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.

This assessment will help address public concerns and IQ comments about concerns about water quality related to dust (IQ-RIE 2009[154], EN-RI KWB Oct 2009[155]).

8.2.2.1 Analytical Methods for Changes in Water Quality Due to Dust Deposition

A simple mass balance approach was used to assess the impacts of dust deposition on metal concentrations and TSS in waterbodies located in the Mine site LAA and Road LAA. Dust deposition data for the LAAs from air deposition modelling was used in this analysis (Tier 3, Appendix 4B). Point estimates of the deposited particulate (Total, PM_{10} and $PM_{2.5}$) and the metals (in the particulate) were provided on a one km grid over most of the Mine LAA, and less frequently along the proposed road alignments in the Road LAA as $\mu g/m^2/s$. The air quality modelling incorporates highly conservative assumptions for emissions of dust and metals. 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 $Bq/m^2/s$) were provided.Three 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):

- Scenario 1 estimates potential lake concentration increases in the Mine site LAA.
- Scenario 2 estimates lake outlet concentrations.
- Scenario 3 estimates lake and lake outlet concentration increases in the Road LAA using Pointer Lake as the model system.

For predicting lake concentrations of TSS, metals, and radionuclides in waterbodies in the Mine LAA and Road LAA, 50% of the annual dust deposition[156] in the upstream watershed (based on average deposition rate observed over that entire specific watershed) reported instantaneously to the most downstream lake in the watershed to obtain an instantaneous load (as a mass unit). This is considered to be a very conservative approach to the prediction of lake concentrations of TSS,

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[154] IQ-RIE 2009*: Elders expressed concern about the potential effects of uranium dust travelling and affecting many people*
[155] EN-RI KWB Oct 2009: *How does dust affect the environment?*
[156] Total suspended particulates (TSP) refer to small particles suspended in air while total suspended solids (TSS) refer to small particles suspended in water. TSP contribute to TSS levels when they enter a waterbody.

metals, and radio nuclides. The lake volume and residence time was used to calculate the annual lake volume available for dilution. For determining possible increases in stream concentrations above background, this same load was divided by the annual stream discharge.

8.2.2.2 Baseline Conditions for Changes in Water Quality Due to Dust Deposition

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. For the metals assessed (arsenic, cadmium, chromium, cobalt, copper, lead, nickel, molybdenum, selenium, uranium and zinc), results for most baseline samples were well below water quality guidelines.

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 Mine site LAA and Road LAA of the 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 site roads and during the pit mining operation (Tier 3, Technical Appendix 4C.

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 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, 2 and 3). For example, predicted uranium concentrations were about 20- to 60- times lower than the guideline (Table 8.2-6). The conservative model applied (Table 8.2-6; Scenario 1), predicted maximum increases of lead to Pointer Lake of 0.000026 mg/L which is 38-fold lower than the guideline. Based on the conservative modeling, no changes in the water quality for metals is predicted in the Mine site LAA and Road LAA of the Project beyond the natural variability noted in the area. As such, metals and radionuclides are screened out from further assessment.

Predicted TSS concentrations were all generally well below 25 mg/L in the Mine LAA and well below 1 mg/L in the Road LAA (outside of the mine LAA; Table 8.2-6). These increases in TSS would most likely happen during the peak of the spring 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). TSS concentrations are predicted to be highest during the ascending and peak flow portions of the spring freshet; TSS concentrations are expected to decline as freshet flows decline. Based on this conservative assessment, TSS is screened out from further assessment.

Table 8.2-6 Screening Assessment of Dust Deposition (Total Suspended Particulate, Metals and Radionuclides) in the Mine and Road LAAs Using A Mass Balance Approach

Scenario 1 - Average Deposition by Lake Watershed for Lake Concentrations

Assumptions:	Assume the annual average dust deposition rate was used to determine the annual watershed load.
	Assume 50% of Lake Basin Annual Load reports to most downstream lake in the watershed of interest.
	Assume lake volumes available for basin load based on actual retention time.

Annual Average Dust Deposition

	TSP (µg/m²/s)	PM10 (µg/m²/s)	PM2.5 (µg/m²/s)	Arsenic (µg/m²/s)	Cobalt (µg/m²/s)	Cadmium (µg/m²/s)	Chromium (µg/m²/s)	Copper (µg/m²/s)	Molybdenum (µg/m²/s)	Nickel (µg/m²/s)	Lead (µg/m²/s)	Selenium (µg/m²/s)	Uranium (µg/m²/s)	Zinc (µg/m²/s)	Lead-210 (Bq/m²/s)	Polonium-210 (Bq/m²/s)
Pointer Lake	1.21E-01	7.00E-03	7.88E-05	2.27E-08	1.18E-07	1.24E-09	7.72E-07	2.34E-07	1.31E-07	3.55E-07	3.22E-07	1.99E-08	3.88E-06	3.47E-07	4.79E-08	4.79E-08
Shack Lake	3.04E-01	1.32E-02	1.41E-04	1.06E-07	1.43E-07	3.30E-09	2.32E-06	3.61E-07	1.32E-07	7.34E-07	5.21E-07	3.96E-08	8.32E-06	4.33E-07	1.03E-07	1.03E-07
Boulder Lake	2.91E-01	1.28E-02	1.37E-04	6.97E-08	1.96E-07	2.89E-09	1.82E-06	5.62E-07	1.97E-07	6.95E-07	4.84E-07	4.83E-08	3.52E-06	5.38E-07	4.35E-08	4.35E-08
Caribou Lake	1.77E-01	8.67E-03	9.30E-05	3.50E-08	1.43E-07	1.74E-09	1.07E-06	3.55E-07	1.59E-07	4.54E-07	3.69E-07	2.97E-08	3.32E-06	4.03E-07	4.10E-08	4.10E-08

Predicted Concentration Increase in Waterbody

	TSP (mg/L)	PM10 (mg/L)	PM2.5 (mg/L)	Arsenic (µg/L)	Cobalt (µg/L)	Cadmium (µg/L)	Chromium (µg/L)	Copper (µg/L)	Molybdenum (µg/L)	Nickel (µg/L)	Lead (µg/L)	Selenium (µg/L)	Uranium (µg/L)	Zinc (µg/L)	Lead-210 (Bq/L)	Polonium-210 (Bq/L)
Pointer Lake	10.0	0.57	0.01	0.002	0.010	0.0001	0.063	0.019	0.011	0.029	0.026	0.002	0.318	0.028	0.004	0.004
Shack Lake	25.2	1.09	0.01	0.009	0.012	0.0003	0.192	0.030	0.011	0.061	0.043	0.003	0.688	0.036	0.008	0.008
Boulder Lake	20.2	0.89	0.01	0.005	0.014	0.0002	0.126	0.039	0.014	0.048	0.034	0.003	0.244	0.037	0.003	0.003
Caribou Lake	14.7	0.72	0.01	0.003	0.012	0.0001	0.089	0.029	0.013	0.038	0.031	0.002	0.275	0.033	0.003	0.003

Scenario 2 - Average Deposition by Lake Watershed for Lake Outlet Concentrations

Assumptions:	Assume the annual average dust deposition rate was used to determine the annual watershed load.
	Assume 50% of lake basin annual load reports to most downstream lake per annum (and hence its outlet).
	Assume annual creek volume available for diluting for basin load.

Annual Average Dust Deposition

	TSP (µg/m²/s)	PM_{10} (µg/m²/s)	$PM_{2.5}$ (µg/m²/s)	Arsenic (µg/m²/s)	Cobalt (µg/m²/s)	Cadmium (µg/m²/s)	Chromium (µg/m²/s)	Copper (µg/m²/s)	Molybdenum (µg/m²/s)	Nickel (µg/m²/s)	Lead (µg/m²/s)	Selenium (µg/m²/s)	Uranium (µg/m²/s)	Zinc (µg/m²/s)	Lead-210 (Bq/m²/s)	Polonium-210 (Bq/m²/s)
Pointer Lake Outlet	1.21E-01	7.00E-03	7.88E-05	2.27E-08	1.18E-07	1.24E-09	7.72E-07	2.34E-07	1.31E-07	3.55E-07	3.22E-07	1.99E-08	3.88E-06	3.47E-07	4.79E-08	4.79E-08
Shack Lake Outlet	3.04E-01	1.32E-02	1.41E-04	1.06E-07	1.43E-07	3.30E-09	2.32E-06	3.61E-07	1.32E-07	7.34E-07	5.21E-07	3.96E-08	8.32E-06	4.33E-07	1.03E-07	1.03E-07
Boulder Lake Outlet	2.91E-01	1.28E-02	1.37E-04	6.97E-08	1.96E-07	2.89E-09	1.82E-06	5.62E-07	1.97E-07	6.95E-07	4.84E-07	4.83E-08	3.52E-06	5.38E-07	4.35E-08	4.35E-08
Caribou Lake Outlet	1.77E-01	8.67E-03	9.30E-05	3.50E-08	1.43E-07	1.74E-09	1.07E-06	3.55E-07	1.59E-07	4.54E-07	3.69E-07	2.97E-08	3.32E-06	4.03E-07	4.10E-08	4.10E-08

Predicted Concentration Increase in Waterbody

	TSP (mg/L)	PM_{10} (mg/L)	$PM_{2.5}$ (mg/L)	Arsenic (µg/L)	Cobalt (µg/L)	Cadmium (µg/L)	Chromium (µg/L)	Copper (µg/L)	Molybdenum (µg/L)	Nickel (µg/L)	Lead (µg/L)	Selenium (µg/L)	Uranium (µg/L)	Zinc (µg/L)	Lead-210 (Bq/L)	Polonium-210 (Bq/L)
Pointer Lake Outlet	10.0	0.58	0.006	0.002	0.010	0.0001	0.064	0.019	0.011	0.029	0.027	0.002	0.319	0.029	0.004	0.004
Shack Lake Outlet	24.8	1.08	0.011	0.009	0.012	0.0003	0.189	0.029	0.011	0.060	0.042	0.003	0.677	0.035	0.008	0.008
Boulder Lake Outlet	18.0	0.79	0.008	0.004	0.012	0.0002	0.113	0.035	0.012	0.043	0.030	0.003	0.218	0.033	0.003	0.003
Caribou Lake Outlet	14.6	0.72	0.008	0.003	0.012	0.0001	0.088	0.029	0.013	0.038	0.030	0.002	0.274	0.033	0.003	0.003

Table 8.2-6 Screening Assessment of Dust Deposition (Total Suspended Particulate, Metals and Radionuclides) in the Mine and Road LAAs Using A Mass Balance Approach

Scenario 3 - Road Allowances - Average Deposition by Lake Watershed for Lake and Outlet Concentrations (using Pointer Lake as a Model System)																
Assumptions:	Assume up to the annual average-predicted deposition rate to Siamese Lake Watershed and road allowances and apply it across the entire basin being examined.															
	Assume 50% of lake basin annual load reports to most downstream lake per annum.															
	Assume lake volumes available for basin load based on actual retention time.															
Road Allowances - Annual Average Deposition																
	TSP (µg/m^2/s)	**PM10 (µg/m^2/s)**	**PM2.5 (µg/m^2/s)**	**Arsenic (µg/m^2/s)**	**Cobalt (µg/m^2/s)**	**Cadmium (µg/m^2/s)**	**Chromium (µg/m^2/s)**	**Copper (µg/m^2/s)**	**Molybdenum (µg/m^2/s)**	**Nickel (µg/m^2/s)**	**Lead (µg/m^2/s)**	**Selenium (µg/m^2/s)**	**Uranium (µg/m^2/s)**	**Zinc (µg/m^2/s)**	**Lead-210 (Bq/m^2/s)**	**Polonium-210 (Bq/m^2/s)**
Pointer Lake	9.93E-03	7.97E-04	1.35E-05	3.51E-09	1.41E-08	1.62E-10	1.03E-07	2.89E-08	1.47E-08	4.49E-08	3.82E-08	2.52E-09	4.75E-07	4.15E-08	5.87E-09	5.87E-09
Pointer Lake Outlet	9.93E-03	7.97E-04	1.35E-05	3.51E-09	1.41E-08	1.62E-10	1.03E-07	2.89E-08	1.47E-08	4.49E-08	3.82E-08	2.52E-09	4.75E-07	4.15E-08	5.87E-09	5.87E-09
Predicted Concentration Increase in Waterbody																
	TSP (mg/L)	**PM10 (mg/L)**	**PM2.5 (mg/L)**	**Arsenic (µg/L)**	**Cobalt (µg/L)**	**Cadmium (µg/L)**	**Chromium (µg/L)**	**Copper (µg/L)**	**Molybdenum (µg/L)**	**Nickel (µg/L)**	**Lead (µg/L)**	**Selenium (µg/L)**	**Uranium (µg/L)**	**Zinc (µg/L)**	**Lead-210 (Bq/L)**	**Polonium-210 (Bq/L)**
Pointer Lake	0.81	0.07	0.001	0.000	0.001	0.00001	0.008	0.002	0.001	0.004	0.003	0.000	0.039	0.003	0.000	0.000
Pointer Lake Outlet	0.82	0.07	0.001	0.000	0.001	0.00001	0.009	0.002	0.001	0.004	0.003	0.000	0.039	0.003	0.000	0.000
Canadian Water Quality Guideline																
				5[(a)]	4[(b)]	0.04[(a)]	8.9[(c)]	2[(a)]	73[(a)]	25[(a)]	1[(a)]	1[(a)]	15[(a)]	30[(a)]	0.2[(d)]	0.2[(e)]

NOTES:

[(a)] = CCME Water Quality Guideline for the Protection of Aquatic Life (1999c with updates to 2014)

[(b)] = BC MOE freshwater aquatic life guideline (2011a)

[(c)] = The CCME Water Quality Guideline for the Protection of Aquatic Life (1999c with updates to 2014) for chromium as chromium (III)

[(d)] = Summary of Guidelines for Canadian Drinking Water Quality (FPTC DW 2012)

[(e)] = Polonium drinking water quality guideline is no longer listed in the current version of Summary of Guidelines for Canadian Drinking Water Quality (FPTC DW 2012), but is still included to provide context for predicted environmental concentrations.

Screening calculations for Pointer Lake were based on: volume of 5.47E+06 m3; annual discharge of 1.52E+06 m^3; basin area of 7.90E+01 km^2; and retention time of 0.36 years.

Screening calculations for Shack Lake were based on: volume of 3.60E+05 m^3; annual discharge of 9.00E+06 m^3; basin area of 4.72E+01 km^2; and retention time of 0.04 years.

Screening calculations for Boulder Lake were based on: volume of 5.47E+06 m^3; annual discharge of 1.52E+07 m^3; basin Area of 6.68E+01 km^2; and retention time of 0.36 years

Screening calculations for Caribou Lake were based on: volume of 4.77E+06 m^3; annual discharge of 1.54E+07 m^3; basin area of 8.09E+01 km^2; and retention time of 0.31 years.

TSP = total suspended particulate; PM_{10} = particulate matter up to 10 micrometres in size; $PM_{2.5}$ = particulate matter up to 2.5 micrometres in size; Bq/m^2/s = Becquerels per square metre per second; µg/m^2/s = micrograms per square metre per second; m^3 = cubic metres; km^2 = square kilometres; mg/L = milligrams per litre; µg/L = micrograms per litre; Bq/L = Becquerels per litre; CWQG = Canadian water quality guideline; CCME = Canadian Council of Ministers of the Environment

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 peak 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 measured 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 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 actual levels are similar to predicted levels (Tier 3, Technical Appendix 4C).

Water quality including TSS, metals and radionuclides will be monitored in appropriate lakes and streams to confirm that changes in water quality from dust deposition are not increasing above predicted or acceptable levels. This monitoring will occur during the spring freshet throughout the operational life of the Project (Tier 3, Technical Appendix 5M).

