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The BACK RIVER PROJECT

Final Environmental Impact Statement

Volume 6: Freshwater Environment

November 2015

Document Structure

MAIN VOLUME

Back River Project
Final Environmental Impact Statement (FEIS)

VOLUME 2

Project Description and Alternatives

- Project Description
- Alternatives

VOLUME 3

Public Consultation, Government Engagement, and Traditional Knowledge

- Public Consultation
- Government Engagement
- Traditional Knowledge

VOLUME 4

Atmospheric Environment

- Air Quality
- Noise and Vibration
- Climate and Meteorology

VOLUME 5

Terrestrial Environment

- Geology and Permafrost
- Landforms and Soils
- Vegetation and Special Landscape Features
- Caribou
- Grizzly Bear
- Muskox
- Wolverines and Furbearers
- Migratory Birds
- Raptors

VOLUME 6

Freshwater Environment

- Surface Hydrology
- Groundwater
- Limnology and Bathymetry
- Water Quality
- Sediment Quality
- Fish/Aquatic Habitat
- Fish Community

VOLUME 7

Marine Environment

- Physical Processes
- Water Quality
- Sediment Quality
- Fish/Aquatic Habitat
- Fish Community
- Marine Wildlife

VOLUME 8

Human Environment

- Archaeology
- Socio-economics
- Land Use
- Country Foods
- Human Health/Environmental Risk Assessment

VOLUME 9

Methodology; Effects of Environment on Project

- General Assessment Methodology
- Effects of Environment on Project Design
- Accidents and Malfunctions
- Marine Spill Modelling

VOLUME 10

Management Plans

- Environmental Management Plan
- Individual Plans

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Back River Project Fact Sheet

November 2015

Location

- Located in the western Kitikmeot Region of Nunavut at approximately 65° north latitude and 106° west longitude. About 400 km south of Cambridge Bay and 525 km northeast Yellowknife.
- Primary communities: Kugluktuk, Cambridge Bay, Gjoa Haven, Kugaaruk, and Taloyoak.
- The closest community areas to the Project are Kingaok, located approximately 160 km north of the Goose Property, and Omingmaktok, located approximately 250 km northeast of the Goose Property.

Reserves

- Four mining areas within the Goose Property: Umwelt, Llama, Goose Main, and Echo.

Mobilization and Construction Phase

- The project could commence as early as 2016 and take four years to mobilize and construct.
- Up to a $695 M initial capital investment.

Operational Phase

- Open pit and underground mines at each of the four Goose deposits.

Production

- Ore production: 19.8 million tonnes of mill feed over the life of mine.
- Projected annual 350,000 ounces of gold for about up to 10 years.

Processing

- Processing plant throughput of 6,000 tonnes per day.
- Standard gravity separation and cyanide leaching circuit.
- Tailings storage facilities in Goose Potential Development Area but purpose-built TSF on Crown land.

Transport

- Gold doré bars shipped out by aircraft.

Access Roads

- All-weather roads within Goose and MLA properties.
- Winter ice road between Goose and MLA properties.
- Winter ice road connection to George Exploration Camp.

Re-supply

- Marine supply via open water seasonal shipping (approximately 3 to 5 vessels per year).
- Year-round by aircraft.
- Winter ice road to connect the Goose and MLA properties.

Environment

- Extensive baseline studies including terrestrial environment, wildlife (particularly caribou), marine environment, freshwater environment, air quality, human environment, and resource utilization.
- Traditional knowledge (TK) information collected and analyzed through an Inuit-owned major study – *Naonaiyaotit Traditional Knowledge Project*.
- Baseline and TK information will form the foundation of Environmental Impact Statement and provide information for development of mitigation and management plans.

Employment

- Fly-in/fly-out operation.
- Direct construction employment up to 1,500 person-years over a four year period.
- Direct operations employment up to 6,970 person-years over a 10 year period.

Social and Economic Benefits

- Inuit Impact Benefits Agreement to be finalized with the Kitikmeot Inuit Association.
- Employment opportunities at the site.
- Opportunities for local businesses.
- Royalties and taxes to governments.

Closure and Post-closure Phase

- Closure will ensure that the former operational footprint is both physically and chemically stable in the long term for protection of people and the natural environment.
- Post-closure environmental monitoring will continue until it has been verified that reclamation has successfully met closure and reclamation objectives.

BACK RIVER PROJECT

FINAL ENVIRONMENTAL IMPACT STATEMENT
Supporting Volume 6:
Freshwater Environment

November 2015
Project #0238709-0002

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Prepared by:

Sabina Gold & Silver Corp.

Volume 6: Revisions Log

Chapter	Section	Subject	Description (Major Revisions Only)
Chapter 1	All sections	George	Removal of reference to the George Property Area.
	All sections	Figures	Updates to figures based on FS Design changes.
	1.1	Baseline Studies	Updated to capture 2015 baseline information.
	1.2	Traditional Knowledge	Added references to KIA 2014 and specific comments from 2014 report.
	1.4	Temporal and Spatial Boundaries	Updated per the new Project Description and to reflect FS design.
	1.5	Effects Assessment	Updated substantially to reflect changes in facility design, water management, and water & load balance.
Chapter 2	All sections	Groundwater modelling	Time steps in groundwater analysis were refined. Water quality and quantities were refined through modelling.
Chapter 3			No significant revisions made.
Chapter 4	All sections	George	Removal of reference to the George Property Area.
	All sections	Figures	Updates to figures based on FS Design changes.
	4.1	Baseline Studies	Updated to capture 2015 baseline information.
	4.2	Traditional Knowledge	Added references to KIA 2014 and specific comments from 2014 report.
	4.4	Temporal and Spatial Boundaries	Updated per the new Project Description and to reflect FS design.
	4.5	Effects Assessment	Updated substantially to reflect changes in facility design, water management, and water & load balance.
Chapter 5	All sections	George	Removal of reference to the George Property Area.
	All sections	Figures	Updates to figures based on FS design changes.
	5.1	Baseline Studies	Updated to capture 2015 baseline information.
	5.2	Traditional Knowledge	Added references to KIA 2014 and specific comments from 2014 report.
	5.4	Temporal and Spatial Boundaries	Updated per the new Project Description and to reflect FS design.
	5.5	Effects Assessment	Updated substantially to reflect changes in facility design, water management, and water & load balance.
Chapter 6	All sections	George	Removal of reference to the George Property Area.
	6.1	Baseline Studies	Updated to capture 2015 baseline information.
	All sections	Figures	Updates to figures based on FS Design changes.
	6.2	Traditional Knowledge	Added references to KIA 2014 and specific comments from 2014 report.
	6.4	Temoporal and Spatial Boundaries	Updated per the new Project Description and to reflect FS design.
	6.5	Effects Assessment	Updated substantially to reflect changes in facility design, water management, and water & load balance.

Chapter	Section	Subject	Description (Major Revisions Only)
Chapter 7	All sections	George	Removal of reference to the George Property Area.
	7.1	Baseline Studies	Updated to capture 2015 baseline information .
	All sections	Figures	Updates to figures based on FS Design changes.
	7.2	Traditional Knowledge	Added references to KIA 2014 and specific comments from 2014 report.
	7.4	Temporal and Spatial Boundaries	Updated per the new Project Description and to reflect FS design.
	7.5	Effects Assessment	Updated substantially to reflect changes in facility design, water management, and water & load balance.

Executive Summary

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Executive Summary

The Back River Project (the Project) is a proposed gold project owned by Sabina Gold & Silver Corp. (Sabina) within the West Kitikmeot region of Nunavut. The Project is comprised of the Goose Property Area, the Marine Laydown Area (MLA), and connecting winter roads. The MLA is located on the western shore of southern Bathurst Inlet, and the Goose Property Area is located approximately 130 km to the southeast of the MLA.

Sabina has prepared an Environmental Impact Statement (EIS) to identify and assess potential environmental and social effects resulting from the Project. It is consistent with the requirements outlined in the Nunavut Land Claim Agreement (NLCA) and the Nunavut Impact Review Board (NIRB) Guidelines for the Preparation of an Environmental Impact Statement for the Back River Project (NIRB File No. 12MN036; NIRB 2013). This supporting volume of the EIS presents the assessment of potential environmental effects to the freshwater environment associated with proposed Project activities following the application of mitigation and management measures.

The scoping of potential Valued Ecosystem Components (VECs) involved Sabina-led public consultations, the use of Traditional Knowledge (TK), regulator consultations and regulatory considerations such as conservation status of species or groups, and recommendations presented in the NIRB EIS guidelines (NIRB 2013). The *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project Report* (KIA 2014) was consulted extensively for TK information. Based on these sources, the following freshwater components were selected as VECs: surface hydrology, freshwater water quality, freshwater sediment quality, freshwater fish/aquatic habitat, and freshwater fish communities. Groundwater, limnology and bathymetry were considered Subjects of Note and all required information from the EIS guidelines (NIRB 2013) is included in this volume.

Potential effects on VECs were evaluated spatially within a Goose Property Local Study Area (LSA) and a larger Freshwater Regional Study Area (RSA). The Goose Property RSA is 6,815 km^2, and includes parts of the Ellice River and Back River Watersheds. The Goose Property LSA followed the boundaries of the Propeller and Big watersheds, covers 365 km^2, and includes the Goose Property Potential Development Area (PDA). Potential effects were assessed during all phases of the Project, including Mobilization and Construction, Operation, Reclamation and Closure, and Post-closure phases. Specific legislation that was considered during the assessment included the *Fisheries Act* and the *Species at Risk Act* (SARA). Canadian Council of Ministers of the Environment (CCME) water and sediment quality guidelines for the protection of freshwater aquatic life were primarily used in the water and sediment quality assessments.

The following presents summaries of the existing environment, activities anticipated to interact with the freshwater VECs, mitigation measures, effects assessment, and if applicable, a cumulative effects assessment for each freshwater VEC.

Surface Hydrology

Baseline hydrology data are available for the Goose Property LSA from 2010 to 2015. Surface hydrology is governed by the Arctic nival regime where peak flow discharges during the spring, shortly after air temperature rises above freezing. In small basins, these high flows can last as little as a few days. Peak flow typically occurs immediately after ice break-up in lakes and channel reaches, especially in the smaller basins. Due to the presence of permafrost, small streams do not receive groundwater

contributions, and flow discharges from these basins may cease after freshet until the late summer rains begin. For rivers draining larger watersheds, the freshet peak may be delayed relative to smaller drainages as snowmelt from upper portions of a watershed is routed through the drainage network. Precipitation events in the late summer and early fall may lead to a second hydrographic peak, but this is generally of lower magnitude than the freshet peak. Channel freeze-up typically occurs between late October and early November. In smaller drainage basins, stream channels typically freeze to their bottom, with zero flow occurring in winter. In very large catchments and larger lake outlets, flow energy and water turbulence may sufficiently maintain streamflow and prevent downstream reaches from freezing completely.

Project activities that could have potential effects on the hydrology VEC include: site water management activities (including water withdrawal from lakes, water diversions and storage, modification of natural drainages, and lake dewatering) and winter ice road construction and maintenance. The potential effects from these activities were assessed using two indicators which were streamflows and lake volumes. The mitigation and management measures designed to eliminate or reduce the potential effects on surface hydrology included: modelling for and establishing water withdrawel limits; confinement of infrastructure to local watersheds; management of non-contact water, contact water, and saline water; and following DFO's measures to avoid causing harm to fish and fish habitat.

Following the application of mitigation and management measures, two residual effects were identified: change in streamflows, and change in lake volumes. The magnitude of the anticipated residual effects is expected to be low, the duration medium term (confined to the life of the Project), continuous in nature, and confined to within the PDA or LSA. The residual effects are also anticipated to be reversible. Contingent on the implementation of mitigation measures outlined in the Site Water Monitoring and Management Plan (Volume 10, Chapter 7), the significance of residual effects for hydrology is predicted to be Not Significant.

A potential cumulative effects assessment was conducted because residual Project effects were predicted. No past, present, or foreseeable projects that could potentially interact with the residual effects of the Back River Project lie within the Back River Project Freshwater RSA. Given that the Project residual effects were confined to the Goose Property LSA, there are no expected cumulative effects on hydrology. Similarly, as the Project residual effects were confined to Nunavut, there was no potential for transboundary effects.

Groundwater

The Project lies within the continuous permafrost zone of the continental Canadian Arctic and as such, groundwater is present deep below the continuous permafrost layer (e.g., > 400 m below surface). Water present in the active layer above the permafrost, is thawed during the summer only, and it can interact with surface waters in general. There is minimal connection between the surface active layer and deep groundwater flow regimes due to the presence of the thick low-permeability permafrost. The deep sub-permafrost groundwater is hydraulically connected with the surface water and the active layer via open taliks (also called through taliks) beneath large lakes, such as below Goose Lake. Structural features in the bedrock, such as the northwest-southeast trending faults commonly found at the Goose Property, may act as preferential flow pathways for groundwater in taliks and beneath the permafrost. In general, the deep groundwater flows from higher elevation large lakes to lower elevation large lakes. Therefore the flow direction can be inferred from the surface elevation of the large lakes that overlie open taliks. Site-specific groundwater data were collected annually from 2012 to 2015 within the Goose Property PDA. Thermistor strings, vibrating wire piezometers, borehole packer testing, and a Westbay Well have been used to characterize the groundwater environment. The

Westbay Well, installed adjacent to the Umwelt deposit in 2013, has been used to conduct groundwater quality sampling. Preliminary results of groundwater sampling indicate that the deep groundwater is more saline than seawater, with total dissolved solid concentrations of 47,000 mg/L and higher, and has elevated levels of chloride and select trace metals. Westbay Well groundwater data analysis will help project the water quality that will seep into the underground mines and be managed as part of the overall Site Water Monitoring and Management Plan (Volume 10, Chapter 7).

Limnology and Bathymetry

Limnological and bathymetric information have been collected in the Project area since 1994. Lakes are generally small and shallow, ranging between 5 and 500 ha in surface area and less than 10 m in maximum depth. Lakes shallower than 2 m are usually frozen to the bottom during the winter months. Lakes are usually well mixed from the surface to the sediments during the open-water season due to wind-driven forcing. Some gradients in temperature and density may occur in deeper lakes or in ice-covered lakes in winter, although this is uncommon. The water clarity of lakes is generally high, despite the potential for wind-driven mixing to the sediments. Water temperatures in lakes and streams tend to follow the Arctic climate, with greatest temperatures observed in August at the height of the short summer.

Freshwater Water Quality

Baseline water quality data have been collected in the Goose Property LSA since 1994, with extensive water sampling programs being carried out from 2010 to 2013, and 2015. The results showed that the lakes and streams in the Goose Property LSA are typical of Arctic freshwater systems. Surface waters have relatively low quantities of dissolved solids and metals, which is likely due to the geology of the area. The lakes and streams are generally soft and poorly buffered, with pH values ranging from slightly acidic to neutral. Lakes and streams typically have low quantities of suspended solids and are clear. Dissolved oxygen concentrations are often high in streams and lakes, but some environments experience oxygen concentrations less than the CCME water quality guidelines during periods of restricted water mixing under the ice (lakes) and low flow conditions in summer (streams). Similarly, nutrient concentrations are low and most lakes and streams are ultra-oligotrophic to oligotrophic. Metal concentrations in lakes and stream are usually low, but are occasionally elevated due to the proximity to metal mineralization in the local geology. As a result of naturally elevated metal concentrations and the generally soft waters of the lakes and streams, the concentrations of cadmium and copper are occasionally greater than the CCME water quality guidelines for the protection of freshwater aquatic life.

Potential Project-related effects on the freshwater water quality VEC included Project activities that could alter the following indicators for water quality: pH, TSS, nutrients, metals, hydrocarbons, BOD, chlorine, and cyanide. Ten potential effects were identified as a result of the Project: construction and decommissioning activities; winter ice roads; site contact water; mine contact water; water use; quarries and borrow pits; explosives; fuels, oils, and PAH; treated sewage discharge; and dust deposition. Mitigation and management measures will be in place to control these pathways, and therefore minimize or eliminate potential Project effects on the freshwater water quality VEC. The Site Water Monitoring and Management Plan (Volume 10, Chapter 7) along with Project design features such as using geochemically suitable material for roads and pads will eliminate or reduce potential effects to freshwater water quality.

Following the application of mitigation and management measures, four residual effects were identified: sediment introduction to surface waters as a result of site mobilization and construction, and decommissioning, water quality changes due to site contact water, water quality changes due to mine contact water, and changes in water quality because of the residues of explosives. The magnitude

of the anticipated residual effects was expected to be low to moderate, the duration short to long term, sporadic in nature, and confined to within the Goose Property LSA. The residual effects were also anticipated to be reversible. Contingent on the implementation of mitigation measures outlined in the Site Water Monitoring and Management Plan (Volume 10, Chapter 7) and the Aquatic Effects Management Plan (AEMP; Volume 10, Chapter 19), the significance of residual effects for freshwater water quality was predicted to be Not Significant.

A potential cumulative effects assessment was conducted because residual Project effects were predicted. No past, present, or foreseeable projects that could potentially interact with the residual effects of the Back River Project lie within the Back River Project Freshwater RSA. Given that the Project residual effects were confined to the Goose Property LSA, there are no expected cumulative effects on freshwater water quality. Similarly, as the Project residual effects were confined to Nunavut, there was no potential for transboundary effects.

Freshwater Sediment Quality

Baseline freshwater sediment quality data have been collected in the Goose Property LSA since 2007, with extensive sampling conducted from 2010 to 2013, and 2015. The results show that the lakes in the Goose Property LSA are comprised of fine materials such as silts and clays (> 89% composition) with generally low levels of organic matter. Streams are composed of coarser materials with the sediments in the LSA made up mainly of sand (43-53%), with small proportions of gravel- and silt-sized particles (22-29%). Arsenic and copper sediment concentrations are naturally above CCME sediment quality guidelines at several lakes and streams within the Goose Property LSA.

Potential effects on the freshwater sediment quality VEC included Project activities that could alter the following indicators for sediment quality: particle size, nutrients and organic carbon, metals, and hydrocarbons. The potential effects from Project activities were assessed based on potential interaction pathways with the freshwater environment, including runoff, water withdrawals, treated discharge, and aerial deposition. Mitigation and management measures will be in place to control these pathways, and therefore minimize or eliminate potential Project effects on the freshwater sediment quality VEC. The Site Water Monitoring and Management Plan (Volume 10, Chapter 7) along with mitigation measures to avoid erosion will eliminate or reduce potential effects to freshwater sediment quality.

Following the application of mitigation and management measures, four residual effects were identified: sediment introduction to freshwater sediments as a result of construction and decommissioning, sediment quality changes due to site contact water, sediment quality changes due to mine contact water, and sediment quality changes because of explosives residues. The magnitude of the anticipated residual effects was expected to be low to moderate, the duration short to long term (confined to the life of the Project), sporadic in nature, and confined to within the Goose Property LSA. The residual effects were also anticipated to be reversible. Contingent on the implementation of mitigation measures outlined in the Site Water Monitoring and Management Plan (Volume 10, Chapter 7) and the Aquatic Effects Management Plan (AEMP; Volume 10, Chapter 19), the significance of residual effects for freshwater sediment quality was predicted to be Not Significant.

A potential cumulative effects assessment was conducted because residual Project effects were predicted. No past, present, or foreseeable projects that could potentially interact with the residual effects of the Back River Project lie within the Back River Project Freshwater RSA. Given that the Project residual effects were confined to the Goose Property LSA, there are no expected cumulative effects on freshwater sediment quality. Similarly, as the Project residual effects were confined to Nunavut, there was no potential for transboundary effects.

Freshwater Fish/Aquatic Habitat

The VEC freshwater fish/aquatic habitat comprises both the physical habitat and the biological resources that sustain the productivity of freshwater fisheries species and the diversity of freshwater fish communities. Comprehensive baseline studies on freshwater fish/aquatic habitat have been conducted in the Goose Property LSA from 2010 to 2015. More than 30 streams have been characterized in the Goose Property LSA.

Within the Goose Property LSA, there are permanent barriers to fish migration along the stream between Pond A and Giraffe Lake and along the stream between Umwelt Lake and Goose Lake. Habitat quality for rearing and spawning Arctic Grayling (*Thymallus arcticus*) is generally best in the reaches immediately upstream and downstream of lakes. High quality habitat is present at Rascal Stream East and Goose Inflow South, the stream system connecting Rascal and Goose lakes. This stream contains small cobble and gravel that supports Arctic Grayling spawning and rearing, as well as providing a migratory corridor between lakes with overwintering habitat.

Large lakes such as Propeller and Goose lakes provide the majority of year-round fish habitat for locally abundant fish species such as Lake Trout (*Salvelinus namaycush*) and Arctic Grayling within the LSA. These deep lakes have sufficient oxygenated water to sustain fish populations during the ice-covered season. In contrast, shallow lakes (< 2 m) and streams freeze completely during the winter and are unavailable as overwintering habitat.

The assessment of potential effects on freshwater fish/aquatic habitat involved the direct effects of Project activities on the physical habitat of freshwater fish. Potential indirect effects are addressed as part of the freshwater water quality and sediment quality assessments. Project activities that have the potential to directly affect freshwater fish/aquatic habitat include the loss of lake, pond and stream habitat due to lake dewatering, development of open pits, water withdrawal for domestic and process use, water management activities, a tailing storage facility, water intake and discharge pipe construction, airstrip and road crossings and winter road construction. The primary mitigation measure to avoid potential effects on freshwater fish/aquatic habitat is the Project design of siting infrastructure to avoid freshwater fish habitat wherever feasible. The camp/plant site, stockpile location, and waste rock storage areas have been located to avoid fish-bearing waters. Another key mitigation measure is the establishment of maximum water volume uses which have been based on protecting critical life stages of fish in Goose, Propeller, and Big lakes. Unavoidable losses of fish habitat (e.g., loss of Llama Lake due to Llama Open Pit and loss of Umwelt Lake due to Saline Storage Pond) will be compensated through the implementation of a Fish Offsetting Plan. Therefore, no residual effects are anticipated on the VEC freshwater fish/aquatic habitat.

As no Project residual effects are anticipated, there are no potential residual effects that could act cumulatively with other project potential effects. Therefore no cumulative effects or transboundary effects are expected.

Freshwater Fish Communities

The freshwater fish communities in the Goose Property LSA are characteristic of Arctic freshwater ecosystems. Baseline studies have been conducted from 2010 to 2015 within the Goose Property LSA. The freshwater fish communities are typical of inland, headwater regions of the Canadian Arctic. Lake Trout (*Salvelinus namaycush*) was the dominant species, followed by Round Whitefish (*Prosopium cylindraceum*), Arctic Grayling (*Thymallus arcticus*), Slimy Sculpin (*Cottus cognatus*), and Ninespine Stickleback (*Pungitius pungitius*). Other species found within the LSA include Burbot (*Lota lota*) and Lake Whitefish (*Coregonus clupeaformis*). No Arctic Char (*Salvelinus alpinus*) have been captured within the Goose Property LSA, although they are likely present within the freshwater RSA.

Potential Project-related effects on the VEC freshwater fish community focused on the two abundant freshwater species in the Goose Property LSA, Lake Trout and Arctic Grayling. The main potential Project-related effect to these species is direct mortality with subsequent decreases in population abundance. The following potential Project activities could contribute to the direct mortality and decreased population abundance of Lake Trout or Arctic Grayling: lake dewatering, building of winter roads, construction of the Project footprint, water withdrawal for domestic and process use or winter road construction, and blasting with explosives. The primary mitigation measure to avoid potential effects on Lake Trout and Arctic Grayling is the Project design of siting infrastructure to avoid freshwater fish habitat wherever feasible. The accomodations area and mill, stockpile location and waste rock storage areas have all been located to avoid fish-bearing waters. Another key mitigation measure is the establishment of maximum water volume uses that are been based on protecting critical life stages of fish in Goose, Propeller, and Big lakes. Unavoidable losses to these freshwater fish species (e.g., loss of Llama Lake due to Llama Open Pit and loss of Umwelt Lake due to Saline Storage Pond) will be compensated through the implementation of a Fish Offsetting Plan.

Following the application of mitigation, management and balancing the loss of fisheries productivity through offsetting, no residual effects are anticipated on the VEC freshwater fish (Lake Trout and Arctic Grayling). This conclusion is contingent on the implementation of mitigation measures outlined within the chapter, the Site Water Monitoring and Management Plan (Volume 10, Chapter 7), the Aquatic Effects Management Plan (AEMP; Volume 10, Chapter 19) and the Conceptual Fish Offsetting Plan (Volume 10, Chapter 21).

As no Project residual effects are anticipated, there are no potential residual effects that could act cumulatively with other project potential effects. Therefore no cumulative effects or transboundary effects are expected.

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ᓴᐃᓇ ᑎᑎᕋᖅᓯᒪᔨᖅ ᐊᕐᕌᑎᑦᑎᓂᖅ ᐊᖅᑐᑦᑕᐃᓚᕐᖅᑐᓂᖅ ᐅᖃᖅᓯᒪᔨᑦ ᓇᓗᓇᐃᖅᓯᒪᔪᓂᒃ ᐊᑦᓚ ᓴᐃᓇ ᖃᐅᔨᓇᓕᓂ ᐊᕐᕌᑎᑦᑎᓂᖅᓂᓗ ᐊᖅᑐᑦᑕᐃᓚᕐᖅᑐᓂᒃ ᐃᓕᓴᕐᕕᒃ, ᐊᑦᓚ ᓇᓂᓕᒫᓂᒃᓴᓪᓗᒍ ᑕᐃᒪᐃᓐᓇᕐᓂᖏᓐᓄᑦ ᐊᑦᓚ ᓇᓂᓕᒫᓂᒃᓴᓪᓗᒍ ᐊᖅᑐᑦᑕᐃᓚᕐᖅᑐᓂᒃ ᐅᖃᖅᓯᒪᔨᑦ ᑕᐃᒪᓐᓇᖅᑐᓂᒃ

ᐅᑯᐊ ᐃᖃᓗᓕᕆᔨᖅ ᑯᓘᖏᓐᓄᑦ ᐊᒻᒪᓗᒃᑐᖅᑐᑦ ᐊᑐᓕᕆᔨᖅ ᑭᖑᓂᖅᑐᑦ ᐊᑐᖅᑭᒃᑐᑦ ᐱᒋᐊᕐᓂᖅ ᐊᑐᖅᑭᒃᑐᑦ ᐊᑐᖅᑭᒃᑐᑦ ᐊᑐᖅᑭᒃᑐᑦ

ᑭᖓᓴ ᒧᑦ ᑕᐅᖅ ᐃᓕᑎᑕᐅᓴᖅᐳᖅ. ᑎᑦᓕᓐᓂᓇᖅᓯᒃ ᑐᑦ ᐊᑐᓕᖅᑎᑕᐅᑎᓪᓗᒍ ᐅᑯᐊᐃᑦᑐᑦ ᐊᐅᓚᐅᖅᑕᐃᓕᓕᑎᑦ ᑎᑎᕋᖅᓯᒪᔪᑦ ᐃᓂᖅᓴᓂ ᐃᒃᑯ ᒥᑦᓴᐃᖅᑕᐅᑎᓪᓗᒍ ᓂᕆᔨᖅᑐᑦ ᐊᐅᓚᐅᖅᑕᐅᑎᓪᓗᐊᖅᑐᓂᒃ ᑲᑦᓇᖅᑐᖓ (ᑎᑎᕋᖅᓯᒪᔪᑦ 10, ᐱᓕᕆ 7), ᐊᖏᖅᑕᒃᓴᓕᖅᓯᒃ ᐱᓯᒪᔪᑦ ᐱᓴᖏᑦ ᓂᕆᔨᖅᑐᑎᓪᓗᐊᖅᑐᓂᒃ ᐊᐅᓚᐅᖅᑕᐃᓕᓕᑎᑦ ᖃᖅᑎᖅᓂᒃ ᓄᓇᕗᒻᒥᐅᑦ ᐃᓕᓴᐃᓐᓇᖅᑐᑦ ᐊᐅᓚᐅᖅᑕᐃᓕᓕᑎᑦ ᓴᓇᔨᓂᒃ ᐃᓂᒋᔭᐅᓂᒃ ᐊᐅᓚᐅᖅᑕᐃᓕᓕᑎᑦ

ᑕᑯᐅᓴᐅᑎᑦ ᑎᑭᖏᑦ ᑕᖃᑐᖅ, ᐊᓂᕆᖏᑦ ᑕᕆᓗᐊᕐᓂ ᐃᓕᓴᕐᓕᐊᑎᑦ ᑎᑦᓗᓂ ᓄᓇᓗᓂ. ᐃᒪᖓᓕ ᐅᖃᑯᓂᖓ ᑕᓯᕆᓂ ᐊᒻᒪᓗ ᑯᓚᖅᑕᑦ ᓴᖅᑭᑦᑕᖃᖅᑐᑦ ᓴᓇᖅᑐᑦ ,ᐅᓇᖅᓯᓯᒪᓕᕐᓂᖅ ᑐᖓ ᐊᑐᓯᒥ ᐅᓇᓗ ᐊᐅᓚᑉᑲᖅ ᓂᖓᓂᑦ.

ᐃᒪᑦ ᑎᑭᓂᖅ ᐱᐊᖅ ᑐᖓᖅᓯᖓ ᑐᓂ ᑐᓗ

ᐃᒥᖏᕐᖃᑦ ᓇᐅᓚᑐᖓᒪᖅᓴᐃᒻᒥᑦ ᑎᑭᓂᐅᖅᓯᓚᑦᑎᓐᓂᑦ ᓇᐅᑦᓯᓕᕆᓂᖅ ᐃᓕᓴᕐᓂᖅ ᐃᓕᓴᕐᓂᖅ ᐃᓕᓴᕐ

ᐅᖃᓕᖅᐹᓪᓚᑦ ᓯᐅᑎᓄᖅ ᓴᑦᑐᓂ ᐱᓕᕆᐊᖅᓴᖅᑐᑦ, ᐱᓕᕆᐊᖃᕐᓂᖅᑐᑦ ᐃᓕᓴᕐᓂᓕᕆᔨᑦ ᐊᖅ ᑐᐃᒪᓕᓴᖅᑐᑦ ᓂᕆᐅᑭᓕᐅᖅᑐᑦ ᐃᓕᑦ ᑎᐊᖏᖅᓯ ᓄᓇᓕᓐᓂ ᐃᓕᓐᓂᐅᔪᓂᖅ ᑐᐃ. ᖃᓄᐃᔾᔨᖅ ᐱᓕᕆᐊᖃᕐᓂᕐᒪᑦ ᐅᐊᖅᑐᑦ ᐃᓕᓐᓂᐅᔪᓂᖅ ᐱᓕᕆᐊᖃᕐᓂᖅ ᐃᓕᓐᓂᐅᔪᓂᖅ ᐃᓕᑦ ᑎᐊᖏᖅᓯᒪᓂᖅ. ᐅᓇ ᑐᐅᓂᖅᑕᐅᔨᖅ **BIPR** ᐱᓕᕆᐊᖃᕐᓂᖅ, ᐅᓇᓗ ᒥᑭᓂᖅ ᐃᓕᖅᓯᒪᓂ ᑕᒪᑦᑎᐅᓂ ᐊᐅᖅᑐᑎᓂ ᐅᑭᐅᖅᑐᑦ ᐊᖏᓂᖅᑐᑦᑎᓂᒃ ᑕᐃᑲᓂ ᐅᐊᖏᓐᓄᖅ ᐱᓇᓐᓄᖅᓯᓗ ᐃᓕᓴᐅᓂ ᓴᓇᔨ ᔫᓗᖅᑲᖅᑐᑦ ᐃᓕᑦ ᑎᐊᖏᖅᓕᒃ ᐊᐊᖅᑐᑦᑎᓂᒃ ᐃᓕᓐᓂᐅᔪᓂᖅᑐᑦ. ᐅᓇ ᒥᑭᔨᖅ ᐃᓕᓴᖅ ᐱᓕᕆᐊᖅᓯᔨᖅ ᐊᐅᖅᑐᑎᓂ ᐅᑭᐅᖅᑐᑦ ᓄᓇᕗᑦ, ᐊᑦᓯᓗᓃ ᐱᓕᕆᐊᖃᕐᓂᖅ ᐃᓐᓇᐃᓐᓇᓕᖅᑐᑦ ᐃᓕᑦ ᑎᐊᖏᖅᓕᒃ ᐃᓐᓇᐃᓐᓇᓕᖅᑐᑦ. ᐅᓇ ᐱᓕᕆᐊᖃᕐᓂᖅ ᓄᓇᕗᑦᓂ ᐃᓕᓐᓂᐅᔪᓂᖅᑐᑦ ᐊᐅᖅᑐᑎᓂ ᑎᑭᓇᓐᓂᖅᑐᑦ ᐃᓕᑦ ᑎᐊᖏᖅᓕᒃ

ᐱᑕᖅᓯᒪᓂ ᑐᖅ ᑭᖑᓂᖅᑎᓂ, ᐃᓐᓇᕆᔨᖅ, ᐅᑎᖅᑯᓯᒪᓂ ᓴᖅᑭᑎᑦᑎᓂᒃ ᐱᓕᕆᔨᒃᑯᑦ , ᑕᐃᒪᓐᓇᕆᔨᒃᑯᑦ ᑕᐃᒪᓐᓇᕆᔨᒃᑯᑦᑐᖅ ᐊᑐᖅᑐᑦ ᑐᑭᓯᐊᖅᑐᑦ ᑐᑭᓯᐊᖅᑐᑦᑕᒫᖅ ᐱᓕᕆᔨᒃᑯᑦ ᑐᑭᓯᐊᖅᑐᑦ ᐱᓕᕆᔨᒃᑯᑦᑐᖅ ᐊᑐᖅᑐᑦ ᐱᓕᕆᔨᒃᑯᑦ ᑐᑭᓯᐊ

ᓄᖅᓯᓂᖅᐸᑕ ᐃᖅᑲᓐᖏᑦ (ᓯᑦᓗ ᐊᓯᐅᑐᓂᓂ ᒡᒪ ᑕᓯ ᐱᐅᔪᓐᓇᖅᑐᑦᓗᒍ ᒡᒪ ᒪᑦᐱᓱᖅᓴᖅ ᐅᓴᕆᖏᓂᐊᑦᓇᖅᑎᑦ) ᐋᖁᐅᓄ ᓯᔪᖅᑲᓂᖅᓂᑦᓂᐊᖅᑐᖅ ᐊᑐᑕᖅᑕᐅᑐᓂᓂ ᐃᖅᑲᖅᑭᑦᓇᖅᑕᐅᑐᓂᓂ ᐱᒪᑦᓂᓂᐅᑐᖅ ᐃᓕᓴᐅᑐᖅ. ᑕᐃᒪᐃᓕᒪᑦ, ᓄᖅᐸᑦᑕᐊᔪᖅᑭᓂᐊᖅᓯᒪᓂᖅ ᐊᐅᑐᖅ ᐃᐅᑲᓂᓂ ᐊᓂᓂᐅᑐᖅ ᐅᒪᔪᓂᓇᖅᑐᖅᓯᒪᔪᑦ ᐊᖏᑎᖓᓄᑦ ᓇᓗ ᐱᓯᒪᔪᑦ ᐃᓕᖅᑐᐃᓐᓇᖅ ᐃᖅᑲᐃᐃ ᐊᓕᑦ ᒪᓗ ᐃᒪᓕᒪᑦᑎᑦᑕᖅᑐᑦ ᐅᒪᔪᑦᑎᐊᖅᑐᑦ ᐃᓕᓴᐅᑐᖅ ᐃᒪᓕᒪᑦᑎᑦᑕᖅᑐᑦ ᐃᓕᓴᐅᑐᖅ ᐃᓕᓴᐅᑐᖅ ᐃᓕᓴᐅᑐᖅ

Immap Niukaknianut Atanguyap Ukauhia

Hannigayukmi Havaak (Havaak) kulmik uyagaktakviuyumayuk nanminigiyauyuk Sabina-Silva unalu Goldnin Uyagakhiuktinin (Sabina) iluani Ualiani Kitikmeot, Nunavumi. Havaak pikakhunguyun havakviuluagumayun: Goose-mi Uyagaktakvik, Umiuyallu Uhiiyakvikhaan (MLA-guyuk) ukuatku apkutihak ukiumi. Taamna uhiiyakvikhak hanianiituk ualliani Kingaugup hinaata, taamna Goose nayugaa ungahiktilaanga 130 kilamiitas paaliani kivalianiivyaktuklu uhiiyakvikhap.

Sabina-kun ihuahaihimayun Nunaptingnut-Hilaptinutlu Aktukningagun Ukauhikmik (EIS-mik) tikuakhiyaagani ilitukhaklugilu aktuktautaaktun Nunaptingni-Hilaptinilu, inuknullu Havaamin, taimaiginiakhunilu atugiakakniginik ukautauyunik Nunavumi Nunataknikun Agikatigigutauyumi (NLCA-mi) Nunavumilu Avatilikiyin Katimayinin (NIRB-kunin) Maliguakuyainik Ihuakhakniginik Nunaptingnut-Hilaptinutlu Aktuknigagun Ukauhikmik Hanigayukmi Havaamin (NIRB-kuni Titikam Napaa 12MN036; NIRB-kuni 2013-mi). Una atautimiuyun EIS-mi piyutikaktuk ilitukhakniginik aktugutaulaktunik Nunaptingnut-Hilaptinutlu hilainakmik piyutikaktunik Havaami hulilugagutinin kiguagun atulikmata ihuakhautin munagiyutilu havaan.

Naunaiyakningin piyutaulaktunik Pikpagiluaktavun Manikkami Pikaknigin (Pikpagiluaktavun Manikkami Pikaknigin-guyun) piyutauyuk Sabina-kunin kitulika ukakaktigiyaagani, atukniginik Igilgaa Kauyimayainik (TK-mik), maliguagakhaliuktin ukakatigiyaagani maliguagakhaniklu ihumagiyauyukhanik ila ilipkamainagiagani angutikhavaluin ilagilunin, atulikuyainiklu ukautauyun NIRB-kun EIS-giyani maliguagakhan (NIRB-kun 2013-mi). *Inuin Igilgaan Kauyimayainik Sabina-kun Hannigayukmi Havaanga, Naunaiyautit Ingilgaat Kauyimayainik Unipkaak (*KIA-kun 2014-mi) ukautaukhaaktun TK-mik hivunikhiyutikhani. Atukata ukua ihuakutin, Ukua imagiknigin imigakhan tikauktauyun Pikpagiluaktavun Manikkami Pikaknigin-nik: kaaganiitun imavaluin, imagiknigin, imigakhan natkani halumanigin, tatini ikaluin, immap nikyutaita nunagiyain, tatinilu ikalukaknigin. Nunami imakaknigin, tikvani imavaluin, itinigilu ihumagiyauyun Ukautauyagiakakniginik tamaitalu piyagiakaktun hivunikhiyutikhanik ukautauyunik EIS-mi maliguagakhani (NIRB-kun 2013-mi) ilauyun uvani atautimiuyuni makpigaani.

Aktuknigilaaktain Pikpagiluaktavun Manikkami Pikaknigin kimilguiyun kanuginiginik iluani nunam ilitugiyumayun (kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-guyum) unalu angitkiyauniaktuk Immiknaktummi Aviktuhimaniini Nayugaini Kimilguinik (RSA) unalu Goose-mi Havakvinga kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-giya ungahiktilaanga 365 kilamitauyuk avatiknun ilikuukhunilu Goose-mi Havakviluanga Pivalianiganik Nunanmi (PDA-guyuk) maliknahuakhugillu kikligin Prupillir, Big-imakaknigin. Goose-mi Havakviluanga RSA-ga 6,815 kilamitauyuk avatiknun ilagivlugulu Kunayum Imakakniga avaluliutivlugulu Goose-mi Havakviluanga PDA-ga unalu kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-galu. Tamaita Havaamin aktutaulaktun ilitukhaktauyun Inigiyauyukhak Ihuakhaktautilugu, Hanayautilugu, Aulaviutilugu, Utiktitauniaktilugulu Ilitkuhianun Umiktiknigalu, Umiktaakan Havaaguyukhan. Maliguagakhaluin ihumagiyauyun ilitukhaktautilugu ilakaktun *Ikalulikinikun Maligakyauk* unalu *Umayun Ihumaluknaktun Maligakyauk* (SARA-guyuk). Kanatami Katimayin Havakviuyun Nunaptingnut-Hilaktinnutlu (CCME-kun) imagikninga hiugaliavlu kanuginigagun maligakhan muanagiyaagani imiktaakhani immap nikyutait atuktauhimayun imagikniganun hiugavaluilu kanuginigagun ilitukhautini.

Ukua naitumik ukautjauyun taja Nunaptingnut-Hilaptinutlu, Havaami hulilukaagutikhanik nahugiyauyunik aktugutaulaktun imiktaakhani Pikpagiluaktavun Manikkami Pikaknigin, ihuakhautikhan, aktuknigagun ilitukhautin, atulakalu, atautimukpalianigin aktukniginik ilitukhautin atuni imiktaaknigani Pikpagiluaktavun Manikkami Pikaknigin.

Nunam Kaangani Imakakningin

Hivuani imakaknigagun naunaipkutin kahaktun Goose-mi Havakviluanga kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-gani 2010-min 2015-mun. Nunam kangani imakakninga maliguagakaktuk Ukiuktaktumi umiaktuktun pijuhiknik ilaa kuvinikaktun upingaami, hila uunakpaliatilugu kikaigaagan. Mikiyuni tahikani, ukua kuvinikaktun ikituni uplunni. kuvinikaktun hikuiyaligaagan tatini ikigahaknilu, ila mikinikhanik tahikkani. Nuna kikumakman, mikiyun kunuin imaiyuitun nunan iluanin, kuvihuikniagunakhiyun ukunanga tahikanin maniktiktaakan auyami nipalikkan kihiani. Kuukan anginikhan, kungiknigin kuvivakniagunakhiyuk imakakpalaangitpan nuna aputin kingiknikhanin imakakningani kuktukman uiguligini kunuani. Nipaluknigin nungulikan auyak ukiakhalihaakallu kugikhitiyutilaktuk, kihiani una mikitkiyauyuk kukninga mahaktikninganin nunam. Ikigahain hikuvaliavaktun nunguligaagan aktupa atulihalikalu Nuviampa. Mikitkiyani kuukani, imavaluin kikivaktun natkanun, kuktukagituk ukiumi. Imakakningit agitkiyanilu tatini, kuknigin immalvu aulaninga kukluaktum paanginilu taman hikuyuittun.

Havaamin aktugutaulaktun imakakniginik Pikpagiluaktavun Manikkami Pikakninginni ilakaktuk imaknik atukninginik, Havakviluanga imaknik munagiyutinun hulilukaangutin, ukiumilu apkutin. Aktuknigilaktain ukunanga hulilugaagutinin ilitukhagauyun atukhutik pigahunik naunaiyautinik kanugaaluk atukniginik imaknik, kuknigin, takilu imakaknigin. Ihuakhiyutinun munagiyutinulu pijutauyun atugiangani mikhivaligiaganilunin atuknigilaktain nunam kaangani imakaknigin ukuanguyun: ihuakhakninga aginikhamik imaknik atuknigin imakaknikluagini munagiyaagani ikaluin nunagiyain, malikhugin DFO-kun pikuyain ukiumi imiktakniginik, iluaniginagiaganilu pikutin inigiyauyumi imakaknigini, malikhugilu ukiumi apkutin hanayaunigin munaginigilu DFO-kun aulanikun ukauhinik.

Maliguaklugin atuknigin ihuakhautin munagiyutilu atuktun, malguk kiguani aktuknigik tikauktauyuk: aalaguknigin kuktun, tatilu imakaknigin. Kanugaaluk nahugiyauyuk kiguani aktuknigin mikauniaknahugiyauyuk, hivituniga tayainak (ilauniniak havakviutilugu Uyagaktakvik), atunakniaktuk ilitkuhigaluagatun, iluanilunilu PDA-guyun kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-nilu. Kigaugun aktuknigin nahugiyauyulu kikluanun aulaligiagani. Atukata atukpalianigin ihuakhautinun piyutin ukautauyun Inigiyauyumi Imaknik Amigiyutinun Munagiyutinulu Upalugaiyaun (Makpigaami 10, Titigaknigani 7), ihumaalutigiyahaittuk kinguagun aktukningin imakakninginik nalautauyut atukningit Ihumaaluknainigani.

Atautimukpalialaktun aktukniginik ilitukhakniganik havaagiyauyuk ila kinguagun Havaak aktuknigin nalautaangnahaukmata. Havaamin kinguagun aktuknigin nakugiyauyun iluaninginakniginik imiktaakhani kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-mi. Kaninikhak havaagiyauyumayuk ilaulaktuk Havaami kiguagun aktuknigini una BIPR-mik havaagiyauyumayuk, pikakman naitumik ukiugaaluk apkutikhamik tunungani ualikhiani kikligata George-mi Iklukpakakvium imiktaakhanik RSA-gani. Nituk apkutauyukhak nahugiyaugituk aktuknikaknihaagun imavaluknik, Havaamilu kiguagun aktuknigin iluanitmata kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-mi, nahugigitun atautimukpaliayunik aktukniginik imavaluin. Havaamin kiguagun aktuknigin iluaninmata imiktaakhani kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-mi, inikaktuk tamaan Nunavumi, pilimagituk tiktaunigin anukimin aktuknigin.

Nunam Iluani Imak

Havaak inikaktuk iluani kikkumainaktum nunam nunakyuami Kanataum Ukiuktaktuani, talvuna imakaktuk nunami ataani kikumainakniganin (ila > 400-mitamik ataaniituk nunap). Imakaktuk auktukataktumi kaangani kikumaniganin, auktukpakman auyamiinak, ilauttaktun nunam kangani imavalukni. Mikiyumik ilaunikaktuk nunam kanganin auktuinakpaktum unanigaaluk nunami imauyun kuknigin pikaktukman hiliktuni auktukpalaayuituni kikumaniganik. Unanigaaluk ataani kikumanigata imakaknigin nunan kukniginin ilauyun nunam kangani imavaluknik auktukataktuvlu nunam kumnigitigun natkani angiyun, imaituni natkani Goose-tahiani. Kanuginigin kaiktuni, ukununatun tunungani kivalikhiani-hivugaani

kivalikhiani kumnigin kaiktuni takukyauvaktun Goose-Havakvingani, kukvigiyaulaktun nunam iluanin imavaluknik ataani nunam kikumaniganin. Kumnigin naniyauvaktun Goose-Havakvingani, kukviulagungnakhiyun nunam iluani imavaluknin ataani kikumanium nunam. Imaituginaktuk, nunam iluani imavaluin kukpaktun kigiknikhanin agiyunin tahiknin (tatin kaaganitun kumnigin) atpanitunun agiyunun tatinun, talvuna kuknikalaktuk nunam kaanganin aginikhanin tatinin kaaginitun kikumanigata nunam iluani aumaniginin. Havakviluanga nunam iluani imakaknigin naunaitkutin katitiktauyun 2012-mi 2015-milu iluani Goose-tahiani Havakvingani PDA-gani. Unatakningagun naunaiyautin, hayuktun alguyan imam hakugikniganin kunmun, ikutaknik himikhiplutin ilitukhakningin, nunamilu iluanin imiktakvik atuktauhimayun naunaiyagiangani nunami imavaluin kanugitahaita. Imiktakvik nunamin, iliyauhimayuk hanigaani uyagaktakvikham Umwelt 2013-mi, atuktauhimayuk nunam ilauni imagikniginik naunaiyagauyuk. Hivuani kanuginigin nunam iluani imakaknigin naunaigutuayuk unanigaaluk nunami imak takyukakluatkiyaungituk takyumin, tamaita avugivalianinga ima 47,000 mg/L-mik anginikhamiklu, klurait-kaktuvlunilu havivalukniklu pakittivaktut. Nunam iluani imagikniga naunaigutauyuk Wistbay-mi imiktakvikmi nunamin taimaijutiniaktuk imaknik kukluaktun avatigiyauyumi nunam ilaunun munagiyaulunilu ilangani tamaini Havakviluanga Imakakninganik Amigiyutini Munagiyutinulu Upalugaiyaunmi (Makpigaak 10-mi, Uiguani 7).

Kimilgukniit Tattit Hunakakniinut unalu Itiniit Tattit

Naunaiyautaulgaktun kimilguinia tattit itiniitlu uuktukkaakhimayavut havakvikhapta iluani 1994-mi. Tatin mikiplutik imaalu ikatutiklu, angitilaagin talimanin 500 ha=hiktair kaangini angitilaagin ikkatkiyauvlutiklu 10-mitamik itinik. Tattin ikkatkiyan 2-mitamik hikuvaktun natkanun ukiumi. Tattin akutauvaktun kaanginin natkanun auyami anukimin. Ilagini aalatkiktun unaknigin takukhauhiuknigilu natka pilaktuk itinikhani tattini hikukaktunilunin tattini ukiumi, una taimaitkalauktilugu. Imagiknigin tattin angiyuk, anukimin akutauniagaluakhutik hiugakakninganun. Imavaluin uunaknigin tattini kuuvaluknilu maliguaginakuktun Ukiuktaktumi unakniganik, unatkiyauyunik August-mi kutiknikhaani naitum auyam.

Imiktahak Imak Uuktuktaunia

Kingulikpak uuktuut imaknut atuktauvaktut talvani Goose havakvihaani talvanga 1994mit, amihunik imaknik ilittukhaijutini havaagiyauvakhuni 2010-min 2013mun, 2015milu. Kanuginigin naunaigutuayun tattin kuuvaluilu imiktaakhaita kimilguiyun kanuginiginik iluani nunam ilitugiyumayuni taimainginaktun Ukiuktaktumi imiktakvikhan atuktun. Kaganitun imavaluin pikakpalangitun ilaliutihimayunik naptuyunik havivalukniklu, taimaitunakhuvuk nunan kanuginingani talvani. Tattin kuuvaluilu aulavalayuitun avatailu ihuagitun, pH-gilu hiiknaktuyaaktumit kanugigingitutiklu. Tattin kuuvaluilu hiugakakpalaangitun halumattiaktun. Ilaliutinigin anikhaaguminaktun ila atuktavun amigaitun kuvalukni tattinilu, kihiani ilagin avatauyun pikaktun anikhaguminaktunik mikinikhanik CCME-mi imauyun halumaniginik maliguagakhani imavaluin aulanikakpalaguigaagata ataani hikum (tattini) imakuginigilu kuktun auyami (kuvaluin). Taimatauk, aullagiikhijutin akiittun amigainikhalu tattin kuvaluillu nauhimayukakpalagitutik mikiyunik naunikaktunun. Havivalukaknigin tatin kuvaluilu mikiyun, kihiani amigaikpatkun huminiganin havivalukaknium kanituani nunami. Inmini havivalukakniganik aulavalaaginigilu imauyun tatini kuvaluknilu, kadmium-kakniga kanguyakniklu angitkiyauyuk CCMEmi imauyun halumaniginik maligakhani hapumiyaagani immap nikyutait.

Havaamin aktugutaulaktun imiktaagakhanik imagikninganik Pikpagiluaktavun Manikkami Pikaknigin-ni ilakaktuk Havaami hulilukaagutinik aalaguktilaktanik ukua naunaitkutin imagiknigagun: pH-mik, TSS-mik, aulagigutikhanik, havivaluknik, pauvaluknik, BOD-mik, kluarin-mik, sainait-miklu. Aktukningilaktain Havaamin hulilukaagutinin ilitukhaktauyun atukhugin ilaulilaktunik aulaninginik imiktagakhaklu inigiyain, kukningilu mahaktiknium, imaiktitpalianiginik, halumaktikhimayun kuviktitauyun, hilainakulu katakpaliayun. Ihuakhautin munagiyutilu atuktukhan inigikhimaniaktun munagiyaagani ukua aulaningin, talvuuna mikinikhauyaagani pikagitaaganilunin Havaamin aktukniginik imiktaagakhanik imagiktunik Pikpagiluaktavun Manikkami Pikaknigin-ni. Havakviluanga Imaknik

Amigiyutinun Munagiyutinulu Upalugaiyaun (Makpigaami 10, Uiguani 7) ukualu Havaami kanuginikhainik ila kinitpan uyakan namainagiagani atuklutik apkutini tungaviknilu takukhauhuiktiniagaa mikhipkakluguluunin aktugutaulaktun imiktaaknianut imagikniganiklu.

Kinguani atulikniganik ihaukhautin munagiyutilu, pigahun kiguagun aktuknigin tikuaktauhimayun: hiukakpalianiga nunam kaagani imavaluin ila Havakvingahak ihuakhaktautilugu, hanayautilugu, agiptiktautilugilu, imagikniga aalagukpaktun Havakviluanga aktuknikaagami imaknik, imagiknigalu aalagukpaktuk uyagaktakvikmin aktukhigumi imavaluin. Agitilaagani kiguagun aktuknigiyauniaknahugiyaan mikauniaknahugiyaan, hivituniga nailuni takivalaagilunilu (uyagaktakviuginaktilugu Havaak), taimaikatalimagituk, ilauniginaklunilu imiktaakhani kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-mi. Kiguagun aktuknigin nahugiyauyun kikluagulakniganik. Pihimakpan atukpalianiganik ihuakhautin ukautauyun Havakviluanga Imaknik Amigiyutinun Munagiyutinulu Upalugaiyaunmi (Makpigaak 10-mi, Uiguani 7) Imakmilu Umayuvaluin Aktukniginik Munagiyutinun Upalugaiyaun (AIMP-guyuk; Makpigaami 10, Uiguani 19), pikakniga kiguagun aktukniginik imiktaakhanik imagiknigagun Ihumaalutauvalaangituk.

Katitiknahugiplugit hiugak imiktakviptingnut uuktutihaanik akuiktukhimayugut ilihimagaptigu kakugu hiugak katitikniakman. Kangagaaluungittuk, haja, imaalu kakuguluuniin havaahat talvani Hannigayup Havaahaani ilauyuk talvani Hannigayup Havaahaani Imiktakvihani Hiugavaluin Halumaningini. Takuyugut talvani havakvingmi Goose, ihumagingitakkut hiugak katitikniagiahaanik. Tahapkua havaap hiukingniit Nunavuinakmi pingmata, ihumaaluutigiyahaituk ahini.

Takyuilgumi Hiugavaluin Halumaningin

Naunaiyagaangan imiktaaknikkata hiugalgit halumaniit naunaitkutin katitigihimayun Goose-mi kimilguiyun kanuginiginik iluani nunam ilitugiyumaplutik talvanga 2007-min, ilitukhaiginnakhutik pihimayun 2010-min 2013-mun uvungalu 2015. Kanuginingin naunaigutauyun una tahik Goose-mi kimilguiyun kanuginiginik iluani nunam ilitugiyumayun pikaktun hiugalianik maklukaktun (>89%-mik ilaginik) kupilgukangituni. Kuuvaluin hiugaliakaktun angitkiyanuanik maklukniklu tamakni Havakvingani kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-mi hiugalianik (43-min 53%-mun), mikiyuniklu uyagalianik (22-min 29%-mun). Arsinik-mik kanguyakmiklu pikaktun hiugalian amigaitkiyauginaktun CCME-mi hiugalianik halumaniginik maliguagakhani iluani Goose-mi Havakviluangani.

Havaamin aktugutaulaktun Takyuilgumi hiugalian halumaniginik Pikpagiluaktavun Manikkami Pikakniginni Havaamin hulilulangutinik aalanguvyaktuk ukua naunaigutin hiugalian halumaninginik: aktilaanginik, aulagikhiyutin mikannuilu pauvaluin, havivaluin, pauvaluilu. Aktuknigilaaktain Havaami hulilukaagutin ilitukhakhimayun atukhugin ilaliutivakningin apkutauyun imiktagahanlu inigiyaini, kuuvaluilu, imaiktitpalianingin, halumatkiyauyuk kuvipkaktitauyun, hilainakmilu tutpaliayun. Ihuakhautin munagijutilu iliyauniaktun munagiyaagani ukua apkutain, mikhivaaligutauniaktun takujutikluunin Havaamin aktuknigin imiktaktahani hiugalian halumanigini pikpagiluaktavun manikkami. Havakviluanga Imakni Amigiyutinun Munagiyutinulu Upalugaiyaun (Makpigaami 10, Uiguani 7) ukualu Imakmiutat Huyaahaita Munaginiit Maligahak (AEMP; Makpigaami10, Uiguani 19), pakitait mikiyunuit ihumaalutihaungittuk.

Atautimuktun aktuknigilaktainik ilitukhaknik uuktuktauyuk kinguagun Havaamin aktukningin nakuugiyaukmata.

Kinguliptingni, haja, talvaniluuniin kakugu havaahat kahautiniakningit iluaniitut taffuma Hannigayup Havaahaani Imak Takyuittuk Hiugainninganutlu Katitikningani. Takuvaktugut taamna havaap hiugakaknia iluaniitpaktuk talvani Goose Havakviinaani, ihumaaluknaittuk hiugakakniagiahaanik imak niukaktuhak. Taamna hiugak imakmi iluaniitman Nunavut, ihumaalungittugut ahinungaungittuk.

Takyuilgumi Ikaluin Umayunuilu Nunagiyain

Takyuilgumi Ikaluin/imakmiutalu nunagiyain pikaktun tamaknik nunagiluakhugit nauvaliayunuilu ihuakutin naupkakpagait takyuilgumi ikaluvaluknik aalatkiiniklu takyuilgumi ikaluin nunagiyain. Naunaipkutikhaluin ilitukhinahuaktain takyuilgumi ikalunik umayunuanilu nunagiyauyun ukuaguyun tamangnik nunagiyain umayunuilu ihuakutin umayutigiyain takyuilgumi ikaluin aalatkin ilalu aalatkikningilu takyuilgumi ikaluin. Tamatkiumayun naunaiyautin takyuilgumi ikaluknik imakmilu nunagiyauyun pihimayun Goose Havakvingani kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-mi 2010-min 2015-mun. Amigaitkiyan 30-nin kuunuin naunaiyaktauyun Goose Havakviluangani.

Ilauni Goose Havakviani, Ikaluin aulakattaalimaittut tahikmit tahimut kikpakvihaittut akungani Tahikkam A uvanggalu Giraffe Tahianit uvanggalu hinaanit kuugalaap haniani Umwelt Tahik unalu Goose tahianit. Nunagiyauyun halumaningin ikalukan angiklitikvin iklikakningitlu Hulukpaugan nakunikhan akianungauyaami tahiup ihuatkiyauyuk. Nunagiyautiktun uknani Rascal-mi Kukami akunani Rascal, Goose-lu tattik. Una kunuak mikiyunik uyagalialik hiugalianiklu Hulukpaugan igligiyain ikalugakakhutiklu, kitpavigivlugulu akungani tattin ukiumi ikaluin kitpavigiyain.

Angiyun tattin Prupillir-tun, Goose-tulu ikalukainaktun ukiugaaluk amigaituvlutiklu aalatkin ikaluin ila Ihuun, Hulukpaugalu ilauni kimilguiyun kanuginiginik iluani nunam ilitugiyumayun. Ukua itiyun tattin umavigivagain ikalugaaluin hikuhimatilugu ukiumi. Ahianitauk, ikatun tattin 2-mitamik itinikaktun kunuilu hikuvaktun natkanun ukiumi atuktaulimagitulu ukiumi ikalunin nunagiyauyaagani.

Ilitukhakninga Havaamin pijutikaktun aktuknigilaaktain Takyuilgumi ikaluknin umayunuanilu nunagiyauyun ilakaktun aktuknigiyaanin Havaami hulilugagutin nunagiyaini imiktakviuyukhani ikaluin. Aktugutautaaktun ukautauyun ilangani imiktakvikhan imagikningini hiugalialu halumaniginik ilitukhautini. Havaamin hulilukagutin aktuknilaktun Takyuilgumi ikaluknik umayunuilu nunagiyainik ilakaktun atuguikninginik tattini nunagiyauyun tahik imaiyaktauniakman, pivalianinga uyagaktakvikham anmukpalialutik, imiktakviuyukhaklu inuin atuktakhainik uyakikiyutikhanulu, ukiumilu apkutiliukata. Kunuilu nunagiyauyun atugiakniagunakhiyun hanayaulikan uyagaktakvikmi pikutinik. Ihuakhautauluaktukhak atugitaagani aktuknigilaktain Takyuilgumi ikaluin umayunuilu nunagiyain Havaami ihuakhakniga iliugagiagani pikutin kahagitaagani Takyuilgumi ikaluin nunagiyain akituvalaagitpan. TIA-guyuk ikaguniklu uyagaktaanik tutkuktigivik inikhaliuktauyuk aktukhigitaagani ikalukaktun imavaluin. Ihuakhautaukmiyuklu inikhimaniganik aginikhanik imaknik atukniginik piyutikaktumik apumiyaagani ikalukan agiklitikvin Goose-mi, Prupillir-mi tattini. Atuginiga ayuknaktuk ahiuniginik ikaluin nunagiyainik (ila atugiukniga Llama Tattimik Uyagaktakviuniakman) himautikakniaktuk atukpalianigagun umiga Ihumagiyauyuk Ikaluknik Ahiaguknikhaagun Upalugaiyaun. Talvuna kigaugun aktuknigin nahugiyaugitun Pikpagiluaktavun Manikkami Pikaknigin-ni Takyuilgumi ikaluin umayunuilu nunagiyainik.

Havaamin kinguagun aktuknikagininga nakuugiyauyuk, pikangituk aktukniginik atautimukpaliayunik ahinin havaanin. Talvuna atautimukpaliayun aktuknigin nutpaliayulunin aktuknigin nahugiyaugitun.

Takyuilgumi Ikalukakningin

Takyuilgumi ikaluin Goose-mi Havakvingani kimilguiyun kanuginiginik iluani nunam ilitugiyumayun aajikutain Ukiuktaktumi imiktakvikhan tattin kanugininginik ilakaktuklu Takyuilgumik umayunuaniklu. Ilitukhautiluan pihimayun 2010-min 2015-mun ilauni kimilguiyun kanugininginik iluani nunam ilitugiyumayun-guyum. Takyuilgumi ikalukaknigin taimaitun tikvani nunami, kukviuyun nunan Kanatami Ukiuktaktumi. Ihun amigainikhan ikalukni, Kapihilin tukliuvlutik, Hulukpaugan, Kanayun, Ukatun itulu. Aalat ikaluin naniyauyun kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-mi ukua Kaligalin Tahikmilu Kapihilin. Ikalukpiktukakhimagituk iluani ukua Goose-mi kimilguiyun kanuginiginik iluani nunam ilitugiyumayun, pikagunakhiyuugaluak imiktakvikhan RSA-gani.

Havaamin aktukhiyutaulaktun Pikpagiluaktavun Manikkami Pikaknigin-nik Takyuilgumi ikalukaknigin ihumagiyakaktun malguknik amigaitun Takyuilgumi utiktaktulunin ikaluin tattinin takyumun utimulu kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-mi, Ihun Hulukpaugalu. Havaamik aktuknigutaulaktuk ukuniga ikaluknik tukugakniginik ikiklivalianiaktulu. Una Havaami hulilugagutinin ilagiagutaulaktuk tukugakniginik ikiklivalianiginiklu Ihun Hulukpaugalu: tahik imaiyaktaukpan, ukiumi apkutiliukniginin, hanayaulikan Havaam inigiyakhaa, imiktaktun inuin atuktakhainik uyakikivikmilu ukiumilunin apkutiliukata, kagaktitaiyulu kagaktitautinun. Ihuakhautauluaktukhak atugitaagani aktuknigilaktain Ihunik Hulukpauganiklu Havaam kanuginniga inikaaktilugin pikutin aktugilugin imikhakvikhani ikaluin nunagiyain akituvalaagitpan. TIA-guyuk uyagaktaaniklu ikakukvik atulimagitunik inikaktitauyuk aktuktailivlutik ikalukaktunik imavaluknik. Ihuakhautaukmiyuklu inikhimaniga aginikhanik imaknik atukniganik piyutikaktumik hapumiyaagnai ikalukan nunagiyain Goose-mi, Prupillir-mi tahikni. Atuginiga ayuknaktuk ahiuniginik ikaluin nunagiyainik (ila atugiukniga Llama Tattimik Uyagaktakviuniakman) himautikakniaktuk atukpalianigagun umiga Ihumagiyauyuk Ikaluknik Ahiaguknikhaagun Upalugaiyaun.

