April-May)	65,800,000 28,000,000	6,580,000 2,800,000	1,960,000	3.0 in the east basin (equivalent of 9.4 cm) 4.0 in the west basin (equivalent of 16.5 cm)
Mushroom Lake	284,000	28,400	25,125	8.8 (equivalent to 34.2 cm)

m^3 = cubic metres; % = percent; cm = centimetres.

An under-ice water level drawdown between 9.4 cm and 16.5 cm in Siamese Lake will result in a loss of potential lake trout spawning habitat area between 1.6% (0.12 ha) and 2.2% (0.16 ha), respectively, depending on different water availability scenarios. A drawdown of 34.2 cm in Mushroom Lake will result in a loss of potential lake trout spawning habitat area of about 11.0% (0.05 ha) each winter during the Sissons Mine Site operations (Table 10.1-3).

Table 10.1-3 Potential Lake Trout Spawning Habitat Loss for Siamese Lake and Mushroom Lake

Waterbody / Scenario	Potential Lake Trout Spawning Area Available (m^2)	Under Ice Water Level Drawdown (cm)	Potential Lake Trout Spawning Habitat Loss		
			Surface Area (m^2)	Surface Area (ha)	Percent of Change (%)
Siamese Lake – both basins together	74,241	9.4 in both basins	1,163	0.12	1.57
Siamese Lake (October-March) and West Basin only (April-May)	74,241	9.4 in east basin 16.5 in west basin	1,631	0.16	2.20
Mushroom Lake	4,132	34.2	455	0.05	11.01

m^2 = square metres; cm = centimeters; % = percent; ha = hectares.

A desktop study was undertaken to identify the potential impact of water drawdown on lake trout spawning habitat, as eggs and larval fish of this fall spawning species will be most susceptible to changes in water levels. Potential suitable spawning locations were determined theoretically by cross-matching available data (e.g., substrate type and size, depth and slope of cobbles, sedimentation rate, winter under-ice dissolved oxygen levels, presence of current, direction of predominant winds, presence of ice scour and cover, and water level fluctuations). Of the data available, the limiting factors for determination of potential lake trout spawning habitat included the presence of cobbles on moderate to high slope areas, high dissolved oxygen levels, and the occurrence of multiple layers of cobble substrate. Through this desktop assessment, locations of potential lake trout spawning habitat were identified between 2 m and 5 m deep throughout Siamese Lake, with the majority of the potential areas being identified in the east basin. Potential lake trout spawning habitat was identified between 2 m and 6 m deep on the north shore of Mushroom Lake.

The potential loss of lake trout spawning habitat in Siamese Lake could be 0.12 ha if both basins of Siamese Lake stay connected in late winter (April and May), or 0.16 ha if the west basin of Siamese Lake becomes separated from the east basin at the end of the winter. The potential loss of lake trout spawning habitat in Mushroom Lake is 0.55 ha. Because this total area (0.17 ha or possibly 0.21 ha) of potential lake trout spawning habitat was identified using desktop methodology, no proposal for compensation of this potential (and theoretical) loss is being made until field verification of lake trout spawning use of the potential habitats has been completed.

During the construction phase of the Project, about 75,000 cubic metres (m^3) of water will be withdrawn annually from lakes along the route of the proposed winter access road between Baker Lake and the Kiggavik site. Calculations show that expected water withdrawal volumes from the lakes along the route represent between 0.01% and 0.87% of the under-ice volume of these lakes (Table 10.1-4). These volumes are all substantially less than the maximum water withdrawal volumes allowed under DFO's policy of a maximum of 10% of the under-ice volume (DFO 2005).

Table 10.1-4 Estimated Maximum Annual Water Withdrawal Volumes for Selected Waterbodies

Waterbody	Under-Ice Volume[a] (m^3)	Maximum Annual Water Withdrawal Volume		
		Maximum of 10% Allowed by DFO (m^3)	Required Volume[b] (m^3)	Required portion of Lake Under-Ice Volume (%)
Siamese Lake	65,821,284	6,582,128	7,275	0.01 (0.2 cm drawdown)
L2 / 20 km Lake	21,215,910	2,121,591	7,275	0.03 (0.2 cm drawdown)
Long Lake	1,573,164	157,316	8,850	0.56 (0.5 cm drawdown)
Audra Lake	30,409,439	3,040,944	27,450	0.09 (0.8 cm drawdown)
Four Unnamed Lakes	1,990,323	199,032	12,075	0.61 (0.5 cm drawdown)
Qinguq Bay	1,389,562	138,956	12,075	0.87 (0.5 cm drawdown)
Total	**122,399,682**	**12,239,968**	**75,000**	**0.06**

Source: Golder Technical Memo to Nicola Banton sent on April 13, 2011.

[a] Estimates based on EBA (2010) ground penetrating radar (GPR) data.

[b] Required volumes were allocated proportionally along the winter access road.

m^3 = cubic metres; % = percent; cm = centimetres.

No long term or population limiting changes to fish habitat are anticipated with the proposed withdrawal of water from LAA lakes for potable water and mill supply purposes, or from water use associated with the annual construction and maintenance of the proposed winter road. As a result, this interaction is ranked as a Category 1 effect and is not carried forward for detailed analysis of residual effects.

10.1.2 Indicators and Measurable Parameters

Aquatic organisms and fish habitat are two components of the freshwater aquatic environment VEC identified by NIRB (2011) for assessment of Project effects. Two measurable parameters were selected for assessing potential effects to aquatic organisms: changes in relative abundance and distribution of aquatic organism species, and changes in the concentrations of radionuclides and identified COPC compared to toxicity benchmarks for aquatic life. Two additional measurable parameters were selected for assessment of Project effects on fish habitat: fish habitat quantity and distribution, and changes in fish habitat quality. Some fish habitats are more important in supporting critical life stages or processes than others, and therefore are considered to be of higher quality (Table 10.1-5).

Changes in any of these measurable parameters provide a direct method of quantifying project effects on aquatic organism populations or fish habitat. Sufficient baseline aquatic organism and fish habitat mapping data is available for lakes and streams in the LAA to confidently estimate potential effects through these measurable parameters.

Table 10.1-5 Measureable Parameters for Aquatic Organisms and Fish Habitat

Environmental Effect	Measurable Parameters	Notes or Rationale for Selection of the Measurable Parameter
Change in abundance and distribution of aquatic organism populations	Relative abundance and distribution of aquatic organism species	Measuring relative abundance and spatial distribution of aquatic organisms allows quantification of changes in their spatial and temporal distribution
	Changes in concentrations of radionuclides and identified COPC compared to toxicity benchmarks	Comparing concentrations of radionuclides and other COPC with baseline levels allows quantification of changes in COPCs spatially and temporally
Change in abundance and distribution of fish habitat	Habitat quantity and distribution Habitat quality	Comparing the abundance, spatial distribution and quality of fish habitat allows quantification of changes in its spatial and temporal distribution, and value

10.1.3 Assessment Boundaries

Spatial and temporal boundaries for the assessment of environmental effects on aquatic organisms and fish habitat are as described in Section 4.5. A technical boundary for the assessment of effects on aquatic biota is the limitation on assessing mixture of compounds (e.g., exposure to multiple metals) and multi-stressors due to limitations in the scientific database.

10.1.4 Residual Environmental Effects Criteria

General descriptions of residual environmental effects criteria are presented in Section 4.6 and apply to effects on aquatic organisms and fish habitat. However, more specific descriptions apply to the magnitude of residual environmental effects.

For fish habitat, magnitude is defined as the amount of change in area relative to the area of various fish habitat types found in the existing environment baseline (e.g., percent loss of area of known or potential Arctic grayling spawning habitat).

- Negligible: The Project will not affect fish habitat in waterbodies in the LAA.
- Minor: The Project will affect fish habitat in waterbodies in the LAA, but these effects will be within the natural range of variability.
- Moderate: The Project will affect fish habitat in waterbodies in the LAA and the effects will be beyond the natural range of variability. The effects do not extend to the RAA.
- High: The Project will affect fish habitat in waterbodies in the LAA and the RAA and the effects will be beyond the natural range of variability.

For other water quality parameters (e.g., dissolved metals), magnitude is defined by whether measured values exceed aquatic biota toxicity values specific for each compartment of aquatic biota.

10.1.5 Standards or Thresholds for Determining Significance

Under the NIRB Project Specific Guidelines the environmental assessment must include a determination of the significance of environmental effects. Threshold criteria or standards for determining the significance of environmental effects were identified for each VEC, beyond which a residual environmental effect would be considered significant. Where available, these were selected in consideration of federal and territorial regulatory requirements, standards, objectives, or guidelines applicable to the VEC (Section 8.3 for Water Quality). In addition, aquatic toxicity data will be used to directly assess the potential effects on aquatic biota.

Toxicity reference values (TRVs) specific for different aquatic biota are used to judge whether the predicted exposures may potentially have an adverse effect on ecological species at the population level. The TRVs for aquatic species are generally based on acute toxicity tests carried out under standardized conditions in the laboratory using sensitive test species (e.g., rainbow trout). Toxicity tests that examined growth, reproduction or survival were considered to be relevant to the persistence of aquatic populations. In general, the concentrations associated with effects in 20% of the biota included in the test are selected. The TRVs selected for use for the Kiggavik Project are consistent with those used in a recently completed EA for the water management project at the Cigar Lake uranium mine in northern Saskatchewan (Cameco 2010).

Table 10.1-6 summarizes the TRVs used in the evaluation of potential effects on aquatic biota. Hardness was included in the modelling; however, it is not a COPC but affects the toxicity of other parameters. For example, the toxicity of several metals is dependent on hardness with decreasing toxicity at higher hardness levels. The background materials for the toxicity reference values selected for this assessment are provided in Appendix 8A.

Table 10.1-6 Selected Toxicity Reference Values for Aquatic Biota

COPC	Units	Aquatic Plants	Phyto-plankton	Zoo-plankton	Benthic Invertebrates
Uranium	µg/L	5,500	400	60	27
Arsenic	µg/L	252	5 [(b)]	340	122
Cadmium	µg/L	16	3	0.07	0.5
Cobalt	µg/L	54.3	212	4.8	4
Copper [(a)]	µg/L	38	9.2	4	4
Lead [(a)]	µg/L	439	114	40	1 [(c)]
Molybdenum	µg/L	15,000	15,000	233	250
Nickel [(a)]	µg/L	84	93.2	38	53.5
Selenium	µg/L	680	31.7	10	10
Zinc [(a)]	µg/L	116	30 [(d)]	30 [(d)]	30 [(d)]
Ammonia (un-ionized)	µg/L		800	160	120
Chloride	mg/L	1260	590	290	143
Sulphate	mg/L	828	1112	246	1056

Note:

a = Toxicity reference values (TRVs) based on low hardness water.

b = TRV set equal to CWQG for arsenic.

c = TRV set equal to CWQG for lead in low hardness water.

d = TRV set equal to CWQG for zinc.

COPC = constituents of potential concern; µg/L = micrograms per litre

For radioactivity, a review of the recommendation by various agencies was provided. Two reference dose rates values were selected for each biota; 10 mGy/d for all biota as well as 3 mGy/d for aquatic plants and plankton and 6 mGy/d for benthic invertebrates.

Potential changes in a measurable parameter or VC resulting from Project or cumulative effects were evaluated against these standards or thresholds, and were rated as either *significant* or *not significant*. A significant effect on aquatic organisms and fish habitat would occur when the change in aquatic organism populations or distribution, and changes in the quantity and quality of fish habitat would result in a population level effect on other biota (including fish) in the aquatic ecosystem. The significant effect could be high in magnitude, occur over a long period of time, and/or have a large spatial extent. An effect on aquatic organisms will be considered not significant when it is small in magnitude or spatial area, is of short duration (temporary), and is not expected to result in population level effects to the ecosystem. Changes in fish habitat will be considered not significant if the amount of fish habitat altered, disrupted or destroyed is compensated for with equivalent or greater areas of fish habitat of similar or superior quality.

10.2 EFFECTS ASSESSMENT FOR AQUATIC ORGANISMS AND FISH HABITAT

The effects of the Project on the Aquatic Organisms and Fish Habitat VEC are changes in the abundance and distribution of aquatic organism populations, and changes in the quantity and quality of fish habitat. These effects are assessed in the following sections.

10.2.1 Assessment of Change in the Abundance and Distribution of Aquatic Organism Populations

The potential implication of the changes in water and sediment concentrations, due to effluent release from the WTP, on the concentrations in aquatic biota will be examined. The particular focus is on Judge Sissons Lake.

10.2.1.1 Analytical Methods for Change in the Abundance and Distribution of Aquatic Organism Populations

Treated effluent discharge from the Kiggavik and Sissons Water Treatment Plants (WTP) may affect surface water quality. These changes will affect the concentration of COPC in aquatic biota (i.e., aquatic plants, benthic invertebrates, plankton). Parameters in water that were identified as COPC include: ammonia, chloride, sulphate, radionuclides (U-238, Th-230, Ra-226, Pb-210, Po-210) and select metals (arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, and zinc). The approach used to predict water concentrations was discussed in Section 8 of this Tier 2 document and is further detailed in Appendix 8A.

The assessment of the potential impact on non-radiological COPC on aquatic biota is conducted by comparison the estimated water concentration to the biota-specific toxicity reference value (TRV). The assessment was based on the total concentration which considers both baseline concentration plus the influence of project emissions. For radioactivity, the potential exposure from internally deposited radionuclides as well as external exposure is included in a dose estimate. The concentration within the aquatic biota is obtained through the use of a transfer factor that relates the concentration in different media (e.g. water and aquatic vegetation). In general, transfer factors were based on site-specific information and, as they are empirically based, include the contribution from all routes of exposure.

Radiation effects on biota depend not only on the absorbed dose, but also on the relative biological effectiveness (RBE) of the particular radiation (i.e., alpha, beta or gamma radiation). Recent recommendations have focused on an RBE of 10 for alpha radiation; however, to illustrate the effects of uncertainty in RBE a range was examined. The total dose, which is based on the baseline plus Project emissions for the sum of the uranium-series radionuclides, is compared to a reference dose rate that is protective of aquatic biota. The bounding scenario carried through the ecological assessment was based on separate discharges from the Kiggavik water treatment plant and Sissons water treatment plant, an extended operating period (25 years) followed by a 22-year period of consolidation where water treatment would be required.

The assessment accounted for the uncertainty and variability in the emissions and the behaviour in the environment.

The details of the assessment are provided in the Ecological Risk Assessment (Appendix 8A).

10.2.1.2 Baseline Conditions for Change in the Abundance and Distribution of Aquatic Organism Populations

Under baseline conditions aquatic biota are exposed to COPC as these constituents are present naturally in the environment. Concentrations of radionuclide COPC in aquatic plants were measured and this baseline information was used to make sure the current conditions are reflected in the pathways assessment.

10.2.1.3 Effect Mechanism and Linkages for Change in the Abundance and Distribution of Aquatic Organism Populations

The release of COPC from the WTP can affect water quality in the receiving environment. The quality of the water is critical for evaluating the potential effect on aquatic biota. The effect on water quality will change with different phases of the project (e.g., operational period, closure). In the final closure period the recovery of the system can be predicted. Other ecological receptors may consume aquatic biota and would be exposure through this pathway.

10.2.1.4 Mitigation Measures and Project Design for Change in the Abundance and Distribution of Aquatic Organism Populations

The design of the WTP was such to provide an effluent that met or exceeded all appropriate regulations (e.g. MMER). Design aspects, operational measures and other mitigation measures have been incorporated into the current Project plans which will minimize project-associated emissions and/or the potential effect of project-related emissions. Further detail on the design of the water treatment plant can be found in Volume 2.

10.2.1.5 Residual Effects for Change in the Abundance and Distribution of Aquatic Organism Populations

In this study, adverse effects from exposure to COPC were characterized by a simple screening index. This index was calculated by dividing the predicted exposure by the toxicity reference value for each ecological receptor as follows:

$$Screening\ Index = \frac{Exposure}{Toxicity\ Reference\ Value}$$

Screening index values are not estimates of the probability of ecological effect. Rather, the index values are correlated with the potential of an effect, i.e. higher index values imply a greater potential of an effect. The exposure includes both the natural baseline levels as well as the effect of the Project emissions. Therefore, a screening index value less than 1.0 indicates that the estimated total exposure is less than that associated with an adverse effect. The screening index values (maximum values at any time and within any segment of Judge Sissons Lake) for aquatic biota are shown in Table 10.2-1.

Table 10.2-1 Screening Index Values for Aquatic Biota

	Aquatic Plants		Phytoplankton		Benthic Invertebrates		Zooplankton	
	Maximum Mean	Maximum 95th Perc	Maximum Mean	Maximum 95th Perc	Maximum Mean	Maximum 95th Perc	Maximum Mean	Maximum 95th Perc
Uranium	n/a	n/a	0.13	0.25	<0.01	<0.01	0.13	0.25
Arsenic	<0.01	<0.01	0.07	0.1	<0.01	<0.01	<0.01	<0.01
Cadmium	0.03	0.05	0.17	0.24	**1.02**	**1.44**	**7.28**	**10.29**
Cobalt	n/a	n/a	<0.01	<0.01	<0.01	<0.01	0.09	0.13
Copper	0.03	0.03	**1.31**	**1.31**	0.05	0.05	**1.27**	**1.27**
Lead	<0.01	<0.01	<0.01	<0.01	0.04	0.05	0.03	0.04
Molybdenum	n/a	n/a	<0.01	<0.01	n/a	n/a	0.03	0.07
Nickel	0.02	0.02	0.66	0.68	<0.01	<0.01	0.07	0.07
Selenium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02
Zinc	<0.01	<0.01	0.65	0.65	0.05	0.05	0.65	0.65
Un-ionized Ammonia	n/a	n/a	0.01	0.02	0.08	0.13	0.06	0.1
Chloride	0.07	0.11	0.15	0.23	0.61	0.94	0.3	0.46
Sulphate	0.32	0.51	0.24	0.38	0.25	0.4	**1.09**	**1.7**
Radioactivity - RBE10	0.022	0.083	n/a	n/a	0.017	0.017	n/a	n/a
Radioactivity - RBE40	0.063	0.091	n/a	n/a	0.052	0.083	n/a	n/a

NOTES:
n/a Not available
SI values for non-radiological COPC are based on the maximum predicted water concentration compared to the TRV
SI values of radiological effects include the contribution from U-238, Th-230, Ra-226, Pb-210 and Po-210
Details of calculation as well as additional results provided in Appendix 8A

The bold shading in Table 10.2-1 indicates SI values that are above 1.0. All COPC have predicted SI values less than 1.0 for all segments of Judge Sissons Lake, with the exception of cadmium for zooplankton and benthic invertebrates, copper for phytoplankton and zooplankton and sulphate for zooplankton.

The exceedances of the toxicity benchmarks for copper are only in JSL-1 and JSL-7 and can be attributed to baseline copper concentrations in the area. JSL-1 and JSL-7 are shallow segments and therefore experience the largest variation between summer and winter concentrations. Due to winter ice cover, water concentrations during the winter months are predicted to increase because of a reduced volume of free-flowing water. The SI values were calculated using the maximum monthly mean and 95th percentile predicted concentrations and therefore represent winter conditions, times of reduce biological activity. Overall, no residual effect was identified for copper.

A potential issue was identified for cadmium exposure to benthic invertebrates. The SI values identified are only slightly above 1 (1.02 at the mean and 1.44 at the 95th percentile). The predicted sediment concentrations did not identify an issue with benthic invertebrates. Considering the minor exceedance and the results of the sediment analysis no effects on benthic invertebrates from exposure to cadmium are expected.

As seen in Table 10.2-1 a potential issue for zooplankton exposure to cadmium was identified in Judge Sissons Lake. An important consideration in the determination of the potential toxicity of cadmium is the hardness. The natural condition of Judge Sissons Lake is very low hardness water. However, as discussed in Section 8 the release of treated effluent will raise the hardness to 100 to 200 mg/L. Under these conditions the toxicity of cadmium will be ameliorated. At a hardness of 100 mg/L the lowest toxicity value for zooplankton available (USGS 2010) is 0.23 µg/L. The SI values for cadmium exposure to zooplankton based on this TRV are shown in Table 10.2-2.

Table 10.2-2 SI Values for Cadmium Exposure to Zooplankton, Hardness Adjusted

Segment	Mean	95th Percentile
JSL-1	**2.21**	**3.13**
JSL-2	**1.46**	**1.99**
JSL-3	**1.19**	**1.92**
JSL-4	**1.05**	**1.55**
JSL-5	0.90	**1.32**
JSL-6	0.55	0.70
JSL-7	**1.72**	**1.96**
JSL-8	0.65	0.79

Note: **BOLD SHADING** indicates an exceedance of 1.0

SI values calculated using a TRV of 0.23 µg/L, which is based on a hardness of 100 mg/L

Table 10.2-1 also identified a potential issue for zooplankton due to exposure to sulphate. SI values above one were identified in JSL-1, JSL-2, JSL-4, JSL-5 (95th percentile only) as well as JSL-3 (mean and 95th percentile). The largest SI value is 1.7 for the 95th percentile in JSL-3. Hardness may also have an ameliorating effect on sulphate toxicity but a definitive relationship has not been developed. Overall, a residual effect was identified for cadmium and sulphate exposure to zooplankton. This is examined further in Table 10.2-3.

Table 10.2-3 Application of Residual Effects Criteria for Aquatic Biota

Attribute	Description	Rating	Comment
Direction	The ultimate long-term trend of the environmental effect	Adverse	Levels of cadmium and sulphate may lead to an effects on zooplankton.
Magnitude	Amount of change in a measurable parameter relative to the baseline case	Medium	It is expected that cadmium and sulphate concentrations in Judge Sissons Lake would be elevated compared to baseline. Changes are less than an order of magnitude (SI values are less than 10).
Geographic Extent	The geographic area within which an environmental effect occurs	Local	The effect is confined to the select segments of Judge Sissons Lake.
Frequency	Number of times that an effect may occur over the life of the project	Continuous	Effect occurs continuously throughout the project.
Duration	Length of time over which the effect is measurable	Medium term	More than one year, but not beyond the end of project decommissioning.
Reversibility	Likelihood that a measurable parameter for a VEC will recover from an environmental effect to baseline conditions	Reversible	Will likely recover to baseline conditions during the final closure phase.

10.2.1.6 Determination of Significance for Change in the Abundance and Distribution of Aquatic Organism Populations

Table 10.2-2 shows potential issues with cadmium exposure to zooplankton. SI values above 1 are identified for JSL-1, JSL-2, JSL-3, JSL-4 and JSL-7; however the magnitude of the potential effect is under 3. The maximums occur in winter during times of reduced biological activity and these segments represent less than 40% of the total lake area. Overall, it is possible that in certain segments of the lake some of the more sensitive zooplankton species will be affected; however considering the moderate SI values and the spatial extent of the impact, the zooplankton population of Judge Sisson Lake is expected to continue to function.

Similar to cadmium, it is possible that in certain segments of the lake some of the more sensitive zooplankton species will be affected; however considering the low SI values and the spatial extent of the impact, the zooplankton population of Judge Sisson Lake is expected to continue to function. Overall, although there are residual effects, no significant adverse effects on the abundance and distribution of aquatic biota are expected due to changes in COPC concentrations in the receiving environment from releases from the WTPs.

10.2.1.7 Compliance and Environmental Monitoring for Change in the Abundance and Distribution of Aquatic Organism Populations

Benthic macroinvertebrate populations and diversity should be monitored regularly (every third year) during mine operation, closure, and post-closure as part of the Environmental Effects Monitoring Program, to determine whether WTP effluent discharges are having quantifiable effects on benthic macro-invertebrate populations. This monitoring program should be combined with a similar water quality monitoring program in each section of Judge Sissons Lake receiving treated effluent, as well as at the outlet of Judge Sissons Lake.

10.2.2 Assessment of Changes in Fish Habitat

Fisheries and Oceans Canada's Policy for the Management of Fish Habitat (DFO 1986) (Policy for no-net-loss of fish habitat) requires the development of a Fish Habitat Compensation Plan (FHCP), which will ensure there will be no residual Project effects on fish habitat. In general, development projects can potentially affect fish habitat in two ways; fish habitat may be lost, or fish habitat may be altered.

10.2.2.1 Analytical Methods for Changes in Fish Habitat

Fish habitat is comprised of a combination of lake and stream characteristics such as lake morphometry (e.g., size, shape, mean and maximum depths.), stream channel type (e.g., runs, pools, riffles), substrate type (e.g., sand, gravel, cobbles, boulders), and fish use (e.g., spawning, rearing, and foraging), and can be quantified by area (square metres) and type of habitat. Existing environment baseline habitat quality has been identified by previous fieldwork, so changes in fish habitat are measured by the change in area of available fish habitat. Because DFO has a Policy of "no-net-loss" of fish habitat, any Project related activity that results in the harmful alteration, disruption or destruction of fish habitat requires an authorization to proceed from DFO. Before an authorization to proceed will be issued, a plan for the mitigation and replacement of habitat losses must be in place and approved by DFO.

10.2.2.2 Baseline Conditions for Changes in Fish Habitat

Baseline conditions for fish habitat in the Kiggavik Project area are described more thoroughly in Section 5.5.5 Freshwater Habitats, and in detail in Appendix 5C (Section 10.0).

In general terms, most lakes and ponds in the Mine Site LAA are shallow and provide only seasonal foraging and rearing habitat for fish. Overwintering habitat is found in a few deeper lakes (i.e., Cigar, Cirque, Judge Sissons, Mushroom, Ridge, and Siamese lakes, and Pointer Pond) in the area. All lakes less than 2.0 m deep, and all area streams and rivers (with the exception of the Thelon River) are thought to freeze to the bottom as winter ice depths up to 2.0 m thick commonly occur. It is uncertain whether five lakes with maximum depths between 2.0 and 3.0 m deep (i.e., Caribou, Crash, Fox, Pointer, and Willow lakes) are capable of supporting fish overwinter.