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 and nitrate . Deposition of sulphate and nitrate 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' North, 116^{o} 00' West). 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, nitrate , and base cations (calcium, magnesium, sodium and potassium). The Snare Rapids site is located approximately 900 kilometres due west of the Kiggavik site (64^{o} 22'N, 97^{o} 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 the Project. 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 Project 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 $CaCO_3$, 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).		
NOTES: ANC = acid neutralizing capacity; 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 CaCO3 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, 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 Project area exhibit high to least acid sensitivity. High acid sensitivity is typical of summertime or open water conditions where the lakes are exposed to the atmosphere. Low and least acid 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).

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 biota are better correlated with ANC than with pH (as reviewed by Sullivan 2000) because pH measurements are sensitive to carbon dioxide effects (Stumm and Morgan 1981).

Table 8.2-8 Summary of Example Lake Characteristics for the Kiggavik Area

Basin	Lake	Estimate	pH	Specific Conductivity µS/cm	Total Alkalinity (mg/L as CaCO3)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	DOC (mg/L)	Lake Sensitivity to Acid
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

NOTES:
µS/cm = microSiemens per centimetre; mg/L = miligrams per litre; $CaCO_3$ = calcium carbonate; Ca^{2+} = calcium ion; Mg^{2+} = magnesium ion; Na^{+} = sodium ion; K^{+} = potassium ion; DOC = dissolved organic carbon

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 sulphate and nitrate 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 sulphate and nitrate 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 nitrate 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 nitrate at Kiggavik is below 5 kg/ha/y for all Lakes, only the sulphate^{-} 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 and nitrate . 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.

8.2.3.4 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 mono-nitrogen oxides (NOx) control systems should be installed on the oil-fired power generators and/or product driers.

8.2.3.5 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 Project 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 Project activities 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).

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-August-90	7.0	9	High	0.508		0.020
		27-August-07	6.8	18	Moderate	0.704		0.020
		20-June-08	6.9	4	High	0.257		0.020
		29-August-08	7.3	14	Moderate	0.620		0.020
		3-September-08	7.1	12	Moderate	0.669		0.020
		Maximum	7.5	25	Low	0.929	0.024	

NOTES:
Shaded cells indicate value not used for assessment.
$CaCO_3$ = calcium carbonate; keq/ha/y = kiloequivalents per hectare per year; PAI = potential acid input

8.2.3.6 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 Project (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.

8.2.3.7 Compliance and Environmental Monitoring for Changes in Water Quality Due to Acid Deposition and Lake Acidification

Water quality including pH will be monitored in appropriate lakes and streams to confirm that acid deposition and lake acidification are not increasing above predicted or acceptable levels. This monitoring will occur during the spring freshet over the operational life of the Project. For lakes, the sampling will also be done in autumn prior to freeze up.

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 Judge Sissons Lake, but are expected to diminish to background levels downstream of the outlet of the lake. Should monitoring results identify any remaining residual effects to water quality leaving Judge Sissons Lake, these effects would have potential to overlap with other projects and activities that occur or may occur in the future, and may therefore act cumulatively on surface water quality.

The screening for cumulative effects to water quality was conducted to determine if cumulative environmental effects are likely 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 Volume 1, Appendix 1B. Of these projects, no local, Nunavut, or Far Future Scenario projects from the Project Inclusion List are expected to affect surface water quality within the spatial (i.e., Judge Sissons Lake) and temporal (i.e., throughout the duration of water quality effects associated with this Project) boundaries. Therefore, no cumulative effects to surface water quality are predicted for the Project.

8.4 Summary of Residual Effects on Water Quality

8.4.1 Project Effects

Based on modelled data effects on water quality from the Project treated effluent discharges to Judge Sissons Lake, the concentration of COPC, with established thresholds, are expected to be below the appropriate threshold value, with the exception of cadmium and selenium. For cadmium, the concentrations within Judge Sissons Lake are generally expected to be below the CCME CWQG once seasonal changes in hardness are considered; however, 95^{th} percentile predicted concentrations exceed the CWQG in winter months. For selenium in JSL-7, concentrations during the operation and final closure phases of the Project are shown to seasonally exceed the CWQG; this is largely due to baseline conditions and seasonal fluctuations. 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 of 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: Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental Context	Significance	Likelihood	Prediction Confidence	Recommended Follow-up and Monitoring
Change in water quality: Treated effluent discharge from the Kiggavik and Sissons WTP may affect surface water quality in the receiving environment. This potential alteration to surface water chemistry has the potential to affect aquatic biota													
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	R	R	U				
Decommissioning and Abandonment		Y	N	L	L	MT	R	R	U				
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	R	R	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	R	R	U				
Decommissioning		Y	N	L	L	ST	R	R	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	R	U				
Decommissioning		N	-	-	-	-	-	-	-				

KEY

Direction:
P Positive
N Negative

Magnitude:
Use quantitative measure; or
L Low: Water quality generally expected to meet applicable benchmarks or no measureable change from baseline conditions; TSS <55mg/L
M Moderate: Water quality within a factor of 5 of benchmarks; TSS 55-148 mg/L
H High: Water quality expected to exceed benchmarks by a factor greater than 5; TSS >148mg/L

Geographic Extent:
Use quantitative measure; or
S Site-specific: area of lake or stream
L Local assessment area
R Regional assessment area

Duration:
Use quantitative measure; or
ST Short term: water quality returns to baseline conditions during operations
MT Medium term: water quality returns to baseline conditions during final closure period
LT Long term: water quality returns to baseline post-closure
P Permanent change in water quality

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 RAA
N Effect will not or is not likely to interact with other past, present or foreseeable projects or activities in RAA

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, the 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

Concerns regarding potential effects on water quality were discussed several times during public engagement (e.g., EN-BL OH 2013[157]; EN-AR OH 2010[158]; EN- BL CLC 2007[159]; EN-RB KIA 2010[160]). Many of the mitigation measures associated with water quality incorporate IQ guiding principles (GN 2009), including Qanuqtuurnunnarniq (being resourceful to solve problems), Avatimik Kamattiarniq (environmental stewardship), and Pilimmaksarniq (skills and knowledge acquisition). A number of mitigation measures and project design modifications will be implemented to limit changes in water quality:

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[157] EN-BL OH 2013:*That water you will use will become contaminated and come to this community and we will get sick. Will you pay us for the water you use. I can go on and on about reasons why not to support this project.*
[158] EN-AR OH 2010: *The water is fluid and moves so it will be more easily contaminated then rock.*
[159] EN- BL CLC 2007: *The trip to Kiggavik was very good, but what will become of that small Lake that was being used or draining out?*
[160] EN-RB KIA 2010: *Will there be affects on water?*

- 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 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 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.
- Contact water and sewage will be treated to meet or exceed required standards prior to release to the environment. For example, the design of the WTP is such to provide an effluent that met or exceeded all appropriate regulations such as the discharge limits for deleterious substances as stipulated in MMER as well as site-specific discharge limits.
- During decommissioning, the ground surface will be recontoured and natural flow patterns will be restored.

8.6 Compliance and Environmental Monitoring for Water Quality

Compliance and environmental monitoring plans associated with water quality incorporate IQ guiding principles (GN 2009), including Qanuqtuurnunnarniq (being resourceful to solve problems), Avatimik Kamattiarniq (environmental stewardship), Pilimmaksarniq (skills and knowledge acquisition) and Piliriqatigiingniq (collaborative relationships or working together for a common purpose). The importance of environmental monitoring was highlighted through IQ interviews and engagement feedback (e.g. EN-BL OH Nov 2013[161]).

- 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 analyzed and documented regularly according to Nunavut regulatory requirements and the MMER during mine operations, and during and after mine closure. The Waste Water Systems Effluent Regulations will be used as guidance to establish the monitoring program for treated sewage.
- 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

[161] EN-BL OH Nov 2013: *What about the environment? How do you know what is in the air and water and lichen that caribou eat?*

operations and closure phases of the Kiggavik Project, and on an annual basis during the post-closure phase (Tier 3, Technical Appendix 5M).

- 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 (Tier 3, Technical Appendix 4C).
- Water quality (metals, radionuclides, TSS, pH) will be monitored in appropriate lakes and streams to confirm results are within predicted or acceptable levels due to dust deposition and air emissions from Project activities. This monitoring will occur during the spring freshet throughout the operational life of the Project (Tier 3, Technical Appendix 5M).
- Water quality monitoring of the reflooded Andrew Lake Pit will 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 acceptable 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 Nunavut Impact Review Board (NIRB) Guidelines for the Kiggavik Project (NIRB, 2011) identify sediment quality as a Valued Environmental 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 environmental components such as water quality, aquatic organisms, fish habitat, and fish populations.

Refer to Section 4.1 for a discussion of issues and concerns raised during Inuit Qaujimajatuqangit (IQ) interviews and engagement initiatives.

Refer to Section 4.1.1 for a description of the influence of IQ and engagement data on the sediment quality assessment.

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/install in-water/shoreline structures	1
	Water transfers and discharge	1
On-Land Construction	Site clearing and pad construction (blasting, earth moving, loading, hauling, dumping, crushing	1

Table 9.1-1 Project – Environment Interactions and Effects – Sediment Quality

Project Phase	Project Activities/Physical Works	Change in Sediment Quality
Operation		
Mining	Mining ore (blasting, loading, hauling)	1
	Mining special waste (blasting, loading, hauling)	1
	Mining clean waste (blasting, loading, hauling)	1
Water Management	Discharge of treated effluents (including greywater)	2
Transportation	Truck transportation	1
	General traffic (Project-related)	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 surface drainage containment	1
	Remove in-water/shoreline structures	1
	Water transfers and discharge	1
On-land Decommissioning	Remove site pads (blasting, earth moving, loading, hauling, dumping)	1

NOTES:

Category 1 activities are those having an interaction with the aquatic environment that is likely to result in a minor environmental change, but a negligible residual effect on a Valued Component (VC) relative to baseline or guideline values in light of planned mitigation. Category 1 interactions are not expected to contribute to effects of other existing or reasonably foreseeable projects. As noted in the following section, screening of these project interactions indicates that Project effects will be minimal and no further assessment is warranted.

Category 2 activities are those activities that do interact with the aquatic environment and could result in a measureable environmental change that could contribute to significant residual effects on a VC relative to baseline or guideline values, despite the planned 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 (BMPs) have been incorporated into the Project design to control surface water runoff and minimize the potential for erosion. Refer to Tier 3, Technical Appendix 5O for a description of BMPs which will be followed to limit erosion and sediment transport and manage water during construction activities. In addition, watercourses diverted away from the mine site development areas will be 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 to result from these activities; 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, the effluent diffuser structure(s) and effluent discharge line(s) in Judge Sissons Lake, and the temporary spud barge dock in Baker 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. Installation of culverts at road crossings may also disturb stream sediments and result in short-term increases in turbidity and TSS levels immediately downstream of the crossing locations. Refer to Tier 3, Technical Appendix 5O, Section 2 for Project activities identified as requiring an erosion and sediment control plan and/or monitoring during construction, operations and decommissioning phases. The mitigation measures and monitoring activities provided in this document provide a conceptual plan; some combination of best management practices identified for each activity group will be used to mitigate changes in sediment quality from activities in and around water.

Because interactions associated with construction of in-water and shoreline structures will follow BMPs to minimize erosion, are limited in areal extent and are of short duration, large scale and/or long-term effects to sediment quality are not anticipated. Therefore, these interactions 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

Sediment disturbances and changes to sediment quality resulting from removal of water intake structures and connecting water intake lines, effluent diffuser structure(s) and effluent discharge line(s), culverts, and the spud barge dock are expected to be similar to those described for 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 and BMPs will be followed (Tier 3, Technical Appendix 5O), they are not expected to affect sediment quality. Therefore, 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

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. Details on BMPs associated with development of Andrew Lake Pit to limit erosion and sediment transport and manage water during construction activities are available in Tier 3, Technical Appendix 5O. 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. Turbidity levels within the portion of Andrew Lake that is being drained must be below the established threshold level for pumping to take place. If turbidity levels are too high to allow discharge into the downstream environment, the water from Andrew Lake will be treated as part of mine water effluent treatment. Because TSS-laden water will not be released from the dewatered portion of Andrew Lake to the downstream environment, no effects to water quality and sediment quality in the downstream environment are anticipated. Therefore, 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 operation of vehicles and heavy equipment, as well as from blasting, loading, and hauling mine ore and mine rock during the operations phase of the Project may affect sediment quality in nearby Local Assessment Area (LAA) lakes. Dust that settles on LAA vegetation in summer and fall, as well as on snow in winter, will be carried into lakes and streams along with the spring snowmelt, and will likely contribute to minor changes in TSS within LAA lakes. As described in Section 8.2.2, increases in TSS are expected to be of small magnitude and short duration. Therefore, this interaction is not expected to affect sediment quality. Therefore, it 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, these activities are not likely to affect sediment quality. Therefore, 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

Water removed from the pits and underground mines, site and stockpile drainage, and sewage will be treated before discharge to the aquatic environment. However, it is possible that treated effluent discharged from the Kiggavik and Sissons WTPs may affect surface water quality and sediment quality. Therefore, potential changes to the concentrations of sediment quality constituents as a result of effluent release are examined further in this assessment to confirm compliance with required standards and thresholds. The assessment is focused on changes to sediment quality constituents in Judge Sissons Lake. The environmental assessment of changes in sediment quality due to treated effluent discharge is presented in Section 9.2.1.

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(s) 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 effects from Project activities to assessment indicators and, ultimately, to VECs. Valued Environmental Components, assessment indicators, and measurable parameters used in assessing effects of Project activities on 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 1999a with updates to 2001). 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 exceed sediment quality guidelines (<CCME PEL).
- High: Project will affect sediment quality to the extent that several parameters exceed sediment quality guidelines (>CCME PEL)

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. A combination of national sediment quality guidelines (CCME, 1999a with updates to 2001), working benchmarks developed by the Canadian Nuclear Safety Commission (CNSC) (Thompson et al. 2005), and regionally-specific toxicity benchmarks (Liber et al. 2011) were used to evaluate potential effects from the Project to sediment quality. Where several benchmarks exist for a particular constituent of concern, the benchmarks were evaluated as a range of concentrations that may indicate possible effects. The CCME guidelines, which include ISQGs and PELs, were developed with the intention of being conservative; the CCME indicates the guidelines are intended to be used in conjunction with other information, including site-specific information related to background concentrations and biological assessments. The Lowest Effect Levels (LEL) and Severe Effect Levels (SEL) from Thompson et al. (2005) are specific to uranium-bearing regions of Canada (e.g, northern Saskatchewan and northern Ontario) and are considered CNSC working benchmarks. Liber et al. (2011) provide experimentally derived, regionally-specific sediment benchmarks for four key Constituents of Potential Concern (COPCs), namely arsenic, molybdenum, nickel and uranium, based on sediment toxicity tests undertaken with sediments collected from Wollaston Lake, Saskatchewan. Benchmarks applicable to sediment quality are summarized in Table 9.1-3.

Table 9.1-3 Summary of Sediment Quality Toxicity Benchmarks Used in the Assessment

	CCME (1999a, with updates to 2001)		Thompson et al. (2005)		Liber et al. (2011) [(a)]	
Constituent	ISQG	PEL	LEL	SEL	NOEC	IC25
Metals (µg/g dw)						
Arsenic	5.9	17	9.8	346.4	-	174
Cadmium	0.6	3.5	-	-	-	-
Cobalt	-	-	-	-	-	-
Copper	35.7	197	22.2	268.8	-	-
Lead	35	91.3	36.7	412.4	-	-
Molybdenum	-	-	13.8	1,238.5	3,589	-
Nickel	18[(b)]	35.9[(b)]	23.4	484	-	189
Selenium	-	-	1.9	16.1	-	-
Uranium	-	-	104.4	5,874.1	-	964
Zinc	123	315	-	-	-	-

Table 9.1-3 Summary of Sediment Quality Toxicity Benchmarks Used in the Assessment

Constituent	CCME (1999a, with updates to 2001)		Thompson et al. (2005)		Liber et al. (2011) [(a)]	
	ISQG	PEL	LEL	SEL	NOEC	IC25
Radionuclides (Bq/g dw)						
Lead-210	-	-	0.9	20.8	-	-
Polonium-210	-	-	0.8	12.1	-	-
Radium-226	-	-	0.6	14.4	-	-
Thorium-230	-	-	-	-	-	-

NOTES:

CCME Canadian Council of Ministers of the Environment

ISQG Interim Sediment Quality Guideline

LEL Lowest Effects Level

PEL Probable Effect Level

SEL Severe Effects Level

NOEC No Observed Effects Concentration

IC25 Inhibitory Concentration yielding a reduction in growth of 25 percent (%)

µg/g dw = micrograms per gram dry weight; - = not available or not applicable; Bq/g dw = Bequerels per gram dry weight

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).