Kinguagun atukpalianinganik ihaukhautin munagijutitlu, atauhik kinguagun aktuninga titigaktauyuk: ikiklivalianikhain Hulupaugan atugiakniganin Llama Tahiuyum hanianilu kukniginin ahinun. Umwilt-mi Kuktuk iglikakviuyuk ikalukanilu nunagiyauyuk Hulukpauganin, kugiguikniganiklu uma kukam ihuitumik aktulaktain Hulukpaugan amigainiginik. Kiguagun aktuknigin nahugiyauyuk agivalaaginiganik, hivituvalaagitunilu (uyagaktakviutilugu Havaak), atuinaktuk, ilauniginaktuklu kimilguiyun kanuginiginik iluani nunam ilitugiyumayun-guyum, kikluagulagunakhiyuklu imakaknigin utiktitaukpata umiktaukpan. Tamaini, angiktilaagan kinguagun aktukningin Hulukpauganik Ihumalutauvalaagituk. Piyutikaktuk atukniganik ihuakhiyutin ukautauyun Iglukpakakvimi Imiktaakhan Amiginiginun Munaginiginulu Upalugaiyaunmi (Makpigaami 10-mi, Uiguani 7) Imakmiutalu Aktukniginik Munagiyutinun Upalguaiyaun (AEMP; Makpigaami 10, Uiguani 19) unalu Katitikhimayut Ikaluit Ihuahiyaangini Maligahak (Makpigaami 10, Uiguani 21).

Nigiungittugut hiugakaknikmit ayukhautihaptingnit, pikangittuk hiugakakluta aktuktaugaluakluni katitigaluakluni hulilimaittuk aalanut havaahanut. Taimaa katitinik hiugalukmik ayukhaujutikagunaittugut Nunavut kikliani.

Table of Contents

Sabina
GOLD & SILVER CORP.

BACK RIVER PROJECT
FINAL ENVIRONMENTAL IMPACT STATEMENT
Supporting Volume 6:
Freshwater Environment

Table of Contents

Executive Summary i

Table of Contents xxi

List of Figures xxix

List of Tables xxxii

List of Appendices xxxvi

Acronyms and Abbreviations xxxix

1. Surface Hydrology 1-1

1.1 Existing Environment and Baseline Information 1-1

1.1.1 Regional Setting 1-1

1.1.1.1 Regional Watersheds 1-1

1.1.1.2 Available Regional Hydrologic Data 1-1

1.1.1.3 Hydrological Processes 1-1

1.1.1.4 Annual Runoff and Seasonal Distribution 1-10

1.1.1.5 Peak Flows 1-13

1.1.1.6 Low Flows 1-13

1.1.2 Local Setting 1-13

1.1.2.1 Hydrometric Monitoring Program 1-13

1.1.2.2 Marine Laydown Area 1-24

1.1.3 Runoff Estimates for Hydrologic Effects Assessment 1-24

1.1.4 Proximity to Designated Environmental Areas 1-26

1.1.5 Anticipated Global Climate Change and its Hydrologic Impacts 1-26

1.1.5.1 Changes to the Active Layer and its Hydrologic Impacts 1-27

1.1.5.2 Changes to Runoff 1-27

1.1.5.3 Changes to Winter Flow 1-28

1.1.5.4 Hydrologic Impacts of Extreme Weather Events 1-28

1.1.5.5 Changes to Other Hydrologic Variables 1-28

1.2 Incorporation of Traditional Knowledge (TK) 1-29

1.2.1 Incorporation of TK for Existing Environment and Baseline Information 1-29

1.2.2 Incorporation of TK for VEC and VSEC Selection 1-31
1.2.3 Incorporation of TK for Spatial and Temporal Boundaries 1-31
1.3 Valued Components 1-31
1.3.1 Potential Valued Components and Scoping 1-31
1.3.2 Valued Components Included in Assessment 1-31
1.4 Spatial and Temporal Boundaries 1-32
1.4.1 Spatial Boundaries 1-32
1.4.1.1 Local Study Area 1-32
1.4.1.2 Regional Study Area 1-32
1.4.1.3 Streamflow Prediction Nodes 1-37
1.4.2 Temporal Boundaries 1-37
1.4.2.1 Mobilization and Construction Phase 1-38
1.4.2.2 Operation Phase 1-39
1.4.2.3 Reclamation and Closure Phase 1-40
1.4.2.4 Post-Closure 1-41
1.5 Potential Project-related Effects Assessment 1-41
1.5.1 Methodology Overview 1-41
1.5.2 Potential Interactions with Project and Characterization 1-43
1.5.3 Identification of Mitigation and Management Measures 1-43
1.5.4 Characterization of Residual Effects 1-46
1.5.4.1 Potential Effects within the LSA 1-47
1.5.4.2 Potential Effects on Streams at the LSA Boundary 1-47
1.5.4.3 Potential Effects on Streams at the RSA Boundary 1-47
1.5.5 Significance of Residual Effects 1-52
1.6 Potential Cumulative Effects Assessment 1-55
1.6.1 Potential Interactions of Residual Effects with Other Projects 1-56
1.7 Transboundary Effects 1-56
1.8 Mitigation and Adaptive Management 1-56
1.9 Impact Statement 1-57

2. Groundwater 2-1
2.1 Existing Environment and Baseline Information 2-1
2.1.1 Regional Setting 2-1
2.1.1.1 Geologic Context 2-1
2.1.1.2 Groundwater Flow 2-1
2.1.1.3 Groundwater Quality 2-2
2.1.2 Local Setting 2-4
2.1.2.1 Data Collection and Analytical Methods 2-4
2.1.2.2 Goose Property 2-10
2.1.2.4 Winter Ice Road Corridors 2-20
2.2 Incorporation of Traditional Knowledge (TK) 2-20

2.2.1 Incorporation of TK for Existing Environment and Baseline Information 2-20
2.2.2 Incorporation of TK for Spatial and Temporal Boundaries 2-20
2.2.3 Incorporation of TK for Mitigation and Adaptive Management 2-21
2.3 Valued Components 2-21
2.3.1 Potential Valued Components and Scoping 2-21
2.3.2 Valued Components Included in Assessment 2-21
2.4 Supporting and Supplemental Information 2-21
2.4.1 Interaction of Groundwater with the Project 2-21
2.4.2 Numerical Groundwater Models and Groundwater Budget 2-22
2.4.3 Supporting Documents 2-23

3. Limnology and Bathymetry 3-1
3.1 Existing Environment and Baseline Information 3-1
3.1.1 Overview and Regional Setting 3-1
3.1.2 Baseline Study Area 3-1
3.1.3 Proximity to Designated Environmental Areas 3-1
3.1.4 Baseline Studies 3-5
3.1.4.1 Information Sources 3-5
3.1.4.2 Baseline Study Methods 3-5
3.1.5 Lake Limnology and Bathymetry 3-7
3.1.5.1 Lake Limnology 3-7
3.1.5.2 Lake Bathymetry 3-10
3.1.6 Stream Temperatures 3-14
3.2 Incorporation of Traditional Knowledge (TK) 3-14
3.2.1 Incorporation of TK for Existing Environment and Baseline Information 3-14
3.2.2 Incorporation of TK for Valued Ecosystem Component (VEC) Selection 3-18
3.3 Valued Components 3-19
3.3.1 Potential Valued Components and Scoping 3-19
3.3.2 Valued Components Included in Assessment 3-19

4. Freshwater Water Quality 4-1
4.1 Existing Environment and Baseline Information 4-1
4.1.1 Overview and Regional Setting 4-1
4.1.2 Proximity to Designated Environmental Areas 4-3
4.1.3 Baseline Study Area 4-3
4.1.4 Baseline Studies 4-3
4.1.4.1 Information Sources 4-3
4.1.4.2 Baseline Study Methods 4-4
4.1.5 Lake Water Quality 4-13
4.1.5.1 General Lake Parameters 4-13
4.1.5.2 Lake Total Suspended Solids and Turbidity 4-13
4.1.5.3 Lake Dissolved Oxygen 4-14

4.1.5.4 Lake Nutrients 4-14
4.1.5.5 Lake Metals 4-16
4.1.5.6 Lake Cyanide 4-18
4.1.6 Stream Water Quality 4-18
4.1.6.1 General Stream Parameters 4-19
4.1.6.2 Stream TSS and Turbidity 4-20
4.1.6.3 Stream Dissolved Oxygen 4-20
4.1.6.4 Stream Nutrients 4-20
4.1.6.5 Stream Metals 4-22
4.1.6.6 Stream Cyanide 4-23
4.2 Incorporation of Traditional Knowledge (TK) 4-23
4.2.1 Incorporation of TK for Existing Environment and Baseline Information 4-24
4.2.2 Incorporation of TK for Valued Ecosystem Component Selection 4-24
4.2.3 Incorporation of TK for Spatial and Temporal Boundaries 4-24
4.2.4 Incorporation of TK for Effects Assessment 4-24
4.2.5 Incorporation of TK for Mitigation and Adaptive Management 4-25
4.3 Valued Components 4-25
4.3.1 Valued Components Included in Assessment 4-25
4.4 Spatial and Temporal Boundaries 4-25
4.4.1 Spatial Boundaries 4-25
4.4.1.1 Local Study Area 4-25
4.4.1.2 Regional Study Area 4-25
4.4.2 Temporal Boundaries 4-26
4.5 Potential Project-Related Effects Assessment 4-26
4.5.1 Methodology Overview 4-26
4.5.1.1 Water Quality Indicators 4-29
4.5.2 Identification and Characterization of Potential Interactions with Project 4-31
4.5.2.1 Construction and Decommissioning Activities 4-36
4.5.2.2 Winter Ice Roads 4-36
4.5.2.3 Site Contact Water 4-36
4.5.2.4 Mine Contact Water 4-37
4.5.2.5 Water Use 4-37
4.5.2.6 Quarries and Borrow Pits 4-37
4.5.2.7 Explosives 4-37
4.5.2.8 Fuels, Oils, and PAH 4-38
4.5.2.9 Treated Sewage Discharge 4-38
4.5.2.10 Dust Deposition 4-38
4.5.3 Identification of Mitigation and Management Measures 4-38
4.5.3.1 Construction and Decommissioning Activities 4-39
4.5.3.2 Winter Ice Roads 4-41
4.5.3.3 Site Contact Water 4-42

4.5.3.4 Mine Contact Water 4-42
4.5.3.5 Water Use 4-42
4.5.3.6 Quarries and Borrow Pits 4-43
4.5.3.7 Explosives 4-43
4.5.3.8 Fuels, Oils, and PAH 4-44
4.5.3.9 Treated Sewage Discharge 4-45
4.5.4 Characterization of Residual Effects 4-45
4.5.4.1 Construction and Decommissioning Activities 4-45
4.5.4.2 Site Contact Water 4-46
4.5.4.3 Mine Contact Water 4-47
4.5.4.4 Explosives 4-56
4.5.5 Significance of Residual Effects 4-56
4.6 Potential Cumulative Effects Assessment 4-57
4.6.1 Methodology Overview 4-57
4.6.2 Potential Interactions of Residual Effects with Other Projects 4-59
4.7 Transboundary Effects 4-59
4.8 Mitigation and Adaptive Management 4-59
4.9 Proposed Monitoring Programs 4-62
4.9.1 Aquatic Effects Management Plan 4-62
4.10 Impact Statement 4-63
4.11 Supporting and Supplemental Information 4-63
4.11.1 Drinking Water Baseline 4-64

5. Freshwater Sediment Quality 5-1
5.1 Existing Environment and Baseline Information 5-1
5.1.1 Overview and Regional Setting 5-1
5.1.2 Proximity to Designated Environmental Areas 5-3
5.1.3 Baseline Study Area 5-3
5.1.4 Baseline Studies 5-3
5.1.4.1 Information Sources 5-3
5.1.4.2 Baseline Study Methods 5-3
5.1.5 Lake Physical and Chemical Sediment Quality Parameters 5-7
5.1.5.1 Lake Sediment Particle Size Composition 5-8
5.1.5.2 Lake Sediment Total Organic Carbon 5-8
5.1.5.3 Lake Sediment Metals 5-8
5.1.6 Stream Physical and Chemical Sediment Quality Characteristics 5-11
5.1.6.1 Stream Sediment Composition 5-11
5.1.6.2 Stream Sediment Total Organic Carbon 5-11
5.1.6.3 Stream Sediment Metals 5-11
5.2 Incorporation of Traditional Knowledge (TK) 5-12
5.2.1 Incorporation of TK for Existing Environment and Baseline Information 5-13

5.2.2 Incorporation of TK for VEC Selection 5-13
5.3 Valued Components 5-13
5.3.1 Valued Components and Scoping 5-13
5.4 Spatial and Temporal Boundaries 5-13
5.4.1 Spatial Boundaries 5-13
5.4.1.1 Local Study Area 5-14
5.4.1.2 Regional Study Area 5-14
5.4.2 Temporal Boundaries 5-14
5.5 Potential Project-related Effects Assessment 5-14
5.5.1 Methodology Overview 5-14
5.5.1.1 Sediment Quality Indicators 5-17
5.5.2 Identification and Characterization of Potential Interactions with Project 5-19
5.5.2.1 Construction and Decommissioning Activities 5-23
5.5.2.2 Site Contact Water 5-23
5.5.2.3 Mine Contact Water 5-23
5.5.2.4 Quarries and Borrow Pits 5-24
5.5.2.5 Explosives 5-24
5.5.2.6 Fuels, Oils, and PAH 5-24
5.5.2.7 Treated Sewage Discharge 5-24
5.5.2.8 Dust Deposition 5-25
5.5.3 Identification of Mitigation and Management Measures 5-25
5.5.3.1 Construction and Decommissioning Activities 5-26
5.5.3.2 Site Contact Water 5-28
5.5.3.3 Mine Contact Water 5-28
5.5.3.4 Quarries and Borrow Pits 5-28
5.5.3.5 Explosives 5-29
5.5.3.6 Fuels, Oils, and PAH 5-30
5.5.3.7 Treated Sewage Discharge 5-31
5.5.4 Characterization of Residual Effects 5-31
5.5.4.1 Construction and Decommissioning Activities 5-31
5.5.4.2 Site Contact Water 5-32
5.5.4.3 Mine Contact Water 5-33
5.5.4.4 Explosives 5-35
5.5.5 Significance of Residual Effects 5-35
5.6 Potential Cumulative Effects Assessment 5-37
5.6.1 Methodology Overview 5-37
5.6.2 Potential Interactions of Residual Effects with Other Projects 5-37
5.7 Transboundary Effects 5-38
5.8 Mitigation and Adaptive Management 5-38
5.9 Proposed Monitoring Programs 5-41
5.9.1 Aquatic Effects Management Plan 5-41

5.10 Impact Statement 5-42

6. Freshwater Fish/Aquatic Habitat 6-1
6.1 Existing Environment and Baseline Information 6-1
6.1.1 Overview and Regional Setting 6-1
6.1.2 Regulatory Framework 6-1
6.1.2.1 *Fisheries Act* 6-1
6.1.2.2 Metal Mining Effluent Regulations 6-3
6.1.3 Proximity to Designated Environmental Areas 6-4
6.1.4 Baseline Study Area 6-4
6.1.5 Baseline Studies 6-7
6.1.5.1 Information Sources 6-7
6.1.5.2 Baseline Study Methods — Lakes and Ponds 6-9
6.1.5.3 Baseline Study Methods — Streams 6-18
6.1.5.4 Fish/Aquatic Habitat QA/QC 6-22
6.1.6 Setting — Lake Habitat 6-22
6.1.6.1 Fish Habitat — Physical Characteristics 6-22
6.1.6.2 Fish Habitat — Biological Resources 6-27
6.1.7 Setting — Stream Habitat 6-28
6.1.7.1 Fish Habitat — Physical Characteristics 6-28
6.1.7.2 Fish Habitat — Biological Resources 6-30
6.1.8 Synthesis of Existing Environment and Baseline Information 6-34
6.2 Incorporation of Traditional Knowledge (TK) 6-35
6.2.1 Incorporation of TK for Existing Environment and Baseline Information 6-35
6.2.2 Incorporation of TK for VEC and VSEC Selection 6-41
6.2.3 Incorporation of TK for Spatial and Temporal Boundaries 6-41
6.2.4 Incorporation of TK for Mitigation and Adaptive Management 6-42
6.3 Valued Components 6-42
6.3.1 Potential Valued Components and Scoping 6-42
6.3.2 Valued Components included in Assessment 6-42
6.4 Spatial and Temporal Boundaries 6-43
6.4.1 Spatial Boundaries 6-43
6.4.1.1 Local Study Area 6-43
6.4.1.2 Regional Study Area 6-43
6.4.2 Temporal Boundaries 6-44
6.5 Potential Project-Related Effects Assessment 6-44
6.5.1 Methodology Overview 6-44
6.5.1.1 Determining the Magnitude and Significance of Residual Effects 6-44
6.5.2 Potential Interactions with Project and Characterization 6-47
6.5.2.1 Loss of Fish Habitat: Project Infrastructure Footprint 6-48
6.5.2.2 Loss of Fish Habitat: Lake Dewatering 6-59

6.5.2.3 Loss of Fish Habitat: Water Use 6-59
6.5.2.4 Deposition of Deleterious Substances 6-60
6.5.2.5 Local and Regional Context for Project Interactions 6-60
6.5.3 Identification of Mitigation and Management Measures 6-61
6.5.3.1 Loss of Fish Habitat: Project Infrastructure Footprint 6-61
6.5.3.2 Loss of Fish Habitat: Water Use 6-63
6.5.3.3 Deposition of Deleterious Substances 6-69
6.5.3.4 Fisheries Offsetting 6-69
6.5.4 Characterization of Residual Effects 6-70
6.5.5 Significance of Residual Effects 6-70
6.6 Potential Cumulative Effects Assessment 6-70
6.6.1 Methodology Overview 6-70
6.6.2 Potential Interactions of Residual Effects with Other Projects 6-70
6.7 Transboundary Effects 6-70
6.8 Mitigative and Adaptive Management 6-71
6.9 Proposed Monitoring Programs 6-74
6.9.1 Aquatic Effects Monitoring Plan 6-74
6.9.2 Fish Offsetting Plan 6-74
6.10 Impact Statement for Fish/Aquatic Habitat 6-74

7. Freshwater Fish Community 7-1
7.1 Existing Environment and Baseline Information 7-1
7.1.1 Overview and Regional Setting 7-1
7.1.2 Regulatory Framework 7-4
7.1.2.1 The *Fisheries Act* 7-4
7.1.2.2 Metal Mining Effluent Regulations 7-5
7.1.3 Proximity to Designated Environmental Areas 7-6
7.1.4 Baseline Study Area 7-6
7.1.5 Baseline Studies 7-6
7.1.5.1 Information Sources 7-6
7.1.5.2 Baseline Study Methods 7-13
7.1.6 Fish Community Setting – Lakes and Ponds 7-15
7.1.7 Fish Community Setting - Streams 7-23
7.1.8 Metals in Fish Tissues 7-24
7.2 Incorporation of Traditional Knowledge (TK) 7-25
7.2.1 Incorporation of TK for Existing Environment and Baseline Information 7-25
7.2.2 Incorporation of TK for VEC and VSEC selection 7-31
7.2.3 Incorporation of TK for Spatial and Temporal Boundaries 7-32
7.2.4 Incorporation of TK for Mitigation and Adaptive Management 7-32
7.3 Valued Components 7-32
7.3.1 Potential Valued Components and Scoping 7-32

7.3.2 Valued Components included in Assessment 7-32
7.4 Spatial and Temporal Boundaries 7-33
7.4.1 Spatial Boundaries 7-33
7.4.1.1 Local Study Area 7-33
7.4.1.2 Regional Study Area 7-33
7.4.2 Temporal Boundaries 7-33
7.5 Potential Project-related Effects Assessment 7-34
7.5.1 Methodology Overview 7-34
7.5.2 Potential Interactions with Project and Characterization 7-37
7.5.2.1 Project Infrastructure Footprint 7-38
7.5.2.2 Water Use 7-44
7.5.2.3 Blasting 7-45
7.5.2.4 Local and Regional Context for Project Interactions 7-45
7.5.3 Identification of Mitigation and Management Measures 7-46
7.5.3.1 Project Infrastructure Footprint 7-46
7.5.3.2 Water Use 7-51
7.5.3.3 Blasting 7-54
7.5.3.4 Fisheries Offsetting 7-55
7.5.4 Characterization of Residual Effects 7-56
7.5.5 Significance of Residual Effects 7-56
7.6 Potential Cumulative Effects Assessment 7-56
7.6.1 Methodology Overview 7-56
7.6.2 Potential Interactions of Residual Effects with Other Projects 7-56
7.7 Transboundary Effects 7-57
7.8 Mitigation and Adaptive Management 7-57
7.8.1 Mitigation by Project Design 7-57
7.8.2 Best Management Practices 7-59
7.8.3 Monitoring 7-59
7.9 Proposed Monitoring Programs 7-60
7.9.1 Aquatic Effects Monitoring Plan 7-60
7.9.2 Fish Offsetting Plan 7-60
7.10 Impact Statement 7-61

List of Figures

Figure 1.1-1. Regional Watersheds of the Back River Project 1-3

Figure 1.1-2. Regional Hydrometric Stations Relevant to the Study Area 1-5

Figure 1.1-3. A Typical Example of Discharge and Runoff in an Arctic Nival River (Atitok Creek near Dismal Lake, 1988), with Air Temperature and Precipitation 1-7

Figure 1.1-4. Historical Mean Monthly Unit Discharge Hydrographs of Regional and Project Stations....1-8

Figure 1.1-5. Monthly Distribution of Annual Runoff at Regional and Project Stations....1-9

Figure 1.1-6. Long-term Annual Runoff at Regional Hydrometric Stations....1-12

Figure 1.1-7. Regional Regression Analysis between Instantaneous Peak Flow and Drainage Area....1-14

Figure 1.1-8. Study Area Drainage Basins – Goose Property Area....1-17

Figure 1.1-9. Annual Unit Hydrographs of Hydrometric Monitoring Stations – Goose Property Area....1-21

Figure 1.1-10. Daily Distribution of Mean Annual Runoff in the Goose Property Area....1-25

Figure 1.4-1. Spatial Boundaries of the Surface Water Hydrology Effects Assessment and Prediction Nodes on the Local Study Area and Regional Study Area Boundaries....1-33

Figure 1.4-2. Surface Water Hydrology Prediction Nodes within the Local Study Area....1-35

Figure 2.1-1. Conceptual Sketch of Groundwater Flow Regimes in a Continuous Permafrost Environment....2-3

Figure 2.1-2. Regional Groundwater Context....2-5

Figure 2.1-3. Regional Groundwater Total Dissolved Solids and Major Ion Concentrations....2-7

Figure 2.1-4. Regional Groundwater Major Ion Concentrations....2-8

Figure 2.1-5. Geologic Structures at the Goose Property....2-12

Figure 2.1-6. Groundwater Levels at the Goose Property....2-13

Figure 2.1-7. Hydraulic Conductivity Measurements at the Goose Property....2-15

Figure 2.1-8. Hydrogeological Conceptual Model at Goose Property....2-19

Figure 3.1-1. Project Location....3-2

Figure 3.1-2. Limnology and Bathymetry Sampling Conducted in the Goose Property Area for the Back River Project, 1994 to 2013....3-3

Figure 3.1-3. Temperature Profiles of Goose Lake (Central Site) and Llama Lake in Ice-covered (April) and Open-water (August) Seasons, 2011 and 2012....3-9

Figure 3.1-4. Bathymetry of Goose Lake, Goose Property Area....3-11

Figure 3.1-5. Bathymetry of Llama Lake, Goose Property Area....3-12

Figure 3.1-6. Bathymetry of Umwelt Lake, Goose Property Area....3-13

Figure 3.1-7. Bathymetry of Propeller Lake, Goose Property Area....3-15

Figure 3.1-8. Bathymetry of Big Lake, Goose Property Area....3-17

Figure 4.1-1. Project Location....4-2

Figure 4.1-2. Waterbodies in the Goose Property Area....4-5

Figure 4.1-3. Locations of Baseline Lake and Stream Water Quality Sampling, Goose Property Area, 1993 to 2015 4-7

Figure 4.1-4. Dissolved Oxygen Concentrations in Lakes in Under-ice and Open-water Conditions in the Goose Property Area, 2010 to 2013 4-15

Figure 4.4-1. Local Study Area and Regional Study Area for Freshwater Water Quality..... 4-27

Figure 4.5-1. Predicted Arsenic Concentrations for Goose Lake with Time..... 4-51

Figure 5.1-1. Project Location 5-2

Figure 5.1-2. Locations of Baseline Lake and Stream Sediment Quality, Goose Property Area, 2007 to 2015..... 5-5

Figure 5.1-3. Sediment Arsenic Concentrations in Goose Property Area Lakes, Back River Project, 2007 to 2012..... 5-10

Figure 5.4-1. Local Study Area and Regional Study Area for Freshwater Sediment Quality..... 5-15

Figure 6.1-1. Project Location 6-2

Figure 6.1-2. Lake/Pond Fish Habitat Baseline Data (2010 – 2015) for the Goose Property Area 6-5

Figure 6.1-3. Lake/Pond Fish Habitat – Aquatic Resources Baseline Data (1997 – 2015) for the Goose Property Area 6-11

Figure 6.1-4. Stream Fish Habitat Baseline Data (2010 – 2015) for the Goose Property Area 6-13

Figure 6.1-5. Stream Fish Habitat – Aquatic Resources Baseline Data (1997 – 2015) for the Goose Property Area 6-15

Figure 6.4-1. Local Study Area and Regional Study Area for Freshwater Fish/Aquatic Habitat 6-45

Figure 6.5-1. Infrastructure Layout and Locations of Potential Fish Bearing Habitat Loss, Goose Property Area 6-49

Figure 6.5-2. Fish Bearing Status within the LSA, Goose Property Area 6-51

Figure 6.5-3. Baseline and Project-affected Flows at Goose Outflow 6-65

Figure 7.1-1. Project Location 7-2

Figure 7.1-2. Lake/Pond Fish Community Baseline Data (2010 to 2015), Goose Property Area 7-7

Figure 7.1-3. Stream Fish Community Baseline Data (2011 to 2015), Goose Property Area 7-9

Figure 7.1-4. Baseline Relative Abundance by Gillnet, Goose Property Area..... 7-17

Figure 7.1-5. Baseline Relative Abundance by Beach Seine, Goose Property Area 7-19

Figure 7.1-6. Fish Bearing Status within the LSA, Goose Property Area 7-21

Figure 7.4-1. Local Study Area and Regional Study Area for Lake Trout and Arctic Grayling..... 7-35

Figure 7.5-1. Infrastructure Layout and Locations of Potential Habitat Loss, Goose Property Area .. 7-39

Figure 7.5-2. Baseline and Project-affected Flows at Goose Outflow 7-53

List of Tables

Table 1.1-1. Regional Water Survey of Canada and Other Regional Stations Relevant to the Study Area 1-2

Table 1.1-2. Annual Runoff and Seasonal Distribution of Water Survey of Canada and other Regional Stations 1-11

Table 1.1-3. Estimated Instantaneous Peak Flows at Regional Hydrometric Stations..... 1-15

Table 1.1-4. Estimated 7-Day Low Flows during June to September at Regional Hydrometric Stations..... 1-15

Table 1.1-5. Hydrometric Monitoring Stations in the Goose Property Area 1-16

Table 1.1-6. Peak Flows and Low Flows in the Goose Property Area 1-20

Table 1.1-7. Annual Runoff and Seasonal Distribution in the Goose Property Area 1-23

Table 1.1-8. Monthly Distribution of Mean Annual Runoff in the Goose Property Area 1-24

Table 1.1-9. Wet and Dry Annual Runoff Estimates for Different Return Periods 1-26

Table 1.3-1. Surface Water Hydrology Valued Ecosystem Component Indicators..... 1-32

Table 1.4-1. Streamflow Prediction Nodes and Assessed Lakes within the Local Study Area and Regional Study Area..... 1-37

Table 1.4-2. Proposed Water Withdrawal Volumes from Goose and Propeller Lakes 1-39

Table 1.5-1. Surface Water Hydrology VEC Indicators and Magnitude Categories 1-41

Table 1.5-2. Maximum Flow Reduction due to the Project during all Phases of the Project 1-48

Table 1.5-3. Maximum Flow Increase due to the Project during all Phases of the Project 1-50

Table 1.5-4. Summary of Predicted Effects on Lake Volumes and Streamflows at Locations Affected by Water Withdrawal from Goose and Big Lakes..... 1-52

Table 1.5-5. Summary of Residual Effects on Surface Water Hydrology and Overall Significance Rating..... 1-53

Table 1.8-1. Surface Water Hydrology Mitigation and Management Measures 1-56

Table 2.1-1. Common Regional Overburden Materials and Hydrogeologic Properties 2-1

Table 2.1-2. Overburden Materials Common at the Goose Property and their Hydrogeologic Properties..... 2-11

Table 2.1-3. Groundwater Quality Parameters Measured for the Umwelt Westbay Subpermafrost Monitoring System..... 2-16

Table 3.1-1. Baseline Lake Limnology Sampling Conducted for the Back River Project 3-6

Table 3.1-2. Baseline Stream Temperatures Collected for the Back River Project.....3-8

Table 3.1-3. Summary of Secchi Depths in Goose Property Area Lakes, Back River Project 3-10

Table 3.1-4. Summary of Lake Morphologies in the Goose Property Area, Back River Project 3-10

Table 3.1-5. Summary of Stream Water Temperatures in the Goose Property Area, Back River Project, 1994 to 2013 3-14

Table 4.1-1. Baseline Lake Water Quality Sampling Conducted for the Back River Project, 1993 to 2015 4-9

Table 4.1-2. Baseline Stream Water Quality Sampling Conducted for the Back River Project, 1993 to 2015 4-11

Table 4.1-3. Summary of Lake Water Chemistry in the Goose Property Area, 1993 to 2013 4-13

Table 4.1-4. Summary of Lake Water TSS and Turbidity in the Goose Property Area, 1993 to 2013 .. 4-14

Table 4.1-5. Summary of Lake Water Nutrient Concentrations in the Goose Property Area, 1994 to 2013 4-16

Table 4.1-6. Distribution of Samples from Waterbodies by CCME Total Phosphorus Trigger Ranges, 1993 to 2013 4-16

Table 4.1-7. Summary of Lake Water Metal Concentrations in the Goose Property Area, 1993 to 2013 4-17

Table 4.1-8. Water Quality Parameters with Sample Concentrations Greater than CCME Guideline Values in Goose Property Lakes, 1997 to 2013 4-18

Table 4.1-9. Summary of Lake Water Free Cyanide Concentrations (mg/L) in the Goose Property Area, 1997 to 2013 4-18

Table 4.1-10. Summary of Stream Water Chemistry in the Goose Property Area, 1993 to 2013 4-19

Table 4.1-11. Summary of pH Data for Goose Property Area Streams Collected using Field Probes in 1994, 2006, and 2007, and using Laboratory Analyses in 1993, 2010, 2011, and 2012 4-19

Table 4.1-12. Summary of Stream Water TSS and Turbidity in the Goose Property Area, 1993 to 2013 4-20

Table 4.1-13. Stream Sites with Water Dissolved Oxygen Concentrations Less than the CCME Guideline for Early Life Stages in the Goose Property Area, 1994 to 2013 4-20

Table 4.1-14. Summary of Stream Water Nutrient Concentrations in the Goose Property Area, 1994 to 2013 4-21

Table 4.1-15. Distribution of Samples from Streams by CCME Total Phosphorus Trigger Ranges, 1993 to 2013 4-21

Table 4.1-16. Summary of Anomalous Total Phosphorus Samples in 2006 from Streams in the Goose Property Area 4-22

Table 4.1-17. Summary of Stream Water Metal Concentrations in the Goose Property Area, 1993 to 2013 4-22

Table 4.1-18. Water Quality Parameters with Sample Concentrations Greater than CCME Guideline Values in Goose Property Area Streams, 1993 to 2013 4-23

Table 4.1-19. Summary of Stream Water Free Cyanide Concentrations (mg/L) in the Goose Property Area, 1997 to 2013 4-23

Table 4.5-1. Rating Criteria for Evaluating the Magnitude of Residual Effects on Freshwater Water Quality VEC..... 4-29

Table 4.5-2. Definitions of Significance Ratings for Freshwater Water Quality VEC 4-29

Table 4.5-3. Freshwater Water Quality Indicators for Effects Assessment..... 4-30

Table 4.5-4. Indicators and Thresholds Used for Magnitude Characterization for Residual Effects Analysis on the VEC Freshwater Water Quality 4-30

Table 4.5-5. Definition of the Components of the Project's Interactions with the VEC Freshwater Water Quality 4-33

Table 4.5-6. Key Indicators of Project Activity Interactions with the Freshwater Environment for Effects Assessment 4-35

Table 4.5-7. Summary of Predicted Water Concentrations of Parameters of Potential Concern in Llama Outflow, Goose Lake Tributary. 4-50

Table 4.5-8. Summary of Predicted Water Concentration of Parameters of Potential Concern in Llama Outflow Upstream, Goose Lake Tributary. 4-52

Table 4.5-9. Summary of Predicted Water Concentrations of Parameters of Potential Concern in Echo Outflow, Goose Lake Tributary..... 4-52

Table 4.5-10. Summary of Predicted Water Concentration of Parameters of Potential Concentration in Goose Inflow Southeast, Goose Lake Tributary..... 4-53

Table 4.5-11. Summary Table of Predicted Residual Effects and Overall Significance Rating 4-58

Table 4.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Water Quality 4-60

Table 4.11-1. Drinking Water Sources for Back River Project 4-64

Table 4.11-2. Baseline Metal Concentrations in Lakes Used as Drinking Water Source..... 4-65

Table 5.1-1. Summary of Lake Sediment Quality Sampling Conducted for the Back River Project.....5-4

Table 5.1-2. Summary of Stream Sediment Quality Sampling Conducted for the Back River Project 5-7

Table 5.1-3. Summary of Lake Sediment Particle Size Composition in the LSA, 2007 to 2013 5-8

Table 5.1-4. Summary of Lake Sediment Total Organic Carbon Concentrations in the LSA, 2007 to 2013.....5-8

Table 5.1-5. Summary of Lake Sediment Metal Concentrations in the LSA, 2010 to 2013 5-9

Table 5.1-6. LSA Lakes with Sediment Metal Concentrations Greater than CCME Sediment Quality Guidelines, 2010 to 2013.....5-9

Table 5.1-7. Summary of Stream Sediment Particle Size Compositions in the LSA, 2011 to 2013 5-11

Table 5.1-8. Summary of Stream Sediment Total Organic Carbon Concentrations in the LSA, 2011 to 2013 5-11

Table 5.1-9. Summary of Stream Sediment Metals Concentrations in the LSA, 2011 to 2013 5-12

Table 5.1-10. LSA Streams with Metal Concentrations Greater than CCME Sediment Quality Guidelines, 2011 to 2013 5-12

Table 5.5-1. Rating Criteria for Magnitude of Freshwater Sediment Quality Residual Effects 5-17

Table 5.5-2. Definitions of Significance Ratings of Residual Effects on the VEC Freshwater Sediment Quality 5-18

Table 5.5-3. The VEC Freshwater Sediment Quality Indicators for Effects Assessment 5-18

Table 5.5-4. Indicator Thresholds for the VEC Freshwater Sediment Quality 5-18

Table 5.5-5. Definition of the Components of the Project's Interactions with the VEC Freshwater Sediment Quality 5-20

Table 5.5-6. Key Indicators of Project Activity Interactions with the Freshwater Environment for Effects Assessment 5-22

Table 5.5-7. Summary Table of Predicted Residual Effects on the VEC Freshwater Sediment Quality and Overall Significance Rating 5-36

Table 5.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Sediment Quality 5-38

Table 6.1-1. Summary of Baseline Lake Phytoplankton Sampling Conducted at the Goose Property Area 6-9

Table 6.1-2. Summary of Baseline Lake Zooplankton Sampling Conducted at the Goose Property Area 6-17

Table 6.1-3. Summary of Baseline Lake Benthos Sampling Conducted at the Goose Property Area 6-17

Table 6.1-4. Overall Habitat Quality Rankings and Criteria 6-19

Table 6.1-5. Summary of Baseline Stream Periphyton Sampling Conducted for the Back River Project 6-19

Table 6.1-6. Summary of Baseline and Historical Stream Benthos Sampling Conducted for the Back River Project, 1997 to 2013 6-21

Table 6.1-7. Summary of Fish Habitat Quality in Goose Property Area Lakes and Ponds Surveyed between 2010 and 2015 6-24

Table 6.1-8. Summary of Habitat Quality in Goose Property Area Streams, 1996 to 2015 6-31

Table 6.5-1. Magnitude Rating for Evaluating Residual Effects on the VEC Freshwater Fish/ Aquatic Habitat 6-47

Table 6.5-2. Definitions of Significance Ratings for the VEC Freshwater Fish/Aquatic Habitat 6-47

Table 6.5-3. Potential Interactions with the VEC Freshwater Fish/Aquatic Habitat 6-48

Table 6.5-4. Project activities and Phases interacting with the VEC Freshwater Fish/ Aquatic Habitat 6-53

Table 6.5-5. Fish-bearing Waterbodies Affected by Project Infrastructure..... 6-57

Table 6.5-6. Volume Limits to Water Use 6-63

Table 6.8-1. Mitigation and Management Measures Summary 6-72

Table 7.1-1. Life History Periodicity of Fish Species in the Back River Project Area 7-3

Table 7.1-2. Summary of Lakes Where Fish Sampling Occurred, 1990 to 2015..... 7-12

Table 7.1-3. Summary of Tissue Metal Samples and Locations, 2011 to 2013 7-14

Table 7.1-4. Fish Bearing Lakes and Ponds in the Goose Property LSA, 1997 to 2015 7-15

Table 7.1-5. Summary of Fish Species Captured in Goose Property Streams, 2006 to 2015 7-24

Table 7.5-1. Rating Criteria for Evaluating the Magnitude of Residual Effects on the VECs Lake Trout and Arctic Grayling 7-34

Table 7.5-2. Definitions of Significance Ratings for the VECs Lake Trout and Arctic Grayling 7-37

Table 7.5-3. Potential Interactions for Freshwater Fish Community VECs Lake Trout and Arctic Grayling 7-37

Table 7.5-4. Summary of Potential Interactions between Freshwater Fish Community and the Project 7-38

Table 7.5-5. Arctic Grayling Spawning and Rearing Habitat adjacent to Goose Lake..... 7-43

Table 7.5-6. Volume Limits for Water Use 7-52

Table 7.8-1. Summary of Mitigation and Management Measures for Lake Trout and Arctic Grayling . 7-58

List of Appendices

Appendix V6-1A. Back River Project: 2011 Hydrology Baseline Report

Appendix V6-1B. Back River Project: 2012 Hydrology Baseline Report

Appendix V6-1C. Back River Project: 2013 Hydrology Baseline Report

Appendix V6-1D. Back River Project: 2014 Hydrology Baseline Report

Appendix V6-1E. Effects of Proposed Development and Water Withdrawal on Hydrologic Indices of Goose and Propeller Lakes

Appendix V6-1F. Effects of Proposed Development and Water Withdrawal on Hydrologic Indices of Big Lake

Appendix V6-2A. Analytical Results of the Umwelt Westbay Groundwater Sampling Program

Appendix V6-2B. Completion Report, Westbay System Monitoring Well: 13-GSE-319

Appendix V6-2C. 2012 Geotechnical and Hydrogeological Drilling Program Factual Data Report

Appendix V6-2D. 2013 Geomechanical and Hydrogeological Site Investigation

Appendix V6-3A. Back River Project: 2010 Lake Water and Sediment Quality Baseline Report

Appendix V6-3B. Back River Project: 2011 Freshwater Baseline Report

Appendix V6-3C. Back River Project: 2012 Freshwater Baseline Report

Appendix V6-3D. Back River Project: Bathymetric Surveys of Lakes in the Goose and George Property Areas

Appendix V6-3E. Geophysical Survey — Sabina Back River Project

Appendix V6-3F. 2014 Bathymetric Survey Report

Appendix V6-4A. 2015 Goose Lake Hydrodynamic Modelling Report: Arsenic Predictions

Appendix V6-4B. Back River Project: 2013 Freshwater Baseline Report

Appendix V6-6A. Back River Project: 2010 Fish and Fish Habitat Baseline Report

Appendix V6-6B. Back River Project: 2011 Fish and Fish Habitat Baseline Report

Appendix V6-6C. Back River Project: 2012 Fish and Fish Habitat Baseline Report

Appendix V6-6D. Back River Project: 2013 Fish and Fish Habitat Baseline Report

Appendix V6-6E. Back River Project: 2014 Fish and Fish Habitat Assessment of the Tailings Impoundment Alternatives Site

Acronyms and Abbreviations

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Acronyms and Abbreviations

Terminology used in this document is defined where it is first used. The following list will assist readers who may choose to review only portions of the document.

ADCP	Acoustic Doppler current profiler
AEMP	Aquatic Effects Monitoring Plan
ALS	ALS Environmental Services
ARD	Acid rock drainage
BACI	Before-after/control-impact
CCME	Canadian Council of Ministers of the Environment
CEA	Cumulative effects assessment
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPUE	Catch-per-unit-effort
DEIS	Draft Environmental Impact Statement
DFO	Fisheries and Oceans Canada
DGPS	Differential Global Positioning System
EEM	Environmental effects monitoring
EIS	Environmental Impact Statement
FEIS	Final Environmental Impact Statement
ICPMS	Inductively coupled plasma – mass spectrometry
ISQG	Interim sediment quality guideline; guideline threshold above which detrimental effects may begin to occur.
KIA	Kitikmeot Inuit Association
km	Kilometre
LSA	Local Study Area
µS	Micro Siemens
m	Metre
MAR	Mean annual runoff
masl	Metres above sea level
mbg	Metres below grade
mg/L	Milligrams per litre

ML	Metal leaching
ML/ARD	Metal leaching/acid rock drainage
MLA	Marine Laydown Area
mm	Millimetre
MMER	Metal Mining Effluent Regulations
mol/kg	Molality (moles per kilogram)
n	Sample size
NIRB	Nunavut Impact Review Board
NNL	No net loss
NSA	Nunavut Settlement Area
NT	Northwest Territories
NTKP	Naonaiyaotit Traditional Knowledge Project
NTU	Nephelometric turbidity units
NU	Nunavut
PAD	Permanent alteration or destruction [of fish habitat]
PAH	Polycyclic aromatic hydrocarbons
PAL	Protection of aquatic life
PDA	Potential Development Area
PEL	Probable effects level; guideline threshold for sediment quality predicted to cause detrimental effects to aquatic life.
QA/QC	Quality assurance/quality control
RSA	Regional Study Area
SARA	*Species at Risk Act*
SD	Standard deviation
SE	Standard error
TDS	Total dissolved solids
TIA	Tailings Impoundment Area
TK	Traditional knowledge
TSS	Total suspended solids
UTM	Universal Transverse Mercator coordinate system
VEC	Valued Ecosystem Component
VSEC	Valued Socio-economic Component
VWP	Vibrating wire piezometer

Westbay system	Westbay sub-permafrost monitoring system
WMF	Water management facility
WRSA	Waste Rock Storage Area
WSC	Water Survey of Canada
wwt	Wetted weight

1. Surface Hydrology

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1. Surface Hydrology

1.1 EXISTING ENVIRONMENT AND BASELINE INFORMATION

1.1.1 Regional Setting

1.1.1.1 Regional Watersheds

The Back River Project (the Project) is located in the west Kitikmeot region of Nunavut, near the watershed boundaries of the Ellice River, Back River, and Western River (Figure 1.1-1). The Project is composed of two main areas, the Goose Property Area and the Marine Laydown Area (MLA), which will be connected by winter ice roads. The majority of proposed infrastructure at the Goose Property area is within the Ellice River Watershed. The Marine Laydown Area (MLA) is a narrow strip of land that drains directly to the west side of Bathurst Inlet.

The Ellice River drains an area of 16,900 km^2 into the Arctic Ocean. It winds 287 km north from its headwaters between Beechey Lake and Pelly Lake to its mouth at Queen Maud Gulf. The Back River Watershed, which lies to the south of the Project, drains an area of 106,500 km^2 and flows more than 974 km northeast to its mouth at Cockburn Bay on the Arctic Ocean in the eastern portion of the Kitikmeot Region, south of Gjoa Haven.

1.1.1.2 Available Regional Hydrologic Data

Regional data are available from hydrometric stations operated by the Water Survey of Canada (WSC) and by mining projects in the region (Table 1.1-1 and Figure 1.1-2). The drainage areas of these stations range from 7 km^2 to 19,600 km^2. Data from these stations were analyzed to provide background information on the regional surface water hydrology.

1.1.1.3 Hydrological Processes

The Project lies within the continuous permafrost zone of the continental Canadian Arctic. The physiography of the region is dominated by vegetated tundra hillslopes with lakes and scattered wetlands. The presence of permafrost is hydrologically influential, as it has very low hydraulic conductivity, and thus acts as a barrier to deep groundwater recharge. This physical restriction tends to increase surface water runoff and decrease infiltration.

Compared to unfrozen regions, permafrost watersheds tend to have higher peak flow and lower baseflow (Kane 1997). Streamflow in the continuous permafrost zone is governed by the Arctic nival regime, where runoff is dominated by high, snowmelt-driven flows in spring (the freshet). Following the freshet, streamflow declines throughout the summer and early fall, with the exception of rare and episodic rainfall-generated runoff (Church 1974).

Channel freeze-up typically occurs between late October and early November. In smaller drainage basins, stream channels typically freeze to their bottom, with zero flow occurring in winter. In very large catchments, and larger lake outlets, depth, flow energy, and water turbulence may be sufficient to maintain streamflow and prevent downstream reaches from freezing completely.

Table 1.1-1. Regional Water Survey of Canada and Other Regional Stations Relevant to the Study Area

WSC Station ID	Station Name	Latitude	Longitude	Drainage Area (km^2)	Period of Record[1]
06MA002	Qinguq Creek near Baker Lake	64°15'42" N	96°18'53" W	432	1969-1994
06OA001	Lorillard River above Daly Bay	64°17'39" N	90°26'53" W	11,000	1978-1992
07RC001	Thonokied River near the mouth	64°8'49" N	108°55'2" W	1,780	1980-1990
10JA004	Acasta River Above Little Crapeau Lake	64°52'32" N	116°8'30" W	2,280	1980-1994
10JE001	Sloan River Near The Mouth	66°31'19" N	117°16'26" W	2,040	1976-1991
10PA001	Coppermine River below Desteffany Lake	64°36'57" N	111°57'17" W	6,116	1998-2011
10PC002	Atitok Creek Near Dismal lakes	67°12'52" N	116°36'32" W	217	1980-1990
10RA001	Back River below Beechey Lake	65°11'14" N	106°05'09" W	19,600	1978-2014[2]
10RA002	Baillie River near the mouth	65°00'38" N	104°29'26" W	14,500	1978-2014[2]
10QA001	Tree River near the mouth	67°38'6" N	111°54'8" W	5,810	1968-2011
10QC001	Burnside River near the mouth	66°43'34" N	108°48'47" W	16,800	1976-2011
10QC002	Gordon River near the mouth	66°48'36" N	107°06'04" W	1,530	1977-1994
10QD001	Ellice River near the mouth	67°42'30" N	104°8'21" W	16,900	1971-2011
n/a	Slipper-Lac de Gras Stream[3]	64°36'33" N	110°50'27" W	185	1995-2014[2]
n/a	Vulture-Polar Stream[3]	64°44'24" N	110°32'56" W	7.2	1997-2014[2]

[1] Period of record used for the regional analysis
[2] Data from 2012 to 2014 were not used for generating regional statistics, rather they were used in the comparison of Back River Project site data to regional data
[3] from Ekati Project (Rescan 2013b)

The regional hydrologic regime is summarized here using two techniques. First, a typical annual hydrograph is described for the WSC station "Atitok Creek near Dismal Lakes" which is located in Nunavut 480 km west of the Project (WSC ID 10PC002; Figures 1.1-2 and 1.1-3). The catchment size of this station is relatively similar to those monitored in the Project area, and the climatic setting is also similar. Second, an inter-comparison of data from all regional hydrometric stations was undertaken using averages of their entire operating records (Figures 1.1-4 and 1.1-5). This technique highlights inter-basin hydrologic differences, while presenting averages illustrates typical hydrologic conditions. To inter-compare data from sites with different watershed areas, discharge records have been divided by drainage area to produce 'unit discharge'.

Arctic hydrographs are characterized by a steep rising limb leading to a peak flow discharge that occurs during the spring, shortly after air temperature rises above freezing (Figures 1.1-3 and 1.1-4). During freshet, water that is stored in the winter snowpack melts and is released quickly, generating high flows that are typically the annual peak. In small basins, high flows can last as little as a few days. Peak flow typically occurs immediately after ice break-up in lakes and channel reaches, especially in smaller basins. Due to the presence of permafrost, small streams do not receive groundwater contributions, and flow discharges from these basins may cease after freshet until the late summer rains begin (Figure 1.1-3). For rivers draining larger watersheds, the freshet peak may be delayed relative to smaller drainages as snowmelt from upper portions of the watershed is routed through the drainage network. Precipitation events in the late summer and early fall may lead to a second hydrograph peak, but this peak is generally lower magnitude than the freshet peak (Figures 1.1-3 and 1.1-4).

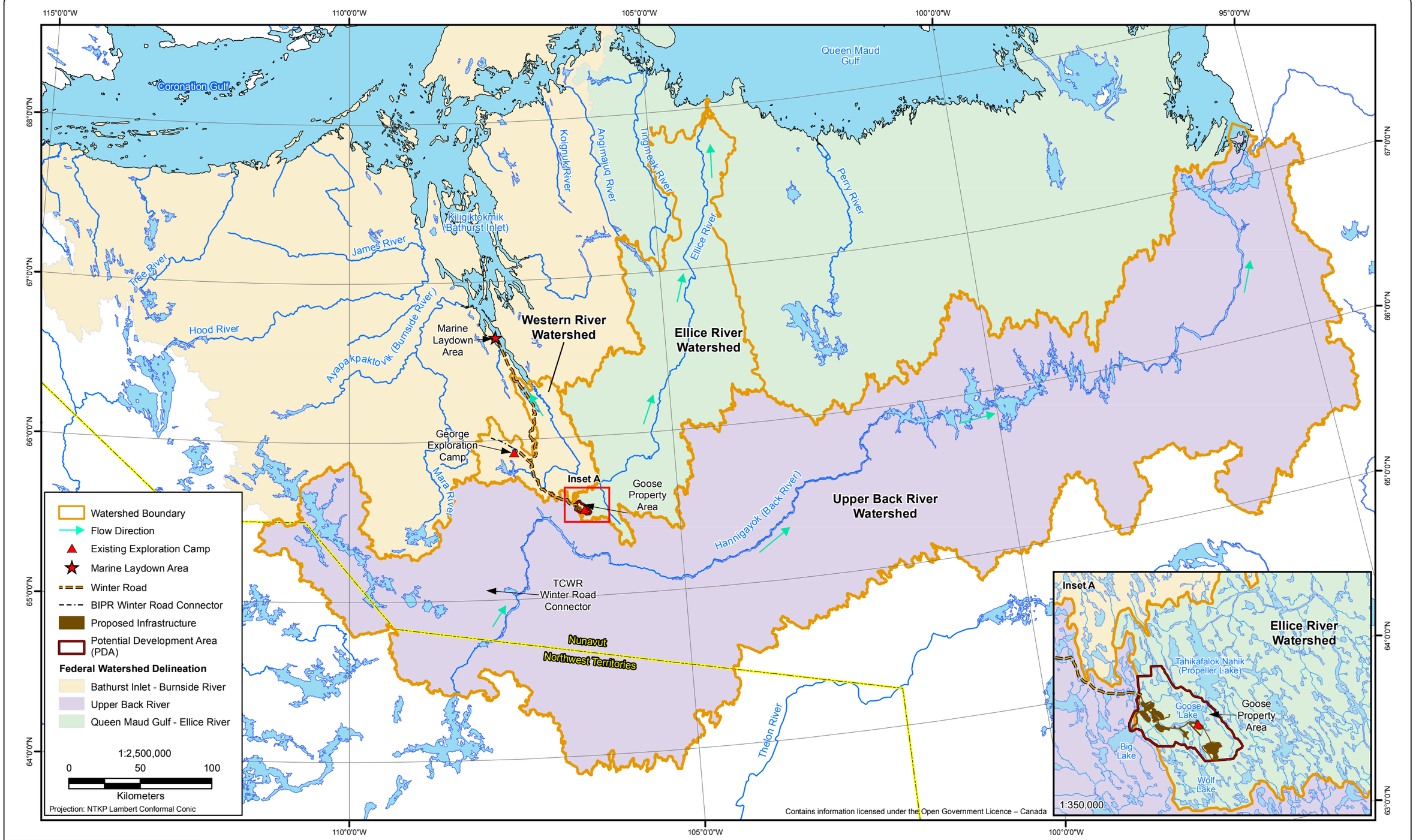

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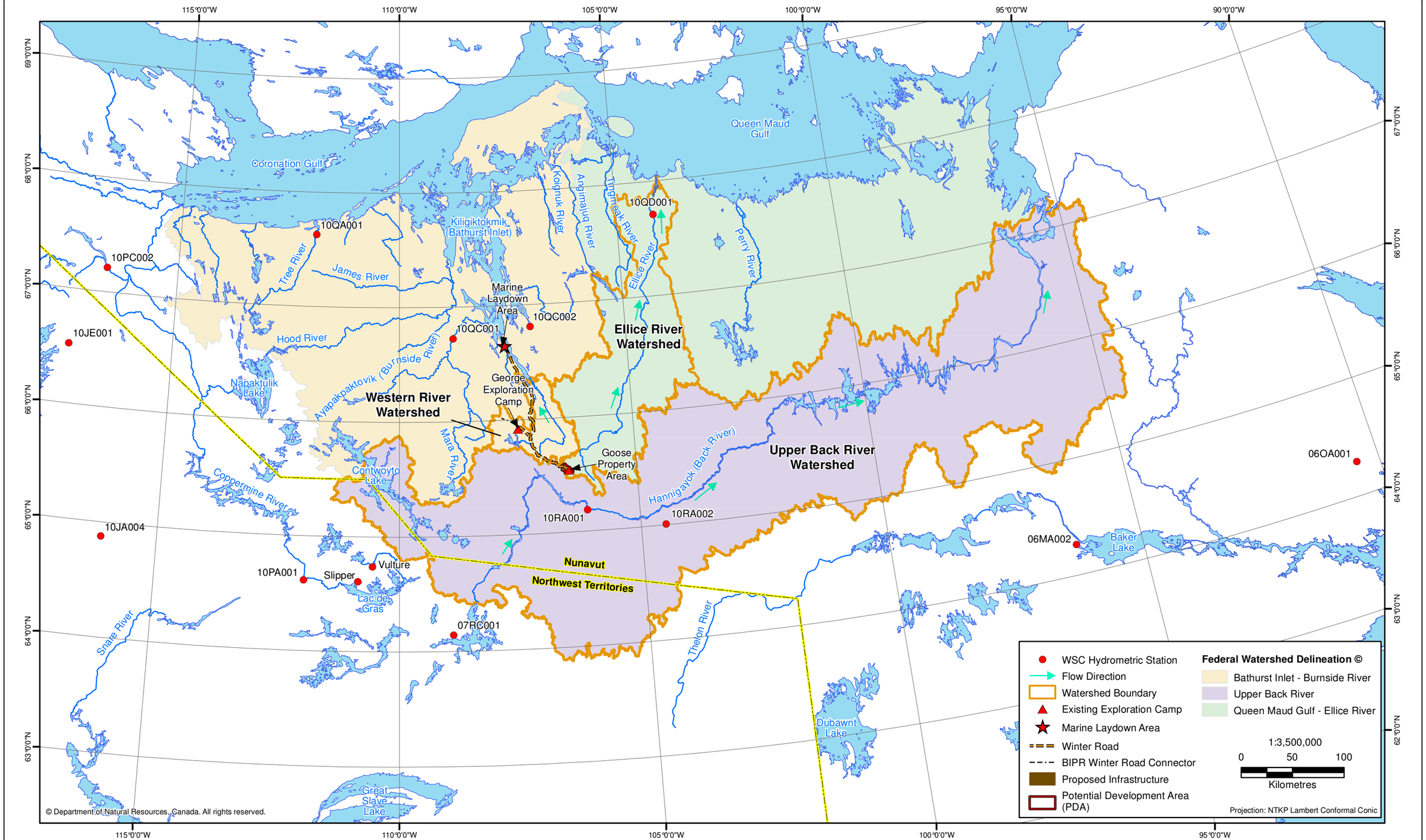
Figure 1.1-1

Regional Watersheds of the Back River Project



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Regional Hydrometric Stations Relevant to the Study Area

Figure 1.1-2

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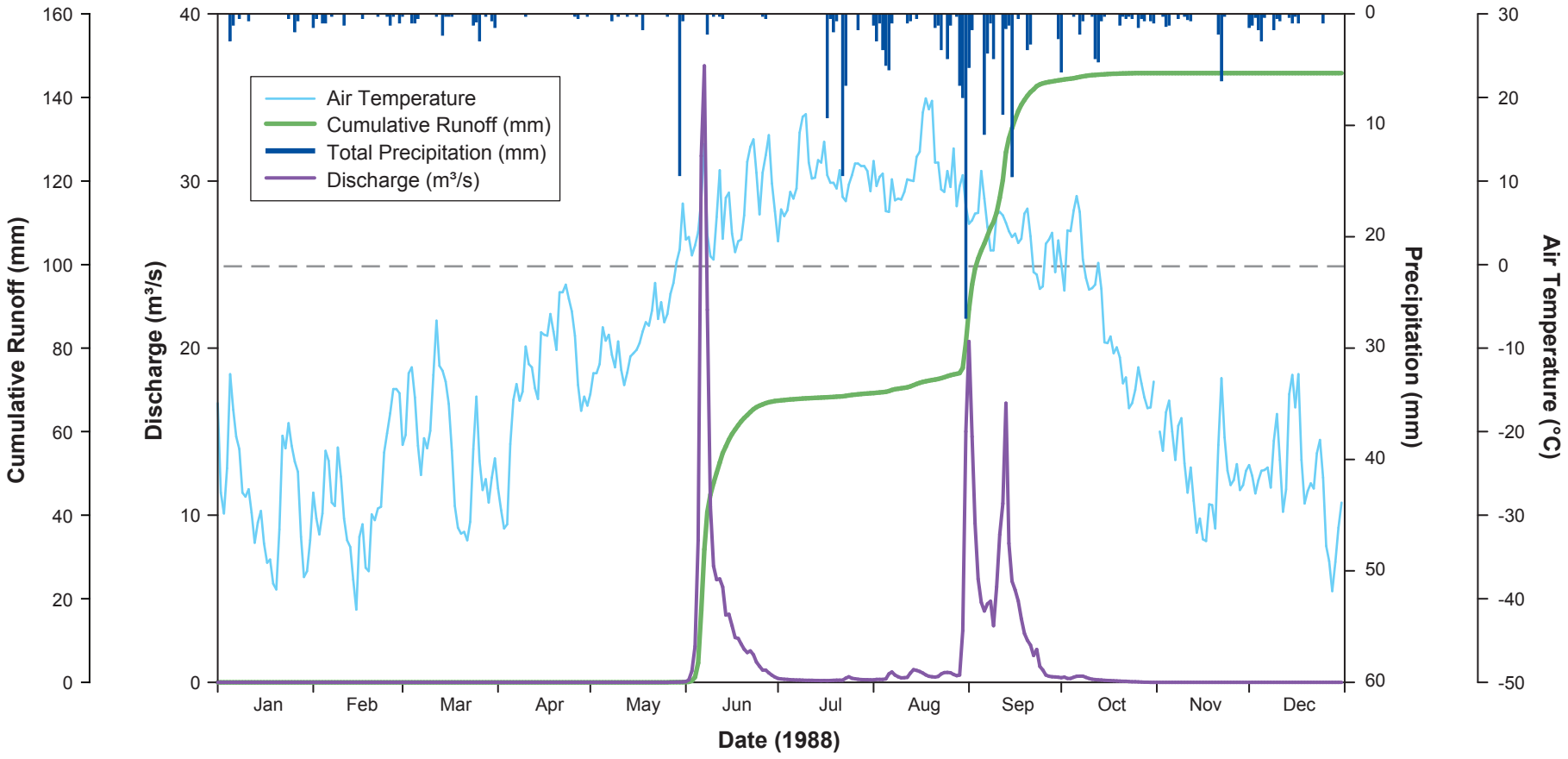

Figure 1.1-3

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A Typical Example of Discharge and Runoff in an Arctic Nival River (Atitok Creek near Dismal Lake, 1988), with Air Temperature and Precipitation

Figure 1.1-3

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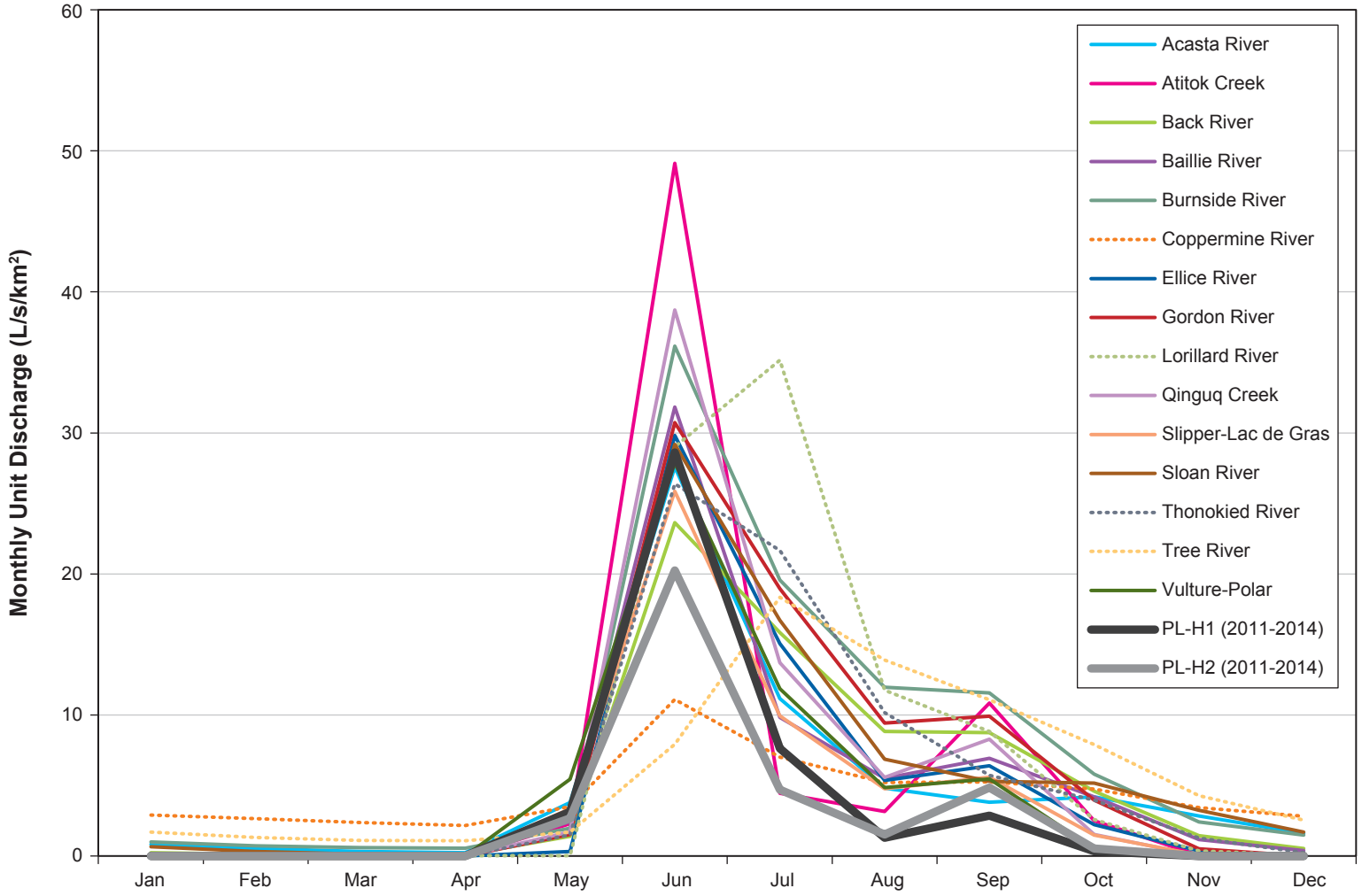

Figure 1.1-4

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Historical Mean Monthly Unit Discharge Hydrographs of Regional and Project Stations

Figure 1.1-4

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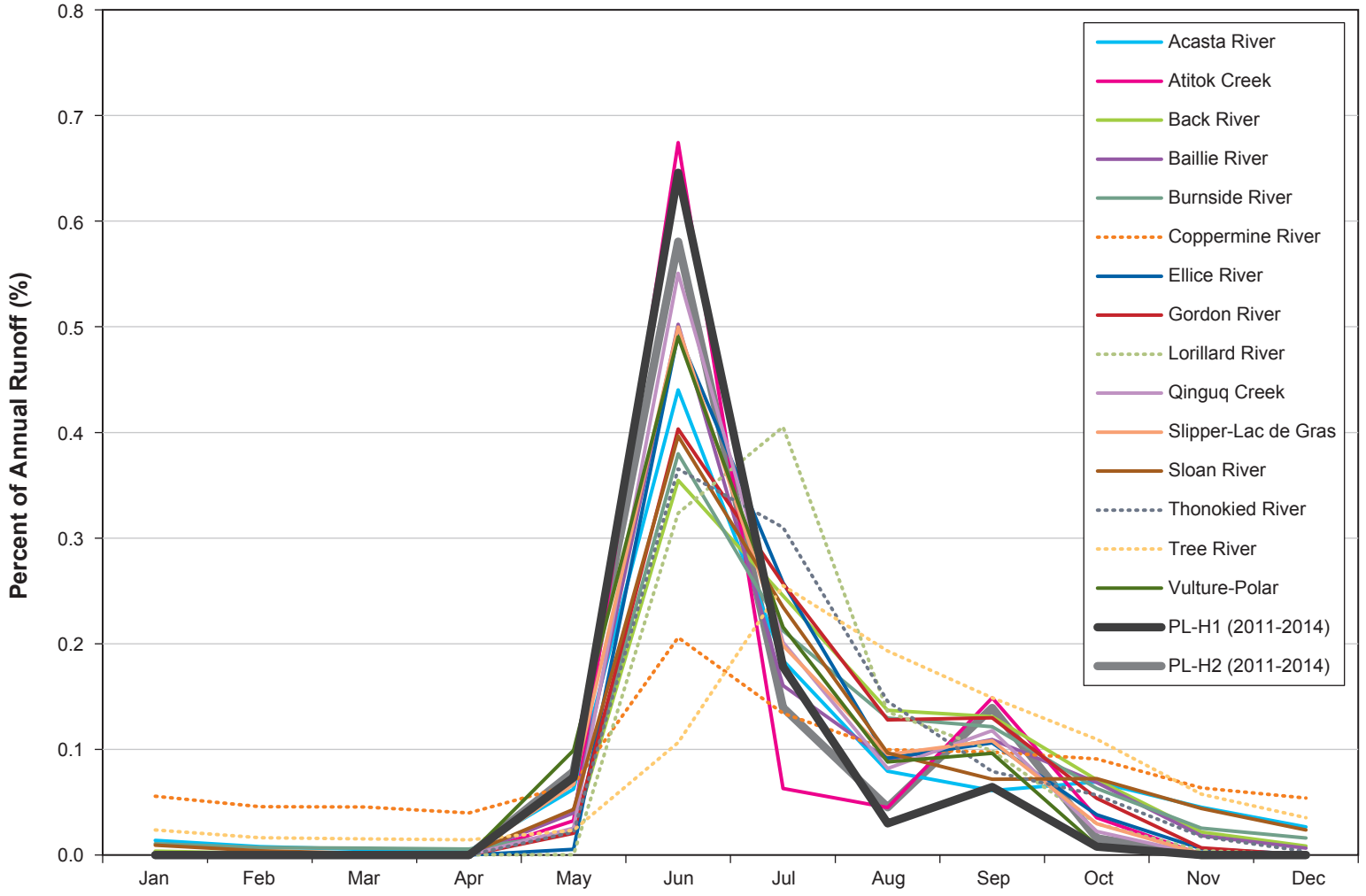

Figure 1.1-5

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Monthly Distribution of Annual Runoff at Regional and Project Stations

Figure 1.1-5

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A number of factors influence the volume of freshet runoff and temporal and spatial variation of annual flows in Arctic watersheds:

- *Amount of snowpack in spring*. Snowpack depth is dependent on the amount of snowfall during the previous winter and the amount of snow remaining in each watershed prior to freshet. Snow can be lost or redistributed due to sublimation, melting, or wind.
- *Air temperature*. Above freezing air temperatures combined with a rapid air temperature increase can produce a high melt rate and high peak flow. Different melt rates occur on north and south facing slopes, which may affect the timing of melt and size of the contributing area. Warm air temperatures can increase evapotranspiration and sublimation, reducing surface water availability.
- *Timing of opening of stream channels at lake outlets*. Snowmelt from hillslopes surrounding lakes can occur before the stream channels draining the lakes become ice free. In this case, meltwater can be stored in the lake and then released once the channels are open to flow.
- *Soil moisture conditions and lake levels at the end of the previous summer*. A dry summer in the previous year can lead to a significant soil moisture deficit and lower lake levels. As a result, a portion of the annual runoff will recharge the lakes and soil moisture before surface waters are transmitted as streamflow from a drainage area.
- Other watershed-specific physiographic controls include watershed size, slope, substrate type, and vegetation.