Many of the larger stream systems in the LAA support Arctic grayling spawning runs, as well as other fish species that move into the streams during the open water period to forage or to escape predatory fish in the over-wintering lakes. The diversity of fish species in streams is highest close to over-wintering lakes, and decreases as you move higher in the watershed (unless a deep, over-wintering lake exists in the headwaters of a stream system).

10.2.2.3 Effect Mechanism and Linkages for Changes in Fish Habitat

A number of Project development activities have the potential to alter, disrupt, or destroy fish habitat. These include diversion of streams away from their current locations, drainage of lakes or portions of lakes, installation of stream crossing structures on all-season ore haul roads and other roads related to constructiong and maintaining Project infrastructure (e.g., roads to water intake and effluent discharge structures and the airstrip).

The following Project activities are likely to result in losses of fish habitat:

- A number of streams and watercourse channels will be diverted to facilitate construction of the Kiggavik and Sissons mines and mill site, and associated infrastructure. However, only one of the stream sections proposed for diversion supports a documented fish population. This is Mushroom-End Grid Stream flowing from Mushroom Lake to End Grid Lake near the Sissons Mine Site. This stream has been documented to support spawning Arctic grayling and foraging lake trout just downstream of the Mushroom Lake outlet during the spring spawning season. Although this fish-bearing section of the stream will not be affected by the Sissons Mine Site development, the majority of the remainder of the stream will be diverted around the Sissons Mine Site and reconnected with itself at a location further downstream. The abandoned section of stream channel connecting End Grid and Mushroom lakes will be filled in as part of developing facilities at the Sissons Mine Site. None of the other streams proposed for diversion or alteration contain any documented fish populations, or the diversions are located in the stream headwaters, upstream of known fish populations.
- Construction of a berm across the north-east portion of Andrew Lake, and subsequent removal of the water from the bermed section for construction of the Andrew Lake Mine Pit. This will result in the loss of an area of Andrew Lake estimated to be 13.5 hectares in area. Andrew Lake provides seasonal rearing and foraging habitat for Arctic grayling, burbot, cisco, and round whitefish. Andrew Lake is too shall to support fish overwinter (i.e., maximum depth 1.0 m; mean depth 0.2 m), as winter ice depths in the region often reach 2.0 m.
- In the event that the North All-Season Road option does get constructed, a loss of fish habitat will occur at the site of the proposed potential ferry crossing on the Thelon River. The rough natural shoreline will require smoothing to make the ferry landing sites (aprons) safe for loading and offloading trucks and other vehicles. The natural rocky shoreline represents good fish habitat that would be lost.

In addition to habitat losses, the following Project activities are likely to result in the following alterations to fish habitat:

- The berm proposed for construction across the north-east end of Andrew Lake will require that rock-riprap be installed along the lakeward edge to protect it from wave and water erosion in Andrew Lake. This rock riprap represents a different habitat type than was present on the natural shoreline of Andrew Lake.
- Fish habitats will be temporarily affected by the installation, and eventual removal, of water intake structures in Siamese and Mushroom Lakes, as well as the installation, and eventual removal, of effluent diffusers at two locations in Judge Sissons Lake. Pipelines connecting the water intakes and effluent diffusers to their respective overland pipelines will also result in minor disturbances to fish habitat.
- Fish habitat will be altered by the installation, and eventual removal, of watercourse crossings during the construction of the Sissons-Kiggavik Ore Haul Road, as well as other associated infrastructure roads to the water intakes, effluent diffusers, and airstrip.
- Fish habitat will be altered by construction of the North All-Season Road between the Kiggavik Mine Site and Baker Lake. The fish habitat alteration is associated with the construction, maintenance, and eventual removal of stream crossings over a number of medium and large fish-bearing watercourses crossed by the route. The current proposed route of the North All-Season Road would involve crossing 42 streams or watercourses. However, only 18 of these crossings would be on potentially fish-bearing streams. The remaining watercourses have undefined or dry channels, or support seasonal spring runoff flows only.

In most cases, the above described fish habitat alterations will be in place for the life of the mine (i.e., 25 years). During Mine Closure, most alterations will be reversed with the removal of the water intake structures, effluent diffusers, and stream crossing structures, and the altered habitats will be returned to pre-development conditions whenever possible.

10.2.2.4 Mitigation Measures and Project Design for Changes in Fish Habitat

Mitigation measures have been incorporated into the Project design, and will be incorporated into various project construction activities in the form of Best Management Practices for road construction and installation of stream crossings. In addition, erosion control measures will be incorporated into the design of stream and watercourse diversions.

The same applies to the installation of the lake water intake structures, and effluent diversion structures. Best management practices will be utilized with the installation of turbidity curtains prior to constructing the berm in Andrew Lake, and proceeding with the dewatering of the east portion of the Andrew Lake basin. Fish salvage will be carried out prior to dewatering in order to minimize the potential for fish losses due to stranding.

Construction of the berm at Andrew Lake and dewatering the north-east end of the lake will result in the loss of approximately 13.5 ha of shallow (less than 1.0 m deep), seasonal use (open-water season) fish habitat. Following consultation with DFO staff on the issue of determining appropriate compensation options, AREVA is preparing a FHCP that proposes to replace the area of lost habitat with a similar amount of shallow, seasonal use habitat. Remote sensing surveys have been undertaken to locate a number of shallow, landlocked, potentially fishless waterbodies in the Kiggavik region, that might be connected to nearby fish-bearing stream systems to make them productive fish habitat. Ground-based fish and engineering surveys would be required to confirm that the target waterbodies are currently fishless, and that connection with adjacent stream systems is possible in terms of elevation differences and other engineering considerations.

Construction of all-season roads as part of the Kiggavik and Sissons Mine Sites and their associated infrastructure will affect fish habitat where the roads cross fish-bearing streams. All crossings will be designed and installed in a manner to facilitate fish passage under all flow conditions up to and including the 1 in 10 year flood. In terms of fish habitat compensation for the culvert installation's footprint on the natural stream bed, limiting fish habitat types will be identified for each affected stream through field surveys, and improvements to instream fish habitat made that would most benefit each individual stream.

The above proposed measures describe the general approaches that will be used to mitigate effects to fish habitat, and compensate for fish habitat losses or alterations. The detailed proposals will be incorporated into a FHCP for the Kiggavik Project. The FHCP will be submitted to NIRB and Fisheries and Oceans Canada (DFO) for review. Only after the FHCP receives approval, and the Project receives DFO's Authorization can any Project work begin that may result in the loss or harmful alteration of fish habitat.

10.2.2.5 Residual Effects for Changes in Fish Habitat

Due to the requirement for a Fish Habitat Compensation Plan and DFO's Policy for "no-net-loss" of fish habitat, a FHCP will be developed in consultation with DFO. Following completion and approval of the FHCP, and implementation of the various compensation works proposed in it, no residual uncompensated losses of fish habitat are anticipated. All habitat losses resulting from the Kiggavik Project will be fully compensated for.

10.2.2.6 Determination of Significance for Changes in Fish Habitat

Predicted changes in fish habitat will not be significant to local or regional fish populations as all fish habitat losses will be compensated for, and all alterations to fish habitat will be mitigated where possible, and compensated for if proposed mitigations are not deemed adequate.

10.2.2.7 Compliance and Environmental Monitoring for Changes in Fish Habitat

The FHCP will specify the works that must be developed to compensate for the loss of fish habitat related to Project development. Once the approved Fish Habitat Compensation works are constructed, a compliance and effectiveness monitoring program will be carried out in order to show that the compensation works have been built as specified and approved, and that they are functioning as effectively as designed. In essence, it will be shown that the compensation works have met the DFO requirement that the Project result in “no-net-loss” of fish habitat.

10.3 CUMULATIVE EFFECTS ANALYSIS FOR AQUATIC ORGANISMS AND FISH HABITAT

10.3.1 Screening for Cumulative Environmental Effects to Aquatic Organism Populations and Fish Habitat

Project-related residual effects to aquatic organism populations and fish habitat will occur within the Mine Site LAA, but will diminish to background levels before reaching the outlet of Judge Sissons Lake. Should any residual effects to aquatic organism populations or fish habitat leave Judge Sissons Lake, they would have potential to overlap with other projects and activities that occur or may occur in the future, and therefore act cumulatively on aquatic organism populations or fish habitat.

The screening for cumulative effects to aquatic organism populations and fish habitat is conducted in order to determine if there is potential for cumulative environmental effects to occur. Potential cumulative effects exist if project-related effects to aquatic organism populations or fish habitat overlap spatially and temporally with those of other past, present and future projects, and activities. Projects considered for cumulative environmental effects are described in Section 6. Of these projects, no local, Nunavut, or Far Future Scenario projects from the Project Inclusion List affect aquatic organism populations or fish habitat and overlap spatially and temporally with effects associated with this Project. Therefore, no cumulative effects to aquatic organism populations or fish habitat are predicted for this project.

10.4 SUMMARY OF RESIDUAL EFFECTS ON AQUATIC ORGANISMS AND FISH HABITAT

10.4.1 Project Effects

Effects’ modelling shows potential issues with cadmium exposure to zooplankton. Screening Index (SI) values above 1 are identified for JSL-1, JSL-2, JSL-3, JSL-4 and JSL-7; however the magnitude of the potential effect is under 3. The maximums occur in winter during times of reduced biological activity and these segments represent less than 40% of the total lake area. Overall, it is possible that in certain segments of the lake some of the more sensitive zooplankton species will be affected; however considering the moderate SI values and the spatial extent of the impact, the zooplankton population of Judge Sisson Lake is expected to continue to function. Overall, although there are residual effects, no significant adverse effects on the abundance and distribution of aquatic biota are expected due to changes in COPC concentrations in the receiving environment from releases from the WTPs.

A number of Project development activities have the potential to alter, disrupt, or destroy fish habitat. These include diversion of streams away from their current locations, drainage of lakes or portions of lakes, installation of stream crossing structures on all-season ore haul roads and other roads related to constructiong and maintaining Project infrastructure (e.g., roads to water intake and effluent discharge structures and the airstrip).

Due to the requirement for a Fish Habitat Compensation Plan and DFO's Policy for "no-net-loss" of fish habitat, a FHCP will be developed in consultation with DFO. Following completion and approval of the FHCP, and implementation of the various compensation works proposed in it, no residual uncompensated losses of fish habitat are anticipated. All habitat losses resulting from the Kiggavik Project will be fully compensated for.

Table 10.4-1 summarizes Project residual environmental effects for water quality.

Table 10.4-1 Summary of Project Residual Environmental Effects and Significance Determinations for Aquatic Organisms and Fish Habitat

				Residual Environmental Effects Characteristics									
Project Phase	**Mitigation/ Compensation Measures**	**Residual Environmental Effect (Y/N)**	**Direction**	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Environmental Context**	**Significance**	**Likelihood**	**Prediction Confidence**	**Recommended Follow-up and Monitoring**
Change in aquatic Biota: Treated effluent discharge from the Kiggavik and Sissons Water Treatment Plants (WTP) may affect surface water quality. These changes can affect the concentration of COPC in aquatic biota (e.g., aquatic plants, benthic invertebrates, plankton).													
Construction		N	-	-	-	-	-	-	-	N	L to M	H	An Environmental Effects Monitoring (EEM) program will be instituted to determine whether effluent discharge from the WTP is having quantifiable effects.
Operation	Design of the WTPs.	Y	N	M	L	MT	C	R	U				
Decommissioning and Abandonment		Y	N	L	L	MT	C	R	U				
Residual environmental effects for all Phases													
Change in fish habitat: Instream construction associated with several Project development activities is expected to result in the alteration, disruption and or loss of fish habitat.													
Construction	Installation of culverts; use of turbidity curtain; completion of fish salvage; implementation of Fish Habitat Compensation Plan.	N	N	L	L	ST	O	R	U	S	L	H	Compliance and effectiveness monitoring program to show that the compensation works have been built as specified and functioning as designed.
Operation		N	-	-	-	-	-	-	-				
Decommissioning		N	P	L	L	ST	O	R	D				
Residual environmental effects for all Phases													

10.4.2 Cumulative Effects

No local, Nunavut, or Far Future Scenario projects from the Project Inclusion List affect aquatic organisms and fish habitat, and overlap spatially and temporally with effects associated with this Project. Therefore, no cumulative effects to aquatic organisms and fish habitat are predicted for this project.

10.4.3 Effects of Climate Change on Project and Cumulative Effects on Aquatic Organisms and Fish Habitat

Twenty three climate change scenarios were explored, of which twenty predict an increase in annual precipitation for the period 2071-2099. The greatest increase in precipitation was 78% greater than historical rates. On average, the models predict a 34% increase in precipitation; this increase is typically distributed throughout the year, however most dramatic increases occur in the autumn.

As summers become warmer and wetter, lake evaporation and evapotranspiration conditions are typically predicted to increase. Although water losses typically increase, under many ensembles, the magnitude does not compensate for the dramatic increases in precipitation. Twenty of the twenty three climate change ensembles predict an increase in runoff at Judge Sisson and Pointer Lake outflows. On average, runoff is estimated to increase 67% and 74% for Pointer Lake and Judge Sissons Lake watersheds, respectively.

Increased precipitation and stream flows associated with climate change would result in reduced buildup of metals and other COPCs in Judge Sissons Lake water and sediments over those levels predicted in this EIA. This is due to the increased volumes of water flowing through the lake, effectively flushing COPCs out of the lake more quickly, giving them less time to build up. Reduced concentrations of COPCs would have an even smaller effect on phyto- and zooplankton, and benthic invertebrates than the minor residual effect predicted in the EIA.

Increased precipitation and runoff would also reduce the drawdown effects of potable and mill water supply use of Siamese and Mushroom lakes. Because the lakes would become ice-free earlier in the spring and freeze-up later in the fall, the volumes of under-ice water withdrawals would be reduced, thereby reducing the potential to effect lake trout spawning habitat in Siamese and Mushroom lakes.

10.5 MITIGATION MEASURES FOR AQUATIC ORGANISMS AND FISH HABITAT

A number of mitigation measures and project design modifications will be implemented to limit changes to aquatic organism abundance and distribution, and to limit changes to fish habitat quantity and quality:

- Site footprint will be minimized and situated such that natural drainage areas and watershed boundaries are maintained.
- The site water system will be designed to recycle water where applicable and water use will be minimized to limit withdrawal requirements and discharge quantities.
- Diversion channels will be designed to keep water within its natural drainage path.
- In-water construction will follow standard protocols and best management practices.
- Andrew Lake pit will be dewatered and refilled at a rate such that effects to water quality and downstream fish habitat are minimized.
- DFO procedures for water withdrawal from ice-covered waterbodies in the Northwest Territories and Nunavut will be followed. Specifically, no more than 10% of the under-ice volume will be withdrawn from a lake during one ice covered season.
- During decommissioning, the ground surface will be recontoured and natural flow patterns will be restored.

10.6 COMPLIANCE AND ENVIRONMENTAL MONITORING FOR AQUATIC ORGANISMS AND FISH HABITAT

- Benthic invertebrate populations and diversity should be monitored regularly (every third year) during mine operation, closure, and post-closure as part of the Environmental Effects Monitoring Program to determine whether WTP effluent discharges are having quantifiable effects on benthic macro-invertebrate populations.
- Carry out compliance and effectiveness monitoring associated with the Fish Habitat Compensation Plan (FHCP) to ensure that fish habitat compensation is constructed /installed as per DFO's Authorization and that it is functioning effectively.

11 EFFECTS ASSESSMENT FOR FISH POPULATIONS

11.1 SCOPE OF THE ASSESSMENT FOR FISH POPULATIONS

The NIRB Guidelines for the Kiggavik Project (NIRB, 2011) identify the freshwater aquatic environment, including aquatic ecology, aquatic biota (including fish, aquatic macrophytes, benthic invertebrates, and other aquatic organisms), and habitat as a single Valued Ecosystem Component (VEC). For the purposes of this assessment, fish populations and fish flesh chemistry will be treated as individual Valued Ecosystem Components (VEC). Ensuring that healthy fish populations and distributions are maintained and available for human consumption in the Local Assessment Area (LAA) and Regional Assessment Area (RAA) has been identified by Inuit and local stakeholders as being important. Having fish populations with flesh of quality safe for human consumption has also been identified as an important component of this VEC.

11.1.1 Project–Environment Interactions and Effects – Fish Populations

Information was gathered from the environmental and engineering teams for the Kiggavik Project, through public engagement, and by NIRB to identify project activities that have potential to result in changes to the abundance or distributions of fish populations, or to the quality and fitness for human or animal use of fish flesh. Relevant project activities and the associated environmental interactions for each Project phase are summarized in Table 11.1-1 for project-environment interactions that were ranked 1 or 2 in Table 4.3-1.

Table 11.1-1 Identification of Project – Environment Interactions and Effects – Fish Populations

	Project Activities/Physical Works	Changes in the relative abundance and distribution of fish	Changes to fish health
Construction:			
In-Water Construction	Construct freshwater diversions and site drainage containment systems (dykes, berms, collection ponds)	1	0
	Water transfers and discharge	1	0
Operation:			
Mining	Mining ore (blasting, loading, hauling)	2	2
	Mine dewatering	0	0
Tailings Management	Pumping and placement of tailings slurry	0	0
Water Management	Create and maintain water levels	0	0
	Potable water treatment	0	0
	Collection of site and stockpile drainage	0	0
	Water and sewage treatment	0	0
	Discharge of treated effluents (including greywater)	0	2
Waste Management	Disposal of sewage sludge	0	0
Final Closure:			
General	Ongoing withdrawal, treatment and release of water, including domestic wastewater	0	2
In-water Decommissioning	Remove freshwater diversions; re-establish natural drainage	0	0
	Remove surface drainage containment	0	0
	Water transfers and discharge	0	0
	Construct fish habitat as per FHCP	0	0
On-land Decommissioning	Remove site pads (blasting, earth moving, loading, hauling, dumping)	0	0
Post Closure			
	Management of restored site	0	0

Category 1 activities are those having an interaction with the aquatic environment; however, based on past experience and professional judgment, the resulting effect can be managed to acceptable levels through standard operating practices and/or through the application of best management or codified practices. No further assessment is warranted.

Category 2 activities are those activities that do interact with the aquatic environment and the resulting effect may exceed acceptable levels without implementation of specified mitigation. Further assessment of the effects of these interactions on the aquatic environment is warranted and is presented in this environmental assessment report.

The rationale for ranking interactions as Category 1 is presented below. Those interactions ranked as Category 2 are discussed in more detail in following sections.

CONSTRUCTION:

Construction of Freshwater Diversions and Site Drainage Containment Systems; Site Clearing and Pad Construction

As part of developing the mine site and infrastructure at the Kiggavik site, the stream between Mushroom Lake and End Grid Lake will have to be diverted around the mine workings. Portions of this stream are known to contain fish during the open water season. In order to minimize construction effects on the fish population, the stream diversion work should take place in late summer or fall after fish have left the stream system to return to over-wintering lakes. If stream diversion work must be carried out when fish are still in the system, fish barriers will be installed in the stream and the fish captured using electro-fishing gear or seine nets. Captured fish will be live transferred to Mushroom Lake, the closest over-wintering lake in the watershed. Because effects on fish populations in the Mushroom Lake area will be small in magnitude and short lived in duration, this Project effect is not carried forward to the detailed analysis of residual effects on fish abundance and distribution.

Construction of the dyke across the east end of Andrew Lake, and the subsequent dewatering of the east section of the lake will result in increased turbidity and TSS levels in the water. In order to minimize turbidity and construction effects on fish, a turbidity curtain will be installed in Andrew Lake prior to dyke construction, and any fish remaining in the east portion of the lake will be salvaged and transferred to the western portion of the lake prior to the east section being dewatered. Because effects on fish populations in Andrew Lake will be small in magnitude and short lived in duration, this Project effect is not carried forward to the detailed analysis of residual effects on fish abundance and distribution.

11.1.2 Indicators and Measurable Parameters

Fish are identified by NIRB (2011) as an important component of the freshwater aquatic environment VEC. Measurable parameters were selected to assess the two potential Project effects on fish. One is designed to document whether the Project will result in changes in the relative abundance and distribution of fish species that occur in the LAA. The second is designed to document Project effects on the suitability of fish flesh for traditional (human and animal) consumption (Table 11.1-2). Changes in measurable parameters provide a direct method of quantifying project effects on fish communities, and on the continued suitability of fish flesh for traditional consumption.

Table 11.1-2 Measureable Parameters for Fish

Environmental Effect	Measurable Parameters	Notes or Rationale for Selection of the Measurable Parameter
Change in abundance and distribution of fish populations	• Relative abundance and distribution of fish species.	• Measuring relative abundance and spatial distribution of fish species allows quantification of changes in their spatial and temporal distribution.
Continued opportunity for traditional use of fish.	• Levels of metals and radionuclides in fish flesh.	• Comparing concentrations of radionuclides and other COPC in fish flesh with baseline concentrations in fish flesh allows determination of whether LAA fish flesh will still be suitable for traditional use.

11.1.3 Assessment Boundaries

Spatial and temporal boundaries for the assessment of environmental effects on fish populations are as described in Section 4.5. A technical boundary for the assessment of effects on aquatic biota is the limitation on assessing mixture of compounds (e.g., exposure to multiple metals) and multi-stressors due to limitations in the scientific database.

11.1.4 Residual Environmental Effects Criteria

General descriptions of residual environmental effects criteria are presented in Section 4.6 and apply to effects on fish populations and distribution, as well as fish flesh chemistry. However, more specific descriptions apply to the magnitude of residual environmental effects.

For fish populations and distributions, magnitude is defined as the amount of change in population numbers or distribution relative to the various fish populations and distributions found in the existing environment baseline (e.g., numbers of fish by species and distribution among lakes and streams in the LAA sub-watersheds).

- Negligible: The Project will not affect fish abundance or distribution in waterbodies in the LAA.
- Minor: The Project will affect fish abundance or distribution in waterbodies in the LAA, but these effects will be within the natural range of variability.

- Moderate: The Project will affect fish abundance or distribution in waterbodies in the LAA and the effects will be beyond the natural range of variability. The effects do not extend to the RAA.
- High: The Project will affect fish abundance or distribution in waterbodies in the LAA and the RAA, and the effects will be beyond the natural range of variability.

For fish health, magnitude is defined as the amount of change in metal or radionuclide levels that would jeopardize fish health or human health if fish flesh is consumed.

11.1.5 Standards or Thresholds for Determining Significance

Under the NIRB Project Specific Guidelines the environmental assessment must include a determination of the significance of environmental effects. Threshold criteria or standards for determining the significance of environmental effects were identified for each VEC, beyond which a residual environmental effect would be considered significant. Where available, these were selected in consideration of federal and territorial regulatory requirements, standards, objectives, or guidelines applicable to the VEC (Section 8.3 for Water Quality).

Toxicity reference values (TRVs) specific for fish are used to judge whether the predicted exposures may potentially have an adverse effect on ecological species at the population level. The TRVs for aquatic species are generally based on toxicity tests carried out under standardized conditions in the laboratory using sensitive test species (e.g., rainbow trout). Toxicity tests that examined growth, reproduction or survival were considered to be relevant to the persistence of aquatic populations. In general, the concentration associated with effects in 20% of the biota included in the test (EC_{20}) are selected. As seen from Table 11.1-3, the TRVs for fish are based on water concentrations; the exception to this is selenium, where the TRVs for fish are based on tissue concentrations since selenium is known to biomagnify in the aquatic environment. The TRVs selected for use for the Kiggavik Project are consistent with those used in a recently completed EA for the water management project at the Cigar Lake uranium mine in northern Saskatchewan (Cameco 2010).

Table 11.1-3 summarizes the TRVs used in the evaluation of potential effects on aquatic biota. Hardness was included in the modelling; however, it is not a COPC but affects the toxicity of other parameters. For example, the toxicity of several metals is dependent on hardness with decreasing toxicity at higher hardness levels. The background materials for the toxicity reference values selected for this assessment are provided in Appendix 8A.

Table 11.1-3 Selected Toxicity Reference Values for Fish

COPC	Units	Forage Fish	Predator Fish
Uranium	µg/L	550	1,500
Arsenic	µg/L	123	630
Cadmium	µg/L	7.3	0.6
Cobalt	µg/L	203	118
Copper (a)	µg/L	6	4
Lead (a)	µg/L	132	14.2
Molybdenum	µg/L	5,000	183
Nickel (a)	µg/L	535	62
Selenium	µg/L	(b)	(b)
Zinc (a)	µg/L	35	30 (c)
Ammonia (un-ionized)	µg/L	173	90
Chloride	mg/L	220	360
Sulphate	mg/L	501	933

Note:
a = Toxicity reference values (TRVs) based on low hardness water.
b = TRV for selenium based on 10 µg/g (dry weight) whole body fish concentration.
c = TRV set equal to CWQG for zinc.
COPC = constituents of potential concern; µg/L = micrograms per litre

For radioactivity, a review of the recommendation by various agencies was provided. Two reference dose rates values were selected; 10 mGy/d for all biota as well as 0.6 mGy/d for fish.

Potential changes in a measurable parameter or VC resulting from Project or cumulative effects were evaluated against these standards or thresholds, and were rated as either *significant* or *not significant*. A significant effect on fish would occur when the change in water and sediment quality, aquatic organism populations or distribution, and changes in the quantity and quality of fish habitat would result in a population level effect on fish, or affect the suitability of the fish to be consumed by humans or animals. The significant effect could be high in magnitude, occur over a long period of time, and/or have a large spatial extent. An effect on fish is not significant when it is small in magnitude or spatial area, is of short duration (temporary), and is not expected to result in population level effects to fish at the ecosystem level, or affect fish flesh chemistry making fish unsuitable for consumption by humans or animals.