(a) IC25 values were reported where available. No effects on survival or growth were observed in test organisms exposed to molybdenum; therefore, the highest test concentration (NOEC) was reported.

(b) Guideline under review by CCME.

The significance of changes in sediment quality parameters is determined by assessing effects to the user of the sediment 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, and are evaluated by comparing measured values with established sediment quality guidelines and toxicity benchmarks (see Table 9.1-3). A low-magnitude consequence is one in which the changes to sediment quality are not expected to affect water users. A high-magnitude 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 WTPs will be examined. The assessment is focused on Judge Sissons Lake.

9.2.1.1 Analytical Methods for Assessing Changes in Sediment Quality

Treated effluent discharge from the Kiggavik and Sissons WTPs may affect surface water quality. Subsequently, changes in surface water may affect sediment through processes such as deposition of settling solids, adsorption, and diffusion. Parameters in water that were identified as COPCs for sediment include: radionuclides (uranium-238, thorium-230, radium-226, lead-210, and polonium-210) and select metals (arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, and zinc). Detailed modelling of COPC concentrations in the receiving environment (i.e., Judge Sissons Lake), was completed using the LAKEVIEW dispersion model (Tier 3, Technical Appendix 8A). The LAKEVIEW model assumes that general parameters such as ammonia, sulphate, total dissolved solids, and chloride do not undergo any removal from the water column to sediments due to sorption. As such, ammonia, sulphate, TSS and chloride were not included as COPCs in the sediment quality effects assessment.

The probabilistic watershed model LAKEVIEW has been applied to several 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 constituents, 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 the Kiggavik Project is provided in Tier 3, Technical 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 estimate the quantities of metals and radionuclides present in the sediment that are available for exchange with the water column. Although different discharge locations and durations of release were examined, modeled sediment quality results changed very little; therefore, the scenario carried through the assessment was based on separate discharges from the Kiggavik water treatment plant and Sissons water treatment plant as well as an extended operating period (25 years) followed by a 22-year period of consolidation where water treatment would be required. It is anticipated the assessment adequately accounted for the uncertainty and variability in the discharges, as well as the behaviour of treated effluent in the environment.

9.2.1.2 Baseline Conditions for Changes in Sediment Quality

Section 5.4 provides a summary of the data collected during the baseline monitoring program (see also Tier, 3, Technical Appendix 5C). Mean and median concentrations of COPCs in the sediment samples were below the appropriate ISQG or LEL. Due to the variability associated with sediment from discrete samples, the comparison of the average concentration to the guideline was considered the most appropriate point of comparison. It is noted however, that with the exception of zinc, the upper 95th percentile and maximum measured concentrations are below the PEL/SEL for all COPCs. The maximum measured zinc concentration in sediment was 440 micrograms per gram dry weight (µg/g dw), which is above the SEL of 315 µg/g dw. This indicates that zinc concentrations may be naturally elevated within area sediments.

9.2.1.3 Effect Mechanism and Linkages for Changes in Sediment Quality

The release of COPCs from the WTP can affect water quality in the receiving environment. Changes in water quality can affect the concentration of COPCs in sediment. Elevated concentrations of COPCs in sediment may affect biota that reside in sediment (e.g., benthic invertebrates), as well as wildlife that may incidentally ingest sediment while feeding on aquatic biota. The potential effect of COPCs in sediment on benthic invertebrates is provided in Section 10 and uptake of sediment to wildlife is presented in Tier 3, Technical Appendix 8A.

9.2.1.4 Mitigation Measures and Project Design for Changes in Sediment Quality

The WTP was designed to provide an effluent that will comply with all appropriate regulations, such as the discharge limits for deleterious substances as stipulated in the Metal Mining Effluent Regulations (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 Tier 2, 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 among the segments; therefore, overall maximums are presented. Applicable sediment quality guidelines and/or toxicity benchmarks are also shown in Table 9.2.1, along with the average baseline concentration from the area (taken from Tier 3, Technical Appendix 8A, Table 3.2-4). For all COPCs with available sediment quality guidelines or benchmarks, predicted sediment concentrations were below the guidelines in all segments of Judge Sissons Lake, with the exception of arsenic, copper and nickel.

The mean and 95th percentile predicted concentrations of arsenic and nickel in sediment are higher than the CCME ISQG (CCME 1999a with updates to 2001) and the 95th percentile predicted concentrations are slightly elevated compared to the Thompson et al. (2005) LEL during all phases of the assessment, including baseline. Baseline arsenic concentrations were estimated to be 8.0 µg/g dw with a 95th percentile baseline concentration of 15 µg/g dw; the upper 95th percentile predicted sediment concentration of 10.5 µg/g dw indicates that the Project will have some effect on the levels of arsenic in sediment, but predicted concentrations are within the natural variation of baseline conditions. Predicted arsenic concentrations in sediment are below the CCME PEL (1999a with updates to 2001) of 17 µg/g dw, well below the Inhibitory Concentration (IC) that would be expected to result in a 25 percent (%) reduction in test organism growth (i.e., IC_{25} = 174 µg/g dw) (Liber et al. 2011), and well below the Thompson et al. (2005) SEL of 346.4 µg/g dw. Baseline nickel concentrations were estimated to be approximately 22.2 µg/g dw; the upper 95th percentile sediment concentration of 26.7 µg/g dw 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 below the CCME PEL (1999a with updates to 2001) of 35.9 µg/g dw, well below the IC that would be expected to result in a 25 percent (%) reduction in test organism growth (i.e., IC_{25} = 189 µg/g dw) (Liber et al. 2011), and well below the Thompson et al. (2005) SEL of 484 µg/g dw.

For copper, the mean and 95th percentile predicted concentrations in sediment are higher than the Thompson et al. (2005) LEL during all phases of the assessment in most segments of Judge Sissons Lake. Baseline copper concentrations were estimated to be 21.1 µg/g dw; the upper 95th percentile predicted sediment concentration of 26.4 µg/g dw indicates that the Project is not expected to have a substantial effect on the levels of copper in sediment. Predicted copper concentrations in sediment are below the CCME ISQG and PEL (1999a with updates to 2001) of 35.7 µg/g dw and 197 µg/g dw, respectively, and well below the Thompson et al. (2005) SEL of 268.8 µg/g dw.

Table 9.2-1 Maximum Predicted Mean and 95th Percentile Concentrations of Sediment Quality Parameters

COPC	Baseline		CCME (1999a)	Thompson et al. (2005)	Liber et al. (2011)[a]	Maximum Predicted Sediment Concentration	
	Average	95th Percentile	ISQG/PEL	LEL/PEL	NOEC/IC25	Mean	95th Percentile
Metals (µg/g dw)							
Arsenic	8.0	15.0	5.9/17	9.8/346.4	-/174	**8.8**	**10.5**
Cadmium	0.17	0.40	0.6/3.5	-	-	0.2	0.2
Cobalt	5.6	10.6	-	-	-	6,5	6.7
Copper	21.1	48.7	35.7/197	22.2/268.8	-	**23.7**	**26.4**
Lead	10.2	17.0	35/91.3	36.7/412.4	-	9.6	10.3
Molybdenum	1.3	3.1	-	13.8/1,238.5	3,589/-	5.2	9.1
Nickel	22.2	40.6	18[b]/35.9[b]	23.4/484	-/189	**23.8**	**26.7**
Selenium	0.4	0.9	-	1.9/16.1	-	0.5	0.7
Uranium	2.7	5.6	-	104.4/5,874.1	-/964	3.5	4.3
Zinc	69.9	130.0	123/315	-	-	76.1	95.2
Radionuclides (Bq/g dw)							
Lead-210	0.1	0.2	-	0.9/20.8	-	0.1	0.1
Polonium-210	0.1	0.2	-	0.8/12.1	-	0.1	0.1
Radium-226	0.04	0.08	-	0.6/14.4	-	0.04	0.05
Thorium-230	0.04	0.09	-	-	-	0.05	0.06

NOTE:

BOLD SHADED values exceed the lowest sediment guideline or toxicity benchmark,

For those COPCs with no applicable guideline, a comparison can be made between predicted concentrations over the timeframe of the Project and baseline conditions..

(a) IC25 values were reported where available. No effects on survival or growth were observed in test organisms exposed to molybdenum; therefore, the highest test concentration (NOEC) was reported.

(b) Guideline under review by CCME.

Based on Table 9.2-1, discharge of treated effluent from the WTPs is not expected to substantially alter concentrations of COPCs in sediment. Maximum predicted 95th percentile concentrations are within the natural variation in measured background concentrations at the site. No residual effects associated with changes in sediment quality have been identified outside of Judge Sissons Lake.

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 will be monitored every three years during the operations and closure phases of the Kiggavik Project as part of the Aquatic Effects Monitoring Plan (Tier 3, Technical Appendix 5M).

9.3 Cumulative Effects Analysis for Sediment Quality

9.3.1 Screening for Cumulative Environmental Effects

Project-related residual effects to sediment quality may occur within Judge Sissons Lake in the Mine Site LAA, but will diminish to background levels before reaching the outlet of Judge Sissons Lake. Should monitoring results identify any residual effects to sediment quality downstream of Judge Sissons Lake, these effects would have potential to overlap with other projects and activities that occur or may occur in the future, and may therefore act cumulatively on sediment quality.

The screening for cumulative effects to sediment quality was conducted to determine if cumulative environmental effects are likely 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 Volume 1, Appendix 1B. Of these projects, no local, Nunavut, or Far Future Scenario projects from the Project Inclusion List are expected to affect sediment quality within the spatial (i.e., in Judge Sissons Lake) and temporal (i.e., throughout the duration of sediment quality effects from the Kiggavik Project) boundaries associated with this Project. Therefore, no cumulative effects to sediment quality are predicted for the Kiggavik Project.

9.4 Summary of Residual Effects on Sediment Quality

9.4.1 Project Effects

Predicted sediment concentrations for all COPCs with available sediment quality guidelines, were below the guideline levels in all segments of Judge Sissons Lake, with the exception of arsenic, copper, and nickel. Based on modelled data for COPCs, the mean and 95th percentile predicted concentrations of arsenic and nickel in sediment were slightly elevated compared to the Thompson et al. (2005) lowest LEL for all phases of the assessment, including baseline. Baseline arsenic concentrations were estimated to be 8.0 µg/g dw with a 95th percentile baseline concentration of 15 µg/g dw. Baseline nickel levels were estimated at 22.2 µg/g with a 95th percentile baseline concentration of 40.6 µg/g dw. Therefore, the upper 95th percentile sediment concentrations of 10.5 µg/g dw and 26.7 µg/g dw of arsenic and nickel, respectively, for the assessment scenario indicates that the Project is not expected to have a substantial effect on the levels of arsenic and nickel in sediment and predicted concentrations are within the natural variability of baseline sediment concentrations. Predicted arsenic and nickel concentrations in sediment are below the CCME PEL (1999a with updates to 2001), well below the Thompson et al. (2005) SEL and the IC that would be expected to result in a 25 percent (%) reduction in test organism growth from Liber et al. (2011).

Similarly for copper, the mean and 95th percentile predicted concentrations in sediment are higher than the Thompson et al. (2005) LEL during all phases of the assessment in most segments of Judge Sissons Lake. Baseline copper concentrations were estimated to be 21.1 µg/g dw with a 95th percentile baseline concentration of 48.7 µg/g dw. The upper 95th percentile predicted sediment concentration of 26.4 µg/g dw indicates that the Project is not expected to have a substantial effect on the levels of copper in sediment. Predicted copper concentrations in sediment are below the CCME ISQG and PEL (1999a with updates to 2001), and well below the Thompson et al. (2005) SEL.

Minor Project-related residual effects to sediment quality are expected to 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 sediment 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 incidentally ingest sediment while feeding on aquatic biota.													
Construction		N	-	-	-	-	-	-	-	N	L	H	Monitoring to confirm metals and radionuclide concentrations in sediment rates are not increasing above predicted levels.
Operation	Design of WTP	Y	N	L	L	LT	C	R	U				
Decommissioning and Abandonment		N	-	-	-	-	-	-	-				

KEY

Direction:

P Positive

N Negative

Magnitude:

Use quantitative measure; or

N Negligible: No discernible effect on sediment quality.

L Low: Project will measurably affect sediment quality but these changes will be within the range of natural variability.

M Medium: Project will affect sediment quality to the extent that some parameters exceed sediment quality guidelines (<CCME PEL).

H High: Project will affect sediment quality to the extent that several parameters exceed sediment quality guidelines (>CCME PEL)

CCME = Canadian Council of Ministers of the Environment

PEL = probable effects levels

Geographic Extent:

Use quantitative measure; or

S Site-specific: area of lake or stream

L Local assessment area

R Regional assessment area

Duration:

Use quantitative measure; or

ST Short term: sediment quality returns to baseline conditions during operations

MT Medium term: sediment quality returns to baseline conditions during final closure period

LT Long term: sediment quality returns to baseline post-closure

P Permanent change in sediment quality

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 RAA

N Effect will not or is not likely to interact with other past, present or foreseeable projects or activities in RAA

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 sediment quality 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. On average, the models predict a 34% increase in precipitation; this increase is typically distributed throughout the year; however, the most dramatic increases are expected occur in fall.

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 23 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 assessment. The increased volumes of water flowing through the lake would flush COPCs out of the lake more quickly, thereby reducing residence times and the potential for accumulation in sediments.

9.5 Mitigation Measures for Sediment Quality

This section summarizes the Project effects considered for sediment quality. Many of the mitigation measures associated with sediment quality incorporate IQ guiding principles (GN 2009), including Qanuqtuurnunnarniq (being resourceful to solve problems), Avatimik Kamattiarniq (environmental stewardship), and Pilimmaksarniq (skills and knowledge acquisition). Mitigation measures and Project design modifications that will be implemented to limit changes to sediment quality are listed below.

- 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 BMPs.
- The Andrew Lake pit will be dewatered at a rate such that effects to sediment quality in Andrew Lake and downstream areas are minimized.
- The Andrew Lake Pit area will be dewatered after the spring freshet and before freeze-up (July/August).
- Water from the Andrew Lake Pit will be discharged into large waterbodies to reduce effects to sediment quality.
- Wastewater and sewage will be treated so that compliance with required standards is achieved prior to release to the environment. For example, the WTP has been designed to produce an effluent that complies with all appropriate regulations, such as the discharge limits for deleterious substances as stipulated in MMER, as well as site-specific discharge limits.
- During decommissioning, the ground surface will be recontoured and natural flow patterns will be restored.

9.6 Compliance and Environmental Monitoring for Sediment Quality

Compliance and environmental monitoring plans associated with sediment quality incorporate IQ guiding principles (GN 2009), including Qanuqtuurnunnarniq (being resourceful to solve problems), Avatimik Kamattiarniq (environmental stewardship), Pilimmaksarniq (skills and knowledge acquisition) and Piliriqatigiingniq (collaborative relationships or working together for a common purpose).

Sediment quality will be monitored in the two receiving basins of Judge Sissons Lake, as well as in the main body of Judge Sissons Lake, every three years as part of the Aquatic Effects Monitoring Plan (Tier 3, Technical Appendix 5M).