After snowmelt-generated runoff ends in summer and fall, the remaining runoff is controlled by rainfall, evaporation, and release of stored water in lakes and the active layer. Smaller basins with minimal lake area tend to exhibit a more rapid response to precipitation than larger basins. Open-water evaporation rates in summer often exceed total rainfall, causing soil moisture deficits in the shallow active layer of the soil. Studies of hillslope processes in northern watersheds have shown that summer rainfall can produce little or no runoff from hillslopes in the permafrost zone (Quinton and Marsh 1998). In this case, streamflow increases only due to rain falling directly onto lake surfaces or when there is major rainfall from short-term/high intensity events, or longer-term/sustained lower intensity events (Dugan et al. 2009).

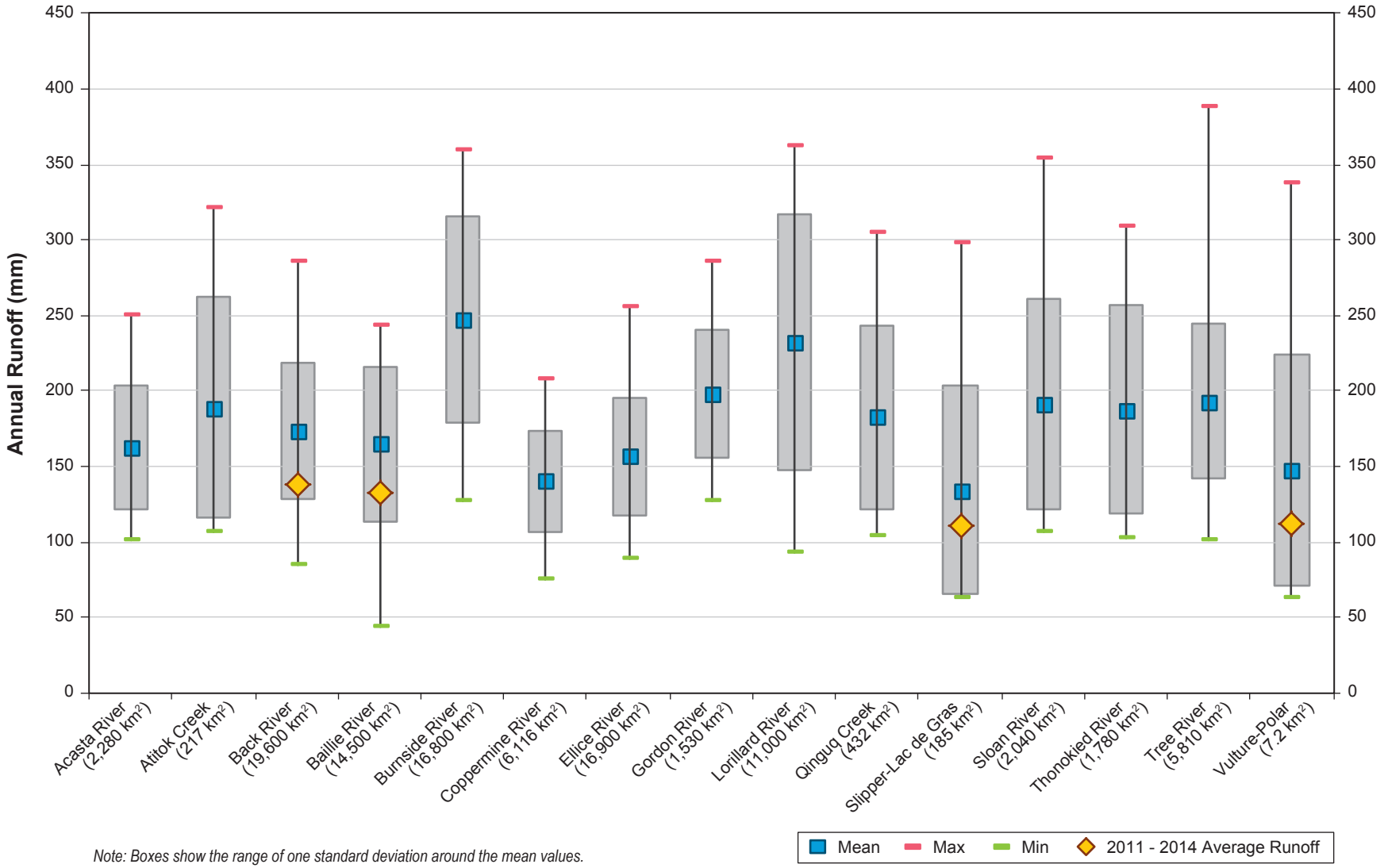
1.1.1.4 Annual Runoff and Seasonal Distribution

Annual average runoff derived from regional hydrologic stations ranges from 134 mm at Slipper-Lac de Gras Stream to 247 mm at Burnside River near the mouth (10QC001; Table 1.1-2 and Figure 1.1-6). Monthly unit discharge (Figure 1.1-4) and monthly distribution of annual runoff (Figure 1.1-5) at these stations follow a generally similar pattern. This pattern is also seen in monthly distribution data from the Project stations (Figures 1.1-4 and 1.1-5) even though they are based on a much shorter period of time. It is seen that among all regional stations, Coppermine River (10PA001), Lorillard River (06OA001), and Tree River (10QA001) are different from other regional stations and least similar to Project stations. Therefore, these three stations are not considered in further hydrologic regional analyses. In all remaining regional stations the majority of seasonal runoff occurs during the summer months (June to September), accounting for 76 to 95% of the annual runoff. The maximum percentage of monthly runoff occurs in June.

For the regional stations with approved 2011 to 2014 annual runoff values, the average of these data are plotted in Figure 1.1-6 along with long-term runoff estimates using data up to 2011 (i.e., mean, standard deviation, minimum, and maximum). The average annual runoff during 2011-2014 (the period during which data was collected from the Project site stations), for all stations with available data, range between 66% of the mean annual runoff (MAR) at Baillie River to 55% of the MAR at Vulture Polar Stream.

Table 1.1-2. Annual Runoff and Seasonal Distribution of Water Survey of Canada and other Regional Stations

Station	Drainage Area (km^2)	Annual Runoff (mm)	Seasonal Distribution (%)											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Acasta River	2,280	162.4	1.4	0.8	0.6	0.4	6.2	44.0	18.4	7.9	6.1	6.9	4.5	2.7
Atitok Creek	217	188.7	0.0	0.0	0.0	0.0	3.3	67.4	6.3	4.5	14.9	3.6	0.1	0.0
Back River	19,600	172.8	0.4	0.2	0.1	0.1	2.2	35.5	24.6	13.7	13.1	7.1	2.2	0.8
Baillie River	14,500	164.3	0.2	0.1	0.1	0.1	4.0	50.2	16.0	9.0	10.9	6.9	1.8	0.6
Burnside River	16,800	246.8	1.1	0.7	0.6	0.6	2.2	38.0	21.2	13.0	12.1	6.3	2.5	1.6
Coppermine River	6,116	140.0	5.6	4.6	4.6	4.0	6.7	20.6	13.4	10.0	9.7	9.1	6.4	5.4
Ellice River	16,900	156.6	0.0	0.0	0.0	0.0	0.5	49.4	25.8	9.2	10.6	3.8	0.6	0.1
Gordon River	1,530	197.5	0.0	0.0	0.0	0.0	2.1	40.3	25.7	12.8	13.0	5.4	0.7	0.0
Lorillard River	11,000	232.3	0.0	0.0	0.0	0.0	0.0	32.4	40.5	13.6	9.9	3.0	0.4	0.1
Qinguq Creek	432	182.3	0.0	0.0	0.0	0.0	2.5	55.1	20.1	8.2	11.8	2.2	0.0	0.0
Slipper-Lac de Gras	185	134.1	0.0	0.0	0.0	0.0	6.7	50.0	19.8	9.5	10.8	3.0	0.1	0.0
Sloan River	2,040	190.8	0.9	0.4	0.2	0.2	4.3	39.6	23.5	9.7	7.2	7.3	4.4	2.4
Thonokied River	1,780	187.2	0.0	0.0	0.0	0.0	2.2	36.5	31.0	14.5	7.9	5.7	1.8	0.4
Tree River	5,810	192.8	2.4	1.7	1.5	1.5	2.4	10.7	25.5	19.3	14.9	11.0	5.8	3.5
Vulture-Polar	7.2	147.4	0.0	0.0	0.0	0.0	9.9	49.0	21.6	8.8	9.6	0.9	0.1	0.0



Note: Boxes show the range of one standard deviation around the mean values.

Figure 1.1-6

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Long-term Annual Runoff at Regional Hydrometric Stations

Figure 1.1-6

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1.1.1.5 Peak Flows

Peak flows at regional stations were estimated by examining flood frequencies for exceedance probabilities, typically referred to as return periods, and presented as a 1 in X year event (Table 1.1-3). The flood frequency analyses were based on recorded maximum daily discharge data from regional hydrometric stations. The peak flow data were analyzed using HYFRAN-PLUS statistical software for the available period of record. Data were tested for independence, stationarity, and homogeneity before distribution functions were fitted. Data from Burnside River Station failed to pass the independence test, and therefore was excluded from further analysis.

Comparison of the maximum daily discharge and peak instantaneous discharge from the regional stations that record both indices showed that the peak instantaneous discharge was on average 20% greater than the maximum daily discharge. Based on this observation, the maximum daily discharge frequency results were converted to instantaneous peak values with a 20% increase factor. These results are summarized in Table 1.1-3. A strong correlation between the instantaneous peak flows with different recurrence periods and the drainage area is seen in Figure 1.1-7. The regression equations in Figure 1.1-7 are based on Stations Acasta, Atitok, Baillie, Ellice, Gordon, Qinguq, Slipper, and Vulture which all have a similar hydrologic regime to the Project stations (see Figures 1.1-4 and 1.1-5).

1.1.1.6 Low Flows

In smaller drainage basins in the region, similar to the Project streams, channel freeze-up typically occurs between late October and early November, with zero flow occurring in winter. During the open-water period (i.e., June to September) low flows are important to stream health aspects such as presence of certain aquatic species, or activities that could impact the quantity or quality of water. This study determined the 7-day low flow, the minimum average consecutive seven day flow, during June to September for the regional stations with sufficient low flow information (Table 1.1-4).

1.1.2 Local Setting

The Project area is characterized by extensive networks of lakes, low relief hummocky topography, and exposed bedrock uplands. To characterize the hydrologic regime and estimate surface water availability, a baseline hydrometric monitoring program was initiated in 2010. Hydrologic data have been collected and analyzed at up to 22 hydrometric monitoring stations during 2010 to 2015 (Appendix V6-1A, Rescan 2012a; Appendix V6-1B, Rescan 2012b; Appendix V6-1C, Rescan 2014a; Appendix V6-1D, Rescan 2014b; Rescan 2015a). Local and regional hydrometric data were used to estimate average and return period runoff values for the Goose Property. This is further presented in the Water and Load Balance Report (Appendix V2-7H).

1.1.2.1 Hydrometric Monitoring Program

The local study area (LSA; Section 1.4.1.1) has approximately 18% lake coverage, an average ground slope of 1.4%, and a total relief of 85 m. The gauged channels within the study area range from small ephemeral channels, less than 1 m in width, to larger rivers with widths exceeding 50 m.

The hydrometric monitoring network varied between 2 and 18 stations, with a total of 22 different stations, during 2010 to 2015. (Table 1.1-5 and Figure 1.1-8). The 2010 data were not used in the hydrologic analyses due to its limited temporal (July to September) and spatial (two stations) coverage. Data from 2011 and 2014 were used for the following sections. The 2015 data will be available in the near future (Rescan 2015a). The monitored drainage areas range from 1.4 km^2 at EL-H1 to 204.4 km^2 at PL-H1. The Big, Giraffe, Goose, Llama, Swan, and Wolf watersheds were delineated using National Hydro Network data, produced by Natural Resources Canada, and confirmed with visual observations. Where more detailed drainage areas were necessary, watershed boundaries were developed using available LiDAR and topographic data in conjunction with visual observations of the area.

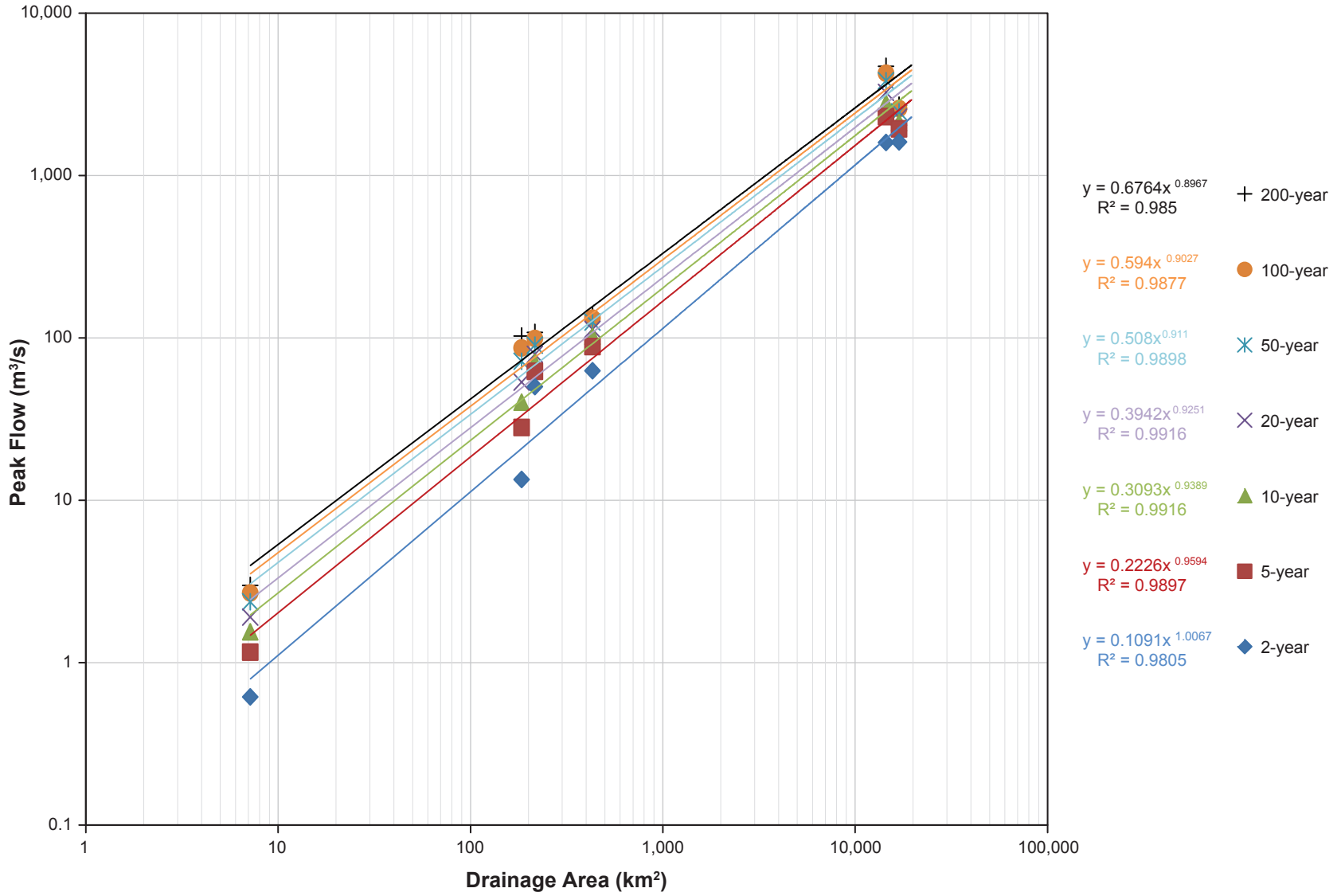

Figure 1.1-7

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Regional Regression Analysis between Instantaneous Peak Flow and Drainage Area

Figure 1.1-7

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Table 1.1-3. Estimated Instantaneous Peak Flows at Regional Hydrometric Stations

Station	Drainage Area (km^2)	Mean Annual Runoff (mm)	Mean Annual Discharge (m^3/s)	Peak Flows (m^3/s)						
				2-yr	5-yr	10-yr	20-yr	50-yr	100-yr	200-yr
Acasta River	2,280	162.4	11.7	112	148	169	187	209	224	239
Atitok Creek	217	188.7	1.3	50	62	71	79	90	99	108
Back River	19,600	172.8	107.4	1,062	1,512	1,752	1,944	2,160	2,292	2,400
Baillie River	14,500	164.3	75.5	1,596	2,304	2,784	3,240	3,828	4,260	4,704
Burnside River	16,800	246.8	131.5	n/a*	n/a	n/a	n/a	n/a	n/a	n/a
Ellice River	16,900	156.6	83.9	1,608	1,932	2,112	2,280	2,460	2,580	2,700
Gordon River	1,530	197.5	9.6	121	226	304	383	487	566	644
Qinguq Creek	432	182.3	2.5	63	88	102	113	125	132	138
Slipper-Lac de Gras	185	134.1	0.8	13	28	40	53	72	87	102
Sloan River	2,040	190.8	12.3	83	149	198	248	314	364	414
Thonokied River	1,780	187.2	10.6	66	114	146	179	221	252	282
Vulture-Polar	7.2	147.4	0.03	0.6	1.2	1.5	1.9	2.4	2.7	3.0

** Probability distribution fitting was not performed because the peak flow data did not pass the Wald-Wolfowitz independence test.*

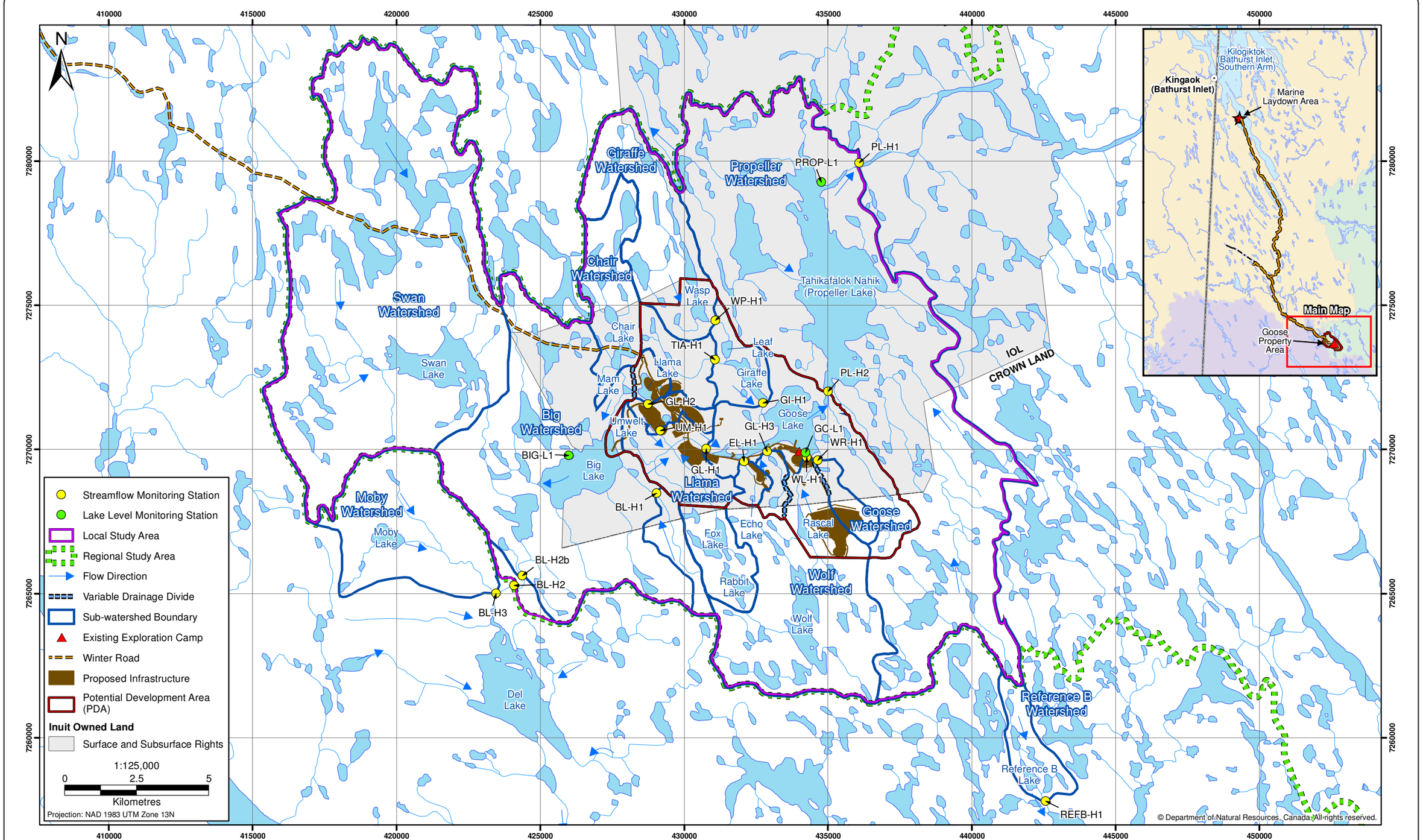
Table 1.1-4. Estimated 7-Day Low Flows during June to September at Regional Hydrometric Stations

Station	Drainage Area (km^2)	Mean Annual Runoff (mm)	Mean Annual Discharge (m^3/s)	Median June-September 7-Day Low Flows (m^3/s)
Acasta River	2,280	**162.4**	11.7	4.02
Atitok Creek	217	**188.7**	1.3	0.077
Back River	19,600	**172.8**	107.4	18.65
Baillie River	14,500	**164.3**	75.5	13.49
Burnside River	16,800	**246.8**	131.5	41.54
Ellice River	16,900	**156.6**	83.9	5.09
Gordon River	1,530	**197.5**	9.6	0.511
Qinguq Creek	432	**182.3**	2.5	0.0122
Slipper-Lac de Gras	185	**134.1**	0.8	0.40
Sloan River	2,040	**190.8**	12.3	5.45
Thonokied River	1,780	**187.2**	10.6	2.64
Vulture-Polar	7.2	**147.4**	0.03	0.011

Table 1.1-5. Hydrometric Monitoring Stations in the Goose Property Area

Hydrometric Station	Location	Geographic Coordinates[1]		Drainage Area (km^2)	Lake Coverage (%)	Period of Operation
		Easting	Northing			
BIG-L1	Big Lake	425,992	7,269,783	n/a	n/a	Jun 9 – Jul 12, 2014 Jun 12 – Aug 16, 2015
BL-H1	Big Lake inflow	429,044	7,268,478	3.6	2.5	Jun 12 to Sep 10, 2012
BL-H2	Swan Lake	424,087	7,265,274	160	18.9	Jun 8 to Sep 9, 2012
BL-H2b	Swan Lake	424,379	7,265,620	158.5	19.1	Jun 9 to Jul 12, 2014 Jun 12 to Aug 16, 2015
BL-H3	Moby Lake outflow	423,467	7,264,998	21.4	4.7	Jun 8 to Sep 9, 2012
CL-L1	South Canyon Lake	438,934	7,287,952	n/a	n/a	Jul 17 to Sep 16, 2013
CL-L2	Canyon Lake	438,683	7,288,549	n/a	n/a	Jul 17 to Sep 16, 2013
EL-H1	Echo Drainage outflow	432,091	7,269,573	1.4	2.2	Jun 13 to Sep 16, 2011 Jun 6 to Sep 7, 2012 31 May to 12 Sep, 2013
GC-L1	Goose Camp	434,226	7.269,887	n/a	n/a	Jun 7 to Oct 4, 2013
GI-H1	Giraffe Lake outflow	432,744	7,271,610	27.4	13.3	Jun 11 to Sep 16, 2011 Jun 9 to Sep 14, 2012 Jun 5 to Sep 10, 2013
GL-H1	Goose Lake inflow	430,772	7,270,016	18.0	10.6	Jul 3 to Sep 13, 2010 Jun 10 to Sep 16, 2011 Jun 5 to Sep 7, 2012 Jun 2 to Sep 12, 2013
GL-H2	Llama Lake outflow	428,746	7,271,567	1.7	23.1	Jul 3 to Sep 13, 2010 Jun 10 to Sep 16, 2011 Jun 5 to Sep 7, 2012 Jun 3 to Sep 11, 2013
GL-H3	Goose Lake inflow	432,891	7,269,919	1.8	7.5	Jun 14 to Sep 16, 2011 Jun 7 to Sep 9, 2012 May 31 to Sep 13, 2013 Jun 13 to Aug 17, 2015
PL-H1	Propeller Lake outflow	436,094	7,279,939	204.4	18.9	Jun 14 to Sep 17, 2011 Jun 6 to Sep 8,2012 Jun 8 to Oct 4, 2013 Jun 8 to Jul 12, 2014
PL-H2	Propeller Lake inflow	435,007	7,272,014	101.5	15.1	Jun 11 to Sep 17, 2011 Jun 12 to Sep 12, 2012 Jun 2 to Oct 4, 2013 Jun 8 to Jul 12, 2014 Jun 11 to Aug 18, 2015
PROP-L1	Propeller Lake	434,782	7,279,265	n/a	n/a	Sep 9 to Oct 4, 2013
REFB-H1	Reference B Lake outflow	442,573	7,257,794	5.3	19.1	Jun 13 to Sep 17, 2011 Jun 9 to Sep 13, 2012 Jun 6 to Sep 16, 2013
TIA-H1	PFS/DEIS tailings impoundment outflow	431,069	7,273,106	5.0	4.4	Jun 5 to Sep 12, 2013
UM-H1	Umwelt Lake outflow	429,166	7,270,649	4.1	17.0	Jun 3 to Sep 16, 2013
WL-H1	Rascal Outflow East	434,269	7,269,719	32.7	16.6	Jun 10 to Sep 17, 2011 Jun 7 to Sep 14, 2012 Jun 1 to Sep 15, 2013 Jun 13 to Aug 14, 2015
WP-H1	Wasp Lake outflow	431,086	7,274,468	17.6	14.0	Jun 5 to Sep 12, 2013
WR-H1	Tailings Storage Facility Outflow	434,687	7,269,635	2.7	2.4	Jun 1 to Sep 15, 2013 Jun 11 to Aug 17, 2015

[1] *UTM, Datum NAD 83, Zone 13 W*



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Study Area Drainage Basins - Goose Property Area

Figure 1.1-8

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Hydrologic data collected and analyzed during the monitoring program include:

- continuous stream water level (stage) measurements during the open-water season;
- more than 300 manual stream discharge measurements and water level surveys;
- development of stage-discharge relationships (rating curves) and annual hydrographs at each of the monitoring locations;
- calculation of hydrologic indices, including annual and monthly runoff, peak flows, and low flows at each of the monitoring locations;
- channel geometry surveys; and
- a total of 8 snow course surveys within the Goose Property. Eighteen bathymetric surveys have also been completed in the Goose Property area (see Chapter 3 in this Volume).

The hydrometric stations operated during the open-water season, from June to late-September. Continuous stage data were collected with Aquistar® PT2X (Instrumentation Northwest Inc. - INW) transducers, or PS-98i® 0-5 PSI vented pressure transducer (INW) paired with an ELF-2 data logger (Terrascience Ltd.).

Manual discharge measurements were primarily performed with the velocity-area technique. These measurements consisted of water current velocity measurements made at known distances along a transect perpendicular to river flow (Herschy 2009). Multiple discharge measurements were completed at all the hydrometric stations during the open-water season. Current velocity measurements were obtained using either a conventional vane or propeller driven current meter (Swoffer 2100™) or an electromagnetic velocity flow meter (Hach FH950 Portable Flow Meter™ or Marsh-McBirney Flo-mate™). Where water depth or velocity conditions were too high to allow safe wading, velocity was determined using a StreamPro™ (Teledyne RD Instruments) acoustic Doppler current profiler (ADCP).

Manual flow measurements were used to develop stage-discharge relationships for each hydrometric station. Once established, the relationships were used to convert water level data (stage) recorded by the automated hydrometric stations into a continuous discharge time-series.

Unit discharge was calculated using daily discharge for the hydrometric monitoring stations that were operated during 2011 to 2014 (Figure 1.1-9). The hydrologic regime in the Project area is characterized by the Arctic nival flow regime. Instantaneous and daily peak flows occurred in early to mid-June in most drainage areas, or in early July for some drainage basins (e.g. GL-H1, GI-H1, and EL-H1 in 2011). Instantaneous peak flows ranged from 0.13 m^3/s at EL-H1 in 2011 and BL-H1 in 2012 to 21.9 m^3/s at PL-H1 in 2011. Instantaneous peak flows were not reported in 2013 and 2014 as the peak flows were estimated using regression analysis, which is more reliable for daily flows than instantaneous flows. At PL-H1, high flows (i.e., flows greater than 8.1 m^3/s) occurred during June 16 to 18, 2011. Hourly variations of the high flows during this period resulted in occurrence of instantaneous and daily peak flows on different dates (Table 1.1-6). Likewise, at EL-H1 the reported instantaneous and daily peak flows occurred on different days because daily peak flow was determined using the estimated freshet daily discharges that were not recorded in the 10 minute (instantaneous) data (Table 1.1-7).

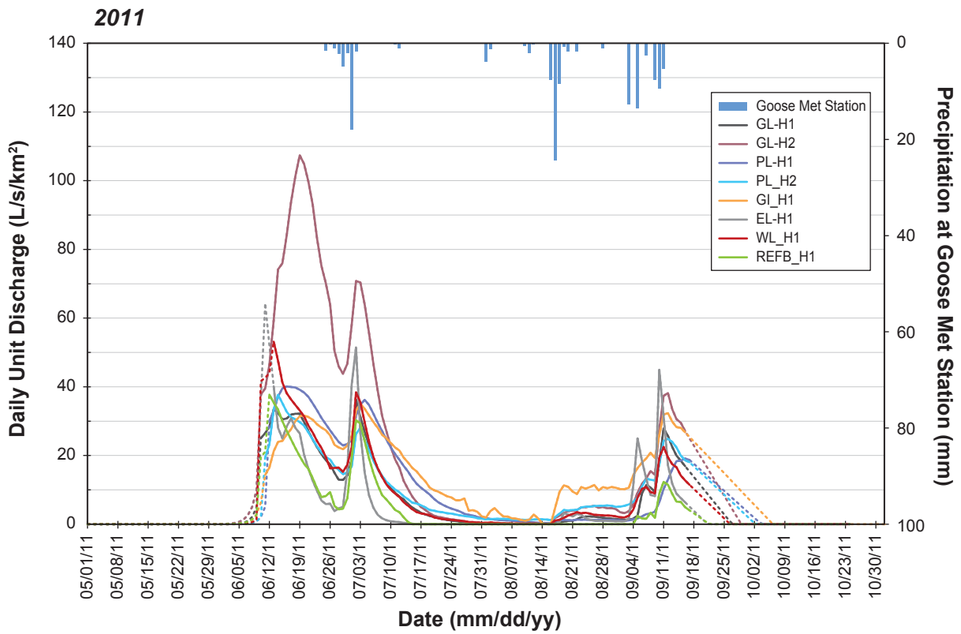
Most streams experienced zero or extreme low flow conditions in August during the open-water period (Table 1.1-6). Flow duration analysis demonstrated that, on average, there was streamflow during 30% of the year for most of the monitored streams.

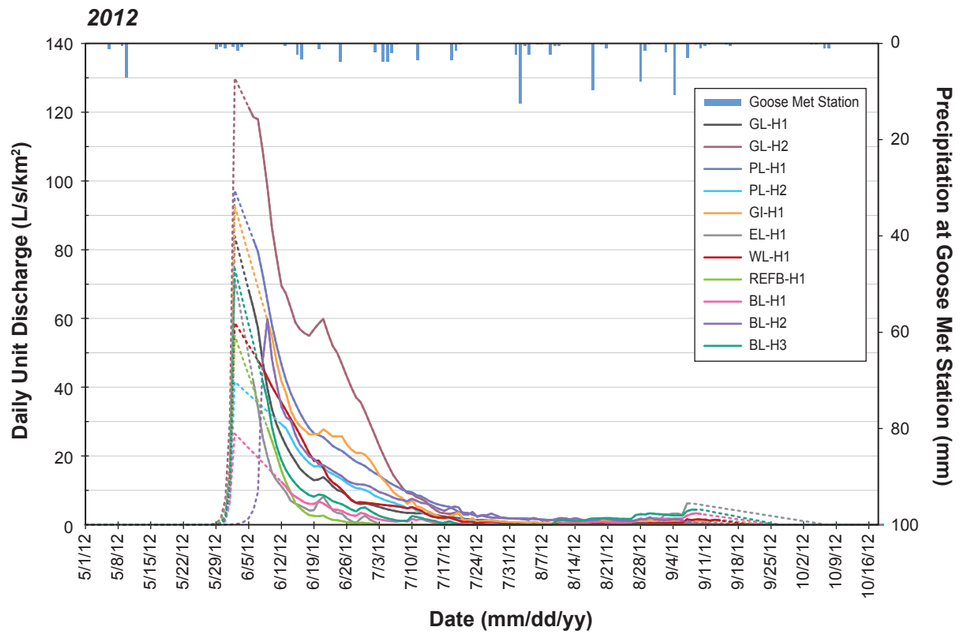
Table 1.1-6. Peak Flows and Low Flows in the Goose Property Area

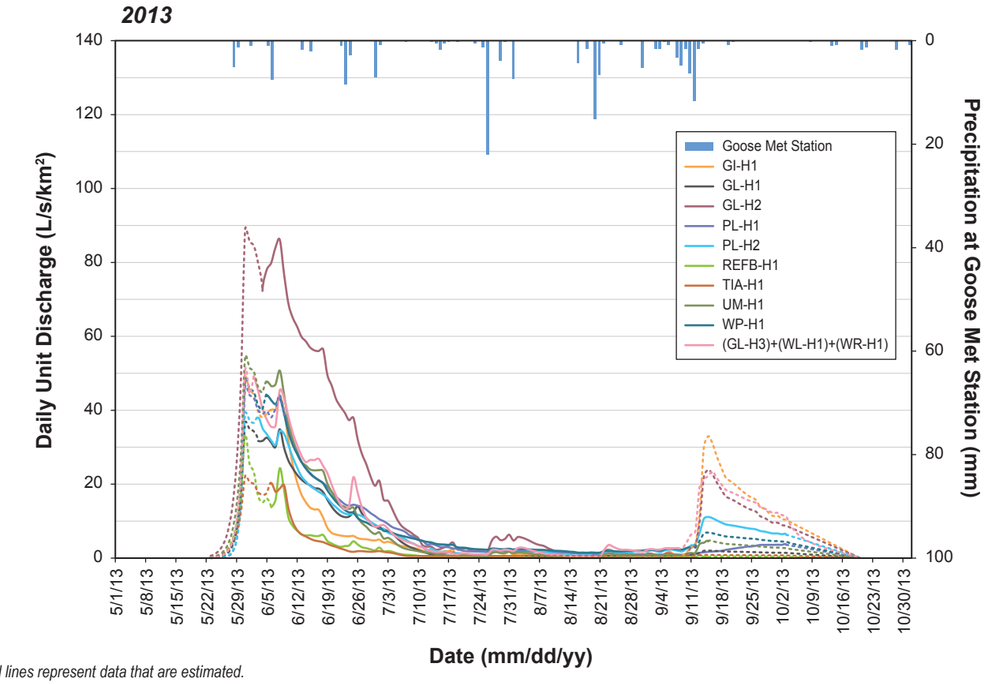
Hydrometric Station	Drainage Area (km^2)	Year	Peak Flow (m^3/s)			Open-Water Low Flow (m^3/s)	
			Instantaneous	Daily	Date	Daily	Date
BL-H1	3.59	2012	*0.130*	*0.0952*	*Jun 2*	0	Jul 29 - Aug 9
BL-H2	160.0	2012	*11.1*	*9.57*	*Jun 9*	0.176	Aug 26
BL-H2b	158.5	2014	-	*5.35*	*May 29*	-	-
BL-H3	21.4	2012	*2.08*	*1.59*	*Jun 2*	0	Jul 21 – Aug 9
EL-H1	1.4	2011	*0.13*	*0.09*	*Jul1/Jun 11*	0	Jul 17 - Aug 16
		2012	*0.148*	*0.100*	*Jun 2*	0	Jul 3 – Aug 31
		2013	-	*0.17*	*Sep 15*	0	Jul 22-26
GI-H1	27.4	2011	0.98	0.96	Jul 3	0.002	Aug 15
		2012	*2.94*	*2.54*	*Jun 2*	0.011	Aug 8
		2013	-	*1.33*	*May 31*	<0.001	Aug 14-15
GL-H1	18.0	2010	-	*0.388*	-		
		2011	0.70	0.65	Jul 2	0.001	Aug 17
		2012	*1.56*	*1.51*	*Jun 2*	0	Aug 16 – Sep 6
		2013	-	*0.66*	*May 31*	0.005	Aug 16-18
GL-H2	1.7	2010	-	-	-		
		2011	0.19	0.18	Jun 19	<0.001	Aug 10
		2012	*0.221*	*0.217*	*Jun 2*	<0.001	Aug 20 - 29
		2013	-	*0.15*	*May 31*	<0.001	Aug 13 - 21
GL-H3	1.8	2011	0.65	0.57	Jun 14	0	Jul 17 - Aug 20
		2012	*0.633*	*0.516*	*Jun 2*	0	Jul 19 – Sep 5
		2013	-	*0.49*	*Jun 2*	0	Aug 9 - 20
PL-H1	204.4	2011	8.44	8.19	Jun 18/Jun 16	0.06	Aug 16
		2012	*21.9*	*19.9*	*Jun 2*	<0.0002	Sep 3 - 6
		2013	-	*9.50*	*May 31*	0.184	Sep 4
		2014	-	*9.00*	*May 29*	-	-
PL-H2	101.5	2011	3.88	3.83	Jun 14	0.122	Aug 16
		2012	*5.25*	*4.22*	*Jun 2*	<0.001	Aug 6 - 7
		2013	-	*3.99*	*May 31*	0.053	Aug 20
		2014	-	*3.78*	*May 29*	-	-
REFB-H1	5.3	2011	0.21	0.20	Jun 12	0	Jul 15 – Sep 4
		2012	*0.350*	*0.292*	*Jun 2*	0	Jul 23 – Sep 13
		2013	-	*0.18*	*May 31*	0	Aug 8 - 22
TIA-H1	5.0	2013	-	*0.11*	*May 31*	0.003[1]	July 7 to Aug 3
UM-H1	4.1	2013	-	*0.22*	*May 31*	0.001	Aug 16 – 18
WL-H1	32.7	2011	1.83	1.74	Jun 13	0.002	Aug 15
		2012	*2.29*	*2.06*	*Jun 2*	0.001	Aug 6-9
		2013	-	*1.09*	*Jun 2*	0.013	Aug 20
WP-H1	17.6	2013	-	*0.85*	*May 31*	0.025	Aug 16 – 18
WR-H1	2.7	2013	-	*0.33*	*May 31*	0	Aug 9 - 20

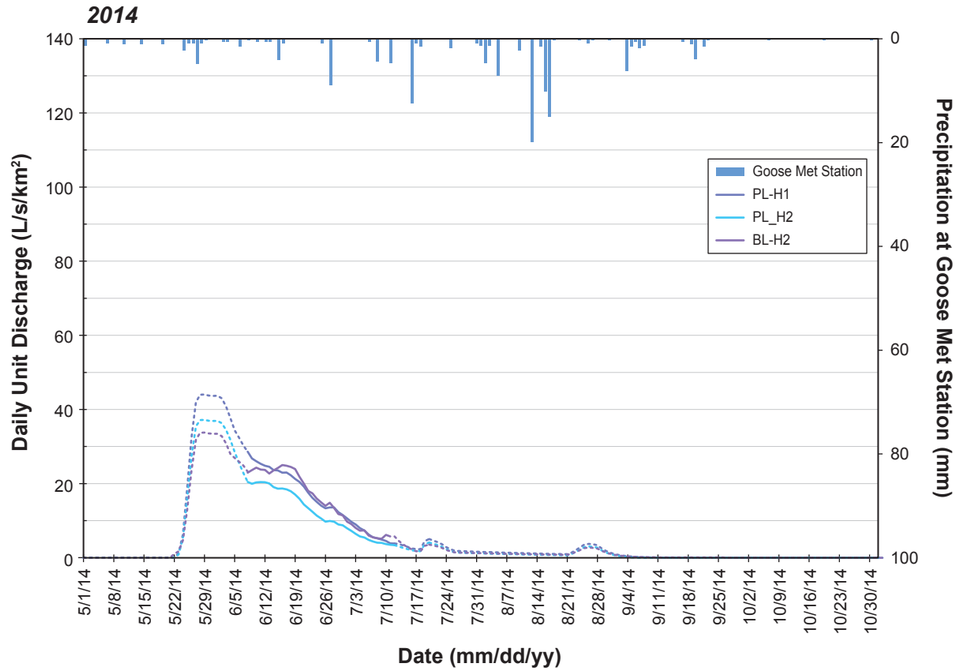
Note: Estimated values are italicized

[1]Flows were not recorded after August 3rd, 2013, but dry channel conditions were observed after this date









Note: Dashed lines represent data that are estimated.

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Figure 1.1-9

Annual Unit Hydrographs of Hydrometric Monitoring Stations - Goose Property Area

Table 1.1-7. Annual Runoff and Seasonal Distribution in the Goose Property Area

Hydrometric Station	Year	Annual (mm)	Seasonal Distribution (%)						
			Jan-May	Jun	Jul	Aug	Sep	Oct	Nov-Dec
BL-H1	2012	36	1	78	6	5	11	0	0
BL-H2	2012	69	0	72	21	6	1	0	0
BL-H2b	2014	92	20	64	12	4	0	0	0
BL-H3	2012	71	0	82	4	5	8	0	0
EL-H1	2011	77	0	54	17	3	26	0	0
	2012	55	1	80	0	0	18	1	0
	2013	215	10	18	1	3	60	7	0
GI-H1	2011	157	0	29	29	10	32	1	0
	2012	126	0	85	11	2	1	0	0
	2013	111	10	46	5	1	30	8	0
GL-H1	2011	95	0	48	24	2	26	0	0
	2012	81	0	90	9	1	0	0	0
	2013	74	12	73	8	2	5	2	0
GL-H2[1]	2011	227	0	58	22	2	18	0	0
	2012	206	0	90	10	0	0	0	0
	2013	223	11	65	7	2	12	3	0
GL-H3[1]	2011	-	-	-	-	-	-	-	-
	2012	216	1	92	7	0	1	0	0
	2013	621	10	60	2	1	25	3	0
PL-H1	2011	123	0	45	33	2	20	0	0
	2012	134	0	84	14	2	0	0	0
	2013	134	10	67	11	4	5	3	0
	2014	103	23	61	11	4	0	0	0
PL-H2	2011	108	0	40	23	7	30	0	0
	2012	72	0	83	12	2	3	0	0
	2013	98	9	58	8	4	16	6	0
	2014	83	24	60	11	4	0	0	0
REFB-H1[2]	2011	56	0	59	28	0	13	0	0
	2012	40	1	99	0	0	0	0	0
	2013	34	24	68	5	0	2	1	0
TIA-H1	2013	34	18	65	6	5	5	2	0
UM-H1	2013	101	14	70	5	2	6	2	0
WL-H1[1]	2011	104	0	54	23	3	20	0	0
	2012	82	0	88	9	1	2	0	0
	2013	92	8	56	9	4	17	6	0
WP-H1	2013	108	10	61	10	5	10	4	0
WR-H1[1]	2013	315	9	32	2	4	39	14	0
GL-H3 + WL-H1 + WR-H1	2013	134	9	53	6	3	22	7	0

[1] *Drainage divide is not fixed; therefore runoff values are uncertain.*
[2] *Reference watershed outside the Local Study Area (LSA)*

Over the 2011-2014 monitoring period, annual runoff estimates ranged from a low of 34 mm at station TIA-H1 in 2013 to a high of 227 mm at station GL-H2 in 2011 (Table 1.1-7). Station GL-H3 and WR-H1 had 615 and 315 mm of runoff, respectively, calculated in 2013. However, water crosses the watershed boundaries dividing GL-H3, WL-H1 and WR-H1 which causes GL-H3 and WR-H1 to demonstrate high runoff, and WL-H1 to have low runoff. When the three stations were treated as a single watershed, the calculated runoff was 134 mm in 2013. The majority of seasonal runoff occurred in June at all stations, with the exception of GI-H1 in 2011 and, EL-H1 and WR-H1 in 2013 when the majority of runoff occurred in September. The runoff in June accounted for a low of 18% of the annual total at station EL-H1 in 2013 and a high of 92% at station GL-H3 in 2012. A very low annual runoff occurred at stations BL-H1 in 2012 and TIA-H1 in 2013 (Table 1.1-7; Figure 1.1-9). The very low annual runoff recorded at BL-H1 in 2012 is likely due to the uncertainty associated with the estimation of runoff outside of the period of record, particularly the estimation of peak flow. The low annual runoff recorded at TIA-H1 in 2013 was attributed to runoff passing the station as subsurface flow (Rescan 2014a).

1.1.2.2 Marine Laydown Area

The Marine Laydown area is a narrow strip of land on the west side of southern Bathurst Inlet. Most streams in this area flow directly to Bathurst Inlet on the west side. These are not within the local study area (LSA) or potential development area (PDA). There are no hydrometric monitoring stations within the Marine Laydown area as the Project infrastructure does not interact with any streams.

1.1.3 Runoff Estimates for Hydrologic Effects Assessment

SRK (Appendix V2-7H) studied the correlation between long-term regional hydrometric data (Section 1.1.1) and local hydrometric data collected during the baseline monitoring program (Section 1.1.2.1). Based on the relationship between the regional and local hydrometric data, the MAR in the Goose Property watersheds was estimated to be 149 mm (Appendix V2-7H). Monthly and daily distributions of this annual runoff estimate are shown in Table 1.1-8 and Figure 1.1-10, respectively.

Table 1.1-8. Monthly Distribution of Mean Annual Runoff in the Goose Property Area

	Runoff	
Month	**(mm)**	**(% of Annual)**
January	0.0	0.0%
February	0.0	0.0%
March	0.0	0.0%
April	0.0	0.0%
May	5.9	4.0%
June	75.3	50.5%
July	28.3	19.0%
August	12.9	8.7%
September	17.8	11.9%
October	8.2	5.5%
November	0.6	0.4%
December	0.0	0.0%
Sum	**149.0**	**100.0%**

A frequency analysis was conducted to estimate annual runoff in the Goose Property during wet and dry years with different return periods (Appendix V2-7H). Results are presented in Table 1.1-9.

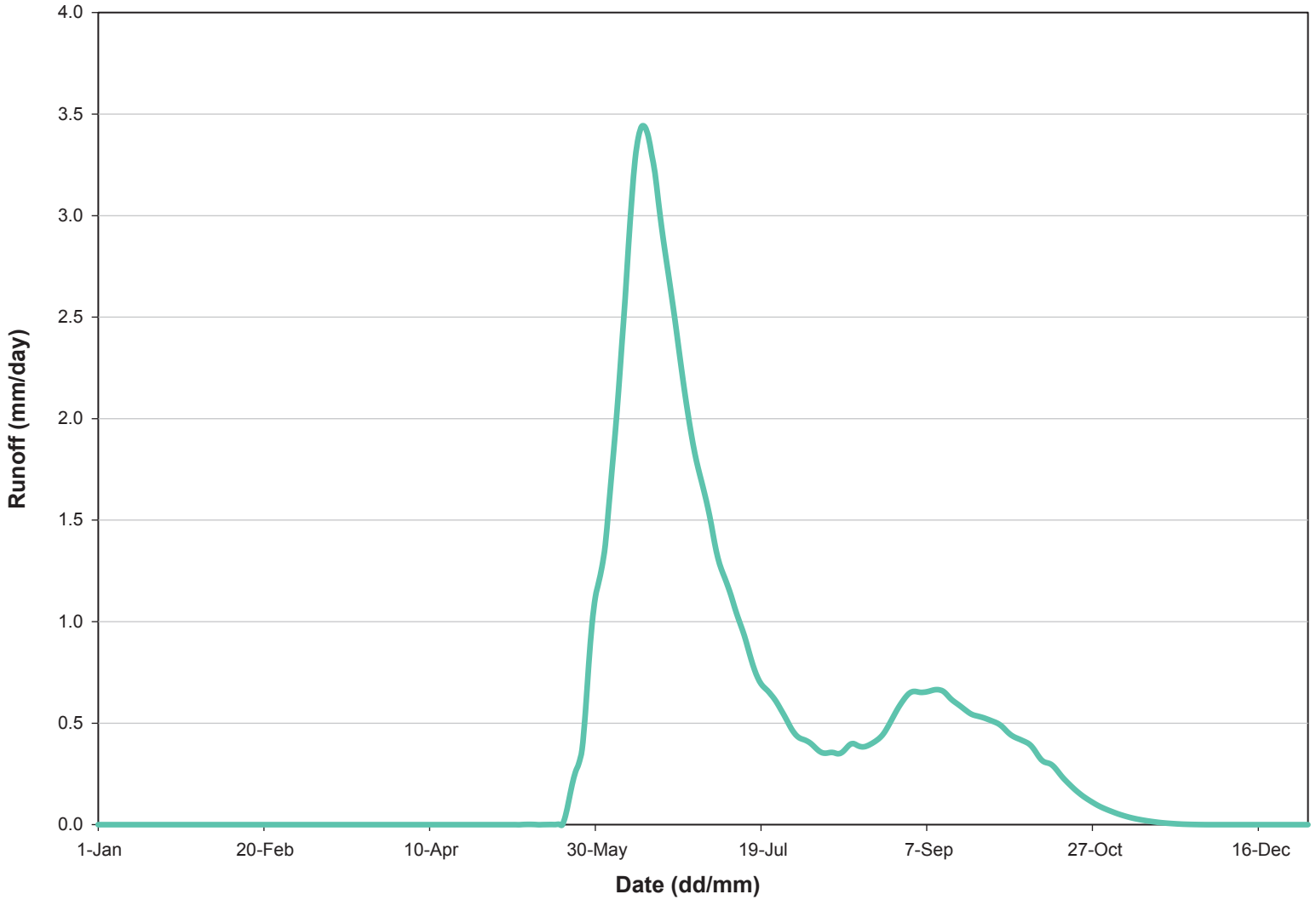

Figure 1.1-10

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Daily Distribution of Mean Annual Runoff in Goose Property Area

Figure 1.1-10

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Table 1.1-9. Wet and Dry Annual Runoff Estimates for Different Return Periods

Hydrological Condition	Return Period (years)	Annual Runoff (mm)
Wet	200	269
	100	258
	50	245
	20	227
	10	210
	5	190
Average	-	149
Dry	5	112
	10	92
	20	75
	50	56
	100	44
	200	32

1.1.4 Proximity to Designated Environmental Areas

No existing or proposed parks or conservation areas are located near the proposed Project. The nearest conservation area is the Queen Maud Gulf Migratory Bird Sanctuary approximately 100 km east of Bathurst Inlet on the far side of the Kent Peninsula. The Draft Nunavut Land Use Plan (Nunavut Planning Commission 2012, 2014) has no designated environmental areas within the Regional Study Area (RSA), and the proposed Project resides within the area designated as a High Mineral Potential area. The proposed Hiukitak River Cultural Area is on the eastern shore of Bathurst Inlet outside of the Freshwater RSA, and is located approximately 60 km northeast of the proposed Marine Laydown Area (MLA). A key bird habitat site has been identified in the north end of Bathurst Inlet, approximately 150 km to the north of the proposed MLA. The Back River is currently the only waterbody within the RSA to be considered as a heritage river. While no formal nomination for the Back River has been put forward thus far, the Project has been designed to avoid impacts to the Back River water system.

1.1.5 Anticipated Global Climate Change and its Hydrologic Impacts

There is a general consensus in the scientific community that the earth's climate is changing and that these changes are 1) anthropogenic, and 2) independent of other climate change mechanisms. The magnitude of 21st century warming and increases in precipitation in the Arctic are expected to be large relative to the rest of the planet (ACIA 2005). Predictions of the magnitude of Arctic climate change vary spatially, according to which emissions scenario and global climate model (GCM) is selected. For northern Canada, mean annual temperature may increase by approximately 2.0ºC for the years 2010 to 2030, and by approximately 6.0ºC for years 2070 to 2100, compared to 1961 to 1990 conditions. Over the same time periods, precipitation could increase from 5 to 8% and 15 to 30%, respectively (see Appendix V4-3B).

The expected duration of the Back River Project is currently 27 years (4 years mobilization and construction, 10 years operations, 8 years closure, and 5 years post-closure). Therefore, the summary below focuses on the impacts of climate change on hydrology that could occur throughout the first half of the twenty-first century. Anticipated hydrologic impacts from climate change are discussed in relation to changes to the active layer, total annual runoff, winter flow, and extreme events. Wherever possible, quantitative modelling studies are cited. However, given the variation in predictions of

different GCMs, multiple emission scenarios, and the limited number of Arctic hydrologic modelling studies that examine climate change impacts, much of the discussion below is qualitative and is based on possible changes to hydrologic processes that would result from increasing mean annual temperature and precipitation in the Arctic and Subarctic.

1.1.5.1 Changes to the Active Layer and its Hydrologic Impacts

The Project lies in the zone of continuous permafrost, and permafrost depth exceeds 500 m (Brown et al. 1998). The maximum depth of the active layer is about 1.3 to 1.7 m in areas of shallow overburden (Rescan 2012c; see Volume 5, Chapter 2). Expected increases in active layer thickness due to climatic warming have been modelled for the Mackenzie Valley. By 2050, active layer thickness is expected to increase by less than 15 cm for areas without a thick insulating organic layer (Woo, Mollinga, and Smith 2007), which is typical for the Back River Project area.

Streams in small watersheds underlain by permafrost tend to have 'flashy' storm hydrographs, since there is little opportunity for infiltration or baseflow, and a large fraction of liquid water runs off quickly. A thickened active layer would lengthen the period when the active layer exists, and increase the potential for water to flow through unfrozen soil. Hydrologically, this would lead to more sustained baseflows, reduced stormflow, and an increase in the number of days per year when unfrozen soil conditions exist (MacLean et al. 1999). In particular, late summer storage would increase with a thickened active layer, since the active layer is thickest at this time. This would cause a decrease in the runoff ratio in late summer.

Most runoff in the Project area is typically snowmelt-derived, and runs off quickly during the freshet, immediately after air temperature rises above freezing (Figure 1.1-3). Warmer air temperatures will affect the timing of the freshet; however, the active layer will be thin during the freshet regardless of its timing. Therefore, while climate change will likely affect the timing of thaw, and the maximum summertime thickness of the active layer, the active layer will always be thin during the freshet, and therefore soil storage changes (which will be more prevalent in the later summer months) will not be as influential.

1.1.5.2 Changes to Runoff

Impacts of climate change on runoff near the Project area are difficult to predict for the following reasons:

1. Spatial variability in observed precipitation and air temperature.
2. Spatial and temporal variability in modelled predictions of precipitation and air temperature. For example, future precipitation and air temperature vary in magnitude with the emissions scenario and GCM used.
3. Watershed-scale variability in parameters. Hydrologic responses in watersheds located close to each other can vary greatly. For example, watershed size, aspect, slope, hydrologic connectivity, effects of snowbanks and drifts, and substrate can greatly affect hydrologic response.
4. Lack of scientific knowledge. Arctic hydrologic processes are only moderately well understood. The impacts of changing air temperature and precipitation on hydrologic processes will be non-linear, making the result more difficult to predict. In addition, very few modelling studies have examined the impacts of Arctic climate change on hydrology.

These uncertainties are sufficiently large that both increases and decreases to Arctic runoff have been predicted (Pohl, Marsh, and Bonsal 2007; Lewis and Lamoureux 2010; Thorne 2011). A GCM predicts the

increases in snowfall, and the intensity and magnitude of summer rain events. These changes would lead to more runoff, if no other hydrologic processes are considered. However, if evapotranspiration or snowpack sublimation sufficiently increases, less snowpack would be available for melt and runoff, and fragmentation could occur. A fragmented snowpack that is not connected to hydrologic pathways would not provide surface water runoff. A thickened active layer, as discussed previously, would lead to more water movement through the subsurface, allowing slow routing, more evapotranspiration and storage, and decreased runoff.