11.2 EFFECTS ASSESSMENT FOR FISH

11.2.1 Assessment of Changes in Relative Abundance and Distribution of Fish

Residual effects to the abundance and distribution of fish have been identified in the Lower Lake watershed, and potentially in the Pointer Lake watershed. These effects are related to the blasting program associated with mining the proposed Andrew Lake Pit at the Sissons Mine Site, and the Main Zone Pit at the Kiggavike Mine Site. The proposed blasting program has the potential to affect fish in streams and lakes near the mine pits through the generation of shock waves and vibrations as explosive charges are detonated. These shock waves and vibrations can result in physical injuries to fish at various life stages, and can disturb adult fish during spawning or migration activities.

11.2.1.1 Analytical Methods Changes in Relative Abundance and Distribution of Fish

Fish presence in water bodies adjacent to the proposed mine pits, and the location of important fish spawning sites were determined as part of baseline data collection for the Kiggavik Project (Kiggavik Project EIS - Aquatics Baseline Document). A geographic information system (GIS) was used to overlay the locations of the proposed mine pits onto the fish and fish habitat use information available for local area waterbodies, in order to determine locations where the fish population could be affected by blasting related over-pressures or vibrations.

The federal *Fisheries Act* includes provisions for the protection of fish and their habitats. Detonation of explosives in or adjacent to fish-bearing waters can disturb, injure, or kill fish, and/or result in the harmful alteration, disruption, or destruction of fish habitat.

Fisheries and Oceans Canada advised the Nunavut Impact Review Board (NIRB) in a January 24, 2011 letter that *DFO Guidelines for the Use of Explosives in or Near Canadian Waters* should be used as guidance in designing a blasting plan for the Kiggavik Project. In the same letter, DFO advised NIRB that the Instantaneous Pressure Change (IPC) threshold should be reduced from 100 kPa to 50 kPa, as experience in northern environments indicated that an IPC threshold of 100 kPa was not adequately protective of fish. For the purpose of this effects assessment, the DFO recommended IPC threshold of 50 kPA has been used.

IPC and vibration effect setback distances (thresholds) were calculated as part of the “Drilling and Blasting Design and Related Regulatory Considerations Report” prepared by Golder Associates for AREVA (April 26, 2011).

11.2.1.2 Baseline Conditions for Changes in Relative Abundance and Distribution of Fish

Andrew Lake is located in the Lower Lake watershed about 8 km upstream of Judge Sissons Lake. Andrew Lake has a surface area of 54.3 ha, however is very shallow with a maximum depth of 1.0 m, and a mean depth of 0.2 m. Four fish species (i.e., Arctic grayling, burbot, cisco, and round whitefish) have been documented as occurring in Andrew Lake. Andrew Lake lies over top of, and immediately adjacent to, the proposed Andrew Lake Pit at the Sissons Mine Site. In addition to Andrew Lake, the inflow (Lunch/Andrew) and outflow (Andrew/Shack) streams are also located near the proposed Andrew Lake Pit.

Andrew Lake, and Lunch/Andrew and Andrew/Shack streams are all shallow and freeze to the bottom during the winter. As such, fish are only present in Andrew Lake and the connecting streams during the open-water season. However, Andrew Lake provides rearing and foraging habitat for several fish species during the open water season. Lunch/Andrew (inflow) and Andrew/Shack (outflow) streams are also used as seasonal migration streams by several fish species. More importantly however, both streams contain important Arctic grayling spawning areas.

At the Kiggavik Mine Site, a small pond located upstream of Pointer Pond is situated close to the proposed rim of the Main Zone Pit. Due to its small size (1.28 ha), and known shallow depth, no baseline fisheries information was collected for this waterbody. This pond is located very close to the site of AREVA's current mining exploration camp.

No large- or small-bodied fish were caught in Pointer Pond, located downstream of the Main Zone Pit pond, in spite of it having a maximum depth of 4.5 metres. However, a single slimy sculpin was captured just at the stream inlet to Pointer Pond. It is assumed that Pointer Pond, with its reasonable over-wintering depth, likely supports at least limited large- and small-bodied fish populations. However, it is doubtful that the small, shallow pond located further upstream in the drainage system would be used for spawning or rearing by any large-bodied fish species, due to its distance from Pointer Pond and the temporary nature of flows in the connecting stream. It is possible, although not likely, that the small pond near the Main Zone Pit may be used seasonally by small-bodied species such as slimy sculpin.

11.2.1.3 Effect Mechanism and Linkages for Changes in Relative Abundance and Distribution of Fish

Potential effects on fish due to blasting in or near waterbodies, include noise and vibration impacts. The detonation of explosives in or near water can produce harmful compressive shock waves that can physically damage the internal organs of fish, especially the swim-bladder. The shock waves can also kill or injure fish eggs and larvae (Wright and Hopky 1998).

Vibrations caused by the detonation of explosives can also damage incubating fish eggs (Wright 1982). Changes in fish behaviour have also been observed as a result of noise produced by detonation of explosives (Wright 1982).

11.2.1.4 Mitigation Measures and Project Design for Changes in Relative Abundance and Distribution of Fish

DFO Guidelines, as modified by DFO's directions to NIRB, state that "No explosive is to be detonated in or near fish habitat that produces, or is likely to produce, an instantaneous pressure change (i.e., overpressure) greater than 50 kPa in the swimbladder of a fish". DFO further states that for confined explosives, setback distances from the land-water interface (e.g., the shoreline), or burial depths from fish habitat (e.g., from under the lakebed) must ensure that explosive charges will meet the 50 kPa overpressure guideline. This guideline applies during periods when fish are present.

Portions of the Andrew Lake Pit (the south-west pit rim) will be located within 50 m of Andrew Lake (separated only by the 50 m wide berm). The blasting setback distances calculated for the two different charge sizes proposed for use at Kiggavik are 131 m for the 150 mm borehole charges, and 160 m for the 187 mm borehole charges. As both of these setback distances are greater than the 50 m distance to Andrew Lake from the rim of the Andrew Lake Pit, mitigation measures will be required if blasting is to occur near Andrew Lake during the open-water season. However, blasting activities that occur near the centre of the Andrew Lake Pit, or on the opposite side of the pit, will be outside of the blasting setback distance and can occur without modification or mitigation.

Potential mitigation measures available for blasting near Andrew Lake include:

- use of smaller charge sizes near Andrew Lake during the open water season to reduce the blasting setback distance to less than 50 metres (the width of the dyke), and
- plan the blasting program to do all required blasting near Andrew Lake during the frozen water period when Andrew Lake and the inflow and outflow streams do not support fish populations. This is approximately eight months of the year.

In addition to the blasting over-pressure setbacks required by DFO, a different guideline specifies that vibrations resulting from explosives detonation must not exceed 13 mm/sec peak particle velocity in a spawning bed during the period of egg incubation (Wright and Hopky 1998). The inflow and outflow streams to Andrew Lake have both been documented as important Arctic grayling spawning habitats during the baseline studies. Based on modelling predictions for the two charge sizes being considered for use at the Andrew Lake Pit, the 150mm borehole charges will require a setback distance of 270 metres during the spring spawning and egg incubation period. The larger 187 mm borehole charges will require a setback distance of 330 m.

The distance from the Andrew Lake Pit edge to the inlet stream spawning area is over 500 m and is therefore outside the setback threshold distance. However, the Arctic grayling egg incubation area in the Andrew Lake outlet stream is only 160 m away from the pit crest. This is well within the setback threshold for both proposed charge sizes being considered (150mm and 187 mm boreholes). Again, it is worth noting that blasting activities that occur near the centre of the Andrew Lake Pit, or on the side of the pit opposite the Andrew Lake outflow stream, are likely to be outside of the blasting setback distance and can occur without modification or mitigation.

Potential mitigation measures available to deal with the blasting vibration issue can include:

- smaller charge sizes to be used near Andrew Lake outlet stream during the egg incubation period (about one month to 6 weeks long from early to mid-June to early to mid-July depending on when spawning begins in a particular year) in order to reduce the blasting setback distance to less than 160 metres, and
- Modify the blasting program to complete the required blasting near the Andrew Lake outlet stream (the south side of the pit) during times of year when egg incubation is not occurring. This is approximately 10.5 to 11 months of the year.

It should be remembered that the predictions of ground vibrations and instantaneous underwater overpressures are based on empirical formulae commonly used in the blasting industry to assess potential blasting effects. These models are intended to be used as first approximations, but should be calibrated with actual on-site blasting data to obtain more refined predictions of effects based on the actual foundation materials under Andrew Lake and the Andrew Lake Pit berm.

11.2.1.5 Residual Effects for Changes in Relative Abundance and Distribution of Fish

Providing effective mitigation measures are enacted, and neither the IPC threshold of 50 kPa, nor the vibration threshold of 13mm/sec peak particle velocity are exceeded, no residual effect on fish population abundance or distribution will occur.

11.2.1.6 Determination of Significance for Changes in Relative Abundance and Distribution of Fish

No significant changes in fish population abundance or distribution are anticipated providing effective mitigation measures are enacted to ensure compliance with DFO's blasting guidelines.

11.2.1.7 Compliance and Environmental Monitoring for Changes in Relative Abundance and Distribution of Fish

The ground vibration and instantaneous underwater overpressure analyses were based on empirical formulae commonly used in the blasting industry to assess potential effects from blasting. These models are intended to provide initial approximations only and should be calibrated with actual site data to refine the estimates. Monitoring programs should be developed and carried out on site at locations away from fish-bearing waterbodies to calibrate and refine the ground vibration and IPC models. This would provide site-tested ground vibration and IPC setback distance thresholds, prior to blasting programs commencing near fish sensitive waterbodies.

11.2.2 Assessment of Changes to Fish Health

The potential implication of the changes in water and sediment concentrations, due to effluent release from the WTP, on the concentrations in fish will be examined and the implication on fish health. The particular focus is on Judge Sissons Lake.

11.2.2.1 Analytical Methods for Changes to Fish Health

Treated effluent discharge from the Kiggavik and Sissons Water Treatment Plants (WTP) may affect surface water quality. These changes will affect the concentration of COPC in fish. Parameters in water that were identified as COPC include: ammonia, chloride, sulphate, radionuclides (U-238, Th-230, Ra-226, Pb-210, Po-210) and select metals (arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, zinc). The approach used to predict water concentrations was discussed in Section 8 of this Tier 2 document and is further detailed in Technical Appendix 8A.

The assessment of the potential impact on non-radiological COPC on fish is conducted by comparison the estimated water concentration to the biota-specific toxicity reference value (TRV). The assessment was based on the total concentration which considers both baseline concentration plus the influence of project emissions.

For the assessment of fish health due to exposure to selenium and radioactivity it is necessary to obtain an estimate of the concentration within the fish. A review of water concentrations versus fish tissue concentrations indicates that concentrations in fish tissue tend to be independent of water concentrations at background levels and increase only after a certain concentration has been reached. It has been postulated that bioregulation or homeostasis is responsible for these observations (Toll Environmental 2005). The fish chemistry database from work carried in 2002 and 2005 other uranium mining sites (McClean Lake and Rabbit Lake) were pooled to provide an estimate of the minimum fish tissue concentration, and the range of water concentration this is associated with, as well as the response above this minimum level. As they are empirically based, the transfer factors include the contribution from all routes of exposure (e.g. gill uptake, exposure through food intake).

The dose from radioactivity includes both the potential exposure from internally deposited radionuclides as well as external exposure to both water and sediment. Radiation effects on biota depend not only on the absorbed dose, but also on the relative biological effectiveness (RBE) of the particular radiation (i.e., alpha, beta or gamma radiation). Recent recommendations have focused on an RBE of 10 for alpha radiation; however, to illustrate the effects of uncertainty in RBE a range was examined. The total dose, which is based on the baseline plus Project emissions for the sum of the uranium-series radionuclides, is compared to a reference dose rate that is protective of aquatic biota.

11.2.2.2 Baseline Conditions Changes to Fish Health

Concentrations of COPC in fish were measured. A number of fish species were sampled, including Arctic grayling, cisco, lake trout, and white roundfish. This baseline information was used to make sure the current conditions are reflected in the pathways assessment.

For selenium, it was found that the fish flesh concentrations (on a wet or fresh weight basis) ranged from 0.15 µg/g to 0.59 µg/g with an average concentration of 0.28 µg/g. This is below the level of concern with respect to selenium levels in fish (10 µg/g on a dry weight basis which is equivalent to 2 µg/g on a wet weight basis).

11.2.2.3 Effect Mechanism and Linkages for Changes to Fish Health

The release of COPC from the WTP can affect water quality in the receiving environment. The quality of the water is critical for evaluating the potential effect on fish. Water quality will change with different phases of the project (e.g., operational period, or closure). Other ecological receptors may consume fish and would be therefore be exposed through this pathway. Fish also represents an important component in diet of people in the area.

11.2.2.4 Mitigation Measures and Project Design for Changes to Fish Health

The design of the WTP was such to provide an effluent that met or exceeded all appropriate regulations (e.g., MMER). Design aspects, operational measures and other mitigation measures have been incorporated into the current Project plans which will minimize project-associated emissions and/or the potential effect of project-related emissions. Further detail on the design of the water treatment plant can be found in Volume 2.

11.2.2.5 Residual Effects for Changes to Fish Health

In this study, adverse effects from exposure to COPC were characterized by a simple screening index. This index was calculated by dividing the predicted exposure by the toxicity reference value for each ecological receptor as follows:

$$Screening\ Index = \frac{Exposure}{Toxicity\ \mathrm{Re}\,ference\ Value}$$

Screening index values are not estimates of the probability of ecological effect. Rather, the index values are correlated with the potential of an effect, i.e. higher index values imply a greater potential of an effect. The exposure includes both the natural baseline levels as well as the effect of the Project emissions. Therefore, a screening index value less than 1.0 indicates that the estimated total exposure is less than that associated with an adverse effect. The screening index values (maximum values at any time and within any segment of Judge Sissons Lake) for fish are shown in Table 11.2-1.

Table 11.2-1 Screening Index Values for Fish

	Predator Fish		Forage Fish	
	Maximum Mean	Maximum 95th Percentile	Maximum Mean	Maximum 95th Percentile
Uranium	<0.01	<0.01	<0.01	<0.01
Arsenic	<0.01	0.01	<0.01	0.01
Cadmium	0.85	**1.2**	0.07	0.1
Cobalt	<0.01	<0.01	<0.01	<0.01
Copper	**1.31**	**1.31**	**1.27**	**1.27**
Lead	0.02	0.03	<0.01	<0.01
Molybdenum	0.06	0.13	<0.01	<0.01
Nickel	0.05	0.05	0.01	0.01
Selenium	0.01	0.02	<0.01	<0.01
Zinc	0.44	0.44	0.24	0.24
Un-ionized Ammonia	0.1	0.17	0.05	0.09
Chloride	0.24	0.37	0.4	0.61
Sulphate	0.29	0.45	0.54	0.84
Radioactivity - RBE10	0.019	0.077	0.022	0.08
Radioactivity - RBE40	0.059	0.083	0.061	0.086

NOTES:

SI values for non-radiological COPC are based on the maximum predicted water concentration compared to the TRV

SI values of radiological effects include the contribution from U-238, Th-230, Ra-226, Pb-210 and Po-210

Details of calculation as well as additional results provided in Appendix 8A

The bold shading in Table 11.2-1 indicates SI values that are above 1.0. All COPC have predicted SI values less than 1.0 for all segments of Judge Sissons Lake, with the exception of cadmium for predator fish and copper for predator and forage fish.

The release of treated water to Judge Sisson Lake does affect the expected concentration of cadmium. In terms of fish, an SI of 1.2 was identified at the 95th percentile for predator fish in JSL-1. While Judge Sissons Lake is deep enough to support fish through the winter, it is unlikely that fish would be present in the shallowest segments (e.g. JSL-1) through the winter months. As the maximum concentration occurs in the winter when fish are not present, there is not expected to be any effects on fish from the cadmium levels in the lake.

The exceedances of the toxicity benchmarks for copper are only in JSL-1 and JSL-7 and can be attributed to baseline copper concentrations in the area. JSL-1 and JSL-7 are shallow segments and therefore experience the largest variation between summer and winter concentrations. Due to winter ice cover, water concentrations during the winter months are predicted to increase because of a reduced volume of free-flowing water. The SI values were calculated using the maximum monthly mean and 95th percentile predicted concentrations and therefore represent winter conditions. Overall, no residual effect was identified for copper.

The toxicity reference values for selenium are for exposure to water only. Exposures for bioaccumulative COPC such as selenium can occur through pathways other than water alone and may be related primarily to the diet. Because it is recognized that selenium has the ability to bioaccumulate through aquatic food webs, a comparison to a fish tissue concentration of 2 µg/g (ww) was done. Predicted fish concentrations in Judge Sissons Lake are expected to be 0.46 µg/g (ww), with an upper 95th percentile concentration of 0.8 µg/g (ww). As these concentrations are below the level of concern, no adverse effects in fish due to bioaccumulation of selenium are expected.

11.2.2.6 Determination of Significance for Changes to Fish Health

The release of treated water to Judge Sisson Lake is not expected to result in any effects on fish from the cadmium levels in the lake. As the maximum concentration occurs in the winter when fish are not likely present in JSL-1 due to its relatively shallow depth, there is not expected to be any effects on fish from cadmium levels in the lake.

The exceedances of the toxicity benchmarks for copper are only in JSL-1 and JSL-7 and can be attributed to baseline copper concentrations in the area. JSL-1 and JSL-7 are shallow segments and therefore experience the largest variation between summer and winter concentrations. Overall, no residual effect was identified for copper.

Exposures for bioaccumulative COPC such as selenium can occur through pathways other than water alone and may be related primarily to the diet. Predicted fish concentrations in Judge Sissons Lake are expected to be 0.46 µg/g (ww), with an upper 95th percentile concentration of 0.8 µg/g (ww). No adverse effects in fish due to bioaccumulation of selenium are expected.

11.2.2.7 Compliance and Environmental Monitoring for Changes to Fish Health

Sampling of fish populations, and analysis of fish flesh for changes to metal and radionuclide concentrations should be carried out regularly (every third year) during mine operation, closure, and post-closure as part of the Environmental Effects Monitoring Program, to determine whether WTP effluent discharges are having quantifiable effects on fish health, or metal and radionuclide concentrations in fish flesh. This monitoring program should be combined with similar water and sediment quality monitoring programs in each of the two sections of Judge Sissons Lake receiving treated effluent, as well as in the main body of Judge Sissons Lake.

11.3 CUMULATIVE EFFECTS ANALYSIS FOR FISH

11.3.1 Screening for Cumulative Environmental Effects

Project-related residual effects to fish and fish health will occur within the Mine Site LAA, but will diminish to background levels before reaching the outlet of Judge Sissons Lake. Should any residual effects to fish or fish health leave Judge Sissons Lake, they would have potential to overlap with other projects and activities that occur or may occur in the future, and therefore act cumulatively on fish or fish health.

The screening for cumulative effects to fish and fish health is conducted in order to determine if there is potential for cumulative environmental effects to occur. Potential cumulative effects exist if project-related effects to fish or fish health overlap spatially and temporally with those of other past, present and future projects and activities. Projects considered for cumulative environmental effects are described in Section 6. Of these projects, no local, Nunavut, or Far Future Scenario projects from the Project Inclusion List affect fish or fish health and overlap spatially and temporally with effects associated with this Project. Therefore, no cumulative effects to fish or fish health are predicted for this project.

11.4 SUMMARY OF RESIDUAL EFFECTS ON FISH

11.4.1 Project Effects

Residual effects to the abundance and distribution of fish have been identified in the Lower Lake watershed, and potentially in the Pointer Lake watershed. These effects are related to the blasting program associated with mining the proposed Andrew Lake Pit at the Sissons Mine Site, and the Main Zone Pit at the Kiggavike Mine Site. The proposed blasting program has the potential to affect fish in streams and lakes near the mine pits through the generation of shock waves and vibrations as explosive charges are detonated. These shock waves and vibrations can result in physical injuries to fish at various life stages, and can disturb adult fish during spawning or migration activities.

Potential mitigation measures available for blasting near Andrew Lake include:

- use of smaller charge sizes near Andrew Lake during the open water season to reduce the blasting setback distance to less than 50 metres (the width of the dyke), and
- plan the blasting program to do all required blasting near Andrew Lake during the frozen water period when Andrew Lake and the inflow and outflow streams do not support fish populations. This is approximately eight months of the year.

Potential mitigation measures available to deal with the blasting vibration issue can include:

- smaller charge sizes to be used near Andrew Lake outlet stream during the egg incubation period (about one month to 6 weeks long from early to mid-June to early to mid-July depending on when spawning begins in a particular year) in order to reduce the blasting setback distance to less than 160 metres, and
- Modify the blasting program to complete the required blasting near the Andrew Lake outlet stream (the south side of the pit) during times of year when egg incubation is not occurring. This is approximately 10.5 to 11 months of the year.

Providing effective mitigation measures are enacted, and neither the IPC threshold of 50 kPa, nor the vibration threshold of 13mm/sec peak particle velocity, are exceeded, no residual effect on fish population abundance or distribution will occur.

Concentrations of three COPCs (cadmium, copper, and selenium) are predicted to be present in Judge Sissons Lake at levels high enough to be of concern. However, the levels are not predicted to be high enough to result in adverse effects.

Table 11.4-1 summarizes Project residual environmental effects for fish populations and fish health.

Table 11.4-1 Summary of Project Residual Environmental Effects and Significance Determinations for Fish Populations and Fish Health

Project Phase	Mitigation/ Compensation Measures	Residual Environmental Effect (Y/N)	Residual Environmental Effects Characteristics: Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental Context	Significance	Likelihood	Prediction Confidence	Recommended Follow-up and Monitoring
Change in Fish Populations: The detonation of explosives (blasting) in or near water results in pressure change and vibration which can physically damage the internal organs of fish, especially the swim-bladder. The shock waves can also kill or injure fish eggs and larvae. Changes in fish behaviour have also been observed as a result of noise produced by detonation of explosives.													
Construction	Use of smaller charge sizes during the open water and/or incubation season; complete program outside of sensitive time periods.	N	N	L	L	ST	S	R	U	N	L	H	Monitoring programs to calibrate and refine the ground vibration and IPC models.
Operation		N	N	L	L	ST	S	R	U				
Decommissioning and Abandonment		N	-	-	-	-	-	-	-				
Residual environmental effects for all Phases													
Change in Fish Populations: The release of COPC from the WTPs can affect water quality in the receiving environment. The quality of the water is critical for evaluating the potential effect on fish. Other ecological receptors (including people) may consume fish and would therefore be exposed through this pathway.													
Construction		N	-	-	-	-	-	-	-	N	M	H	An Environmental Effects Monitoring (EEM) program will be instituted to determine whether effluent discharge from the WTP is having quantifiable effects on fish populations.
Operation	Design of the WTPs.	Y	N	L	L	MT	C	R	U				
Decommissioning		Y	N	L	L	MT	C	R	U				
Residual environmental effects for all Phases													

KEY			
Direction: P Positive N Negative ***Magnitude:*** Use quantitative measure; or L Low: Define Proportion of local or regional population or habitat that is affected M Moderate: Define Proportion of local or regional population or habitat that is affected H High: Define Proportion of local or regional population or habitat that is affected. ***Geographic Extent:*** Use quantitative measure; or S Site-specific: Define L Local: Define R Regional: Define	***Duration:*** Use quantitative measure; or ST Short term: Define in relation to duration of effect relative to VC or KI MT Medium term: Define in relation to duration of effect relative to VC or KI LT Long term: Define in relation to duration of effect relative to VC or KI P Permanent Define in relation to duration of effect relative to VC or KI ***Frequency:*** Use quantitative measure; or O Occurs once. S Occurs sporadically at irregular intervals. R Occurs on a regular basis and at regular intervals. C Continuous. ***Reversibility:*** R Reversible I Irreversible	***Environmental Context:*** U Undisturbed: Area relatively or not adversely affected by human activity D Developed: Area has been substantially previously disturbed by human development or human development is still present N/A Not Applicable ***Significance:*** S Significant N Not Significant ***Prediction Confidence:*** Based on scientific information and statistical analysis, professional judgment and effectiveness of mitigation L Low level of confidence M Moderate level of confidence H High level of confidence	***Likelihood:*** Based on professional judgment L Low probability of occurrence M Medium probability of occurrence H High probability of occurrence ***Cumulative Effects*** Y Potential for effect to interact with other past, present or foreseeable projects or activities in RSA N Effect will not or is not likely to interact with other past, present or foreseeable projects or activities in RSA

11.4.2 Cumulative Effects

No local, Nunavut, or Far Future Scenario projects from the Project Inclusion List affect fish health and fish populations, and overlap spatially and temporally with effects associated with this Project. Therefore, no cumulative effects to fish health and fish are predicted for this project.

11.4.3 Effects of Climate Change on Project and Cumulative Effects on Fish

Twenty three climate change scenarios were explored, of which twenty predict an increase in annual precipitation for the period 2071-2099. The greatest increase in precipitation was 78% greater than historical rates. On average, the models predict a 34% increase in precipitation; this increase is typically distributed throughout the year, however most dramatic increases occur in the autumn.

As summers become warmer and wetter, lake evaporation and evapotranspiration conditions are typically predicted to increase. Although water losses typically increase, under many ensembles, the magnitude does not compensate for the dramatic increases in precipitation. Twenty of the twenty three climate change ensembles predict an increase in runoff at Judge Sisson and Pointer Lake outflows. On average, runoff is estimated to increase 67% and 74% for Pointer Lake and Judge Sissons Lake watersheds, respectively.