10 Effects Assessment for Aquatic Organisms and Fish Habitat

10.1 Scope of the Assessment for Aquatic Organisms and Fish Habitat

The Nunavut Impact Review Board (NIRB) Guidelines for the Kiggavik Project (the Project) 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 Environmental Component (VEC) (NIRB 2011). Potential effects to the components of this VEC were identified as areas of concern during public engagement (EN-BL NIRB 2010[162]). For the purposes of this assessment, aquatic organisms and fish habitat have been combined into a single VEC because they are supporting environmental components for maintaining healthy fish populations. Aquatic organism populations and fish habitat must be healthy and productive if fish populations are to remain healthy, resilient, and available for human consumption. Healthy aquatic organism populations and fish habitats are supported by good quality water and sediments. Fish populations, distributions, and tissue chemistry are considered as a separate VEC; these are described in Section 11.

Refer to Section 4.1 for a discussion of issues and concerns raised during Inuit Qaujimajatuqangit (IQ) interviews and engagement initiatives.

Refer to Section 4.1.1 for a description of the influence of IQ and engagement data on the aquatic organisms and fish habitat assessment.

10.1.1 Project–Environment Interactions and Effects

Information was gathered from the environmental and engineering teams for the 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 4.4-1.

[162]EN-BL NIRB 2010: *Concerns regarding water quality, terrestrial wildlife and their habitat, marine mammals and their habitat, birds and their habitat, fish and their habitat, heritage resources in the area, Inuit harvesting activities, local development in the area, tourism in the area, and human health.*

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/install 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
Supporting Activities	Transport fuel and construction materials	1	0
	Air transport of personnel and supplies	1	0
Operation			
Water Management	Freshwater withdrawal	0	1
	Collection of site and stockpile drainage	1	0
	Water and sewage treatment	1	0
	Discharge of treated effluents (including grey water)	2	0
Transportation	Truck transportation	1	2
	Marine transportation	1	0
	Air transportation of personnel, goods and supplies	1	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

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
On-land Decommissioning	Remove site pads (blasting, earth moving, loading, hauling, dumping)	0	2
Category 1 activities are those having an interaction with the aquatic environment that is likely to result in a minor environmental change, but a negligible residual effect on a Valued Component (VC) relative to baseline or guideline values in light of planned mitigation. Category 1 interactions are not expected to contribute to effects on other existing or reasonably foreseeable projects. As noted in the following section, screening of these Project interactions indicates that Project effects will be minimal and no further assessment is warranted. **Category 2** activities are those activities that do interact with the aquatic environment and could result in a measureable environmental change that could contribute to significant residual effects on a VC relative to baseline or guideline values, despite the planned 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 Project-environment 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 completed to prepare areas for development of mine and mill site infrastructure. To facilitate infrastructure development, stream crossing structures will be installed on the ore haul road between the Kiggavik and Sissons mine sites, the access roads to the water intake locations and effluent discharge points, and the road to the airstrip. Because most medium- to large-sized streams support fish during the summer months, installation of stream crossing structures is likely to result in the permanent alteration or destruction of fish habitat. To reduce and mitigate these effects, best management practices (BMPs) will be incorporated into stream crossing design and installation (Tier 3, Technical Appendix 5O) to minimize the amount of fish habitat permanently altered or destroyed at each crossing.

Three stream channels will be diverted to facilitate mine site and infrastructure development at the Kiggavik site. The diverted stream sections will include the middle section of the northeast inflow to Pointer Lake, the top section of a tributary to the northeast inflow of Pointer Lake, and the top section of the northwest inflow to Pointer Lake (Volume 2, Appendix 2E). The diversions will be located on stream sections that are not reported as fish-bearing and/or are located well upstream of documented fish assemblages.

As part of developing the mine site and infrastructure at the Sissons site, the lower portion of the stream between Mushroom Lake and End Grid Lake (i.e., Mushroom/End Grid Stream) will be diverted and reconnected with its natural drainage system at End Grid Lake. The diverted portion will be in-filled to allow for construction of the Sissons mine site. The diverted portion of the stream is not considered to be critical fish habitat; use of the stream is thought to be limited to seasonal fish passage during the spring freshet. No fish of any species or size were captured or observed in this stream section during baseline surveys (Technical Appendix 5C, Table 11.2-1). The shallow depth of the stream (maximum depth of 0.2 metres [m] in the main channel) and other waterbodies in the Lower Lake sub-basin, means that overwintering habitat is restricted to Mushroom, Cigar, and Judge Sissons lakes (Tier 3, Technical Appendix 5C, Section 11.2.5.2). Because ice thicknesses commonly reach 2.5 m or greater at the Project site, it is likely that this stream will freeze to its substrates in winter. This is expected to prevent lake trout (*Salvelinus namaycush*), which require unfrozen substrates for their overwintering eggs, from spawning in Mushroom/End Grid Stream. The shallow depth is also unlikely to be suitable for spawning Arctic grayling (*Thymallus arcticus*); the portion of stream proposed for diversion is also too far downstream from Mushroom Lake (at least 500 m), has a braided channel, and has generally unsuitable substrates for Arctic grayling spawning (primarily silt, with some cobble, gravel and boulder). Arctic grayling prefer to spawn in fast-flowing streams over clean cobble and gravel substrates. As a result, this interaction was classified as Category 1 for effects to fish habitat, and was not carried forward to the residual effects analysis.

During the mine development process, a portion of Andrew Lake will be dyked off and dewatered to construct the Andrew Lake mine pit at the Sissons site. Construction of the berm in Andrew Lake will result in the permanent alteration or destruction of 13.5 hectares (ha) of seasonal-use fish habitat in the east end of Andrew Lake. Andrew Lake is shallow (maximum depth = 1 m, mean depth = 0.2 m) and freezes to the bottom during the winter. As such, fish are only present in Andrew Lake and the connecting streams during the open-water season. Use of habitat in Andrew Lake by fish appears to be limited to foraging and rearing activities during the open-water season; fish habitat surveys indicate that Andrew Lake does not support spawning activities. Fish that are present in Andrew Lake during the open water period migrate there from downstream overwintering lakes such as Judge Sissons Lake. Therefore, the loss of 13.5 ha of seasonal foraging habitat will reduce the availability of forage and rearing habitat within Andrew Lake, but will not change spawning and overwintering conditions in the Local Assessment Area (LAA). All of the fish species documented in Andrew Lake under baseline conditions are expected to continue to access the lake seasonally following the construction of the berm. The permanent alteration or destruction of seasonal fish habitat in Andrew Lake is addressed in the Conceptual Fisheries Offsetting Plan (CFOP) for the Project. However, because the CFOP has not been accepted by Fisheries and Oceans Canada (DFO) and finalized, this interaction is classified as Category 2, and is carried forward to the analysis of residual effects.

Final-closure

Removal of Freshwater Diversions and Site Drainage Containment Systems; Site Pad Removal

All stream diversions and stream crossing structures will be removed during the final closure phase of the Project, and stream substrates restored to pre-development conditions. Although no long term or large scale changes to fish habitat associated with freshwater diversions and road construction are anticipated, this Project effect is carried forward to the detailed analysis of residual effects because the CFOP has not been finalized.

Type 3 mine rock at the Sissons site will be placed into the mined-out Andrew Lake open pit and covered. The Andrew Lake pit will then be flooded to create a pit lake (Tier 2, Volume 2, Section 13.4.2). Flooding will either be allowed to occur naturally as the result of rain, snow melt, and seepage, or the natural filling of the pit may be complemented by diverting flow from a larger waterbody, such as Judge Sissons Lake or Andrew Lake. During community engagement, concerns were raised regarding whether ...*a decommissioned lake [will] have fish habitat* (EN-CH OH 2010[163]). Concentrations of constituents of potential concern (COPCs) associated with the natural filling rate and enhanced pit filling conditions are not anticipated to represent a risk to aquatic life; pit water could discharge to surrounding surface water bodies without concern after closure (Tier 3, Technical Appendix 2R, Attachment A). From a Project management perspective, the outcome of flooding the pit needs to be known before the end of the physical decommissioning period. Acceptable surface water quality in the flooded pit is a prerequisite to removing the dewatering berm in Andrew Lake and thus restoring the lake to its original state. It is therefore possible that the Andrew Lake pit could potentially support some fish habitat in the future, beyond decommissioning.

Construction

Construction and Installation of In-Water/Shoreline Structures

Installation of water intake structures and connecting water intake lines in Mushroom and Siamese lakes, the effluent diffuser structure and effluent line in Judge Sissons Lake, and the temporary spud barge dock in Baker Lake is expected to result in the permanent alteration or destruction of fish habitat. Concerns regarding potential impacts to fish habitat in Baker Lake from construction of the dock and other in-water activities were raised during public engagement (EN-CH NIRB 2010[164]; EN-

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[163] EN-CH OH 2010: *Does a decommissioned lake have fish habitat?*
[164] EN-CH NIRB 2010: *Concerns regarding the barges travelling up the Chesterfield Inlet into Baker Lake and the building of a dock and wharf in Baker Lake. Potential impacts to fish, fish habitat and consumption of fish by the people of Baker Lake. Lake is shallow and it is a concern.*

CI NIRB 2010[165]). Accidents and malfunctions such as spills are addressed in Tier 2, Volume 10. If an all-season access road is required for the Project (see Tier 2, Volume 2, Section 10.4.4.1), construction of aprons at the ferry crossing site on the Thelon River will also result in the permanent alteration or destruction of a small area of fish habitat. Any permanent alteration or destruction of fish habitat is identified in the CFOP for the Project. The CFOP also identifies measures to avoid, mitigate or offset potential serious harm to fish, including the permanent alteration or destruction of supporting fish habitats. Because the CFOP 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.

Final-closure

Removal of In-Water/Shoreline Structures

Removal of water intake structures and connecting water intake lines in Mushroom and Siamese lakes, the effluent diffuser structure and effluent line in Judge Sissons Lake, and the temporary spud barge dock in Baker Lake is also expected to result in the permanent alteration or destruction of fish habitat. Should a ferry crossing be required to facilitate the optional all-season access road (see Tier 2, Volume 2, Section 10.4.4.1), removal of the ferry crossing aprons from the shoreline of the Thelon River may also result in the permanent loss or alteration of fish habitat. However, any effects are expected to be reduced from that incurred during the initial structure construction and/or installation. Any predicted permanent alteration or destruction of fish habitat is identified in the CFOP for the Project; the CFOP also identifies avoidance, mitigation, and offsetting measures that are expected to maintain or improve area fisheries, in light of potential Project effects. The CFOP has not yet received the approval of DFO or the government of Nunavut. Therefore, 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. Water balance calculations have been completed for the Mushroom and Siamese lakes to confirm 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 5.0% of the under-ice volumes of Siamese Lake and 8.0% of the under-ice volume of

[165] EN-CI NIRB 2010*: Concerns regarding the location of the potential dock in Baker Lake and need to consider building it in deeper water. Concerns over potential spills and impacts to Baker Lake, the lake, the fish and aquatic environment and potential for the spill to travel downstream.*

Mushroom Lake; these percentages are below the 10% under-ice volume maximum acceptable withdrawal limit set by DFO for Arctic waters (DFO 2010) (Table 10.1-2). Winter drawdowns are expected to be about 10.4 centimetres (cm) for Mushroom Lake, and between about 15 cm and 20 cm in Siamese Lake, depending on the water availability scenarios that were evaluated (Table 10.1-3).

Table 10.1-2 Estimated Maximum Annual Water Withdrawal Volumes for Selected Waterbodies

Waterbody	Under-Ice Volume (m^3)	Maximum Winter 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	4.0 (equivalent of about 15 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 about 6 cm) 5.0 in the west basin (equivalent of about 20cm)
Mushroom Lake	240,000	24,000	20,100	8.0 (equivalent to 10.4 cm)

NOTES:

m^3 = cubic metres; % = percent; DFO = Fisheries and Oceans Canada; cm = centimetres.

Based on the water availability scenarios that were assessed, an under-ice water level drawdown between about 15 cm and 20 cm would destroy between 1.6% (0.12 ha) and 2.2% (0.16 ha), respectively, of potential lake trout spawning habitat in Siamese Lake. A drawdown of about 10.4 cm in Mushroom Lake would likely destroy approximately 11.0% (0.05 ha) of the potential lake trout spawning habitat area in Mushroom Lake (Table 10.1-3).

Table 10.1-3 Lake Trout (*Salvelinus namaycush*) Spawning Habitat Potentially Destroyed in Siamese Lake and Mushroom Lake

Waterbody / Scenario	Potential Lake Trout Spawning Area Available (m^2)	Estimated Under Ice Water Level Drawdown (cm)	Estimated Potential Lake Trout Spawning Habitat Loss		
			Surface Area (m^2)	Surface Area (ha)	Percent of Change (%)
Siamese Lake – both basins together	74,241	15 in both basins	1,163	0.12	1.57
Siamese Lake (October-March) and West Basin only (April-May)	74,241	6 in east basin 20 in west basin	1,631	0.16	2.20
Mushroom Lake	4,132	10.4	455	0.05	11.01

NOTES:

m^2 = square metres; cm = centimeters; ha = hectares; % = percent.

Although the proposed water withdrawals for both Siamese and Mushroom lakes are below the 10% maximum under-ice volume withdrawal limits specified by DFO (2010), a desktop study was completed to conservatively estimate the area of lake trout spawning habitat potentially altered by water withdrawal . It is anticipated that 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-referencing available data (e.g., substrate type and size, depth and slope of cobble substrates, 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. Locations of potential lake trout spawning habitat were identified at depths 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 at depths between 2 m and 6 m deep on the north shore of Mushroom Lake.

The quantity of lake trout spawning habitat potentially destroyed in Siamese Lake could be equal to approximately 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 quantity of lake trout spawning habitat potentially destroyed in Mushroom Lake is expected to be approximately 0.05 ha.

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 that allows a maximum withdrawal equivalent to 10% of the under-ice volume (DFO 2010).

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: Tier 3, Technical Appendix 5P Aquatic Technical Assessments of Water Withdrawal Locations and Baker Lake Dock Site.

NOTES:

[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; DFO = Fisheries and Oceans Canada; km = kilometres; cm = centimetres.

Withdrawal of water from LAA lakes for potable and mill supply purposes, as well as annual construction and maintenance of the proposed winter road, is not anticipated to result in substantial effects to fish habitat, and is unlikely to affect fish populations. Therefore, this interaction is ranked as a Category 1 effect and is not carried forward for detailed analysis of residual effects.

Construction and Operation

Air transportation of personnel, goods, and supplies; Transport fuel and construction materials; Marine transportation

A non-indigenous species is an introduced species living outside of its native distributional range. An invasive species is a non-indigenous species that adversely affects the new ecosystem's structure and/or function, resulting in ecological, social or economic harm to the area. Not all non-indigenous species are considered invasive.

The biological invasion process includes a number of factors required for the establishment of a non-indigenous or invasive species into a new area (Chan et al. 2012; DFO 2012):

1. Transport - founding individuals must be taken up by, and survive conditions within, a transport vector to be moved from the source region to a new environment.
2. Survival - once released, the founding individuals must survive in the new environment.
3. Establishment - enough individuals of a species successfully arrive, survive, and form a reproductive population.
4. Expansion – established population may then spread from the initial, localized area by various means to become widespread in a region.

The Canadian Council of Fisheries and Aquaculture Ministers Aquatic Invasive Species Task Group (CCFAM-AISTG 2004) notes that the most effective approach to dealing with invasive species is to manage the pathways through which invasive species enter and spread through Canadian waters. For the Kiggavik Project, the potential pathway for aquatic invasive species to enter the LAA is through shipping. In this context, shipping includes marine transportation and air transportation during Project construction and operation. Ground shipping or truck transportation is not considered as a pathway for invasive species since all vehicular traffic will originate and end within the LAA. There are no roads connecting Baker Lake to other Kivalliq communities or areas of Canada.