The largest uncertainty appears to be from GCMs. Variability in GCM inputs (e.g., emissions scenarios) and outputs (e.g., air temperature and precipitation) have large effects on modelled hydrologic responses (Thorne 2011). For example, runoff in the Liard River Basin, in the western Mackenzie River basin, between Dease Lake and Fort Nelson, is predicted to vary by -3% to +22% depending on the GCM used (Thorne 2011). Similarly, in the Trail Valley Creek Watershed (Mackenzie Delta, between Inuvik and Tuktoyaktuk), the volume of runoff by 2050 is predicted to change from -10 to +40% (Pohl, Marsh, and Bonsal 2007).

Despite these uncertainties, most predictions of the impacts of climate change on Arctic river flow show increases in runoff and discharge in the 21st century, although the amount of increase varies greatly. Of the quantitative climate change impact studies published to date, the hydrologic effects of climate change within the Project area should be most similar to those predicted for Trail Valley Creek, given their relatively similar climatic and physiographic settings.

1.1.5.3 Changes to Winter Flow

Winter flows have the potential to markedly increase in the Arctic and Subarctic. For a 6°C increase in global mean temperature, winter flows in the Liard River Watershed are predicted to increase by 31% (Thorne 2011). Flow under ice may also extend in duration under warmer climate scenarios. However, due to the small size of the watersheds in the Project area, it is unlikely that winter flow currently occurs in any Project area streams and it is considered unlikely that anticipated warming during the Project lifespan would lead to winter flow in the Project area.

1.1.5.4 Hydrologic Impacts of Extreme Weather Events

The intensity of precipitation during extreme events is predicted to increase, though the magnitude varies between GCMs and emission scenarios (Pohl, Marsh, and Bonsal 2007; Lewis and Lamoureux 2010; Thorne 2011). From a hydrologic perspective, increased rainfall is important because runoff ratios are high in extreme events. In large rainfall-runoff events, the surface can saturate, flow pathways can connect, and water runs off quickly and efficiently. By contrast, in lower intensity events, flow pathways can remain disconnected, evapotranspiration and infiltration are more efficient, and a lower fraction of the rainfall runs off. An increase in extreme events could non-linearly increase sediment transport, cause channel aggradation, erosion, avulsion, and extreme flows. These changes have the potential to negatively impact water management structures and project infrastructure, such as aggradation or erosion of diversion channels or event ponds, however the magnitudes of these impacts are currently unknown.

1.1.5.5 Changes to Other Hydrologic Variables

Other predictions of hydrologic impacts due to climate change are more certain and consistent than runoff. The melt season is expected to lengthen, and the date of freshet is expected to advance throughout the Arctic. By 2050 at the Trail Valley Creek Watershed, the date of peak flow is predicted to advance by 14 days, and the date of the initiation of melt is expected to increase by up to 17 days.

Modelled freeze-up is delayed (from late September or early October to late October or early November), and the modelled snow-free period is extended (Pohl, Marsh, and Bonsal 2007).

1.2 INCORPORATION OF TRADITIONAL KNOWLEDGE (TK)

The effects assessment relies on the information collected from Inuit-led TK information, public scoping, focus group meetings, government engagement, and scientific knowledge. To the extent possible, available TK is incorporated into the evaluation of the potential effects of the Project on the environment. The following reports were reviewed for TK specific information related to surface water hydrology features:

- *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* (KIA 2012) (Appendix V3-3A of FEIS);
- *Naonaiyaotit Traditional Knowledge Project - Hannigayok (Sabina Gold & Silver Corp. Proposed Back River Project). Results from Data Gaps Workshops, Final Report (June 2014)* (KIA 2014) (Appendix V3-3B of FEIS); and
- *Back River Project: Existing and Publically Available Traditional Knowledge from Selected Aboriginal Groups in the Northwest Territories* (Appendix V3-3C of FEIS).

1.2.1 Incorporation of TK for Existing Environment and Baseline Information

The *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* report (KIA 2012) was reviewed for information pertinent to surface water hydrology. According to the TK information provided in the NTKP report, Inuit have seen changes in hydrology over the past few decades.

TK information documented in the NKTP report (KIA 2012) reflects observations of some hydrologic processes including the ice break-up process in the streams:

> *These rivers that we call flooded sometimes overflow before the land melts. The river is flowing under the snow and over top of the ice. That is what we call flooded. The ice and river would be flooded and the ice would be opening up when the river overflows. Once the rivers overflow, it's hard on the people who are hunting because they get stuck in between the rivers. If they didn't have a boat they would have to wait for the water to subside.*

In addition, TK information in the NKTP report (KIA 2012) and the *BIPR Traditional Knowledge of Wildlife, Fish and Water Quality Report* (Rescan 2007) included observations of shallower lakes and rivers and reductions in river flow. The changes were attributed to less rain and snowfall and changes in weather. The consultants in the NTKP report stated:

> *The water too, everything has changed, even the land here. It would never completely dry up. That's what people have mentioned during the summer. Even the rivers, everything has changed. In the past, when people went walking, they would have hard time finding water; sometimes they wouldn't find water at all. It's not like that anymore, it seems to rain more. Summer would never come when it rains too much. It's colder now too. It wasn't like that a long time ago. It was fun then. The ocean doesn't freeze up like it used to, maybe it's getting warmer? It must be getting warmer that's why it doesn't freeze up like it used to.*

> *Everything is changing and getting tougher. Sometimes you don't even know what to do. The rivers seem to get lower than they used to and the land seems to have more water…* (KIA 2012).
>
> *The water is so different now. When it doesn't rain in the summer the lakes have less water in them or when the weather is too hot it evaporates* (Rescan 2007).
>
> *The rivers have less water. In winter there's hardly any water in them. You can see rocks* (Rescan 2007).
>
> *The major rivers didn't get too shallow until the fall. Now they are like that (all the time)…I don't know why (water levels) are changing every year. There could be lots of snow during the winter and still they dry up. Long ago this river near Cambridge Bay (Freshwater Creek) used to be deep. We would use our boat to go up river but now we can't…*
>
> *…When it gets too hot during the summer the water gets shallow. The land underground (permafrost) is thawing out compared to long ago. I think that is why. I think the water is seeping into the ground when it thaws. Even the small lakes are drying up because the water is seeping into the ground and (the ground) is staying thawed longer. I think it's like that now even around Ahiak. (He mapped an area at the Kugyoak or Perry River delta near the mouth.) It must be starting to get like that. That is why the small lakes are drying up* (Rescan 2007).
>
> *Long ago the rivers had a lot of water and were quite high. When the rivers broke the ice going down river would be tossed around. At Katimanak (where the James and Hood Rivers meet) where Inuit fished, the rivers used to be very strong. Now these rivers don't get very high water and don't toss the river ice anymore, not like long ago. I remember the ice being tossed on top of one another. It doesn't happen like that anymore. When the rivers go in the spring the ice used to go high on the banks of the rivers. It was really thick ice. Now these rivers seem to have very little water and are weak* (Rescan 2007).

According to the TK information, less change had been seen inland compared to coastal areas.

Naonaiyaotit Traditional Knowledge Project - Hannigayok (Sabina Gold & Silver Corp. Proposed Back River Project). Results from Data Gaps Workshops, Final Report (June 2014) (KIA 2014) included observations of changes in river and ocean levels. The changes were attributed to climate change and in some cases to the land rising:

> *Now the Burnside River is open all year.*
>
> *You can see that the island used to be under water but now you can see the whole island.*
>
> *We've noticed over the years in Bathurst Inlet area it's been dry, really dry, over all those years.*
>
> *I think it's probably due to land rising also. That could be happening.*

Floods were generally observed during spring break up. Consultants noted one particular extreme flood that had happened five or six years ago (KIA 2014):

> *Some years you get a lot of snow, lots of water. Five or six years ago, during breakup the water was 10, 15 feet higher, probably due to our snow to the south. During breakup, around Bathurst, it was probably 10 to 15 feet higher. The water was higher. I guess it was like that all over. It took some cabins, moved some cabins that were in lower spots. But this was just one time that I noticed that in my lifetime. This summertime, the water level was quite low[er] than in other years. Just that one time, the water level was that high.*

1.2.2 Incorporation of TK for VEC and VSEC Selection

The results of the Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP) report (KIA 2012) were used for scoping and refining the potential VEC/VSEC list (see Volume 9, Chapter 1). The TK report presents clear maps of valued animal species, environmental components, and traditional land use activities. This information was used to determine if these valued aspects potentially interacted with the proposed Project, and if so, they were included in the initial VEC/VSEC list. This information, along with information from public consultation, consultation with regulatory agencies, and regulatory considerations, was used to determine the final VEC/VSEC list. The final list was submitted to NIRB on April 8, 2013 and posted on the NIRB ftp site.

1.2.3 Incorporation of TK for Spatial and Temporal Boundaries

The Project footprint will not overlap with any known hydrology-related TK (e.g., fish habitat TK). Based on Figure 30 in KIA (2012), fish species are distributed outside of the freshwater regional study area (see Figure 1.4-1). Therefore, no interaction is expected between project-related changes in surface water hydrology and these locations of identified fish species.

1.3 VALUED COMPONENTS

1.3.1 Potential Valued Components and Scoping

Surface water hydrology was identified as a potential VEC in the EIS guidelines (Section 7.6.1 in NIRB 2013). During the scoping process (see Volume 9, Chapter 1), surface water hydrology was identified to have potential interaction with the Project. Few or no comments were expressed through consultation with communities and TK information; however, moderate to significant comments were expressed and significant regulatory considerations were identified through consultation with regulatory agencies and regulatory considerations (see Volume 9, Chapter 1). Therefore, surface water hydrology was selected as a VEC for the EIS.

1.3.2 Valued Components Included in Assessment

Surface water hydrology, which was identified as a potential VEC (NIRB 2013), was included as a VEC in the EIS.

It is important that a VEC can actually be measured and/or monitored. Clear cause-effect pathways that are measureable must exist (i.e., there is an understood relationship between the proximal cause of an effect and its receptor) so that an accurate characterization of the Project's direct and indirect effects on a VEC can be made. In addition, adequate data and analytical tools must be available to measure potential effects.

Surface water hydrology is a broad area, and in order to be able to predict the potential effects of the Project on the VEC, more specific and quantifiable indicators need to be identified for assessment purposes.

In order to account for the aforementioned considerations and needs, two specific indicators were selected to assess the surface water hydrology VEC (Table 1.3-1). These include:

- *Streamflows*. Integrity of fish/aquatic habitat is dependent on streamflows. Reduction in flow may also affect downstream fish and fish habitat, as well as terrestrial wildlife relying on these waters.
- *Lake volumes*. Reduction in lake volumes is particularly important during the winter. Excessive amounts of water withdrawn from ice-covered waterbodies can impact fish through oxygen depletion, loss of over-wintering habitat and/or reductions in littoral habitat (DFO 2010).

Table 1.3-1. Surface Water Hydrology Valued Ecosystem Component Indicators

Indicator	Rationale for Selection
Streamflows	Essential to the integrity of fish/aquatic habitat
Lake Volumes	Essential to the integrity of fish/aquatic habitat

1.4 SPATIAL AND TEMPORAL BOUNDARIES

Assessment boundaries define the maximum limit within which the effects assessment is conducted. They encompass the areas within and times during which the Project is expected to interact with the VEC. The definition of these assessment boundaries is an integral part of the assessment process of surface water hydrology. The definition of assessment boundaries encompasses possible direct, indirect, and induced effects on the surface water hydrology.

1.4.1 Spatial Boundaries

The spatial boundary used for the assessment of the VEC hydrology included the Goose Property Potential Development Area (PDA), the Goose Property Local Study Area (LSA), and an overall Freshwater Regional Study Area (RSA). Potential effects related to the MLA are addressed in the Marine Environment Volume (Volume 7).

1.4.1.1 Local Study Area

The LSA includes areas where there exists the reasonable potential for immediate effects due to Project activities, ongoing normal activities, or to possible abnormal operating conditions (NIRB 2013). The LSA used for the assessment of effects on the VEC hydrology for the Goose Property is 365 km^2 and includes the Goose Property PDA and the boundaries of the Propeller and Big watersheds (Figures 1.4-1 and 1.4-2). The Goose Property PDA includes an area that encompasses planned infrastructure.

1.4.1.2 Regional Study Area

The RSA includes the Goose Property PDA, the LSA, and additional areas within which there is the potential for indirect or cumulative effects. The RSA used for the assessment of effects on the VEC hydrology is 6,815 km^2 and encompasses the Goose Property PDA and LSA. The RSA includes small sections of the Ellice and Back River Watersheds, and includes the upper ~80 km of the Ellice Watershed (Figure 1.4-1).

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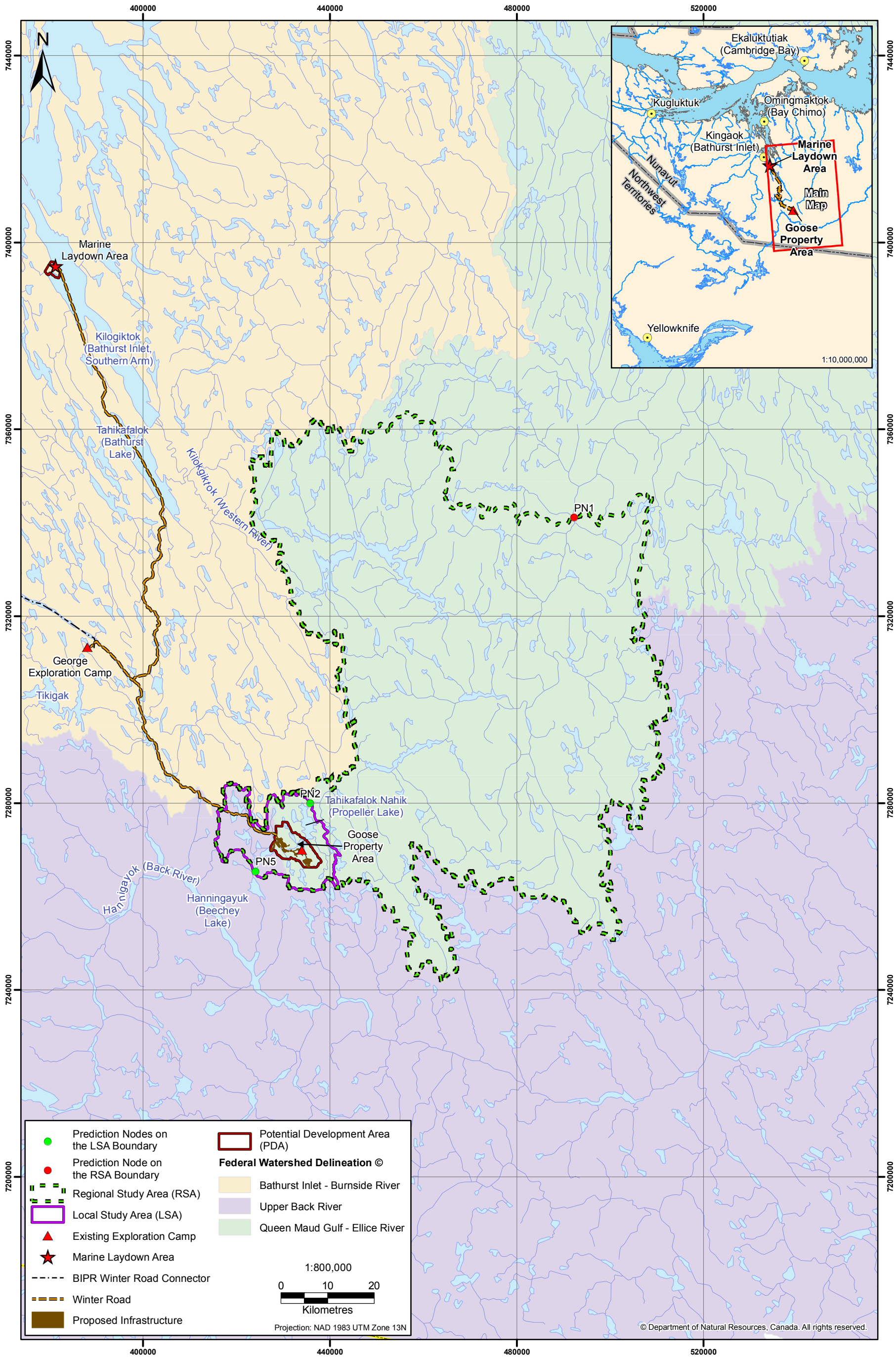
September 21 2015



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Spatial Boundaries of the Surface Water Hydrology Effects Assessment and Prediction Nodes on the Local Study Area and Regional Study Area Boundaries

Figure 1.4.1

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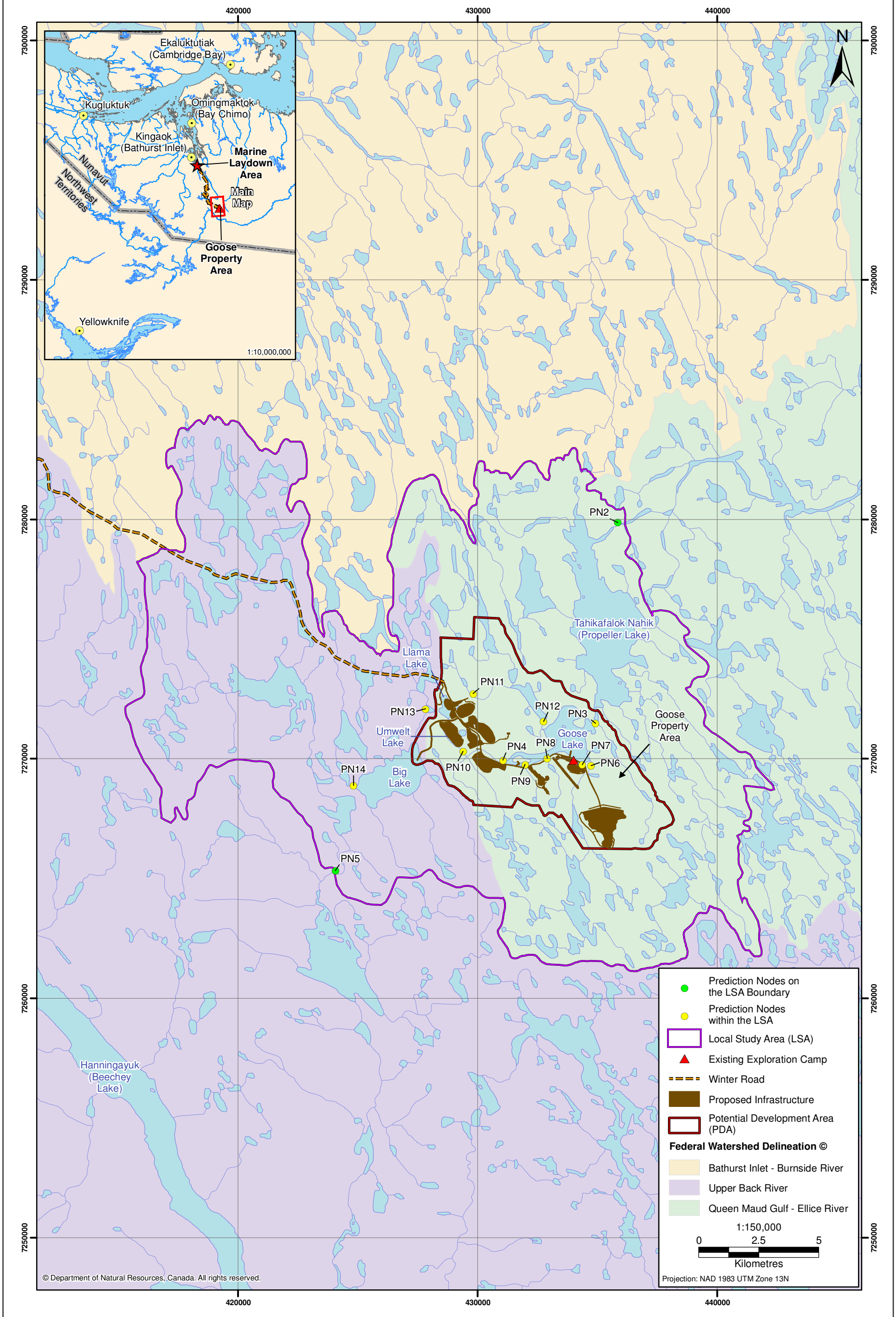

Figure 1.4.2

Surface Water Hydrology Prediction Nodes within the Local Study Area

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1.4.1.3 Streamflow Prediction Nodes

Streamflow was assessed at 14 prediction nodes. From these nodes, 11 are within the LSA, two are on the LSA boundary, and one is on the RSA boundary. The locations of streamflow prediction nodes on the LSA and RSA boundaries can be seen in Figures 1.4-1. Prediction nodes within the LSA are shown in Figure1.4-2. Likewise, the volume of five lakes within the LSA (i.e., Llama, Umwelt, Goose, Propeller, and Big lakes) were assessed (Figure 1.4-2). All streamflow prediction nodes and assessed lakes are described in Table 1.4-1.

Table 1.4-1. Streamflow Prediction Nodes and Assessed Lakes within the Local Study Area and Regional Study Area

Streamflow Prediction Node / Assessed Lake	Coordinates[1,2]		Assessment Type	Location Compared to LSA and RSA
	Easting (m)	Northing (m)		
PN01 – Ellice River	492,324	7,341,045	Streamflow	RSA Boundary
PN02 – Propeller Lake Outflow	435,853	7,279,862	Streamflow	LSA Boundary
PN03 – Goose Lake Outflow	434,920	7,271,479	Streamflow	Within LSA
PN04 – Goose Lake Inflow (West)	431,063	7,269,934	Streamflow	Within LSA
PN05 – LSA Boundary downstream of Big Lake	424,081	7,265,332	Streamflow	LSA Boundary
PN06 – TSF Outflow	434,732	7,269,708	Streamflow	Within LSA
PN07 – Rascal Outflow (East)	434,367	7,269,743	Streamflow	Within LSA
PN08 – Gander Pond Outflow	432,907	7,270,016	Streamflow	Within LSA
PN09 – Echo Lake Outflow	431,994	7,269,754	Streamflow	Within LSA
PN10 – Umwelt Lake Outflow	429,402	7,270,302	Streamflow	Within LSA
PN11 – Tributary of Giraffe Lake Inflow	429,813	7,272,716	Streamflow	Within LSA
PN12 – Giraffe Lake Outflow	432,754	7,271,545	Streamflow	Within LSA
PN13 – Mam Lake Outflow	427,834	7,272,088	Streamflow	Within LSA
PN14 – Big Lake Outflow	424,824	7,268,882	Streamflow	Within LSA
Llama Lake	n/a[3]	n/a[3]	Lake Volume	Within LSA
Umwelt Lake	n/a[3]	n/a[3]	Lake Volume	Within LSA
Goose Lake	n/a[3]	n/a[3]	Lake Volume	Within LSA
Propeller Lake	n/a[3]	n/a[3]	Lake Volume	Within LSA
Big Lake	n/a[3]	n/a[3]	Lake Volume	Within LSA

[1] *UTM, Datum NAD 83, Zone 13 W*
[2] *Coordinates based on Appendix V2-7H*
[3] *Not a node – location shown on Figure 1.4-2*

1.4.2 Temporal Boundaries

Section 7.5.2 of the EIS guidelines (NIRB 2013) requires that the following Project phases have defined temporal boundaries: construction, operation, maintenance, temporary closure, final closure, and post-closure periods, including planned exploration.

The temporal boundaries for the Project phases were defined as follows (Volume 9, Chapter1):

- Construction phase (including Mobilization): 4 years
- Operational phase: 10 years
- Reclamation and Closure phase: 8 years

- Post-Closure phase: 5 years
- other potential phases:
  - Temporary Closure: less than 2 years
  - Care and Maintenance Phase: 2 to 10 years
  - Exploration: included in Construction and Operational phases.

Water management infrastructure and activities during these Project phases are described in the following sections. All information can be found in the Water and Load Balance Report (Appendix V2-7H), the Site-Wide Water Management Report (Appendix V2-7I), and the Site Water Monitoring and Management Plan (Volume 10, Chapter 7). Specific details are provided below, but water management activities could change throughout the permitting process as well as during operations as needed.

1.4.2.1 Mobilization and Construction Phase

According to the Water and Load Balance Report, Llama Lake will be dewatered to Goose Lake during July to September of Year -3 to allow Umwelt Pit development. Prior to dewatering, diversion berms will be constructed to divert upstream runoff from entering Llama Lake. Umwelt Lake is similarly dewatered in Year -3 to allow construction of the Saline Water Pond in Year -2. Both dewatering cases will require some treatment for total suspended solids (TSS) prior to discharge. Sludge from treatment will be stored in the Umwelt Waste Rock Storage Area (WRSA).

Saline mine water, a result of the Llama underground development, will be stored in the Saline Water Pond (formerly Umwelt Lake). To minimize surface flows towards the Saline Water Pond, it will be isolated by means of diversion dams.

Early construction contact water is pumped to, and stored in the dewatered Llama Lake, which becomes the Llama Reservoir. Contact water during this time includes waste rock runoff from the Umwelt WRSA, runoff from the ore stockpile, and water collected in the Umwelt Pit. The Llama underground portal is built on a pad graded towards Llama Pit to allow runoff to flow directly into the pit. Runoff is diverted via diversion berms around the Umwelt WRSA to the Umwelt WRSA Pond to the south and to the Primary Pond to the north. Diversion berms divert contact water around the ore stockpile to the Ore Stockpile Pond. All contact water is pumped or diverted to the Primary Pond, adjacent to the Umwelt WRSA, at which point it is pumped to Llama Reservoir.

Contact water collected in the Llama Reservoir is treated at the water treatment plant during the open water season of Year -2 and Year -1. The treated water is then discharged into Goose Lake.

The Goose airstrip is constructed in Year -1, crossing the Rascal Stream East. A culvert crossing will facilitate drainage through the airstrip. A second culvert crossing will be installed at the haul road, upstream of the Rascal Stream East discharge into Goose Lake, denoted as the Goose culvert. Two additional culvert crossings along the haul road are constructed in Year -1, including the Goose Neck culvert south of Umwelt Pit, and the Echo culvert north of the Echo Pit development area.

Freshwater required for construction and dust suppression is pumped from Goose Lake. Additional freshwater is required from Big Lake for industrial and domestic water usage (Table 1.4-2).

Table 1.4-2. Proposed Water Withdrawal Volumes from Goose and Propeller Lakes

Project Phase	Goose Lake		Big Lake	
	Year-round Withdrawal (m^3/day)	Additional June to October Withdrawal (m^3/day)	Year-round Withdrawal (m^3/day)	Additional June to October Withdrawal (m^3/day)
Construction	400	n/a	350	n/a
Operations	900	400	350	n/a
Reclamation and Closure	400	n/a	350	n/a
Post-Closure	n/a	n/a	n/a	n/a

1.4.2.2 Operation Phase

According to the Water and Load Balance Report, milling begins at the Goose Process Plant, and tailings are deposited in the TSF. Freshwater required for the plant and dust suppression is pumped from Goose Lake. Additional freshwater is required from Big Lake similar to the construction phase (Table 1.4-2).

Mining of Llama Pit begins in Year 1. Contact water from the Llama WRSA Pond will be pumped to the Primary Pond, which is ultimately pumped to the TSF. Additional inflows to the Primary Pond include the Umwelt WRSA Pond, Ore Stockpile Pond, and pit inflows into Llama Pit and Umwelt Pit.

Underground development at Umwelt starts in Year 2, and mining continues in the Llama underground mine. The Umwelt underground portal will be graded towards Umwelt Pit to allow runoff to flow directly into the pit. All saline groundwater inflows are pumped to the Saline Water Pond. Umwelt Pit mining continues until Year 2, at which point the Umwelt WRSA is closed.

At the end of Year 2, tailings deposition is transitioned from the TSF into Umwelt Pit. At this stage, Umwelt Pit becomes a tailings facility (Umwelt TF). Reclaim water is pumped from the TSF until it is dewatered and reclaim is no longer possible. The Llama WRSA Pond and Umwelt WRSA Pond continue to pump water to the Primary Pond, which is pumped to the Umwelt TF.

Goose Main Pit mining begins at the end of Year 2. A diversion berm routes non-contact water flows from the Rascal Stream East around the Goose Main Pit and into the Goose culvert. The Goose culvert discharges the non-contact water into a tributary to Goose Lake (TSF Outflow East). Contact water in Goose Main Pit is collected and pumped to the Echo WRSA Pond, which is built at end of Year 2, prior to open pit mining at Echo. As part of progressive reclamation, waste rock from Goose Main is stored in the TSF, which becomes the TSF WRSA. The TSF WRSA diversion berm collects seepage and runoff from the TSF WRSA downstream of the Main TSF dam. Water collected from within the TSF WRSA diversion berms is pumped back into the TSF WRSA Pond. The TSF WRSA Pond will form along the western extents of the Main TSF Dam, and will collect surface runoff and infiltration through the waste rock, which will be pumped to the Echo WRSA Pond, and then to Umwelt TF.

At the end of Year 3, when Llama Pit mining is completed, the Llama Pit returns to being a contact water storage facility, Llama Reservoir.

Echo Pit mining begins in Year 4 and is completed in Year 5. Contact water in the pit is collected and pumped to the Echo WRSA Pond, which also collects runoff from the Echo WRSA and the Echo underground pad. Runoff from the upstream area south of the Echo Pit is collected in the Echo Diversion Pond, which is contained by the Echo Containment Dam, and the East Echo Diversion berm,

built in Year 4. Non-contact water collected in this pond is pumped to the West Echo Diversion berm, which discharges to the Echo stream and culvert, and finally Goose Lake.

Goose Main underground mining begins in Year 4, and Echo underground mining begins in Year 5. All groundwater inflows into Goose Main underground facility, as well as Llama and Umwelt underground facilities are pumped to the Saline Water Pond. Echo underground does not have groundwater inflows. The Goose Main underground pad is graded to drain into the Goose Main Pit. The Echo underground laydown pad drains towards the Echo WRSA Pond.

Llama underground development is expected to be completed at the end of Year 4. In Year 5, 325,000 m^3 of saline water is pumped from the Saline Water Pond into Llama underground mine. From Year 5 onwards, all saline groundwater into the Saline Water Pond will be pumped at a rate of 500 m^3/day to the bottom of the partially flooded Llama Reservoir to create a meromictic lake. In total, just over 1 million cubic meters of saline water will be pumped into the Llama Reservoir over the remaining life of mine.

Goose Main Pit mining continues until the beginning of Year 6, at which point the TSF WRSA is closed.

In Year 6, tailings deposition is transitioned from the Umwelt TF to Goose Main Pit, which then becomes Goose Main TF.

Contact water runoff collected in the TSF WRSA Pond, Ore Stockpile Pond, Primary Pond, and Echo, Umwelt and Llama WRSA Ponds are pumped to Goose TF. Water treatment begins in Year 6 from the Goose TF to reduce copper loading in the facility. The clean water effluent is recirculated back into Goose TF to ensure a sufficient water volume is available for reclaim.

Umwelt and Goose Main underground mining continues, until Year 9 and 10, respectively, with all groundwater inflows being pumped to the Saline Water Pond and then on to the bottom of the Llama Reservoir as described previously. Once mining is completed, all remaining saline water from the Saline Water Pond is pumped to Umwelt and Goose Main undergrounds.

1.4.2.3 Reclamation and Closure Phase

According to the Water and Load Balance Report, milling ends in the second quarter of Year 10. The Saline Water Pond is decommissioned once dewatering is complete, with all dams and berms being breached. Details regarding the closure and reclamation of the area within the Saline Water Pond are presented in the Site-Wide Water Management Report and the Mine Closure and Reclamation Plan (Volume 10, Chapter 29).

After the Saline Water Pond closure and reclamation is complete, the diversion berms around the Llama Reservoir are breached, and the reservoir is allowed to fill with non-contact water.

Diversion berms around the Umwelt WRSA and Llama WRSA will remain in place, routing runoff to the Umwelt TF and Llama Reservoir, respectively.

Freshwater withdrawal from Goose and Big Lakes will be the same in the closure phase as at the end of the construction phase (Table 1.4-2).

In Year 10, the Echo Diversion Pond, Echo WRSA Pond, and Ore Stockpile Pond are breached. The Echo Pit will be allowed to fill with non-contact water from the south, and will eventually discharge into the Echo stream and Goose Lake. Umwelt TF will be allowed to fill with water and will be breached at the northern extent of the pit in Year 10, discharging into the Umwelt Lake system.

Water treatment will continue during the open water season months only, with clean water being recirculated back into Goose TF. Runoff collected in the TSF WRSA Pond will be pumped to the Goose TF.

Llama Reservoir overtops in Year 12 under average hydrologic conditions, discharging towards the south and into the reclaimed Saline Water Pond catchment.

1.4.2.4 Post-Closure

According to the Water and Load Balance Report, in Year 18, water treatment from Goose Main TF will be decommissioned. The Goose Diversion berm, south of the Goose Main TF, will be breached, allowing the Rascal Stream East to discharge into the Goose TF. The Goose airstrip culvert will also be removed at this time, and the airstrip will be breached. The Goose Pit Lake will be allowed to fill with non-contact water, and will be breached to discharge towards the tributary to Goose Lake, along the historical Rascal Stream East alignment.

The TSF WRSA Pond is also breached in Year 18, allowing runoff to flow into Goose Main TF. At this time, all dams and berms on site will be breached, and all culvert crossings removed.

1.5 POTENTIAL PROJECT-RELATED EFFECTS ASSESSMENT

The EIS guidelines (NIRB 2013) state that the EIS shall assess the direct, indirect, short-term, and long-term effects of the Project on the biophysical and socio-economic environments, and the interactions between them, focusing on the anticipated response of the VECs and VSECs.

1.5.1 Methodology Overview

The effect assessment process comprises a number of steps that collectively assess the manner in which the Project will interact with the VEC surface water hydrology. The overall methodology follows that outlined in Volume 9, Chapter 1. The Project-related effects assessment process can be summarized as follows (these steps are explained in Sections 1.5.2 to 1.5-5):

1. Identify potential interactions between the Project and surface water hydrology, focusing on the indicators identified in Table 1.5-1, and characterize these potential effects.
2. Identify mitgation or management measures that could be taken to eliminate or reduce the potential effects.
3. Characterize any residual effects.
4. Determine the significance of predicted residual effects.

Table 1.5-1. Surface Water Hydrology VEC Indicators and Magnitude Categories

VEC/ VSEC	Indicator	Magnitude	Description
Surface Water Hydrology	Streamflows	Negligible	The change in streamflow is not detectable (i.e., less than 1% of the baseline flow)
		Low	The change in streamflow is less than 10% of the baseline flow[1]
		Moderate	The change in streamflow is between 10% and 50% of the baseline flow
		High	The change in streamflow is greater than 50% of the baseline flow

(continued)

Table 1.5-1. Surface Water Hydrology VEC Indicators and Magnitude Categories (completed)

VEC/ VSEC	Indicator	Magnitude	Description
Surface Water Hydrology *(cont'd)*	Lake volumes	Negligible	The change in lake volume is not detectable (i.e., less than 1% of the baseline volume)
		Low	The change in lake volume is less than 10% of the baseline volume[2]
		Moderate	The change in lake volume is between 10% and 50% of the baseline volume
		High	The change in lake volume is greater than 50% of the baseline volume

[1] *Established by fish habitat requirements (DFO 2013a)*
[2] *The 10% threshold is based on the DFO protocol for winter water withdrawal (DFO 2010).*

The rating criteria for significance determination are outlined in Volume 9, Chapter 1. The detailed magnitude descriptors for each indicator of the VEC surface water hydrology are provided in Table 1.5-1.

Key to characterization of the Project effects on surface water hydrology indicators is the identification of thresholds, beyond which a significant effect would be considered to occur. These thresholds or criteria for the two surface water hydrology indicators are summarized in Table 1.5-1.

Due to inherent data and modelling uncertainty in hydrologic studies, it is reasonable to account for at least a 5% error. From an environmental assessment perspective, it was conservatively assumed that any streamflow change less than 1% of the baseline flows could be an artifact of data and/or modelling uncertainty, and hence, was considered as a negligible change (Table 1.5-1). A variation of 10% from baseline conditions was assumed to be within the natural variability of the riverine system, and therefore streamflow effects are low magnitude (Table 1.5-1). This is in agreement with recommendations from the Science Advisory, Fisheries and Oceans Canada (DFO 2013a), and with recent studies in the region (Baffinland 2012). The relative values of high and low magnitude effects (i.e., 50% and 10%) were aligned with recent studies in the region (Baffinland 2012).

Similar to streamflows, a 1% threshold was assumed for negligible lake volume changes. To determine the threshold for low magnitude changes in lake volumes, DFO (2010) protocol was consulted. DFO (2010) provides guidance for winter water withdrawal limits to mitigate impact on fish through oxygen depletion, loss of overwintering habitat and/or reductions in littoral habitat (DFO 2010). In one winter season, total water withdrawal from a single waterbody is not to exceed 10% of the available water volume calculated using the appropriate maximum expected ice thickness. For the purpose of this study, the winter season is assumed to be October through May during which there is no inflow to the lake (Rescan 2012a, 2012b). The maximum ice thickness in the Project area, which is above the tree line, is 2 m (DFO 2010; Appendix V6-3B, Rescan 2012d; Appendix V6-3C, Rescan 2012e). This criterion (i.e., 10% change in volume) was used as a threshold to identify whether the magnitude of effects on lake volumes are low or moderate (Table 1.5-1). As previously mentioned, lake volumes are primarily important in the winter. Similar to streamflows, a 50% threshold was assumed to identify high magnitude effects (Table 1.5-1).

Effects of the Project components on streamflows at 14 prediction nodes and on lake volumes at five lakes within the LSA and RSA (Table 1.4-1) were estimated.

Collected data from the 2011 to 2014 hydrometric monitoring programs (see Section 1.1.2 and Rescan 2012a, 2012b, 2014a, 2014b) were used to support the effect assessment. Information collected from regional hydrometric stations was analyzed to augment the on-site data (see Section 1.1.1).

A water balance model (Appendix V2-7H) with monthly input data was used to predict the effects of the Project on streamflows during different phases of the Project (Appendix V2-7H). For lake volumes and outflows that could be affected by water withdrawal (i.e., Goose, Propeller, and Big lakes), the effects assessment was refined with daily time-steps (Appendices V6-1E and V6-1F).

1.5.2 Potential Interactions with Project and Characterization

Surface water hydrology LSA included catchment areas that overlap with the proposed Project; therefore, interaction with the Project is expected. The following Project components and activities could have potential interactions with the VEC surface water hydrology and affect streamflows and lake volumes.

Potential Interactions during Construction, Operations, Closure, and Post-Closure

- Site Water Management Activities:
  - *Water Withdrawal from Lakes:* Water withdrawals from Goose and Big lakes for domestic and industrial uses are planned during the construction, operations, and closure (Table 1.4-2). These activities could affect streamflow, and lake volumes.
  - *Water Diversions and Storages*. Water management infrastructure upstream of Goose Lake will divert contact water and a portion of non-contact water and store water in the TSF and pits. These activities could affect the streamflows, and lake volumes during all phases of the Project.
  - *Modification of Natural Drainage*. The runoff coefficient at waste rock storage areas is expected to be less than the natural baseline conditions. Reduced runoff coefficients could affect the streamflows, and lake volumes during all phases of the Project.
  - *Lake Dewatering*. Dewatering of lakes or portions of lakes will be required to construct mine pits, expand the pits, or to develop new pits during the operations. This activity could affect the streamflows and lake volumes during construction and operations.
- *Winter Ice Road Construction and Maintenance*. Use of water to annually build and maintain the winter ice roads could affect the streamflows, and lake volumes along the alignment.

A watershed-based approach was used to collectively characterize the potential effects of the site water management activities (i.e. water withdrawal from lakes, water diversions and storage, modification of natural drainage, and lake dewatering) on surface water hydrology.

1.5.3 Identification of Mitigation and Management Measures

Mitigation measures that will either eliminate or reduce the effects of the Project activities on surface water hydrology are described here.

Site Water Management (Including Water Withdrawal, Water Diversions and Storage, Modification of Natural Drainage, and Lake Dewatering)

Site water management activities will follow the required mitigation and management measures detailed in the Site Water Monitoring and Management Plan. Post FEIS, a Type A water licence application will be submitted to identify the water withdrawal limits. Water withdrawal will adhere to the following guidelines from DFO's Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut (DFO 2010):

- In one ice-covered season, total water withdrawal from a single waterbody will not exceed 10% of the available water volume calculated using the appropriate maximum expected ice thickness;

- In cases where there are multiple users withdrawing water from a single waterbody, the total combined withdrawal volume will not exceed 10% of the available water volume;
- Only waterbodies that are more than 1.5 m deeper than their corresponding maximum expected ice thickness will be considered for water withdrawal;;
- To further mitigate the impacts of water withdrawal, water will be removed from deep areas of waterbodies (>2m below the ice surface) wherever feasible, to avoid the removal of oxygenated surface waters that are critical to over-wintering fish; and
- The littoral zone will be avoided as a water withdrawal location.

Water on the project site has been classified into three types: non-contact water, contact water and saline water. Non-contact water originating from undisturbed areas will be diverted around the Project infrastructure with diversion channels, ponds and pipelines to minimize the volume of contact water on site. Contact water that has been impacted by mine workings such as pits, roads, tailings or other site infrastructure will be contained using diversion channels, ponds and tailings facilities, and will be treated prior to discharge to Goose Lake. Saline water originating from groundwater inflows to pits and underground workings will be stored in the Saline Water Pond, and subsequently pumped back underground or into the bottom of the Llama Reservoir (Appendix V2-7I).

The use of reclaim water has been incorporated into the mill design; this will reduce the amount of water required from local natural surface waters.

Locations of infrastructure, waste rock storage areas, and the TSF have been selected to be confined to the local watersheds where the deposits are located (Volume 10, Chapter 7). Therefore, potential changes to water quantity (hydrology) will be confined to the local drainage areas.

Dewatering of Llama and Umwelt lakes into Goose Lake in Year -3 will be limited to three months, i.e., July to September. Water balance modelling results show that this dewatering scheme will not cause flooding. Goose Lake outflow under average hydrologic conditions will be increased by less than 10% and 20% during the months of July and August, respectively, in Year -3 (Appendix V2-7H).

Goose Pit Diversion and Llama East Diversion will increase flow in two stream reaches: the TSF Outflow (PN06) and a tributary of Giraffe Lake (PN11). Increased flow within these reaches will be staged over a period of more than one year (Volume 10, Chapter 7). During this period conveyance capacity of these reaches will be monitored and re-assessed. Depending on results of such an assessment and monitoring program, additional flood mitigation measures (e.g., channelization and/or berming) may be required (Volume 10, Chapter 7).

<u>Winter ice road Construction and Maintenance</u>

- Winter ice road construction and maintenance will follow the required mitigation and management measures (Road Management Plan, Volume 10, Chapter 14). Following DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013b) will be considered during road construction and maintenance:
- Work in water will be minimized and timed to respect timing windows to protect different life stages of fish;
- Instream work will be conducted during periods of low flow;
- Activities and works in waterbodies will be designed and planned such that loss or disturbance to aquatic habitat is minimized and sensitive spawning habitats are avoided;

- Approaches to the waterbody will be designed and constructed such that they are perpendicular to the watercourse to minimize loss or disturbance to riparian vegetation;
- Avoid building structures on meander bends, braided streams, alluvial fans, active floodplains or any other area that is inherently unstable and may result in erosion and scouring of the stream bed or the built structures;
- All instream activities will be undertaken in isolation of open or flowing water to maintain the natural flow of water downstream and avoid introducing sediment into the watercourse;
- Effective erosion and sediment control measures will be installed before starting work to prevent sediment from entering the waterbody;
- Measures will be in place for managing water flowing onto the site, as well as water being pumped/diverted from the site such that sediment is filtered out prior to the water entering a waterbody;
- Erosion and sediment control measures and structures will be regularly inspected and maintained during the course of construction;
- Erosion and sediment control measures and structures will be repaired if damage occurs;
- Clearing of riparian vegetation will be kept to a minimum;
- Minimize the removal of organic debris, rocks, sand or other materials from the banks, the shoreline or the bed of the waterbody below the ordinary high water mark;
- Shoreline or banks disturbed by any activity associated with the project will be immediately stabilized to prevent erosion and/or sedimentation;
- Bed and banks of the waterbody will be restored to their original contour and gradient; if the original gradient cannot be restored due to instability, a stable gradient that does not obstruct fish passage should be restored;
- If replacement rock reinforcement/armouring is required to stabilize eroding or exposed areas, then appropriately-sized, clean rock will be used, and rock will be installed at a similar slope to maintain a uniform bank/shoreline and natural stream/shoreline alignment;
- All construction materials will be removed from site upon project completion;
- In-water activities, or associated in-water structures, will not interfere with fish passage, constrict the channel width, or reduce flows.
- Whenever possible, machinery will be operated on land above the high water mark, on ice, or from a floating barge in a manner that minimizes disturbance to the banks and bed of the waterbody;
- Machinery fording of the watercourse will be limited to a one-time event (i.e., over and back), and only if no alternative crossing method is available. If repeated crossings of the watercourse are required, a temporary crossing structure will be constructed;
- Temporary crossing structures or other practices to cross streams or waterbodies with steep and highly erodible (e.g., dominated by organic materials and silts) banks and beds will be used. For fording equipment without a temporary crossing structure, stream bank and bed protection methods (e.g., swamp mats, pads) will be used if minor rutting is likely to occur during fording.

Water use for road construction and maintenance will be in conformance with the guidelines (DFO 2013b) summarized above, and best management practices provided in the Road Management Plan.

The mitigation measures are expected to eliminate all potential effects of road construction and maintenance on surface water hydrology.

1.5.4 Characterization of Residual Effects

Mitigation measures will eliminate the effects of winter ice road construction and maintenance on streamflows and lake volumes as the road construction and maintenance activity will not include any water removal or stream alteration beyond those specified in the guidelines and best management practices (Section 1.5.3).

Analyses undertaken to support this assessment (Appendices V2-7H, V6-1E, and V6-1F) show that after consideration of the mitigation and management measures, the site water management activities (including water withdrawal, water diversions and storage, modification of natural drainage, and lake dewatering) will have some residual effects on streamflows and on lake volumes. The mitigation measures will:

- reduce the effects on streamflows (potential residual effects to be characterized); and
- reduce the effects on lake volumes (potential residual effects to be characterized).

The potential residual effects on streamflows and lake volumes are characterized in the following section.

A standard ecological risk assessment framework with three tiers of detail and data requirements (Volume 9 Chapter 1) was used to assess the residual effects on surface water hydrology, after implementation of the proposed mitigation measures (Section 1.5.3). These tiers are as follows:

- **Tier 1:** qualitative (expert opinion, including traditional and local knowledge, literature review, and existing site information, if available);
- **Tier 2:** semi-quantitative (measured site-specific data and existing site information); and
- **Tier 3:** quantitative (recent field surveys, detailed quantitative methods, e.g., predictive modelling).

For surface water quantity, a Tier 3 assessment was employed. That is:

- recent field surveys and data collected during the hydrometric monitoring program (Rescan 2012a, 2012b, 2014a, 2014b) were used to characterize the baseline conditions;
- statistical modelling was performed to estimate regional hydrologic indices using data collected from regional hydrometric stations;
- where data were lacking (e.g., data collected through the baseline hydrometric program were not considered as long-term data), professional judgment and other sources of data (e.g., regional hydrologic analysis) were used to determine the potential effects; and
- the Project components and activities (e.g., water withdrawal, diversion, and storage) interact with each other, and with surface water hydrology. A watershed-based approach was used to systematically characterize the potential effects of Project components and activities in Section 1.5.2 that were not eliminated by the mitigation measures detailed in Section 1.5.3. The effects assessment was conducted using two assessment tools:
    1. A water balance model with monthly input data (Appendix V2-7H) was developed with GoldSim, a dynamic simulation software package, to predict the effects of the Project on

streamflows at prediction nodes within the LSA and RSA (Table 1.4-1) during different phases of the Project. Long-term predictions for monthly streamflow in the absence of, and resulting from, the Project, are presented in Appendix V2-7H. Monthly flows without the Project represent a projection of baseline streamflow in the future, i.e., if the Project is not developed. Baseline and Project-affected streamflows are predicted for average hydrological conditions, as well as for 1-in-20-year dry and 1-in-20-year-wet conditions (Appendix V2-7H).

2. Winter water withdrawal from Goose and Big lakes can delay the onset of lake outflow at Goose, Propeller, and Big lakes. This delay, which is a fraction of a month, cannot be captured by a model with monthly input data and time-step. Likewise, baseline flows during the month of May occur only during a few days. Therefore, effects of the aforementioned delay on lake outflows in May cannot be addressed by a model with monthly input data either. A spreadsheet model with daily input data and time-step was developed and used to refine effects assessment, i.e., flow and volume reduction, for Goose, Propeller, and Big lakes (Appendices V6-1E and V6-1F). The daily-based spreadsheet incorporated conservative assumptions to estimate reduction in streamflow and lake volume. For example, it was assumed that no water from any disturbed catchments upstream of Goose Lake will flow into the lake.

Results of the GoldSim-based water balance model, i.e., effects on monthly streamflows, are summarized in Tables 1.5-2 and 1.5-3. Likewise, results of the spreadsheet modelling with daily time-step are summarized in Table 1.5-4 (Details are available in Appendices V6-1E and V6-1F). Residual effects on streamflows and lake volumes, Tables 1.5-2 to 1.5-4, are characterized in the following sections. As previously mentioned, the daily-based spreadsheet incorporated conservative assumptions for flow reduction, and therefore predicted flow reductions in Table 1.5-4 are greater than those in Table 1.5-2.

1.5.4.1 Potential Effects within the LSA

Site water management activities (including water withdrawal from lakes, diversions and storages, modification of natural drainage, and lake dewatering) alter drainage patterns within the LSA. Streamflow at some headwaters of the LSA within the PDA may cease (e.g., PN07; Table 1.5-2), notably decrease (e.g., up to 58% and 82% flow reduction at PN09 and PN10; Table 1.5-2), or considerably increase (e.g., up to 530% and 146% flow increase at PN06 and PN11; Table 1.5-3). Llama and Umwelt lakes within these headwater catchments will be dewatered (100% volume reduction; Table 1.5-4).

Effects of increased flow at PN06 and PN11 will be mitigated by monitoring the flow and re-assessment of their conveyance capacity during the period when the flow in these streams will gradually increase from baseline conditions (Volume 10, Chapter 7).

Streamflow reduction in larger watersheds within the LSA is less notable than flow reduction in headwater catchments. Streamflow reductions at Goose lake outflow (PN03) and Big Lake outflow (PN14) are less than 20% and 5%, respectively (Tables 1.5-2 to 1.5-4). Likewise, volume of Goose and Big lakes are reduced by 4% and 2%, respectively, due to winter water withdrawal.

1.5.4.2 Potential Effects on Streams at the LSA Boundary

Effects of the Project on streamflow at the LSA boundary are low. Streamflow alteration at these locations is less than 10% of baseline flows (Tables 1.5-2 to 1.5-4).

1.5.4.3 Potential Effects on Streams at the RSA Boundary

Streamflow alteration at the RSA boundary (PN01) is negligible (i.e., less than 1%; Tables 1.5-2 and 1.5-3).

Table 1.5-2. Maximum Flow Reduction due to the Project during all Phases of the Project

Month	Hydrologic Condition	Location											
		PN01 (RSA boundary)	PN02 (LSA boundary)	PN03 (within LSA)	PN04 (within LSA)	PN06 (within LSA)	PN07 (within LSA)	PN08 (within LSA)	PN09 (within LSA)	PN10 (within LSA)	PN11 (within LSA)	PN12 (within LSA)	PN13 (within LSA)
Jan	Dry[1]	-	-	-	-	-	-	-	-	-	-	-	-
	Average[2]	-	-	-	-	-	-	-	-	-	-	-	-
	Wet[3]	-	-	-	-	-	-	-	-	-	-	-	-
Feb	Dry[1]	-	-	-	-	-	-	-	-	-	-	-	-
	Average[2]	-	-	-	-	-	-	-	-	-	-	-	-
	Wet[3]	-	-	-	-	-	-	-	-	-	-	-	-
Mar	Dry[1]	-	-	-	-	-	-	-	-	-	-	-	-
	Average[2]	-	-	-	-	-	-	-	-	-	-	-	-
	Wet[3]	-	-	-	-	-	-	-	-	-	-	-	-
Apr	Dry[1]	-	-	-	-	-	-	-	-	-	-	-	-
	Average[2]	-	-	-	-	-	-	-	-	-	-	-	-
	Wet[3]	-	-	-	-	-	-	-	-	-	-	-	-
May	Dry[1]	n/a[4]	n/a[4]	n/a[4]	34%	-	100%	-	58%	82%	-	-	-
	Average[2]	n/a[4]	n/a[4]	n/a[4]	34%	-	100%	-	58%	82%	-	-	-
	Wet[3]	n/a[4]	n/a[4]	n/a[4]	34%	-	100%	-	58%	82%	-	-	-
Jun	Dry[1]	<1%	5%	12%	34%	-	100%	-	58%	82%	-	-	-
	Average[2]	<1%	5%	11%	34%	-	100%	-	58%	82%	-	-	-
	Wet[3]	<1%	5%	11%	34%	-	100%	-	58%	82%	-	-	-
Jul	Dry[1]	<1%	6%	12%	34%	-	100%	-	47%	82%	-	-	-
	Average[2]	<1%	5%	11%	34%	-	100%	-	47%	82%	-	-	-
	Wet[3]	<1%	5%	11%	34%	-	100%	-	47%	82%	-	-	-
Aug	Dry[1]	<1%	7%	16%	34%	-	100%	-	47%	82%	-	-	-
	Average[2]	<1%	6%	12%	34%	-	100%	-	47%	82%	-	-	-
	Wet[3]	<1%	5%	11%	34%	-	100%	-	47%	82%	-	-	-

(continued)

Table 1.5-2. Maximum Flow Reduction due to the Project during all Phases of the Project (completed)

Month	Hydrologic Condition	Location											
		PN01 (RSA boundary)	PN02 (LSA boundary)	PN03 (within LSA)	PN04 (within LSA)	PN06 (within LSA)	PN07 (within LSA)	PN08 (within LSA)	PN09 (within LSA)	PN10 (within LSA)	PN11 (within LSA)	PN12 (within LSA)	PN13 (within LSA)
Sep	Dry[1]	<1%	7%	15%	34%	-	100%	-	47%	82%	-	-	-
	Average[2]	<1%	5%	12%	34%	-	100%	-	47%	82%	-	-	-
	Wet[3]	<1%	5%	11%	34%	-	100%	-	47%	82%	-	-	-
Oct	Dry[1]	<1%	8%	15%	34%	-	100%	-	47%	82%	-	-	-
	Average[2]	<1%	6%	12%	34%	-	100%	-	47%	82%	-	-	-
	Wet[3]	<1%	5%	11%	34%	-	100%	-	47%	82%	-	-	-
Nov	Dry[1]	-	-	-	-	-	-	-	-	-	-	-	-
	Average[2]	-	-	-	-	-	-	-	-	-	-	-	-
	Wet[3]	-	-	-	-	-	-	-	-	-	-	-	-
Dec	Dry[1]	-	-	-	-	-	-	-	-	-	-	-	-
	Average[2]	-	-	-	-	-	-	-	-	-	-	-	-
	Wet[3]	-	-	-	-	-	-	-	-	-	-	-	-

[1] Based on the 5th percentile results of Monte Carlo simulation with 100 realization (Appendix V2-7H). Represent 1-in-20-year dry conditions.
[2] Based on the 50th percentile results of Monte Carlo simulation with 100 realization (Appendix V2-7H). Represent average precipitation and runoff conditions.
[3] Based on the 95th percentile results of Monte Carlo simulation with 100 realization (Appendix V2-7H). Represent 1-in-20-year wet conditions.
[4] Onset of flow occurs in late-May and streamflow is affected by water withdrawal from Goose Lake. Therefore, monthly-averaged simulated flow for the month of May would not meaningfully show flow reductions. A separate daily-based modelling approach was used to predict the effects of the Project on delay in onset of flow.
Note: Prediction Nodes PN05 and PN14 were not included in the GoldSim water balance model. These assessment nodes were considered in the daily-based modelling approach.

Table 1.5-3. Maximum Flow Increase due to the Project during all Phases of the Project

Month	Hydrologic Condition	Location											
		PN01 (RSA boundary)	PN02 (LSA boundary)	PN03 (within LSA)	PN04 (within LSA)	PN06 (within LSA)	PN07 (within LSA)	PN08 (within LSA)	PN09 (within LSA)	PN10 (within LSA)	PN11 (within LSA)	PN12 (within LSA)	PN13 (within LSA)
Jan	Dry[1]	-	-	-	-	-	-	-	-	-	-	-	-
	Average[2]	-	-	-	-	-	-	-	-	-	-	-	-
	Wet[3]	-	-	-	-	-	-	-	-	-	-	-	-
Feb	Dry[1]	-	-	-	-	-	-	-	-	-	-	-	-
	Average[2]	-	-	-	-	-	-	-	-	-	-	-	-
	Wet[3]	-	-	-	-	-	-	-	-	-	-	-	-
Mar	Dry[1]	-	-	-	-	-	-	-	-	-	-	-	-
	Average[2]	-	-	-	-	-	-	-	-	-	-	-	-
	Wet[3]	-	-	-	-	-	-	-	-	-	-	-	-
Apr	Dry[1]	-	-	-	-	-	-	-	-	-	-	-	-
	Average[2]	-	-	-	-	-	-	-	-	-	-	-	-
	Wet[3]	-	-	-	-	-	-	-	-	-	-	-	-
May	Dry[1]	<1%	3%	6%	-	490%	-	-	-	-	146%	11%	28%
	Average[2]	<1%	2%	5%	-	503%	-	-	-	-	146%	11%	28%
	Wet[3]	<1%	2%	5%	-	509%	-	-	-	5%	146%	11%	28%
Jun	Dry[1]	<1%	3%	7%	1%	519%	-	-	<1%	15%	146%	11%	28%
	Average[2]	<1%	3%	7%	1%	520%	-	-	<1%	15%	146%	11%	28%
	Wet[3]	<1%	3%	7%	1%	520%	-	-	<1%	16%	146%	11%	28%
Jul	Dry[1]	<1%	8%	16%	-	506%	-	-	-	2%	146%	11%	28%
	Average[2]	<1%	3%	6%	-	512%	-	-	-	8%	146%	11%	28%
	Wet[3]	<1%	3%	6%	-	515%	-	-	-	11%	146%	11%	28%
Aug	Dry[1]	<1%	17%	36%	-	501%	-	-	-	-	146%	11%	28%
	Average[2]	<1%	8%	18%	-	520%	-	-	-	5%	146%	11%	28%
	Wet[3]	<1%	5%	11%	-	513%	-	-	-	9%	146%	11%	28%

(continued)

Table 1.5-3. Maximum Flow Increase due to the Project during all Phases of the Project (completed)

Month	Hydrologic Condition	Location											
		PN01 (RSA boundary)	PN02 (LSA boundary)	PN03 (within LSA)	PN04 (within LSA)	PN06 (within LSA)	PN07 (within LSA)	PN08 (within LSA)	PN09 (within LSA)	PN10 (within LSA)	PN11 (within LSA)	PN12 (within LSA)	PN13 (within LSA)
Sep	Dry[1]	<1%	3%	6%	1%	519%	-	-	<1%	15%	146%	11%	28%
	Average[2]	<1%	3%	7%	1%	530%	-	-	<1%	15%	146%	11%	28%
	Wet[3]	<1%	3%	7%	1%	520%	-	-	<1%	16%	146%	11%	28%
Oct	Dry[1]	<1%	4%	6%	5%	531%	-	-	7%	26%	146%	11%	28%
	Average[2]	<1%	3%	6%	2%	524%	-	-	3%	19%	146%	11%	28%
	Wet[3]	<1%	3%	6%	2%	523%	-	-	2%	18%	146%	11%	28%
Nov	Dry[1]	-	-	-	-	-	-	-	-	-	-	-	-
	Average[2]	-	-	-	-	-	-	-	-	-	-	-	-
	Wet[3]	-	-	-	-	-	-	-	-	-	-	-	-
Dec	Dry[1]	-	-	-	-	-	-	-	-	-	-	-	-
	Average[2]	-	-	-	-	-	-	-	-	-	-	-	-
	Wet[3]	-	-	-	-	-	-	-	-	-	-	-	-

[1] Based on the 5th percentile results of Monte Carlo simulation with 100 realization (Appendix V2-7H). Represent 1-in-20-year dry conditions.
[2] Based on the 50th percentile results of Monte Carlo simulation with 100 realization (Appendix V2-7H). Represent average precipitation and runoff conditions.
[3] Based on the 95th percentile results of Monte Carlo simulation with 100 realization (Appendix V2-7H). Represent 1-in-20-year wet conditions.
Note: Prediction Nodes PN05 and PN14 were not included in the GoldSim water balance model. These assessment nodes were considered in the daily-based modelling approach.

Table 1.5-4. Summary of Predicted Effects on Lake Volumes and Streamflows at Locations Affected by Water Withdrawal from Goose and Big Lakes

Location (Lake or Streamflow Prediction Node)	Hydrologic Condition	Reduction in Annual Flow (% of Baseline Flows)	Delay in Onset of Lake Outflow or Streamflow (days)[1,2]	Accelerated Ceasing of Lake Outflow or Streamflow in Fall (days)[1,2]	Maximum Winter Withdrawal (% of Under-ice Volume)
Llama Lake (within LSA)	Dry[3]	100%	n/q[5]	n/q[5]	100%
	Average[4]	100%	n/q[5]	n/q[5]	100%
Unwelt Lake (within LSA)	Dry[3]	100%	n/q[5]	n/q[5]	100%
	Average[4]	100%	n/q[5]	n/q[5]	100%
Goose Lake and PN03 (within LSA)	Dry[3]	17%	6	4	4%
	Average[4]	13%	5	2	4%
Propeller Lake and PN02 (LSA boundary)	Dry[3]	8%	3	1	0%
	Average[4]	6%	1	1	0%
Big Lake and PN14 (within LSA)	Dry[3]	5%	6	1	2%
	Average[4]	2%	5	1	2%
PN05 (LSA Boundary)	Dry[3]	1%	2	0	n/a[6]
	Average[4]	< 1%	0	0	n/a[6]

[1] Difference between baseline and project-affected conditions. Details available in Appendices V6-1E and V6-1F.
[2] Flows less than a minimum useful flow threshold (i.e., 30% of baseline mean annual discharge) were considered zero (Appendices V6-1E and V6-1F).
[3] Based on the 5th percentile results of Monte Carlo simulation with 100 realization (Appendix V2-7H). Represent 1-in-20-year dry conditions.
[4] Based on the 50th percentile results of Monte Carlo simulation with 100 realization (Appendix V2-7H). Represent average precipitation and runoff conditions.
[5] This lake gets fully dewatered and therefore annual outflow, as well as dates for onset and ceasing of lake outflow, cannot be quantified.
[6] Not a lake

1.5.5 Significance of Residual Effects

The residual effects identified in Section 1.5.4 were characterized using the attributes presented in Volume 9, Chapter 1, and the magnitude criteria provided in Table 1.5-1. The determination of significance was based on Table 1.2-6 in Volume 9, Chapter 1. The attributes used to characterize residual effects included direction, magnitude, extent, frequency, duration, reversibility, certainty, and probability.

The assessment of residual effects on surface water hydrology and their significance are explained here and summarized in Table 1.5-5. The significance of a residual effect can be rated as Positive, Not Significant, or Significant (Table 1.5-5). For example, residual effects receive a rating of 'Not Significant' if typically they are expected to be one of the following: negligible or low magnitude, confined to LSA, moderate to high reversibility, or short duration (Volume 9). However, given the qualitative nature of the assessment, these ratings are evaluated for biophysical VECs on a case by case basis.