Increased precipitation and stream flows associated with climate change would result in reduced concentrations of metals and other COPCs in Judge Sissons Lake water and sediments over those levels predicted in this EIA. This is due to the increased volumes of water flowing through the lake, effectively flushing COPCs out of the lake more quickly, giving them less time to build up. Reduced concentrations of COPCs would have even smaller effects on potential buildups of metals and radionuclides in fish flesh than the minor residual effects predicted in this EIA.

11.5 MITIGATION MEASURES FOR FISH

A number of mitigation measures and project design modifications will be implemented to limit changes to fish populations and fish health:

- In-water construction will follow standard protocols and best management practices;
- Andrew Lake pit will be dewatered at a rate such that effects to water quality are minimized;
- Andrew Lake Pit area will be dewatered after the spring spawning and fry rearing periods are complete (mid-July to end of August);

- Water will be sourced and discharged into large waterbodies to reduce effects to water quality and fish;
- The design of the WTP is such as to provide an effluent that meets or exceeds all appropriate regulations (e.g., MMER). Design aspects, operational measures and other mitigation measures have been incorporated into the current Project plans which will minimize project-associated emissions and/or the potential effect of project-related emissions.

Potential mitigation measures available for blasting near Andrew Lake include:

- use of smaller charge sizes near Andrew Lake during the open water season to reduce the blasting setback distance to less than 50 metres (the width of the dyke), and
- plan the blasting program to do all required blasting near Andrew Lake during the frozen water period when Andrew Lake and the inflow and outflow streams do not support fish populations. This is approximately eight months of the year.

Potential mitigation measures available to deal with the blasting vibration issue can include:

- smaller charge sizes to be used near Andrew Lake outlet stream during the egg incubation period (about one month to 6 weeks long from early to mid-June to early to mid-July depending on when spawning begins in a particular year) in order to reduce the blasting setback distance to less than 160 metres, and
- Modify the blasting program to complete the required blasting near the Andrew Lake outlet stream (the south side of the pit) during times of year when egg incubation is not occurring. This is approximately 10.5 to 11 months of the year.

11.6 COMPLIANCE AND ENVIRONMENTAL MONITORING FOR FISH

- Sampling of fish populations, and analysis of fish flesh for changes to metal and radionuclide concentrations should be carried out regularly (every third year) during mine operation, closure, and post-closure as part of the Environmental Effects Monitoring Program, to determine whether WTP effluent discharges are having quantifiable effects on fish health, or metal and radionuclide concentrations in fish flesh.
- Blasting effects models should be calibrated with actual on-site blasting data to obtain more refined predictions of effects based on the actual foundation materials under Andrew Lake and the Andrew Lake Pit berm.
- On-site examination of the Arctic grayling spawning area downstream of Andrew Lake (Andrew/Shack Stream) should be carried out during blasting activities in the Andrew Lake Pit to determine whether shock waves and vibrations associated with the blasting are disturbing Arctic grayling on the spawning beds.

12 SUMMARY OF RESIDUAL EFFECTS ON THE AQUATIC ENVIRONMENT AND SUSTAINABILITY

12.1 PROJECT EFFECTS

12.1.1 Hydrology

Project activities have potential to directly affect Judge Sissons Lake, Siamese Lake, Mushroom Lake, Andrew Lake, Pointer Lake and their outflow streams, site access lakes (20 km Lake, Long Lake, Audra Lake, Unnamed Ponds, and Qinguq Bay), and watersheds associated with the project footprint. Effects to flow rates are predicted to remain below 3% of the baseline peak flow. Changes in lake levels are predicted to be highest at Andrew Lake, with a short-term increase of approximately 24 cm during dewatering of the Andrew Lake Pit area, however this will occur after the spring freshet when water levels are naturally declining. All other potential changes in lake level are estimated to remain below 8 cm during the active flow season and 34.2 cm during the inactive flow season. Changes to under-ice volumes will follow Fisheries and Oceans Canada protocol and will remain below 10% during an ice-covered season. Runoff contributing drainage areas for Pointer Lake Outflow and Andrew Lake Outflow (the receiving environments for the Kiggavik and Sissons Sites, respectively) are predicted to decrease by less than 1% and 3%.

12.1.2 Hydrogeology

Effects on hydrogeology, groundwater and surface water receptors where groundwater discharges resulting from Project activities are expected to be low, for both current permafrost conditions and potential no-permafrost conditions that would result from dramatic warming conditions. Given the project design features and the low hydraulic conductivty of the rock mass, all project effects on hydrogeology are predicted to be not significant.

12.1.3 Water Quality

The concentration of constituents of potential concern (COPC), with established thresholds, are expected to be below the appropriate threshold value, with the exception of cadmium. However, because baseline levels of cadmium are below detection levels the concentration change may not be measureable during a summer monitoring program. Changes in water quality are expected to occur during the operation and final closure stages of the project but return to baseline levels at post closure. Overall, no significant adverse effects on water quality are expected.

Changes in water quality due to dust deposition are predicted to be minor and will occur primarily during the period of spring freshet flows. The annual minor increases in metals, radionuclides and TSS will occur over the operational life of the mine (about 25 years), but are not expected to exceed any applicable water quality guideline or objective, or be measurable above natural background variation.

Potential changes to lake pH due to increased atmospheric acid deposition as a result of the Project are predicted to occur primarily during the summer, open water, period. However, any potential changes would be small (i.e. below the critical load value) and likely brief, due to the short residence times of the lakes (0.04 to 0.36 years). No significant adverse effects on water quality are expected.

12.1.4 Sediment Quality

Predicted sediment concentrations for all constituents of potential concern (COPC) with sediment quality guidelines available, were below the guideline levels in all segments of Judge Sissons Lake, with the exception of nickel. Baseline levels of nickel in Judge Sissons sediment are slightly elevated. However, the Project is not expected to substantially increase these levels. It is expected that Project-related residual effects to sediment quality will occur within the Mine Site LAA, but will diminish to background levels before reaching the outlet of Judge Sissons Lake. Overall, no significant adverse effects on sediment quality are expected.

12.1.5 Aquatic Organisms and Fish Habitat

Effects' modelling shows potential issues with cadmium exposure to zooplankton. It is possible that in certain segments of the lake some of the more sensitive zooplankton species will be affected; however considering the moderate SI values and the spatial extent of the impact, the zooplankton population of Judge Sisson Lake is expected to continue to function. Overall, although there are residual effects, no significant adverse effects on the abundance and distribution of aquatic biota are expected due to changes in COPC concentrations in the receiving environment from releases from the WTPs.

A number of Project development activities have the potential to alter, disrupt, or destroy fish habitat. These include diversion of streams away from their current locations, drainage of lakes or portions of lakes, installation of stream crossing structures on all-season ore haul roads and other roads related to constructiong and maintaining Project infrastructure (e.g., roads to water intake and effluent discharge structures and the airstrip). Due to the requirement for a Fish Habitat Compensation Plan and DFO's Policy for "no-net-loss" of fish habitat, a FHCP (see Kiggavik EIS, Volume 5L "Conceptual Fish Habitat Compensation Plan") will be developed in consultation with DFO. Following completion and approval of the FHCP, and implementation of the various compensation works proposed in it, no residual uncompensated losses of fish habitat are anticipated. All habitat losses resulting from the Kiggavik Project will be fully compensated for.

12.1.6 Fish Populations and Fish Health

Residual effects to the abundance and distribution of fish have been identified in the Lower Lake watershed, and potentially in the Pointer Lake watershed. These effects are related to the blasting program associated with mining the proposed Andrew Lake Pit at the Sissons Mine Site, and the Main Zone Pit at the Kiggavike Mine Site. The proposed blasting program has the potential to affect fish in streams and lakes near the mine pits through the generation of shock waves and vibrations as explosive charges are detonated. These shock waves and vibrations can result in physical injuries to fish at various life stages, and can disturb adult fish during spawning or migration activities. Providing effective mitigation measures are enacted, and neither the IPC threshold of 50 kPa, nor the vibration threshold of 13mm/sec peak particle velocity, are exceeded, no residual effect on fish population abundance or distribution will occur.

Concentrations of three COPCs (cadmium, copper, and selenium) are predicted to be present in Judge Sissons Lake at levels high enough to be of concern. However, the levels are not predicted to be high enough to result in adverse effects.

12.2 CUMULATIVE EFFECTS

Project-related residual effects to water quality occur within the Mine Site LAA, but are expected to diminish to background levels downstream of the outlet of Judge Sissons Lake. Any remaining residual effects leaving Judge Sissons Lake would have potential to overlap with other projects and activities that occur or may occur in the future, and therefore act cumulatively on surface water quality.

However, no local, Nunavut, or Far Future Scenario projects from the Project Inclusion List affect hydrology, geohydrology, surface water quality, sediment quality, aquatic organisms, fish, or fish habitat, and overlap spatially and temporally with effects associated with this Project. Therefore, no cumulative effects to surface water quality are predicted for this project.

12.3 EFFECTS OF CLIMATE CHANGE ON PROJECT AND CUMULATIVE EFFECTS ON THE AQUATIC ENVIRONMENT

The effects of climate change on the Project effects were assessed assuming a warming trend scenario over the next 100 years where the mean annual surface temperature increases from -7°C to -2°C (i.e. 5 degree rise in temperature). This increase in temperature is predicted to result in warmer and wetter conditions year-round, which is likely to result in increased evaporation and evapotranspiration rates but overall increase in runoff. For example, runoff is predicted to reach 177% and 200% of historical discharge for Pointer Lake and Judge Sissons

Lake watersheds, respectively. The hydrological effects resulting from climatic changes are orders of magnitude greater than those generated from Project activities.

Although runoff volumes are predicted to increase by 2071-2099, potential changes in the intensity of precipitation events is unknown. Most site designs, particularly those of high hydrological importance such as diversion channels, are designed based on a probable maximum precipitation (PMP) event. This design criterion is not sensitive to annual runoff rates, but rather the intensity of specific rainfall events. Therefore, if the intensity of rainfall events remains consistent with historical conditions, climate change will not affect the effectiveness of Project designs based on a PMP event.

One of the main objectives of modelling this climate change scenario was to assess the effect of a significant warming trend on the extent of permafrost in the tailings management facility (TMFs) areas. Model results show that if the mean annual surface temperature rises the change is manifested as a reduction in depth of permafrost at the base, and not at the surface. Modelling results suggest that the warming trend may result in long term permafrost depths of about 50 m to 90 m from surface. Therefore it is conservative to conclude that the base of all the TMF's may be exposed to a thawed state over the long term.

Increased precipitation and stream flows associated with climate change would result in reduced concentrations of COPCs in Judge Sissons Lake water quality and sediment quality over those levels predicted in this EIA. This is due to the increased volumes of water flowing through the lake, effectively flushing COPCs out of the lake more quickly, giving them less time to concentrate. As well, reduced concentrations of COPCs would have smaller effects on phyto- and zooplankton, benthic invertebrates, and fish than the minor residual effects predicted in the EIA. Reduced concentrations of COPCs would reduce the potential for metals and radionuclides to build up in fish flesh as well.

Increased precipitation and runoff would reduce the drawdown effects of potable and mill water supply use of Siamese and Mushroom lakes. Because the lakes would become ice-free earlier in the spring and freeze-up later in the fall, the volumes of under-ice water withdrawals would be reduced, thereby reducing the potential to effect lake trout spawning habitat in Siamese and Mushroom lakes.

13 SUMMARY OF MITIGATION MEASURES FOR THE AQUATIC ENVIRONMENT

A number of mitigation measures and project designs will be implemented to limit changes to surface hydrology, ground water, water quality, sediment quality, aquatic organisms, and fish and fish habitat. The following list summarizes mitigation measures identified in the Aquatics component of the EIS:

13.1 SURFACE HYDROLOGY

- Site footprint will be minimized and situated such that natural drainage areas and watershed boundaries are maintained;
- The site water management system will be designed to recycle water where applicable and water use will be minimized to limit withdrawal requirements and discharge quantities;
- Diversion channels will be designed to intercept freshwater from upslope, divert it around development areas, and reintroduce it to natural stream channels downstream;
- Sedimentation ponds will be designed with a control structure so that evaporative losses can be minimized;
- In-water construction will follow standard protocols and best management practices;
- Snow fences will be constructed to limit snow drifting on site;
- Andrew Lake pit will be pumped and refilled at a rate such that effects to surface hydrology are minimized.
- DFO procedures for water withdrawal from ice-covered waterbodies in the Northwest Territories and Nunavut will be followed. Specifically, no more than 10% of the under-ice volume will be withdrawn from a lake during one ice covered season.
- Water will be sourced and discharged into large waterbodies to reduce effects to surface hydrology;
- During decommissioning, the ground surface will be recontoured and natural flow patterns will be restored; and

- Andrew Lake Pit area will be dewatered after the spring freshet and before freeze-up (July/August).

13.2 GROUNDWATER

- The proposed tailings management plan for the Kiggavik Project has been designed to avoid interaction between tailings and natural water bodies, to maximize the use of mine workings for long-term management of tailings and to ensure the long-term protection of terrestrial, aquatic and human environments;
- The tailings treatment system in the mill and the TMFs are designed to minimize the release of COPC into the aquatic environment.

13.3 WATER QUALITY

- Site footprint will be minimized and situated such that natural drainage areas and watershed boundaries are maintained;
- The site water system will be designed to recycle water where applicable and water use will be minimized to limit withdrawal requirements and discharge quantities;
- Diversion channels will be designed to keep water within its natural drainage path;
- In-water construction will follow standard protocols and best management practices;
- Andrew Lake pit will be de-watered at a rate such that effects to water quality are minimized;
- Andrew Lake Pit area will be dewatered after the spring spawning season and before freeze-up (July/August;
- Measures will be taken to minimize the amount of dust generated at the two mine sites and along the main haul road between the mine sites;
- Water will be sourced and discharged into large waterbodies to reduce effects to water quality; and
- During decommissioning, the ground surface will be recontoured and natural flow patterns will be restored.

13.4 SEDIMENT QUALITY

- The site footprint will be minimized and situated such that natural drainage areas and watershed boundaries are maintained.

- The site water system will be designed to recycle water where applicable and water use will be minimized to limit withdrawal requirements and discharge quantities.
- Diversion channels will be designed to keep water within its natural drainage path.
- In-water construction will follow standard protocols and best management practices.
- Andrew Lake pit will be dewatered at a rate such that effects to sediment quality in Andrew Lake and downstream areas are minimized.
- Andrew Lake Pit area will be dewatered after the spring freshet and before freeze-up (July/August).
- Water will be discharged into large waterbodies to reduce effects to sediment quality.
- During decommissioning, the ground surface will be recontoured and natural flow patterns will be restored.

13.5 AQUATIC ORGANISMS

- The design of the WTP was such to provide an effluent that met or exceeded all appropriate regulations (e.g. MMER).
- Design aspects, operational measures and other mitigation measures have been incorporated into the current Project plans which will minimize project-associated emissions and/or the potential effect of project-related emissions.

13.6 FISH HABITAT

- Mitigation measures have been incorporated into the Project design, and will be incorporated into various project construction activities in the form of Best Management Practices for road construction and installation of stream crossings.
- Erosion control measures will be incorporated into the design of stream and watercourse diversions.
- Erosion control and turbidity management procedures will be used during the installation of the lake water intake structures, and effluent diffuser structures.
- Best management practices will be utilized with the installation of turbidity curtains prior to constructing the berm in Andrew Lake, and proceeding with the dewatering of the east portion of the Andrew Lake basin. Fish salvage will be carried out prior to dewatering in order to minimize the potential for fish losses due to stranding.
- Construction of the berm at Andrew Lake and dewatering the north-east end of the lake will result in the loss of approximately 13.5 ha of shallow (less than 1.0 m deep),

seasonal use (open-water season) fish habitat. Following consultation with DFO staff on the issue of determining appropriate compensation options, AREVA is preparing a FHCP that proposes to replace the area of lost habitat with a similar amount of shallow, seasonal use habitat. Remote sensing surveys have been undertaken to locate a number of shallow, landlocked, potentially fishless waterbodies in the Kiggavik region, that might be connected to nearby fish-bearing stream systems to make them productive fish habitat. Ground-based fish and engineering surveys would be required to confirm that the target waterbodies are currently fishless, and that connection with adjacent stream systems is possible in terms of elevation differences and other engineering considerations.

- Construction of all-season roads as part of the Kiggavik and Sissons Mine Sites and their associated infrastructure will affect fish habitat where the roads cross fish-bearing streams. All crossings will be designed and installed in a manner to facilitate fish passage under all flow conditions up to and including the 1 in 10 year flood. In terms of fish habitat compensation for the culvert installation's footprint on the natural stream bed, limiting fish habitat types will be identified for each affected stream through field surveys, and improvements to instream fish habitat made that would most benefit each individual stream.
- The above proposed measures describe the general approaches that will be used to mitigate effects to fish habitat, and compensate for fish habitat losses or alterations. The detailed proposals will be incorporated into a FHCP for the Kiggavik Project. The FHCP will be submitted to NIRB and Fisheries and Oceans Canada (DFO) for review. Only after the FHCP receives approval, and the Project receives DFO's Authorization can any Project work begin that may result in the loss or harmful alteration of fish habitat.

13.7 FISH

- In-water construction will follow standard protocols and best management practices;
- Andrew Lake pit will be dewatered at a rate such that effects to water quality are minimized;
- Andrew Lake Pit area will be dewatered after the spring spawning and fry rearing periods are complete (mid-July to end of August);
- Water will be sourced and discharged into large waterbodies to reduce effects to water quality and fish;
- The design of the WTP is such as to provide an effluent that meets or exceeds all appropriate regulations (e.g., MMER). Design aspects, operational measures and other mitigation measures have been incorporated into the current Project plans which will minimize project-associated emissions and/or the potential effect of project-related emissions.

Potential mitigation measures available for blasting near Andrew Lake include:

- use of smaller charge sizes near Andrew Lake during the open water season to reduce the blasting setback distance to less than 50 metres (the width of the dyke), and
- plan the blasting program to do all required blasting near Andrew Lake during the frozen water period when Andrew Lake and the inflow and outflow streams do not support fish populations. This is approximately eight months of the year.

Potential mitigation measures available to deal with the blasting vibration issue can include:

- smaller charge sizes to be used near Andrew Lake outlet stream during the egg incubation period (about one month to 6 weeks long from early to mid-June to early to mid-July depending on when spawning begins in a particular year) in order to reduce the blasting setback distance to less than 160 metres, and
- Modify the blasting program to complete the required blasting near the Andrew Lake outlet stream (the south side of the pit) during times of year when egg incubation is not occurring. This is approximately 10.5 to 11 months of the year.

14 SUMMARY OF MONITORING FOR THE AQUATIC ENVIRONMENT

14.1 COMPLIANCE MONITORING PROGRAM FRAMEWORK

Compliance monitoring is undertaken to confirm that Project design features, mitigation measures, environmental protection measures, or benefit agreements are being effectively implemented.

14.1.1 Hydrology Monitoring

- **Water levels:** Staff gauges and continuous water level sensors will be installed on Andrew Lake, Siamese Lake, Mushroom Lake, Judge Sissons Lake, and their outflow channels and levels will be manually recorded during periods in which effects may occur;
- **Waterbody volumes:** Under-ice volumes will be confirmed by annual ice thickness measurements at Siamese Lake, Mushroom Lake, and ice road lakes.

14.1.2 Groundwater Monitoring

- Water quality in lakes and streams adjacent to and downstream of the the Kiggavik and Sissons areas will be monitored during the spring freshet each year during the operational life of the Project to confirm that COPC do not increase as a result of tailings management of mine rock management activities.

14.1.3 Water Quality

- Water withdrawal and wastewater/effluent discharge rates will be continually documented during the construction, operations, and closure phases of the mine;
- Wastewater/effluent discharge quality will be analysed and documented regularly according to Nunavut regulatory requirements during mine operations, and during and after mine closure;
- Water quality in each section of Judge Sissons Lake receiving treated effluent, as well as at the outlet of Judge Sissons Lake, will be monitored on a monthly basis during the operations and closure phases of the Kiggavik Project, and on an annual basis during the post-closure phase;

14.1.4 Sediment Quality

- Sediment quality in lakes adjacent to and downstream of the Mine LAA will be monitored every three years to confirm that metals and radionuclide concentrations, and lake sedimentation rates are not increasing above predicted levels. Sediment monitoring will occur during the operational and closure phases of the Project.
- Sediment quality will be monitored in the two receiving basins, and in the main body of Judge Sissons Lake every three years as part of the Environmental Effects Monitoring Plan.

14.1.5 Aquatic Organisms and Fish Habitat

- Benthic invertebrate populations and diversity should be monitored regularly (every third year) during mine operation, closure, and post-closure as part of the Environmental Effects Monitoring Program to determine whether WTP effluent discharges are having quantifiable effects on benthic macro-invertebrate populations.
- Compliance and effectiveness monitoring of the Fish Habitat Compensation Plan (FHCP) will be carried out to ensure that fish habitat compensation is constructed /installed as per DFO's Authorization and that it is functioning effectively.

14.1.6 Fish

- Sampling of fish populations, and analysis of fish flesh for changes to metal and radionuclide concentrations should be carried out regularly (every third year) during mine operation, closure, and post-closure as part of the Environmental Effects Monitoring Program, to determine whether WTP effluent discharges are having quantifiable effects on fish health, or metal and radionuclide concentrations in fish flesh.

14.2 ENVIRONMENTAL MONITORING PROGRAM FRAMEWORK

Environmental and follow-up monitoring programs are used to:

- verify predictions of environmental effects;
- determine the effectiveness of mitigation measures, environmental protection measures or benefits agreements in order to modify or implement new measures where required;
- support the implementation of adaptive management measures to address previously unanticipated adverse environmental effects; and
- support environmental management systems used to manage the environmental effects of projects.

14.2.1 Hydrology Monitoring

- Instantaneous discharge measurements will be taken at Andrew Lake Outflow, Siamese Lake Outflow, Mushroom Lake Outflow, and Judge Sissons Lake Outflow while effects are predicted to occur. These flow rates can be used to develop and maintain stage-discharge rating curves so that water level data can be used to estimate continuous discharge. In addition, water withdrawal and treated effluent and greywater discharge rates will be continually documented;

14.2.2 Groundwater Monitoring

- Monitoring of hydrogeological effects can be completed through the collection of specific data at waterbodies potentially affected by project activities (i.e., End Grid Lake, Mushroom Lake and Pointer Lake) in a manner consistent with monitoring for changes in surface hydrology.
- A groundwater monitoring program will be implemented. The program will consist of an array of monitoring points to track changes in ground temperature, pressure gradients (flow direction) and water quality in the deep, sub-permafrost, groundwater flow regime. The proposed monitoring system will be phased in as the project moves from planning and design, through operations, and finally into closure. Groundwater pressures and chemistry will be established in the rock mass surrounding the proposed TMF prior to excavation of the pits, and then monitored as the excavation base penetrates the permafrost base and as the pit is filled with tailings material. This will require an increasing array of monitoring points in order to detect changes brought about by the mining activities.
- Contingency plans are intended to address unforeseen circumstances which could result in a significant increase in the mass flux of solutes to the receptors. Extensive investigations into the chemical and physical properties of tailings has been undertaken at Kiggavik and will continue to be undertaken as part of a Tailings Optimization and Validation Program (TOVP), similar to the program that was initiated at McClean Lake Operation and has been a successful audit program for the behaviour of the tailing produced at that site in Northern Saskatchewan.

14.2.3 Water Quality

- Air and dust emission levels, and dust deposition should be monitored on a regular basis near both the Kiggavik and Sissons mining operations, and adjacent to the ore haul road between the two sites to determine whether actual levels are similar to predicted levels;
- Water quality in lakes and streams adjacent to and downstream of the Mine LAA will be monitored each spring during freshet, and in the case of lakes, once again during autumn prior to freezeup, to confirm that metals and radionuclide concentrations, TSS and acid deposition levels, and lake acidification are not increasing above predicted

levels. This monitoring will occur during the operational and closure phases of the Project.

- Water quality monitoring of the reflooded Andrew Lake Pit should be carried out to determine if and when the dyke separating Andrew Lake from the reflooded mine pit should be breached and the two waterbodies connected. If water quality is high then the two water bodies could be connected. If water quality is poor or unsuitable for fish use, the waterbodies should remain unconnected.

14.2.4 Aquatic Organisms and Fish Habitat

- Benthic invertebrate populations and diversity should be monitored regularly (every third year) during mine operation, closure, and post-closure as part of the Environmental Effects Monitoring Program to determine whether WTP effluent discharges are having quantifiable effects on benthic macro-invertebrate populations.
- Carry out compliance and effectiveness monitoring associated with the Fish Habitat Compensation Plan (FHCP) to ensure that fish habitat compensation is constructed /installed as per DFO's Authorization and that it is functioning effectively.

14.2.5 Fish

- Blasting effects models should be calibrated with actual on-site blasting data to obtain more refined predictions of effects based on the actual foundation materials under Andrew Lake and the Andrew Lake Pit berm.
- On-site examination of the Arctic grayling spawning area downstream of Andrew Lake (Andrew/Shack Stream) should be carried out during blasting activities in the Andrew Lake Pit to determine whether shock waves and vibrations associated with the blasting are disturbing Arctic grayling on the spawning beds.