Marine shipping includes two main vectors for invasive species: ballast water and hull fouling (Molnar 2008; DFO 2012). AREVA's Shipping Management Plan (Tier 3, Technical Appendix 2R Marine Transportation) outlines best practices for ballast water management and use of anti-fouling coatings on vessels to minimize potential introduction of non-indigenous or invasive freshwater species through marine shipping activities. Project shipping activities from marine areas into Baker Lake (freshwater) are not likely to introduce freshwater aquatic invasive species. Ships traveling to Baker Lake and Chesterfield Inlet will not contain much or any ballast water, since ships arriving at these ports will be fully loaded with material (cargo, fuel) for delivery. Any freshwater species that may foul ship hulls are likely to die in transit as vessels travel to and from Baker Lake through marine waters. Ships which pass through highly variable environments, such as moving from low salinity coastal waters to euhaline ocean waters, pose lower invasion risk than ships operating within a more continuous environment (DFO 2012).

There are few scenarios where non-indigenous or invasive aquatic species could be taken up on a plane and survive air transportation into the LAA. Considering the supplies and materials that may be shipped via air, aquatic field sampling equipment may be the only vector with the potential to introduce non-indigenous aquatic species. Environmental consultants contracted to help with AREVA's aquatic monitoring programs may bring equipment which was previously used in water bodies in other areas of Canada. To mitigate the entry of freshwater species through air transportation AREVA will require that aquatic field sampling equipment such as boats, motors, and dredges be cleaned, drained, and dried prior to arrival and use in Kiggavik Project area water bodies. This type of mitigation is commonly recommended to prevent the potential spread of invasive species from recreational boating (Self and Larratt 2013).

As outlined above, introduction of non-indigenous freshwater aquatic species into the LAA through Project activities is unlikely; subsequent survival and establishment of non-indigenous species are additional barriers to full biological invasion. Climatic conditions are expected to be a major barrier to establishment of freshwater invasive species into the Kiggavik Project area as a result of Project activities. Survival of non-native species in Nunavut is limited by the cold climate (GN DoE 2014, internet site). The adaptations necessary to survive Arctic conditions generally limits the ability of many non-indigenous species to survive and/or become invasive.

Although the Aquatic Effects Monitoring Plan (AEMP; Tier 3, Technical Appendix 5M) is not specifically designed to monitor for invasive species, regular sampling of benthic invertebrate and fish communities provides an opportunity to detect non-indigenous or invasive species throughout the life of the Project. Indeed research in Ontario notes that a high percentage of non-indigenous aquatic species were detected incidentally through other (non-targeted) monitoring programs (Lui et al. 2007). Should any non-indigenous aquatic species be detected during the AEMP this information will be communicated to the GN DoE as per their guidelines (GN DoE 2014, internet site). AREVA is also aware that DFO is proposing regulations to manage the threat of aquatic invasive species in Canada. AREVA will review and assess compliance with the Aquatic Invasive Species Regulations once available.

The potential for introduction of aquatic non-indigenous or invasive species through marine and air transportation is low and is not anticipated to result in substantial effects to aquatic organism abundance or distribution. Therefore, 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 COPCs relative 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 are therefore considered to be of higher quality (Table 10.1-5). In terms of habitat quality, Inuit Qaujimajatuqangit (IQ) indicates that *…[i]nland trout are seen with more red meat compared to the past. Meat is less red if there is less sand and rock in the rivers* (IQ-ARVJ 2011[166]). There is concern that the Project may change the types of substrates (i.e., sand, rock) available to fish in rivers, and that such changes may alter the quality of fish flesh (IQ-AR IQ 2011[167]). One IQ comment described an understanding that fish flesh can change depending on water depths (IQ-AR IQ 2011[168]).

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 are available for lakes and streams in the LAA to confidently estimate potential changes to 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
COPC = Constituent of Potential Concern.		

166 IQ-ARVJ 2011: *Inland trout are seen with more red meat compared to in the past. Meat is less red if there is less sand and rock in the rivers.*
167 IQ-AR IQ 2011:*…. less sand and rock in the rivers, the trout will have less red meat. Fish in shallower water are darker in colour…..*
168 IQ-AR IQ 2011:*…. less sand and rock in the rivers, the trout will have less red meat. Fish in shallower water are darker in colour…..*

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 mixtures of compounds (e.g., exposure to multiple metals) and multiple stressors that results from limitations in the scientific database. These boundaries were identified and the assessment took this uncertainty into account through:

- a conservative assessment approach,
- adoption of an Ecological Risk Assessment (ERA) process (see Tier 3, Technical Appendix 8A), and
- a commitment to aquatic monitoring during operations to confirm Environmental Assessment (EA) predictions. An Environmental Effects Monitoring (EEM) program under Metal Mine Effluent Regulations (MMER) will be instituted to determine whether effluent discharge is having quantifiable effects on the aquatic ecosystem (see Tier 3, Technical Appendix 5M).

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 spawning habitat). Descriptors of the magnitude of effect are listed below.

- Negligible: The Project will not affect fish habitat in waterbodies in the LAA.
- Low: 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 Regional Assessment Area (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 water quality parameters (e.g., metals), magnitude is defined by whether measured values exceed aquatic biota toxicity values specific for each compartment (e.g., macrophytes, invertebrates) of aquatic biota.

10.1.5 Standards or Thresholds for Determining Significance

Under the NIRB Project Specific Guidelines, the environmental assessment (EA) 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; effects beyond threshold criteria are expected to elicit a residual environmental effect that would be considered significant. These threshold criteria and standards were selected in consideration of available federal and territorial regulatory requirements, standards, objectives, or guidelines applicable to the VEC (see Section 8.3 for Water Quality). In addition, aquatic toxicity data were used to directly assess the potential effects on aquatic biota.

Toxicity reference values (TRVs) specific to different aquatic biota were used to judge whether the predicted exposures may potentially have an adverse effect on aquatic 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. 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 were selected. The TRVs selected for use for the 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 because although it is not a COPC, hardness 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 Tier 3, Technical Appendix 8A, Attachment G.

For radioactive parameters, recommendations from various agencies were reviewed. Based on N288.6 (CSA 2012), a reference dose limit of 9.6 milliGray per day (mGy/d) was selected for all types of aquatic biota.

Table 10.1-6 Selected Toxicity Reference Values for Aquatic Biota

COPC	Units	Aquatic Plants	Phytoplankton	Zooplankton	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 Canadian Water Quality Guideline (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

Potential changes in a measurable parameter or Valued Component (VC) resulting from Project or cumulative effects were evaluated against 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, or change 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 unless the permanent alteration or destruction of fish habitat is anticipated to adversely affect the sustainability and productivity of commercial, recreational, or Aboriginal (CRA) fisheries in the Project area.

10.2 Effects Assessment for Aquatic Organisms and Fish Habitat

The effects of the Project on the Aquatic Organisms and Fish Habitat VEC are defined in terms of 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

This section examines the potential effects to aquatic organism populations that may result from effluent release at the water treatment plant (WTP) and subsequent changes to concentrations of COPCs in water and sediment. The assessment is focused on Judge Sissons Lake.

10.2.1.1 Analytical Methods for Assessing Changes in the Abundance and Distribution of Aquatic Organism Populations

Treated effluent discharge from the Kiggavik and Sissons WTPs may affect surface water quality (Section 8.2.1). These changes are expected to affect the concentrations of COPCs in aquatic biota (i.e., aquatic macrophytes, benthic invertebrates, and plankton). Parameters in water that were identified as COPCs include: ammonia, chloride, sulphate, radionuclides (uranium-238, thorium-230, radium-226, lead-210, and polonium-210) and select metals (arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, and zinc). The approach used to predict concentrations of COPCs in water was discussed in Section 8 of this Tier 2 document and is described in further detail in Technical Appendix 8A.

The assessment of potential impacts from non-radiological COPCs to aquatic biota was conducted by comparing the estimated water concentrations to the biota-specific TRVs. The assessment was based on the total concentrations of each COPC, which considers both the baseline concentration plus the influence of Project emissions. For radioactive COPCs, the potential exposure from internally deposited (i.e., ingested) radionuclides, as well as external exposure, was included in a dose estimate. The concentration within aquatic biota was obtained through the use of a transfer factor that links the concentrations in different media (e.g. water and aquatic vegetation). In general, transfer factors were based on site-specific information and, because they were empirically based, included 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 type (i.e., alpha, beta or gamma radiation). Recent recommendations have focused on an RBE of 10 for alpha radiation and this value is consistent with N288.6 (CSA 2012). 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 WTP (to Judge Sissons Lake segment 2; Figure 8.2-5) and Sissons WTP (to Judge Sissons Lake segment 8; Figure 8.2-5), as well as 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 of radioactive COPCs in the environment.

The details of the assessment are provided in the Ecological Risk Assessment for the Project (Tier 3, Technical Appendix 8A).

10.2.1.2 Baseline Conditions for Change in the Abundance and Distribution of Aquatic Organism Populations

Because COPCs are naturally present in the environment, aquatic biota are exposed to these constituents in water and sediment under baseline conditions. Concentrations of radioactive COPCs in aquatic plants were measured and this baseline information was used to confirm the current (i.e., pre-Project) 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 COPCs from the WTPs can affect water quality in the receiving environment (assessment in Tier 2, Volume 5, Section 8.2.1). The quality of the water is critical for evaluating the potential effect on aquatic biota. Also, other ecological receptors, such as fish and wildlife, may consume aquatic biota and would be exposed to COPCs through this pathway.

The effects on water quality (Section 8.2.1) are expected to change with different phases of the Project (e.g., operational period, closure). Recovery of aquatic systems can be predicted in the final closure period of the Project.

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 meets or exceeds all appropriate regulations such as the discharge limits for deleterious substances as stipulated in the Metal Mining Effluent Regulations (MMER) as well as site-specific discharge limits. Design aspects, operational measures and other mitigation measures have been incorporated into the current Project plans to minimize Project-associated emissions and/or the potential effect of Project-related emissions. Further detail on the design of the WTP can be found in Tier 2, 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 COPCs were characterized by a simple screening index (SI). This index was calculated by dividing the predicted exposure by the TRV for each ecological receptor as follows:

$$Screening\ Index = \frac{Exposure}{Toxicity\ \mathrm{Re}ference\ Value}$$

Screening index (SI) values are not estimates of the probability of ecological effect. Rather, the SI values are correlated with the potential of an effect; higher SI values imply a greater potential for an effect. The exposure includes both the natural baseline levels as well as the influence of the Project emissions. Therefore, an SI value less than 1.0 indicates that the estimated total exposure is less than that associated with an adverse effect. The SI 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 in Judge Sissons Lake

	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	<0.01	<0.01	<0.01	<0.01	0.05	0.07	0.02	0.03
Arsenic	<0.01	<0.01	0.42	0.45	0.02	0.02	<0.01	<0.01
Cadmium	0.01	0.02	0.06	0.09	0.33	0.57	**2.4**	**4.1**
Cobalt	0.01	0.01	<0.01	<0.01	0.16	0.16	0.13	0.13
Copper	0.21	0.21	0.85	0.85	**1.9**	**1.9**	**1.9**	**1.9**
Lead	<0.01	<0.01	<0.01	<0.01	0.98	0.98	0.02	0.02
Molybdenum	<0.01	<0.01	<0.01	<0.01	0.01	0.03	0.02	0.03
Nickel	0.07	0.07	0.06	0.06	0.11	0.11	0.15	0.16
Selenium	<0.01	<0.01	0.03	0.03	]0.10	0.11	0.10	0.11
Zinc	0.34	0.34	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**
Un-ionized Ammonia	n/a	n/a	<0.01	0.01	0.06	0.10	0.05	0.07
Chloride	0.05	0.08	0.11	0.17	0.45	0.71	0.22	0.35

Table 10.2-1 Screening Index Values for Aquatic Biota in Judge Sissons Lake

	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
Sulphate	0.24	0.36	0.18	0.27	0.19	0.28	0.81	**1.2**
Radioactivity	0.01	0.01	0.16	0.16	0.02	0.02	0.04	0.04

NOTES:

Perc = percentile; n/a = not available; RBE = relative biological effectiveness; SI = screening index; COPC = constituent of potential concern; TRV = toxicity reference value

SI values for non-radiological COPCs are based on the maximum predicted water concentration compared to the TRV

SI values of radiological effects include the contribution from uranium-238, thorium-230, radium-226, lead-210 and polonium-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 COPCs have predicted SI values less than 1.0 for all segments of Judge Sissons Lake, with the exception of cadmium for zooplankton, copper for benthic invertebrates and zooplankton, zinc for phytoplankton, benthic invertebrates, and zooplankton, and sulphate for zooplankton.

Exceedances of the toxicity benchmarks for copper and zinc are only expected to occur in the JSL-7 section of Judge Sissons Lake and can be attributed to baseline copper concentrations in the area (refer to Figure 8.2-6 – the area labeled 'Base' on the left-hand side of each panel is the baseline water quality for each parameter). JSL-7 is the most shallow segment of the lake, and therefore it experiences the largest variation between summer and winter concentrations (Figure 8.2-5). A reminder that the model considers discharge of the Kiggavik WTP to JSL-2 and Sissons WTP to JSL-8. Due to winter ice cover, copper and zinc concentrations in water during the winter months are predicted to increase because of a reduced volume of free-flowing water. The SI values for copper and zinc were calculated using the maximum monthly mean and 95th percentile predicted concentrations and are therefore representative of winter conditions, and therefore times of reduced biological activity. Overall, no residual effect was identified for copper and zinc.

Table 10.2-1 indicates that exposure to cadmium may have implications for zooplankton in Judge Sissons Lake. Water hardness is an important consideration in the determination of the potential toxicity of cadmium. The water hardness in Judge Sissons Lake is naturally very low. However, as discussed in Section 8, the release of treated effluent will likely raise the water hardness to 100 to 200 milligrams per litre (mg/L). Under these conditions the toxicity of cadmium will be ameliorated. At a hardness of 100 mg/L, the lowest toxicity value available for zooplankton is 0.23 micrograms per litre (µg/L) (United States Geological Survey [USGS] 2010). The SI values that were derived for cadmium exposure in 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

Judge Sissons Lake Segment	Mean	95th Percentile
JSL-1	0.44	0.68
JSL-2	0.73	**1.16**
JSL-3	0.70	**1.23**
JSL-4	0.61	0.95
JSL-5	0.51	0.88
JSL-6	0.22	0.38
JSL-7	0.48	0.87
JSL-8	0.25	0.44

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 water hardness of 100 mg/L

JSL = Judge Sissons Lake; SI = screening index; TRV = toxicity reference value; µg/L = micrograms per litre; mg/L = milligrams per litre.

Based on the data presented in Table 10.2-1, sulphate exposure may result in adverse effects to zooplankton in Judge Sissons Lake. The JSL-3 and JSL-4 (95th percentile only) areas of Judge Sissons Lake were associated with SI values greater than 1.0 for sulphate exposure in zooplankton. The largest SI value was 1.2, and was determined for the 95th percentile in JSL-3. Hardness has an ameliorating effect on sulphate toxicity and this was demonstrated in the recent review of information and derivation of guidelines completed by the BC MOE (2013).

Overall, a residual effect was identified for cadmium and sulphate exposure to zooplankton. This is examined further in Table 10.2-3.

With regard to monitoring zooplankton, as part of the update of the Canadian Metal Mine Effluent Regulations (MMER), the Canada Centre for Mineral and Energy Technology (CANMET) Aquatic Effects Technology Evaluation (AETE) program was established to review appropriate technologies for assessing the impacts of mine effluent on the aquatic environment (AQUAMIN 1996). The Aquatic Effects Technology Evaluation Program concluded that the seasonal and highly variable nature of phytoplankton and zooplankton populations and community compositions limited their use as routine monitoring tools for evaluating environmental performance of a facility. Hence, zooplankton monitoring is not proposed within the Kiggavik routine monitoring program. It is noted that an Environmental Effects Monitoring (EEM) program under MMER will be implemented for the Project which is designed to identify potential effects on fish and fish habitat (benthic invertebrates). Any effects identified within the EEM are subject to further investigation into the cause of the observed differences. Proposed monitoring is discussed in Section 10.2.1.7 and Tier 3, Technical Appendix 5M.