Direction

Only the negative effects of the Project, i.e., streamflow and lake volume reduction, are discussed in this assessment (Tables 1.5-2 to 1.5-4T).

Table 1.5-5. Summary of Residual Effects on Surface Water Hydrology and Overall Significance Rating

	Significance Criteria			Likelihood of Occurrence			Overall Significance Rating		
Description of Residual Effects	**Direction** (*positive, neutral, negative*)	**Magnitude** (*low, moderate, high*)	**Duration** (*short, medium, long*)	**Frequency** (*once, sporadic, continuous*)	**Geographic Extent** (*footprint, local, regional, beyond regional*)	**Reversibility** (*reversible, reversible with effort, irreversible*)	**Probability** (*unlikely, moderate, likely*)	**Confidence** (*low, medium, high*)	**Not Significant** *(N)*; **Significant** *(S)*; **Positive** *(P)*
Change in streamflows	Negative	Low*	Medium	Continuous	Local	Reversible	Likely	High	N
Change in lake volumes	Negative	Low*	Medium	Continuous	Project Footprint	Reversible	Likely	High	N

** Low magnitude at the boundary of the LSA*

Magnitude

- Streamflows: The magnitude of effects within the LSA, on the LSA boundary, and on the RSA boundary is high, low, and negligible, respectively, based on Table 1.5-1. The magnitude of effects varies within the LSA. Effects with high magnitude are predicted within the PDA at headwater catchments of the LSA where streamflows will cease (PN07) or be reduced by more than 50% of baseline flows (PN09 and PN10). On the LSA boundary, the residual effect on streamflow is low, i.e., less than 10% of baseline flows. At the RSA scale, the effect on streamflow is less than 1% (i.e. negligible).

  In establishing an overall determination of magnitude for effects of the Project on streamflows within the LSA, a watershed approach was adopted. That is, although the magnitude of effects were moderate to high at the upstream assessment points within the LSA, the effects were of low magnitudes at the downstream assessment points. At the boundaries of the LSA (i.e., PN02 and PN05), the magnitude of the effects was low. Therefore, the overall magnitude was estimated to be low.

- Lake volumes: effects of the Project on lake volumes vary from high magnitude (i.e., completely dewatered) at Llama and Umwelt lakes to low magnitude (less than the 10% threshold in Table 1.5-1) at Goose and Big lakes. The same watershed approach as the one explained for streamflows, above, was adopted for lake volumes. That is, although the magnitude of effects on lake volumes were high at the headwaters of the LSA (i.e., within the PDA), the effects were of low and negligible magnitude at Goose and Propeller lakes). Therefore, the overall magnitude was estimated to be low.

Duration

Project-related activities that potentially interact with surface water hydrology (Section 1.5.2) and will not be completely eliminated by mitigation measures (Section 1.5.3) occur during mobilization and construction, operations, and closure. Dewatering Llama and Umwelt lakes will modify natural drainage and runoff coefficients permanently. However, such an effect is limited to these headwater catchments. Therefore, at the LSA scale, a medium duration is considered for effects on streamflows and lake volumes.

Frequency

Project-related activities that potentially interact with surface water hydrology (Section 1.5.2) and will not be completely eliminated by mitigation measures (Section 1.5.3), continuously affect the watershed. Therefore, the effects on streamflows and lake volumes are continuous.

Geographic Extent

- Streamflows: the reduction in streamflows in excess of the 10% threshold for low magnitude effects (Table 1.5-1) would be confined to within the LSA.
- Lake volumes: the reduction in lake volumes is estimated to be greater than the 10% threshold for low magnitude effects (Table 1.5-1) only within the Project Footprint (i.e., only at Llama and Umwelt lakes).

Reversibility

All Project components were assumed to be left in a physically and environmentally stable condition at post-closure. Therefore, effects are expected to be fully reversible.

Overall Significance Rating

Given the magnitude, duration, frequency, geographic extent, and reversibility of the effects, as explained above and summarised in Table 1.5-5, effects of the Project on streamflows and lake volumes were rated as **Not Significant**.

Given the quality of the baseline data and the quantitative assessment method (see Section 1.5.1 for details), the effects on streamflows and lake volumes are likely to occur, and the assessment is considered to be undertaken with a high level of certainty.

1.6 POTENTIAL CUMULATIVE EFFECTS ASSESSMENT

The potential for cumulative effects arises when residual effects of the Project affect (i.e., overlap and interact with) the same resource/receptor that is affected by the residual effects of other past, existing or reasonably foreseeable projects or activities. When residual effects were identified for the Project, the Cumulative Effects Assessment (CEA) followed the process detailed in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1) and is comprised of the following steps:

1. Undertaking a scoping exercise to identify the potential for Project-related residual effects to interact with residual effects from other human activities and projects within a specified CEA boundary. For freshwater water quality, the boundary is the freshwater environment RSA.
2. Identifying and predicting potential cumulative effects that may occur and implementing additional mitigation measures to minimize the potential for cumulative effects where possible.
3. Identifying cumulative residual effects after the implementation of mitigation measures.
4. Determining the significance of any cumulative residual effects.

The cumulative residual effects were analyzed using the same criteria as the Project-related effects assessment (Section 4.5.1): direction, magnitude, duration, frequency, geographic extent, reversibility, probability of occurrence, and confidence in the analyses and conclusions. The magnitude of potential cumulative effects applied the same criteria as the Project-related effects assessment (Table 4.5-1). Using a weight of evidence and relative ranking approach, combined with best professional judgement, the cumulative residual effect was characterized as either significant (S), not significant (N), or positive (P) in the same manner as the Project-related effects assessment (Table 4.5-2).

Past, existing, and reasonably foreseeable major projects with potential residual effects that occur within the RSA for the VEC freshwater water quality were considered and are listed in Table 3.4-1 in the Effects Assessment Methodology (Volume 9, Chapter 1). The list includes projects within Nunavut and the Northwest Territories to consider the outermost spatial boundary, and reflects a comprehensive evaluation of potential interactions. As per the EIS guidelines (NIRB 2013), the list of projects considered conforms to the requirement to consider a larger spatial boundary for the CEA as well as a longer temporal scale.

The expected timing and duration of Project-related residual effects was compared with that of residual effects from other past, existing, and future human activities to identify temporal overlap. As identified in the EIS guidelines (NIRB 2013), a longer timeline than the development and operations phases of the Project was considered.

1.6.1 Potential Interactions of Residual Effects with Other Projects

The following residual Projects effects on hydrology were identified:

- streamflows, and
- lake volumes.

The spatial boundary of the CEA was the RSA (see Section 1.4.1). The temporal boundary for the CEA was any past, present, or reasonably foreseeable future projects (see list of projects in Volume 9, Chapter 1).

No past, present, or foreseeable projects that could potentially interact with the residual effects of the Back River Project lie within the Back River Project RSA. Given that the Project residual effects were confined to the LSA, there are no expected cumulative effects on the VEC hydrology.

1.7 TRANSBOUNDARY EFFECTS

As outlined in Section 4 of Volume 9 (Chapter 1), the potential for transboundary effects of the Project were determined based on whether residual Project effects could operate cumulatively with effects of projects in other jurisdictions. Transboundary effects can occur when VECs or the zone of influence of a project moves across jurisdictional borders external to the Nunavut Settlement Area (NSA). The non-significant Project residual effects for hydrology are expected to remain confined to the LSA, which lies entirely within the Nunavut Settlement Area. As the Project residual effects were confined to Nunavut, there was no potential for transboundary effects.

1.8 MITIGATION AND ADAPTIVE MANAGEMENT

Mitigation and management measures to eliminate or reduce effects of the Project on surface water hydrology (see Section 1.5.3 for details) are considered in the Site Water Monitoring and Management Plan, Road Management Plan, Aquatic Effects Management Plan (Volume 10, Chapter 19), and Mine Closure and Reclamation Plan. Key mitigation approaches, applicable to surface water hydrology, along with mitigation measure proposed for each approach, are provided in Table 1.8-1.

Table 1.8-1. Surface Water Hydrology Mitigation and Management Measures

Mitigation Category	Mitigation Measures
Mitigation by Project Design	
	Water management infrastructure, including water withdrawal and diversion components, waste rock storage areas, and the TSF has been confined to the LSA, thereby confining potential changes to water quantity (hydrology) to the LSA.
	Non-contact water originating from undisturbed areas will be diverted around the Project infrastructure with diversion channels, ponds and pipelines to minimize the volume of contact water on site. Contact water that has been impacted by mine workings such as pits, roads, tailings or other site infrastructure will be contained using diversion channels, ponds and tailings facilities, and will be treated prior to discharge to Goose Lake. Saline water originating from groundwater inflows to pits and underground workings will be stored in the Saline Water Pond, and subsequently pumped back underground or into the bottom of the Llama Reservoir.
	Design of infrastructure minimizes the footprint of infrastructure in order to minimize changes to local drainage patterns.
	The mill has been designed to use reclaim water from the TSF, thereby reducing the amount of water required from local natural surface waters.

(continued)

Table 1.8-1. Surface Water Hydrology Mitigation and Management Measures (completed)

Mitigation Category	Mitigation Measures
2. Regulatory Requirements	
	Water withdrawal will comply with a future Type A Water Licence and follow DFO's Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories (DFO 2010).
3. Best Management Practices	
	The dewatering of Llama Lake will follow an approved dewatering plan, whereby water will not be transferred to surface waters unless it meets the specifications of the Plan. The Plan will outline the allowable volume of Llama Lake water that can be transferred to local surface waters relative to the baseline conditions of local surface waters (e.g., as a percentage of background flow for a stream). Water metering and water conservation measures will be implemented where possible. BMP guidelines that are relevant to Project road and crossing construction activities are taken from DFO's Measures to Avoid Causing Harm (DFO 2013b).
4. Adaptive Management	
	The need for any corrective actions to on-site management or installation of additional control measures will be determined on a case-by-case basis. Indications of the need for corrective actions and additional control measures may include: • if results from the Surveillance Network monitoring program (which will be outlined in the future Type A Water Licence) show non-compliance; • if results of monitoring the TSF Outflow and PN11 tributary indicate that additional flood mitigation measures (e.g., channelization and/or berming) are required; or • if results from the Aquatic Effects Monitoring Program, which will monitor the receiving environment around the mine infrastructure and activities, or the Fish Offsetting Monitoring Program, show adverse effects to fish or fish habitat due to water quantity issues.
5. Monitoring	
	There will be a Site Surveillance Network Monitoring Program that will be outlined in the future Type A Water Licence. This Program will consist of all of the site compliance monitoring that will be required for managing/moving and releasing water from all potential containment areas. Fish and Fish Habitat, which could be directly influenced by water levels and quantities, will be monitored as part of the Aquatic Effects Monitoring Program and the Fish Offsetting Monitoring Program.

1.9 IMPACT STATEMENT

Two potential effects were identified for the VEC hydrology as a result of the Project: altering streamflows, and altering lake volumes. Potential effects were characterized using key indicators and quantitative thresholds as well as experience from other Northern projects and best professional judgement. Mitigation and management measures were described and their effectiveness was evaluated in the process of identifying residual effects. Two residual effects were identified after mitigation and management:

- Alteration of streamflows; and
- Alteration of lake volumes.

Using quantitative methods, each of these residual effects were rated with a *low* magnitude at the boundary of the LSA and ultimately were rated as **Not Significant** because of the limited spatial extent of residual effects, and the implementation of the mitigation and management measures outlined in

the Site Water Monitoring and Management Plan and other management plans presented in Volume 10. All residual effects to hydrology were predicted to be restricted to the LSA. The freshwater environment was predicted to be resilient to the predicted residual Project effects.

No cumulative effects were predicted to occur as no interactions between other projects and the Back River Project hydrology residual effects were expected because the effects were confined to the LSA. Similarly, as the Project residual effects were confined to Nunavut, there was no potential for transboundary effects.

2. Groundwater

2. Groundwater

2.1 EXISTING ENVIRONMENT AND BASELINE INFORMATION

2.1.1 Regional Setting

2.1.1.1 Geologic Context

The majority of the Back River Project (the Project) area is underlain by clastic metasedimentary rock (turbidites including greywacke and mudstone) of the Slave Province. Sedimentary rocks of the Bear Province (conglomerates, sandstones, siltstones, breccias) underlying the Marine Laydown Area (MLA) and northern reaches of the winter ice road alignment. A complete description of Project bedrock geology is provided in Volume 5 Chapter 1: Geology.

Overburden materials are characteristic of a post-glacial environment. At the regional scale morainal sediments are dominant, covering nearly half the landscape. Other sediments commonly found include glaciofluvials, organics, marine sediments (primarily in proximity to Bathurst Inlet), and exposed weathered bedrock. Proportions of various sediments found at the regional scale, and their hydrogeologic attributes, are provided in Table 2.1-1. Overburden thicknesses vary from 1 m (e.g., outcropping weathered bedrock in highlands) to 37 m and are generally thicker at topographic lows. A description of Project overburden geology is provided in Volume 5 Chapter 3: Landforms and Soils.

Table 2.1-1. Common Regional Overburden Materials and Hydrogeologic Properties

Surficial Material	Landscape Cover (%)[a]	Hydraulic Conductivity[b]	Topographic Setting[c]	Active Layer Depth[c, d]
Morainal	44	Low to moderate	Blankets > 1 m at lower slope and lowlands, veneers < 1m thick at upper slopes and crests	Low to moderate
Glaciofluvial	9.5	Moderate to high	Forming eskers or veneers over adjacent morainal deposits, slope grades up to 12%	High
Organics	6.5	Low to moderate	Lowlands	Low
Marine	5.1	Low to high	Variable, dominating the setting around Bathurst inlet	Low
Weathered bedrock	3.7	Moderate to high	Highlands and upper slopes, highly variable slope grades	Low to high
Open Water	23.6	-	-	-

[a] Obtained from Volume 5, Chapter 4 (Terrestrial Environment, Landforms and Soils)
[b] Low: < 10^{-8} m/s; moderate: 10^{-8} to 10^{-5} m/s; high > 10^{-5} m/s; as adapted from Freeze & Cherry (1979)
[c] Obtained from Rescan (2013)
[d] Low: < 50 cm; Moderate: 50-100 cm; high > 100 cm. Active layer depths were measured in late June and early July and do not reflect maximum active layer thickness.

2.1.1.2 Groundwater Flow

The Project is situated in a continuous permafrost environment (Volume 5, Chapter 2). Two groundwater flow regimes are present in the continuous permafrost context: shallow flow in the active layer, and deep flow beneath the base of the permafrost. The shallow and deep flow regimes can be connected where open (through) taliks exist beneath large surfacial waterbodies; these are waterbodies with

depths greater than two-thirds mean annual ice thickness and a smaller width dimension greater than 200 m. The permafrost is essentially impermeable to fresh water. A conceptual sketch of a typical groundwater system in a continuous permafrost environment is provided in Figure 2.1-1.

Groundwater in the active layer is only fluid during the summer months and is bounded below by frozen sediments or bedrock. Surface topography and hydraulic conductivity of the overburden materials control the groundwater flow direction and rate in the active layer. Flow is conveyed within and towards high hydraulic conductivity materials, and directed to topographic lows. Steeper terrain and higher hydraulic conductivity materials convey flow more quickly. Groundwater in the active layer discharges into lakes and the surface water drainage network. The base flow component of streams is sourced predominantly in the active layer, with a much smaller component potentially sourced from taliks.

The active layer begins to thaw from ground surface during freshet (June), at which time it also receives recharge from snowmelt. As the summer progresses, higher conductivity materials at topographic highs gradually drain (e.g., eskers, weathered bedrock, and coarse morainal and marine sediments in local highland areas). Lower hydraulic conductivity materials in highland areas (fine morainal and marine materials) drain less quickly. Materials at lower elevations that receive recharge from surface waterbodies may sustain a saturated zone through the summer until freeze-up in the fall. Additional recharge throughout the active layer is provided by precipitation.

Where open taliks exist beneath lakes, recharge from the lakes drives the regional groundwater flow system below the permafrost. In general, the deep groundwater flows from higher elevation lakes towards lower elevation lakes, therefore the flow direction can be inferred from the surface elevation of the lakes.

The subpermafrost groundwater throughout the Property footprint is inferred to flow generally northward towards the Arctic Ocean (Figure 2.1-2). Groundwater beneath the Goose Property is expected to flow northeastward, trending towards and along the Ellice River within the Queen Maud Gulf (Ellice River) Watershed. Groundwater beneath the winter ice road alignment is expected to flow trending northward towards Bathurst Inlet.

A component of deep groundwater flow is expected to be driven by fluid density differences. Upward diffusion of deep-seated brines is thought to occur (DeBeers 2010). Downward flow of higher density groundwater may occur during periods of basal aggradation (downward growth) of the permafrost.

2.1.1.3 Groundwater Quality

The published dataset of deep and subpermafrost groundwater quality in Canada's North has been emerging since the 1980s. Figures 2.1-3 and 2.1-4 display compilations of total dissolved solids (TDS) and major ion concentrations documented for groundwater at a number of other exploration and mine sites in the continuous permafrost zone of mainland Nunavut. Locations of sites are indicated in Figure 2.1-2.

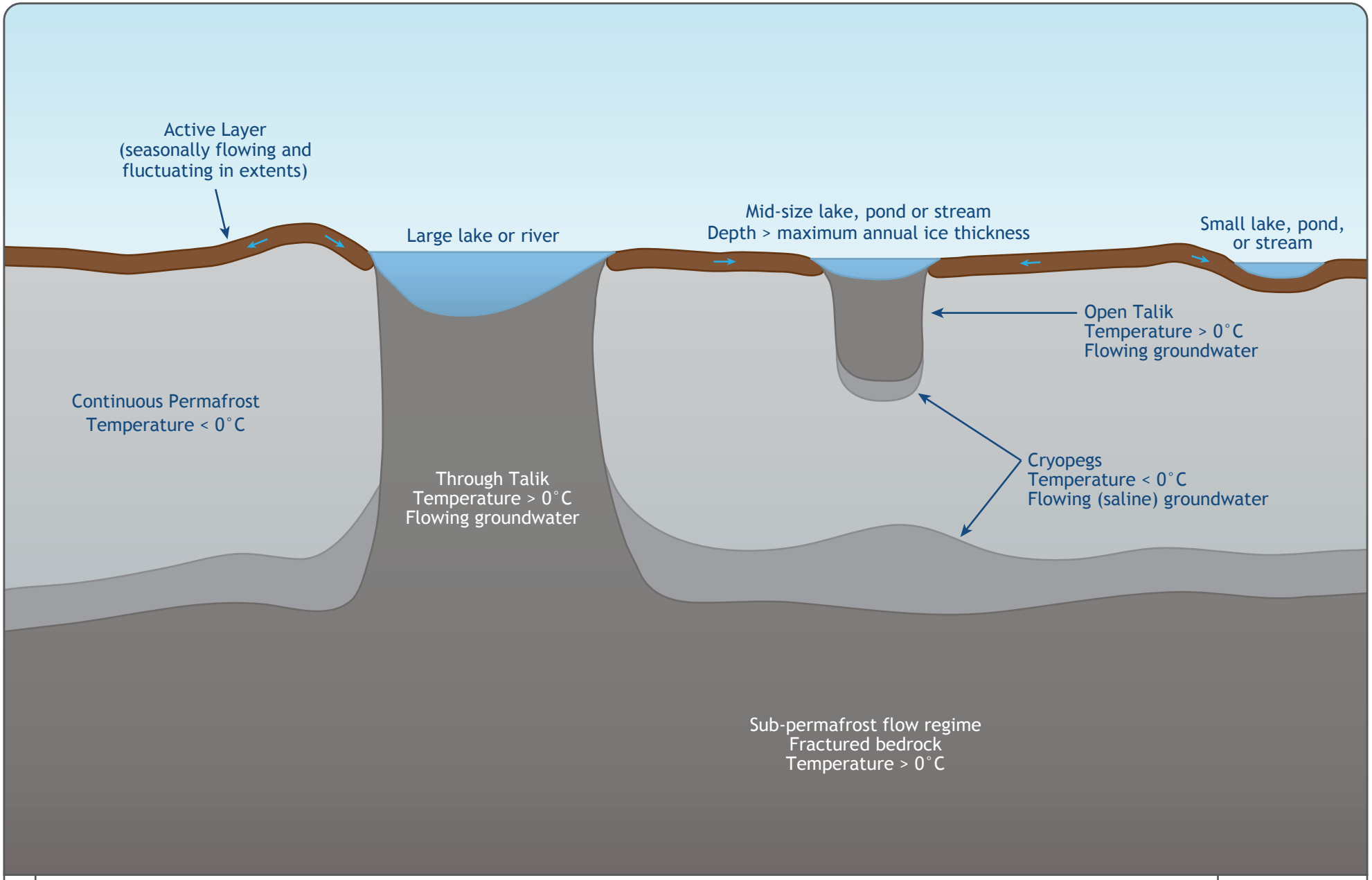

Figure 2.1-1

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Conceptual Sketch of Groundwater Flow Regimes in a Continuous Permafrost Environment

Figure 2.1-1

Rescan Engineers & Scientists

Frape et al. (1984) and Frape & Fritz (1987) document deep groundwater quality at a number of excavated mine sites across Canada, as far north as the vicinity of Yellowknife, NT. Brackish to saline water was observed at depths exceeding 300 mbgs, with a trend of increasing TDS with depth. Calcium and chloride tended to dominate the major ions at depth, alongside elevated concentrations of sodium, bromide, and magnesium. Sulphate and bicarbonate concentrations were not elevated with respect to near-surface conditions. Sodium was often a dominant ion at shallower sampling locations.

Subpermafrost groundwater has been sampled once from a straddle packer zone at the Kiggavik Site (Areva 2011). Sampled water was brackish and neutral, with TDS and pH in the range of 3,000 mg/L and 7.8, respectively. Chloride dominated the major ions with a concentration of 1,280 mg/L. Elevated cation concentrations of calcium, sodium, and magnesium were measured. The measured TDS of the subpermafrost groundwater is much lower than that measured at other sites in the continuous permafrost regions of mainland Nunavut. The Kiggavik site is closest to the transition from continuous to discontinuous permafrost among the sites with subpermafrost groundwater quality data in mainland Nunavut. Groundwater quality at the Kiggavik site may be under greater influence from interactions with the surface water than other sites due to the relatively thin permafrost and frequent open taliks.

A Westbay subpermafrost groundwater monitoring system was installed at the Meliadine Project site, as documented by Golder (2013). Water samples collected from a zone 454 mbgs at the Meliadine site indicate very saline water (TDS of 60,000 to 70,000 mg/L). Dissolved constituents at Meliadine were dominated by chloride and sodium, with concentrations ranging from 31,000 to 34,000 mg/L and 16,500 to 18,000 mg/L, respectively. Elevated concentrations of calcium, magnesium, potassium, and sulphate were also observed. The considerable purge volume removed from the Meliadine Westbay system and contrast between drilling brine and groundwater quality suggest the findings are reliable.

Sampling results for a Westbay subpermafrost groundwater monitoring system installed at the Hope Bay Project Doris Central site are documented by Newmont (2011). Water samples collected from three zones, ranging in depth from 63 m to 550 m, suggested increasing TDS with depth (ranging from 23 g/L to 48 g/L from the shallowest to deepest zones). Chloride, calcium and sodium dominated the major ions. Elevated concentrations of magnesium and sulphate were also reported.

Research studies carried out at the Lupin Mine (Stotler et al. 2009) show variability in major ion concentrations related to depth, source of recharge, and geology. Shallower subpermafrost water was dominated by sodium and chloride, whereas deeper water was dominated by calcium and chloride. A general trend of increasing TDS with depth was identified. Samples were collected within and around the excavated mine shafts. Mine-related activity (e.g., dewatering) may have influenced the observed hydrogeochemistry.

The available data suggest generally increasing TDS with depth. Concentrations on the scale of tens of grams per litre have been measured at depths of 500 mbgs and deeper beneath continuous permafrost. Dominance of chloride among the anions is prevalent, with calcium and sodium dominating the cations. Magnesium is consistently at elevated concentrations.

2.1.2 Local Setting

2.1.2.1 Data Collection and Analytical Methods

Groundwater Levels

Groundwater levels were measured directly and obtained indirectly at the Goose Property by three approaches as follows.

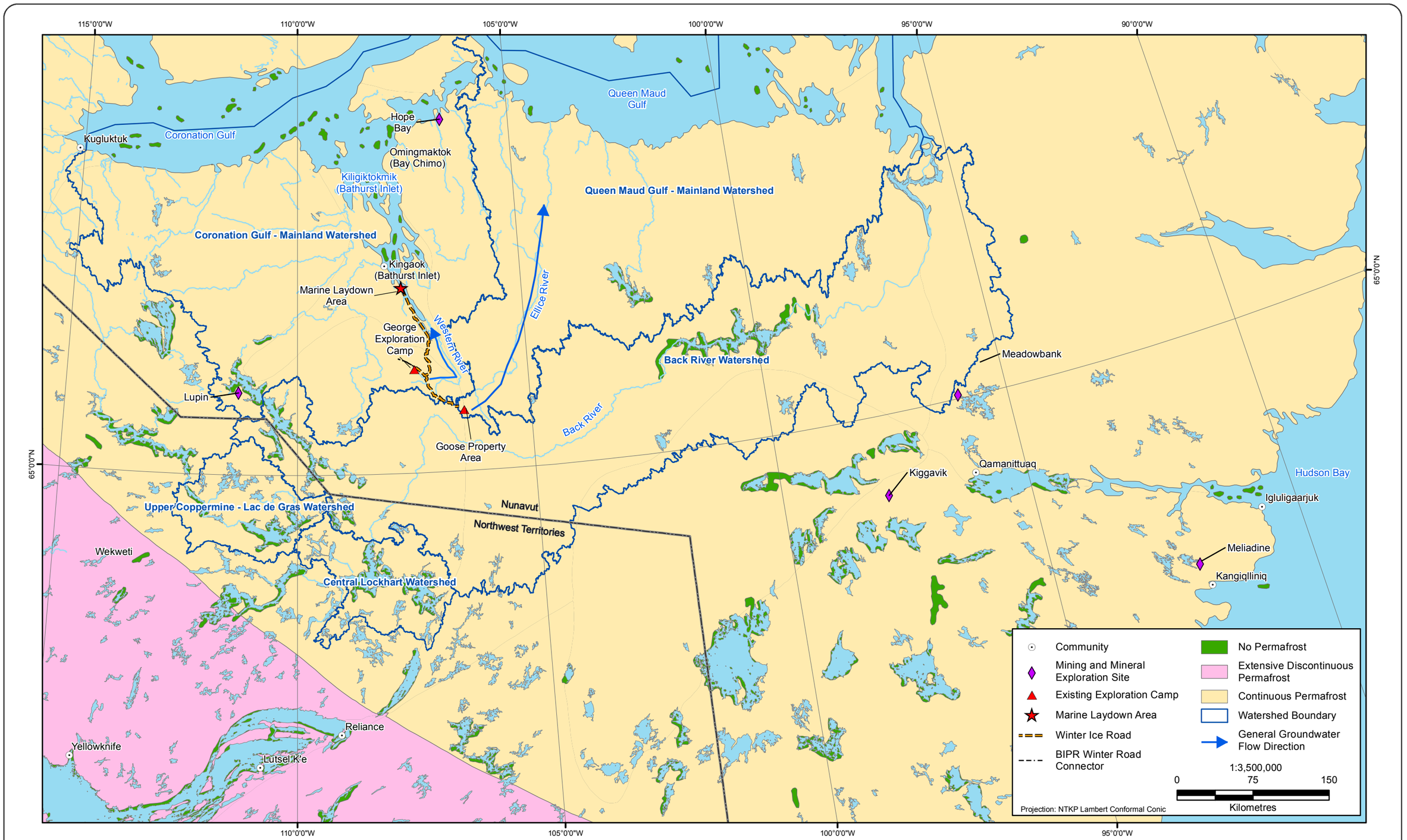

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Figure 2.1-2

Regional Groundwater Context

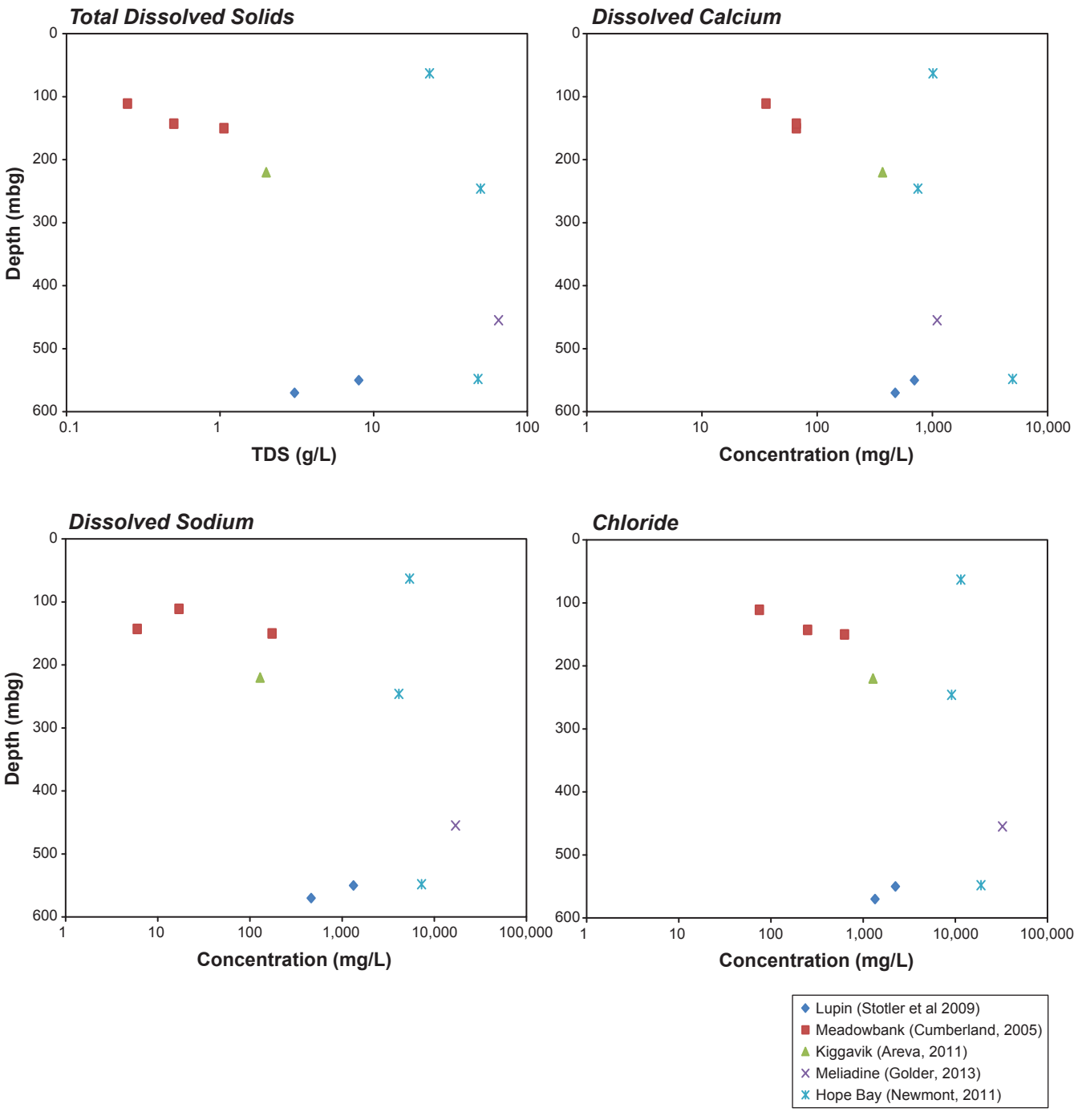

Figure 2.1-3

Regional Groundwater Total Dissolved Solids and Major Ion Concentrations

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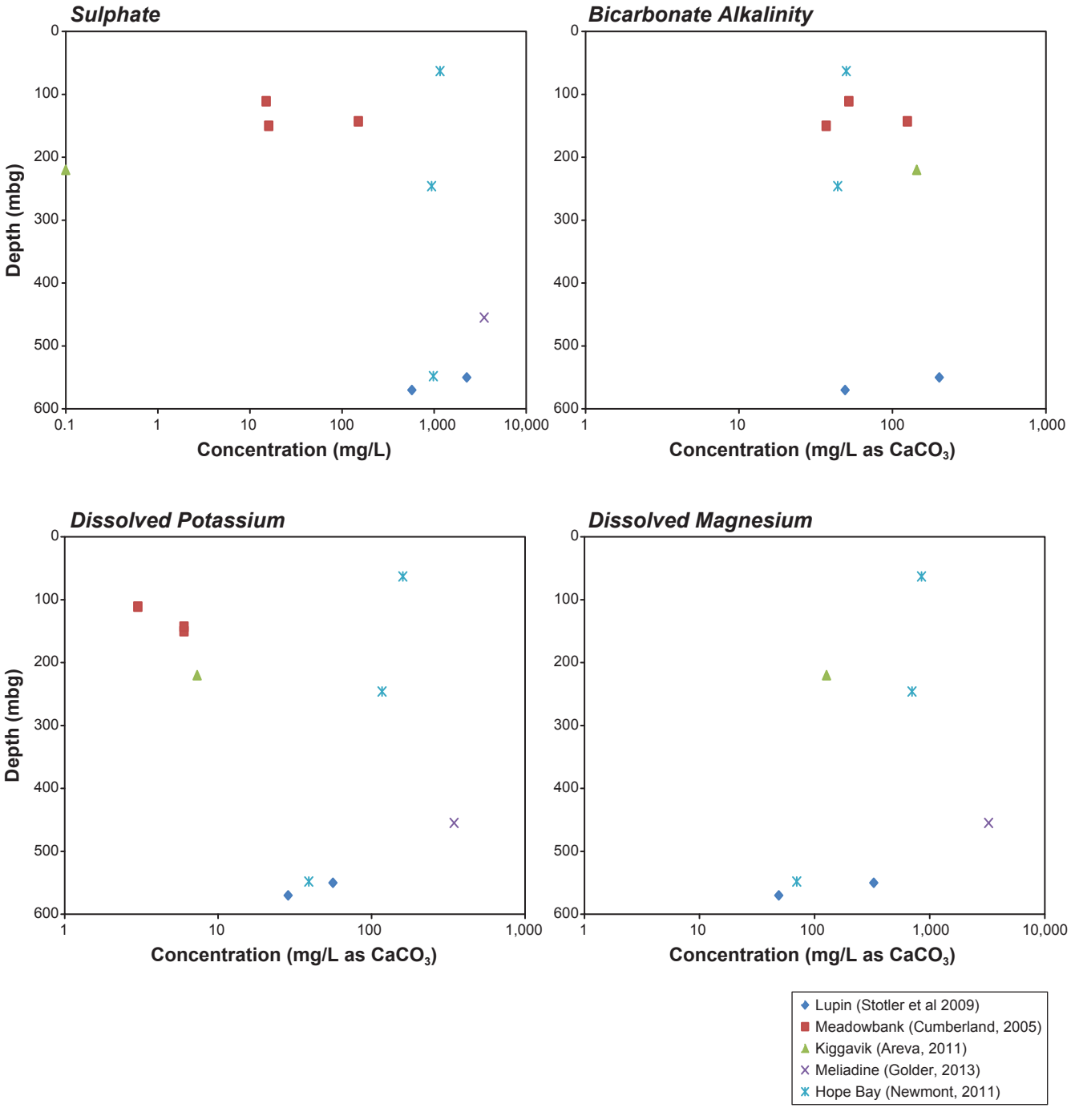

Figure 2.1-4

Regional Groundwater Major Ion Concentrations

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Vibrating wire piezometers (VWPs) — Three VWPs were installed at the Goose Property in 2012 by SRK Consulting (SRK; Appendix V6-2C), as well as 11 by Knight Piésold Consulting in 2013 (Appendix V6-2D). All VWPs were calibrated prior to installation and connected to programmed data loggers. A number of the installed VWPs lost functionality due to freezing within the permafrost or damage during installation. Certain VWPs recorded mounting pressures following installation, indicative of freeze-back. Water pressures were determined from the raw resistivity measurements by applying calibration coefficients and correcting for temperature and atmospheric pressure. A density correction was also applied to account for salinity of the groundwater.

Westbay Subpermafrost Monitoring System (Westbay system) — The Westbay system is described in the Groundwater Quality section that follows and in the Westbay System Completion Report (Appendix V6-2B). Pressure measurements were recorded at installed sampling zones using a pressure transducer installed in a sampling probe. A density correction was applied to account for the salinity of the natural groundwater in addition to an atmospheric pressure correction.

Lakes Overlying Open (Through) Taliks — One-dimensional steady-state analytical geothermal models were used to assess talik depths beneath a number of lakes (refer to Volume 5, Chapter 2: Permafrost, and Appendix V2-7A). Lakes which present conditions predicted to result in an open talik were identified. Open taliks present hydraulic connections between the surface water and subpermafrost groundwater. Water surface elevations of those lakes predicted to overlay open taliks provide evidence of the subpermafrost water levels and flow directions.

Hydraulic Conductivities

Packer testing has been conducted in a number of boreholes. Test intervals spanned a diverse range of hydrogeologic settings, including shallow bedrock (e.g., less than 200 mbgs) within the permafrost and taliks, and deeper bedrock within and beneath the permafrost.

Hydraulic conductivities were calculated for 20 injection packer tests conducted by SRK in 2012 at the Goose Property and for 23 falling head packer tests conducted by KP in 2013. In 2015, SRK completed one falling head test and Rescan completed eight shut-in tests. Test methodologies and results for the injection packer tests are documented in Appendix V6-2C. Test methodologies and results for the falling head packer tests are documented in Appendix V6-2D. Single hydraulic packer configurations were used, whereby a packer is inflated with an anti-freeze liquid at the base of the drill string. Inflation pressures were monitored throughout tests. Hydraulic responses were monitored within a calcium chloride brine solution.

Tabulated and mapped test interval locations are provided in the reports documenting test results: Appendices V6-2C and V6-2D.

Groundwater Quality

Groundwater samples were collected in 2013 through 2015 from beneath the permafrost near the Umwelt Deposit using a Westbay Subpermafrost Groundwater Monitoring System (Westbay system; Appendix V6-2A).

The Westbay system was installed in a 782 m long borehole. Drilling was conducted by a heli-portable Duralite hydraulic diamond drill operated by Major Drilling Group International, using a calcium chloride brine solution (approximately 15% $CaCl_2$ by mass) as drilling fluid. Fracture characterization and hydrogeologic logging was conducted on the core recovered from depths exceeding the postulated basal permafrost boundary. Westbay system monitoring zones were designed based on the hydrogeologic log.

Methods used for the Westbay system installation are documented in Appendix V6-2B.

Purging and sampling of the Westbay subpermafrost zones was conducted using the MOSDAX sampler system. One-litre samples were collected during successive round trips down the well casing using an electronic probe mounted on a cable winch. Field parameters (pH, electrical conductivity, fluorescence, ORP, and turbidity) were measured at regular intervals.

Samples were sent to ALS Laboratories for analysis at regular intervals as purging progressed. Extracted fluids were decanted into plastic bottles, preserved, and shipped. Analyses included physical parameters, major anions and nutrients, and dissolved. Field quality-control samples included a duplicate from one Westbay zone and an equipment/field blank. The duplicate sample was obtained by homogenizing 3 L of extracted fluid (three round-trip winch runs) in a volumetric flask prior to preservation. The equipment/field blank was obtained by passing deionized water (supplied by ALS Laboratories, Yellowknife, NT) through the Westbay sampling probe and bottles and then decanting it into laboratory sample containers.

Diagnostic data collected during installation, purging, and sampling of the Westbay system enabled documentation of system functionality. The hydraulic integrity of the well casing was tested upon completion of casing installation. Pressure and fluid volumes were measured during packer inflation. Laboratory analyses routinely included glycols (propylene glycol was used as anti-freeze inside the well casing) to assess for cross-contamination of the sample zones.

A series of diagnostic measurements were integrated into the purge sample collection procedure. Probe functionality, including measurements of valve seal integrity, lever arm, and shoe control, was tested at ground surface. Fluid pressure inside the Westbay casing was recorded before and after sampling.

Residual drilling brine in the subpermafrost zones was accounted for to estimate true subpermafrost water quality parameters in zones that were not completely purged. Brine proportions in submitted samples varied. Linear regression analysis was conducted to develop a relationship between brine proportion and concentration for each individual constituent. Trend-lines were extrapolated to estimate concentrations at a brine proportion of zero.

The linear regression model assumes a linear relationship between constituent concentrations and drilling brine proportion in samples. This assumption implies chemical stability as purging progresses.

Permafrost and Talik Extents

Permafrost and talik extents were assessed using thermistor strings, geothermal models, and groundwater quality data. The results are documents in Volume 5 Chapter 2: Permafrost.

One-dimensional analytical geothermal models were used to indicate the likelihood of through talik presence beneath lakes at the Goose Property. Through taliks are assumed to be present beneath lakes for which the models indicated moderate to high likelihood of through talik presence. Analysis methods and results can be found in Appendix V2-7A: Hydrogeological Characterisation and Modeling Report.

2.1.2.2 Goose Property

Local Geologic Context

An overview of the local geologic setting at the Goose Property is provided in Volume 5, Chapter 1: Geology. The Goose Property is underlain by folded turbidite meta-sedimentary rock (greywacke and mudstone) of the Beechey Lake Group, hosting banded iron formations. The stratigraphic sequence includes (from oldest to youngest) the central greywacke, lower iron formation, middle mudstone, upper iron formation, and upper sediments.

Folding generally trends to the northwest. Brittle structures (e.g., faults) have been identified (by core and air photo interpretations), striking to the north and northwest and associated with the folding (Appendix V6-2C). Brittle structures tend to dip steeply (50° from horizontal to near-vertical). Structures identified are shown in Figure 2.1-5.

Overburden materials are characteristic of a post-glacial environment. At the Goose Property morainal sediments are dominant, covering more than half the landscape. Other sediments commonly found include glaciofluvials, organics, and exposed weathered bedrock. Proportions of various sediments and their hydrogeologic attributes, are provided in Table 2.1-2. Overburden thicknesses range up to 37 m (average of 11 m) and are generally thicker at topographic lows. An overview of overburden geology is provided in Volume 5, Chapter 3: Landforms and Soils.

Table 2.1-2. Overburden Materials Common at the Goose Property and their Hydrogeologic Properties

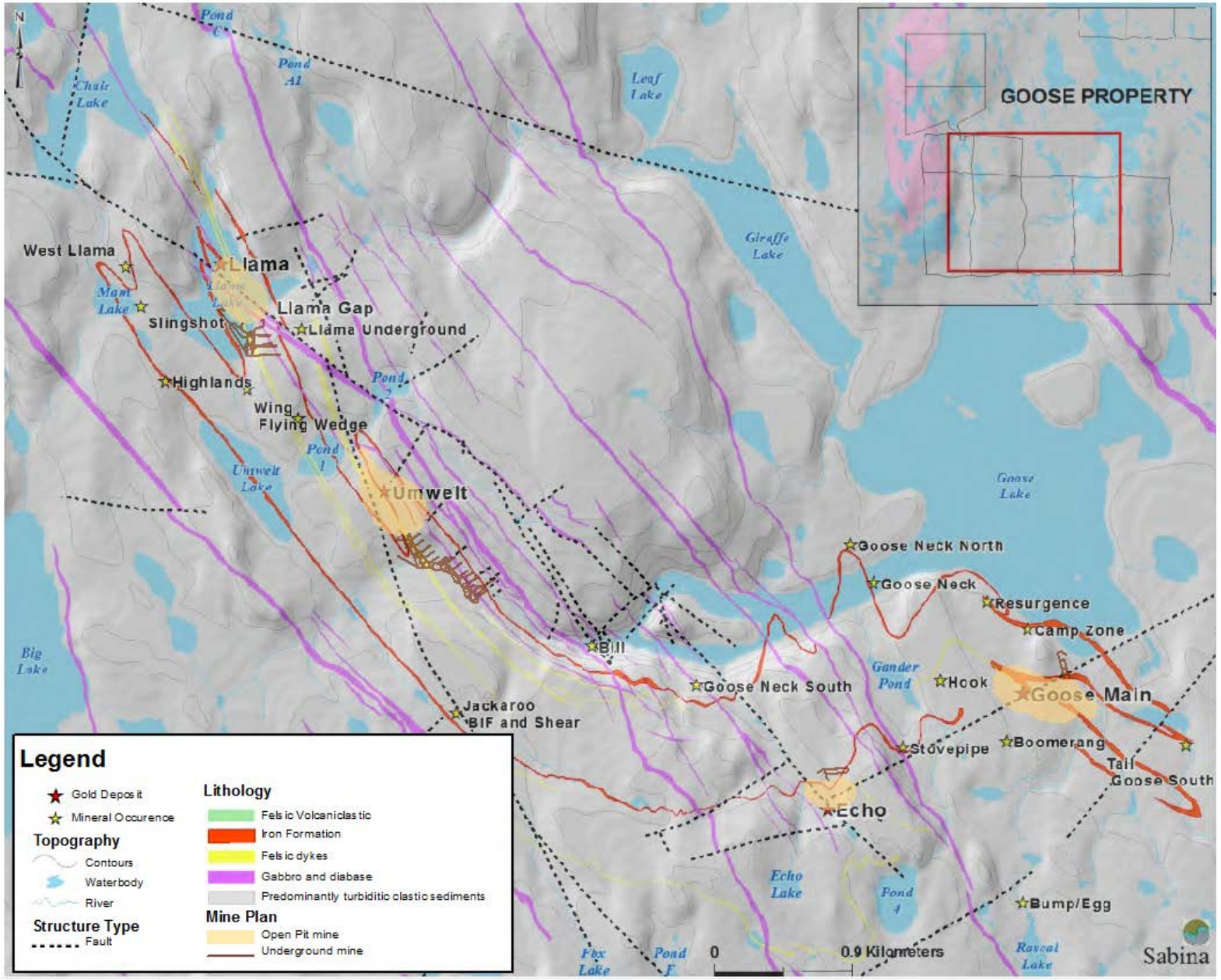
Surficial Material	Landscape Cover (%)[a]	Hydraulic Conductivity[b]	Topographic Setting[c]	Active Layer Depth[c,d]
Morainal	62.2	Low to moderate	Blankets > 1 m at lower slope and lowlands, veneers < 1m thick at upper slopes and crests	Low to moderate
Glaciofluvial	7.0	Moderate to high	Forming eskers or veneers over adjacent morainal deposits, slope grades up to 12%	High
Organics	8.7	Low to moderate	lowlands	Low
Weathered bedrock	0.3	Moderate to high	Highlands and upper slopes, highly variable slope grades	Low to high
Open Water	15.0	-	-	-

[a] *Adapted from Volume 5, Chapter 3 (Terrestrial Environment, Landforms and Soils)*
[b] *Low: < 10^{-8} m/s; moderate: 10^{-8} to 10^{-5} m/s; high > 10^{-5} m/s; as adapted from Freeze & Cherry (1979)*
[c] *Obtained from Rescan (2013)*
[d] *Low: < 50 cm; Moderate: 50-100 cm; high > 100 cm. Active layer depths were measured in late June and early July and do not reflect maximum active layer thickness.*

Groundwater Levels and Flow Directions

The water levels shown in Figure 2.1-6 indicate a general trend from west to east across the Goose Property. Propeller Lake has the lowest elevation of lakes predicted to have open taliks, with higher lake water levels trending westward. Instruments installed beneath the permafrost indicate that the subpermafrost groundwater behaves as a confined flow system, with pressures that exceed the elevation of the base of the permafrost.

Lakes overlying open taliks at lower elevations may receive water from the deep groundwater, but there is no evidence to indicate as such here. Lake elevation differences suggest horizontal hydraulic gradients may vary from 0.01 to 0.0005. Large lakes located at higher elevations near watershed divides (e.g., Wasp Lake, Fox Lake, Llama Lake) provide head for the greatest gradients. The gradient is low between Goose and Propeller Lakes, where the elevation difference is one metre.



Source: Tetra Tech, Report,
Mineral Resource Update for the Back River
Gold Property, Nunavut, Canada
Figure 7.3

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Filename: BackRiver_LandFigs_8x11_1CS020.008_rev01

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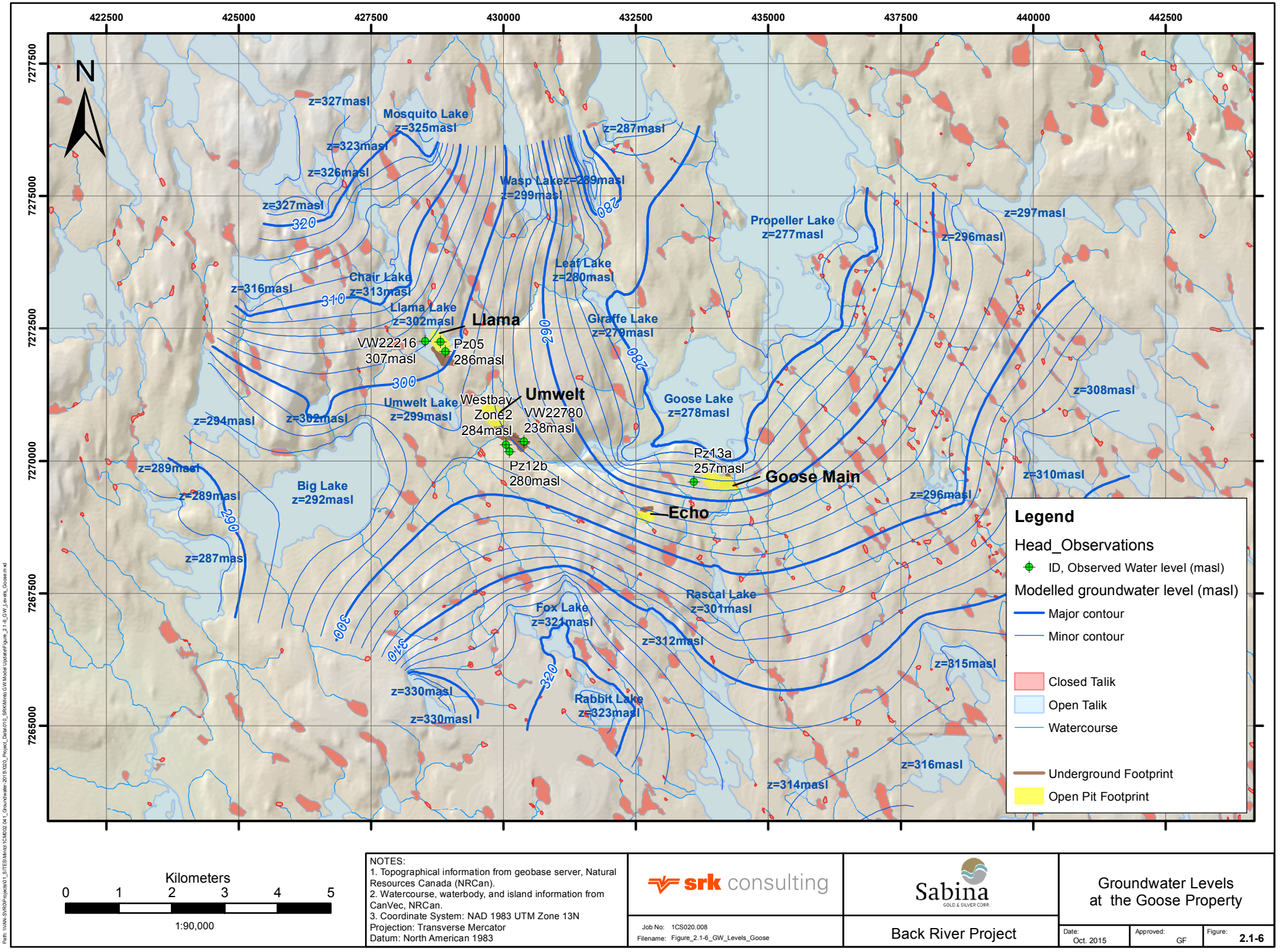
Back River Project

Hydrogeological Characterization and Modeling

Geologic Structures at Goose Property

Date:	Approved:	Figure:
Sep. 2015	GF	**2.1-5**



NOTES:
1. Topographical information from geobase server, Natural Resources Canada (NRCan).
2. Watercourse, waterbody, and island information from CanVec, NRCan.
3. Coordinate System: NAD 1983 UTM Zone 13N
Projection: Transverse Mercator
Datum: North American 1983

srk consulting

Job No: 1CS020.008
Filename: Figure_2.1-6_GW_Levels_Goose

Sabina GOLD & SILVER CORP.

Back River Project

Groundwater Levels at the Goose Property

Date: Oct. 2015
Approved: GF
Figure: 2.1-6

Path: \\VAN-SVR0\Projects\1_SITES\Mnbn\1CM002.0\41_Groundwater 2015\02\2_Project_Data\010_SRK\Mines GW Model Update\Figure_2.1-6_GW_Levels_Goose.mxd

Groundwater in the active layer is expected to flow following surface topography and the surface water drainage network. The western reaches of the Goose Potential Development Area (PDA) drain towards Llama and Umwelt lakes. Northern reaches drain towards Giraffe Lake, and southern reaches towards Goose Lake. Goose Lake is the focal point for flow in the active layer within the PDA. Highland areas in the south and centre of the PDA are expected to drain following freshet, due to the absence of recharge from large ponds or lakes. The highlands to the southeast of Goose Lake are expected to drain particularly quickly due to the abundance of glaciofluvial sediments. Other areas are expected to sustain a saturated zone through the summer until fall freeze-up.

Hydraulic Conductivity Measurements

Based on the data collected at site, the spatial distribution of hydraulic conductivity (K) in the unfrozen bedrock does not show any particular pattern and there is no obvious correlation with lithology. The only discernible trend is the progressive decrease in K with increasing depth (Figure 2.1-7), which is a reasonable relationship considering that fractures tend to close with depths. On average, K values are generally low, ranging between 1E-11 and 6E-6 m/s, with a geometric mean of 3E-9 m/s and arithmetic mean of 3E-7 m/s, and highly variable, ranging over four orders of magnitude for elevations above about 170 masl and three orders of magnitude below 170 masl. The shallow (less than 100 m deep) fractured bedrock exhibits hydraulic conductivities with a geometric mean around 2E-8 m/s (measurements varied from 10-9 m/s to nearly 10-5 m/s). At greater depths (50 to 150 mbgs), fractured bedrock exhibits bulk hydraulic conductivities with a geometric mean around 1E-8 m/s (measurements were as low as 4E-10 m/s and as high as 1E-6 m/s). Between the 150 and 250 masl elevation range, hydraulic conductivity was measured as high as 10-8 m/s in a zone where a fault is present; outside of this zone, the deep bedrock typically exhibits a hydraulic conductivity of 1E-9 m/s or less (measurements were as low as 4E-10 m/s).

Permeabilities in the active layer are expected to be highly heterogeneous due to the abundance of glacial till (morainal deposits). Particularly high permeability is expected within the glaciofluvial deposits found to the southeast of Goose Lake and to the southeast of Llama Lake.

The permafrost is expected to be essentially impermeable to fresh water.

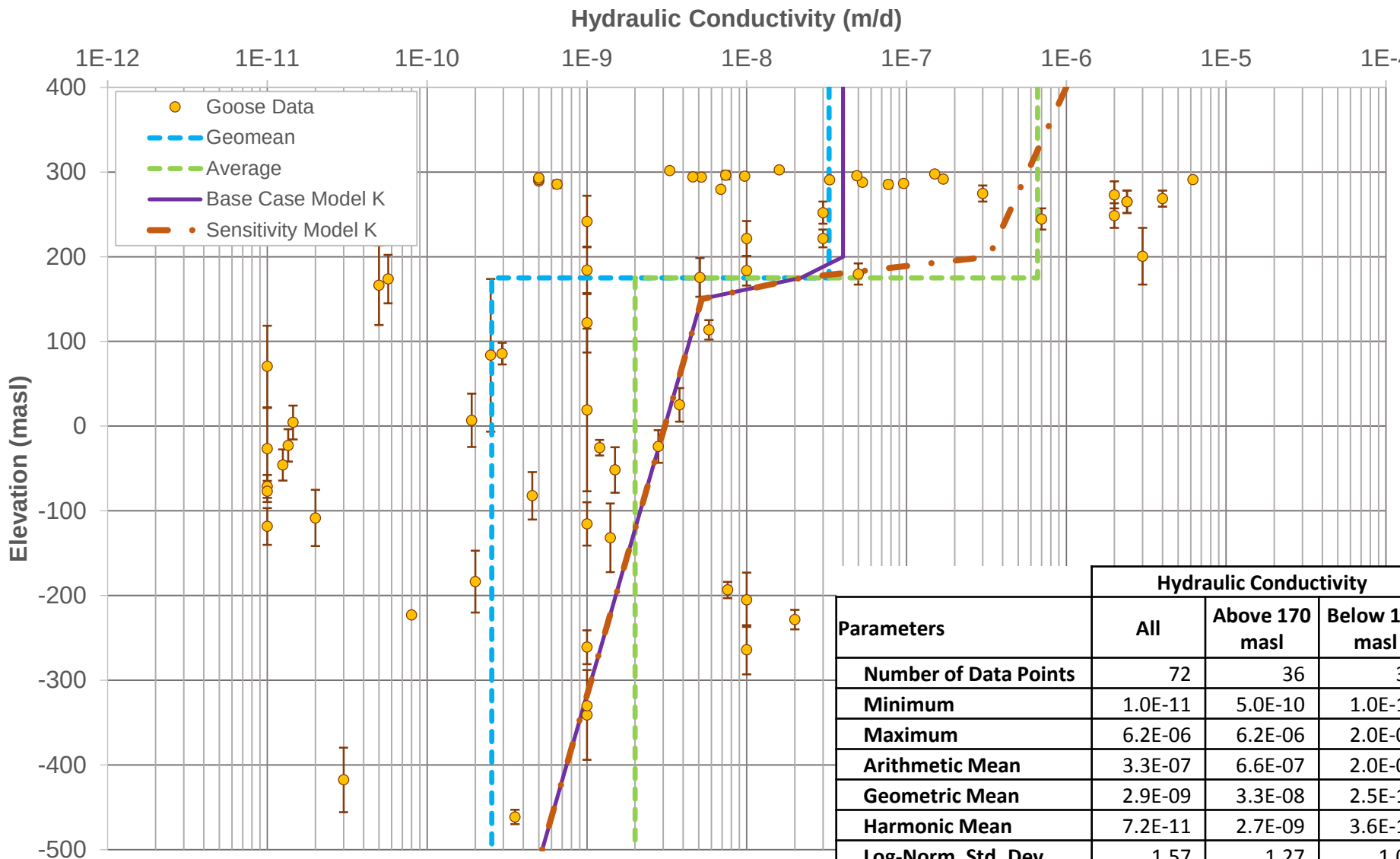
Groundwater Quality

Two Westbay system sampling zones were purged adequately to determine concentrations of analytes in natural groundwater: zone 3 (620 mbgs) and zone 5 (515 mbgs). The results indicate that the groundwater is hypersaline and dominated by calcium chloride and sodium chloride salts (Table 2.1-3).

The groundwater has neutral pH and becomes slightly alkaline upwards towards the base of the permafrost. Salinity increases with depth alongside rising domination of calcium chloride salt. Very high concentrations of magnesium (900 to 1,100 mg/L), strontium (200 to 400 mg/L), bicarbonate (140 to 230 mg/L), and bromide (400 to 460 mg/L) have been estimated.

Concentrations of most metals are below guidelines for the protection of freshwater aquatic life (refer to Table 2.1-3) published by the Canadian Council of Ministers of the Environment (CCME); however, concentrations of fluoride, iron, arsenic, and zinc exceed these CCME guidelines. Guidelines are provided as comparative benchmarks and are not intended to gauge the suitability of the groundwater as freshwater habitat.

Laboratory detection limits for certain trace metals exceeded the CCME guidelines: chromium, selenium, silver, and thallium. Trace metal concentrations were determined by inductively coupled plasma - mass spectrometry, with pre-treatment to improve precision in the presence of high salinity.



Parameters	Hydraulic Conductivity		
	All	Above 170 masl	Below 170 masl
Number of Data Points	72	36	36
Minimum	1.0E-11	5.0E-10	1.0E-11
Maximum	6.2E-06	6.2E-06	2.0E-08
Arithmetic Mean	3.3E-07	6.6E-07	2.0E-09
Geometric Mean	2.9E-09	3.3E-08	2.5E-10
Harmonic Mean	7.2E-11	2.7E-09	3.6E-11
Log-Norm. Std. Dev.	1.57	1.27	1.06
Geometric COV	1718%	630%	346%

Source: BackRiver_Modeling_Assumptions.xlsx

Note:

COV	Coefficient of Variation
Log.Norm. Std. Dev	LOG normalized standard deviation

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Filename: BackRiver_LandFigs_8x11_1CS020.008_rev01

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Back River Project

Hydrogeological Characterization and Modeling

Hydraulic Conductivity Measurements at Goose Property

Date: Sep. 2015 | Approved: GF | Figure: **2.1-7**

Considerable dilution was required for certain trace metals due to the abundance of calcium, resulting in elevated detection limits.

Complete results of the Westbay System sampling program are provided in Appendix V6-2A.