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Attachment A

Table 5.3-2
Summary of Water Chemistry Data for Lakes and Streams in the Kiggavik Project Area, 1974-2009

Parameter	Units	Guidelines		Willow Lake Sub-Basin			Lower Lake Sub-Basin		
				All Lakes	Northeast Inflow of Pointer Lake	All Other Streams	Mushroom Lake	Andrew Lake	All Other Lakes
				1979, 1980, 1986, 1988, 1989, 1991, 2007, 2008, 2009	2008, 2009	1988, 2007, 2008, 2009	1991, 2008	2007, 2008, 2009	1991, 2007, 2008
		SSWQO[a]	CWQG[b]	n = 43[c]	n = 4[c]	n = 20[c]	n = 14[c]	n = 3[c]	n = 22[c]
Conventional Parameters (Field-Measured)									
Dissolved Oxygen	mg/L	[d]	[d]	10.32 - 12.06	10.66 - 11.31	10.03 - 12.58	-	11.19 - 11.63	11.84 - 11.97
Water Temperature	°C	-	-	6.30 - 14.80	4.92 - 14.4	1.91 - 13.11	8.21 - 17.14	7.42 - 9.80	6.01 - 13.10
pH	pH units	-	6.5-9.0	6.65 - 9.90	6.64 - 7.87	6.34 - 8.03	6.96 - 7.13	7.33 - 7.59	**6.36** - 7.96
Specific Conductivity	µS/cm	-	-	12 - 58	16 - 39	12 - 45	-	30 - 31	25 - 34
Conventional Parameters (Laboratory-Measured)									
pH	pH units	-	6.5-9.0	5.6 - 7.55	6.56 - 6.90	6.60 - 7.39	6.70 - 7.08	6.94 - 7.24	6.35 - 7.54
Specific Conductivity	µS/cm	-	-	10.2 - 141[e]	16 - 40	14 - 116	20.3 - 50	31 - 36	13 - 53
Total Alkalinity	mg $CaCO_3$/L	-	-	1 - 53[e]	4 - 7	3 - 26	4 - 15	10 - 14	2 - 23
Alkalinity (pH 3.8)	mg $CaCO_3$/L	-	-	12 - 27[e]	-	23	-	-	-
Gran alkalinity	mg $CaCO_3$/L	-	-	2.6 - 56[e]	-	-	3.8 - 16	-	2.4 - 13.0
Total Hardness	mg $CaCO_3$/L	-	-	3.5 - 57[e]	7 - 17	6 - 44	9.0 - 15.9	14 - 16	4 - 22
Total Dissolved Solids	mg/L	-	-	2 - 58 (2 < DL)	18 - 45	11 - 80	22 - 25	34 - 35	13 - 45
Total Suspended Solids	mg/L	-	-	<1 - 10 (4 < DL)	<1 - 5 (2 < DL)	<1 - 8 (4 < DL)	<1 - <2 (4 < DL)	2 - 4	<1 - 10 (4 < DL)
Turbidity	NTU	-	-	0.57 - 4.6	0.7 - 6.2	0.6 - 3.0	0.5 - 1.1	1.8 - 2.2	0.7 - 6
True Colour (Co-Pt)	-	-	-	8 - 41	-	73	9 - 14	-	9 - 14
Chlorophyll a	µg/L	-	-	0.64 - 1.58	-	-	-	-	-
Chlorophyll *a*	mg/m^3	-	-	2.1 - 5.0	-	2.1 - 3.3		3.0 - 3.1	
Absorbance at 254 nm	-	-	-	0.066 - 0.124	-	0.404	-	-	-
Nutrients									
Ammonia as nitrogen	mg N/L	0.24[f]	0.24[f]	<0.01 - 0.23 (4 < DL)	<0.01 - 0.1 (1 < DL)	<0.01 - 0.11 (3 < DL)	0.008 - 0.029 (2 < DL)	0.03 - 0.1	<0.01 - **0.35** (2 < DL)
Nitrate and Nitrite as nitrogen	mg N/L	-	-	<0.01 - 0.04 (6 < DL)	<0.01 - 0.02 (1 < DL)	<0.01 - 0.01 (6 < DL)	<0.01 (2 < DL)	<0.01 - 0.01 (1 < DL)	<0.01 (10 < DL)
Nitrate[g]	mg/L	-	13 [h]	<0.003 - 0.24 (17 < DL)	<0.04 - 0.09 (1 < DL)	<0.02 - 0.04 (6 < DL)	<0.01 - <0.04 (5 < DL)	<0.04 (1 < DL)	<0.01 - <0.04[i] (9 < DL)
Nitrite	mg/L	-	0.197 [j]	<0.001 - <0.1[i] (10 < DL)	-	0.002	<0.01 (3 < DL)	-	<0.01 - 0.01 (2 < DL)
Total Kjeldahl Nitrogen	mg/L	-	-	0.10 - 1.34[e]	0.41 - 0.52	0.34 - 0.69	0.20 - 0.46	0.43 - 0.64	0.25 - 1.3
Total Nitrogen	mg/L	-	-	0.10 - 0.89	0.41 - 0.44	0.35 - 0.68	0.20 - 0.36	0.64	0.27 - 0.66
Total Phosphorous	mg/L	-	-	<0.001 - 0.08 (17 < DL)	<0.01 - 0.02 (2 < DL)	0.005 - 0.02 (13 < DL)	0.006 - <0.01 (2 < DL)	<0.01 (3 < DL)	0.008 - 0.09 (5 < DL)
Dissolved Phosphorus	mg/L	-	-	<0.01 - 0.04 (9 < DL)	<0.01 - 0.02 (2 < DL)	<0.01 - 0.04 (11 < DL)	<0.01 (2 < DL)	<0.01 (2 < DL)	<0.01 - 0.07 (5 < DL)
Soluble Reactive Phosphorous	mg/L	-	-	<0.001 - 0.001 (12 < DL)	-	<0.001 (1 < DL)	<0.001 (3 < DL)	-	<0.001 - 0.003 (2 < DL)
Orthophosphate-P	mg/L	-	-	<0.1 (7 < DL)	-	-	-	-	-
Total Carbon	mg/L	-	-	4 - 19	4 - 10	4 - 23	6 - 7	9 - 10	4 - 13
Total Inorganic Carbon	mg/L	-	-	<1 - 7 (1 < DL)	1 - 2	<1 - 6 (1 < DL)	2 - 3	3	1 - 6
Total Organic Carbon	mg/L	-	-	2.3 - 12	2.7 - 8.7	3.1 - 18	3.6 - 4.6	5.6 - 7.3	3.3 - 9
Dissolved Inorganic Carbon	mg/L	-	-	0.7 - 13.4[e]	-	4.0	1.6 - 3.5	-	<0.5 - 3.9 (1 < DL)
Dissolved Organic Carbon	mg/L	-	-	2.5 - 26[e]	2.9 - 10	3.1 - 18	3.6 - 6.7	6.0 - 8.4	3.4 - 10
Major Ions									
Bicarbonate	mg/L	-	-	1 - 39	5 - 9	4 - 32	12 - 13	12 - 17	5 - 28
Calcium	mg/L	-	-	0.85 - 16.8[e]	1.5 - 4.3	1.4 - 13.3	2.3 - 4.8	3.5 - 4.3	0.1 - 6.2
Carbonate	mg/L	-	-	<1 (16 < DL)	<1 (4 < DL)	<1 (17 < DL)	<1 (2 < DL)	<1 (3 < DL)	<1 (10 < DL)
Chloride	mg/L	-	-	0.17 - 3.2[e] (1 < DL)	0.3 - 2.6	0.3 - 22	0.35 - 0.74	1.8 - 2.3	0.32 - 3.4
Fluoride	mg/L	-	-	<0.01 - 0.16 (1 < DL)	0.04 - 0.11	0.03 - 0.35	0.06 - 0.15	0.22 - 0.27	0.07 - 0.45
Hydroxide	mg/L	-	-	<1 (16 < DL)	<1 (4 < DL)	<1 (17 < DL)	<1 (2 < DL)	<1 (3 < DL)	<1 (10 < DL)
Magnesium	mg/L	-	-	0.30 - 5.2[e]	0.7 - 1.6	0.5 - 2.6	0.8 - 1.5	1.2 - 1.4	0.05 - 1.7
Potassium	mg/L	-	-	0.10 - 2.1[e]	0.3 - 0.5	<0.1 - 1.25 (1 < DL)	0.2 - 0.75	0.3 - 0.5	0.1 - 0.5
Silica (as Si0$_2$)	mg/L	-	-	0.08 - 0.58	-	2.5	0.28	-	0.48
Silicates	mg/L	-	-	0.43 - 0.97	-	-	-	-	-
Sodium	mg/L	-	-	0.2 - 2.5[e] (15 < DL)	0.4 - 0.7	0.2 - 1.5	0.3 - 0.5 (2 < DL)	0.5 - 0.7	0.3 - 0.8 (2 < DL)
Sulphate	mg/L	-	-	0.038 - 3.2[e]	0.6 - 6.9	0.3 - 2.9	0.4 - 0.99	0.5 - 0.8	0.2 - 1.5
Sum of Ions	mg/L	-	-	5 - 52	9 - 22	8 - 43	17 - 19	22 - 25	8 - 39
Sum of ions	%	-	-	-	-	-	-	-	-
Total Metals									
Aluminum[k]	mg/L	0.005-0.1 [l]	0.005-0.1 [l]	0.013 - **0.1** (2 < DL)	0.079 - 0.094	0.016 - **0.138**	0.015 - 0.04 (1 < DL)	0.023 - 0.031	**0.018** - 0.057
Antimony	mg/L	-	-	<0.0002 - 0.0002 (15 < DL)	<0.0002 (4 < DL)	<0.0002 (17 < DL)	<0.0002 (2 < DL)	<0.0002 (3 < DL)	<0.0002 (10 < DL)
Arsenic	µg/L	5	5	0.1 - <5 (22 < DL)	0.2	0.1 - <1 (1 < DL)	0.1 - <5 (3 < DL)	<0.1 - 0.1 (1 < DL)	<0.1 - 2 (3 < DL)
Barium	mg/L	-	-	0.02 - 0.37[e]	0.057 - 0.095	0.027 - 0.14	0.02 - 0.04	0.05 - 0.055	0.01 - 0.098
Beryllium	mg/L	-	-	<0.0001 - <0.005 (23 < DL)	<0.0001 (4 < DL)	<0.0001 (17 < DL)	<0.0001 (2 < DL)	<0.0001 (3 < DL)	<0.0001 (10 < DL)
Boron	mg/L	-	-	<0.01 - 0.01 (15 < DL)	<0.01 - 0.01 (3 < DL)	<0.01 (17 < DL)	<0.01 (2 < DL)	<0.01 (3 < DL)	<0.01 - 0.01 (9 < DL)
Bromide	mg/L	-	-	-	-	-	-	-	-

Table 5.3-2
Summary of Water Chemistry Data for Lakes and Streams in the Kiggavik Project Area, 1974-2009

Parameter	Units	Guidelines		Willow Lake Sub-Basin			Lower Lake Sub-Basin		
				All Lakes	Northeast Inflow of Pointer Lake	All Other Streams	Mushroom Lake	Andrew Lake	All Other Lakes
				1979, 1980, 1986, 1988, 1989, 1991, 2007, 2008, 2009	2008, 2009	1988, 2007, 2008, 2009	1991, 2008	2007, 2008, 2009	1991, 2007, 2008
		SSWQO[a]	CWQG[b]	n = 43[c]	n = 4[c]	n = 20[c]	n = 14[c]	n = 3[c]	n = 22[c]
Cadmium[k]	mg/L	0.000017 [m]	0.000017 [m]	<0.00001 - **0.017** (25 < DL)	<0.00001 - *<0.0001* (4 < DL)	<0.00001 - **0.0004** (15 < DL)	*<0.0001 - <0.002* (4 < DL)	<0.00001 - *<0.0001* (3 < DL)	*<0.0001* - **0.002** (12 < DL)
Chromium[k]	mg/L	-	0.0010/0.0089 [n]	<0.0005 - *<0.5* [i] (35 < DL)	<0.0005 (4 < DL)	<0.0005 - 0.001 (16 < DL)	<0.0005 - *<0.01* (4 < DL)	<0.0005 - 0.0021 (2 < DL)	<0.0005 - *< 0.01* (13 < DL)
Cobalt	mg/L	-	-	<0.0001 - <0.01[i] (27 < DL)	<0.0001 - 0.0001 (2 < DL)	<0.0001 - 0.001 (12 < DL)	<0.0001 - <0.01 (4 < DL)	<0.0001 (3 < DL)	<0.0001 - <0.01[i] (8 < DL)
Copper[k]	mg/L	0.002 [o]	0.002 [o]	<0.0005 - **0.0143**[p] (6 < DL)	0.0014 - **0.0035**	0.0004 - **0.0045**	0.0007 - **0.005** (1 < DL)	0.0009 - 0.0012	0.0005 - *<0.005* (2 < DL)
Iron	mg/L	0.3	0.3	0.03 - **0.98**	0.048 - 0.230	0.055 - **2.5**	0.04 - 0.14	0.10 - 0.11	<0.02 - **0.32** (1 < DL)
Lead[k]	mg/L	0.001 - 0.002 [q]	0.001 - 0.002 [q]	<0.0001 - **0.59** (23 < DL)	<0.0001 (3 < DL)	<0.0001 - **0.001** (9 < DL)	<0.0001 - **0.02** (2 < DL)	0.0001	<0.0001 - *<0.02* [i] (3 < DL)
Manganese	mg/L	-	-	0.001 - 0.088 (7 < DL)	0.0007 - 0.0060	0.0018 - 0.113	0.0055 - <0.01 (2 < DL)	0.0015 - 0.0031	0.0005 - <0.01 (2 < DL)
Mercury[k, r]	µg/L	0.026 [s]	0.026 [t]	<0.005 - *<10* [i] (36 < DL)	<0.005 - *<0.05* (4 < DL)	<0.005 - *<0.05* (18 < DL)	*<0.05* (4 < DL)	<0.02 - *<0.05* (3 < DL)	*<0.05* - **0.3** (11 < DL)
Molybdenum	mg/L	-	0.073	<0.0001 - <0.01[i] (13 < DL)	<0.0001 - 0.0003 (1 < DL)	<0.0001 - 0.0002 (14 < DL)	<0.0001 - 0.0001 (1 < DL)	<0.0001 - 0.0001 (2 < DL)	<0.0001 - 0.0001 (6 < DL)
Nickel	mg/L	0.025 [u]	0.025 [u]	0.0003 - <0.01 (17 < DL)	0.0013 - 0.0016	0.0003 - 0.002	0.0004 - <0.01 (2 < DL)	0.0004 - 0.0005	0.0002 - <0.01 (2 < DL)
Selenium	mg/L	0.001[v]	0.001[v]	<0.0001 - 0.0002 (12 < DL)	<0.0001 - 0.0001 (3 < DL)	<0.0001 - 0.0002 (13 < DL)	0.0001	<0.0001 - 0.0001 (2 < DL)	<0.0001 - 0.0001 (8 < DL)
Selenium [k]	µg/L	1 [v]	1.0 [v]	<0.1 - < 0.5[i] (17 < DL)	-	<0.1 (1 < DL)	*<2* (2 < DL)	-	*<2* - **2** (2 < DL)
Silicon	mg/L	-	-	-	-	-	-	-	-
Silver[k]	mg/L	0.0001	0.0001	<0.00001 - **0.0001** (26 < DL)	*<0.0001* (4 < DL)	*<0.0001* (18 < DL)	*<0.0001* - **0.00054** (2 < DL)	*<0.0001* (3 < DL)	*<0.0001* - **0.00048** (11 < DL)
Strontium	mg/L	-	-	<0.01 - 0.13[e] (1 < DL)	0.013 - 0.031	0.010 - 0.038	0.01 - 0.03	0.048 - 0.059	0.0084 - 0.095 (1 < DL)
Tellurium	µg/L	-	-	<2 (4 < DL)	-	-	-	-	-
Thallium	mg/L	-	0.0008	<0.0002 (16 < DL)	<0.0002 (4 < DL)	<0.0002 (17 < DL)	<0.0002 (2 < DL)	<0.0002 (3 < DL)	<0.0002 (10 < DL)
Tin	mg/L	-	-	<0.0001 - 0.0016 (13 < DL)	<0.0001 - 0.0001 (3 < DL)	<0.0001 - 0.0001 (16 < DL)	<0.0001 - 0.0001 (1 < DL)	<0.0001 (3 < DL)	<0.0001 - 0.0001 (8 < DL)
Titanium	mg/L	-	-	0.0002 - 0.0016	0.0005 - 0.0008	0.0002 - 0.0008	<0.0002 - 0.0005 (1 < DL)	0.0003 - 0.0004	<0.0002 - 0.0018 (1 < DL)
Uranium	µg/L	15	-	<0.1 - 8.6 (23 < DL)	<0.1 - 0.2 (2 < DL)	<0.1 - 11 (17 < DL)	<0.1 - <0.5[i] (2 < DL)	<0.1 - 0.2 (2 < DL)	<0.1 - <0.5[i] (8 < DL)
Uranium - preconcentrated	µg/L	-	-	0.15	-	-	0.5	-	0.5
Uranium - whole water	µg/L	-	-	0.005 - 0.5	-	-	-	-	-
Vanadium	mg/L	-	-	<0.0001 - <0.01[i] (8 < DL)	0.0001	<0.0001 - 0.0002 (1 < DL)	<0.0001 (2 < DL)	0.0001	<0.0001 - 0.0002 (2 < DL)
Zinc	mg/L	0.03	0.03	0.00001 - **8.19** (14 < DL)	0.0021 - 0.0087	<0.0005 - 0.0078 (2 < DL)	0.0015 - <0.01 (1 < DL)	0.0026 - 0.0087	<0.0005 - 0.02 (2 < DL)
Dissolved Metals									
Aluminum	mg/L	-	-	0.0036 - 0.024	0.055 - 0.085	0.0073 - 0.0660	0.0100 - 0.0094	0.0063 - 0.018	0.0037 - 0.0170
Antimony	mg/L	-	-	<0.0002 - 0.0002 (15 < DL)	<0.0002 (4 < DL)	<0.0002 (17 < DL)	<0.0002 (2 < DL)	<0.0002 (3 < DL)	<0.0002 - 0.0005 (9 < DL)
Arsenic	µg/L	-	-	0.1 - 0.5	0.1 - 0.2	0.1 - 0.3	<0.1 - 0.1 (1 < DL)	0.1	<0.1 - 0.2 (3 < DL)
Barium	mg/L	-	-	0.03 - 0.09	0.054 - 0.096	0.024 - 0.088	0.023	0.048 - 0.056	0.013 - 0.095
Beryllium	mg/L	-	-	<0.0001 (16 < DL)	<0.0001 (4 < DL)	<0.0001 (17 < DL)	<0.0001 (2 < DL)	<0.0001 (3 < DL)	<0.0001 (10 < DL)
Boron	mg/L	-	-	<0.01 - 0.04 (15 < DL)	<0.01 (4 < DL)	<0.01 (17 < DL)	<0.01 (2 < DL)	<0.01 (3 < DL)	<0.01 (10 < DL)
Cadmium	mg/L	-	-	<0.00001 - <0.0001 (16 < DL)	<0.00001 - 0.0001 (3 < DL)	<0.00001 - 0.0001 (11 < DL)	<0.0001 (2 < DL)	<0.00001 - <0.0001 (3 < DL)	<0.0001 (10 < DL)
Chromium	mg/L	-	-	<0.0005 (16 < DL)	<0.0005 - 0.0007 (3 < DL)	<0.0005 - 0.0005 (15 < DL)	<0.0005 (2 < DL)	<0.0005 (3 < DL)	<0.0005 - 0.0044 (9 < DL)
Cobalt	mg/L	-	-	<0.0001 - 0.0001 (14 < DL)	<0.0001 - 0.0005 (3 < DL)	<0.0001 - 0.0001 (13 < DL)	<0.0001 (2 < DL)	<0.0001 - 0.0001 (2 < DL)	<0.0001 - 0.0001 (8 < DL)
Copper	mg/L	-	-	0.0006 - 0.0038	0.0011 - 0.0035	0.0005 - 0.0016	0.0007 - 0.0008	0.0009 - 0.0012	0.0006 - 0.0013
Iron	mg/L	-	-	0.0092 - 0.15	0.034 - 0.094	0.013 - 0.350	0.023 - 0.035	0.02 - 0.045	0.0057 - 0.17
Lead	mg/L	-	-	<0.0001 - 0.0008 (11 < DL)	<0.0001 - 0.0001 (2 < DL)	<0.0001 - 0.0002 (8 < DL)	<0.0001 - 0.0001 (1 < DL)	<0.0001 - 0.0001 (1 < DL)	<0.0001 - 0.0001 (7 < DL)
Manganese	mg/L	-	-	<0.0005 - 0.0150 (2 < DL)	0.0006 - 0.0023	0.0012 - 0.0130	0.0006 - 0.0029	0.0006 - 0.0018	<0.0005 - 0.0036 (1 < DL)
Molybdenum	mg/L	-	-	<0.0001 - 0.0004 (9 < DL)	<0.0001 - 0.0003 (2 < DL)	<0.0001 - 0.0002 (3 < DL)	<0.0001 - 0.0001 (1 < DL)	<0.0001 - 0.0001 (2 < DL)	<0.0001 - 0.0002 (6 < DL)
Nickel	mg/L	-	-	0.0003 - 0.0007	0.0009 - 0.0016	0.0003 - 0.0011	0.0004 - 0.0005	0.0004 - 0.0005	0.0002 - 0.0009
Selenium	mg/L	-	-	<0.0001 - 0.0002 (10 < DL)	0.0001	<0.0001 - 0.0003 (5 < DL)	<0.0001 - 0.0002 (1 < DL)	<0.0001 - 0.0002 (1 < DL)	<0.0001 - 0.0002 (7 < DL)
Silver	mg/L	-	-	<0.0001 (16 < DL)	<0.0001 (4 < DL)	<0.0001 (17 < DL)	<0.0001 (2 < DL)	<0.0001 (3 < DL)	<0.0001 (10 < DL)
Strontium	mg/L	-	-	0.012 - 0.052	0.013 - 0.031	0.010 - 0.038	0.018 - 0.020	0.049 - 0.059	0.0083 - 0.0940
Thallium	mg/L	-	-	<0.0002 (16 < DL)	<0.0002 (4 < DL)	<0.0002 (17 < DL)	<0.0002 (2 < DL)	<0.0002 (3 < DL)	<0.0002 (10 < DL)
Tin	mg/L	-	-	<0.0001 - 0.0061 (3 < DL)	0.0001 - 0.0016	<0.0001 - 0.0011 (4 < DL)	0.0002 - 0.0005	<0.0001 - 0.0002 (1 < DL)	<0.0001 - 0.0062 (2 < DL)
Titanium	mg/L	-	-	<0.0002 - 0.0005 (9 < DL)	0.0003 - 0.0004	<0.0002 - 0.0005 (11 < DL)	<0.0002 (2 < DL)	<0.0002 - 0.0002 (2 < DL)	<0.0002 - 0.0004 (7 < DL)
Uranium	µg/L	-	-	<0.1 - 0.1 (14 < DL)	<0.1 - 0.2 (2 < DL)	<0.1 (17 < DL)	<0.1 (2 < DL)	<0.1 - 0.1 (2 < DL)	<0.1 - 0.1 (7 < DL)
Vanadium	mg/L	-	-	<0.0001 - 0.0001 (6 < DL)	0.0001	<0.0001 - 0.0001 (8 < DL)	<0.0001 (2 < DL)	<0.0001 (3 < DL)	<0.0001 - 0.0001 (7 < DL)
Zinc	mg/L	-	-	0.0009 - 0.0088	0.0016 - 0.0089	0.0011 - 0.0080	0.0043 - 0.0045	0.0023 - 0.0065	0.0012 - 0.0099
Radionuclides									
Lead-210	Bq/L	-	-	<0.02 - <0.2[i] (25 < DL)	<0.02 - 0.03 (3 < DL)	<0.02 - 0.48 (16 < DL)	<0.02 (2 < DL)	<0.02 (3 < DL)	<0.02 (10 < DL)
Lead-210	pCi/L	-	-	<0.5 - 2 (6 < DL)	-	-	-	-	-
Polonium-210	Bq/L	-	-	<0.005 - 0.037 (15 < DL)	<0.005 - 0.008 (3 < DL)	<0.005 - 0.47 (11 < DL)	<0.005 (2 < DL)	0.007 - 0.010	<0.005 - 0.010 (3 < DL)
Polonium-210 - preconcentrated	Bq/L	-	-	0.0029		-	-	-	-
Polonium-210 - whole water	Bq/L	-	-	-		-	-	-	-

Table 5.3-2
Summary of Water Chemistry Data for Lakes and Streams in the Kiggavik Project Area, 1974-2009

Parameter	Units	Guidelines		Willow Lake Sub-Basin			Lower Lake Sub-Basin		
				All Lakes	Northeast Inflow of Pointer Lake	All Other Streams	Mushroom Lake	Andrew Lake	All Other Lakes
				1979, 1980, 1986, 1988, 1989, 1991, 2007, 2008, 2009	2008, 2009	1988, 2007, 2008, 2009	1991, 2008	2007, 2008, 2009	1991, 2007, 2008
		SSWQO[(a)]	CWQG[(b)]	n = 43[(c)]	n = 4[(c)]	n = 20[(c)]	n = 14[(c)]	n = 3[(c)]	n = 22[(c)]
Radium-226	Bq/L	-	-	0.00096 - 0.13 (23 < DL)	<0.005 (4 < DL)	<0.005 - 0.88 (14 < DL)	<0.002 - 0.005 (2 < DL)	<0.005 - 0.007 (2 < DL)	0.002 - 0.008 (7 < DL)
Radium-226	pCi/L	-	-	<0.1 - 1.0 (2 < DL)		-	-	-	-
Radium-226 - preconcentrated	Bq/L	-	-	0.0022		-	<0.002 (2 < DL)	-	<0.002 - 0.002 (1 < DL)
Radium-226 - whole water	Bq/L	-	-	-		-	-	-	-
Thorium	µg/L	-	-	1 - 8		-	-	-	-
Thorium-228	Bq/L	-	-	0.00059 - <0.02 (15 < DL)	<0.01 - 0.01 (3 < DL)	0.0084 - 0.02 (14 < DL)	<0.01 (2 < DL)	<0.01 (2 < DL)	<0.01 (7 < DL)
Thorium-228	pCi/L	-	-	<0.3 (3 < DL)		-	-	-	-
Thorium-228 - preconcentrated	Bq/L	-	-	0.0004		-	-	-	-
Thorium-228 - whole water	Bq/L	-	-	-		-	-	-	-
Thorium-230	Bq/L	-	-	0.000087 - <0.01 (23 < DL)	<0.01 - 0.03 (2 < DL)	<0.01 - 0.45 (16 < DL)	<0.01 - 0.01 (1 < DL)	<0.01 (3 < DL)	<0.01 - 0.01 (9 < DL)
Thorium-230	pCi/L	-	-	<0.3 (3 < DL)		-	-	-	-
Thorium-230 - preconcentrated	Bq/L	-	-	0.002		-	-	-	-
Thorium-230 - whole water	Bq/L	-	-	-		-	-	-	-
Thorium-232	Bq/L	-	-	0.000059 - 0.03 (20 < DL)	<0.01 (4 < DL)	<0.01 - 0.0038 (16 < DL)	<0.01 (2 < DL)	<0.01 (2 < DL)	<0.01 - 0.02 (6 < DL)
Thorium-232	pCi/L	-	-	<0.3 (2 < DL)		-	-	-	-
Thorium-232 - preconcentrated	Bq/L	-	-	<0.00005		-	-	-	-
Thorium-232 - whole water	Bq/L	-	-	-		-	-	-	-

Source: Modified from Appendix 5C, Tables X.II-1 to X.II-8.