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 effect 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 >2 and <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 Valued Environmental Component (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 there is potential for effects to zooplankton in Judge Sissons Lake as a result of cadmium exposure. Screening index (SI) values above 1.0 are identified for JSL-2 and JSL-3; however, the magnitude of the potential effect is classified as medium (Table 10.2-3). This is because the maximum SI values are expected to be achieved in winter, during a time of reduced biological activity, and the affected segments of Judge Sissons Lake represent less than 11% 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.

Like cadmium, increased sulphate exposure may affect some of the more sensitive zooplankton species in certain segments of Judge Sissons Lake; however, considering the low SI values (exceedance of SI only at the 95th percentile only) and the spatial extent of the impact, the zooplankton population of Judge Sisson Lake is expected to continue to function. Acknowledging that sulphate toxicity is ameliorated by hardness, consideration of the marginal exceedance of a non-hardness adjusted TRV and that sulphate levels are expected to meet the BC WQG, no effects are expected due to the presence of sulphate.

Overall, no significant adverse effects on the abundance and distribution of aquatic biota are expected to result from changes in COPC concentrations in the receiving environment from releases from the WTP, despite the identification of possible residual effects.

10.2.1.7 Compliance and Environmental Monitoring for Changes in the Abundance and Distribution of Aquatic Organism Populations

Benthic macroinvertebrate populations will be monitored regularly (i.e., every third year) during mine operation, closure, and post-closure as part of the Environmental Effects Monitoring (EEM) Program under the MMER for the Project 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 that will receive treated effluent, as well as at the outlet of Judge Sissons Lake.

10.2.2 Assessment of Changes to Fish Habitat

The federal Application for Authorization under Paragraph 35(2)(b) of the *Fisheries Act* (Government of Canada 2013) requires the development of a Fisheries Offsetting Plan (FOP) that will ensure there will be no residual adverse Project effects on the productivity of CRA fisheries. In general, development projects can potentially affect fish habitat in three ways: fish habitat may be temporarily altered, permanently altered, or destroyed. Permanent alteration and/or destruction of fish habitat are considered serious harm under the *Fisheries Act*, and have the potential to affect fisheries productivity.

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, foraging), and can be described according to area (square metres [m^2]) and type of habitat. Changes to fish habitat from the Project are measured according to the changes in area of available fish habitat; measured changes are considered to reflect temporary disturbances to fish habitat, as well as the permanent alteration and destruction of fish habitat. Under the serious harm prohibition in Section 35 of the *Fisheries Act*, any Project-related work, undertaking, or activity that results in serious harm to fish, including the permanent alteration and destruction of fish habitat, requires an

Authorization from DFO to proceed. Before an Authorization to proceed will be issued, a plan for the avoidance, mitigation and offsetting of serious harm 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, Section 10.0 of Technical Appendix 5C, and Attachment 5C-1.

In general, 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, as well as 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 since winter ice depths are usually up to 2.5 m thick. It is uncertain whether Caribou, Crash, Fox, Pointer, and Willow lakes, which have maximum depths between 2.0 and 3.0 m deep, are capable of supporting fish over winter.

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 overwintering lakes. The Thelon River flows year round and supports fall-spawning fish species. The diversity of fish species in streams is highest close to overwintering lakes, and decreases as you move upstream in the watershed (unless a deep, overwintering 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 permanently alter 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 constructing and maintaining Project infrastructure (e.g., roads to water intake and effluent discharge structures and the airstrip), and installation of the spud barge dock in Baker Lake.

Project activities that are likely to result in the permanent alteration and/or destruction of fish habitat are listed below.

- Four stream channels will be diverted to facilitate construction of the Kiggavik and Sissons sites. However, only one of the stream sections proposed for diversion is expected to support a documented fish assemblage. This is Mushroom/End Grid Stream, which flows 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. It is also assumed that fish species could use the Mushroom/End Grid Stream to migrate between the Mushroom and End Grid lakes during the high-flow period associated with spring freshet. Although the section of the stream immediately downstream of Mushroom Lake that is known to support fish will not be affected by Sissons Mine Site development, the majority of the remainder of the stream will be diverted around the Sissons Mine Site and reconnected with its natural drainage system 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. Mushroom and End Grid lakes, as well as the connecting Mushroom/End Grid Stream, are not considered traditional fishing areas. However, fish that use these areas on a seasonal basis (i.e., during the spring freshet) are able to access habitats in Judge Sissons Lake. Judge Sissons Lake is considered a traditional fishing area. Therefore, fish and seasonal-use habitats identified in the Mushroom/End Grid Stream may potentially contribute to a CRA fishery (see Technical Appendix 5L). None of the other stream sections proposed for diversion contain any documented fish communities, or the diversions are located in the stream headwaters, upstream of known fish assemblages.

- Development of the Andrew Lake Mine Pit will require construction of a berm across the north-east portion of Andrew Lake and subsequent removal of the water from the bermed section. This will destroy approximately 13.5 ha of shallow aquatic habitat in Andrew Lake. Andrew Lake provides seasonal rearing and foraging habitat for Arctic grayling, burbot (Lota lota), cisco (Coregonus artedi), and round whitefish (Prosopium cylindraceum). Andrew Lake is too shallow to support overwintering fish (i.e., maximum depth of 1.0 m; mean depth of 0.2 m) because winter ice depths in the region often reach 2.5 m. No traditional (i.e., Aboriginal), fishing is reported to occur at Andrew Lake. However, fish that use Andrew Lake seasonally originate from Judge Sissons Lake, which supports a CRA fishery.
- In the event that the All-Season Road option is constructed, permanent alteration and/or destruction of fish habitat will occur at the site of the proposed 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 permanently altered or destroyed. The estimated size of each apron is 30 m along the shoreline by 10 m towards deeper water, for a surface area of 0.030 ha each. On each bank, half of this surface area will be considered fish habitat loss (0.015 ha) due to construction, while the other half will be considered fish habitat alteration (0.015 ha) due to the rock rip rap that will replace the original fish habitat
- The spud barge dock in Baker Lake is designed to be a temporary structure and the amount of fill placed at the dock approach will have a limited footprint (Tier 2, Volume 2). The docking facility will be constructed by building a clean rock-fill approach approximately 30 to 40 m out into Baker Lake from the shoreline into sufficient depth of water (3 to 5 m) to float the spud barge dock. No dredging of the lake bottom is

anticipated. The area of shoreline habitat permanently altered or destroyed as a result of in-filling at the approach location will be small (between 0.06 and 0.08 ha).

- 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. This rock riprap represents a different habitat type than was present on the natural shoreline of Andrew Lake.
- Fish habitat will be altered by the installation, and eventual removal, of watercourse crossings along the Sissons-Kiggavik Ore Haul Road, and along other infrastructure roads to the water intakes, effluent diffusers, and airstrip.
- Fish habitat will be altered if an All-Season Road between the Kiggavik Mine Site and Baker Lake is constructed. 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.
- Fish habitats will be temporarily altered by the installation and eventual removal of water intake structures in Siamese and Mushroom Lakes, as well as by 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.

In most cases, the effects to fish habitat described above will be in place for the life of the mine (i.e., 25 years). During mine closure, most effects will be reversed with the removal of the water intake structures, effluent diffusers, and stream crossing structures, and the affected habitats will be returned to pre-development conditions whenever possible.

10.2.2.4 Mitigation Measures and Project Design for Changes in Fish Habitat

Avoidance and mitigation measures for the protection of fish habitat have been incorporated into the Project design, and will be incorporated into various Project construction activities. Best Management Practices for road construction and installation of stream crossings will be used. The same applies to the installation of the water intake structures, and effluent diversion structures. Erosion and sediment control measures will be incorporated into the design of stream and watercourse diversions. Similarly, turbidity/total suspended solids (TSS) control measures, turbidity/TSS monitoring requirements, and in-water construction timing windows will be followed during construction of the dock in Baker Lake. Refer to Tier 3, Technical Appendix 5O, Section 2 for Project activities identified as requiring an erosion and sediment control plan and/or monitoring during construction, operations and decommissioning phases. The mitigation measures and monitoring activities provided in this document provide a conceptual basis; some combination of best management practices identified for each activity group will be used to mitigate changes in water quality from activities in and around water to facilitate protection of fish habitat.

Best management practices will be implemented and turbidity curtains will be installed prior to construction of the berm in Andrew Lake and during dewatering of the east portion of the Andrew Lake basin. Refer to Tier 3, Technical Appendix 5O Section 2.9 for a discussion of the conceptual erosion and sediment control plan and associated best management practices for Andrew Lake Pit and Berm construction. A 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 of the north-east end of the lake will result in the destruction of seasonal use (open-water season) fish habitat. Fish species that use these seasonal habitats are expected to contribute, in part, to the CRA fishery on Judge Sissons Lake. However, the loss of 13.5 ha of seasonal habitat in Andrew Lake is not anticipated to be critical to the ongoing productivity of area fisheries.

Road construction completed to develop the Kiggavik and Sissons Mine Site infrastructure, as well as construction of the optional All-Season Road, if required, will affect fish habitat where the roads cross fish-bearing streams. However, a number of Best Management Practices (BMPs) will be incorporated into stream crossing designs (Tier 3, Volume 5, Appendix 5O) to minimize effects on fish passage and fish habitat. Culverts will be installed in the dry and outside DFO's restricted activity timing windows. Work areas will be isolated from flowing water by placing cofferdams at the upstream and downstream ends of the work areas. All culverts will be sized to pass a 1:10 year three-day delay flow and meet fish passage criteria for velocity. These culverts are designed with a large end area that limits flow constriction and supports fish passage. This design is typically larger than what is required for conveyance of the 1:100 year design flow. In addition to meeting requirements for fish passage, it is anticipated that alteration or destruction of fish habitat resulting from culvert installation or culvert footprints will not be limiting to fish populations. The loss or alteration of habitat should be limited to the culvert footprint. If limiting fish habitat types are identified for an affected stream during culvert installation, the crossing design will be modified be accordingly. If an All-Season Road and Thelon River ferry crossing are required for the Project, construction of the ferry aprons is expected to result in some permanent loss or alteration of fish habitat. The relatively small area (i.e., 0.06 ha, total) of fish habitat that will be permanently altered or destroyed as a result of the optional ferry crossing is unlikely to limit fish productivity in the Thelon River.

The above proposed measures describe the general approaches that will be used to avoid or mitigate effects to fish habitat. Details of the proposed mitigations have been incorporated into the CFOP for the Project. The CFOP will be submitted to NIRB and DFO for review. The CFOP must be approved and finalized, and a DFO Authorization received, before commencement of any Project works, undertakings, or activities that may result in serious harm to fish.

10.2.2.5 Residual Effects for Changes in Fish Habitat

Due to the requirement for a FOP under the Applications for Authorization under Paragraph 35(2)(b) of the *Fisheries Act* (Government of Canada 2013), a CFOP was developed (Tier 3, Technical

Appendix 5L). The CFOP indicates that any permanent alteration or destruction of fish habitat that might result from the Project can be mitigated to acceptable levels (i.e., levels that will not affect a CRA fishery). It is anticipated that no fisheries offsetting will be required.

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. Therefore, it is anticipated that fisheries offsetting will not be required (refer to Tier 3, Technical Appendix 5L). Implementation of proposed mitigations will adequately avoid or mitigate serious harm to fish such that any permanent alteration or destruction of fish habitat will not diminish the productive capacity of CRA fisheries.

10.2.2.7 Compliance and Environmental Monitoring for Changes in Fish Habitat

The CFOP specifies that no fisheries offsetting will be required to offset serious harm to fish that may result from Project-related changes to fish habitat. However, it is anticipated that monitoring may be required to confirm that avoidance and mitigation measures are installed and functioning as planned, and that implementation of additional contingency measures for the protection of fish habitat are not required. Details are provided in Tier 3, Technical Appendix 5L, Section 5.

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 extend beyond 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 was conducted 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 Volume 1, Appendix 1B. No local, Nunavut, or Far Future Scenario projects from the Project Inclusion List are expected to have effects to aquatic organism populations or fish habitat that will overlap spatially and temporally (i.e., throughout the duration of potential effects to aquatic organisms and fish habitat from the Kiggavik Project) with predicted effects from the Kiggavik 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

There is potential for effects to zooplankton in Judge Sissons Lake as a result of cadmium exposure. Screening index (SI) values above 1.0 are identified for JSL-2 and JSL-3; however, the magnitude of the potential effect is classified as medium (Table 10.2-3). This is because the maximum SI values are expected to be achieved in winter, during a time of reduced biological activity, and the affected segments of Judge Sissons Lake represent less than 11% 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 toxicity modifying effects of hardness, 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 to result from changes in COPC concentrations in the receiving environment due to releases from the WTPs.

A number of Project development activities have the potential to permanently alter or destroy fish habitat. These include diversion of streams away from their current locations, drainage of lakes or portions of lakes, and installation of stream crossing structures on all-season ore haul roads and other roads related to constructing and maintaining Project infrastructure (e.g., roads to water intake and effluent discharge structures and the airstrip).

To align the Project with DFO's fisheries protection provisions and comply with the Applications for Authorization under Paragraph 35(2)(b) of the *Fisheries Act* (Government of Canada 2013), a CFOP was developed for the Project. The FOP will be finalized following DFO consultation and approval. Because anticipated effects to fish habitat will not be of sufficient magnitude to affect the productivity of CRA fisheries, it is anticipated that fisheries offsetting works, including habitat restoration or creation activities, will not be required for the Project. Serious harm to fish, including the permanent alteration or destruction of fish habitat, and any subsequent effects to CRA fisheries is discussed in Technical Appendix 5L.

Table 10.4-1 summarizes Project residual environmental effects for aquatic organisms and fish habitat.

Table 10.4-1 Summary of Project Residual Environmental Effects and Significance Determinations for Aquatic Organisms and Fish Habitat

Project Phase	Mitigation 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 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 conducted to determine whether effluent discharge from the WTP is having quantifiable effects.
Operation	Design of the WTPs.	Y	N	L	L	MT	C	R	U				
Decommissioning and Abandonment		Y	N	L	L	MT	C	R	U				
Change in fish habitat: Instream construction associated with several Project development activities is expected to result in the permanent alteration or destruction of fish habitat.													
Construction	Installation of culverts; use of turbidity curtain; completion of fish salvage.	N	N	L	L	ST	O	R	U	N	L	H	None.
Operation		N	-	-	-	-	-	-	-				
Decommissioning		N	N	L	L	ST	O	R	D				

KEY

Direction:

P Positive

N Negative

Magnitude:

Use quantitative measure; or

N Negligible: The Project will not affect the health of aquatic biota or fish habitat in waterbodies in the LAA; SI maximum mean value <1

L Low: The Project may affect the health of aquatic biota or fish habitat in waterbodies but these effects will be within the natural range of variability: SI maximum mean value 1-5

M Medium: The Project may affect the health of aquatic biota or fish habitat in waterbodies in the LAA and the effects will be beyond the natural range of variability. SI maximum mean value >5 <15

H High: The Project will affect aquatic biota or fish habitat in waterbodies in the LAA and the RAA and the effects will be beyond the natural range of variability; SI maximum mean value >15

Geographic Extent:

Use quantitative measure; or

S Site-specific: area of lake or stream

L Local assessment area

R Regional assessment area

Duration:

Use quantitative measure; or

ST Short term: fish habitat or SI returns to baseline conditions during operations

MT Medium term: fish habitat or SI returns to baseline conditions during final closure period

LT Long term: fish habitat SI returns to baseline post-closure

P Permanent alteration in fish habitat or permanent toxicological risk

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 RAA

N Effect will not or is not likely to interact with other past, present or foreseeable projects or activities in RAA

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 predicted precipitation rate was estimated to be 78% greater than historical rates. On average, the models predict a 34% increase in precipitation; this increase is typically distributed throughout the year, however, the most dramatic increases are expected to occur in fall.