Table 2.1-3. Groundwater Quality Parameters Measured for the Umwelt Westbay Subpermafrost Monitoring System

			Sample Zone 3 620 mbgs		Sample Zone 5 515 mbgs	
Analyte [D]	**Unit**	**CCME FWAL Guideline [P]**	**Raw Data (2013)**	**Corrected for 10% Brine**	**Raw Data (2013)**	**Corrected for 10% Brine**
pH	-	6.5 - 9.0	6.92	-	8.01	-
Total Dissolved Solids	mg/L	-	82,900	76,611	73,400	66,056
Hardness	mg/L as $CaCO_3$	-	52,400	45,167	51,900	44,611
Anions and Nutrients						
Total Alkalinity [B]	mg/L as $CaCO_3$	-	10.7	12	16.2	20
Ammonia - Total	mg/L as N	0.017 – 190 [S]	0.477	0.137	0.591	0.264
Bromide	mg/L	-	584	523	618	561
Chloride	mg/L	120	50,300	46,439	45,400	40,994
Fluoride	mg/L	0.12 [F]	0.70	0.64	0.57	0.50
Nitrate	mg/L	13	<0.5	<0.5	<0.5	<0.5
Nitrite	mg/L	0.06	<0.1 [N]	<0.1 [N]	<0.1 [N]	<0.1 [N]
Orthophosphate - Dissolved	mg/L as P	-	0.041	0.042	0.077	0.082
Phosphorus - Total	-	-	0.176	0.187	0.237	0.255
Sulfate	mg/L	-	<50	<50	<50	<50
Major Cations and Dissolved Metals						
Aluminum	mg/L	0.1 [G]	<0.1	0.08	<0.1	0.08
Antimony	mg/L	-	<0.005	<0.005	<0.005	<0.005
Arsenic	mg/L	0.005	0.0075	0.0069	0.0080	0.0074
Barium	mg/L	-	8.68	9.37	2.82	2.86
Beryllium	mg/L	-	<0.005	<0.005	<0.005	<0.005
Bismuth	mg/L	-	<0.05	<0.05	<0.05	<0.05
Boron	mg/L	1.5	4.08	3.26	5.30	4.62
Cadmium	mg/L	Zone 3 = 0.007 Zone 5 = 0.005 [H]	<0.001	<0.001	<0.001	<0.001
Calcium	mg/L	-	19,300	16,222	19,500	16,444
Chromium	mg/L	0.001 to 0.0089 [J]	<0.01 [N]	0.0062	<0.01 [N]	0.0062
Cobalt	mg/L	-	<0.01	<0.01	<0.01	<0.01

(continued)

Table 2.1-3. Groundwater Quality Parameters Measured for the Umwelt Westbay Subpermafrost Monitoring System (completed)

			Sample Zone 3 620 mbgs		Sample Zone 5 515 mbgs	
Analyte [D]	Unit	CCME FWAL Guideline [P]	Raw Data (2013)	Corrected for 10% Brine	Raw Data (2013)	Corrected for 10% Brine
Copper	mg/L	Zone 3 = 2.3; Zone 5 = 1.9 [K]	<0.02	0.008	<0.02	0.008
Iron	mg/L	0.3	6.16	6.73	0.89	0.88
Lead	mg/L	Zone 3 = 8 ; Zone 5 = 6 [L]	<0.005	<0.005	<0.005	<0.005
Lithium	mg/L	-	8.09	5.0	11.8	9.1
Magnesium	mg/L	-	1,040	1,151	801	885
Manganese	mg/L	-	3.24	3.54	2.03	2.19
Mercury	mg/L	-	<0.00001	<0.00001	<0.00001	<0.00001
Molybdenum	mg/L	0.073	0.056	0.025	0.0873	0.060
Nickel	mg/L	Zone 3 = 10; Zone 5 = 9 [M]	0.011	0.011	0.011	0.011
Potassium	mg/L	-	370	202	446	287
Selenium	mg/L	0.001	<0.01 [N]	<0.01 [N]	<0.01 [N]	<0.01 [N]
Silicon	mg/L	-	<1	<1	<1	<1
Silver	mg/L	0.0001	<0.001 [N]	<0.001 [N]	<0.001 [N]	<0.001 [N]
Sodium	mg/L	-	7,180	7,870	5,200	5,670
Strontium	mg/L	-	399	360	338	292
Thallium	mg/L	0.0008	<0.005 [N]	<0.005 [N]	<0.005 [N]	<0.005 [N]
Tin	mg/L	-	<0.01	<0.01	<0.01	<0.01
Titanium	mg/L	-	<0.20	<0.20	<0.20	<0.2
Uranium	mg/L	0.015	<0.001	<0.001	<0.001	<0.001
Vanadium	mg/L	-	<0.05	<0.05	<0.05	<0.05
Zinc	mg/L	0.03	0.35	0.37	0.24	0.24

Notes: A Indexing parameters used to estimate groundwater concentrations from samples containing residual drilling brine.
B Determined from field titration measurements.
C Determined from field measurements using calibrated electronic probe.
D Values determined based on laboratory tests (methods and results documented in Appendix V6-2C) unless specified otherwise.
E Laboratory analysis indicated concentration below detection limit for sample with lowest drilling fluid proportion.
F Interim Guideline.
G Aluminum guideline concentration 0.005 mg/L if pH < 6.5 and 0.10 mg/L if pH > 6.5.
H Cadmium guideline $100.86[\log10(\text{hardness})]-3.2$ µg/L.
J Chromium Hexavalent 0.001 mg/L and Chromium Trivalent 0.0089 mg/L.
K Copper guideline concentration = $e^{0.8545[\ln(\text{hardness})]-1.465 * 0.2}$ µg/L.
L Lead guideline concentration = $e^{1.273[\ln(\text{hardness})]-4.705}$ µg/L.
M Nickel guideline concentration = $e^{0.76[\ln(\text{hardness})]+1.06}$ µg/L.
N Detection limits exceeds CCME guideline.
P Published in CCME 2013 as guidelines for the protection of freshwater aquatic life. Guidelines for all metals except aluminium and iron are intended for total concentrations.
Q Range is within precision of estimate.
R Calculated lower limit of range is a negative concentration: rounded to zero.
S Total ammonia guideline pH and temperature dependent.

Site Conceptual Model

Five hydrostratigraphic units may be used to categorize the diversity of hydrogeologic conditions present in the subsurface at the Goose Property Area, as follows.

Active Layer — Up to 2 m thick (indicated by thermistor strings, refer to Volume 5, Chapter 2) and spanning the surficial soils and exposed bedrock. Flow occurs along the topographic drainage network. Hydraulic conductivities are highly variable, with preferential flow within coarse sediments (e.g., glaciofluvial sediments). Flow in the active layer is coupled with the surface water.

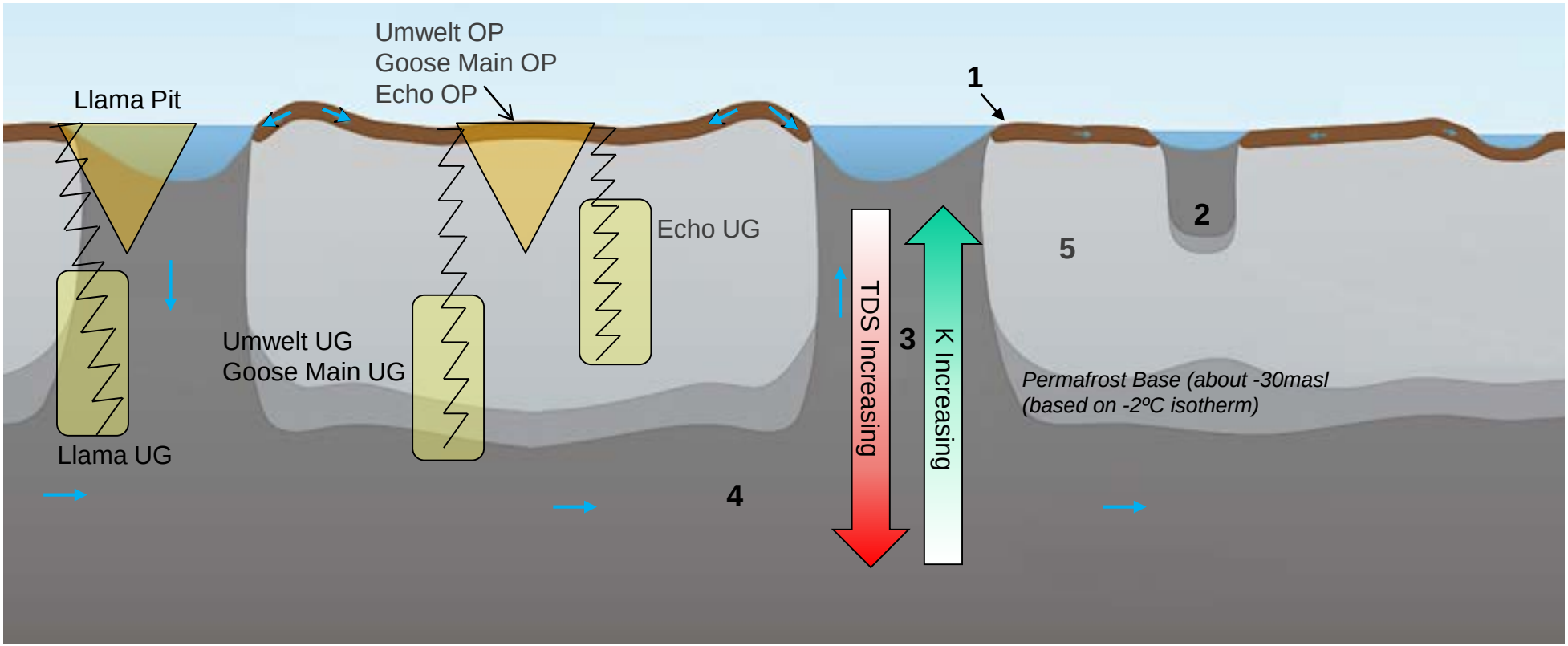
Shallow Taliks (up to 50 mbgs) — This hydrostratigraphic unit exists beneath lakes which exceed 1.3 m depth, where taliks are present. Beneath the lake sediments the shallow bedrock is primarily fine-grained sedimentary rock (greywacke, mudstone, iron formation). The bedrock is moderately fractured, with a bulk hydraulic conductivity around 2E-8 m/s. Flow trends downwards where taliks are connected to the subpermafrost flow regime below (through taliks). In open taliks, the hydraulic gradient driving flow is expected to be extremely low, as the overlying lake provides lateral hydraulic equilibrium. Groundwater is expected to increase in salinity with depth, with TDS as high as 30 g/L at the depth of 50 metres below lake bottoms (as observed at the Doris Central Westbay, Newmont 2011, Figure 2.1-2).

Middle Taliks — This unit includes fractured bedrock 50 to 200 mbgs beneath large lakes that overly through taliks and extensive open taliks. Bedrock is primarily fine-grained sedimentary and meta-sedimentary rock (greywacke, mudstone, iron formation). The bedrock is moderately fractured, with a bulk hydraulic conductivity around 1E-8 m/s. Local heterogeneity exists with bulk hydraulic conductivities as high as 10-6 m/s. While no geological structure such as a fault or open fracture has been identified to promote high K, the presence of such features cannot be completely ruled out. Flow is expected to concentrate along persistent faults if present. Faults strike predominantly to the northwest and dip steeply to the northeast (SRK 2012). Hydraulic gradients are downwards where the taliks are connected to the subpermafrost flow regime below (through taliks). In open taliks the hydraulic gradients driving flow are likely extremely low, as the overlying lake provides lateral hydraulic equilibrium. Groundwater is expected to be hypersaline with TDS around 40 g/L and generally increasing with depth (as observed at the Doris Central Westbay, Newmont 2011, Figure 2.1-2).

Deep Taliks and Subpermafrost — Fractured bedrock at depths exceeding 200 mbgs in through taliks and beneath the permafrost (depths exceeding 400 mbgs outside of through taliks) typically exhibits very tight fractures due to the confining pressure of the overlying rock. Rock is predominantly fine-grained sedimentary and meta-sedimentary (greywacke, mudstone, iron formation). Bulk hydraulic conductivity is 10^{-9} m/s or less, except along one major fault where measurements as high as 10^{-8} m/s have been recorded. Hydraulic gradients are downwards within the through taliks, and eastward beneath the permafrost. Groundwater is hypersaline with TDS of 70 g/L dominated by sodium chloride and calcium chloride salts. Deep cryopegs situated beneath the frozen ground and along deeper extremities of taliks are grouped into the subpermafrost hydrostratigraphic unit. By convention, cryopegs are considered part of the permafrost.

Permafrost — The permafrost is regarded as impermeable to fresh water, as it freezes shortly after exposure to temperatures below freezing. The bedrock (predominantly sedimentary and meta-sedimentary units consisting of greywacke, mudstone, and iron formation) within the permafrost exhibits considerable heterogeneity ranging from extensive zones of competent rock, to moderate wide-spread fracturing within 50 m of ground surface, to heavy fracturing along major faults. The solutions contained in fractures within the permafrost are considered to be frozen and therefore immobile, excepted in cryopegs.

Figure 2.1-8 depicts the interpreted hydrogeologic conceptual model in close proximity to proposed infrastructure at the Goose Property.



PERMAFROST COMPONENTS:

1 – Active layer.
2 – Closed talik caused by mid-size lake, pond or stream.
3 – Open talik caused by large lake or river.
4 – Sub-permafrost.
5 – Permafrost.

GROUNDWATER FLOW REGIMES

1 – Seasonally flowing[1]
2 – Flowing, not connected to sub-permafrost.
3 – Flowing, connected to sub-permafrost.
4 – Flowing, connected to open taliks.
5 – No flow.

[1]The interception of active layer flow by the pits is considered insignificant because it is not particularly thick, only fluid during the summer months, volumes are small, and the water quality is not saline.

LEGEND

- Open Pit
- Decline
- Underground
- Groundwater Flow Direction

Note:
OP – Open Pit
UG - Underground

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Job No: 1CS020.008 Filename: BackRiver_LandFigs_8x11_1CS020.008_rev01	Back River Project	**Hydrogeological Conceptual Groundwater Model at Goose Property** Date: Sep. 2015 | Approved: GF | Figure: **2.1-8**

2.1.2.4 Winter Ice Road Corridors

The hydrogeologic environment along the winter ice road corridors is expected to be similar to those at the Goose Property. Groundwater exposed to ground surface is limited to the active layer and taliks beneath lakes. Geologic materials and active layer flow and permeability trends along the winter ice road corridors reflect those discussed for the regional setting (refer to Section 2.1.1).

2.2 INCORPORATION OF TRADITIONAL KNOWLEDGE (TK)

The effects assessment relies on the information collected from Inuit-led TK information, public scoping, focus group meetings, government engagement, and scientific knowledge. To the extent possible, available TK is incorporated into the evaluation of the potential effects of the Project on the environment. The following reports were reviewed for TK-specific information related to groundwater:

- *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* (KIA 2012) (Appendix V3-3A);
- *Naonaiyaotit Traditional Knowledge Project - Hannigayok (Sabina Gold & Silver Corp. Proposed Back River Project). Results from Data Gaps Workshops, Final Report (June 2014)* (KIA 2014) (Appendix V3-3B); and
- Back River Project: Existing and Publically Available Traditional Knowledge from Selected Aboriginal Groups in the Northwest Territories (Appendix V3-3C).

2.2.1 Incorporation of TK for Existing Environment and Baseline Information

The TK cites "underground streams and cold water springs" as a traditional source of water (KIA 2012; 2014). Springs were noted to occur in sands near eskers (KIA 2014). A trend of decreasing spring abundance was noted, and suggested to be a result of climate change (KIA 2014).

Underground streams and springs correspond with the active layer. Recreational and subsistence land users may source water from the active layer where it is accessible and suitable for drinking and recreational uses. This is thought to be applicable where the surficial geology consists of cobbles and boulders, as the active layer water in these areas is not heavily sediment-laden, and it is accessible in large voids and beneath boulders that may be displaced.

The accessibility of shallow groundwater in bouldery areas is dependent on precipitation. A year with low snowfall would sustain lower water levels in the active layer following thaw. The result of lower active layer water levels is less ponding on ground surface following freshet and more rapid drying up of small ponds later into the summer.

Springs draining from eskers develop when an esker behaves as a high-permeability subsurface pathway draining from an up-stream reservoir (e.g., lake or stream). The piezometric pressure and flow rate in a spring emerging from an esker would vary based on the water level in the up-stream reservoir, which in-turn varies based on meteorological trends.

The impact of climate change on meteorology is discussed in Section 3.4.1. Drinking water is addressed in the FEIS in Volume 6, Chapter 4 (Freshwater Water Quality).

2.2.2 Incorporation of TK for Spatial and Temporal Boundaries

There are no references to spatial or temporal boundaries relating to groundwater or its degradation in the traditional knowledge reports.

2.2.3 Incorporation of TK for Mitigation and Adaptive Management

There are no references to mitigation or adaptive management measures associated with groundwater or its degradation in the traditional knowledge reports.

2.3 VALUED COMPONENTS

2.3.1 Potential Valued Components and Scoping

Groundwater was included in the scoping and refining process with all other potential VECs/VSECs. Groundwater was classified as a Subject of Note as determined from Sabina-led public consultation, the TK report (KIA 2012), consultation with regulatory agencies, and regulatory considerations.

2.3.2 Valued Components Included in Assessment

Groundwater is considered a Subject of Note for the FEIS. All information requested in the NIRB-issued EIS guidelines related to Groundwater is included in this FEIS.

2.4 SUPPORTING AND SUPPLEMENTAL INFORMATION

The following text provides information requested in the EIS guidelines relating to groundwater that was not addressed in previous sections of this chapter.

2.4.1 Interaction of Groundwater with the Project

The continuous permafrost found throughout the Goose Property is expected to limit interaction of the groundwater with the Project. However all components of the groundwater environment (active layer, talik, and subpermafrost groundwater) are expected to interact with the Project to some degree.

The active layer may interact with Project components located on the ground surface. Changes to flow patterns within the active layer would be similar to those within the surface water (Chapter 4) as flow in the active layer is governed by topography. For example, a surface water diversion would also capture and divert flow within the active layer in the corresponding catchment area.

A closed talik may form beneath the Tailings Storage Facility (TSF) or the Saline Water Pond (SWP) due to the introduction of heat from the ponds. The extent of these taliks will be dependent on the temperature and size (width and depth) of the pond. The permafrost is thought to contain high-salinity water which would be released into a mobile state when thawed. However, the talik beneath the TSF and the SWP will be hydraulically isolated due to the construction of dams (and related permafrost aggradation into the dams resulting in frozen cores) around the down-gradient facility perimeters and the presence of continuous permafrost at depth.

The faces of the open pit mines would freeze in response to the excavation, dewatering, and exposure to cold atmospheric air temperatures. A period of geothermal transience would occur following initiation of excavation and dewatering, with development and thickening of a frozen layer beneath the deepening excavation each winter. No metal leaching or acid rock drainage (ML/ARD) is expected to contact the groundwater due to dewatering (as needed) and development of an ice layer beneath. Flooding of the open pits would result in the thaw of pit faces and would isolate the exposed bedrock from further oxidation.

The Umwelt, Llama, and Goose Main underground mines will penetrate through the permafrost and contact the groundwater in the basal cryopeg (approximately 490 to 570 mbgs) and beneath the permafrost (greater than 500 mbgs). Not that Echo underground mine will not penetrate through the

basal permafrost, and as such, no groundwater inflows are expected in this mine. A mine inflow study for the three underground mines penetrating permafrost (i.e. Umwelt, Llama, and Goose Main) has been conducted (Appendix V2-7A). These underground mines are expected to behave as a local groundwater sink when being dewatered, with groundwater flowing within the fractures radially towards the mine. No ML/ARD is expected to contact the groundwater while the underground mines are operational due to dewatering and the resulting radial-inward groundwater flow. Water extracted from underground will be pumped to the Saline Water Pond. Flooding of a mine would result in the resurgence of taliks and would isolate the exposed bedrock from further oxidation.

2.4.2 Numerical Groundwater Models and Groundwater Budget

A three-dimensional numerical groundwater flow and solute transport model (Appendix V2-7A) was developed to estimate the quantity and quality of groundwater flow into the mine workings at the Goose Property. The model simulates the progressive excavation of the open pit and underground mines according to the mine plan. The model predicts the yearly average inflow rates and TDS levels of groundwater reporting to the Llama open pit mine as well as Llama, Umwelt, and Goose Main underground mines.

Results from the numerical groundwater model indicate that total groundwater inflows requiring management for the Goose Property will reach a peak of about 830 m^3/day in Year 3 of Operations. More than half of the mine inflows are predicted to come from Umwelt underground, with very minor inflows predicted to occur at Goose Main underground. These will be supplemented by meltwater and surface runoff at the Llama open pit. Actual groundwater pumped volumes may be somewhat less, due to the effects of turbulent flow losses in small aperture fractures adjacent to the mine workings, the removal of some inflow water through evaporation, and removal with waste rock and ore.

At the end of mining, maximum estimated groundwater TDS concentrations at the Umwelt underground are expected to be 60,200 mg/L. Estimated TDS concentrations for other parts of the Goose Property are lower; 22,350 mg/L at the Llama underground, 12,000 mg/L at the Llama open pit, and 34,360 mg/L at the Goose Main underground. Groundwater is anticipated to be calcium-sodium-chloride-dominant. Peak salt loading is expected to occur in Year 5, with an estimated yearly average of 35 tonnes of salt per day. The great majority of salt loading is estimated to come from Umwelt underground.

These estimates are all subject to a degree of uncertainty and represent best estimates only. Sensitivity analyses show inflows are sensitive to assumptions for K, faults and permafrost; inflow quality is sensitive to the assumed baseline TDS profile with depth. The salt loading will be reducing according to the amount of water removed with waste rock and ore.

The results of the numerical model serves as input to the design of the Project water management system. Inflows to the Umwelt, Llama, and Goose Main underground mines, as well as inflows to Llama open pit, will be pumped to the Saline Water Pond during operations. Dewatering of these mines has been included as a component of the Site Water Monitoring and Management Plan (Volume 10, Chapter 7). Details on water volumes can be found in the Water and Load Balance Report (Appendix V2-7H), and the Site-wide Water Management Report (Appendix V2-7I). No other groundwater extractions are planned.

2.4.3 Supporting Documents

Supporting documents describing the groundwater environment and related data collection and analytical methods and results include the following:

- Volume 5 Chapter 2: Permafrost;
- Analytical Results of the Umwelt Westbay Groundwater Sampling Program (Appendix V6-2A);
- Completion Report, Westbay System Monitoring Well: 13-GSE-319 (Appendix V6-2B);
- *Back River 2012 Geotechnical and Hydrogeological Drilling Program Factual Data Report* prepared by SRK Consulting Inc. for Sabina Gold and Silver Corporation (Appendix V6-2C);
- *2013 Geomechanical and Hydrogeological Site Investigation* prepared by Knight Piésold Consultants Inc. for Sabina Gold and Silver Corporation (Appendix V6-2D); and
- *2012 Terrain and Soils Baseline Report* prepared by Rescan Environmental Services Ltd. For Sabina Gold and Silver Corporation (Appendix V5-3A).

3. Limnology and Bathymetry

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3. Limnology and Bathymetry

3.1 EXISTING ENVIRONMENT AND BASELINE INFORMATION

3.1.1 Overview and Regional Setting

The Back River Property (the Property) is located in western Nunavut in the continuous permafrost zone of the continental Canadian Arctic. The Back River Project (the Project) is composed of two main areas, the Goose Property Area and the Marine Laydown Area (MLA), which will be connected by winter ice roads (Figure 3.1-1). The majority of proposed infrastructure at the Goose Property lies within the regional Ellis River Watershed, which flows to the north and enters the Queen Maud Gulf (see Federal Watershed map in Chapter 1 of this Volume). The Back River Watershed lies to the south and east of the majority of proposed infrastructure and flows to the east eventually entering the Arctic Ocean south of Gjoa Haven.

The region containing the Property is characterized by extensive networks of lakes and streams within a hummocky landscape with low elevation relief and exposed bedrock uplands. Winter is characterized by extreme cold (mean monthly temperatures -33°C), and ice cover is present on lakes between October and July. Air temperatures are highest in July, reaching a mean monthly temperature of 14°C. Regional meteorological stations report total annual precipitation between 125 mm (2009) to 344 mm (2007) for the interval 2006 to 2012 (see Volume 4, Chapter 3 for additional information). Ice depths on waterbodies are typically 1.5 to 2 metres thick, and shallow waterbodies (< 1.5 m) freeze to the bottom (Rescan 2011, 2012, 2013a, 2013b).

3.1.2 Baseline Study Area

Freshwater baseline studies have been carried out in the Project area since 1994, with the most continuous sampling conducted by Rescan from 2010 to 2013. Figure 3.1-2 shows the Goose Property Area and associated waterbodies along with the proposed Project infrastructure.

3.1.3 Proximity to Designated Environmental Areas

No existing or proposed parks or conservation areas are located near the proposed Project. The nearest conservation area is the Queen Maud Gulf Migratory Bird Sanctuary approximately 100 km east of Bathurst Inlet on the far side of the Kent Peninsula. The Draft Nunavut Land Use Plan (Nunavut Planning Commission 2012, 2014) has no designated environmental areas within the Freshwater Regional Study Area (RSA), and the proposed Project resides within the area designated as a High Mineral Potential area. The proposed Hiukitak River Cultural Area is on the eastern shore of Bathurst Inlet outside of the Freshwater RSA, and is located approximately 60 km northeast of the proposed Marine Laydown Area (MLA). A key bird habitat site has been identified in the north end of Bathurst Inlet, approximately 150 km to the north of the proposed MLA. The Back River is currently the only waterbody within the RSA to be considered as a heritage river. While no formal nomination for the Back River has been put forward thus far, the Project has been designed to avoid impacts to the Back River water system.

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Figure 3.1-1

Project Location

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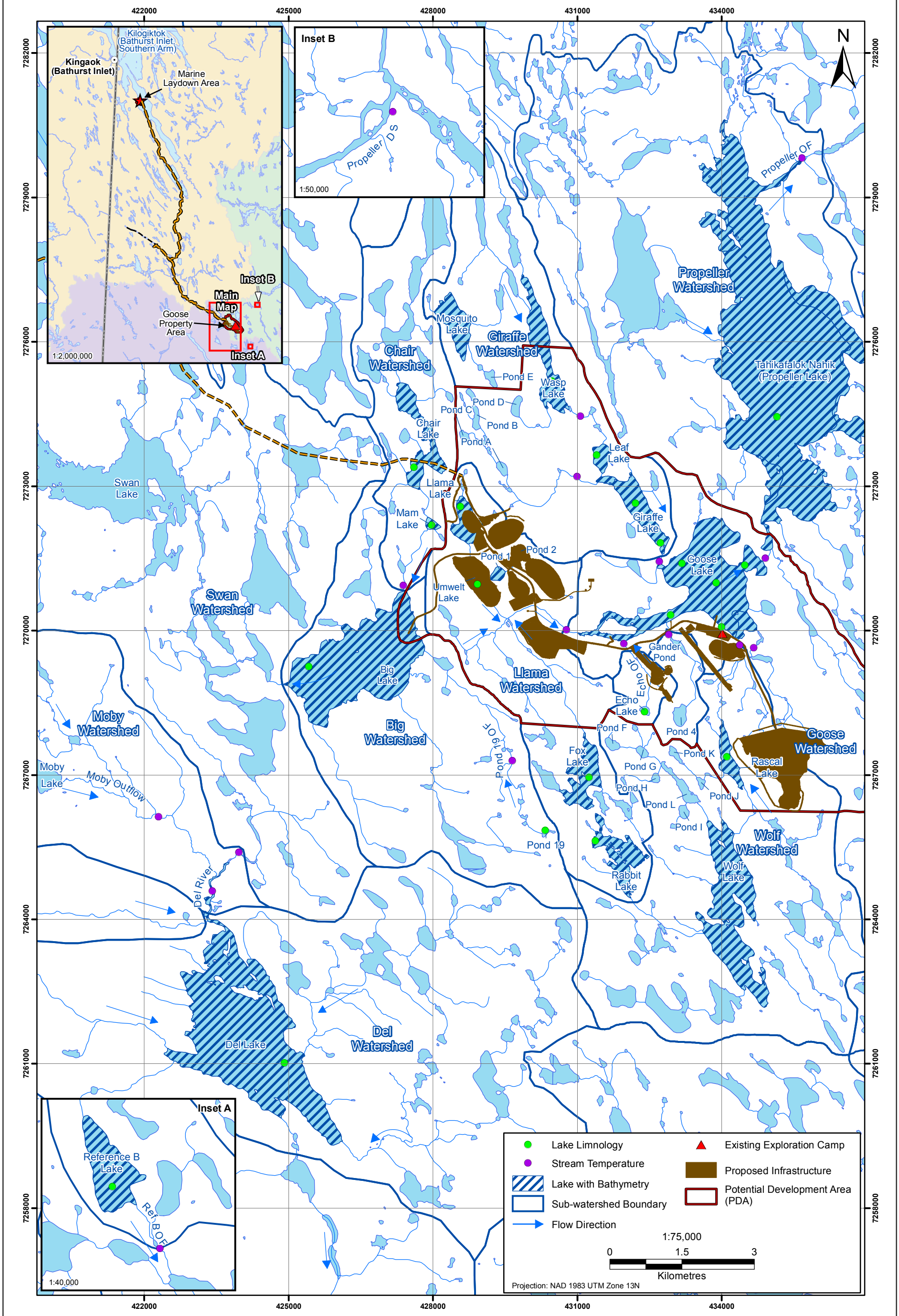

Figure 3.1-2

Limnology and Bathymetry Sampling Conducted in the Goose Property Area for the Back River Project, 1994 to 2013

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3.1.4 Baseline Studies

3.1.4.1 Information Sources

The baseline data on freshwater limnology and lake bathymetry were compiled from recent site-specific surveys in the Project area. The primary sources of baseline physical limnology and bathymetry information used in the FEIS were the following reports:

- *Back River Project: 2010 Lake Water and Sediment Quality Baseline Report* (Rescan 2011; Appendix V6-3A);
- *Back River Project: 2011 Freshwater Baseline Report* (Rescan 2012; Appendix V6-3B);
- *Back River Project: 2012 Freshwater Baseline Report* (Rescan 2013a; Appendix V6-3C); and
- *Back River Project: 2013 Freshwater Baseline Report* (Rescan 2013b).

Other sources of supplementary physical limnology and bathymetry data used in this section included:

- *Environmental Pilot Survey — Goose Lake, NWT* (Bion Research Inc. and Hubert and Associates Ltd. 1994);
- *Back River Project: Environmental Baseline Studies, September 2006* (Golder Associates Ltd. 2007);
- *Field Report — Back River Project Freshwater Aquatic Resources 2007* (Gartner Lee Ltd. 2008); and
- *Back River Geophysical Report 2013* (EBA 2013; Appendix V6-3E).

3.1.4.2 Baseline Study Methods

Lake Limnology and Bathymetry

Sampling for lake limnology and bathymetric information has been conducted from 1994 to 2013, with the details summarized in Table 3.1-1. The sampling components included measuring temperature profiles, bathymetry, and recording the depth of light penetration (water clarity). Temperature profiles in lakes in the 2010 to 2013 baseline programs were recorded at 0.5 m intervals down the water column using a calibrated YSI Pro-ODO optical dissolved oxygen meter. The profiles ended at approximately 0.5 m above the sediment surface to avoid re-suspension of bottom sediments. Prior to 2010, temperature data were collected using an YSI Sonde on discrete water samples collected by Van Dorn and Kemmerer sampling bottles.

Bathymetric surveys from 2010 to 2013 consisted of two parts:

1. The collection of continuous depth measurements along perpendicular and perimeter transects on the lake and pond surfaces using a Differential Global Positioning System (DGPS) and a Garmin depth sounder; and
2. Establishing on-land benchmarks via DGPS surveys of the lake shorelines.

A Trimble PF Power DGPS was used for positioning during the depth survey, and a Garmin depth sounder and a Trimble TSC1 datalogger were used to collect and store the depth data in electronic files. The DGPS and sounder were mounted on the boat for surveys along the lake surfaces.

Table 3.1-1. Baseline Lake Limnology Sampling Conducted for the Back River Project

Year	1994	2006	2007	2010	2011	2012	2013
Sampling month(s)	August	September	July, August, September	August	April, August	April, August	April, July
Sampling agency	Bion Research Inc. & Hubert and Associates Ltd.	Golder Associates	Gartner Lee	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.
Sampling method	Van Dorn discrete sampling bottle	Van Dorn discrete sampling bottle	Grab samples; Kemmerer vertical sampler	YSI Sonde, bathymetry with GPS-integrate depth sounder, Secchi disk	YSI Sonde, DGPS-assisted bathymetry, Secchi disk	YSI Sonde, DGPS-assisted bathymetry, Secchi disk	YSI Sonde, DGPS-assisted bathymetry, Secchi disk
Data collected	Temperature	Temperature	Temperature	Temperature	Temperature, Bathymetry	Temperature, Bathymetry	Temperature, Bathymetry
Lake(s) sampled	Goose Lake	Goose Lake	Goose Lake	Llama Lake* Umwelt Lake* Chair Lake* Mam Lake* Reference B Lake*	Giraffe Lake Llama Lake Pond 1* Pond 2* Umwelt Lake Goose Lake Propeller Lake Reference B Lake	Giraffe Lake* Rabbit Lake* Fox Lake* Echo Lake Rascal Lake Goose Lake* Propeller Lake Pond 19 Big Lake* Moby Lake Del Lake*	Mosquito Lake* Wasp Lake* Leaf Lake† Pond A Giraffe Lake Pond 1* Umwelt Lake Wolf Lake† Rascal Lake* Goose Lake Arrow Lake Propeller Lake* Reference B Lake
Number of replicates per site	1 per depth	1 per depth	1 per depth	1 profile per site	1 profile per site	1 profile per site	1 profile per site
Depths of replicates (m)	Four depths: surface, 10 m, 18 m, and 27 m	7 depths in Goose Lake (0.5 m, 2 m, 4 m, 6 m, 8 m, 10 m, 12 m); 0.5 m in other lakes	1 m below surface and 1 m above sediment in Goose Lake; 1 m below surface in all others	Profile of 0.5 m intervals from 1 m above sediments to surface	Profile of 0.5 m intervals from 1 m above sediments to surface	Profile of 0.5 m intervals from 1 m above sediments to surface	Profile of 0.5 m intervals from 1 m above sediments to surface

Notes:

* *Indicates bathymetry was conducted.*

† *Proposed winter ice road routes were surveyed by ground-penetrating radar in April 2013 (EBA 2013). Various waterbodies were included in this survey. See Appendix V6-3E for details.*

Under-ice bathymetric surveys were conducted in April 2013 using a ground-penetrating radar system following protocols that conformed to DFO requirements for estimating under-ice volumes of winter ice road water sources (EBA 2013; Table 3.1-1). The system used was MALA's Ramac CUII with a 50 MHz rough-terrain antenna. The radar traces were positioned in real-time positioning using a Topcon HyperLite+ GPS/Glonass unit. Surveys were conducted by regularly-spaced transects across the narrow axis of the lake, followed by a longitudinal transect. The data were corrected for ice thickness and GPS offsets, and then interpolated to create the bathymetric model of the lake.

Depth surveys were carried out by navigating a course of regularly spaced transects across the width of each lake, followed by a longitudinal transect through the long axis of the lake (i.e., e-line). A hand-held GPS, pre-loaded with transect tracks, was used to maintain the correct course with the boat.

Light attenuation was estimated in each lake using a 20 cm, black and white Secchi disk. Measurements were collected at each site by lowering the disk on a metred line through the water column on the shaded side of the boat until it disappeared from sight. The depth of disappearance was identified as the Secchi depth.

Stream Temperatures

Baseline stream temperatures were measured in situ using an YSI Sonde (Table 3.1-2; Figure 3.1-2).

3.1.5 Lake Limnology and Bathymetry

Data is available for 18 lakes from the Goose Property Area. A list of the data available for each lake is shown in Table 3.1-1 and lakes are shown on Figure 3.1-2.

3.1.5.1 Lake Limnology

Baseline limnology data has been collected from the Goose Property Area from 2010 to 2013 (Rescan 2011, 2012, 2013a, 2013b). Additional information was collected in the Goose Property Area in 1994, 2006, and 2007 (Table 3.1-1). Physical limnology data included temperature and dissolved oxygen profiles, and Secchi depths for sampled lakes.

Waterbodies were ice covered from October into June, with ice thickness ranging between 1.5 to 2 m (measured in April). Shallow lakes were frozen to the bottom or to a point where very little liquid water existed between the sediments and ice (e.g., Pond 19, Rabbit and Echo lakes in April 2012; Rescan 2013a). Under this solid ice cover, the water column in sampled lakes had a vertical gradient in temperature moving from ~0°C near the ice-water interface to between 3 and 4°C near the sediment-water interface (Figure 3.1-3). These gradients were caused by conductive heat loss combined with minimal mixing and this vertical structure dissipated after ice-out and wind-driven mixing.

During the open water season, most lakes were vertically mixed (e.g., Goose Lake; Figure 3.1-3). Only Llama Lake (depth: 13.6 m) in 2011 had appreciable depth-related changes in water temperature, with a weak thermocline present between 3 and 7 m depth (Figure 3.1-3). Sampled lakes were also sensitive to weather conditions and had considerable variability in water temperatures between months and between years. For example, August temperatures were generally between 10 and 12°C in 2007 and 2012, but were substantially higher in August 2011 around 15°C.

Table 3.1-2. Baseline Stream Temperatures Collected for the Back River Project

Year	1994	2006	2007	2011	2012	2013
Sampling month(s)	August	September	July, August, September	June, August, September	June, August, September	June, July
Sampling agency	Bion Research Inc. & Hubert and Associates Ltd.	Golder Associates	Gartner Lee	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.
Sampling method	YSI Sonde	YSI Sonde	YSI Sonde	YSI Sonde	YSI Sonde	YSI Sonde
Data collected	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature
Stream(s) sampled	Wolf OF Goose IF RM Goose OF	Goose IF RM Echo OF Goose OF	Echo OF Wolf OF Goose IF SE Goose OF Propeller OF	Giraffe OF Llama OF Echo OF Wolf OF Goose OF Propeller OF Propeller D/S Chair OF Reference B OF	Giraffe OF Llama OF Echo OF Wolf OF Goose OF Propeller OF Chair OF Pond 19 OF Del US Moby OF Del IF Reference B OF	Wasp OF TIA OF Giraffe OF Umwelt OF Llama OF Goose Neck IF Goose OF Propeller OF Reference B OF
Number of replicates per site	1	1	1	1	1	1

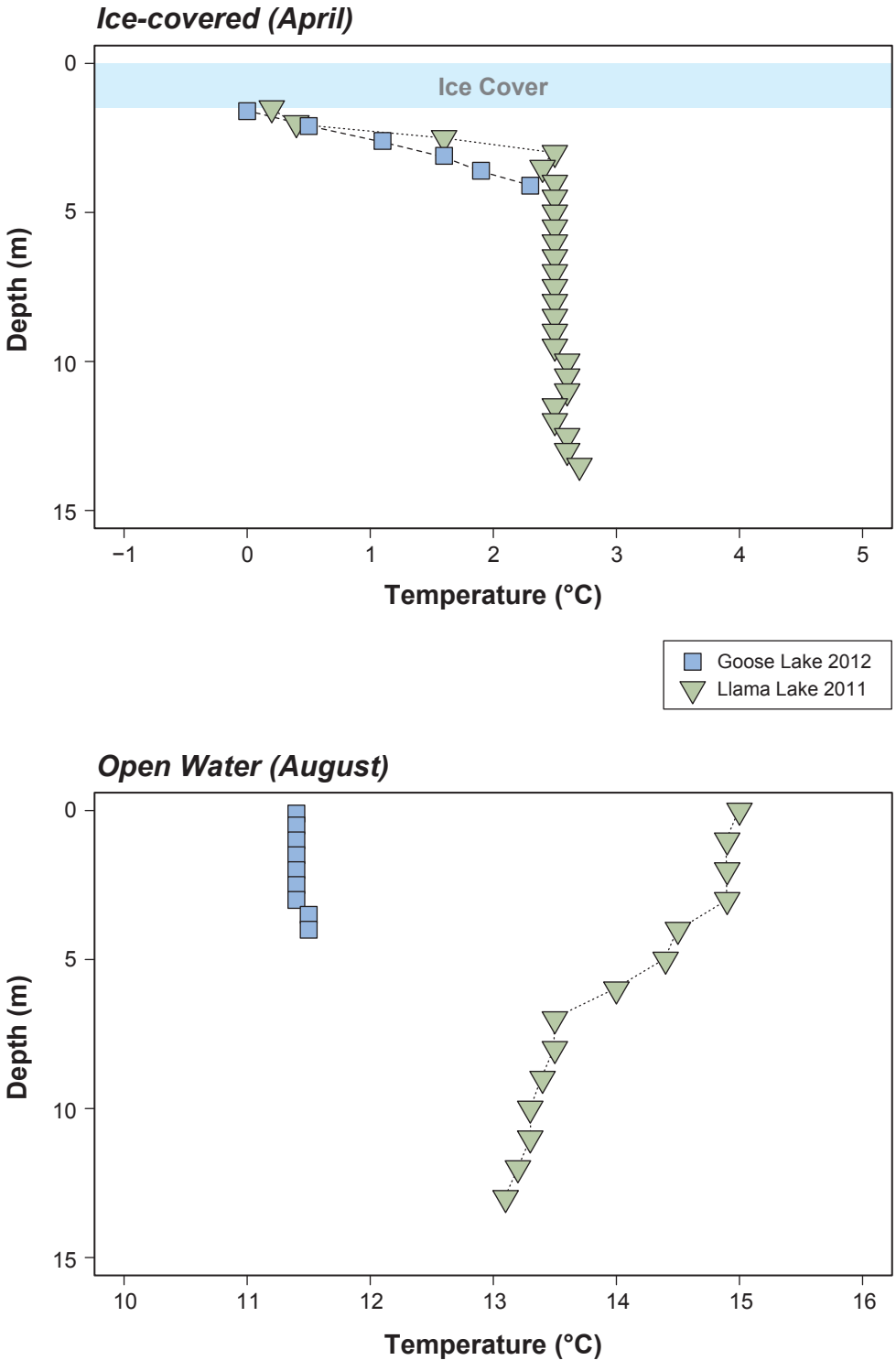


Figure 3.1-3

Temperature Profiles of Goose Lake (Central Site) and Llama Lake in Ice-covered (April) and Open-water (August) Seasons, 2011 and 2012

Sabina GOLD & SILVER CORP.

Rescan an ERM company

Light penetration was estimated by the measured Secchi depths. Secchi depths were generally deeper than the bottom in shallower lakes (i.e., light reached the bottom of the lakes), and ranged from 4.8 to 8.4 m in the deeper lakes (Table 3.1-3). The euphotic depth, the depth with sufficient sunlight for net photosynthesis, generally extended throughout the water column. This indicated that net photosynthesis could occur throughout the entire water column as well as in the benthic habitat.

Table 3.1-3. Summary of Secchi Depths in Goose Property Area Lakes, Back River Project

	Depth, D (m)			Mean Secchi Depth*, D_s (m)	% of Lakes with D_s = D
	Min	Median	Max		
Goose Property Area	0.4	4.5	35	5.7	37

**Only sites with Secchi depths greater than the bottom depth were included in the calculation of mean Secchi depth.*

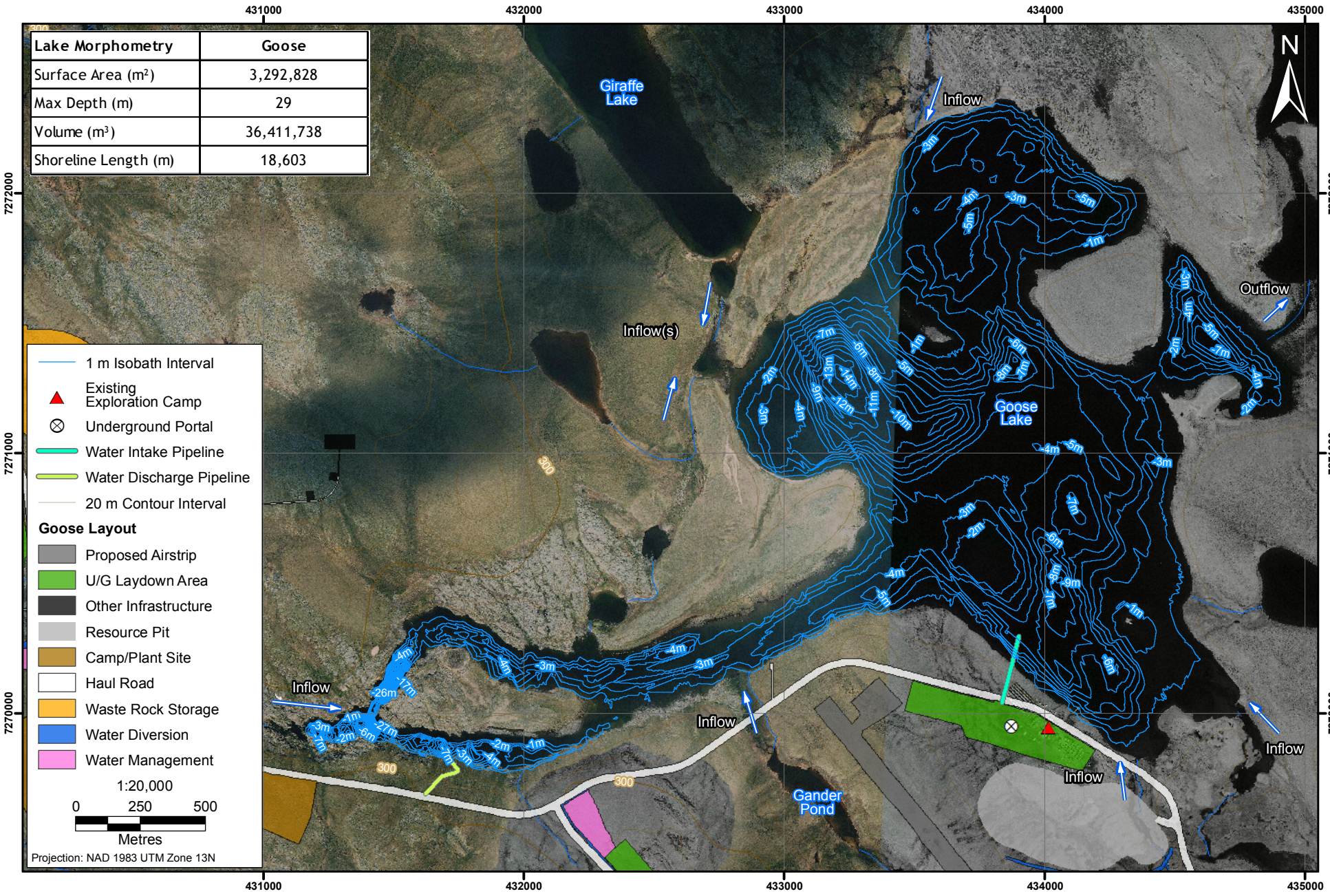
3.1.5.2 Lake Bathymetry

A summary of the lake morphologies including maximum depths are presented in Table 3.1-4 and additional information can be found in Appendix V6-3D. Overall, lakes in the Goose Property Area were shallow due to the low elevation relief in the area, with most lakes sampled having a maximum depth less than 8 m, and a median site depth of 4.0 to 4.5 m (Figures 3.1-4 to 3.1-8). Goose Lake, which is proximate to the majority of the Project infrastructure in the Goose Property Area, had a broad central basin with depths between 4 and 14 m, and a significantly deeper (maximum depth 34.6 m) western arm (Figure 3.1-5). Only the larger lakes (Goose (34.6 m), Llama (13.6 m), and Chair (10.3 m)) had maximum depths greater than 10 m.

Table 3.1-4. Summary of Lake Morphologies in the Goose Property Area, Back River Project

Waterbody	Max Depth (m)	Volume (m^3)	Surface Area (m^2)	Shoreline Length (m)	Source
Goose Property					
Mosquito Lake	6.4	876,290	515,310	4,180	Rescan (2013b)
Wasp Lake	15.7	2,520,390	835,680	8,760	Rescan (2013b)
Leaf Lake†	3.9	367,700	156,000	n/a	EBA (2013)
Giraffe Lake	8.3	1,445,680	631,430	5,570	Rescan (2013a)
Llama Lake	13.6	1,130,610	365,930	3,210	Rescan (2011)
Pond 1	1.8	58,080	66,720	990	Rescan (2012)
Pond 2	1.2	15,280	35,620	1,000	Rescan (2012)
Umwelt Lake	2.7	240,130	193,600	2,410	Rescan (2011)
Rabbit Lake	4.0	645,770	595,760	8,430	Rescan (2013a)
Fox Lake	6.9	1,526,160	720,640	8,960	Rescan (2013a)
Wolf Lake†	2.3	5,148,320	2,270,000	n/a	EBA (2013)
Rascal Lake	3.7	385,390	292,360	3,790	Rescan (2013b)
Goose Lake	34.6	10,669,530	3,295,740	18,600	Rescan (2013a)
Propeller Lake	17.1	52,778,800	12,647,950	38,870	Rescan (2013b)
Chair Lake	10.3	1,355,660	706,280	7,590	Rescan (2011)
Mam Lake	3.8	60,940	76,930	1,380	Rescan (2011)
Big Lake	6.0	12,141,340	4,037,590	12,330	Rescan (2013a)
Del Lake	3.2	10,320,720	6,296,250	22,370	Rescan (2013a)

† Measured under ice using ground penetrating radar (EBA 2013).



Lake Morphometry	Goose
Surface Area (m²)	3,292,828
Max Depth (m)	29
Volume (m³)	36,411,738
Shoreline Length (m)	18,603

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Figure 3.1-4

Bathymetry of Goose Lake, Goose Property Area

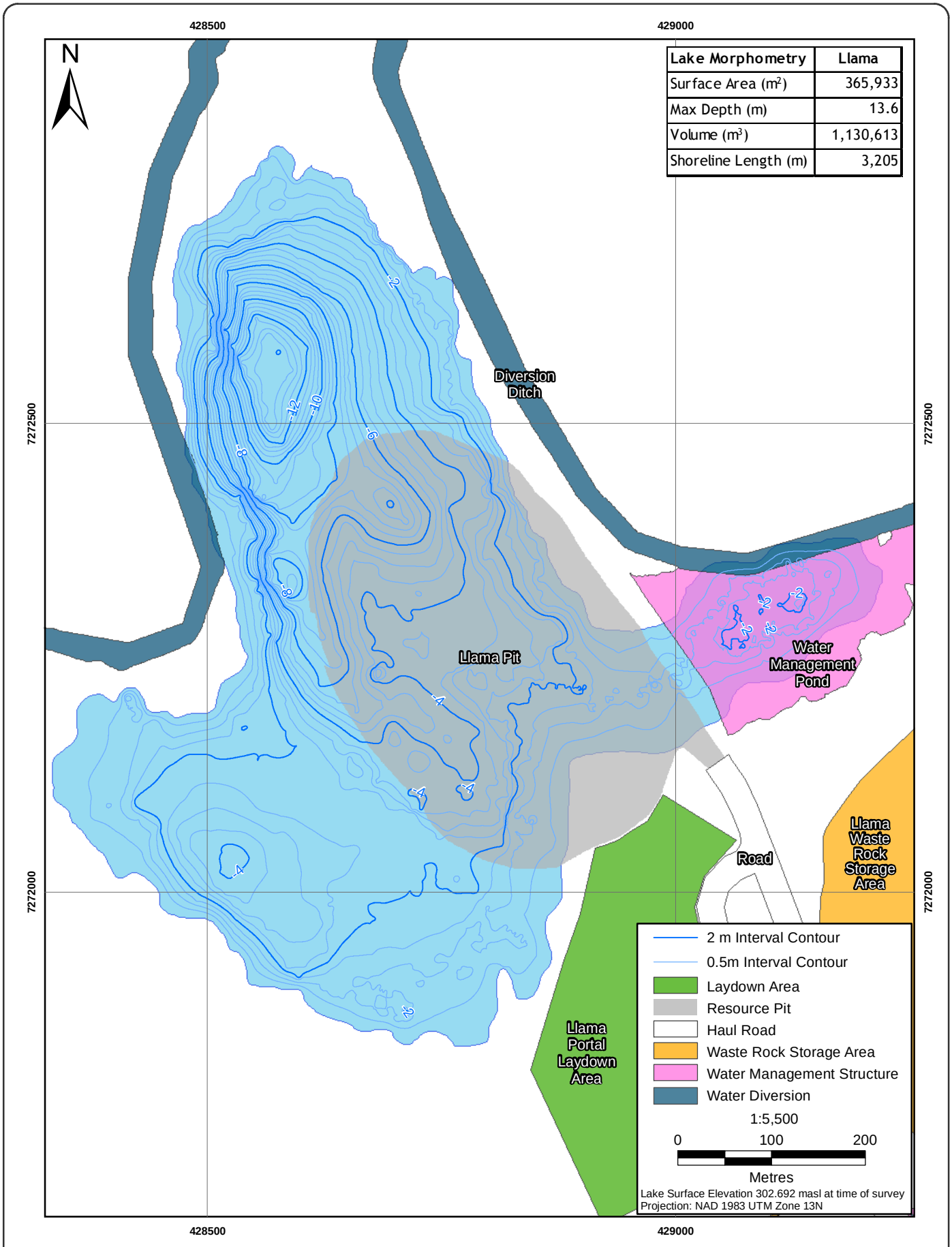

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Figure 3.1-5

Bathymetry of Llama Lake, Goose Property Area

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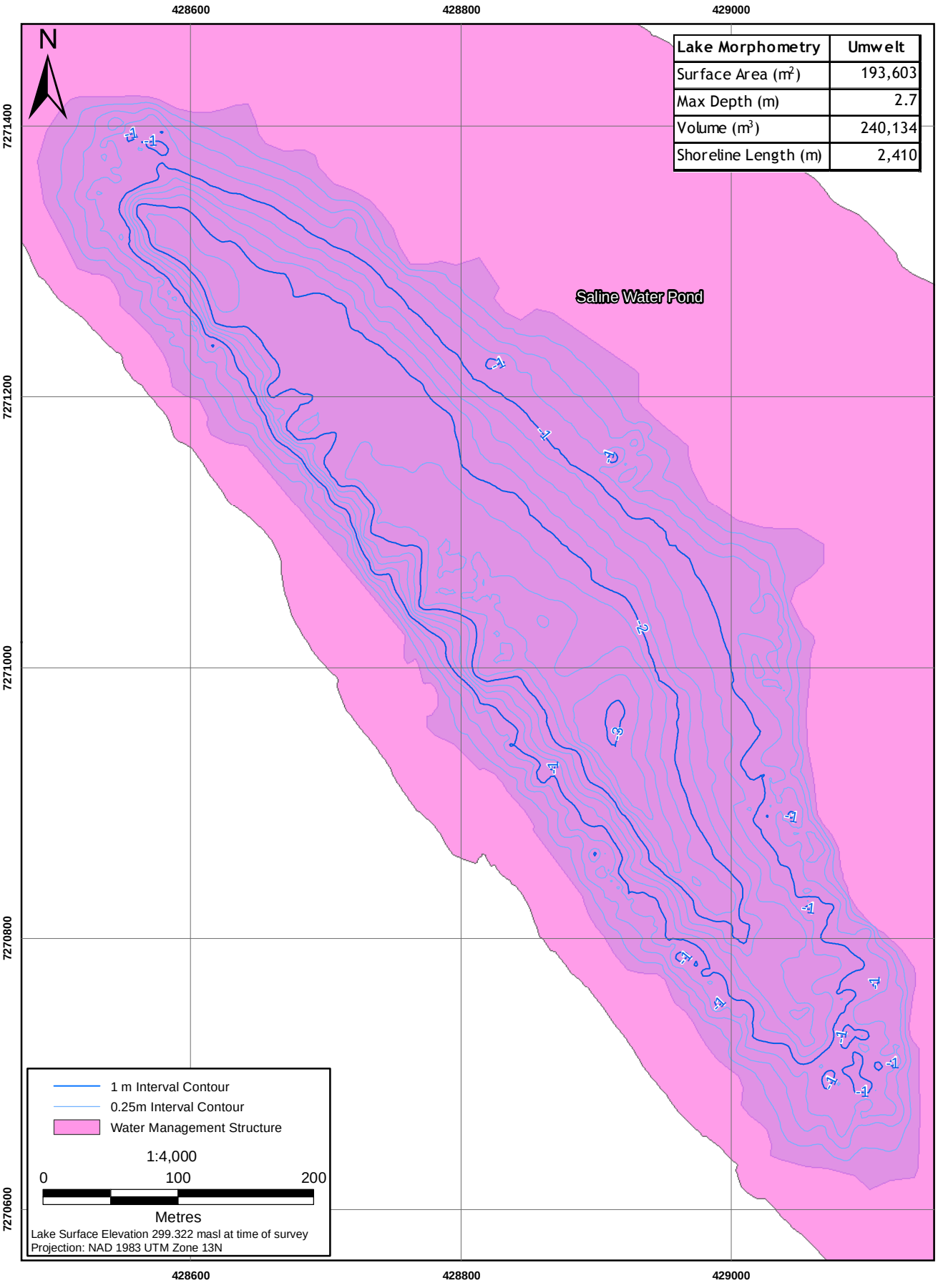

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Bathymetry of Umwelt Lake, Goose Property Area

Figure 3.1-6

Rescan an ERM company

3.1.6 Stream Temperatures

Data are available for 18 streams from the Goose Property Area. A list of the sampled streams is presented in Table 3.1-2 and displayed in Figure 3.1-2.

Stream water temperatures during the freshet in June ranged from 4 to 15°C, and increased to between 8 and 19°C by in August (Table 3.1-5). Temperatures cooled to 1 to 12°C in September along with the falling air temperatures. Substantial inter-annual variation was observed in stream temperatures; for example, June 2012 stream water temperatures were ~7°C cooler than in June 2007 and June 2013.

Table 3.1-5. Summary of Stream Water Temperatures in the Goose Property Area, Back River Project, 1994 to 2013

	Stream Temperature (°C)			
	Min	Mean	Max	n
Goose Property Area				
June	3.5	7.4	14.6	25
July	8.3	13.3	17.8	9
August	7.6	12.6	18.9	30
September	0.7	5.9	12.0	28

3.2 INCORPORATION OF TRADITIONAL KNOWLEDGE (TK)

The effects assessment relies on the information collected from Inuit-led Traditional Knowledge (TK) information, public scoping, focus group meetings, government engagement, and scientific knowledge. To the extent possible, available TK was incorporated into the evaluation of the potential effects of the Project on the environment. The following reports were reviewed for TK specific information related to (VEC or VSEC) features:

- *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* (KIA 2012; Appendix V3-3A of FEIS);
- *Naonaiyaotit Traditional Knowledge Project - Hannigayok (Sabina Gold & Silver Corp. Proposed Back River Project). Results from Data Gaps Workshops, Final Report (June 2014)* (KIA 2014; Appendix V3-3B of FEIS); and
- *Back River Project: Existing and Publically Available Traditional Knowledge from Selected Aboriginal Groups in the Northwest Territories* (Appendix V3-3C of FEIS).

3.2.1 Incorporation of TK for Existing Environment and Baseline Information

The report *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* (KIA 2012) was reviewed for information on freshwater limnology and bathymetry. According to the TK information provided in the NTKP report, Inuit have seen many changes in limnology over the past few decades. TK information documented in the NKTP report and the *BIPR Traditional Knowledge of Wildlife, Fish and Water Quality Report* (Rescan 2007) included observations of shallower lakes and rivers, and reductions in river flow. The changes were attributed to less rain and snowfall and changes in weather. The consultants in the KIA (2012) report stated:

> *"The water is so different now. When it doesn't rain in the summer the lakes have less water in them or when the weather is too hot it evaporates."* (Rescan 2007)

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Lake Morphometry	Propeller
Surface Area (m^2)	12,647,951
Max Depth (m)	17.1
Volume (m^3)	52,652,320
Shoreline Length (m)	34,351

Goose Property Area

5 m Interval Isobath
1 m Interval Isobath
50 m Contour Interval
10 m Contour Interval
Potential Development Area (PDA)

1:24,000

0 500 1,000

Metres

Projection: NAD 1983 UTM Zone 13N

Figure 3.1-7

Bathymetry of Propeller Lake, Goose Property Area

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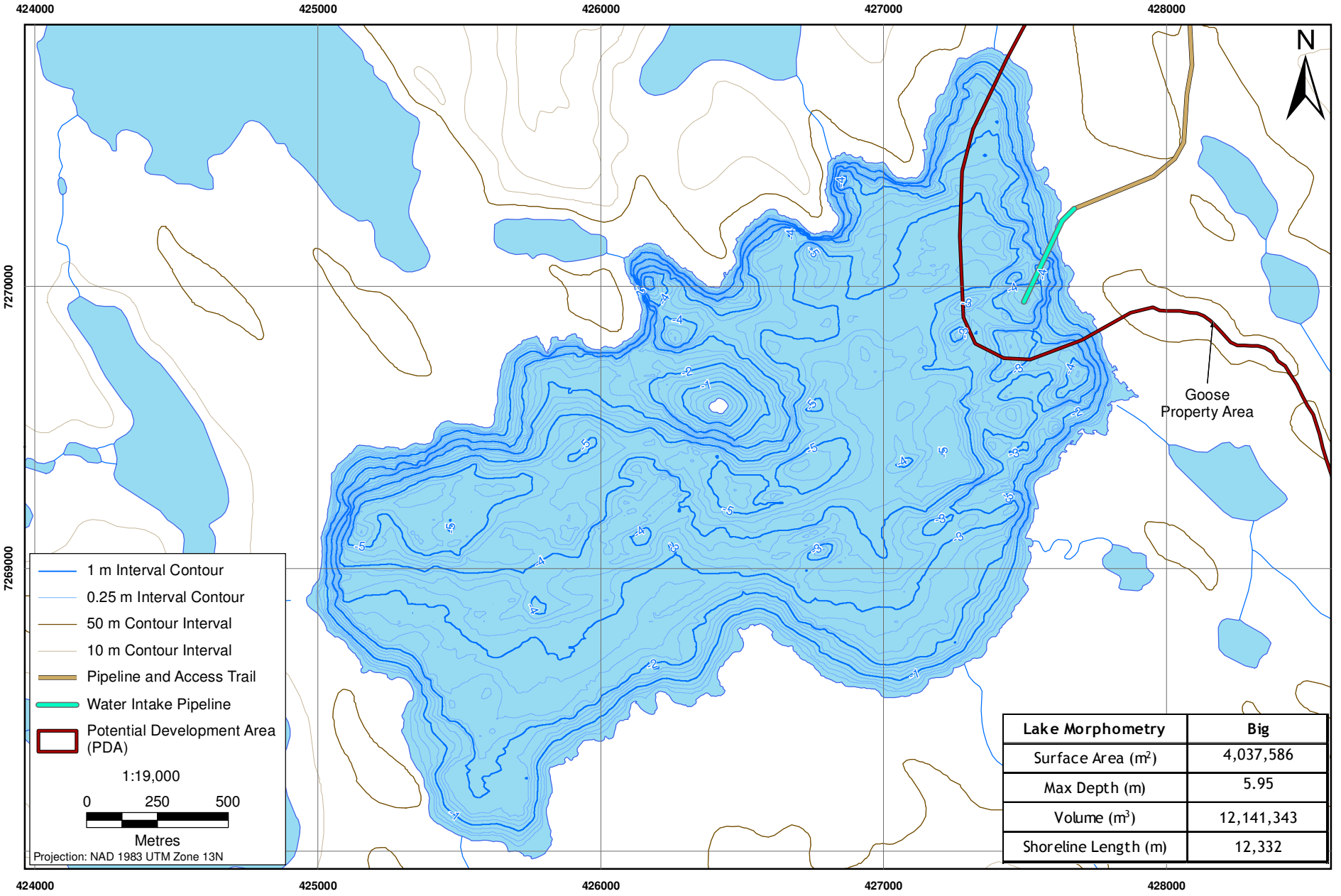

Sabina GOLD & SILVER CORP.

Bathymetry of Big Lake, Goose Property Area

Figure 3.1-8

Rescan an ERM company

> *"The rivers have less water. In winter there's hardly any water in them. You can see rocks."* (Rescan 2007)
>
> *"Water quality at some of the lakes is changing. Some of the lakes are drying up or getting shallower each year. (This has occurred near) that place called Kolgayok (Tingmeak River)…Etibliakyok (Kent Peninsula isthmus), and even around Naoyak (Parry Bay). Some of the lakes and rivers used to be deep and now some are very shallow…*
>
> *The major rivers didn't get too shallow until the fall. Now they are like that (all the time)…I don't know why (water levels) are changing every year. There could be lots of snow during the winter and still they dry up. Long ago this river near Cambridge Bay (Freshwater Creek) used to be deep. We would use our boat to go up river but now we can't…*
>
> *…When it gets too hot during the summer the water gets shallow. The land underground (permafrost) is thawing out compared to long ago. I think that is why. I think the water is seeping into the ground when it thaws. Even the small lakes are drying up because the water is seeping into the ground and (the ground) is staying thawed longer. I think it's like that now even around Ahiak. (He mapped an area at the Kugyoak or Perry River delta near the mouth.) It must be starting to get like that. That is why the small lakes are drying up."* (Rescan 2007)
>
> *"Long ago the rivers had a lot of water and were quite high. When the rivers broke the ice going down river would be tossed around. At Katimanak (where the James and Hood Rivers meet) where Inuit fished, the rivers used to be very strong. Now these rivers don't get very high water and don't toss the river ice anymore, not like long ago. I remember the ice being tossed on top of one another. It doesn't happen like that anymore. When the rivers go in the spring the ice used to go high on the banks of the rivers. It was really thick ice. Now these rivers seem to have very little water and are weak."* (Rescan 2007)

A consultant in the KIA (2014) report noted that open water is present all year on Ekalokhiokvik, which is near the proposed MLA:

> *"… Sometimes they have to go from here by the lakes all the way but you have to be really careful where you go because its open water here (south Ekalokhiokvik). Open year round. They have to travel up to there, through this lake, but you have to go either this way or this way. You end up going all the way up through these lakes (a winter travel route on west side of Bathurst Inlet)."*

According to the TK information, less change had been seen in inland compared to coastal areas.