Notes: Multiple entries for single stations and parameters represent laboratory replicates; composite samples consisting of water from several lakes were analyzed but are not included in this analysis. The waterbodies included in the composite samples include: Drum-Scotch-Sik Sik Lakes; Meadow-Escarpment-Felsenmeer L

Values that are equal to or exceed the SSWQO are bolded. Values that are equal to or exceed the CWQG are underlined. Non-detect values that are higher than one or more guideline are italized.

(a) Saskatchewan Environment's (2006) Saskatchewan Surface Water Quality Objectives (SSWQO).

(b) Canadian Council of Ministers of the Environment's (CCME) Canadian water quality guidelines (CWQG) for the protection of aquatic life - freshwater (CCME 2007).

(c) Not all parameters were analysed during each sampling period.

(d) Guideline for Cold-water biota- early stages (9.5 mg/L), other stages (6.5 mg/L).

(e) Highest value came from winter sampling.

(f) The guidelines for ammonia are dependent on temperature and pH; therefore, the guideline for each station was calculated and the lowest overall value was used for screening. However, the guideline could not be calculated for historical data due to lack of water temperature information.

(g) = For 2008 data, nitrate values were calculated using the equation Nitrate Concentration = Nitrate-Nitrite Concentration * 62/14; non-detect values were substituted with the detection limit in calculations.

(h) The guideline for nitrate is 13 mg NO_3/L or 2.9 mg N/L. It was assumed that the reported values were expressed in mg NO_3/L.

(i) Highest detected value was between the range of non-detected values presented.

(j) The guideline for nitrite is 0.197 mg NO_2/L or 0.06 mg N/L.

(k) Values below detection limits were often equal to or exceeded the SSWQO and CWQG.

(l) The guidelines for aluminum are pH-dependent; the guideline is 0.005 mg/L at pH<6.5; 0.1 mg/L at pH ≥6.5. Field pH values were used in the screening.

(m) The guidelines for cadmium are hardness-dependent; at hardnesses ranging from 0 to 48.5 mg/L as $CaCO_3$, the guideline is 0.000017 mg/L.

(n) The guideline for chromium is speciation-dependent; the guideline is 0.0089 mg/L for trivalent chromium and 0.0010 mg/L for hexavalent chromium.

(o) The guidelines for copper are hardness-dependent; at hardnesses ranging from 0 to 120 mg/L as $CaCO_3$, the guideline is 0.002 mg/L.

(p) Original document states the measured unit is µg/mL, but based on results from other studies in the project area this is assumed to be an error with the actual unit being µg/L.

(q) The guidelines for lead are hardness-dependent; at hardnesses ranging from 0 to 60 mg/L as $CaCO_3$, the guideline is 0.001 mg/L; at hardnesses ranging from 60 to 120 mg/L as $CaCO_3$, the guideline is 0.002 mg/L.

(r) In 2007, mercury was determined on a nitric-acid preserved sample as a potassium dichromate/nitric-acid perserved sample was not supplied.

(s) Mercury objective is for inorganic mercury only.

(t) Mercury guidelines differ depending on mercury type: inorganic mercury = 0.026 µg/L; methylmercury = 0.004 µg/L.

(u) The guidelines for nickel are hardness-dependent; at hardnesses ranging from 0 to 60 mg/L as $CaCO_3$, the guideline is 0.025 mg/L.

(v) Selenium guideline is based on waterborne exposure. However, selenium has a bioaccumulation pathway similar to mercury; therefore, the guideline may not be protective of effects through reproductive impairment due to maternal transfer, resulting in embryotoxicity and teratogenicity (Chapman et al. 2009).

(w) Conducted by the Water Survey of Canada (BEAK 1990).

n = number of samples analyzed; °C = degrees Celsius; µS/cm = microSiemens per centimetre; µg/L = micrograms per litre; mg/L = milligrams per litre; mg $CaCO_3$/L = milligrams of calcium carbonate per litre; nm = nanometre; Bq/L = Becquerels per litre; pCi/L = picoCuries per litre; NTU = Nephlometric Turbidity Units; % =

Table 5.3-2
Summary of Water Chemistry Data for Lakes and Streams in the Kiggavik Project Area, 1974-2009

Parameter	Units	Guidelines		Lower Lake Sub-Basin		Caribou Lake Sub-Basin		Judge Sissons Lake Sub-Basin	
				Mushroom/End Grid Stream	All Other Streams	All Lakes	All Streams	Judge Sissons Lake	Inlet of Judge Sissons Lake
				2008	1990, 1991, 2007, 2008	1979, 1980, 1986, 1988, 1989, 1991, 2007, 2008	2007, 2008	1979, 1986, 1988, 1989, 1991, 2008, 2009	1979, 1980
		SSWQO[a]	CWQG[b]	n = 2[c]	n = 22[c]	n = 41[c]	n = 14[c]	n = 62[c]	n = 3[c]
Conventional Parameters (Field-Measured)									
Dissolved Oxygen	mg/L	[d]	[d]	-	11.98	11.64 - 12.08	12.02 - 12.11	9.88 - 12.86	-
Water Temperature	°C	-	-	5.97 - 7.16	4.12 - 10.55	4.71 - 15.80	4.95 - 12.16	5.60 - 15.16	-
pH	pH units	-	6.5-9.0	6.92 - 7.20	6.93 - 7.54	6.89 - 7.55	6.60 - 7.59	6.68 - 8.35	-
Specific Conductivity	µS/cm	-	-	-	33	11 - 25	7 - 25	21 - 24	-
Conventional Parameters (Laboratory-Measured)									
pH	pH units	-	6.5-9.0	6.88 - 7.13	6.45 - 7.51	5.9 - 7.24	6.43 - 7.26	5.45 - 7.25	-
Specific Conductivity	µS/cm	-	-	20 - 28	12.9 - 46	8.0 - 48	14 - 29	3 - 39	-
Total Alkalinity	mg $CaCO_3$/L	-	-	7 - 10	4 - 22	2 - 14	3 - 16	<1 - 12 (1 < DL)	-
Alkalinity (pH 3.8)	mg $CaCO_3$/L	-	-	-	-	16	-	21	-
Gran alkalinity	mg $CaCO_3$/L	-	-	-	4.3 - 7.5	2.5 - 13.8	-	0.1 - 10.1	-
Total Hardness	mg $CaCO_3$/L	-	-	9 - 13	6 - 22	3.3 - 14	6 - 13	<1 - 13 (1 < DL)	-
Total Dissolved Solids	mg/L	-	-	20 - 34	10 - 42	2 - 35 (1 < DL)	14 - 29	<10 - 33 (1 < DL)	-
Total Suspended Solids	mg/L	-	-	<1 - 1 (1 < DL)	<1 - 8 (4 < DL)	<1 - 4 (6 < DL)	<1 - 3 (3 < DL)	<1 - 2 (17 < DL)	-
Turbidity	NTU	-	-	0.6 - 0.9	0.4 - 6.6	0.7 - 3.1	0.5 - 6.2	0.4 - 2	-
True Colour (Co-Pt)	-	-	-	-	7 - 20	10 - 12	-	<1 - 6 (1 < DL)	-
Chlorophyll a	µg/L	-	-	-	-	-	-	1.48	-
Chlorophyll *a*	mg/m^3	-	-	-	-		-	1 - 2.9	-
Absorbance at 254 nm	-	-	-	-	-	0.079 - 0.109	-	0.060 - 0.063	-
Nutrients									
Ammonia as nitrogen	mg N/L	0.24[f]	0.24[f]	0.04	<0.01 - 0.08 (3 < DL)	<0.01 - 0.08 (4 < DL)	<0.01 - 0.14 (1 < DL)	<0.005 - 0.09 (10 < DL)	-
Nitrate and Nitrite as nitrogen	mg N/L	-	-	<0.01 - 0.01 (1 < DL)	<0.01 - 0.02 (8 < DL)	<0.01 - 0.02 (8 < DL)	<0.01 - 0.02 (6 < DL)	<0.01 - 0.04 (10 < DL)	-
Nitrate[g]	mg/L	-	13 [h]	<0.04 - 0.04 (1 < DL)	<0.01 - 0.01 (6 < DL)	<0.003 - 0.09 (14 < DL)	<0.04 - 0.09 (6 < DL)	0.003 - <0.04 (18 < DL)	-
Nitrite	mg/L	-	0.197 [j]	-	<0.01 - 0.09 (9 < DL)	0.001 - <0.1 (6 < DL)	-	0.001 - <0.1 (7 < DL)	-
Total Kjeldahl Nitrogen	mg/L	-	-	0.38 - 0.4	0.32 - 0.57	0.16 - 0.62	0.23 - 0.39	0.04 - 1.50	-
Total Nitrogen	mg/L	-	-	0.38 - 0.41	0.34 - 0.57	0.23 - 0.45	0.23 - 0.40	0.18 - 1.50	-
Total Phosphorous	mg/L	-	-	<0.01 - 0.01 (1 < DL)	0.001 - 0.06 (9 < DL)	<0.001 - 0.05 (3 < DL)	<0.01 - 0.04 (9 < DL)	<0.001 - 0.04 (10 < DL)	-
Dissolved Phosphorus	mg/L	-	-	0.01 - 0.02	<0.01 - 0.03 (8 < DL)	<0.01 - 0.05 (3 < DL)	<0.01 - 0.06 (6 < DL)	<0.01 - 0.05 (10 < DL)	-
Soluble Reactive Phosphorous	mg/L	-	-	-	<0.001 (2 < DL)	<0.001 - 0.005 (1 < DL)	-	<0.001 - 0.003 (3 < DL)	-
Orthophosphate-P	mg/L	-	-	-	-	<0.1 (4 < DL)	-	<0.1 (1 < DL)	-
Total Carbon	mg/L	-	-	7 - 11	6 - 15	5 - 10	5 - 11	5 - 10	-
Total Inorganic Carbon	mg/L	-	-	2	1 - 6	2 - 4	1 - 4	2 - 4	-
Total Organic Carbon	mg/L	-	-	5.2 - 8.4	5.1 - 12	3.5 - 6.7	3.8 - 7	2.5 - 7.8	-
Dissolved Inorganic Carbon	mg/L	-	-	-	<0.5 - 3.9 (1 < DL)	0.7 - 3.0	-	<0.5 - 2.5 (1 < DL)	-
Dissolved Organic Carbon	mg/L	-	-	5.2 - 9	4.5 - 13	1.8 - 6.0	2.7 - 6.2	<0.5 - 8.2 (1 < DL)	-
Major Ions									
Bicarbonate	mg/L	-	-	9 - 12	5 - 27	2 - 17	4 - 20	7 - 15	-
Calcium	mg/L	-	-	2.3 - 3.3	1.4 - 5.9	0.85 - 4.3	1.4 - 3.1	0.05 - 3.3	-
Carbonate	mg/L	-	-	<1 (2 < DL)	<1 (15 < DL)	<1 (12 < DL)	<1 (14 < DL)	<1 (16 < DL)	-
Chloride	mg/L	-	-	0.4 - 0.7	0.27 - 3.0	0.17 - 0.65	0.2 - 0.4	0.22 - <1 (1 < DL)	-
Fluoride	mg/L	-	-	0.03 - 0.07	0.07 - 0.43	0.01 - 0.07	<0.01 - 0.03 (4 < DL)	<0.01 - 0.11 (2 < DL)	-
Hydroxide	mg/L	-	-	<1 (2 < DL)	<1 (15 < DL)	<1 (12 < DL)	<1 (14 < DL)	<1 (16 < DL)	-
Magnesium	mg/L	-	-	0.8 - 1.2	0.5 - 1.7	0.30 - 1.55	0.6 - 1.2	<0.05 - 1.1 (1 < DL)	-
Potassium	mg/L	-	-	0.4 - 0.9	0.10 - 1.2	0.10 - 0.85	0.1 - 0.6	<0.05 - 0.60 (1 < DL)	-
Silica (as $Si0_2$)	mg/L	-	-	-	0.18	0.26 - 0.74	-	0.05 - 0.16	-
Silicates	mg/L	-	-	-	-	-	-	-	-
Sodium	mg/L	-	-	0.5 - 2.4	0.2 - 3.8 (1 < DL)	0.2 - 5 (7 < DL)	<0.1 - 1.1 (4 < DL)	0.3 - 1.0 (6 < DL)	-
Sulphate	mg/L	-	-	0.7 - 1.3	0.20 - 1.6	<0.2 - 1.1 (1 < DL)	0.3 - 1.1	<0.1 - 1.1 (1 < DL)	-
Sum of Ions	mg/L	-	-	17 - 19	9 - 37	7 - 24	8 - 26	12 - 21	-
Sum of ions	%	-	-	-	-	-	-	-	-
Total Metals									
Aluminum[k]	mg/L	0.005-0.1 [l]	0.005-0.1 [l]	0.032 - 0.056	0.01 - 0.067	0.013 - **0.12**	0.012 - **0.19**	0.0017 - 0.0420 (6 < DL)	-
Antimony	mg/L	-	-	<0.0002 (2 < DL)	<0.0002 (15 < DL)	<0.0002 (12 < DL)	<0.0002 (14 < DL)	<0.0002 (16 < DL)	-
Arsenic	µg/L	5	5	0.1 - 0.2	<0.1 - 2 (11 < DL)	<0.1 - <2 (9 < DL)	0.1 - 0.2	<0.1 - 2 (8 < DL)	<0.2 - <0.5 (2 < DL)
Barium	mg/L	-	-	0.022 - 0.027	0.019 - 0.096	0.025 - 0.1	0.028 - 0.072	<0.01 - 0.04 (1 < DL)	-
Beryllium	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 (15 < DL)	<0.0001- <0.005 (16 < DL)	<0.0001 (14 < DL)	<0.0001 - <0.005 (17 < DL)	-
Boron	mg/L	-	-	<0.01 (2 < DL)	<0.01 (15 < DL)	<0.01 (12 < DL)	<0.01 (14 < DL)	<0.01 - 0.03 (15 < DL)	-
Bromide	mg/L	-	-	-	<0.05 (5 < DL)	-	-	-	-

Table 5.3-2
Summary of Water Chemistry Data for Lakes and Streams in the Kiggavik Project Area, 1974-2009

Parameter	Units	Guidelines		Lower Lake Sub-Basin		Caribou Lake Sub-Basin		Judge Sissons Lake Sub-Basin	
				Mushroom/End Grid Stream	All Other Streams	All Lakes	All Streams	Judge Sissons Lake	Inlet of Judge Sissons Lake
				2008	1990, 1991, 2007, 2008	1979, 1980, 1986, 1988, 1989, 1991, 2007, 2008	2007, 2008	1979, 1986, 1988, 1989, 1991, 2008, 2009	1979, 1980
		SSWQO[a]	CWQG[b]	n = 2[c]	n = 22[c]	n = 41[c]	n = 14[c]	n = 62[c]	n = 3[c]
Cadmium[k]	mg/L	0.000017 [m]	0.000017 [m]	*<0.0001* (2 < DL)	*<0.0001* - *<0.002* [i] (20 < DL)	*<0.0001* - **0.002** (16 < DL)	*<0.0001* (14 < DL)	<0.00001 - < *0.01* [i] (21 < DL)	*<0.0005* - **0.002** (1 < DL)
Chromium[k]	mg/L	-	0.0010/0.0089 [n]	<0.0005 (2 < DL)	<0.0005 - *<0.01* (21 < DL)	<0.0005 - 0.005 (17 < DL)	<0.0005 - 0.0520 (12 < DL)	<0.0005 - <0.01[i] (21 < DL)	<0.0005 (2 < DL)
Cobalt	mg/L	-	-	<0.0001 - 0.0001 (1 < DL)	<0.0001- <0.01[i] (15 < DL)	<0.0001 - **0.01** (17 < DL)	<0.0001 - 0.0001 (10 < DL)	<0.0001 - <0.01[i] (20 < DL)	-
Copper[k]	mg/L	0.002 [o]	0.002 [o]	0.0007 - 0.0010	0.0005 - *<0.005* (7 < DL)	<0.0005 - **0.0148**[p] (6 < DL)	0.0005 - 0.0014	0.00012[p] - *<0.005* (3 < DL)	0.00011[p] - 0.0012
Iron	mg/L	0.3	0.3	0.066 - 0.160	0.058 - **0.400**	0.04 - 0.16	0.045 - 0.190	<0.02 - 0.14 (5 < DL)	-
Lead[k]	mg/L	0.001 - 0.002 [q]	0.001 - 0.002 [q]	<0.0001 (2 < DL)	<0.0001 - *<0.02* [i] (15 < DL)	<0.0001 - **0.84** (8 < DL)	<0.0001 - 0.0001 (9 < DL)	<0.0001 - *<0.05* [i] (11 < DL)	**0.002** - **0.011**
Manganese	mg/L	-	-	0.0043 - 0.0083	0.0018 - 0.013 (7 < DL)	0.0006 - 0.0120 (4 < DL)	0.002 - 0.019	<0.002 - 0.02 (3 < DL)	-
Mercury[k, r]	µg/L	0.026 [s]	0.026 [t]	*<0.05* (2 < DL)	*<0.05* (22 < DL)	<0.02 - *<10* [i] (18 < DL)	*<0.05* (14 < DL)	<0.005 - *<10* (23 < DL)	0.01
Molybdenum	mg/L	-	0.073	<0.0001 (2 < DL)	<0.0001 - 0.0003 (10 < DL)	<0.0001 - <0.01[i] (10 < DL)	<0.0001 - 0.0002 (7 < DL)	<0.0001 - <0.01[i] (12 < DL)	-
Nickel	mg/L	0.025 [u]	0.025 [u]	0.0005 - 0.0008	0.0003 - <0.01 (7 < DL)	0.0004 - <0.01 (6 < DL)	0.0004 - 0.0011	0.0002 - <0.01 (6 < DL)	-
Selenium	mg/L	0.001[v]	0.001[v]	<0.0001 (2 < DL)	<0.0001 - 0.0001 (13 < DL)	<0.0001 - 0.0001 (11 < DL)	<0.0001 - 0.0001 (11 < DL)	<0.0001 - 0.0001 (9 < DL)	-
Selenium [k]	µg/L	1 [v]	1.0 [v]	-	*<1* - *<2* (7 < DL)	<0.1 - *<2* (7 < DL)	-	<0.1 - <2 (7 < DL)	<0.5 (1 < DL)
Silicon	mg/L	-	-	-	0.18 - 0.52	-	-	-	-
Silver[k]	mg/L	0.0001	0.0001	*<0.0001* (2 < DL)	*<0.0001* - *<0.005* (22 < DL)	<0.00001 - *<0.0001* [i] (17 < DL)	*<0.0001* (14 < DL)	0.00005 - **0.0002** (19 < DL)	-
Strontium	mg/L	-	-	0.015 - 0.020	0.01 - 0.09	<0.00001 - 0.03 (2 < DL)	0.010 - 0.020	<0.01 - 0.022 (1 < DL)	-
Tellurium	µg/L	-	-	-	-	*<2* (1 < DL)	-	<2 (1 < DL)	<2 (1 < DL)
Thallium	mg/L	-	0.0008	<0.0002 (2 < DL)	<0.0002 (15 < DL)	<0.0002 (12 < DL)	<0.0002 (14 < DL)	<0.0002 (16 < DL)	-
Tin	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 - 0.0002 (12 < DL)	<0.0001 - 0.0022 (10 < DL)	<0.0001 - 0.0001 (13 < DL)	<0.0001 - 0.0018 (10 < DL)	-
Titanium	mg/L	-	-	0.0004 - 0.0005	<0.0002 - 0.0029 (1 < DL)	0.0002 - 0.0017	0.0002 - 0.00028	<0.0002 - 0.0013 (7 < DL)	-
Uranium	µg/L	15	-	<0.1 (2 < DL)	<0.1 - <0.5[i] (16 < DL)	<0.1 - <0.5 (16 < DL)	<0.1 - 0.1 (13 < DL)	<0.1 - 1.1 (19 < DL)	<0.5 (3 < DL)
Uranium - preconcentrated	µg/L	-	-	-	-	-	-	0.08 - 0.5	-
Uranium - whole water	µg/L	-	-	-	-	0.005	-	0.5	-
Vanadium	mg/L	-	-	<0.0001 - 0.0001 (1 < DL)	<0.0001 - 0.0002 (5 < DL)	<0.0001 - <0.01[i] (7 < DL)	<0.0001 - 0.0002 (5 < DL)	<0.0001 - <0.005[i] (15 < DL)	-
Zinc	mg/L	0.03	0.03	0.0031 - 0.0037	0.0009 - 0.01 (6 < DL)	<0.00001 - **8.53** (8 < DL)	0.0007 - 0.0084	<0.00001 - **0.08** (6 < DL)	0.0016 - **0.07**
Dissolved Metals									
Aluminum	mg/L	-	-	0.026 - 0.037	0.0056 - 0.0550	0.0085 - 0.0700	0.0072 - 0.1100	<0.0005 - 0.0240 (1 < DL)	-
Antimony	mg/L	-	-	<0.0002 (2 < DL)	<0.0002 (15 < DL)	<0.0002 (12 < DL)	<0.0002 (14 < DL)	<0.0002 (16 < DL)	-
Arsenic	µg/L	-	-	0.1 - 0.2	<0.1 - 0.2 (7 < DL)	0.1 - 0.3	<0.1 - 0.2 (1 < DL)	<0.1 -0.2 (4 < DL)	-
Barium	mg/L	-	-	0.021 - 0.027	0.019 - 0.093	0.028 - 0.074	0.028 - 0.069	0.023 - 0.032	-
Beryllium	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 (15 < DL)	<0.0001 (12 < DL)	<0.0001 (14 < DL)	<0.0001 (16 < DL)	-
Boron	mg/L	-	-	<0.01 (2 < DL)	<0.01 (15 < DL)	<0.01 (12< DL)	<0.01 (14 < DL)	<0.01 (16 < DL)	-
Cadmium	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 - 0.0001 (14 < DL)	<0.0001 (2 < DL)	<0.0001 (14 < DL)	<0.00001 - <0.0001 (16 < DL)	-
Chromium	mg/L	-	-	<0.0005 (2 < DL)	<0.0005 - 0.0032 (12 < DL)	<0.0005 - 0.0016 (11 < DL)	<0.0005 (14 < DL)	<0.0005 - 0.0017 (14 < DL)	-
Cobalt	mg/L	-	-	<0.0001 - 0.0001 (1 < DL)	<0.0001 - 0.0001 (10 < DL)	<0.0001 - 0.0001 (10 < DL)	<0.0001 - 0.0002 (12 < DL)	<0.0001 - 0.0001 (15 < DL)	-
Copper	mg/L	-	-	0.0008 - 0.0011	0.0005 - 0.0016	0.0006 - 0.0017	0.0006 - 0.0014	0.0002 - 0.0010	-
Iron	mg/L	-	-	0.045 - 0.120	0.045 - 0.140	0.011 - 0.110	0.020 - 0.096	0.0033 - 0.0590	-
Lead	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 - 0.0001 (9 < DL)	<0.0001 - 0.0002 (5 < DL)	<0.0001 - 0.0001 (12 < DL)	<0.0001 - 0.0002 (7 < DL)	-
Manganese	mg/L	-	-	0.0034- 0.0055	0.0016 - 0.0100	<0.0005 - 0.0033 (3 < DL)	0.001 - 0.016	<0.0005 - 0.0120 (4 < DL)	-
Molybdenum	mg/L	-	-	<0.0001 - 0.0001 (1 < DL)	<0.0001 - 0.0002 (7 < DL)	<0.0001 - 0.0004 (6 < DL)	<0.0001 - 0.0002 (9 < DL)	<0.0001 - 0.0001 (11 < DL)	-
Nickel	mg/L	-	-	0.0005 - 0.0008	0.0003 - 0.0012	0.0004 - 0.0010	0.0004 - 0.001	0.0002 - 0.0008	-
Selenium	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 - 0.0002 (6 < DL)	<0.0001 - 0.0001 (10 < DL)	<0.0001 - 0.0003 (11 < DL)	<0.0001 - 0.0001 (13 < DL)	-
Silver	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 (15 < DL)	<0.0001 (12 < DL)	<0.0001 (14 < DL)	<0.0001 (16 < DL)	-
Strontium	mg/L	-	-	0.015 - 0.020	0.011 - 0.091	0.012 - 0.021	0.01 - 0.02	0.0100 - 0.0220	-
Thallium	mg/L	-	-	<0.0002 (2 < DL)	<0.0002 (15 < DL)	<0.0002 (12 < DL)	<0.0002 (14 < DL)	<0.0002 (16 < DL)	-
Tin	mg/L	-	-	0.0001	<0.0001 - 0.0012 (1 < DL)	<0.0001 - 0.0022 (8 < DL)	<0.0001 - 0.0260 (6 < DL)	<0.0001 - 0.0061 (3 < DL)	-
Titanium	mg/L	-	-	<0.0002 - 0.0004 (1 < DL)	<0.0002 - 0.0003 (7 < DL)	<0.0002 - 0.0009 (7 < DL)	<0.0002 - 0.0013 (7 < DL)	<0.0002 - 0.0002 (15 < DL)	-
Uranium	µg/L	-	-	<0.1 (2 < DL)	<0.1 - 0.2 (11 < DL)	<0.1 (12 < DL)	<0.1 (14 < DL)	<0.1 - 0.1 (15 < DL)	-
Vanadium	mg/L	-	-	<0.0001 - 0.0001 (1 < DL)	<0.0001 - 0.0001 (9 < DL)	<0.0001 - 0.0002 (7 < DL)	<0.0001 - 0.0001 (10 < DL)	<0.0001 - 0.0001 (15 < DL)	-
Zinc	mg/L	-	-	0.0023 - 0.0027	0.0024 - 0.0110	0.0024 - 0.0180	0.0017 - 0.0097	<0.0005 - 0.0110 (1 < DL)	-
Radionuclides									
Lead-210	Bq/L	-	-	<0.02 (2 < DL)	<0.02 - 0.08 (19 < DL)	<0.02 - <0.04 (14 < DL)	<0.02 (14 < DL)	<0.02 - <0.03 (17 < DL)	0.026 - 0.04 (1 < DL)
Lead-210	pCi/L	-	-	-	-	<0.5 - <1 (2 < DL)	-	<1 (1 < DL)	<0.5 - 1 (1 < DL)
Polonium-210	Bq/L	-	-	<0.005 - 0.009 (1 < DL)	<0.005 - 0.04 (8 < DL)	<0.005 - 0.007 (11 < DL)	<0.005 - 0.030 (8 < DL)	<0.005 - <0.05 (17 < DL)	-
Polonium-210 - preconcentrated	Bq/L	-	-	-	-	-	-	0.0026	-
Polonium-210 - whole water	Bq/L	-	-	-	-	-	-	-	-