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 Sissons and Pointer lake outflows. On average, runoff is estimated to increase 67% and 74% for the 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 the water and sediments of Judge Sissons Lake, such that levels may be below those predicted in this EA. 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 EA.

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 affect lake trout spawning habitat in Siamese and Mushroom lakes.

10.5 Mitigation Measures for Aquatic Organisms and Fish Habitat

Many of the mitigation measures associated with aquatic organisms and fish habitat incorporate IQ guiding principles (GN 2009), including Qanuqtuurnunnarniq (being resourceful to solve problems), Avatimik Kamattiarniq (environmental stewardship), and Pilimmaksarniq (skills and knowledge acquisition). A number of mitigation measures and Project design features will be implemented to minimize changes to aquatic organism abundance and distribution, and to minimize changes to fish habitat quantity and quality. These include:

- 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 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.
- In-water construction will follow standard protocols, BMPs and fish habitat protection measures.
- The 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.
- Wastewater and sewage will be treated to comply with applicable standards prior to release to the environment. For example, the WTP is designed to provide an effluent that meets, or improves upon, all appropriate regulations, such as the discharge limits for deleterious substances stipulated in the MMER, as well as site-specific discharge limits.

10.6 Compliance and Environmental Monitoring for Aquatic Organisms and Fish Habitat

Results of engagement activities completed for the Project indicate that monitoring of aquatic life in lakes and rivers potentially affected by the Project is important to area stakeholders (EN-AR NIRB 2010[169]). Compliance and environmental monitoring plans associated with aquatic organisms and fish habitat incorporate IQ guiding principles (GN 2009), including Qanuqtuurnunnarniq (being resourceful to solve problems), Avatimik Kamattiarniq (environmental stewardship), Pilimmaksarniq (skills and knowledge acquisition) and Piliriqatigiingniq (collaborative relationships or working together for a common purpose).

[169] EN-AR NIRB 2010: *Would like to see wildlife monitored as well as aquatic life in the lakes and rivers.*

Compliance and environmental monitoring will be implemented to confirm predictions made in the EIS to aquatic organisms and fish habitat.

- Benthic invertebrate populations and diversity will be monitored regularly (every third year) during mine operation, closure, and post-closure as part of the EEM Program to determine whether WTP effluent discharges are having quantifiable effects on benthic macro-invertebrate populations.
- Because any permanent alteration or destruction of fish habitat resulting from the Project is not expected to adversely affect CRA fisheries, it is anticipated fisheries offsetting will not be required. However, monitoring may be required to confirm the avoidance and mitigation measures, standards, and protocols have been implemented as planned..

11 Effects Assessment for Fish Populations

11.1 Scope of the Assessment for Fish Populations

The Nunavut Impact Review Board (NIRB) Guidelines for the Kiggavik Project (the 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 environmental component (VEC). For the purposes of this assessment, fish populations and fish flesh chemistry will be treated as individual VECs.

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 (EN-KIV OH 2009[170]; EN-BL NIRB 2010[171]; EN-BL EL 2012[172]; IQ-BL02 2008[173]). The importance of fish is highlighted in an IQ comment from a Baker Lake Elder: *As long as there have been lakes, it has been a tradition to fish* (IQ-BL16 2008). As such, having fish populations with flesh of quality safe for human consumption has also been identified as an important component of this VEC (EN-KIV OH 2009[174]; EN-BL HTO 2009[175]; IQ-ARVJ 2011[176]). Elders described how Arctic char, whitefish, northern pike, lake trout, cisco, cod and sculpin were traditionally fished using techniques such as netting, fishing rods and spearing (IQ-BL02 2008[177][178]; IQ-ARVJ 2011[179][180]; IQ-RBH 2011[181]; IQ-Riewe 1992[182][183][184]; IQ-CHAH 2009[185]; IQ-Freeman 1976[186][187]; IQ-CI02 2009[188]). Arctic grayling, lake cisco, round

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[170] EN-KIV OH 2009: *How will uranium affect our water, fish, etc.?*
[171] EN-BL NIRB 2010: *Concerns regarding the environment and impacts from industrial activities, human activities, and radiation. Concerns also raised on the tailings and potential impacts downstream of the project. Impacts already being seen from exploration/drilling already on the fish in the area. They have become very poor, have white spots, are skinny and are not good to eat, effects on water.*
[172] EN-BL EL 2012: *Fish (lake trout) near Princess Mary Lake, Pitz Lake have really changed*
[173] IQ-BL02 2008: *Annigguq Lake now has unhealthy trout due to the drilling occurring in the region around the lake.*
[174] EN-KIV OH 2009: *What was your impact on fish and caribou in Saskatchewan and will it be the same in Nunavut?*
[175] EN-BL HTO 2009: *Are the fish you catch edible? Can you provide more information on the arsenic levels that were above government guidelines?*
[176] IQ-ARVJ 2011: *Fish in shallow water are fatter and darker red in colour. This may be due to the increased feeding from the river or lake bottom.*
[177] IQ-BL02 2008: *Caught species included pike, whitefish, trout and arctic char.*
[178] IQ-BL02 2008: *Annigguq Lake now has unhealthy trout due to the drilling occurring in the region around the lake.*
[179] IQ-ARVJ 2011: *Caught species included pike, whitefish, trout and arctic char.*
[180] IQ-ARVJ 2011: *Fish in shallow water are fatter and darker red in colour. This may be due to the increased feeding from the river or lake bottom.*
[181] IQ-RBH 2011: *Char and lake trout are fished with nets in the summer.*
[182] IQ-Riewe 1992: *Cisco was also caught in the past.*
[183] IQ-Riewe 1992; *Gill nets and jigging were used to take lake trout, Arctic Char, cod, sculpin, and cisco.*
[184] IQ-Riewe 1992: *The main catches were Arctic char and lake trout.*
[185] IQ-CHAH 2009:*Trout and char fishing are still very popular.*
[186] IQ-Freeman 1976: *In the past, char and trout were speared, harvested at weirs lakes, and fished from river shores during the summer throughout the inland.*
[187] IQ-Freeman 1976: *Whitefish was also an important fish in the past.*
[188] IQ-CI02 2009: *Fish harvesting techniques include gill netting through ice in winter on the lakes, as well as in open water in the warmer months. 'Rodding' (using fishing rods), is also used close to shore.*

whitefish, lake trout, burbot, lake whitefish, longnose sucker, and arctic char were found during baseline fish surveys that were done in lakes and streams in or near some of the fishing areas identified by IQ (Figure 4.1-1A and Figure 4.4-1B).

Refer to Section 4.1 for a discussion of issues and concerns raised during Inuit Qaujimajatuqangit (IQ) interviews and engagement initiatives.

Refer to Section 4.1.1 for a description of the influence of IQ and engagement data on the fish population assessment.

11.1.1 Project–Environment Interactions and Effects – Fish Populations

Information was gathered by AREVA, through public engagement and IQ interviews, and by the NIRB to identify project activities that have potential to result in changes to the abundance or distributions of fish, 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
	Construction/Installation of in-water/shoreline structures (i.e., culverts)	1	0
	Water transfers and discharge	1	0
On-Land Construction	Site clearing and pad construction (blasting, earth moving, loading, hauling, dumping, crushing)	1	0

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
Operation			
Mining	Mining ore (blasting, loading, hauling)	2	2
	Mining special waste (blasting, loading, hauling)	2	2
	Mining clean waste (blasting, loading, hauling)	2	2
Water Management	Discharge of treated effluents (including greywater)	0	2
Final Closure			
General	Ongoing withdrawal, treatment and release of water, including domestic wastewater	0	2
In-water Decommissioning	Water transfers and discharge	1	1
NOTES: **Category 1** activities are those having an interaction with the aquatic environment that is likely to result in a minor environmental change, but a negligible residual effect on a valued component (VC) relative to baseline or guideline values in light of planned mitigation. Category 1 interactions are not expected to contribute to effects of other existing or reasonably foreseeable projects. As noted in the following section, screening of these project interactions indicates that project effects will be minimal and no further assessment is warranted. **Category 2** activities are those activities that do interact with the aquatic environment and could result in a measureable environmental change that could contribute to significant residual effects on a VC relative to baseline or guideline values, despite the planned 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; Construction/Installation of In-Water/Shoreline Structures; Site Clearing and Pad Construction

As part of developing the mine site and infrastructure at the Kiggavik Mine Site, the lower portion of the stream between Mushroom Lake and End Grid Lake will be diverted and reconnected with the drainage system at End Grid Lake. The diverted portion will be in-filled to allow for construction of the Sissons Mine Site. This portion of the stream is currently used for seasonal fish passage (spring freshet). The diversion channel is designed with fish passage as a primary objective (see Tier 3, Volume 2 Project Description and Assessment Basis, Technical Appendix 2E, Section 5.1.1). To minimize construction effects on fish that may use this stream for seasonal passage, the stream diversion work will take place in late summer or fall after fish have left the stream system to return to overwintering 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 overwintering lake in the watershed. A turbidity curtain will be installed to minimize turbidity and construction effects on fish. Because effects on fish 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 effects on fish abundance and distribution.

The need for blasting to facilitate the construction of the diversion channel between the upstream portion of the Mushroom/End Grid stream and End Grid Lake will be determined at the fisheries authorization stage. As necessary, best management practices to reduce or mitigate effects on fish will be determined and presented at that stage. Thus, this Project effect is not carried forward to the detailed analysis of 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. 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 (Tier 3, Technical Appendix 5O, Section 2.9). “Are there fish in Andrew Lake?” was a concern raised during public engagement (EN-CH OH 2012[189]). Because effects on fish the fish assemblage using Andrew Lake will be small in magnitude and short lived in duration, this Project effect is not carried forward to the detailed analysis of effects on fish abundance and distribution. Dewatering of a portion of Andrew Lake is considered in Tier 3, Technical Appendix 5L.

Proposed stream crossings for the Project are of three types: culverts, bridges, and an optional ferry crossing (Tier 2, Volume 2). Culvert-type stream crossings may act as barriers to fish migration if the design or installation is inappropriate for the site, which could limit access to critical spawning, rearing, overwintering, and foraging habitats, or minimize opportunities for genetic mixing within a species. To support fish passage, culverts installed on streams that are used by fish, or are assumed to be used by fish, will be designed to pass a 1:10 year 3-day delay flow and meet velocity-based fish passage criteria. Plans for monitoring fish passage at stream crossings are incorporated into the Aquatic Effects Monitoring Plan (AEMP; Tier 3, Technical Appendix 5M).

[189] EN-CH OH 2012: *Are there fish in Andrew Lake?*

Operation

Mining ore, special waste, clean waste (blasting, loading, hauling); Water Management - Discharge of treated effluents (including greywater)

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. Because blasting activities associated with mining may interact with fish populations, and the resulting effect may exceed acceptable levels without implementation of specified mitigation, further assessment of the potential effects of these interactions is warranted. The environmental assessment of potential changes in relative abundance and distribution of fish associated with blasting is presented in Section 11.2.1.

Treated effluent discharge from the Kiggavik and Sissons WTPs may affect water quality and as a result, fish populations. The potential change in fish health 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 (e.g. toxicity reference values), further assessment of the potential effects of these interactions on fish health is warranted. The environmental assessment of changes in fish health related to treated effluent discharge is presented in Section 11.2.2.

Final Closure

Water Transfers and Discharge

Water quality in the flooded Andrew Lake Pit is predicted to meet Canadian Council of Ministers of the Environment (CCME) water quality guidelines for the protection of aquatic life for all parameters except aluminum (Section 7.2.2.5.2 and Technical Appendix 5F). However, given the conservative assumptions used in the pit water quality model, it is more likely that aluminum concentrations will not will exceed CCME guidelines. During pit flooding and the subsequent evolution in pit water quality, there will be time to monitor and assess the potential pit water chemistry, which will allow verification of the predicted water quality and time to develop mitigation strategies if the concentrations of some constituents of potential concern (COPC) exceed the CCME guidelines (Tier 3, Technical Appendix 2R). If the water quality meets CCME guidelines for the protection of aquatic life, 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 CCME guidelines then the dyke separating the two waterbodies will not be breached. Because there will be no water quality effects on the downstream environment (the Andrew Lake drainage system), and therefore on fish populations, this interaction is ranked as Category 1 and is not carried forward to the detailed analysis of residual effects on fish populations.

If Andrew Lake Pit is reconnected to Andrew Lake, then options to re-landscape the pit shoreline or engineer fish habitat features in the pit to provide habitat for aquatic biota would be considered and included in the Detailed Decommissioning Plan as applicable (see Technical Appendix 2R for Preliminary Decommissioning Plan).

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.	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. This boundary was identified and the assessment took this uncertainty into account through:

- a conservative assessment approach,
- adoption of an Ecological Risk Assessment (ERA) process (see Technical Appendix 8A), and
- a commitment to aquatic monitoring during operations to confirm Environmental Assessment (EA) predictions. An Environmental Effects Monitoring (EEM) program under Metal Mine Effluent Regulations (MMER) will be instituted to determine whether effluent discharge is having quantifiable effects on the aquatic ecosystem (see Tier 3, Technical Appendix 5M).

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 distribution, magnitude is defined as the amount of change in population numbers or distribution relative to the various fish population abundances 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.
- Low: 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 regional assessment area (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

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 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 Technical 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; mg/L = milligrams per litre; µg/g = microgram s per gram

For radioactivity, a review of the recommendation by various agencies was provided. For consistency with N288.6 (CSA 2012), a reference dose rate of 9.6 mGy/d was selected for fish.

Potential changes in a measurable parameter or valued component (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

Potential effects to the abundance and distribution of fish have been identified in the Lower Lake watershed, and possibly 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 Kiggavik 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 Project (Kiggavik Project EIS - Aquatics Baseline Document) and from IQ. 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 fish communities could be affected by blasting related over-pressures or vibrations.

The federal *Fisheries Act* (the *Act)* includes provisions for the protection of fish and fish habitats that are part of, or support, a commercial, recreational, or Aboriginal (CRA) fishery. Detonation of explosives in or adjacent to fish-bearing waters can disturb, injure, or kill fish, and/or affect fish habitat. Works, undertakings, or activities, including blasting, that result the death of fish and/or the permanent alteration or destruction of fish habitat are considered “serious harm to fish”, and are prohibited under the *Act*.

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* (Wright and Hopky 1998) should be used as guidance in designing a blasting plan for the Kiggavik Project. In the same letter, Fisheries and Oceans Canada (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 Tier 3, Technical Appendix 2B.

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 in Andrew Lake (see Technical Appendix 5C). 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 overwintering 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.

Proposed mitigation measures for blasting near Andrew Lake include:

- adhering to DFO's "Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky 1998);
- installing a fish exclusion barrier in Andrew Lake to prevent fish from entering the area of Andrew Lake adjacent to the Andrew Lake Pit;
- using 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
- Planning 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. 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/s 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 150 mm 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 160 m away from the pit crest. This is within the setback threshold for both proposed charge sizes being considered (150mm and 187 mm boreholes). 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 abundance or distribution will occur. Therefore, fisheries offsetting is not required since serious harm to fish (i.e., the death of fish) is not anticipated to occur as a result of blasting.

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 comply with DFO's blasting guidelines. Because no significant changes in fish population abundance and distribution are anticipated, impacts to CRA fisheries are not expected to occur, and fisheries offsetting will not be required (Tier 3, Technical Appendix 5L).