3.2.2 Incorporation of TK for Valued Ecosystem Component (VEC) Selection

The results of the NKTP report (KIA 2012) were used for scoping and refining the potential Valued Ecosystem Component (VEC) list. The NTKP report presents clear maps of valued animal species, environmental components, and traditional land use activities. This information was used to determine if these valued aspects potentially interacted with the proposed Project, and if so, they were included in the VEC list.

There were few comments related to physical limnology and bathymetry in the TK report, and limnology and bathymetry are considered a Subject of Note for the FEIS. However, information on water quality, including potable water, was present in the TK reports, and water quality and quantity are VECs in the FEIS (see Chapters 1 and 4 of Volume 6).

3.3 VALUED COMPONENTS

3.3.1 Potential Valued Components and Scoping

Physical limnology and bathymetry were included in the scoping and refining process with all other potential VEC/VSECs (see Volume 9, Chapter 1). Based on Sabina-led public consultation, the KIA (2012) report, consultation with regulatory agencies, and regulatory considerations physical limnology and bathymetry was classified as a Subject of Note.

3.3.2 Valued Components Included in Assessment

Physical limnology and bathymetry are considered a Subject of Notes for the FEIS. All information requested in the FEIS Guidelines (NIRB 2013) relating to physical limnology and bathymetry is included in this FEIS.

4. Freshwater Water Quality

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4. Freshwater Water Quality

4.1 EXISTING ENVIRONMENT AND BASELINE INFORMATION

4.1.1 Overview and Regional Setting

The Back River Project (the Project) is located in western Nunavut in the continuous permafrost zone of the continental Canadian Arctic. The Project is composed of two main areas, the Goose Property Area and the Marine Laydown Area (MLA), which will be connected by winter ice roads (Figure 4.1-1). The majority of proposed infrastructure at the Goose Property lies within the regional Ellis River Watershed, which flows to the north and enters the Queen Maud Gulf (see Federal Watershed map in Chapter 1 of this Volume). The Back River Watershed lies to the south and east of the majority of proposed infrastructure and flows to the east eventually entering the Arctic Ocean south of Gjoa Haven.

The freshwater environment Regional Study Area (RSA) is characterized by extensive networks of lakes and streams within a hummocky landscape with low elevation relief and exposed bedrock uplands. Winter is characterized by extreme cold (mean monthly temperatures -33°C), and ice cover is present on lakes between October and July. Air temperatures are highest in July, reaching a mean monthly temperature of 14°C. Regional meteorological stations report total annual precipitation between 125 mm (2009) to 344 mm (2007) for the interval 2006 to 2012 (see Volume 4, Chapter 3 for additional information). Ice depths on waterbodies are typically 1.5 to 2 metres thick, and shallow waterbodies (< 1.5 m) freeze to the bottom (Rescan 2011, 2012, 2013a, 2013b).

Hydrology in the Back River Project area is snowmelt dominated, with peak flows occurring from early May to mid-June in most watersheds. Occasional rainfall-driven high flow events may occur between June and September. The climate and the presence of permafrost results in one major flood period (freshet) in June followed by a rapid return to base flow and peak flow events throughout the rest of the summer and early fall periods in response to storms. Winter flow is absent as streams are frozen to the sediment bed and because of negligible groundwater reserves outside of the permafrost. Streams in the Project area are generally small and shallow and tend to have low flow and low water levels during summer. Many streams are ephemeral, flowing only during freshet.

Mean annual temperature may increase in Canada's North by approximately 2.0°C for the climate normal period for the years 2010 to 2030 (Volume 4, Chapter 3). Over the same time periods, projections suggest that total annual precipitation could increase from 5 to 8% (Lemmen et al. 2008). The projected increase in mean annual air temperatures would lead to effects on the regional cryosphere. This would likely include alterations to sea, river, and lake ice regimes, and winter snow pack, especially during shoulder seasons of spring and fall, as well as to permafrost conditions. Studies of Arctic freshwater systems in the context of climate change conclude that ice-free seasons will be longer resulting in increased evaporation and water temperatures, increased lake stratification, and reduced permafrost (Prowse et al. 2006).

High quality freshwater is considered very important to the Inuit in the area for the provision of potable water and good quality habitat for fish and wildlife (see Section 4.2). High water clarity is one of the key characteristics used by the Inuit to determine water quality.

Figure 4.1-1

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Project Location

4.1.2 Proximity to Designated Environmental Areas

No existing or proposed parks or conservation areas are near the proposed Project. The nearest conservation area is the Queen Maud Gulf Migratory Bird Sanctuary approximately 100 km east of Bathurst Inlet on the far side of the Kent Peninsula. The Draft Nunavut Land Use Plan has no designated environmental areas within the Freshwater RSA and the proposed Project resides within the area designated as a High Mineral Potential area (Nunavut Planning Commission 2014). The proposed Hiukitak River Cultural Area is on the eastern shore of Bathurst Inlet outside of the Freshwater RSA, and is approximately 60 km northeast of the proposed Marine Laydown Area (MLA). A key bird habitat site has been identified in the northern end of Bathurst Inlet, approximately 150 km north of the proposed MLA. The Back River is currently the only waterbody within the RSA to be considered as a heritage river. While no formal nomination for the Back River has been put forward thus far, the Project has been designed to avoid impacts to the Back River water system.

4.1.3 Baseline Study Area

Freshwater baseline studies have been carried out in the Project area from 1993 to 2015, with the most continuous sampling conducted by Rescan Environmental Services Ltd. (Rescan) from 2010 to 2013. Sampling conducted near the MLA is covered in the Marine Environment volume (Volume 7). Figure 4.1-2 shows the Goose Property Local Study Area (LSA) with the proposed Project infrastructure.

4.1.4 Baseline Studies

4.1.4.1 Information Sources

The baseline data on freshwater water quality were compiled from recent site-specific surveys in the Project area. The primary sources of baseline water quality information used in the EIS were the following reports:

- *Back River Project: 2010 Lake Water and Sediment Quality Baseline Report* (Rescan 2011; Appendix V6-3A);
- *Back River Project: 2011 Freshwater Baseline Report* (Rescan 2012; Appendix V6-3B);
- *Back River Project: 2012 Freshwater Baseline Report* (Rescan 2013a; Appendix V6-3C); and
- *Back River Project: 2013 Freshwater Baseline Report* (Rescan 2013b).

Other sources of supplementary water quality data used in this section included:

- *Homestake Goose Lake Project: 1993 Water Quality Report, Goose Lake* (Norecol Dames and Moore 1993);
- *Environmental Pilot Survey — Goose Lake, NWT*. (Bion Research Inc. and Hubert and Associates Ltd. 1994);
- *George Lake Project: 1997 Data* (Norecol Dames and Moore 1997);
- *Summary of Environmental Baseline Data for the Area of George Lake and Goose Lake, Nunavut* (Hubert and Associates Ltd. 2004);
- *Back River Project: Environmental Baseline Studies, September 2006* (Golder Associates Ltd. 2007); and
- *Field Report — Back River Project Freshwater Aquatic Resources 2007* (Gartner Lee Ltd. 2008).

4.1.4.2 Baseline Study Methods

Lakes

Baseline lake water quality data for the area are available from 1993, 1994, 1997, 2010, 2011, 2012, and 2013. Lake water quality data were also collected in 2015, and results will be available in a future report (Rescan 2015). A list of the data available for each lake is shown in Table 4.1-1 and the sampled lakes are shown on Figure 4.1-3.

Water quality samples were collected using a variety of water sampling devices, including acid-washed Niskin or GO-FLO water sampling bottles for the core baseline sampling program from 2010 to 2015 (Table 4.1-1). In the comprehensive baseline surveys from 2010 to 2015, water quality sampling depths were determined based on the water column structure (as determined by the temperature profiles) and whether the sites were deep (> 6 m; two samples per site) or shallow (< 5 m; single sample at 1 m). At the deeper sites, samples were collected 1 m below the water surface (or the bottom of the ice during ice-covered periods) and ~1.5 m above the bottom (ice-covered periods) or mid-depth (open-water).

In the comprehensive baseline surveys from 2010 to 2015, subsamples for the various water quality indicators (e.g., nutrients and metals) were drawn from the GO-FLO/Niskin bottles, with the scientist wearing powder-free nitrile gloves, with care being taken not to bring the bottle or bottle cap into contact with the plastic spigot or other possible sources of contamination. After collection and preservation, all samples were kept cold and in the dark while in the field and refrigerated at camp prior to transport to the analytical laboratory.

Dissolved oxygen profiles in lakes in the 2010 to 2015 baseline programs were recorded at 0.5 m intervals down the water column using a calibrated YSI Pro-ODO optical dissolved oxygen meter. The profiles ended at approximately 0.5 m above the sediment surface to avoid re-suspension of bottom sediments.

Streams

Stream water quality data are available from 1993, 1994, 1997, 2006, 2007, 2010, 2011, 2012, and 2013. Stream water quality data were also collected in 2015, and results will be available in a future report (Rescan 2015). A list of the data available for each stream is shown in Table 4.1-2 and the sampled streams are shown on Figure 4.1-3.

Stream water samples were collected from each site using clean techniques. Where reduced flow was present, samples were collected from stream banks or rocks to prevent contamination from sediments. Samples were always collected where flow was evident. Where flow was high, the field sampler stood facing upstream being careful not to disturb sediments. Where possible, samples were collected from 10 cm depth. After collection and preservation, all samples were kept cold and in the dark while in the field and refrigerated at camp prior to transport to the analytical laboratory.

Water Quality QA/QC

Field duplicates were collected for approximately 20% of samples during each water quality survey. All water quality samples were recorded on chain of custody forms before being sent to the analytical laboratory. Equipment, field, and travel blanks were processed and submitted with the water samples as part of the QA/QC program.

GIS # **BAC-01-106a**

November 9, 2015

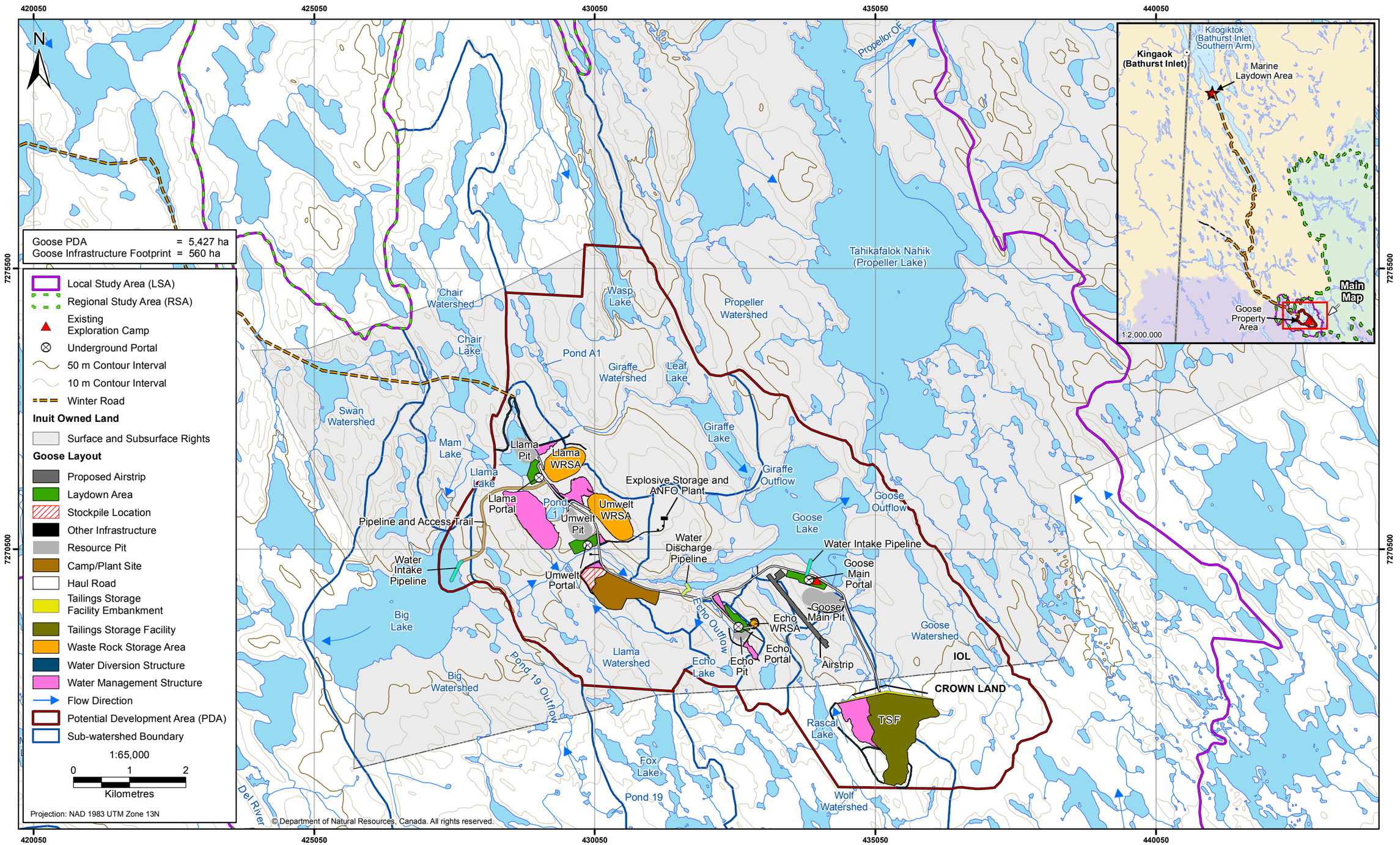

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Figure 4.1-2

Waterbodies in the Goose Property Area

Rescan an ERM company

GIS # BAC-01-106b

November 09 2015

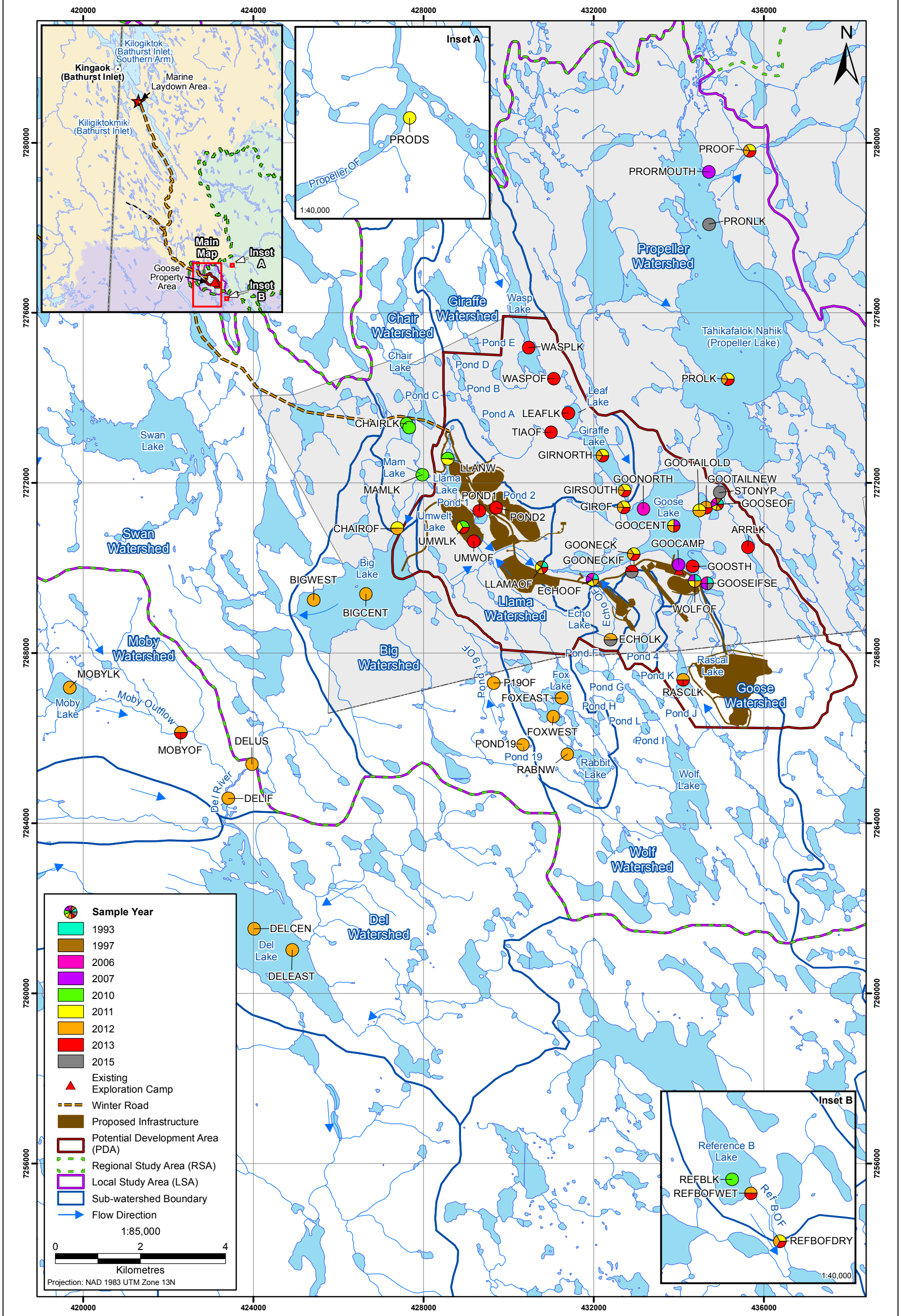


Figure 4.1-3

Locations of Baseline Lake and Stream Water Quality, Goose Property Area, 1993 to 2015

Sabina GOLD & SILVER CORP.

Rescan an ERM company

Table 4.1-1. Baseline Lake Water Quality Sampling Conducted for the Back River Project, 1993 to 2015

Year	1993	1994	1997	2007	2010	2011	2012	2013	2015
Sampling Month(s)	Jun, Aug	Jun, Aug	May, Jul, Aug	Jun/Jul, Aug, Sept	August	April, August	April, August	April, July	August
Sampling Agency	Norecol, Dames and Moore	Bion Research Inc. and Hubert and Associates Ltd.	Norecol, Dames and Moore	Gartner Lee	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	ERM
Sampling Method	Shoreline grab sample	Van Dorn bottle	Methods unavailable	Kemmerer vertical sampler	Niskin (Apr), GO-FLO (August)	Niskin (Apr), GO-FLO (August)	Niskin (Apr), GO-FLO (August)	Niskin (Apr), GO-FLO (August)	GO-FLO
Analytical Lab	ALS Environmental	ALS Environmental	Philip Analytical	ALS Environmental	ALS Environmental	ALS Environmental	ALS Environmental	ALS Environmental	ALS Environmental
Data Collected	Routine, anions, nutrients, total and dissolved metals	Dissolved oxygen, routine, anions, nutrients, total and dissolved metals	Dissolved oxygen, routine, anions, nutrients, total and dissolved metals	Dissolved oxygen, routine, anions, nutrients, total and dissolved metals	Dissolved oxygen, routine, anions, nutrients, total and dissolved metals	Dissolved oxygen, routine, anions, nutrients, total and dissolved metals, cyanides	Dissolved oxygen, routine, anions, nutrients, total and dissolved metals, cyanides	Dissolved oxygen, routine, anions, nutrients, total and dissolved metals, cyanides	Dissolved oxygen, routine, anions, nutrients, total and dissolved metals, cyanides
Lake(s) Sampled	Goose Lake	Goose Lake	Goose Lake	Goose Lake	Llama Lake Umwelt Lake Chair Lake Mam Lake Reference B Lake	Giraffe Lake Llama Lake Umwelt Lake Goose Lake Propeller Lake Reference B Lake	Giraffe Lake Rabbit Lake Fox Lake Echo Lake Rascal Lake Goose Lake Propeller Lake Pond 19 Big Lake Moby Lake Del Lake Reference B Lake	Wasp Lake Leaf Lake Giraffe Lake Umwelt Lake Rascal Lake Goose Lake Arrow Lake Propeller Lake Reference B Lake	Goose Lake Stony Pond Echo Lake Propeller Lake
Number of Replicates per Site	n = 1	n = 1	n = 2	n = 1 at shallow lakes and n = 2 at deep lakes (3 m), with ~10% replication	n = 1 at shallow lakes and n = 2 at deep lakes, with ~10% replication	n = 1 at shallow lakes and n = 2 at deep lakes (5 m), with ~20% replication	n = 1 at shallow lakes and n = 2 at deep lakes (6 m), with ~20% replication	n = 1 at shallow lakes and n = 2 at deep lakes (6 m), with ~20% replication	n = 1 at shallow lakes and n = 2 at deep lakes, with ~20% replication
Depths of Replicates (m)	Unknown	Unknown	Unknown	1 m below the surface and in deep lakes (3 m) 1 m above sediment	1 m below the surface and in deep lakes (5 m) mid depth	1 m below the ice/surface and in deep lakes (5 m) either ~ 1.5 m above sediment (Apr) or mid depth (Aug)	1 m below the ice/surface and in deep lakes (6 m) either ~ 1.5 m above sediment (Apr) or mid depth (Aug)	1 m below the ice/surface and in deep lakes (6 m) either ~ 1.5 m above sediment (Apr) or mid depth (Aug)	1 m below the surface and mid depth

Table 4.1-2. Baseline Stream Water Quality Sampling Conducted for the Back River Project, 1993 to 2015

Year	1993	1994	1997	2006	2007	2011	2012	2013	2015
Sampling Month(s)	June, August	June, August	May, July, August	September	June/July, August, September	June, August, September	June, August, September	June, July	August
Sampling Agency	Norecol, Dames and Moore	Bion Research Inc. and Hubert and Associates Ltd.	Norecol, Dames and Moore	Golder Associates	Gartner Lee	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	ERM
Sampling Method	Grab samples	Grab samples	Grab samples	Grab samples	Grab samples	Grab samples	Grab samples	Grab samples	Grab samples
Analytical Lab	ALS Environmental,	Field measurements	Philip Analytical	Alberta Research Council Laboratory	ALS Environmental	ALS Environmental	ALS Environmental	ALS Environmental	ALS Environmental
Data Collected	Routine, anions, nutrients, total and dissolved metals	Routine[†], anions, nutrients, total and dissolved metals	Routine, anions, nutrients, total and dissolved metals	Routine[†], anions, nutrients, total and dissolved metals	Routine[†], anions, nutrients, total and dissolved metals	Routine, anions, nutrients, total and dissolved metals, cyanides	Routine, anions, nutrients, total and dissolved metals, cyanides	Routine, anions, nutrients, total and dissolved metals, cyanides	Routine, anions, nutrients, total and dissolved metals, cyanides
Stream(s) Sampled	Llama OF Echo OF Goose Neck IF Wolf OF Goose Southeast IF	Llama OF Echo OF Goose Neck IF Wolf OF Goose Southeast IF Goose OF	Llama OF Goose OF	Echo OF Goose Southeast IF Goose OF	Echo OF Wolf OF Goose Southeast IF Goose OF Propeller OF Downstream	Giraffe OF Llama OF Wolf OF Goose OF Propeller D/S Chair OF Reference B OF	Giraffe OF Llama OF Echo OF Wolf OF Goose OF Propeller OF Chair OF Pond 19 OF Del US Moby OF Del IF Reference B OF	Wasp OF Giraffe IF Giraffe OF Umwelt OF Llama OF Goose Neck IF Goose OF Propeller OF Reference B OF	Goose Neck IF Goose Southeast IF
Number of Replicates per Site	n = 1	n = 1	n = 1	n = 1	n = 1	n = 2	n = 2	n = 2	n = 2

[†]pH measurements of stream water were conducted using field probes and laboratory measurements in 1994, 2006, and 2007. Otherwise, the reported baseline pH data were collected from discrete water quality samples.

4.1.5 Lake Water Quality

Lakes are important parts of the freshwater system because they are habitats for aquatic organisms, serve as water sources for many terrestrial organisms, and are significant sources of water for human uses. Lakes are a significant component of the landscape in the Project area and comprise 13% of the LSA (Volume 6, Chapter 1). Water quality is defined as a suite of chemical and physical parameters that describe the characteristics of water in terms of meeting the needs of aquatic and terrestrial organisms, ecosystem functions, human uses, and aesthetics. All water quality parameters are naturally variable due to heterogeneity in the landscape, biogeochemical cycling, weather, and climate. The baseline sampling program served to measure this natural variation to identify potential Project effects on water quality.

4.1.5.1 General Lake Parameters

General chemical characteristics of lake water include pH, alkalinity, hardness, conductivity, and total dissolved solids. pH is an important indicator that describes the acid-base balance of water and influences many chemical reactions that can in turn shape biological communities through species-specific tolerances. Alkalinity describes the buffering capacity of water, whereas hardness, conductivity, and total dissolved solids are measures of the quantity of dissolved compounds. The toxicity of some metals and compounds may depend on the pH or hardness of the water.

Lakes in the LSA were generally slightly acidic to neutral (Table 4.1-3). The lakes tended to be more acidic during the open-water season than during the ice-covered season, perhaps due to increased inputs from acid sources in runoff or decreased rates of open-water photosynthesis (Rescan 2011, 2012, 2013a, 2013b). pH levels below the CCME guideline range of 6.5 to 9.0 were periodically observed in Goose Lake (June and August 1993, May 1997), Chair, Mam and Reference B lakes (August 2010), Goose Lake (August 2011) and Rabbit and Rascal lakes (August 2012).

Table 4.1-3. Summary of Lake Water Chemistry in the Goose Property Area, 1993 to 2013

Parameter	n	Min	Mean	Max	% Samples Outside of CCME Guidelines
pH	98	4.8	6.9	8.1	10
Total Alkalinity (mg $CaCO_3$/L)	95	2.3	6.4	32.5	-
Hardness (mg $CaCO_3$/L)	98	3.6	15.3	81.5	-
Conductivity (µS/cm)	98	11	39.5	174	-
Total Dissolved Solids (mg/L)	98	4	30.0	128	-

** The minimum value for total alkalinity shown is calculated as ½ of the lowest analytical detection limit.*

Lakes in the LSA had soft water (mean hardness (< 60 mg $CaCO_3$/L) and were poorly buffered (mean total alkalinity < 15 mg $CaCO_3$/L), with low levels of total dissolved solids and conductivity (Table 4.1-3).

4.1.5.2 Lake Total Suspended Solids and Turbidity

The concentration of total suspended solids (TSS) and turbidity are related measures describing the quantity of particulate material, primarily sediment, suspended in the water and therefore affect water clarity. Lakes in the Project LSA had low TSS and turbidity levels (Table 4.1-4), which was consistent the generally clear water found in Arctic lakes (Volume 6, Section 3.1.5.1). The Project area is characterized by igneous geology that weathers slowly and generally low overland water flow. These factors limit particulate material in runoff. The natural variation in TSS concentrations and

turbidity result from spatial differences in terrestrial runoff, surrounding cover, bathymetry, and mixing due to temporal changes from season and weather.

Table 4.1-4. Summary of Lake Water TSS and Turbidity in the Goose Property Area, 1993 to 2013

Parameter	n	Min	Mean	Max
TSS (mg/L)	98	0.5*	1.63	7.0
Turbidity (NTU)	93	0.13	0.35	1.1

**The minimum value shown is calculated as ½ of the lowest detection limit.*

4.1.5.3 Lake Dissolved Oxygen

Dissolved oxygen concentration is an important environmental parameter that has major effects on the chemistry and aquatic life of freshwater ecosystems. Atmospheric influx is the largest source of oxygen for most aquatic systems, with aquatic photosynthesis supplying oxygen when conditions favour the growth of primary producers. Respiration and the re-mineralization of organic matter consume oxygen. Therefore, the dissolved oxygen concentration, at any moment, is the balance between oxygen consumption, oxygen production (photosynthesis), and atmospheric influx. Water column mixing processes are very important for oxygen concentrations, particularly at depth, given the principal role of atmospheric influx.

Dissolved oxygen concentrations generally decreased from the ice-water interface toward the sediments during the ice-covered season (Figure 4.1-4). At the ice-water interface, dissolved oxygen concentrations were between 12 mg/L and 15 mg/L and over 90% saturated in most lakes. This suggests that actively photosynthesizing algae were the likely oxygen source during the under-ice period, since atmospheric exchange was limited by the ice-cover. Near-sediment oxygen concentrations less than 1 mg/L were observed under the ice in Propeller, Big, and Giraffe lakes. Many lakes in the LSA had near-sediment dissolved oxygen concentrations less than the CCME water quality guideline for the protection of aquatic life for all life stages (6.5 mg/L).

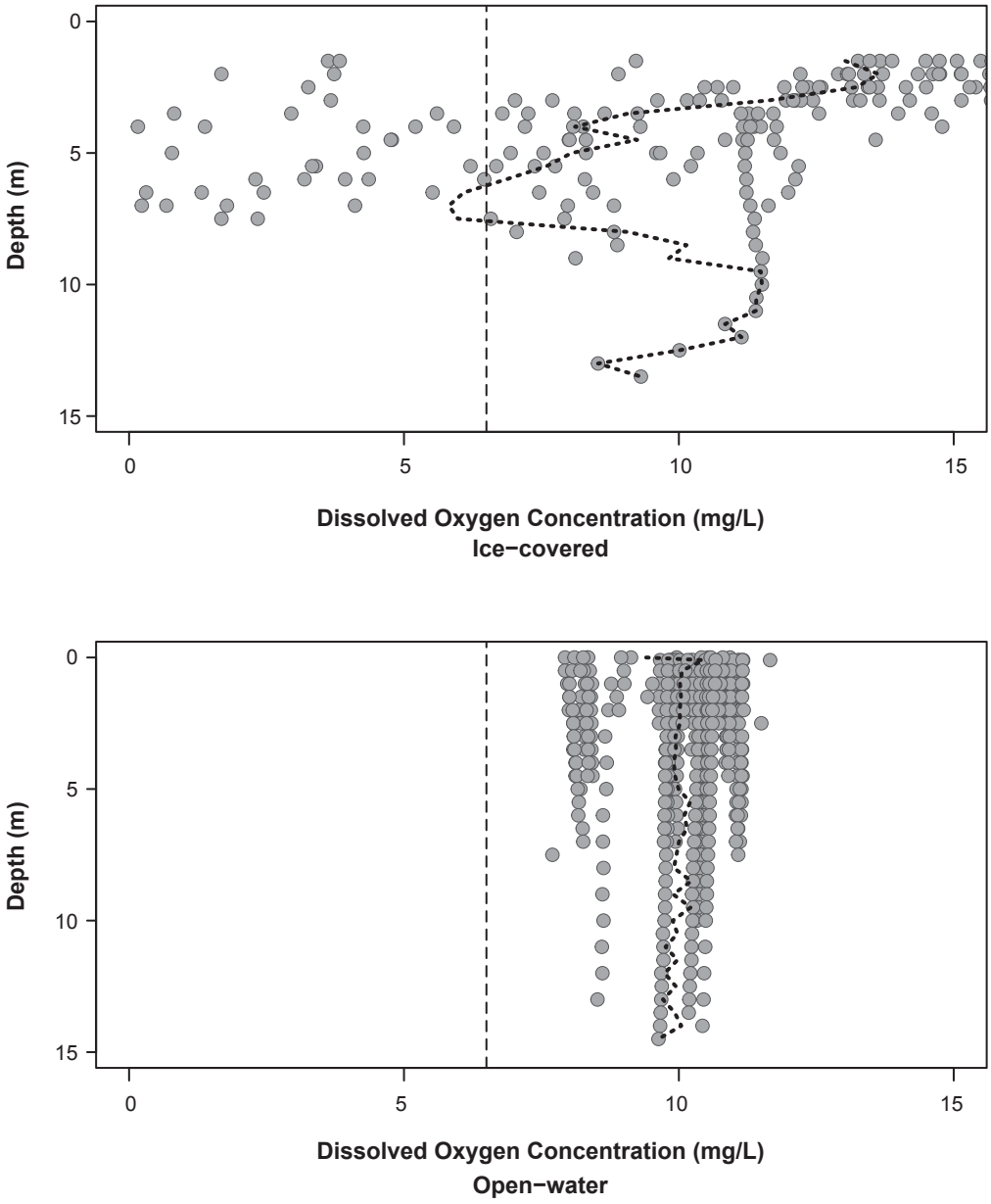
Dissolved oxygen concentrations averaged 10.0 mg/L (ranged between 7 mg/L and 12 mg/L) in LSA lakes. Dissolved oxygen saturation levels followed a similar trend, ranging from 85 to 100%.

Dissolved oxygen concentrations were greater than the CCME guideline for early life stages (9.5 mg/L) and other life stages (6.5 mg/L; CCME 2015) at all LSA lake sites at all depths in the open-water season.

4.1.5.4 Lake Nutrients

Nutrients are the chemicals required by photosynthetic organisms for growth and productivity and ultimately serve as building blocks for organic matter flowing through aquatic food webs. Variation in nutrient concentrations can be caused by periodic mixing, terrestrial runoff events, changes in allochthonous inputs from the surrounding terrestrial environment, and variations in nutrient uptake by primary producers.

The LSA lakes were considered nutrient poor, with concentrations often less than their analytical detection limits (Table 4.1-5). Ammonia and nitrate concentrations were usually greater in April than in August, likely due to utilization by primary producers in summer (Table 4.1-5). Ammonia concentrations were always less than 0.1 mg/L and were much less than relevant pH- and temperature-dependent CCME guidelines (CCME 2015). Nitrate-N concentrations were generally less than 0.04 mg/L, except in Del Lake where they were nearly an order of magnitude greater (0.31 mg/L) in April 2012 (Rescan 2013a). Nitrite concentrations were always less than their analytical detection limits (0.001 mg/L) and the CCME guideline concentration of 0.06 mg/L (CCME 2015).



Notes: The dotted line shows the mean dissolved oxygen concentration at that depth from all lakes in that season and property area. The dashed line shows the CCME Water Quality Guideline for the Protection of Aquatic Life for dissolved oxygen at all life stages except for early life (6.5 mg/L).

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Dissolved Oxygen Concentrations in Lakes in Under-ice and Open-water Conditions in the Goose Property Area, 2010 to 2013

Figure 4.1-4

Rescan Engineers & Scientists

Table 4.1-5. Summary of Lake Water Nutrient Concentrations in the Goose Property Area, 1994 to 2013

Nutrient	n	Min	Mean	Max	% of Samples with Concentrations above CCME Guidelines‡
Nitrate-N (mg/L)†	96	0.0025*	0.014	0.31	0
Ammonia-N (mg/L)	98	0.0025*	0.013	0.081	0
Total Phosphorus (mg/L)	95	0.002	0.005	0.040	0
Orthophosphate (mg/L)	96	0.0005*	0.0006	0.004	0

Note: Lake total phosphorus samples from 2007 were excluded from the baseline information because only the orthophosphate chemical form, and not total phosphorus, was analyzed. To ensure the baseline data were comparable across years, and comparable to relevant guidelines, only water quality data with measurements of total phosphorus were included in the baseline analysis.

‡ CCME water quality guidelines for the protection of aquatic life (CCME 2015).

** The minimum value shown is calculated as ½ of the lowest detection limit.*

† All nitrate concentrations were significantly less than the conservative long-term CCME guideline for nitrate of 13 mg/L.

Orthophosphate concentrations were at or less than detection limits for all lakes and total phosphorus concentrations were generally low (Table 4.1-5). Most lakes could be classified as ultra-oligotrophic (< 0.004 mg TP/L) or oligotrophic (0.004 to 0.01 mg TP/L) according to CCME trigger ranges for phosphorus in freshwater systems (Table 4.1-6; CCME 2015). However, variation was observed within lakes and between seasons and years that could result in changes according to the CCME trigger ranges. Exceptions included Del Lake in April, which had a total phosphorus concentration of 0.0101 mg/L, just above the 0.01 to 0.02 mg/L CCME trigger range for mesotrophic lakes, and the shallow Echo Lake that would be classified as meso-eutrophic (0.02 to 0.035 mg/L; Rescan 2013a).

Table 4.1-6. Distribution of Samples from Waterbodies by CCME Total Phosphorus Trigger Ranges, 1993 to 2013

Trophic Status	Total Phosphorus Concentration	Lakes
Ultra-oligotrophic	< 0.004 mg/L	Big Lake, Fox Lake, Giraffe Lake, Goose Lake, Leaf Lake, Llama Lake, Moby Lake, Pond 19, Propeller Lake, Rabbit Lake, Rascal Lake, Reference B Lake, Umwelt Lake, Wasp Lake
Oligotrophic	0.004 – 0.010 mg/L	Big Lake, Chair Lake, Fox Lake, Del Lake, Giraffe Lake, Goose Lake, Llama Lake, Mam Lake, Propeller Lake, Rascal Lake, Reference B Lake, Umwelt Lake, Wasp Lake
Mesotrophic	0.010 – 0.020 mg/L	Arrow Lake, Del Lake, Umwelt Lake
Meso-eutrophic	0.020 – 0.035 mg/L	Echo Lake, Goose Lake
Eutrophic	0.035 – 0.1 mg/L	Goose Lake
Hypereutrophic	>0.1 mg/L	-

Note: Total phosphorus trigger ranges may vary within lakes between years and seasons; as a result, lakes may be listed under multiple trigger ranges. Note the variability of total phosphorus concentrations in some lakes like Goose Lake, which ranged from the ultra-oligotrophic to eutrophic trigger ranges in the baseline sampling program.

4.1.5.5 Lake Metals

Many metals are biologically significant chemical constituents of water because they are required nutritional co-factors for organisms. However, some metals may become toxic to aquatic organisms at elevated concentrations, particularly in acidic, soft-water environments. Understanding the natural variability in metal concentrations is an important component of the baseline water quality sampling program. Overall, the Project area lakes generally had low metal concentrations (Table 4.1-7). Metals

concentrations were sometimes greater during the ice-covered season due to solute exclusion during ice formation, changes in redox chemistry, increased remineralization, and/or decreased biological uptake. There was no clear spatial trend in metal concentrations, with no sites having consistently high or low metal concentrations. Complete details of the baseline data for metals in freshwater were provided in baseline reports (Rescan 2011, 2012, 2013a, 2013b). Many metal samples were near or less than their analytical detection limits, particularly measurements of arsenic, cadmium, chromium, lead, mercury, and uranium.

Table 4.1-7. Summary of Lake Water Metal Concentrations in the Goose Property Area, 1993 to 2013

Metal	n	Total Metal Concentration (mg/L)			% of Samples with Concentrations above CCME Guidelines*
		Min	Mean	Max	
Aluminum	91	0.0015[†]	0.017	0.071	9
Arsenic	91	0.000025[†]	0.00026	0.0016	0
Boron	91	0.0025[†]	0.0053	0.026	0
Cadmium[‡]	91	0.000005[†]	0.000008	0.000044	19[a]
Copper	91	0.00073	0.0020	0.0068	35
Iron	91	0.005[†]	0.060	0.59	3
Lead	91	0.000025[†]	0.00024	0.0099	2
Mercury[b]	93	0.000005[†]	0.000006	0.000025[a]	0
Molybdenum	91	0.000025[†]	0.000033	0.0002	0
Nickel	91	0.0007	0.0055	0.047	1
Uranium	88	0.000005[†]	0.000007	0.000032	0
Zinc	91	0.0005[†]	0.0024	0.019	0

Note: Samples collected in the 2006 and 2007 programs were excluded because of high analytical detection limits.
** CCME water quality guidelines for the protection of aquatic life (CCME 2015).*
[†] The minimum value shown is calculated as ½ the lowest detection limit.
[‡] 75% of cadmium concentrations were less than analytical detection limits.
[a] Cadmium guidelines are hardness-dependent and were frequently less than analytical detection limits. Only samples with values above the analytical detection limits were considered for comparison with the CCME guidelines.
[b] 99% of mercury concentrations were less than analytical detection limits.

Naturally elevated concentrations of copper and cadmium were observed in some lakes and likely resulted from the proximity of the lakes to metal-bearing minerals in the landscape (Table 4.1-7). These naturally-elevated metal concentrations were greater than their CCME guideline levels in a number of lake samples in the Project area (Table 4.1-8). Copper concentrations were greater than their CCME guideline in 35% of LSA lake samples. Many lakes proximate to proposed Project activities had naturally elevated copper concentrations (e.g., Goose Lake). Aluminum, iron, lead, and nickel concentrations were rarely greater than CCME guidelines in a subset of Project lakes proximate to deposits and proposed activities (e.g., Goose, Echo, and Rascal lakes).

Cadmium and mercury concentrations were frequently near or less than analytical detection limits, which inhibited confident interpretation of trends. The data for cadmium and mercury were included for completeness. In addition, the analytical detection limit for cadmium concentrations were also frequently near or greater than the hardness-dependent CCME guidelines and only the samples with cadmium concentrations greater than the analytical detection limits were included in the analysis.

Table 4.1-8. Water Quality Parameters with Sample Concentrations Greater than CCME Guideline Values in Goose Property Lakes, 1997 to 2013

Lake	Parameters with Values Greater than CCME Guidelines
Goose Lake	pH*, Al, Cd, Cu
Llama Lake	Cu
Umwelt Lake	Cu
Chair Lake	pH*, Al
Mam Lake	pH*, Al
Giraffe Lake	Cd, Cu
Wasp Lake	Cd, Cu, Pb
Echo Lake	Cu, Fe
Pond 19	Cu
Arrow Lake	Cu, Fe
Leaf Lake	Cu
Propeller Lake	Cd
Big Lake	Cu
Del Lake	Cd, Cu, Fe
Moby Lake	Cd, Cu, Ni
Reference B Lake	pH*, Al
Rascal Lake	pH*, Al, Cu
Fox Lake	Pb
Rabbit Lake	pH*, Al, Cu

Note: Exceedances are listed if sample concentration was greater than the CCME guidelines.
Al = aluminum, Cd = cadmium, Cu = copper, Fe = iron, Pb = lead, Ni = nickel.
** CCME water quality guidelines for pH in freshwater environments range from 6.5 to 9.0; all observations of pH outside of this range in Goose Property lakes were less than 6.5.*

4.1.5.6 Lake Cyanide

Cyanide is a naturally-occurring organic nitrogen compound produced by micro-organisms and plants. Baseline sampling for cyanide concentrations in lake water has been conducted since 1997. Free cyanide was only detected in one sample from Goose Lake (August 2011) and was less than the CCME guideline for free cyanide (0.005 mg/L) in freshwater (Table 4.1-9).

Table 4.1-9. Summary of Lake Water Free Cyanide Concentrations (mg/L) in the Goose Property Area, 1997 to 2013

n	Min	Mean	Max
69	0.0005*	0.0008†	0.0029‡

** The analytical detection limits for total cyanide ranged from 0.001 to 0.005 mg/L; the minimum value shown is calculated as ½ of the lowest detection limit.*
† The mean value was inflated due to elevated analytical detection limits and not necessarily due to greater water cyanide concentrations.
‡ All lake water free cyanide concentrations were less than the CCME guideline of 0.005 mg/L (CCME 2015).

4.1.6 Stream Water Quality

Streams are the other significant component of freshwater environments in the Project area. Streams are hosts to many aquatic organisms, serve as water sources for many terrestrial organisms, and are valuable sources of water for human uses. Streams in the Project area are seasonal and usually

flow between June and September, with many streams flowing ephemerally during this period. Like in lakes, all water quality indicators in streams are naturally variable due to heterogeneity in the landscape, biogeochemical cycling, weather, and climate. The baseline sampling program served to measure this natural variation to identify any future Project effects on water quality.

4.1.6.1 General Stream Parameters

The streams in the LSA were largely circum-neutral, with pH levels ranging from 5.6 to 8.2 (Table 4.1-10; Rescan 2011, 2012, 2013a, 2013b). Laboratory-measured pH values were presented because field-measured pH baseline data was only available for 2006 and 2007. Furthermore, calibration records for the 2006 and 2007 field pH were not available. In general, field pH measurements were circum-neutral, but were modestly higher than laboratory measurements from the same sampling locations (Table 4.1-11).

Most streams had their lowest pH in June and highest pH in August, with the seasonal differences likely due to seasonal variation in runoff (highest in June) and photosynthesis and biogeochemical cycling (higher in August). The lowest pH levels were less than the CCME guideline range (6.5 to 9.0) at Chair OF in June 2012 (6.1) and Echo OF in June and Sept 2012 (6.0; Rescan 2013a). Echo OF was also less than the CCME guideline range in 2011, with an average pH of 5.87 (Rescan 2012).

Similar to lakes, streams in the LSA also had low buffering capacity and soft water (hardness < 60 mg $CaCO_3$/L; Table 4.1-10; Rescan 2011, 2012, 2013a, 2013b).

Table 4.1-10. Summary of Stream Water Chemistry in the Goose Property Area, 1993 to 2013

Parameter	n	Min	Mean	Max	% Samples Outside of CCME Guidelines
pH	109	5.6	6.7	7.5	20
Total Alkalinity (mg/L $CaCO_3$)	104	1.8	5.0	17	-
Hardness (mg $CaCO_3$/L)	109	0.5*	16	133	-
Conductivity (µS/cm)	109	10.5	40	334	-
Total Dissolved Solids (mg/L)	109	1*	36	403	-

** The minimum value shown is calculated as ½ the lowest detection limit*

Table 4.1-11. Summary of pH Data for Goose Property Area Streams Collected using Field Probes in 1994, 2006, and 2007, and using Laboratory Analyses in 1993, 2010, 2011, and 2012

		Laboratory-measured pH			
Site	Field-measured pH	Min	Median	Max	*n*
Echo OF	7.6 (2006) 6.13 (2007)	5.72	6.10	6.6	15
Goose IF SE	7.0 (1994) 8.9 (2006) 6.42, 7.00, 7.03 (2007)	5.75	6.60	7.1	6
Goose Neck IF	6.53 (2007)	6	*n/a*	6.2	2
Goose OF	7.0 (1994) 8.5 (2006) 7.15, 8.76 (2007)	6.33	6.77	6.85	20
Llama OF	7.0 (1994) 5.62 (2007)	6.2	6.60	7	20
Wolf OF	7.0 (1994) 6.80, 6.84 (2007)	5.6	6.73	7.19	16

4.1.6.2 Stream TSS and Turbidity

In general, Project area streams had clear water. Most streams had TSS concentrations less than the detection limit (3 mg/L; Table 4.1-12) and detectable TSS concentrations were only observed in samples from Chair OF, Echo OF, Reference B OF, and Del IF (Rescan 2011, 2012, 2013a, 2013b). Turbidity levels were also low at most streams, ranging from 0.14 to 2.4 NTU (Table 4.1-12). The highest mean values were observed in Del IF in June 2011 (1.8 NTU) and Reference B OF in September 2012 (2.1 NTU; Rescan 2012, 2013a).

Table 4.1-12. Summary of Stream Water TSS and Turbidity in the Goose Property Area, 1993 to 2013

Parameter	n	Min	Mean	Max
TSS (mg/L)	109	0.5*	1.8	11
Turbidity (NTU)	101	0.14	0.63	2.4

**The minimum value shown is calculated as ½ of the detection limit.*

4.1.6.3 Stream Dissolved Oxygen

Dissolved oxygen concentration is an important environmental parameter that has major effects on the chemistry and aquatic life of freshwater ecosystems. Dissolved oxygen concentrations in stream water are affected by the oxygen content of the stream's source (i.e., lake or groundwater) and mixing processes with the atmosphere, as well as *in situ* respiration and photosynthesis.

Dissolved oxygen concentrations ranged between 3.7 mg/L and 13.1 mg/L in Goose Property streams, with the lowest values observed in the Llama OF in August 2011 (Rescan 2011). Stream dissolved oxygen concentrations were generally greater in September than in August, due to the higher solubility of oxygen in the colder September waters.

Dissolved oxygen concentrations were less than the CCME guidelines for the protection of aquatic life for early life stages (9.5 mg/L) in nine LSA streams (Table 4.1-13). Llama OF had dissolved oxygen concentrations less than the CCME guideline for other life stages (6.5 mg/L) in August 2011 and August and September 2012 (Rescan 2012, 2013a). Llama OF had relatively low flows through a boulder field that may have inhibited oxygen exchange with the atmosphere.

Table 4.1-13. Stream Sites with Water Dissolved Oxygen Concentrations Less than the CCME Guideline for Early Life Stages in the Goose Property Area, 1994 to 2013

Property	Stream Site
Goose	Chair OF, Giraffe OF, Goose OF, Llama OF, Pond 19 OF, Propeller DS, Propeller OF, Reference B OF, Wolf OF

4.1.6.4 Stream Nutrients

Like the surveyed lakes, streams in the Project area had low nutrient concentrations. Most stream sites had ammonia concentrations near the analytical detection limit (0.005 mg/L; Table 4.1-14) in all seasons. Nitrate concentrations were lowest in June, with concentrations in most streams less than detection limits (0.005 mg/L). Greater nitrate concentrations were observed in August and September, with concentrations in most streams less than 0.16 mg/L. Exceptions were Llama OF (0.26 to 0.60 mg/L NO_3-N in 2011, 2012, and 2013). All streams had ammonia, nitrate and nitrite concentrations much less than their respective CCME guideline concentrations (CCME 2015).

Table 4.1-14. Summary of Stream Water Nutrient Concentrations in the Goose Property Area, 1994 to 2013

Nutrient	n	Min	Mean	Max	% Samples Outside of CCME Guidelines
Nitrate-N (mg/L)	106	0.0025*	0.039	0.61	0
Ammonia-N (mg/L)	109	0.0025*	0.0076	0.049	0
Total Phosphorus (mg/L)	97	0.0010*	0.0059	0.022	0
Orthophosphate (mg/L)	106	0.0005*	0.0010	0.005	0

Note: Stream total phosphorus samples from 2007 were excluded from the baseline information because only the orthophosphate chemical form, and not total phosphorus, was analyzed. To ensure the baseline data were comparable across years, and comparable to relevant guidelines, only water quality data with measurements of total phosphorus were included in the baseline analysis.
** The minimum value shown is calculated as ½ of the lowest detection limit.*

All streams sampled had total phosphorus concentrations less than 0.03 mg/L (Table 4.1-14) and most would be considered either ultra-oligotrophic (< 0.004 mg TP/L) or oligotrophic (0.004 to 0.01 mg TP/L) based on the CCME trigger ranges for total phosphorus (Table 4.1-15; CCME 2015). A subset of streams had samples that were within mesotrophic and meso-eutrophic trigger ranges: Chair OF, Goose Neck IF, and Reference B OF.

Stream total phosphorus concentrations collected in 2006 were excluded from the analysis because of anomalously high total phosphorus concentrations. The 2006 total phosphorus measurements could not be corroborated with paired orthophosphate concentrations because orthophosphate analysis was not conducted. Table 4.1-16 tabulates the anomalous total phosphorus concentrations in 2006 for Echo OF, Goose SE IF, and Goose OF in the context of equivalent samples collected during other sampling campaigns.

Table 4.1-15. Distribution of Samples from Streams by CCME Total Phosphorus Trigger Ranges, 1993 to 2013

Trophic Status	Total Phosphorus Concentration	Stream
Ultra-oligotrophic	< 0.004 mg/L	Echo OF, Giraffe OF, Goose OF, Llama OF, Moby OF, Pond 19 OF, Propeller OF, Propeller DS, Giraffe IF, Umwelt OF, Wolf OF
Oligotrophic	0.004 – 0.010 mg/L	Chair OF, Del IF, Del US, Echo OF, Giraffe OF, Goose IF SE, Goose Neck IF, Goose OF, Llama OF, Moby OF, Pond 19 OF, Propeller OF, Propeller DS, Reference B OF, Giraffe IF, Umwelt OF, Wasp OF, Wolf OF
Mesotrophic	0.010 – 0.020 mg/L	Chair OF, Goose Neck IF, Reference B OF
Meso-eutrophic	0.020 – 0.035 mg/L	Reference B OF
Eutrophic	0.035 – 0.1 mg/L	-
Hypereutrophic	> 0.1 mg/L	-

Note: Total phosphorus trigger ranges may vary within streams between years and seasons; as a result, streams may be listed under multiple trigger ranges. Note the variability total phosphorus concentrations in some streams like Reference B Outflow, which ranged from the ultra-oligotrophic to eutrophic trigger ranges in the baseline sampling program.

Table 4.1-16. Summary of Anomalous Total Phosphorus Samples in 2006 from Streams in the Goose Property Area

Site	Total Phosphorus Concentration, 2006	Total Phosphorus Concentrations, 1993 to 1997 and 2010 to 2013			
		Min	Median	Maximum	*n*
Echo OF	0.022 mg/L	0.0032 mg/L	0.0038 mg/L	0.005 mg/L	11
Goose IF SE	0.027 mg/L	0.005 mg/L	*n/a*	0.008 mg/L	2
Goose OF	0.028 mg/L	0.0033 mg/L	0.0044 mg/L	0.0078 mg/L	16

4.1.6.5 Stream Metals

The Project area streams are generally low-metal environments, with metal concentrations varying both spatially and temporally with some instances of elevated concentrations (Table 4.1-17). Aluminum, boron, chromium, and iron tended to be greater in several LSA streams. There was no clear spatial trend in metal concentrations because no stream had consistently high or low metal concentrations. Many samples had metal concentrations that were near or less than their analytical detection limits, particularly measurements of arsenic, cadmium, chromium, copper, lead, mercury, and uranium (Table 4.1-17; Rescan 2011, 2012, 2013a, 2013b).

Table 4.1-17. Summary of Stream Water Metal Concentrations in the Goose Property Area, 1993 to 2013

Metal	n	Metal Concentration (mg/L)			% of Samples with Concentrations Greater than CCME Guidelines*
		Min	Mean	Max	
Aluminum	83	0.0045	0.036	0.16	12
Arsenic	83	0.000025[†]	0.00028	0.0014	0
Boron	83	0.0025[†]	0.0074	0.078	0
Cadmium[‡]	83	0.000005[†]	0.000028	0.00022	5[a]
Copper	83	0.00074	0.0019	0.012	30
Iron	83	0.000025	0.000041	0.00028	12
Lead	83	0.005[†]	0.16	2.01	0
Mercury[b]	94	0.000005[†]	0.000009	0.00017	2
Molybdenum[c]	83	0.000025[†]	0.000036	0.0002	0
Nickel	83	0.00084	0.0070	0.055	2
Uranium[d]	78	0.000005[†]	0.000009	0.00003	0
Zinc	83	0.0015[†]	0.0035	0.024	0

Note: Samples collected in the 2006 and 2007 programs were excluded because of elevated analytical detection limits.
** CCME water quality guidelines for the protection of aquatic life (CCME 2012).*
[†] The minimum value shown is calculated as ½ the lowest detection limit.
[‡] 57% of cadmium concentrations were less than analytical detection limits.
[a] Cadmium guidelines are hardness-dependent, and frequently less than analytical detection limits. Only samples with values above the analytical detection limits were considered for comparison with the CCME guidelines.
[b] 96% of mercury concentrations were less than analytical detection limits.
[c] 99% of molybdenum concentrations were less than analytical detection limits.
[d] 58% of uranium concentrations were less than analytical detection limits.

Naturally elevated copper concentrations were observed in several Project streams (e.g., Goose OF and Propeller OF), and were likely related to the presence of metal-bearing minerals in the particular

stream watershed. These greater concentrations were often measured in higher order streams such as Goose OF and Propeller OF. These concentrations were often greater than CCME guideline levels (Table 4.1-18; CCME 2015).

Table 4.1-18. Water Quality Parameters with Sample Concentrations Greater than CCME Guideline Values in Goose Property Area Streams, 1993 to 2013

Lake	Parameters with Values Greater than CCME Guidelines
Llama OF	pH*, Al, Cu, Hg
Echo OF	pH*, Al, Cu
Wolf OF	pH*
Goose IF Southeast	pH*
Goose IF Neck	pH*, Cd, Fe
Goose OF	pH*, Al, Cd, Cu, Hg
Giraffe OF	pH*, Al, Cu
Giraffe IF	Cu
Umwelt OF	pH*, Al
Pond 19 OF	Cu
Moby OF	Cu, Fe, Ni
Chair OF	Al, Cu, Fe
Propeller OF	Cd
Del IF	Cu
Reference B OF	Fe

Note: Exceedances are listed if sample concentration was greater than the CCME guidelines.
Cd = cadmium, Cu = copper, Fe = iron, Pb = lead, Ni = nickel.
** CCME Water Quality Guidelines for pH in freshwater environments range from 6.5 to 9.0.*

4.1.6.6 Stream Cyanide

Baseline sampling for cyanide concentrations in stream water has been conducted since 1997. Free cyanide was only detected in samples from Llama Lake OF (August 2011) and Reference B Lake OF (September 2011) and concentrations were less than the CCME guideline for free cyanide in freshwater (0.005 mg/L; Table 4.1-19).

Table 4.1-19. Summary of Stream Water Free Cyanide Concentrations (mg/L) in the Goose Property Area, 1997 to 2013

n	Min	Mean	Max
78	0.0005*	0.0008†	0.0025‡

** The analytical detection limits for total cyanide ranged from 0.001 to 0.005 mg/L; the minimum value shown is calculated as ½ of the lowest detection limit.*
† The mean value was inflated due to elevated analytical detection limits and not necessarily due to greater water cyanide concentrations.
‡ All lake water free cyanide concentrations were less than the CCME guideline of 0.005 mg/L.

4.2 INCORPORATION OF TRADITIONAL KNOWLEDGE (TK)

The effects assessment relies on the information collected from Inuit-led TK information, public scoping, focus group meetings, government engagement, and scientific knowledge. To the extent

possible, available TK is incorporated into the evaluation of the potential effects of the Project on the environment. The following reports were reviewed for TK specific information related to (VEC or VSEC) features:

- *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* (KIA 2012; Appendix V3-3A of FEIS);
- *Naonaiyaotit Traditional Knowledge Project - Hannigayok (Sabina Gold & Silver Corp. Proposed Back River Project). Results from Data Gaps Workshops, Final Report (June 2014)* (KIA 2014; Appendix V3-3B of FEIS); and
- Back River Project: Existing and Publically Available Traditional Knowledge from Selected Aboriginal Groups in the Northwest Territories (Appendix V3-3C of FEIS).

4.2.1 Incorporation of TK for Existing Environment and Baseline Information

Available TK from the *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP) report* (KIA 2012) and the *Naonaiyaotit Traditional Knowledge Project - Hannigayok (Sabina Gold & Silver Corp. Proposed Back River Project). Results from Data Gaps Workshops, Final Report* (KIA 2014) were reviewed for information on freshwater water quality (see Volume 3, Chapter 3). No water quality information was specifically noted and no traditional drinking water sources were identified within the project area (KIA 2012, 2014). Therefore, no direct incorporation of TK was possible for freshwater water quality because of the lack of available information.

4.2.2 Incorporation of TK for Valued Ecosystem Component Selection

The results of the *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* report (KIA 2012) were used for scoping and refining the potential VEC/VSEC list (see Volume 9, Chapter 1). The TK report presents clear maps of valued animal species, environmental components, and traditional land use activities. This information was used to determine if these valued aspects potentially interacted with the proposed Project, and if so, they were included in the initial VEC/VSEC list. This information, along with information from public consultation, consultation with regulatory agencies, and regulatory considerations, was used to determine the final VEC/VSEC list. The final list was submitted to NIRB on April 8, 2013 and posted on the NIRB ftp site. As part of this process, freshwater water quality was selected as a VEC.

4.2.3 Incorporation of TK for Spatial and Temporal Boundaries

No traditional drinking water sources were identified within the freshwater water quality RSA. Wildlife and fish important to the Inuit were found in the wildlife and fish community VEC RSA (Volume 5; Volume 6, Chapters 6 and 7), and the quality of the freshwater environment may affect these organisms. Inuit travel routes were noted to pass through the Goose Property Area; the topography along the travel route through the Goose Property area offered easier paths for travel from Contwoyto to Bathurst Inlet (KIA 2014).

4.2.4 Incorporation of TK for Effects Assessment

No direct TK information regarding freshwater water quality in the Project area was available for incorporation in the effects assessment.

4.2.5 Incorporation of TK for Mitigation and Adaptive Management

Natural variability has been documented as part of the baseline studies and the TK report; this variability will be incorporated into future monitoring programs. If a valued potable water source is identified in the Project area, then specific management measures would be enacted to ensure this water source was protected.

4.3 VALUED COMPONENTS

4.3.1 Valued Components Included in Assessment

Surface freshwater water quality was identified as a potential VEC from a comprehensive list in the EIS guidelines (Section 7.6.1; NIRB 2013a) and was identified as potentially interacting with the Project during the scoping process (see Volume 9, Chapter 1). Moderate to significant comments regarding surface water quality were expressed in consultation with communities and TK information, and moderate regulatory considerations were also identified as water quality will be protected under the Metal Mine Effluent Regulations. Given these features, surface freshwater quality was selected as a VEC for the EIS.

4.4 SPATIAL AND TEMPORAL BOUNDARIES

The freshwater water quality VEC spatial and temporal boundaries were defined as the maximum limits within which the assessment was conducted. The boundaries were determined by the criteria specified in the EIS guidelines (NIRB 2013a), and outlined in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1).

4.4.1 Spatial Boundaries

The spatial boundary used for the assessment of the VEC freshwater water quality included the Goose Property Potential Development Area (PDA), the Goose Property Local Study Area (LSA), and an overall Freshwater Regional Study Area (RSA). The MLA is a narrow strip of land on the west side of southern Bathurst Inlet. Most streams in this area flow directly to Bathurst Inlet to west and these streams are not within the MLA PDA. Project infrastructure and activities were not expected to interact with any streams. Potential effects related to the MLA are addressed in the Marine Environment Volume (Volume 7) and are not considered further in the freshwater water quality assessment.

4.4.1.1 Local Study Area

The LSA includes areas where there exists the reasonable potential for immediate effects due to Project activities, ongoing normal activities, or to possible abnormal operating conditions (NIRB 2013b). The LSA used for the assessment of effects on the VEC freshwater water quality for the Goose Property is 365 km^2 and includes the PDA and the boundaries of the Propeller and Big watersheds (Figure 4.4-1). The PDA includes an area that encompasses planned infrastructure.

4.4.1.2 Regional Study Area

The freshwater RSA includes the PDA, the LSA, and additional areas within which there is the potential for indirect or cumulative effects. The RSA used for the assessment of effects on the VEC freshwater water quality is 6,815 km^2 and encompasses the PDA and LSA. The RSA includes small sections of the Ellice and Back River Watersheds, and includes the upper ~80 km of the Ellice Watershed.

4.4.2 Temporal Boundaries

The temporal boundaries used for the assessment of effects on the VEC freshwater water quality align with the duration of Project phases as described in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1). The temporal boundaries for the Project phases were defined as follows:

- Mobilization and Construction Phase—4 years;
- Operations Phase—10 years;
- Reclamation and Closure Phase—8 years;
- Post-closure Monitoring Phase—5 years;
- Other potential phases:
  - Temporary Closure—less than 2 years;
  - Care and Maintenance Phase—2-10 years; and
  - Exploration: included in Construction and Operations Phases.