Table 5.3-2

Summary of Water Chemistry Data for Lakes and Streams in the Kiggavik Project Area, 1974-2009

Parameter	Units	Guidelines		Lower Lake Sub-Basin		Caribou Lake Sub-Basin		Judge Sissons Lake Sub-Basin	
				Mushroom/End Grid Stream	All Other Streams	All Lakes	All Streams	Judge Sissons Lake	Inlet of Judge Sissons Lake
				2008	1990, 1991, 2007, 2008	1979, 1980, 1986, 1988, 1989, 1991, 2007, 2008	2007, 2008	1979, 1986, 1988, 1989, 1991, 2008, 2009	1979, 1980
		SSWQO[a]	CWQG[b]	n = 2[c]	n = 22[c]	n = 41[c]	n = 14[c]	n = 62[c]	n = 3[c]
Radium-226	Bq/L	-	-	0.006 - 0.007	<0.002 - 0.010 (17 < DL)	0.0008 - 0.037 (11 < DL)	<0.005 - 0.008 (7 < DL)	<0.0015 - <0.02[i] (17 < DL)	<0.004 - 0.03 (1 < DL)
Radium-226	pCi/L	-	-	-	-	<0.2 - 1.0 (1 < DL)	-	0.3	<0.1 - 0.8 (1 < DL)
Radium-226 - preconcentrated	Bq/L	-	-	-	-	-	-	0.0004 - <0.002 (2 < DL)	-
Radium-226 - whole water	Bq/L	-	-	-	-	-	-	-	-
Thorium	µg/L	-	-	-	-	<1 (1 < DL)	-	<1 (1 < DL)	<1 (1 < DL)
Thorium-228	Bq/L	-	-	<0.01 - 0.01 (1 < DL)	<0.01 - 0.01 (10 < DL)	<0.01 - 0.01 (8 < DL)	<0.01 - 0.01 (10 < DL)	0.0012 - <0.01 (16 < DL)	<0.01 (1 < DL)
Thorium-228	pCi/L	-	-	-	-	<0.3 (1 < DL)	-	-	<0.3 (2 < DL)
Thorium-228 - preconcentrated	Bq/L	-	-	-	-	-	-	0.0002	-
Thorium-228 - whole water	Bq/L	-	-	-	-	-	-	-	-
Thorium-230	Bq/L	-	-	<0.01 (2 < DL)	<0.01 - <0.02[i] (19 < DL)	<0.01 - 0.01 (12 < DL)	<0.01 - 0.02 (11 < DL)	0.00025 - <0.01 (17 < DL)	<0.01 (1 < DL)
Thorium-230	pCi/L	-	-	-	-	<0.3 (1 < DL)	-	-	<0.3 (2 < DL)
Thorium-230 - preconcentrated	Bq/L	-	-	-	-	-	-	0.00026	-
Thorium-230 - whole water	Bq/L	-	-	-	-	-	-	-	-
Thorium-232	Bq/L	-	-	<0.01 (2 < DL)	<0.01 (14 < DL)	<0.01 - <0.04[i] (10 < DL)	<0.01 - 0.01 (11 < DL)	0.00012 - <0.01 (16 < DL)	<0.004 - <0.01 (3 < DL)
Thorium-232	pCi/L	-	-	-	-	<0.3 (1 < DL)	-	-	<0.3 (2 < DL)
Thorium-232 - preconcentrated	Bq/L	-	-	-	-	-	-	0.00002	-
Thorium-232 - whole water	Bq/L	-	-	-	-	-	-	-	-

Source: Modified from Appendix 5C, Tables X.II-1 to X.II-8.

Notes: Multiple entries for single stations and parameters represent laboratory replicates; composite sanLakes; Ridge-Cirque Lakes; Crash-Caribou Lakes.

Values that are equal to or exceed the SSWQO are bolded. Values that are equal to or exceed the CWQ

(a) Saskatchewan Environment's (2006) Saskatchewan Surface Water Quality Objectives (SSWQO).

(b) Canadian Council of Ministers of the Environment's (CCME) Canadian water quality guidelines (CWQ

(c) Not all parameters were analysed during each sampling period.

(d) Guideline for Cold-water biota- early stages (9.5 mg/L), other stages (6.5 mg/L).

(e) Highest value came from winter sampling.

(f) The guidelines for ammonia are dependent on temperature and pH; therefore, the guideline for each s

(g) = For 2008 data, nitrate values were calculated using the equation Nitrate Concentration = Nitrate-Nitr

(h) The guideline for nitrate is 13 mg NO_3/L or 2.9 mg N/L. It was assumed that the reported values were

(i) Highest detected value was between the range of non-detected values presented.

(j) The guideline for nitrite is 0.197 mg NO_2/L or 0.06 mg N/L.

(k) Values below detection limits were often equal to or exceeded the SSWQO and CWQG.

(l) The guidelines for aluminum are pH-dependent; the guideline is 0.005 mg/L at pH<6.5; 0.1 mg/L at pH

(m) The guidelines for cadmium are hardness-dependent; at hardnesses ranging from 0 to 48.5 mg/L as C

(n) The guideline for chromium is speciation-dependent; the guideline is 0.0089 mg/L for trivalent chromiu

(o) The guidelines for copper are hardness-dependent; at hardnesses ranging from 0 to 120 mg/L as CaC

(p) Original document states the measured unit is µg/mL, but based on results from other studies in the pı

(q) The guidelines for lead are hardness-dependent; at hardnesses ranging from 0 to 60 mg/L as $CaCO_3$

(r) In 2007, mercury was determined on a nitric-acid preserved sample as a potassium dichromate/nitric-a

(s) Mercury objective is for inorganic mercury only.

(t) Mercury guidelines differ depending on mercury type: inorganic mercury = 0.026 µg/L; methylmercury

(u) The guidelines for nickel are hardness-dependent; at hardnesses ranging from 0 to 60 mg/L as CaCO

(v) Selenium guideline is based on waterborne exposure. However, selenium has a bioaccumulation path

(w) Conducted by the Water Survey of Canada (BEAK 1990).

n = number of samples analyzed; ºC = degrees Celsius; µS/cm = microSiemens per centimetre; µg/L = percent; < = less than; NO_3 = nitrate; N = nitrogen; NO_2 = nitrite; - = no data.

Table 5.3-2
Summary of Water Chemistry Data for Lakes and Streams in the Kiggavik Project Area, 1974-2009

Parameter	Units	Guidelines		Aniguq River Sub-Basin	Siamese Lake Sub-Basin	Skinny Lake Sub-Basin	Kavisilik Lake Sub-Basin	Squiggly Lake Sub-Basin	Baker Lake Sub-Basin
				Aniguq River	Siamese Lake	Skinny Lake	Kavisilik Lake	Squiggly Lake	Baker Lake
				1980, 2009	2008	1986, 1988, 1989, 2007, 2008	1980	1980, 2008	1974-1982[w], 1989[w], 2008, 2009
		SSWQO[a]	CWQG[b]	n = 3[c]	n = 2[c]	n = 7[c]	n = 1[c]	n = 2[c]	n = 17[c]
Conventional Parameters (Field-Measured)									
Dissolved Oxygen	mg/L	[d]	[d]	11.54 - 12.29	-	11.65	-	-	-
Water Temperature	°C	-	-	10.02 - 10.31	10.61 - 10.76	8.01 - 8.36	-	8.68	-
pH	pH units	-	6.5-9.0	7.92 - 8.09	6.62 - 6.79	6.86 - 7.14	-	6.58	-
Specific Conductivity	µS/cm	-	-	28 - 30	-	16	-	-	-
Conventional Parameters (Laboratory-Measured)									
pH	pH units	-	6.5-9.0	7.18 - 7.2	6.88 - 7.03	6.1 - 7.06	-	6.61	5.6 - 7.2
Specific Conductivity	µS/cm	-	-	29 - 30	15	11.3 - 25	-	13	32 - 2180
Total Alkalinity	mg $CaCO_3$/L	-	-	13 - 22	6	<1 - 8 (1 < DL)	-	5	3.0 - 12.0
Alkalinity (pH 3.8)	mg $CaCO_3$/L	-	-	-	-	14 - 15	-	-	-
Gran alkalinity	mg $CaCO_3$/L	-	-	-	-	4.5 - 9	-	-	8.9 - 9.6
Total Hardness	mg $CaCO_3$/L	-	-	11 - 12	6 - 7	5 - 7	-	6	18.5 - 64
Total Dissolved Solids	mg/L	-	-	26 - 29	12	6 - 60 (1 < DL)	-	12	17 - 1040
Total Suspended Solids	mg/L	-	-	<1 - 2 (1 < DL)	<1 - 1 (1 < DL)	<1 - 10 (2 < DL)	-	<1 (1 < DL)	<2 - 6 (1 < DL)
Turbidity	NTU	-	-	38 - 40	0.4 - 0.5	0.49 - 0.9	-	0.5	-
True Colour (Co-Pt)	-	-	-	-	-	9 - 14	-	-	7 - 10
Chlorophyll a	µg/L	-	-	-	-	-	-	-	-
Chlorophyll *a*	mg/m^3	-	-	0.5 - 2.6					
Absorbance at 254 nm	-	-	-	-	-	0.086 - 0.118	-	-	0.073
Nutrients									
Ammonia as nitrogen	mg N/L	0.24[f]	0.24[f]	<0.01 - 0.04 (1 < DL)	0.02 - 0.07	<0.01 - 0.08 (1 < DL)	-	<0.01 (1 < DL)	<0.01 - 0.09 (1 < DL)
Nitrate and Nitrite as nitrogen	mg N/L	-	-	-	<0.01 (2 < DL)	<0.01 - 0.01 (1 < DL)		<0.01 (1 < DL)	<0.01 (9 < DL)
Nitrate[g]	mg/L	-	13 [h]	-	<0.04 (2 < DL)	<0.003 - 0.06 (4 < DL)	-	<0.04 (1 < DL)	0.02 - 0.09
Nitrite	mg/L	-	0.197 [j]	-	-	<0.001 - <0.1[i] (2 < DL)	-	-	0.003
Total Kjeldahl Nitrogen	mg/L	-	-	0.33 - 0.35	0.1 - 0.11	0.12 - 0.38	-	0.49	0.23 - 41 (1 < DL)
Total Nitrogen	mg/L	-	-	-	0.1 - 0.11	0.19		0.49	
Total Phosphorous	mg/L	-	-	<0.01 - 0.04 (1 < DL)	<0.01 - 0.02 (1 < DL)	0.002 - 0.01 (1 < DL)	-	<0.01 (1 < DL)	<0.003 to 0.033 (7 < DL)
Dissolved Phosphorus	mg/L	-	-	<0.01 - 0.03 (1 < DL)	<0.01 - 0.04 (1 < DL)	<0.01 (1 < DL)		0.01	
Soluble Reactive Phosphorous	mg/L	-	-	-	-	<0.001 (4 < DL)	-	-	<0.001 (3 < DL)
Orthophosphate-P	mg/L	-	-	-	-	<0.1 (1 < DL)	-	-	<0.01 (9 < DL)
Total Carbon	mg/L	-	-	7 - 8	4	5		3	
Total Inorganic Carbon	mg/L	-	-	3 - 5	2	2		1	
Total Organic Carbon	mg/L	-	-	2.9 - 3.9	2 - 2.3	3.2 - 4.0	-	1.9	2.1 - 3.6
Dissolved Inorganic Carbon	mg/L	-	-	-	-	1.1 - 2.5	-	-	2.1 - 2.2
Dissolved Organic Carbon	mg/L	-	-	3.1 - 4	2.1 - 2.4	2.2 - 4.5	-	1.3	2.6 - 2.7
Major Ions									
Bicarbonate	mg/L	-	-	16 - 27	7	<1 - 10 (1 < DL)	-	6	10 - 15
Calcium	mg/L	-	-	3.1 - 3.3	1.7 - 1.8	1.40 - 2.65	-	1.4	1.8 - 24
Carbonate	mg/L	-	-	<1 (2 < DL)	<1 (2 < DL)	<1 (2 < DL)	-	<1 (1 < DL)	-
Chloride	mg/L	-	-	0.8 - 1.7	0.4	0.25 - 0.42	-	0.3	3.2 - 580
Fluoride	mg/L	-	-	0.04 - 0.05	<0.01 (2 < DL)	0.11 - 0.18	-	<0.01 (1 < DL)	0.05 - 0.08
Hydroxide	mg/L	-	-	<1 (2 < DL)	<1 (2 < DL)	<1 (2 < DL)	-	<1 (1 < DL)	-
Magnesium	mg/L	-	-	0.8 - 1	0.5	0.50 - 0.95	-	0.5	1.7 - 12
Potassium	mg/L	-	-	0.4	0.2 - 0.3	0.15 - 0.40	-	0.3	0.5 - 12
Silica (as $Si0_2$)	mg/L	-	-	-	-	0.24 - 0.6	-	-	0.44 - 0.52
Silicates	mg/L	-	-	-	-	0.47	-	-	-
Sodium	mg/L	-	-	0.6 - 1.1	0.3	0.4 - 0.50 (4 < DL)	-	0.3	5.8 - 94
Sulphate	mg/L	-	-	0.7 - 0.8	0.5 - 0.6	0.40 - 0.65	-	0.5	1.7 - 68
Sum of Ions	mg/L	-	-	23 - 35	11	4 - 14	-	9	-
Sum of ions	%	-	-	-	-	-	-	-	-
Total Metals									
Aluminum[k]	mg/L	0.005-0.1 [l]	0.005-0.1 [l]	0.0074 - 0.0130	0.0036 - 0.0040	0.0099 - 0.055	-	0.0077	0.0039 - **0.11** (1 < DL)
Antimony	mg/L	-	-	<0.0002 (2 < DL)	<0.0002 (2 < DL)	<0.0002 (2 < DL)	-	<0.0002 (1 < DL)	-
Arsenic	µg/L	5	5	0.1 - 0.2 (1 < DL)	<0.1 - 0.1 (1 < DL)	<0.1 - <2[i] (4 < DL)	<0.2	<0.1 - <0.2 (2 < DL)	<0.1 - <1[i] (6 < DL)
Barium	mg/L	-	-	0.027 - 0.034	0.049 - 0.050	0.03 - 0.06	-	0.021	0.018 to 0.1 (1 < DL)
Beryllium	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 (2 < DL)	<0.0001 - <0.005 (3 < DL)	-	<0.0001 (1 < DL)	-
Boron	mg/L	-	-	<0.01 (2 < DL)	<0.01 (2 < DL)	<0.01 (2 < DL)	-	<0.01 (1 < DL)	-
Bromide	mg/L	-	-	-	-	-	-	-	-

Table 5.3-2
Summary of Water Chemistry Data for Lakes and Streams in the Kiggavik Project Area, 1974-2009

Parameter	Units	Guidelines		Aniguq River Sub-Basin	Siamese Lake Sub-Basin	Skinny Lake Sub-Basin	Kavisilik Lake Sub-Basin	Squiggly Lake Sub-Basin	Baker Lake Sub-Basin
				Aniguq River	Siamese Lake	Skinny Lake	Kavisilik Lake	Squiggly Lake	Baker Lake
				1980, 2009	2008	1986, 1988, 1989, 2007, 2008	1980	1980, 2008	1974-1982[w], 1989[w], 2008, 2009
		SSWQO[a]	CWQG[b]	n = 3[c]	n = 2[c]	n = 7[c]	n = 1[c]	n = 2[c]	n = 17[c]
Cadmium[k]	mg/L	0.000017 [m]	0.000017 [m]	<0.00001 (2 < DL)	*<0.0001* (2 < DL)	*<0.0001* - **0.0008** (3 < DL)	**0.002**	*<0.0001* (1 < DL)	*<0.0001* - **0.001** (15 < DL)
Chromium[k]	mg/L	-	0.0010/0.0089 [n]	<0.0005 (3 < DL)	<0.0005 (2 < DL)	<0.0005 - *<0.01* [i] (5 < DL)	<0.0005	<0.0005 (2 < DL)	<0.0005 - 0.01 (16 < DL)
Cobalt	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 (2 < DL)	<0.0001 - <0.01 (6 < DL)	-	<0.0001 (1 < DL)	<0.001 - 0.001 (3 < DL)
Copper[k]	mg/L	0.002 [o]	0.002 [o]	0.0003 - 0.0008	0.0002 - 0.0003	<0.0005 - *<0.005* [i] (3 < DL)	0.0008	0.0004 - 0.0008	<0.0002 - 0.001 (6 < DL)
Iron	mg/L	0.3	0.3	0.029 - 0.041	0.014 - 0.018	0.025 - 0.08	-	0.014	0.0012 - 0.16 (1 < DL)
Lead[k]	mg/L	0.001 - 0.002 [q]	0.001 - 0.002 [q]	<0.0001 (2 < DL)	<0.0001 (2 < DL)	<0.0001 - *<0.05* [i] (5 < DL)	**0.002**	<0.0001 - **0.0020** (1 < DL)	<0.0001 - **0.005** (13 < DL)
Manganese	mg/L	-	-	0.0025 - 0.0039	0.0027 - 0.0032	0.0024 - 0.016 (1 < DL)	-	0.0016	0.008 - 0.012 (1 < DL)
Mercury[k, r]	µg/L	0.026 [s]	0.026 [t]	<0.02 (2 < DL)	*<0.05* (2 < DL)	*<0.05* (5 < DL)	*0.05*	<0.01 - *<0.05* (2 < DL)	*<0.05* (3 < DL)
Molybdenum	mg/L	-	0.073	0.0001	<0.0001 (2 < DL)	<0.0001 - <0.01[i] (1 < DL)	-	<0.0001 (1 < DL)	<0.0001 - 0.0001 (3 < DL)
Nickel	mg/L	0.025 [u]	0.025 [u]	0.0002 - 0.0003	0.0002	0.0003 - <0.01 (3 < DL)	-	0.0002	<0.0001 - 0.005 (7 < DL)
Selenium	mg/L	0.001[v]	0.001[v]	<0.0001 - 0.0001 (1 < DL)	<0.0001 (2 < DL)	<0.0001 - 0.0001 (1 < DL)	-	<0.0001 (1 < DL)	<0.0001 - 0.0002 (8 < DL)
Selenium [k]	µg/L	1 [v]	1.0 [v]	-	-	<0.1 (3 < DL)	-	-	<0.1 - 0.1 (1 < DL)
Silicon	mg/L	-	-	-	-	-	-	-	-
Silver[k]	mg/L	0.0001	0.0001	*<0.0001* (2 < DL)	*<0.0001* (2 < DL)	*<0.0001* (5 < DL)	-	*<0.0001* (1 < DL)	*<0.0001* (16 < DL)
Strontium	mg/L	-	-	0.015 - 0.016	0.013 -0.014	<0.00001 - 0.013 (1 < DL)	-	0.0068	0.00003 - 0.085
Tellurium	µg/L	-	-	-	-	-	-	-	-
Thallium	mg/L	-	0.0008	<0.0002 (2 < DL)	<0.0002 (2 < DL)	<0.0002 (2 < DL)	-	<0.0002 (1 < DL)	<0.0002 (13 < DL)
Tin	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 - 0.0001 (1 < DL)	<0.0001 - 0.0021 (1 < DL)	-	<0.0001 (1 < DL)	-
Titanium	mg/L	-	-	<0.0002 (2 < DL)	<0.0002 (2 < DL)	<0.0002 - 0.0004 (1 < DL)	-	<0.0002 (1 < DL)	-
Uranium	µg/L	15	-	<0.1 - <0.5 (3 < DL)	<0.1 (2 < DL)	<0.1 - 0.5 (4 < DL)	<0.5	<0.1 - <0.5 (2 < DL)	<0.1 (13 < DL)
Uranium - preconcentrated	µg/L	-	-	-	-	-	-	-	0.37
Uranium - whole water	µg/L	-	-	-	-	-	-	-	0.5
Vanadium	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 (2 < DL)	<0.0001 - <0.005 (3 < DL)	-	<0.0001 (1 < DL)	<0.001 - 0.003 (1 < DL)
Zinc	mg/L	0.03	0.03	0.0015 - 0.0020	0.0058 - 0.0068	<0.00001 - 0.0050 (4 < DL)	0.0028	0.0085 - **4.6**	<0.0005 - 0.012 (6 < DL)
Dissolved Metals									
Aluminum	mg/L	-	-	0.0025 - 0.0059	0.0013 - 0.0016	0.0065 - 0.0098	-	0.0036	-
Antimony	mg/L	-	-	<0.0002 (2 < DL)	<0.0002 (2 < DL)	<0.0002 (2 < DL)	-	<0.0002 (1 < DL)	-
Arsenic	µg/L	-	-	0.1 - 0.2	<0.1 (2 < DL)	<0.1 - 0.1 (1 < DL)	-	<0.1 (1 < DL)	-
Barium	mg/L	-	-	0.027 - 0.034	0.047 - 0.049	0.042	-	0.021	-
Beryllium	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 (2 < DL)	<0.0001 (2 < DL)	-	<0.0001 (1 < DL)	-
Boron	mg/L	-	-	<0.01 (2 < DL)	<0.01 (2 < DL)	<0.01 (2 < DL)	-	<0.01 (1 < DL)	-
Cadmium	mg/L	-	-	<0.00001 (2 < DL)	<0.0001 (2 < DL)	<0.0001 (2 < DL)	-	<0.0001 (1 < DL)	-
Chromium	mg/L	-	-	<0.0005 (2 < DL)	<0.0005 - 0.0019 (1 < DL)	<0.0005 (2 < DL)	-	<0.0005 (1 < DL)	-
Cobalt	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 (2 < DL)	<0.0001 (2 < DL)	-	<0.0001 (1 < DL)	-
Copper	mg/L	-	-	0.0003 - 0.0004	0.0002 - 0.0003	0.0005 - 0.0006	-	0.0003	-
Iron	mg/L	-	-	0.0075 - 0.0260	0.0021 - 0.0022	0.017	-	0.0035	-
Lead	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 (2 < DL)	<0.0001 - 0.0002 (1 < DL)	-	<0.0001 (1 < DL)	-
Manganese	mg/L	-	-	0.0006 - 0.0020	<0.0005 (2 < DL)	<0.0005 - 0.0006 (1 < DL)	-	<0.0005 (1 < DL)	-
Molybdenum	mg/L	-	-	0.0001	<0.0001 - 0.0001 (1 < DL)	<0.0001 - 0.0001 (1 < DL)	-	<0.0001 (1 < DL)	-
Nickel	mg/L	-	-	0.0002 - 0.0003	0.0002	0.0003	-	0.0002	-
Selenium	mg/L	-	-	0.0001 - 0.0002	0.0001	<0.0001 - 0.0001 (1 < DL)	-	<0.0001 (1 < DL)	-
Silver	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 (2 < DL)	<0.0001 (2 < DL)	-	<0.0001 (1 < DL)	-
Strontium	mg/L	-	-	0.016	0.013 - 0.014	0.012 - 0.013	-	0.0067	-
Thallium	mg/L	-	-	<0.0002 (2 < DL)	<0.0002 (2 < DL)	<0.0002 (2 < DL)	-	<0.0002 (1 < DL)	-
Tin	mg/L	-	-	0.0001	0.0001 - 0.0002	0.0010 - 0.0022	-	0.0001	-
Titanium	mg/L	-	-	<0.0002 (2 < DL)	<0.0002 (2 < DL)	<0.0002 (2 < DL)	-	<0.0002 (1 < DL)	-
Uranium	µg/L	-	-	<0.1 (2 < DL)	<0.1 (2 < DL)	<0.1 (2 < DL)	-	<0.1 (1 < DL)	-
Vanadium	mg/L	-	-	<0.0001 (2 < DL)	<0.0001 (2 < DL)	<0.0001 - 0.0001 (1 < DL)	-	<0.0001 (1 < DL)	-
Zinc	mg/L	-	-	-	0.0032 - 0.0043	0.0022 - 0.0047	-	0.0039	-
Radionuclides									
Lead-210	Bq/L	-	-	<0.02 (3 < DL)	<0.02 (2 < DL)	<0.02 - <0.2 (4 < DL)	0.033	<0.02 (2 < DL)	<0.02 (12 < DL)
Lead-210	pCi/L	-	-	-	-	-	0.9	<0.5	-
Polonium-210	Bq/L	-	-	<0.005 - 0.007 (1 < DL)	<0.005 (2 < DL)	<0.005 - <0.03 (4 < DL)	-	<0.005 (1 < DL)	<0.005 (12 < DL)
Polonium-210 - preconcentrated	Bq/L	-	-	-	-	-	-	-	0.0028
Polonium-210 - whole water	Bq/L	-	-	-	-	-	-	-	-