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 water treatment plants (WTPs), 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 WTPs 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 (uranium-238, thorium-230, radium-226, lead-210, polonium-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 comparing the estimated water concentration to the biota-specific 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; this is consistent with N288.6 (CSA 2012) and used for the assessment. 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 round whitefish. 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 (Section 8.2.1). 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 WTPs was focused on providing an effluent that meets or exceeds all appropriate regulations such as the discharge limits for deleterious substances as stipulated in the MMER as well as site-specific discharge limits. 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:

$$Screening\ Index = \frac{Exposure}{Toxicity\ Reference\ Value}$$

Screening index (SI) 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	0.02	0.02
Cadmium	0.28	0.47	0.02	0.04
Cobalt	<0.01	<0.01	<0.01	<0.01
Copper	**2.0**	**2.0**	**1.3**	**1.3**
Lead	0.07	0.07	<0.01	<0.01
Molybdenum	0.02	0.03	<0.01	<0.01
Nickel	0.09	0.10	0.01	0.01
Selenium	0.23	0.40	0.23	0.40
Zinc	**1.3**	**1.3**	**1.1**	**1.1**
Un-ionized Ammonia	0.08	0.13	0.04	0.07
Chloride	0.18	0.28	0.29	0.46
Sulphate	0.21	0.32	0.40	0.60
Radioactivity	<0.01	<0.01	<0.01	<0.01

NOTES:

Shaded cells indicate a SI greater than 1.0

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 uranium-238, thorium-230, radium-226, lead-210 and polonium-210

Details of calculation as well as additional results provided in Appendix 8A

RBE = relative biological effectiveness

All COPC have predicted SI values less than 1.0 for all segments of Judge Sissons Lake, with the exception of copper and zinc for predator and forage fish (Table 11.2-1).

The exceedances of the toxicity benchmarks for copper and zinc are only in Judge Sissons Lake, segment 7 (JSL-7) and can be attributed to baseline concentrations in the area. JSL-7 is a shallow segment and therefore experiences 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. A reminder that the model considers discharge of the Kiggavik WTP to JSL-2 and Sissons WTP to JSL-8 (Figure 8.2-5). 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 and zinc.

The TRV 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 wet weight (ww) was done. Predicted fish concentrations in Judge Sissons Lake are expected to be 0.45 μg/g (ww), with an upper 95th percentile concentration of 0.80 μg/g (ww) (refer to Tier 3, Technical Appendix 8A, Table 8.1-3). 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 exceedances of the toxicity benchmarks for copper and zinc are only in JSL-7 and can be attributed to baseline concentrations in the area (refer to Figure 8.2-6 – the area labeled 'Base' on the left-hand side of each panel is the baseline water quality for each parameter). JSL-7 is a shallow segment and therefore experiences the largest variation between summer and winter concentrations. Overall, no residual effects were identified for copper and zinc.

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 0.45 μg/g (ww), with an upper 95th percentile concentration of 0.80 μg/g (ww). No adverse effects in fish due to bioaccumulation of selenium are expected.

Changes to fish health that may result from the release of treated effluent are not anticipated to result in residual serious harm to fish. Therefore, no effects to CRA fisheries are anticipated, and no fisheries offsetting will be required for this Project component.

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 EEM 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

No Project-related residual effects to fish abundance, distribution and fish health are anticipated with blasting and treated effluent discharge. The screening for cumulative effects to fish and fish health was conducted to determine if cumulative environmental effects are likely 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 Volume 1, Appendix 1B. Of these projects, no local, Nunavut, or Far Future Scenario projects from the Project Inclusion List are expected to affect fish or fish health within the spatial (i.e., Judge Sissons Lake) and temporal (i.e., throughout the duration of fish or fish health effects associated with this Project) boundaries. Therefore, no cumulative effects to fish or fish health are predicted for the Project.

11.4 Summary of Residual Effects on Fish

11.4.1 Project Effects

Potential 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 Kiggavik 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:

- adhering to DFO's "Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky 1998);
- installing a fish exclusion barrier in Andrew Lake to prevent fish from entering the area of Andrew Lake adjacent to the Andrew Lake Pit;
- using 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
- planning 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. 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. Subsequently, the sustainability and productivity of area fisheries are not expected to be negatively impacted by blasting.

Predicted concentrations of COPCs in fish flesh are not predicted to be high enough to result in adverse effects or cause serious harm to fish that are part of, or support a fishery. No residual effects on fish health were identified in relation to treated effluent release.

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)	Direction	Residual Environmental Effects Characteristics						Significance	Likelihood	Prediction Confidence	Recommended Follow-up and Monitoring
				Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental Context				
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	-	-	-	-	-	-	-				
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	N	N	L	L	MT	C	R	U				
Decommissioning		N	N	L	L	MT	C	R	U				

KEY

Direction:

P Positive

N Negative

Magnitude:

Use quantitative measure; or

N Negligible: The Project will not affect fish abundance, distribution and health in waterbodies in the LAA.

L Low: The Project will affect fish abundance, distribution and health in waterbodies in the LAA, but these effects will be within the natural range of variability.

M Moderate: The Project will affect fish abundance, distribution and health in waterbodies in the LAA and the effects will be beyond the natural range of variability. The effects do not extend to the regional assessment area (RAA).

H High: The Project will affect fish abundance, distribution and health in waterbodies in the LAA and the RAA, and the effects will be beyond the natural range of variability.

Geographic Extent:

Use quantitative measure; or

S Site-specific: area of lake or stream

L Local assessment area

R Regional assessment area

Duration:

Use quantitative measure; or

ST Short term: fish abundance, distribution and health return to baseline conditions during operations

MT Medium term: fish abundance, distribution and health return to baseline conditions during final closure period

LT Long term: fish abundance, distribution and health return to baseline post-closure

P Permanent alteration in fish abundance, distribution and health

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 RAA

N Effect will not or is not likely to interact with other past, present or foreseeable projects or activities in RAA

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, the 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

Many of the mitigation measures associated with fish populations incorporate IQ guiding principles (GN 2009), including Qanuqtuurnunnarniq (being resourceful to solve problems), Avatimik Kamattiarniq (environmental stewardship), and Pilimmaksarniq (skills and knowledge acquisition). 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.
- Wastewater and sewage will be treated to meet or exceed required standards prior to release to the environment. For example, the design of the WTP is such as to provide an effluent that meets or exceeds all appropriate regulations such as the discharge limits for deleterious substances as stipulated in MMER as well as site-specific discharge limits. 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:

- adhering to DFO's "Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky 1998);
- installing a fish exclusion barrier in Andrew Lake to prevent fish from entering the area of Andrew Lake adjacent to the Andrew Lake Pit;
- using 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
- planning 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. 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

Compliance and environmental monitoring plans associated with fish populations incorporate IQ guiding principles (GN 2009), including Qanuqtuurnunnarniq (being resourceful to solve problems), Avatimik Kamattiarniq (environmental stewardship), Pilimmaksarniq (skills and knowledge acquisition) and Piliriqatigiingniq (collaborative relationships or working together for a common purpose).

- 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 confirm that WTP effluent discharges are not having quantifiable effects on fish health as measured by 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.

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 20 cm during the inactive flow season. Changes to under-ice volumes will follow the Fisheries and Oceans Canada (DFO) 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 Mine Site and Sissons Mine Site, respectively) are predicted to decrease by less than 1% and 3%.

12.1.2 Hydrogeology

Effects on hydrogeology, groundwater and surface water receptors are expected to be low, for both current permafrost conditions and potential changes to no-permafrost conditions associated with climate change. This includes potential effects of a worst case scenario where no permafrost exists and changes occur to the hydrogeological regimes. 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.

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 and selenium. For cadmium, the expected concentrations within Judge Sissons Lake are predicted to be below the CCME CWQG once seasonal changes in hardness are considered; however, 95th percentile predicted concentrations exceed the CWQG in winter months. For selenium in JSL-7, concentrations during the operation and final closure phases of the project are shown to seasonally exceed the CWQG; this is largely due to baseline conditions and seasonal fluctuations. 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 total suspended solids (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 COPC with sediment quality guidelines available, were below the guideline levels in all segments of Judge Sissons Lake, with the exception of arsenic, copper, and nickel. Concentrations of these COPC are predicted to be slightly elevated above average baseline levels in Judge Sissons sediment. However, the Project is not expected to substantially increase these levels concentrations remain within the natural variation in baseline sediments. It is expected that Project-related residual effects to sediment quality will occur within Judge Sissons Lake, 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

Ecological Risk Assessment modelling shows potential exceedances of toxicity reference values cadmium and sulphate exposure for 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 screening index (SI) values and the spatial extent of the impact, the zooplankton population of Judge Sisson Lake is expected to continue to function. Radiological dose to zooplankton was also indicated as a potential issue using the lower set of dose rate guidelines and a RBE of 40. Calculation of the radiological dose using a RBE of 10 or calculation of a SI value using the higher set of dose rate guidelines does not indicate any potential effects for zooplankton in Judge Sissons Lake. 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 water treatment plants (WTPs).

A number of Project development activities have the potential to permanently alter 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 constructing and maintaining Project infrastructure (e.g., roads to water intake and effluent discharge structures and the airstrip). However, implementation of measures to avoid or mitigate effects to fish habitat is expected to minimize serious harm to fish and negate the requirement for fisheries offsetting (see Technical Appendix 5L “Conceptual Fisheries Offsetting Plan” [CFOP]). None of the changes to fish habitat resulting from the Kiggavik Project will affect the sustainability or productivity of commercial, recreational and Aboriginal (CRA) fisheries.

12.1.6 Fish Populations and Fish Health

Potential 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 Kiggavik Mine Site. The proposed blasting program has the potential to cause serious harm to 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. Given that effective mitigation measures will be employed (i.e., the IPC threshold of 50 kPa, and the vibration threshold of 13mm/s peak particle velocity will not be exceeded), no residual effects on fish abundance or distribution are anticipated. Therefore, no effects to CRA fisheries are expected, and no measures to offset the effects of blasting will be required.

Toxicity benchmarks for copper and zinc will be exceeded for predator and forage fish however, the predicted changes are related to elevated baseline conditions and as such, no appreciable adverse effects on fish health are expected. No serious harm to fish is anticipated.

12.2 Cumulative Effects

Project-related residual effects to water quality occur within Judge Sissons Lake, but are expected to diminish to background levels downstream of the outlet of the lake. Should monitoring results identify any remaining residual effects to water quality outside of Judge Sissons Lake, these effects would have potential to overlap with other projects and activities that occur or may occur in the future, and may therefore act cumulatively on surface water quality.

The screening for cumulative effects to water quality was conducted to determine if cumulative environmental effects are likely 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 Volume 1, Appendix 1B. Of these projects, no local, Nunavut, or Far Future Scenario projects from the Project Inclusion List are expected to affect surface water quality within the spatial (i.e., Judge Sissons Lake) and temporal (i.e., throughout the duration of water quality effects associated with this

Project) boundaries. Therefore, no cumulative effects to surface water quality are predicted for the 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 also an 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. Many of the mitigation measures associated with the aquatic environment incorporate IQ guiding principles (GN 2009), including Qanuqtuurnunnarniq (being resourceful to solve problems), Avatimik Kamattiarniq (environmental stewardship), and Pilimmaksarniq (skills and knowledge acquisition). 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.
- 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 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.
- The site Water Management Plan (Tier 3, Volume 2, Appendix 2I) provides consolidated information on water management strategies for intercepting, collecting, containing, and monitoring potentially contaminated water from the site, to manage site runoff and mitigate effects on the aquatic environment.
- 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.
- Wastewater and sewage will be treated to meet or exceed required standards prior to release to the environment. For example, the design of the WTP is such to provide an effluent that met or exceeded all appropriate regulations such as the discharge limits for deleterious substances as stipulated in Metal Mining Effluent Regulations (MMER) as well as site-specific discharge limits.
- During decommissioning, the ground surface will be recontoured and natural flow patterns will be restored.
- Andrew Lake flooded pit will remain isolated from the natural part of Andrew Lake until water quality in the flooded pit meets criteria for removing the berm constructed for dewatering.

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.
- Wastewater and sewage will be treated to meet or exceed required standards prior to release to the environment. For example, the design of the WTP is such to provide an effluent that met or exceeded all appropriate regulations such as the discharge limits for deleterious substances as stipulated in MMER as well as site-specific discharge limits.
- During decommissioning, the ground surface will be recontoured and natural flow patterns will be restored.

13.5 Aquatic Organisms

- Wastewater and sewage will be treated to meet or exceed required standards prior to release to the environment. For example, the design of the WTP was such to provide an effluent that met or exceeded all appropriate regulations such as the discharge limits for deleterious substances as stipulated in MMER as well as site-specific discharge limits.

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 (Tier 3 Technical Appendix 5O).
- Erosion control measures will be incorporated into the design of stream and watercourse diversions (Tier 3 Technical Appendix 5O).
- Erosion control and turbidity management procedures will be used during the installation of the lake water intake structures, effluent diffuser structures, and the spud barge dock in Baker Lake (Tier 3 Technical Appendix 5O).
- Best management practices will be used 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 (Tier 3 Technical Appendix 5O).

- 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. However, this destruction of fish habitat is not anticipated to result in effects to fish that are part of, or support, a CRA fishery. Therefore, no associated fisheries offsetting is proposed in the CFOP for the Project.
- 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 fisheries offsetting for the culvert installation's footprint on the natural stream bed, no effects to the productivity of CRA fisheries are anticipated to occur, and no offsetting is therefore required.
- The above proposed measures describe the general approaches that will be used to avoid and mitigate effects to fish habitat. Fisheries offsetting for the project is described in detail in the CFOP (Tier 3, Technical Appenendix 5L). The CFOP will be submitted to NIRB and DFO for review. Once the CFOP is finalized and receives approval, and the Project receives DFO's Authorization, Project work that may result in the permanent alteration or destruction of fish habitat may begin.

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.
- Wastewater and sewage will be treated to meet or exceed required standards prior to release to the environment. For example, the design of the WTP is such as to provide an effluent that meets or exceeds all appropriate regulations such as the discharge limits for deleterious substances as stipulated in MMER as well as site-specific discharge limits. 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:

- adhering to DFO's "Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky 1998);
- installing a fish exclusion barrier in Andrew Lake to prevent fish from entering the area of Andrew Lake adjacent to the Andrew Lake Pit;
- 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. 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 m, 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. Compliance and environmental monitoring plans associated with the aquatic environment incorporate IQ guiding principles (GN 2009), including Qanuqtuurnunnarniq (being resourceful to solve problems), Avatimik Kamattiarniq (environmental stewardship), Pilimmaksarniq (skills and knowledge acquisition) and Piliriqatigiingniq (collaborative relationships or working together for a common purpose).

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 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 analyzed and documented regularly according to Nunavut regulatory requirements and the MMER 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 will be monitored in the two receiving basins, and in the main body of Judge Sissons Lake every three years as part of the Aquatic 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 invertebrate populations.

14.1.6 Fish

- Sampling of fish, 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 EEM 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

Public engagement sessions identified environmental monitoring as an area of interest to residents, “are you monitoring the lakes as well? 2) Is there such a thing as monitoring the plankton in the lakes and rivers?” (EN-CH KIA 2007[190]) and “do they only monitor just the few or all of the lakes?” (EN-BL CLC Oct 2010[191]). 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.

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[190] We’ve gotten quite a bit of information. The locations where you detect and do monitoring, are you monitoring the lakes as well? Is there such a thing as monitoring the plankton in the lakes and rivers?
[191191] Any drill sites by the small Lakes? Where do the people working on fish work? Do they only monitor just the few or all of the Lakes?

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, similar to the program that was initiated at McClean Lake Operation and has been a successful audit program for the behavior 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 (metals, radionuclides, TSS, pH) will be monitored in appropriate lakes and streams to confirm results are within predicted or acceptable levels due to dust deposition

and air emissions from Project activities. This monitoring will occur during the spring freshet throughout the operational life 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 will 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 invertebrate populations.

14.2.5 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.

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