Table 5.3-2

Summary of Water Chemistry Data for Lakes and Streams in the Kiggavik Project Area, 1974-2009

Parameter	Units	Guidelines		Aniguq River Sub-Basin	Siamese Lake Sub-Basin	Skinny Lake Sub-Basin	Kavisilik Lake Sub-Basin	Squiggly Lake Sub-Basin	Baker Lake Sub-Basin
				Aniguq River	Siamese Lake	Skinny Lake	Kavisilik Lake	Squiggly Lake	Baker Lake
				1980, 2009	2008	1986, 1988, 1989, 2007, 2008	1980	1980, 2008	1974-1982[w], 1989[w], 2008, 2009
		SSWQO[a]	CWQG[b]	n = 3[c]	n = 2[c]	n = 7[c]	n = 1[c]	n = 2[c]	n = 17[c]
Radium-226	Bq/L	-	-	<0.005 - 0.03 (2 < DL)	0.006 - 0.009	<0.005 - <0.02 (4 < DL)	0.007	<0.005 - <0.007 (2 < DL)	<0.005 (12 < DL)
Radium-226	pCi/L	-	-	-	-	-	0.2	<0.2	-
Radium-226 - preconcentrated	Bq/L	-	-	-	-	-	-	-	0.0016
Radium-226 - whole water	Bq/L	-	-	-	-	-	-	-	-
Thorium	µg/L	-	-	-	-	-	-	-	-
Thorium-228	Bq/L	-	-	<0.01 (3 < DL)	<0.01 (2 < DL)	<0.01 (1 < DL)	<0.01	<0.01 (2 < DL)	-
Thorium-228	pCi/L	-	-	-	-	-	<0.3	<0.3	-
Thorium-228 - preconcentrated	Bq/L	-	-	-	-	-	-	-	0.0006
Thorium-228 - whole water	Bq/L	-	-	-	-	-	-	-	-
Thorium-230	Bq/L	-	-	<0.01 (3 < DL)	<0.01 (2 < DL)	<0.002 - 0.01 (3 < DL)	<0.01	<0.01 - 0.02 (1 < DL)	<0.01 (12 < DL)
Thorium-230	pCi/L	-	-	-	-	-	<0.3	0.5	-
Thorium-230 - preconcentrated	Bq/L	-	-	-	-	-	-	-	0.0008
Thorium-230 - whole water	Bq/L	-	-	-	-	-	-	-	-
Thorium-232	Bq/L	-	-	<0.01 (3 < DL)	<0.01 (2 < DL)	<0.005 - <0.01 (2 < DL)	<0.01	<0.01 - 0.01 (1 < DL)	-
Thorium-232	pCi/L	-	-	-	-	-	<0.3	<0.3	-
Thorium-232 - preconcentrated	Bq/L	-	-	-	-	-	-	-	0.0001
Thorium-232 - whole water	Bq/L	-	-	-	-	-	-	-	-

Source: Modified from Appendix 5C, Tables X.II-1 to X.II-8.

Notes: Multiple entries for single stations and parameters represent laboratory replicates; composite sam

Values that are equal to or exceed the SSWQO are bolded. Values that are equal to or exceed the CWQ

[a] Saskatchewan Environment's (2006) Saskatchewan Surface Water Quality Objectives (SSWQO).

[b] Canadian Council of Ministers of the Environment's (CCME) Canadian water quality guidelines (CWQ(

[c] Not all parameters were analysed during each sampling period.

[d] Guideline for Cold-water biota- early stages (9.5 mg/L), other stages (6.5 mg/L).

[e] Highest value came from winter sampling.

[f] The guidelines for ammonia are dependent on temperature and pH; therefore, the guideline for each s

[g] = For 2008 data, nitrate values were calculated using the equation Nitrate Concentration = Nitrate-Nitr

[h] The guideline for nitrate is 13 mg NO_3/L or 2.9 mg N/L. It was assumed that the reported values were

[i] Highest detected value was between the range of non-detected values presented.

[j] The guideline for nitrite is 0.197 mg NO_2/L or 0.06 mg N/L.

[k] Values below detection limits were often equal to or exceeded the SSWQO and CWQG.

[l] The guidelines for aluminum are pH-dependent; the guideline is 0.005 mg/L at pH<6.5; 0.1 mg/L at pH

[m] The guidelines for cadmium are hardness-dependent; at hardnesses ranging from 0 to 48.5 mg/L as C

[n] The guideline for chromium is speciation-dependent; the guideline is 0.0089 mg/L for trivalent chromiu

[o] The guidelines for copper are hardness-dependent; at hardnesses ranging from 0 to 120 mg/L as CaC

[p] Original document states the measured unit is µg/mL, but based on results from other studies in the pr

[q] The guidelines for lead are hardness-dependent; at hardnesses ranging from 0 to 60 mg/L as $CaCO_3$

[r] In 2007, mercury was determined on a nitric-acid preserved sample as a potassium dichromate/nitric-a

[s] Mercury objective is for inorganic mercury only.

[t] Mercury guidelines differ depending on mercury type: inorganic mercury = 0.026 µg/L; methylmercury

[u] The guidelines for nickel are hardness-dependent; at hardnesses ranging from 0 to 60 mg/L as CaCO

[v] Selenium guideline is based on waterborne exposure. However, selenium has a bioaccumulation path

[w] Conducted by the Water Survey of Canada (BEAK 1990).

n = number of samples analyzed; °C = degrees Celsius; µS/cm = microSiemens per centimetre; µg/L =

Table 5.4-4
Summary of Sediment Chemistry Data for Lakes in the Kiggavik Project Area, 1979-2009

Parameter	Units	CCME Sediment Quality Guidelines		Thompson et al. (2004) values		Willow Lake Sub-Basin	Lower Lake Sub-Basin			Caribou Lake Sub-Basin	Boulder Lake Sub-Basin	Judge Sissons Lake Sub-Basin	Siamese Lake Sub-Basin	Skinny Lake Sub-Basin	Squiggly Lake Sub Basin	Baker Lake Sub-Basin
						All Lakes	Mushroom Lake	Andrew Lake	All Other Lakes	All Lakes	Boulder Lake	Judge Sissons Lake	Siamese Lake	Skinny Lake	Squiggly Lake	Baker Lake
						1979, 1986, 1988, 1991, 2007, 2008, 2009	2008	2007, 2008, 2009	1990, 1991, 2007, 2008	1986, 1988, 2007, 2008	1986	1979, 1986, 1988, 1991, 2008, 2009	2008	1986, 2007, 2008	2008	2008, 2009
		ISQG(a)	PEL(b)	LEL	SEL	n = 60(c)	n = 3(c)	n = 18(c)	n = 22(c)	n = 18(c)	n = 1(c)	n = 47(c)	n = 2(c)	n = 5(c)	n = 3(c)	n = 14(c)
Physical Properties																
Gravel	%	-	-	-	-	<0.01 - 26.76 (23 < DL)	<1 - 1 (2 < DL)	0.16 - 4 (4 < DL)	<0.01 - 6.58 (5 < DL)	<0.01 - 19.31 (4 < DL)	-	0 - 17 (14 < DL)	<1 (2 < DL)	-	-	-
Coarse Sand	%	-	-	-	-	0.04 - 20 (15 < DL)	1 - 36	36.2 - 63	<0.01 - 57 (1 < DL)	0.13 - 40.06	-	<1 - 69 (8 < DL)	<1 (2 < DL)	-	-	-
Fine Sand	%	-	-	-	-	<1 - 61 (2 < DL)	13 - 53	25 - 44.81	1.52 - 68	5 - 71	-	2 - 61	7 - 35	-	-	-
Silt	%	-	-	-	-	16 - 87	10 - 72	5 - 18	8 - 81	16.47 - 74.07	-	3 - 75	60 - 83	-	-	-
Clay	%	-	-	-	-	2 - 48	1 - 14	<1.0 - 3.58 (3 < DL)	1 - 18.76	3.0 - 25.17	-	<1 - 27 (2 < DL)	6 - 11	-	-	-
Moisture in particle size sample	%	-	-	-	-	34.8 - 82.7	32.9 - 56.5	24.6 - 52.1	28.2 - 76.4	39.9 - 76.2	-	18.1 - 87.6	72.0 - 74.5	-	-	-
Moisture in chemistry sample	%	-	-	-	-	41.11 - 75.92	49.88 - 75.44	27.6 - 58.3	24.25 - 86.18	33.8 - 79.15	-	27.51 - 87.7	77.32 - 82.09	53.92 - 77.44	68.2 - 76.5	-
Loss on Ignition	%	-	-	-	-	4.3 - 28	-	0.53 - 2.42	2.38 - 21.5	5.86 - 18.2	10.5	1.0 - 17.2	-	9.7	-	-
Cation Exchange Capacity	meq/100g	-	-	-	-	3.6 - 11.0	-	-	-	-	-	-	-	-	-	-
Chemical Oxygen Demand	%	-	-	-	-	1.23 - 6.7	-	-	-	1.9 - 6.7	4.3	0.75 - 0.82	-	3.6	-	-
Nutrients																
Total Nitrogen	%	-	-	-	-	0.174 - 0.816	-	0.045 - 0.076	-	-	-	0.041 - 0.745	-	-	-	-
Ammonia as Nitrogen	µg/g dw	-	-	-	-	30 - 140	-	7 - 20	6 - 100	40 - 120	-	-	-	120	-	-
Nitrite+Nitrate Nitrogen	µg/g dw	-	-	-	-	9 - 10	-	4 - 5	4 - 10	8 - 20	-	-	-	5	-	-
Total Kjeldahl Nitrogen	µg/g dw	-	-	-	-	390 - 8,600	-	-	610 - 7,400	2,600 - 7,700	4,800	790 - 1,560	-	140	-	-
Total Phosphorous	µg/g dw	-	-	-	-	710 - 1,930	-	240 - 290	290 - 950	460 - 4,700	830	320 - 2,130	-	1,260 - 1,420	-	310 - 830
Total Organic Carbon	%	-	-	-	-	1.15 - 7.3	0.9 - 3.6	<0.01 - 2.9 (1 < DL)	0.16 - 18.6	1.3 - 6.3	-	0.24 - 7.68	5.6 - 8.5	-	-	-
Major Ions		-	-													
Calcium	µg/g dw	-	-	-	-	1,650 - 6,200	2,030 - 3,680	1,250 - 1,800	1,620 - 5,980	2,150 - 4,280	1,940	1,200 - 3,760	2,620 - 2,750	1,920 - 3,030	2,230 - 2,770	2,020 - 4,200
Magnesium	µg/g dw	-	-	-	-	2,950 - 9,730	2,160 - 6,520	1,570 - 1,900	880 - 8,200	2,630 - 7,400	3,100	1,620 - 6,160	3,230 - 3,280	3,110 - 4,580	4,220 - 7,030	4,310 - 6,760
Potassium	µg/g dw	-	-	-	-	1,830 - 10,600	2,340 - 8,900	1,170 - 1,950	230 - 7,420	2,010 - 8,650	1,600	1,150 - 6,240	3,070 - 3,460	2,600 - 7,570	4,670 - 17,800	5,030 - 8,660
Sodium	µg/g dw	-	-	-	-	<1 - 440 (1 < DL)	40 - 120	<1 - 34 (3 < DL)	<10 - 400 (2 < DL)	41 - 480	170	<1 - 1,180 (6 < DL)	89 - 120	100 - 300	44 - 180	300 - 490
Sulphate	µg/g dw	-	-	-	-	490 - 2,900	840 - 1,900	<10 - 1,100 (2 < DL)	140 - 5,000	370 - 2,700	-	80 - 4,300	3,600 - 4,600	700 - 2,400	2,100 - 4,300	-
Metals and Metalloids																
Aluminum	µg/g dw	-	-	-	-	9,000 - 39,900	7,950 - 31,500	3,900 - 7,100	1,760 - 28,400	7,500 - 32,000	6,300	4,800 - 23,200	12,900 - 14,200	12,500 - 26,100	22,100 - 57,100	10,600 - 28,400
Antimony	µg/g dw	-	-	-	-	<0.2 (27 < DL)	<0.2 (3 < DL)	<0.2 (6 < DL)	<0.2 (8 < DL)	<0.2 (6 < DL)	-	<0.2 (30 < DL)	<0.2 (2 < DL)	<0.2 (3 < DL)	<0.2 (3 < DL)	-
Arsenic	µg/g dw	5.9	17.0	-	-	2 - **34**	2.5 - **8.7**	1.2 - 2.4	<1 - **9.8** (3 < DL)	3.1 - **60**	3.0	2.0 - **39**	**6.2 - 7.1**	3 - **12**	**8.7 - 14**	2 - **9.1**
Arsenic	µg/g ww	-	-	-	-	0.86 - 2.32	-	-	-	-	-	4.48	-	-	-	-
Barium	µg/g dw	-	-	-	-	130 - 440	64 - 230	54 - 100	20 - 290	58 - 620	158	64 - 320	190	160 - 330	210 - 340	91 - 340
Beryllium	µg/g dw	-	-	-	-	0.6 - 2 (2 < DL)	0.5 - 2.2	0.2 - 0.4	0.2 - 2.0 (3 < DL)	0.4 - 2.3	<1 (1 < DL)	0.2 - 1.6 (2 < DL)	0.9	1 - 2.7	1.4 - 2.6	0.4 - 1.1
Boron	µg/g dw	-	-	-	-	<1 - 39 (23 < DL)	22 - 53	<1 - 5 (7 < DL)	<1 - 31 (8 < DL)	<1 - 50 (2 < DL)	-	<1 - 20 (28 < DL)	<1 (2 < DL)	<1 - 4 (2 < DL)	<1 - 160 (1 < DL)	<1 - 150 (6 < DL)
Cadmium	µg/g dw	0.6	3.5	-	-	<0.1 - <1(d) (15 < DL)	<0.1 - 0.3 (2 < DL)	<0.1 (8 < DL)	<0.1 - 1 (11 < DL)	<0.1 - **0.6** (7 < DL)	<1 (1 < DL)	<0.1 - 0.5 (20 < DL)	0.2 - 0.3	<0.1 - 0.4 (1 < DL)	0.3 - **0.6**	-
Chromium	µg/g dw	37.3	90	-	-	11 - **100**	**42 - 66**	6.2 - 37	8.6 - 68	27 - **76**	19	3.8 - **82.5**	23 - **41**	13 - 34	15 - 25	11 - **89**
Cobalt	µg/g dw	-	-	-	-	3 - 17	2.5 - 7	1.2 - 1.9	<0.5 - 9.3 (1 < DL)	3.3 - 13	2	1.5 - 30	4.3 - 4.8	2.8 - 14	5.9 - 9.9	3.2 - 7.5
Copper	µg/g dw	35.7	197	-	-	7.3 - **63**	5.7 - **40**	2.3 - **130**	2.0 - **120**	6.4 - **59**	17	1.7 - **43**	27	9.5 - **62**	28 - **50**	3.3 - 7.8
Iron	µg/g dw	-	-	-	-	2,700 - 94,000	10,100 - 31,200	5,200 - 8,900	3,000 - 30,900	2,000 - 85,000	9,100	6,600 - 79,200	18,200 - 20,100	3,100 - 61,500	17,600 - 36,200	10,300 - 18,600
Lead	µg/g dw	35	91.3	-	-	<5 - 18 (3 < DL)	4.5 - 15	2.4 - 13	2.5 - 20	4.9 - 20	10	2.6 - 16 (1 < DL)	11 - 13	7.5 - 16	12 - 19	3.1 - 12
Manganese	µg/g dw	-	-	-	-	78 - 670	120 - 350	38 - 110	32 - 330	86 - 700	107	50 - 1,060	150 - 180	110 - 380	210 - 340	49 - 1,720
Mercury	µg/g dw	0.17	0.486	-	-	0.006 - 0.08 (22 < DL)	-	<0.05 (7 < DL)	<0.02 - **3** (9 < DL)	0.01 - 0.06 (8 < DL)	0.03	<0.01 - 0.06 (26 < DL)	-	<0.05 - 0.11 (1 < DL)	-	-
Molybdenum	µg/g dw	-	-	-	-	0.3 - 4 (4 < DL)	0.5 - 1.5	<0.1 - 0.4 (1 < DL)	<0.1 - 4.5 (3 < DL)	0.4 - 17 (1 < DL)	<2 (1 < DL)	0.2 - 4.9 (1 < DL)	1.2	0.3 - 2.1 (1 < DL)	1.6 - 3.0	<0.1 - 1.3 (4 < DL)
Nickel	µg/g dw	-	-	-	-	14 - 42	10 - 29	4.7 - 11	5.2 - 34	10 - 48	13	5 - 71	19	11 - 24	26 - 39	9.8 - 17
Selenium	µg/g dw	-	-	-	-	<0.1 - <2(d) (8 < DL)	0.1 - 0.7	<0.1 -- 1.2 (6 < DL)	<0.1 - 1.3 (7 < DL)	<0.1 - 0.9 (3 < DL)	<0.5 (1 < DL)	<0.1 - 1.0 (13 < DL)	0.6 - 0.7	0.2 - 0.8 (1 < DL)	0.7 - 1.0	-
Selenium	µg/g ww	-	-	-	-	0.02 - 0.09	-	-	-	-	-	0.034	-	-	-	-
Silver	µg/g dw	-	-	-	-	<0.1 - 0.6 (26 < DL)	<0.1 - 0.3 (2 < DL)	<0.1 (8 < DL)	<0.1 - 0.8 (13 < DL)	<0.1 - 0.3 (7 < DL)	-	<0.1 - <0.5(d) (19 < DL)	0.1	<0.1 - 0.2 (1 < DL)	0.2 - 0.3	-
Strontium	µg/g dw	-	-	-	-	18 - 300	58 - 130	33 - 52	19.5 - 230	18 - 180	13	12 - 180	83 - 110	14 - 110	110 - 210	48 - 150
Tellurium	µg/g ww	-	-	-	-	<0.1 (1 < DL)	-	-	-	-	-	-	-	-	-	-
Thallium	µg/g dw	-	-	-	-	<0.2 - 0.4 (20 < DL)	<0.2 - 0.4 (2 < DL)	<0.2 (6 < DL)	<0.2 - 0.2 (7 < DL)	<0.2 - 0.4 (2 < DL)	-	<0.2 - 0.2 (29 < DL)	<0.2 (2 < DL)	<0.2 - 0.3 (1 < DL)	<0.2 - 0.4 (1 < DL)	-
Tin	µg/g dw	-	-	-	-	<0.1 - 0.9 (1 < DL)	-	-	-	-	-	-	-	-	-	-
Titanium	µg/g dw	-	-	-	-	290 - 880	230 - 560	150 - 250	60 - 910	180 - 620	-	170 - 550	290 - 350	230 - 430	190 - 590	330 - 1,200
Uranium	µg/g dw	-	-	-	-	1.1 - 4.6	1.1 - 5.7	0.7 - 1.4	0.4 - 6.0	0.8 - 15	2.6	<0.5 - 5.8 (1 < DL)	2.5	2.5 - 7.2	4.3 - 7.1	0.8 - 10
Vanadium	µg/g dw	-	-	-	-	15 - 52	14 - 40	8.2 - 12	5.0 - 48	15 - 44	-	9.8 - 41	22	18 - 28	26 - 46	16 - 53
Zinc	µg/g dw	123	315	-	-	31 - 120	24 - 71	14 - **440**	8 - **410**	29 - **150**	38	14 - 120	48 - 56	40 - **170**	80 - 120	16 - 46
Radionuclides																
Lead-210	Bq/g dw	-	-	0.5 - 0.9	9.7 - 20.8	<0.02 - 4.4 (8 < DL)	0.08 - 0.16	<0.02 - 0.07 (6 < DL)	<0.02 - 0.25 (6 < DL)	<0.02 - 0.18 (2 < DL)	0.15	<0.02 - 5.7 (17 < DL)	0.16 - 0.18	0.06 - 0.24	0.12 - 0.38	<0.02 - 0.09 (2 < DL)
Polonium-210	Bq/g dw	-	-	0.6 - 0.8	8.7 - 12.1	0.02 - 0.19	0.08 - 0.15	<0.01 - 0.07 (1 < DL)	0.01 - 0.30	0.01 - 0.15	-	0.02 - 0.28	0.19 - 0.22	0.07 - 0.28	0.19 - 0.45	0.008 - 0.08
Polonium-220	Bq/g dw	-	-	-	-	0.045 - 0.22	-	-	-	0.09	-	0.095	-	-	-	-
Radium-226	Bq/g dw	-	-	0.1 - 0.6	13 - 14.4	0.012 - 1.3	0.01 - 0.08	<0.01 - 0.03 (1 < DL)	<0.01 - 0.11 (3 < DL)	0.02 - 0.08	0.018	<0.01 - 1.4 (1 < DL)	0.03 - 0.04	0.03 - 0.10	0.03 - 0.07	0.03 - 0.06
Radium-228	Bq/g dw	-	-	-	-	<0.2 (3 < DL)	-	-	-	<0.2 (1 < DL)	-	<0.2 (1 < DL)	-	-	-	-
Thorium-228	Bq/g dw	-	-	-	-	0.03 - 3.2	0.02 - 0.07	<0.02 - 0.04 (3 < DL)	<0.02 - 0.07 (1 < DL)	0.03 - 0.08	-	<0.02 - 2.4 (6 < DL)	0.07	0.06 - 0.13	0.08 - 0.11	-
Thorium-230	Bq/g dw	-	-	-	-	0.02 - 1.9	0.03 - 0.07	<0.02 - 0.03 (4 < DL)	<0.02 - 0.07 (3 < DL)	0.03 - 0.15	0.03	0.01 - 1.6 (10 < DL)	0.04 - 0.05	0.06 - 0.11	0.06 - 0.08	0.02 - 0.08
Thorium-232	Bq/g dw	-	-	-	-	0.02 - 2.9	0.02 - 0.07	<0.02 - 0.03 (4 < DL)	<0.02 - 0.09 (2 < DL)	0.04 - 0.095	0.042	0.011 - 1.7 (6 < DL)	0.04 - 0.06	0.06 - 0.10	0.06 - 0.08	-

Table 5.4-4
Summary of Sediment Chemistry Data for Lakes in the Kiggavik Project Area, 1979-2009

Parameter	Units	CCME Sediment Quality Guidelines		Thompson et al. (2004) values		Willow Lake Sub-Basin	Lower Lake Sub-Basin			Caribou Lake Sub-Basin	Boulder Lake Sub-Basin	Judge Sissons Lake Sub-Basin	Siamese Lake Sub-Basin	Skinny Lake Sub-Basin	Squiggly Lake Sub Basin	Baker Lake Sub-Basin
						All Lakes	Mushroom Lake	Andrew Lake	All Other Lakes	All Lakes	Boulder Lake	Judge Sissons Lake	Siamese Lake	Skinny Lake	Squiggly Lake	Baker Lake
						1979, 1986, 1988, 1991, 2007, 2008, 2009	2008	2007, 2008, 2009	1990, 1991, 2007, 2008	1986, 1988, 2007, 2008	1986	1979, 1986, 1988, 1991, 2008, 2009	2008	1986, 2007, 2008	2008	2008, 2009
		ISQG[a]	PEL[b]	LEL	SEL	n = 60[c]	n = 3[c]	n = 18[c]	n = 22[c]	n = 18[c]	n = 1[c]	n = 47[c]	n = 2[c]	n = 5[c]	n = 3[c]	n = 14[c]

Source: Modified from Appendix 5C, Table X.III-1 to X.III-6.
Values greater than or equal to ISQGs are **bolded**.
Values greater than or equal to PELs are **bolded** and underlined.
Non-detect values that have detection limits that are greater than guidelines are italized.
[a] ISQG = Interim Freshwater Sediment Quality Guidelines (CCME 2002).
[b] PEL = Probable Effect Levels (CCME 2002).
[c] Not all parameters were analysed during each sampling period.
[d] Highest detected value was between the range of non-detected values presented.
CCME = Canadian Council of Ministers of the Environment; n = number of samples analyzed; % = percentage; meq/100 g = milliequivalents per 100 grams; µg/g dw = micrograms per gram dry weight; µg/g ww = microgram per gram in wet weight; mg/g dw = milligrams per gram in dry weight; Bq/g dw = Becquerels per gram in dry weight;
LEL = lowest effects level; SEL = severe effects level; < = less than; - = no data collected.