The temporal boundaries used for the freshwater water quality VEC was defined in relation to planned activities over the lifetime of the Project within which a reasonable expectation of interaction with components of the freshwater environment can be predicted.

4.5 POTENTIAL PROJECT-RELATED EFFECTS ASSESSMENT

4.5.1 Methodology Overview

The Project-related effects assessment for freshwater water quality followed the step-wise process detailed in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1):

1. Identification of potential interactions of the Project with freshwater water quality;
2. Characterization of potential effects;
3. Identification of mitigation and management measures to be taken that would eliminate or reduce potential effects;
4. Characterize residual effects using the primary attributes of direction (i.e., positive, neutral, or negative), magnitude, reversibility, confidence, and probability, and the secondary attributes of their extent, frequency, and duration; and
5. Determine the significance of the residual effects.

If mitigation and management measures were considered entirely effective, potential Project-related effects to the VEC freshwater water quality were deemed negligible and not identified as residual effects. Attributes used to characterize residual effects included direction, magnitude, reversibility, confidence, probability, extent, frequency, and duration. The rating criteria used for these attributes are provided in tables in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1). Table 4.5-1 presents the ratings specific for the magnitude of residual effects to the VEC freshwater water quality. The CCME guidelines for water quality were used, when available, as the threshold for determining the magnitude of residual effects since they are designed to be protective of all forms of aquatic life and all aspects of aquatic cycles, including the most sensitive species over the long term (CCME 2007, 2015).

PROJECT # 0194096-0040 GIS # BAC-01-064_S September 03 2015

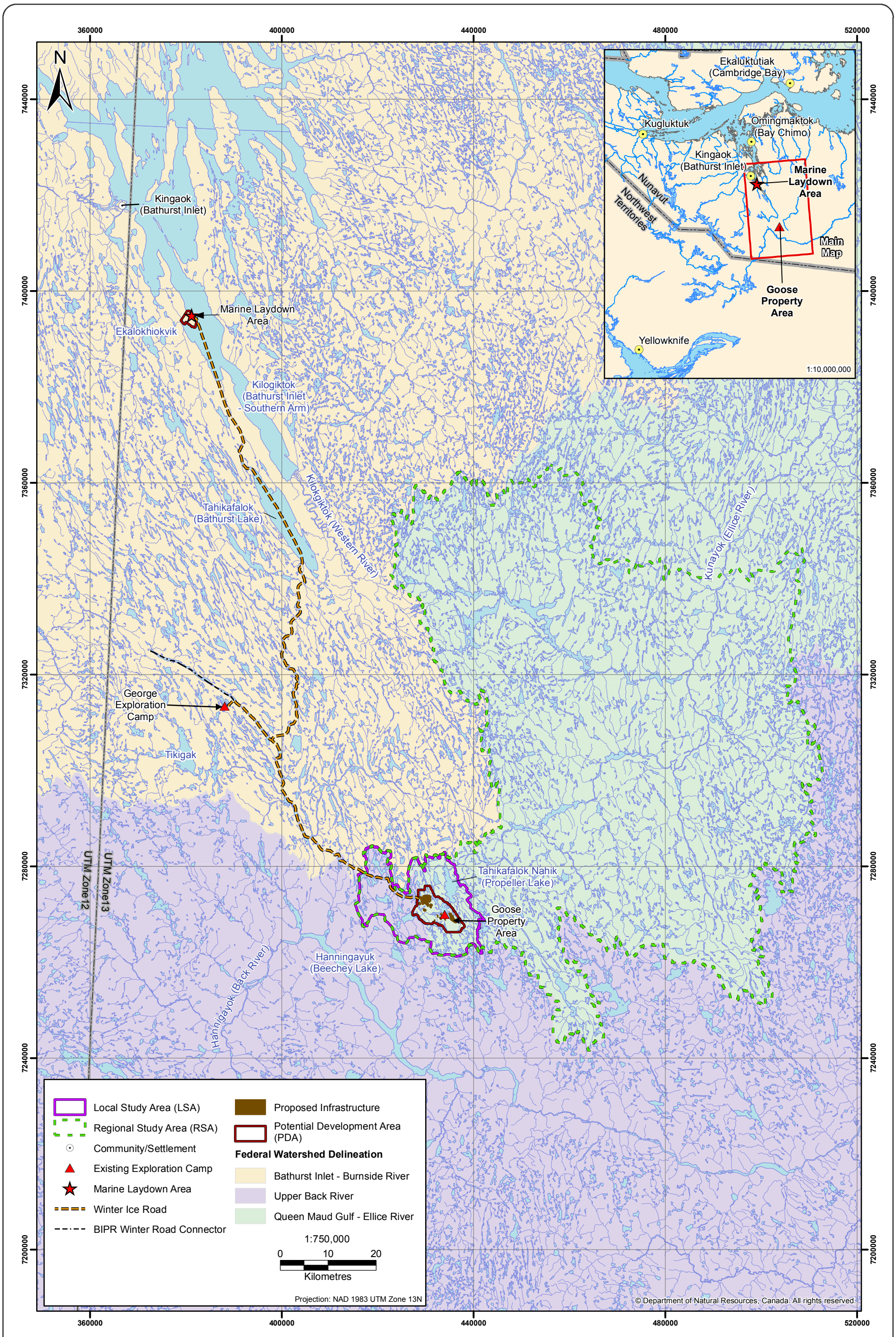

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Figure 4.4-1

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Local Study Area and Regional Study Area for Freshwater Water Quality

Table 4.5-1. Rating Criteria for Evaluating the Magnitude of Residual Effects on Freshwater Water Quality VEC

Criteria		Classification
Magnitude	Negligible	No change from baseline values
	Low	Within the CCME guideline, *or* less than the 90% percentile of baseline values if indicator is naturally greater than threshold
	Moderate	Greater than CCME guideline, *or* greater than the 90% percentile of baseline values if indicator is naturally greater than threshold *Less than 10× threshold*
	High	Greater than CCME guideline, *or* greater than the 90% percentile of baseline values if indicator is naturally greater than threshold *Greater than 10× threshold*

Under these rating criteria, residual effects from Project activities classified in the *Low* magnitude would result in changes in freshwater water quality that would be less than the CCME guidelines. *Low* magnitude residual effects would, therefore, be predicted to not result in any effects in aquatic organisms because of the conservative design of the CCME guidelines (CCME 2015). If particular metals were naturally above CCME guidelines (e.g., arsenic), then a *Low* magnitude effect would apply if concentrations were within the 90% percentile of baseline values.

Combined with the probability that the effect will occur, the significance of the effect was rated as positive, not significant, or significant (Table 4.5-2). For example, residual effects receive a rating of 'Not Significant' if typically they are expected to be one of the following: negligible or low magnitude, confined to LSA, moderate to high reversibility, or short duration (Volume 9). However, given the qualitative nature of the assessment, these ratings are evaluated for biophysical VECs on a case by case basis.

Table 4.5-2. Definitions of Significance Ratings for Freshwater Water Quality VEC

Significance	Descriptor of Significance
Positive	Effect could result in improvements in freshwater water quality, relative to the baseline within the RSA into the foreseeable future.
Significant	Effect is expected to result in a decline in freshwater water quality that is long-lasting or permanent within the zone of influence of the Project relative to reference conditions; levels may be variable or stable over years, but significantly lower on average than the natural variation of water quality and compared to reference sites elsewhere. Regional management actions such as research, monitoring, and recovery initiatives may be required should changes to freshwater water quality be deemed above acceptable risk thresholds.
Not Significant	Effect may result in a decline in freshwater water quality within the zone of influence of the Project relative to reference conditions during the life of the project, but water quality should return to baseline conditions in the shorter-term after Project closure. Monitoring may be initiated to confirm the ratings of the effects assessment.

4.5.1.1 Water Quality Indicators

Water quality is a complex of multiple parameters and indicators, as discussed in the Existing Environment (Section 4.1). Project activities will interact with the freshwater environment along a number of pathways and may change water quality parameters or indicators to levels outside of natural or threshold ranges. For example, if unmitigated, runoff from waste rock storage areas may carry suspended material and metals into a receiving freshwater environment. The deposition of that suspended material, and the associated metals, may increase concentrations beyond natural levels.

The water quality effects assessment was based on the analysis of seven water quality indicators that represent the most probable and significant potential interactions between Project activities and the freshwater environment (Table 4.5-3). It is important to note that the key indicators of freshwater quality outlined in Table 4.5-3 are subject to natural variation, but guidelines and thresholds have been established to protect aquatic life (CCME 2015). For the purposes of this assessment, the contaminants of potential concern (COPC) identified in the CCME guidelines were used as indicators. The thresholds for the residual effects analysis were based on the CCME guidelines, when available, and are detailed in Table 4.5-4.

Table 4.5-3. Freshwater Water Quality Indicators for Effects Assessment

Indicator	Description	Project Interactions	Pathway
pH	Acid-base balance of water	Project activities may increase pH outside of natural range through runoff, deposition, and discharge	Runoff, aerial deposition, discharge
TSS	Quantity of suspended material	Project activities may disturb in-water sediments, increase runoff of deposited sediment, or discharge suspended material	In-water or near-water works, runoff, aerial deposition, discharge
Nutrients	Chemical compounds that may contribute to aquatic plant and algal growth, and/or alter community structure	Project activities may contribute nutrients to waterbodies	Runoff, discharge, aerial deposition
Metals	Metals suspended or dissolved in water	Project activities may contribute metals to waterbodies in runoff, discharge or deposition	Runoff, aerial deposition, discharge
Hydrocarbons	Petroleum hydrocarbon compounds	Project activities may contribute hydrocarbon compounds in runoff, discharge, or aerial deposition	Runoff, aerial deposition, discharge
BOD	Organic compounds that may enhance aquatic respiration	Project activities may contribute organic compounds to waterbodies by discharge	Discharge
Chloride and Cyanide	Chemical compounds from natural or human sources	Underground water may have high concentrations of chloride, cyanide is a process chemical	Discharge

Table 4.5-4. Indicators and Thresholds Used for Magnitude Characterization for Residual Effects Analysis on the VEC Freshwater Water Quality

Indicator	Parameter	CCME Guidelines for the Protection of Aquatic Life
pH		6.5 – 9.0[a]
TSS		Narrative
Nutrients	Ammonia N (total)	pH- and temperature-dependent[b]
	Ammonia N (un-ionized)	0.019 mg/L
	Nitrate N	124 mg/L (short term) 3 mg/L (long term)
	Nitrite N	0.06 mg/L
	Total P	Guidance framework[c]

(continued)

Table 4.5-4. Indicators and Thresholds Used for Magnitude Characterization for Residual Effects Analysis on the VEC Freshwater Water Quality (completed)

Indicator	Parameter	CCME Guidelines for the Protection of Aquatic Life
Metals	Aluminum	0.005 mg/L (if pH < 6.5) 0.1 mg/L (if pH ≥ 6.5)
	Arsenic	0.005 mg/L
	Boron	640 mg/L (short term) 1.5 mg/L (long term)
	Cadmium	hardness dependent[d]
	Chromium	0.001 mg/L (hexavalent) 0.0089 mg/L (trivalent)
	Copper	0.002 mg/L[e]
	Iron	0.3 mg/L
	Lead	0.001 mg/L[f]
	Mercury	0.000026 mg/L
	Molybdenum	0.073 mg/L
	Nickel	0.025 mg/L[g]
	Selenium	0.001 mg/L
	Silver	0.0001 mg/L
	Thallium	0.0008 mg/L
	Uranium	0.033 mg/L (short term) 0.015 mg/L (long term)
	Zinc	0.03 mg/L
Other indicators	Dissolved Oxygen	9.5 mg/L (early life stages) 6.5 mg/L (other life stages)
	Petroleum Hydrocarbons	*range of guidelines for petroleum hydrocarbon compounds (CCME 2015)*
	Chloride	640 mg/L (short term) 120 mg/L (long term)
	Cyanide	0.005 mg/L (as free cyanide)
	BOD	*no established CCME guideline*

[a] *pH values in pH units.*
[b] *The CCME guideline for total ammonia depends on pH and temperature. For circum-neutral freshwater (pH 6.5 - 7.5) at conservative temperatures (15°C), the guideline for total ammonia is 2.22 to 22.0 mg/L.*
[c] *See Section 4.1.6.4.*
[d] *The CCME guideline for total cadmium is hardness dependent. The guideline for the average hardness of lakes in the Goose Property Area (15 mg/L $CaCO_3$) was 0.000007 mg/L.*
[e] *The CCME guideline for copper is hardness dependent, but hardness values in the Project area were generally less than the lower hardness limit (~80 mg/L $CaCO_3$) and, therefore, the minimum guideline value was 0.002 mg/L.*
[f] *The CCME guideline for lead is hardness dependent. However, average hardness values (15 mg/L $CaCO_3$ for the Goose Property Area) were less than the minimum guideline value of 0.001 mg/L.*
[g] *The CCME guideline for nickel is hardness dependent. However, average hardness values were less than the minimum guideline value of 0.025 mg/L.*

4.5.2 Identification and Characterization of Potential Interactions with Project

Project activities have the potential to influence the VEC freshwater water quality. Potential interactions between the Project and the VEC freshwater water quality were based on the matrix provided in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1) and further refined using the EIS guidelines (NIRB 2013a) and professional judgement based on extensive

experience at other similar projects in Nunavut and the Northwest Territories. Activities that will occur throughout the duration of the Project were considered for their potential interactions with the freshwater environment.

Some Project interactions with the freshwater environment are likely to occur through non-point source pathways (runoff and deposition). Non-point source pathways were assessed for the Project as a whole, rather than considering the effects on each individual receiving environment. Many of these pathways have the potential to vary substantially in timing and magnitude during the life of the Project, and therefore a qualitative effects assessment approach using conservative assumptions of potential Project effects was generally used for the effects assessment. The effects of dust on freshwater water quality were assessed quantitatively as part of the Country Foods Assessment (Volume 8, Chapter 5) and the results are described in Section 4.5.2.10.

The interactions of Project activities and the VEC freshwater water quality were grouped by related Project activities, shared pathways to the freshwater environment, and shared key water quality indicators for the effects assessment (Table 4.5-5). For example, the construction of water crossings and the clearing of surfaces for pad construction were grouped into the *Construction and Decommissioning Activities* Project Interaction Group because both activities will be occurring during similar stages in the Project development and both activities have the potential to contribute to erosion and deposition of suspended material into freshwater receiving environments through the shared pathway of runoff. The identified Project interaction groups are:

- *Construction and Decommissioning Activities* - Project activities that include the clearing of overburden, dewatering, earthworks, and construction activities for pads and infrastructure.
- *Winter Ice Roads* - Project activities related to the construction and operation of winter ice roads.
- *Site Contact Water* - the runoff from Project infrastructure including pad areas, laydown areas, roads, and airstrips.
- *Mine Contact Water* - water that contacts mine surfaces and operations, including runoff from waste rock storage areas and ore storage areas, water management structures (e.g. Saline Water Pond), drilling water from exploration, and open pit and underground water.
- *Water Use* - Project activities requiring the withdrawal of water from waterbodies.
- *Quarries and Borrow Pits* - activities related to the operation of quarries and borrow pits.
- *Explosives* - Project activities related to the transport, manufacture, storage, and use of explosives.
- *Fuels, Oils, and PAH (Polycyclic aromatic hydrocarbons)* - Project activities related to the storage of fuels, fueling and maintenance operations, and the combustion of waste.
- *Treated Sewage Discharge* - discharge of effluent from domestic water treatment facilities.
- *Dust Deposition* - Project activities that generate dust, including vehicle traffic, mining operations, and milling, that can then be deposited in freshwater receiving environments.

In some cases, the pathways and interactions will change between locations or Project phases, and those changes are considered in the effects assessment. For example, once the site water management infrastructure is completed, site contact water (e.g., runoff from site pad areas) will be diverted to the water management facilities and not directly reach the freshwater environment. As a result, the assessment of effects from site contact water would necessarily be different in the Operations Phase than during the Construction Phase.

Table 4.5-5. Definition of the Components of the Project's Interactions with the VEC Freshwater Water Quality

		Project Interaction Group									
Project Phase	**Project Activity**	**Construction and Decommissioning Activities**	**Winter Ice Roads**	**Site Contact Water**	**Mine Contact Water**	**Water Use**	**Quarries and Borrow Pits**	**Explosives**	**Fuels, Oils, and PAH**	**Treated Sewage Discharge**	**Dust Deposition**
Mobilization and Construction	Camps and mill facility construction, local site roads, airstrip, equipment laydown areas, pad areas	X									
	Quarry development						X				
	Water use					X					
	Dam or dyke construction for water management facilities and dewatering activities	X									
	Pit pre-stripping, waste rock pile construction, head-frame and underground development				X						
	Winter ice roads		X								
	Machinery and vehicle refueling; fuel storage and handling			X					X		
	Sewage treatment plant and discharge									X	
	Landfill construction and solid waste management	X		X							
	Chemical and hazardous material storage and management			X							
	Explosives storage and handling							X			
Operations	Open pits: drilling, blasting, and excavation				X			X			X
	Underground: drilling, blasting, and excavation				X			X			X
	Waste rock storage areas				X						X
	TSF operation				X						X
	In-pit and surface water management				X						
	Mill and domestic water use					X					
	Road and airstrip use and maintenance			X			X				X

(continued)

Table 4.5-5. Definition of the Components of the Project's Interactions with the VEC Freshwater Water Quality (completed)

		Project Interaction Group									
Project Phase	**Project Activity**	**Construction and Decommissioning Activities**	**Winter Ice Roads**	**Site Contact Water**	**Mine Contact Water**	**Water Use**	**Quarries and Borrow Pits**	**Explosives**	**Fuels, Oils, and PAH**	**Treated Sewage Discharge**	**Dust Deposition**
Operations *(cont'd)*	Winter ice roads		X								
	Sewage treatment and discharge									X	
	Solid waste management			X							
	Equipment maintenance and fuel storage and handling			X					X		
	Chemical and hazardous material storage and management			X							
	Explosives storage and handling							X			
Reclamation and Closure	Open pits				X						
	Underground mines				X						
	TSF				X						
	Water use for tailings management					X					
	Waste rock storage areas				X						
	Winter Ice Roads		X								
	Road reclamation of site roads	X									
	Solid waste management			X							
	Equipment maintenance and fuel storage and handling			X					X		
	Chemical and hazardous material storage and management			X							
	Airstrip reclamation	X									
	Landfill closure	X									
	Quarry decommissioning	X					X				

The pathway describes the linkage between each Project interaction group and the freshwater water quality VEC. The four identified pathways for interaction between Project activities and the freshwater environment are:

- *runoff*, which describes the transport of material or compounds from the terrestrial environment into the freshwater environment by precipitation or snowmelt;
- *water withdrawal*, which describes the influence that changes in volume and flow may have on freshwater waterbodies;
- *discharge*, which is the direct input of Project water into freshwater waterbodies; and
- *aerial deposition*, which is the direct input of material and chemical compounds from the air into the freshwater environment.

The pathway(s) for each Project interaction group were identified (Table 4.5-6), and then used to describe the potential effects, identify mitigation and management measures, and characterize the potential for residual effects from Project activities.

Table 4.5-6. Key Indicators of Project Activity Interactions with the Freshwater Environment for Effects Assessment

Project Activity	Pathway	Indicators	Project Phases
Construction and decommissioning activities	Runoff, discharge	pH, TSS, nutrients, metals, hydrocarbons	Mobilization and Construction, Operations, Reclamation and Closure
Winter ice roads	Runoff, water withdrawal	TSS, metals, hydrocarbons	Mobilization and Construction, Operations, Reclamation and Closure
Site contact water	Runoff	pH, TSS, nutrients, metals, hydrocarbons	Mobilization and Construction, Operations, Reclamation and Closure, Temporary Closure, Care and Maintenance, Post-closure
Mine contact water	Runoff, discharge	pH, TSS, nutrients, metals, chloride, cyanide	Operation, Reclamation and Closure, Temporary Closure, Care and Maintenance, Post-closure
Water use	Water withdrawal	pH, TSS, nutrients, metals, hydrocarbons	Mobilization and Construction, Operations, Reclamation and Closure
Quarries and borrow pits	Runoff	pH, TSS, metals, hydrocarbons	Mobilization and Construction, Operations
Explosives	Runoff, aerial deposition	Nutrients, hydrocarbons	Mobilization and Construction, Operations
Fuels, Oils, and PAH	Runoff, aerial deposition	Hydrocarbons	Mobilization and Construction, Operations, Reclamation and Closure
Treated Sewage Discharge	Discharge	TSS, nutrients, hydrocarbons, BOD	Mobilization and Construction, Operations, Reclamation and Closure
Dust deposition	Aerial deposition	TSS and metals	Mobilization and Construction, Operations, Reclamation and Closure

The potential effects of each of the Project activities identified in Tables 4.5-5 and 4.5-6 are characterized in the Sections 4.5.2.1 to 4.5.2.10. The potential effects analysis considered the proposed Project activities (Volume 2) and the pathway(s) linking the Project activities to the freshwater environment. The potential effects are identified and characterized in the absence of mitigation or management measures.

4.5.2.1 Construction and Decommissioning Activities

Ground preparation will be required in the Mobilization and Construction Phase throughout the PDA to construct necessary Project infrastructure, including buildings, roads, and mine works. These activities will involve vegetation clearing, the removal and relocation of surficial materials, and the construction of pad areas from surficial material, borrow material, and quarried rock. The activities would also include the construction of water management structures, such as ditches, diversion structures, and berms to mitigate runoff, and earthworks for the TSF. The decommissioning and reclamation of Project infrastructure will similarly require surface contact and the transportation and relocation of surficial materials. The production of methylmercury will be negated by stripping and stockpiling organic material as part of construction activities.

Landscape contact (ground works) has the potential for effects on freshwater water quality. The primary pathway for these potential effects would be runoff (i.e., the transport of material in overland flow). This would occur primarily during snowmelt and freshet in the spring, during precipitation events in the summer and fall, and would be absent in the winter. Some in-water or near-water activities required during the Mobilization and Construction and the Reclamation and Closure phases also carry the potential for effects on water quality. Additional effects may occur via dust deposition, and these are presented separately (Section 4.5.2.10).

Llama and Umwelt lakes will need to be dewatered as part of the development of the Project. The primary pathway of potential effects will be through the discharge of water into nearby receiving environments during dewatering activities.

Runoff from prepared and decommissioned areas could affect the VEC freshwater water quality by changing pH (interaction with surficial material), and contributing TSS (erosion), metals (TSS and dissolution), nutrients (vegetation removal and blasting residue), and hydrocarbons (mechanical use of fuel, oil, and grease) into the freshwater environment.

4.5.2.2 Winter Ice Roads

Winter ice roads will be used to connect the Goose Property Area to the MLA. Winter ice roads will be used in the Mobilization and Construction and Operations phases, and possibly in the Reclamation and Closure Phase, with the pathways of interaction through runoff and water withdrawals. The construction of winter ice roads may affect vegetation cover along the shores of waterbodies, which could increase runoff and erosion. Winter ice road construction and maintenance may also affect the VEC freshwater water quality through water withdrawals that reduce lake water volumes. This may influence mixing processes that could resuspend sediments, metals, nutrients, and dissolved oxygen concentrations in affected waterbodies.

4.5.2.3 Site Contact Water

Site contact water was defined as the runoff from snowmelt and precipitation events that interacts with geochemically neutral site surfaces including roads, laydown areas, and buildings. The interaction of runoff and Project infrastructure could transport acid equivalents, suspended material, metals,

nutrients, and petroleum hydrocarbon compounds into the freshwater environment if not managed or mitigated. The potential for effects from site contact water could occur during all phases of the Project.

4.5.2.4 Mine Contact Water

Mine contact water was defined as the underground water removed from mine works, the runoff from mine surfaces, WRSAs, and ore stockpiles, water management structures (e.g., Saline Water Pond), drilling fluids from ongoing exploration activities, mill process water, and water in the TSFs. The pathways of interaction between mine contact water and the freshwater environment are runoff and discharge. Seepage was not considered a significant pathway because of the active water management during the Operations and Closure phases, which included the interception of seepage. Potential effects from mine contact water may occur during all Project Phases. Mine contact water, including water interacting with overburden, waste rock, and tailings, could affect the VEC freshwater water quality by changing pH (interaction with surficial material), and contributing TSS (erosion), metals (TSS and dissolution), nutrients (contact with blasting residues), hydrocarbons (mechanical use of fuel, oil, and grease), and other water quality indicators such as chloride (drilling salts) into the freshwater environment.

4.5.2.5 Water Use

Water for domestic and process use will be drawn from Goose and/or Big lakes and is anticipated to occur during all phases of the Project. Additional waterbodies may be identified for water use to support closure activities (see Volume 2; Chapter 8). Water withdrawals could potentially affect the VEC freshwater water quality by reducing water depth in the source waterbody. This may influence mixing processes that could resuspend sediments, metals, nutrients, and dissolved oxygen concentrations in affected waterbodies.

In streams, reduction in water depths can reduce flow, change currents, change the location of depositional areas, change the quantity or size structure of material deposited, increase temperature, reduce dissolved oxygen concentrations, and expose sediments.

4.5.2.6 Quarries and Borrow Pits

Quarries and borrow sources will be developed to meet the requirements for construction and maintenance. The pathway of interaction between quarries and the freshwater environment is through runoff, and this may occur during the Mobilization and Construction and Operations phases. Contact water in quarries and borrow pits may transport acid equivalents, metals, and suspended sediments into the freshwater environment. Runoff from quarries and borrow pits could affect the VEC freshwater water quality by changing pH (interaction with surficial material), and contributing TSS (erosion), metals (TSS and dissolution), nutrients (contact with blasting residues - covered in the *Explosives* interaction pathway), and hydrocarbons (mechanical use of fuel, oil, and grease) into the freshwater environment.

4.5.2.7 Explosives

Ammonium nitrate (AN) and fuel oil (FO) will be used as the explosive for quarries and mine development and production. Ammonium nitrate and fuel oil will be shipped and stored on site in bulk bags and bulk liquid fuel. The ANFO explosive will then be mixed on site. Both components of the ANFO explosive have the potential for effects on freshwater water quality—AN disassociates in water into ammonia and nitrate and FO is a mixture of petroleum hydrocarbons. The pathways of interaction between explosives and the freshwater environment are runoff and aerial deposition, and the potential effects may occur during Mobilization and Construction and Operations phases.

Runoff and deposition of explosives (or blasting residues) into the freshwater environment can affect water quality by increasing the concentrations of ammonia, nitrate, and petroleum hydrocarbons.

4.5.2.8 Fuels, Oils, and PAH

The Fuels Project interaction group was defined as the Project activities that include the storage and transport of fuels and petroleum hydrocarbons, fueling and maintenance operations that have the potential for introducing hydrocarbons into the environment, and the incineration of waste that may create PAHs by incomplete combustion. The primary pathways of interactions between these sources of hydrocarbons and the freshwater environment are runoff and aerial deposition. Activities at facilities, laydown areas, fuel storage areas, and waste management areas can deposit hydrocarbon compounds, such as oil or grease, onto surfaces that can subsequently be transported into freshwater environments in runoff.

Combustible waste, including the solids from sewage treatment, will be combusted using an incinerator. Incomplete combustion can create airborne hydrocarbons that can be deposited into freshwater environment via deposition or runoff.

The potential effects from fuels and other hydrocarbons may occur during the Mobilization and Construction, Operations, and Reclamation and Closure phases.

4.5.2.9 Treated Sewage Discharge

Treated sewage from domestic water treatment facilities will be discharged to Llama Lake during the Mobilization and Construction Phase and TSFs during the Operation Phase. Therefore, the pathway of interaction between treated sewage and the freshwater environment is discharge. Discharge of sewage effluent could affect the VEC freshwater water quality by contributing nutrients or organic compounds and influencing the oxygen demand (and subsequently reducing oxygen concentrations) in receiving freshwater environments. The potential effects from treated sewage discharge may occur during the Mobilization and Construction, Operations, and Reclamation and Closure phases.

4.5.2.10 Dust Deposition

Dust can be generated by a variety of Project activities, including vehicle traffic, blasting activities, quarry operations, rock processing, and mining activities in open pits. Areas cleared for infrastructure (i.e., laydown areas) can also be sources of dust. The aerial deposition of the Project-generated dust is the primary pathway of interaction. Dust deposition into the freshwater environment could affect the VEC freshwater water quality by introducing suspended material and associated metals and nutrients into surrounding waterbodies. The potential effects from dust deposition may occur during all phases of the Project. No residual effects from dust deposition were predicted in the Environmental Risk Assessment (Volume 8, Chapter 6), so no further assessment of potential dust deposition effects on the VEC freshwater water quality was conducted.

4.5.3 Identification of Mitigation and Management Measures

The following section details mitigation and management measures designed to enhance Project benefits and reduce or eliminate negative Project effects. If mitigation and management measures were considered entirely effective, potential Project-related effects to the VEC freshwater water quality were deemed negligible and not identified as residual effects. Once these are taken into account, any remaining residual Project effects on the VEC freshwater water quality are characterized in Section 4.5.4.

The proposed mitigation and management measures would be actions to prevent, avoid, minimize, offset, or restore freshwater water quality on-site within the spatial and temporal boundaries of the Project. Mitigation and management measures to eliminate or reduce Project effects on freshwater quality include design and planning, engineered structures, the application of control technologies, best management practices, regulatory requirements, and monitoring and adaptive management. The relevant mitigation and management measures, including the spatial and temporal boundaries of the proposed actions, are considered and described for each Project activity in Sections 4.5.3.1 to 4.5.3.9. All mitigation and management measures will be applied, when applicable, throughout the life of the Project. The Aquatic Effects Management Plan (Volume 10, Chapter 19) details the mitigation and management measures for the receiving freshwater environment. The Site Water Monitoring and Management Plan (Volume 10, Chapter 7) is the key plan for site and mine contact water. The following environmental management plans relevant to the VEC freshwater water quality will be applied during the Project:

- Risk Management and Emergency Response Plan (Volume 10, Chapter 3);
- Fuel Management Plan (Volume 10, Chapter 4);
- Spill Contingency Plans (Volume 10, Chapter 5);
- Mine Waste Rock Management Plan (Volume 10, Chapter 9);
- Waste Management Plan (Volume 10, Chapter 10);
- Incineration Management Plan (Volume 10, Chapter 11);
- Hazardous Materials Management Plan (Volume 10, Chapter 12);
- Explosives Management Plan (Volume 10, Chapter 13);
- Road Management Plan (Volume 10, Chapter 14);
- Borrow Pits and Quarry Management Plan (Volume 10, Chapter 16);
- Air Quality Monitoring and Management Plan (Volume 10, Chapter 17);
- Conceptual Fish Offsetting Plan (Volume 10, Chapter 21);
- Tailings Management Plan (Volume 10, Chapter 22); and
- Mine Closure and Reclamation Plan (Volume 10, Chapter 29).

4.5.3.1 Construction and Decommissioning Activities

The primary pathway of interaction between the Project activities in the Construction and Decommissioning interaction group and the freshwater environment is runoff. The proposed mitigation and management measures will minimize the potential for erosion and the transport of material in runoff (Aquatic Effects Management Plan, Volume 10, Chapter 19; Site Water Monitoring and Management Plan, Volume 10, Chapter 7). The Project will minimize runoff and the transport of material into the freshwater environment by the following planning and design measures:

- Infrastructure and waste rock storage areas will be confined to the local watersheds where the deposits are located to limit potential effects on water quality to local drainage areas;
- Infrastructure will be located, whenever feasible, on competent bedrock or appropriate base material that will limit permeability and the transport of potentially lower quality water into the active layer and ultimately to the freshwater environment;

- The Project infrastructure will be designed to minimize the footprint area, such as being located near the deposits; and
- Restoration of the landscape will occur as soon as possible to minimize erosion potential.

The Project will use Best Management Practices (BMP) drawn from governmental organizations and specific Arctic experience to minimize erosion and reduce the entrainment of potential chemical compounds into runoff. Project activities near water will follow the DFO Nunavut Measures to Avoid Causing Harm to Fish and Fish Habitat (Fisheries and Oceans Canada 2013a). In-water work will be conducted during approved timing windows (Fisheries and Oceans Canada 2013b). Only geochemically suitable rock quarries and borrow sources that provide non-potentially acid-generating rock will be used to construct roads, pads, and structures (Mine Waste Rock Management Plan, Volume 10, Chapter 9; Tailings Management Plan, Volume 10, Chapter 22). Exposed landscape surfaces will be protected, where possible, by the installation of covering material like riprap, aggregate, or rolled erosion control products. Runoff flow may be controlled by a combination of measures, including:

- slope texturing/grading to slow runoff and reduce effect slope lengths;
- installation of synthetic permeable barriers and/or fibre rolls to reduce runoff velocities and retain sediments; and
- check dams, gabions, and energy dissipation structures to reduce flow velocities in channels.

Sediment levels in runoff will be minimized, where applicable by intercepting sediment before it reaches the freshwater environment. In addition to measures aimed at controlling runoff flow, the quantity of transported material in runoff may be controlled by measures including:

- preservation of riparian zones to trap sediment and to reduce flow velocities;
- installation of silt fences as required;
- installation of sediment basins to reduce flow velocities and encourage sediment deposition;
- stockpiles located well away from watercourses; and
- Refuelling and maintenance activities not occurring within 30 m of a watercourse or waterbody except where required due to equipment breakdown or approved activities near water.

The dewatering effects on freshwater water quality will be mitigated as outlined in the Lake Dewatering Plan (Site Water Monitoring and Management Plan, Volume 10, Chapter 7). Dewatering will be staged to seasonal flows, when possible, to minimize adverse effects to water quality and quantity. Acceptable volumes of water transferred to the receiving environment will be determined to avoid effects associated with water level fluctuations in the receiving environment. Clean water transferred to the receiving environment will remain within 10% of base flow or water levels if possible.

Depending on the volume of clean water to be discharged to the receiving environment, lake dewatering may be conducted in the fall when there is some ice cover on the shore that will limit resuspension of lakebed sediments. This would allow for the maximum amount of clean water to be transferred by keeping the TSS levels low in the lake to be dewatered longer. However, the fall is also when base flows are at their lowest, so the amount of clean water that could be transferred may be limited depending on the receiving environment location.

Clean lake water will be transferred and monitored for turbidity and TSS, until the TSS threshold is reached (Site Water Monitoring and Management Plan (Volume 10, Chapter 7). Water transferred during

dewatering activities will meet a TSS or turbidity threshold equivalent to the MMER limit for TSS (15 mg/L). Water that does meet established criteria will be treated prior to discharge. The water from Llama Lake during dewatering was predicted to have elevated arsenic concentrations (Water and Load Balance Report, Volume 2, Appendix V2-7H). Therefore, treatment for suspended sediments and arsenic will be conducted as necessary during Llama Lake dewatering prior to discharge to Goose Lake.

Changes to water quality during construction and decommissioning activities will be monitored under the Site Water Monitoring and Management Plan (Volume 10, Chapter 7) and the Aquatic Effects Monitoring Program (AEMP; Volume 10, Chapter 19) and to ensure drainage and erosion controls are effective. Previously designed and executed aquatic effects monitoring programs have been shown to be effective at monitoring construction activities of other Arctic projects (Rescan 2012b). Necessary repairs and adjustments to operations will be conducted as needed to ensure water quality does not surpass the CCME guidelines for water quality parameters in fish-bearing receiving waters and is maintained within baseline variability (Table 4.5-3; CCME 2015). The need for any corrective actions to on-site management or installation of additional control measures will be determined on a case-by-case basis. Indications of the need for corrective actions and additional control measures may include:

- if results from the Site Water Monitoring Program (Volume 10, Chapter 7; to be outlined in the future Type A Water Licence) show non-compliance; or
- if results from the Aquatic Effects Monitoring Program (Volume 10, Chapter 19), which will monitor the receiving environment around the mine infrastructure and activities, show negative effects to the freshwater environment attributable to Project activities.

Potential residual effects from construction and decommissioning activities on freshwater water quality may occur.

4.5.3.2 Winter Ice Roads

The two interaction pathways for potential effects from winter ice roads on the freshwater water quality VEC are water withdrawals and runoff (during ice off). Water withdrawals for winter ice roads will follow DFO's Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut (Fisheries and Oceans Canada 2010) and DFO's Operational Statement on Mineral Exploration Activities (Fisheries and Oceans Canada 2009). Withdrawals will be limited to less than 10% of the total under-ice volume. Project effects from winter ice roads through runoff will be mitigated by:

- being constructed during the winter months;
- application of the BMP for the construction of ice bridges and winter ice roads (Fisheries and Oceans Canada 2009);
- by the maintenance and repair of any potential leaks of fuels and petroleum hydrocarbons (Fuel Management Plan; Volume 10, Chapter 4); and
- the BMP for refueling and the operation of vehicles on the winter ice roads (Road Management Plan; Volume 10, Chapter 14).

The effects from winter ice roads on the VEC freshwater water quality through the water withdrawal and runoff pathways were predicted to be negligible because winter ice road operations will be in compliance with regulations and guidelines. Thus, no residual effects from winter ice roads are predicted on the VEC freshwater water quality.

4.5.3.3 Site Contact Water

Runoff is the interaction pathway for site contact water. The primary mitigation measure will be to intercept and divert site contact water before it reaches the freshwater environment (Site Water Monitoring and Management Plan; Volume 10, Chapter 7). Infrastructure will be designed such that its footprint is minimized to limit the changes to local drainage patterns. All roads and surfaces will be constructed using geochemically suitable material (i.e., non-acid-drainage-generating rock; Mine Waste Rock Management Plan, Volume 10, Chapter 9; Tailings Management Plan, Volume 10, Chapter 22). Non-contact water will be diverted around infrastructure, as much as is feasible, and directed to natural downstream drainage networks to maintain local drainage patterns. Site contact water will be directed to tailings storage facilities and water management infrastructure and will not contact the surrounding freshwater environment. Clean water and snow will be managed such that they do not contribute to potentially poor quality water and will be diverted to maintain natural drainage networks as much as possible.

Monitoring and adaptive management will be used to ensure the goals of the Site Water Monitoring and Management Plan and Aquatic Effects Management Plan are met (Volume 10, Chapters 7 and 19). Regular inspections of water management facilities will be conducted by Environmental Personnel under the Site Water Monitoring and Management Plan (Volume 10, Chapter 7). The need for any corrective actions to on-site management or installation of additional control measures will be determined on a case-by-case basis. Residual effects on freshwater water quality from site contact water may occur.

4.5.3.4 Mine Contact Water

Mine contact water will interact with the freshwater water quality VEC through the runoff and discharge pathways. The primary mitigation and management measure will be diverting mine contact water away from the freshwater environment. All mine contact water from runoff and inflow sources will be collected and directed to the water management and tailings storage facilities as soon as the water management infrastructure is completed in the Construction Phase. The water management plan includes the collection/management of runoff from WRSAs, ore stockpiles, and stored tailings. There is the potential for residual effects from mine contact water on freshwater water quality.

4.5.3.5 Water Use

Water use may affect the VEC freshwater water quality through the water withdrawal pathway. The effects of water withdrawals will be mitigated by restricting withdrawals to less than 10% of the outflow volume of Big Lake and restricting water withdrawals to maximum limits in Goose Lake, with AEMP monitoring (Volume 10, Chapter 19) tracking potential changes to freshwater water quality. The anticipated reductions in water level in Goose and Big lakes were designed to not adversely affect resident fish populations and are expected to be within acceptable natural variability (Volume 6, Chapter 6, Section 6.5.3.2). The water withdrawals were concluded to be within DFO guidelines (Fisheries and Oceans Canada 2009, 2010) as ice thickness varies up to 0.2 m among years and locations and water level fluctuates more than 0.3 m during the open-water period (Rescan 2012, 2013a).

Potential effects on the VEC freshwater water quality arising out of water use are predicted to be negligible when the designed mitigation measures are followed. Water withdrawals will be managed by restricting them to the maximum limits outlined in the Fish Habitat Chapter (Volume 6, Chapter 6) and Hydrology Chapter (Volume 6, Chapter 1). Therefore, no residual effects from water use are predicted on the VEC freshwater water quality.

4.5.3.6 Quarries and Borrow Pits

Quarries will interact with the VEC freshwater water quality through the runoff pathway. Mitigation and management measures for the construction and operation of quarries and borrow pits will be focused on minimizing the material and compounds potential transported in runoff, and minimizing the runoff reaching the freshwater environment (Site Water Monitoring and Management Plan - Volume 10, Chapter 7; Borrow Pits and Quarry Management Plan - Volume 10, Chapter 16). The materials and compounds in quarry runoff will be minimized by the following measures:

- quarries will be developed using only geochemically suitable material (Mine Waste Rock Management Plan, Volume 10, Chapter 9; Tailings Management Plan, Volume 10, Chapter 22); and
- machinery will be maintained and repaired to avoid potential leaks of fuels and petroleum hydrocarbons (Fuel Management Plan; Volume 10, Chapter 4).

The effects of runoff from quarries will be minimized by the following measures:

- local drainage patterns will be maintained and the flow of water into the quarry minimized by the diversion of non-contact water around quarries; and
- quarries and borrow pits will have water collection and control infrastructure (Borrow Pits and Quarry Management Plan; Volume 10, Chapter 16). If the runoff is turbid but chemically-unaltered, it will be allowed to infiltrate into the ground.

Runoff will be monitored and managed to ensure the receiving environment will meet CCME water quality guidelines. Adjacent waterbodies will be monitored for water quality through the Site Water Monitoring and Management Plan (Volume 10, Chapter 7) and the Aquatic Effects Management Plan (Volume 10, Chapter 19). Due to the mitigation and management measures, including monitoring and adaptive management of quarry runoff, no residual effects from quarries and borrow pits were predicted on the VEC freshwater water quality.

4.5.3.7 Explosives

Potential effects from explosives will interact with the freshwater environment through the runoff and aerial deposition pathways. Deposition of explosives and blasting residues on surfaces, with the subsequent possibility of transport in runoff to freshwater environments, will be mitigated and managed by:

- explosive products will be stored on site in accordance with Territorial and Federal regulations (1990; C.R.C., c. 599);
- the handling and manufacture of explosives will be contracted to a licensed operator;
- runoff from explosive storage and manufacture facilities will be intercepted and collected before reaching the freshwater environment (Mobilization and Construction Phase) or diverted to the water management infrastructure or tailings storage facilities (Operations Phase); and
- BMP will be adopted for blasting and the handling of explosives to avoid spillage and minimize ammonium and nitrate residues after blasting.

The BMP for explosives use will manage dust and excess blasting residues (Explosives Management Plan; Volume 10, Chapter 13). Blasting residues will be monitored in Project lakes through the AEMP (Volume 10, Chapter 19) and Site Water Monitoring Program (Volume 10, Chapter 7).

Explosives will be used during Operations and Reclamation and Closure phases, primarily for mining operation, with minor quarry and borrow pit activities for maintenance materials and potential closure activities. It is expected that all contact water will be diverted to the water management facilities and therefore any blasting residues will be diverted to these facilities and not to the freshwater environment. However, some blasting residues may contact the freshwater environment through the runoff pathway after the water management infrastructure is decommissioned and reclaimed Project infrastructure area is re-connected to natural drainage networks. Therefore, residual effects were predicted from the use, storage, and transportation of explosives on the VEC freshwater water quality.

The effects from blasting residues on water quality through the aerial deposition pathway was predicted to be negligible due to the mitigation and management measures for explosives use and air quality (Volume 10, Chapters 13 and 17). The quantity of explosives will be designed to minimize the generation of dust and further dust management measures will minimize the transport of any generated dust particles.

4.5.3.8 Fuels, Oils, and PAH

The fuels, oils, and PAH Project interaction group activities will interact with the freshwater environment through runoff and aerial deposition (for PAH). The mitigation and management measures for runoff are focused on preventing hydrocarbons from being transported in runoff and may consist of the follow measures:

- machinery will be routinely inspected for leaks and refuelling will occur, when feasible, at a designated refuelling point with drainage capture/collection installed. In the event that refuelling occurs elsewhere, drip trays may be used under vehicles and equipment;
- appropriate secondary containment systems will be used for petroleum product storage tanks to prevent spills and releases to water, including the prevention of diesel release from pickups carrying tidy-tanks;
- bulk fuel storage areas and hazardous materials storage areas will be bermed and lined with impermeable barriers to minimize leaks and spills; and
- Oily water treatment plants at equipment maintenance facilities will be used to minimize water and surface hydrocarbon compounds.

In the event that hydrocarbons are transported in runoff, runoff from camp pads, laydown areas, and waste management areas will be directed to the water management structures and will not be discharged into the freshwater environment. Prior to the completion of the water management infrastructure during the Mobilization and Construction Phase, runoff will be collected in sumps and discharged only if it meets water quality standards. Fuels, oils, and PAHs will be managed under the Fuel Management Plan (Volume 10, Volume 4) and the Hazardous Materials Management Plan (Volume 10, Chapter 12).

For the aerial deposition pathway, the primary mitigation measure will be the efficient operation of the incinerator (Incineration Management Plan; Volume 10, Chapter 11). The operation of the incinerator will comply with Nunavut guidelines (Government of Nunavut 2012), Canada-Wide Standards for Dioxins and Furans (CCME 2001) and Canada-Wide Standards for Mercury Emissions (CCME 2000). Management measures will include the following:

- a waste segregation program will be implemented (i.e., materials that are unsuitable for incineration, e.g., chlorinated plastics, will be diverted to alternate waste disposal facilities);

- personnel will be properly trained in incinerator operations; and
- stack testing during commissioning and adaptive management to ensure compliance with standards.

Project activities related to fuels and other petroleum hydrocarbons were predicted to have negligible effects on the VEC freshwater water quality through the runoff and aerial deposition pathways because of the proposed mitigation and management measures. No hydrocarbon compounds or sediments from Project activities in the camps, laydown areas, fuel areas, or waste storage areas were predicted to reach the freshwater environment because of the BMPs for machinery operation, maintenance, and fueling, and the direction of runoff carrying potential compounds to the water management facilities. The incinerator will be operated according to guidelines and standards, and therefore negligible aerial deposition of PAH into the freshwater environment were predicted. Therefore, no residual effects from fuels, oils, and PAHs are predicted on the VEC freshwater water quality.

4.5.3.9 Treated Sewage Discharge

The pathway of interaction between treated sewage and the freshwater environment is discharge. Treated sewage will be discharged to Llama Lake during the Construction Phase and to tailings storage facilities during the Operations and the Closure phases. Since Llama Lake will be dewatered, residual effects to Llama Lake were not considered. The diversion of treated sewage during the Operations and Closure phases was predicted to ensure no effects from sewage would occur in the receiving environment. Thus, it is anticipated there will be no residual effects from treated sewage discharge on the VEC freshwater water quality.

4.5.4 Characterization of Residual Effects

In Section 4.5.3, nine potential effects were evaluated for whether they would result in residual effects after mitigation. Residual effects are those effects predicted to remain after the application of mitigation and management. Four of these potential effects were identified as residual effects: 1) *construction and decommissioning activities*; 2) *site contact water*; 3) *mine contact water*; and 4) *explosives*. The significance of these residual effects is evaluated below. Each residual effect is described in this section in terms of eight descriptors (Volume 9; Chapter 1), including: direction, magnitude, duration, frequency, geographic extent, reversibility, probability, and confidence. The magnitude of the residual effect was evaluated by using the information in Table 4.5-1. Table 4.5-2 provides a description of the significance ratings used for residual effects.

4.5.4.1 Construction and Decommissioning Activities

The mitigation and management measures were predicted to be effective and minimize potential effects from runoff associated with construction and decommissioning activities. The use of only geochemically suitable material for construction of roads and pads will eliminate the potential for acid-rock drainage (Mine Waste Rock Management Plan, Volume 10, Chapter 9; Tailings Management Plan, Volume 10, Chapter 22). The proposed mitigation and management measures will minimize the quantity of material transported in runoff (e.g., TSS and metals) and the likelihood of runoff reaching the freshwater environment. Some runoff into nearby waterbodies could be possible during the early stages of construction (Mobilization and Construction Phase) before water management structures are fully operational (e.g., TSF, sediment ponds, and diversion ditches). Once the water management structures are in place, any runoff from cleared areas is expected to be fully mitigated.

Water transferred during dewatering activities will meet a TSS or turbidity threshold equivalent to the MMER limit for TSS (15 mg/L). This threshold is less than the CCME water quality guideline for TSS and any increase in the TSS due to the discharge of water during dewatering would be transient and restricted to the PDA. In addition, any increases in sediment concentrations from the construction of

retention dykes would likely be transient and restricted to the PDA. Water treatment will be used during the dewatering of Llama Lake to reduce arsenic and suspended sediment concentrations. The treated effluent was predicted to have arsenic concentration less than or equal to 0.015 mg/L. Arsenic concentrations in the receiving environment were expected to be immediately diluted below the proposed site-specific water quality objective of 0.01 mg/L (see Section 4.5.4.3). The loadings of arsenic from the Llama Lake dewatering activities to Goose Lake were included in the Project Water and Load Balance model (Volume 2, Appendix V2-7H), and therefore assessed with Mine Contact Water in Section 4.5.4.3 below.

Residual effects from construction and decommissioning activities are predicted on the VEC freshwater water quality during the Mobilization and Construction Phase when water management features are in the process of being constructed and commissioned. Only small amounts of runoff would be expected to reach the surrounding waterbodies while the water management features are being constructed. The extensive mitigation and management measures incorporating design, BMPs, and adaptive management are predicted to minimize the transport of sediments through runoff into the freshwater environment. Water transferred during dewatering activities will meet a TSS or turbidity threshold equivalent to the MMER limit for TSS (15 mg/L). This threshold is less than the CCME water quality guideline for TSS and any increase in the TSS due to the discharge of water during dewatering would be transient and restricted to the PDA. In addition, any increases in sediment concentrations from the construction of retention dykes would likely be transient and restricted to the PDA. The predicted magnitude of the residual effect from all construction and decommissioning activities was *low*.

The magnitude of the residual effect was evaluated in the context of the final receiving environment for fish-bearing waters with respect to the thresholds given by the CCME water quality guidelines. Upstream sources close to construction and decommissioning activities may have higher TSS concentrations, but the residual effects were evaluated for the nearby fish-bearing environments. During peak freshet flows, streams in the LSA had TSS concentrations ~10 mg/L greater than they had during average flows (TSS concentrations ~1.8 mg/L; Section 4.1.7.2), which suggest that periodic high-sediment conditions are a feature of the freshwater environment. Therefore, the effects on the VEC freshwater water quality from construction and decommissioning activities were predicted to be within natural variation and less than CCME water quality guidelines because of the mitigation and management measures and natural variability.

The effects were predicted to be footprint (within the PDA) or *local* (restricted to the LSA), *short-term* in duration, and *sporadic* as runoff would only occur during snowmelt and large precipitation events. The freshwater environment has the capacity to recover and the effects were predicted to be fully *reversible*. The probability of occurrence was estimated to be *moderate* due to the uncertainties related to precipitation, and confidence was *high* because of the quantitative input from the baseline environmental data, the predictable nature of this potential effect, and the confidence in the mitigation and management strategies.

Overall, the residual effect of construction and decommissioning activities, which describes the disturbance of the landscape due to the construction and reclamation of Project infrastructure, is predicted to be **Not Significant** on the VEC freshwater water quality.

4.5.4.2 Site Contact Water

The mitigation and management measures were predicted to be effective and minimize the potential effects from runoff associated with site contact water. Once the site water management infrastructure is complete (Site Water Monitoring and Management Plan; Volume 10, Chapter 7), all site contact water will be diverted to the water management facilities and will not contact the freshwater

environment. Therefore, no residual effects on the VEC freshwater water quality from site contact water were predicted during the Operations, Temporary Closure, Care and Maintenance, and Reclamation and Closure phases. No residual effects from site contact water were predicted after reclamation and decommissioning is complete in the Post-Closure Phase. However, Project activities will occur when the site water management infrastructure is not functional (e.g., before commissioning during the Mobilization and Construction Phase). Some runoff into nearby waterbodies could be possible during this period; therefore, residual effects from site contact water are predicted on the VEC freshwater water quality during the Mobilization and Construction Phase when the water management features are in the process of being constructed and commissioned.

Site contact water was predicted to have no residual effects on the VEC freshwater water quality during the subsequent Project phases because of the comprehensive site water management that will divert all site contact water (from roads, pads, buildings, and infrastructure) to the water management facilities.

Only during the Mobilization and Construction Phase would site contact water potentially reach the freshwater environment, and only small amounts of runoff would be expected to reach the surrounding waterbodies while the water management features were being constructed. In the event that site contact water did contact the freshwater environment, the water quality indicators were predicted to be within the range of natural variation and within CCME water quality guidelines (as discussed in Section 4.5.5.1), so the predicted magnitude of the residual effect was *low*. The effects were predicted to be footprint (within the PDA) or *local* (restricted to the LSA), *short-term* in duration because the potential effects would be confined to the Mobilization and Construction Phase, and *sporadic* as runoff would only occur during snowmelt and large precipitation events. The freshwater environment was predicted to be resilient and the effects were predicted to be fully *reversible*. The probability of occurrence was estimated to be *moderate* due to the uncertainties related to precipitation, and confidence was *high* because of the quantitative input from the baseline environmental data and the confidence in the mitigation and management strategies.

The residual effect of site contact water on the VEC freshwater water quality is predicted to be **Not Significant**.

4.5.4.3 Mine Contact Water

The mitigation and management measures were predicted to be effective and minimize the potential effects from runoff and discharge associated with mine contact water. Once the site water management infrastructure is complete (Site Water Monitoring and Management Plan; Volume 10, Chapter 7), all mine contact water, including underground water and runoff from WRSAs, will be diverted to the water management facilities and will not contact the freshwater environment until water management infrastructure is decommissioned and reclaimed. The Project Water and Load Balance Report (Volume 2, Appendix V2-7H) details the quantitative water quality model used to predict loadings of mine contact water in the vicinity of the mine.

In order to assess the potential effects of mine contact water on the freshwater receiving environment and the VEC freshwater water quality, the following additional tasks were completed:

- Development of a site-specific water quality objective for arsenic in Goose Lake;
- Development of a site-specific water quality objective for copper in Goose Lake;
- Development of a Goose Lake hydrodynamic model to predict arsenic concentrations in Goose Lake (see Rescan 2015d, Volume 6, Appendix V6-4A); and

- Screening of load balance results with relevant guidelines (for assessment of streams) to assess Goose Lake inflow tributaries.

The following sections provide the details of the arsenic and copper site specific Water Quality Objectives (WQOs) for Goose Lake, details of the Goose Lake arsenic predictions model, details of the Goose Lake inflow loading results, followed by a detailed assessment of each of the parameters found to be elevated above applicable guidelines (aluminum, arsenic, chloride, copper, iron, and mercury).

4.5.4.3.1 Development of Arsenic Site Specific Water Quality Objective for Goose Lake

Arsenic is a natural component of the aquatic environment, and was observed to be present in substantial quantities in the surficial sediments of Goose Lake (Volume 6, Chapter 5, Section 5.1.5.3). A site-specific water quality objective of 0.01 mg/L was developed for Goose Lake based on the toxicology of arsenic to aquatic organisms similar to organisms resident in Goose Lake. The generic CCME water quality guideline of 0.005 mg/L is based on a 10-fold safety factor applied to the lower observed toxicological threshold to an aquatic organism, which is an EC_{50} of 0.048 mg/L for As(V) with the freshwater alga *Scenedesmus obliquus* (Vocke et al. 1980; CCME 2015). Primary producers are the most sensitive components of the aquatic ecosystem to arsenic. The lowest reported toxicological thresholds for aquatic invertebrates and fish ranged between the following:

- EC_{50} of 0.520 mg/L for As(V) for the invertebrate *Daphnia magna* (Biesinger and Christensen 1972);
- low effect concentration of 0.530 mg/L for As(V) for the fish *Pimpephales promelas* (Birge 1978);
- LC_{50} of 0.540 mg/L and EC_{50} of 0.550 mg/L for As(III) for the fish *Oncorhynchus mykiss* (DeFoe 1982; EPA 1985);
- low effect concentration of 0.633 mg/L for As(III) for *Daphnia magna* (Lima et al. 1984);
- EC_{50} of 0.850 mg/L for As(V) for the invertebrate *Bosmina longirostris* (Passino and Novak 1984); and
- LC_{50} of 1.1 mg/L for As(III) for various freshwater fish (McIntyre and Linton 2012).

However, substantial variation has been observed in the arsenic toxicology of desmid chlorophytes—observed toxicological endpoints ranged between the following:

- 0.048 mg/L for As(V) with *Scenedesmus obliquus* (Vocke et al. 1980);
- 0.159 mg/L for As(V) with *Scenedesmus obliguus* (Chen, Chen, and Dai 1994);
- 0.256 mg/L for As(V) with *Ankistrodesmus falcatus* (Vocke et al. 1980); and
- 8.7 mg/L for As(V) with *Scenedesmus quadricauda* (Bringmann and Kühn 1980).

The geometric mean for the three lowest reported toxicological values for desmid phytoplankton is 0.125 mg/L. The proposed site-specific water quality objective of 0.010 mg/L is 5-fold less than the 0.048 mg/L toxicological threshold, and more than 12-fold lower than the geometric mean of comparable toxicological assays on the most sensitive group of aquatic organisms (desmid phytoplankton).

The site-specific water quality objective for arsenic in Goose Lake of 0.01 mg/L is used to assess the magnitude of residual effects for arsenic in the sections below. The WQO was also used for inflow tributaries to Goose Lake.

4.5.4.3.2 Development of Copper Site Specific Water Quality Objective for Goose Lake

Copper is naturally abundant in Goose Lake and its tributaries, and was observed to be naturally greater than CCME water quality guidelines in Goose Lake, Llama OF, Echo OF, and other waterbodies in the Project area (Section 4.1.6.5). A proposed site-specific water quality objective for copper in Goose Lake was calculated from the baseline total copper concentrations. In the baseline data, the median total copper concentration was 0.0018 mg/L and the 95% quantile copper concentration was 0.0042 mg/L (n = 35). The proposed water quality objective, therefore, was 0.0042 mg/L, which describes the upper limit of natural variation in copper concentrations.

The site-specific water quality objective for copper in Goose Lake of 0.0042 mg/L is used to assess the magnitude of residual effects for copper in the sections below. The WQO was also used for inflow tributaries to Goose Lake.

4.5.4.3.3 Goose Lake Hydrodynamic Model: Arsenic Predictions

For the assessment of arsenic concentrations in Goose Lake, a hydrodynamic model was developed which included all areas of Goose Lake (all depths and locations) and included all Project Phases (see Rescan 2015d, Volume 6, Appendix V6-4A).

For the Construction and Operations phases, results indicate that predicted arsenic concentrations remain below the CCME guideline for the protection of freshwater aquatic life (0.005 mg/L) in all parts of the lake at all times. Predicted arsenic concentrations at the known Lake Trout Spawning Habitat area and the Fish Overwintering Habitat area are predicted to remain below the CCME during these Project phases (see Figures 4.1-1 and 4.1-2 in the *2015 Goose Lake Hydrodynamic Modelling Report: Arsenic Perditions*; Rescan 2015d, Volume 6, Appendix V6-4A).

For the Closure phase, results indicate that predicted arsenic concentrations remain below the CCME guideline in the main basin of the lake. However, small, localized areas in the western and southern parts of the lake are predicted to have arsenic concentrations above the CCME guideline but at or below the site specific WQO for Goose Lake (0.01 mg/L). These localized elevated concentrations are a result of arsenic inputs from the Llama/Umwelt system (where the Llama and Umwelt open pits, waste rock storage areas, water management ponds, and Saline Water Pond are located) and the Goose Main Pit overflow and upstream tailings facility/waste rock storage facility system. These localized areas are predicted to dilute rapidly and arsenic concentrations in the main basin remain below the CCME guideline. Predicted arsenic concentrations at the known Lake Trout Spawning Habitat area and the Fish Overwintering Habitat area are predicted to remain below the CCME guideline for the protection of freshwater aquatic life (0.005 mg/L). Please see Figure 4.1-3 in the *2015 Goose Lake Hydrodynamic Modelling Report: Arsenic Perditions*; Rescan 2015d, Volume 6, Appendix V6-4A.

For the Post-Closure phase, the 'worst-case' year is presented, along with the last year of available modelled information. This is to provide predicted results for the expected long-term concentrations in the lake. The highest predicted arsenic concentrations occur at the beginning of the Post-Closure phase (year 2038). For the 'worst-case' year, predicted arsenic concentrations are greater than the CCME guideline throughout the lake during all seasons and at all depths. However, predicted concentrations remain below the WQO (0.01 mg/L) for the main basin of the lake. The main input of arsenic contributing to the Goose Lake concentrations is the overflow of the closed Goose Main Pit and the closure of the upstream tailings facility/waste rock storage area. The Llama/Umwelt system also continues to contribute to arsenic loading during this period.

However, for the Late Post-Closure phase, predicted arsenic concentrations return to levels at or below the CCME guideline in the majority of the lake during the open-water season. The exception is localized,

slightly elevated concentrations in the western end of the lake as a result of slight loadings from the Llama/Umwelt system. Please see Figures 4.1-4 and 4.1-5 in the *2015 Goose Lake Hydrodynamic Modelling Report: Arsenic Perditions*; Rescan 2015d, Volume 6, Appendix V6-4A.

Overall, Goose Lake is predicted to have arsenic concentrations close to or below the CCME guideline for the protection of freshwater aquatic life (0.005 mg/L) for the long-term (Figure 4.5-1).

Please refer to the *2015 Goose Lake Hydrodynamic Modelling Report: Arsenic Perditions* (Rescan 2015d, Volume 6, Appendix V6-4A) for additional figures and details of the Goose Lake arsenic modelling work.

4.5.4.3.4 Goose Lake Inflow Tributary Water Quality Data

To assess the potential effects on the streams entering Goose Lake, results from the water and load balance model were compared against relevant water quality guidelines (CCME 2015). Three inflow tributaries of Goose Lake were predicted to have concentrations greater than CCME guidelines: Llama Outflow, Echo Outflow, and Goose Inflow Southeast (SE; Figure 4.1-3). The following parameters are predicted to be elevated over applicable guidelines in at least one of these Goose Lake inflow locations: aluminum, arsenic, chloride, copper, iron, and mercury. A summary of the predicted concentrations along with a comparison to relevant CCME guidelines for the protection of freshwater aquatic life are provided in Tables 4.5-7 to 4.5-10.

Table 4.5-7. Summary of Predicted Water Concentrations of Parameters of Potential Concern in Llama Outflow, Goose Lake Tributary.

Parameter	Phase	Baseline Concentration (mg/L)[1]	CCME Guideline (mg/L)	Median Predicted Concentration (mg/L)	Maximum Predicted Concentration (mg/L)	Frequency of Predicted Values above Guideline
Arsenic	Construction	0.00020	0.005 (WQO=0.01 mg/L)	0.0015	0.0015	0
	Operations			0.0015	0.0022	0
	Closure			0.0062	0.0096	29
	Post-closure			0.0068	0.0083	118
Chloride	Construction	1	150	1	1	0
	Operations			1	184	6
	Closure			34	55	0
	Post-closure			5	20	0
Copper	Construction	0.0014	0.002[2] (WQO=0.0042 mg/L)	0.0014	0.0014	0
	Operations			0.0014	0.0015	0
	Closure			0.0019	0.0021	5
	Post-closure			0.0019	0.0021	23

[1] *Modelled baseline.*
[2] *Hardness-dependent guideline for soft water (hardness less than 80 mg/L) baseline.*

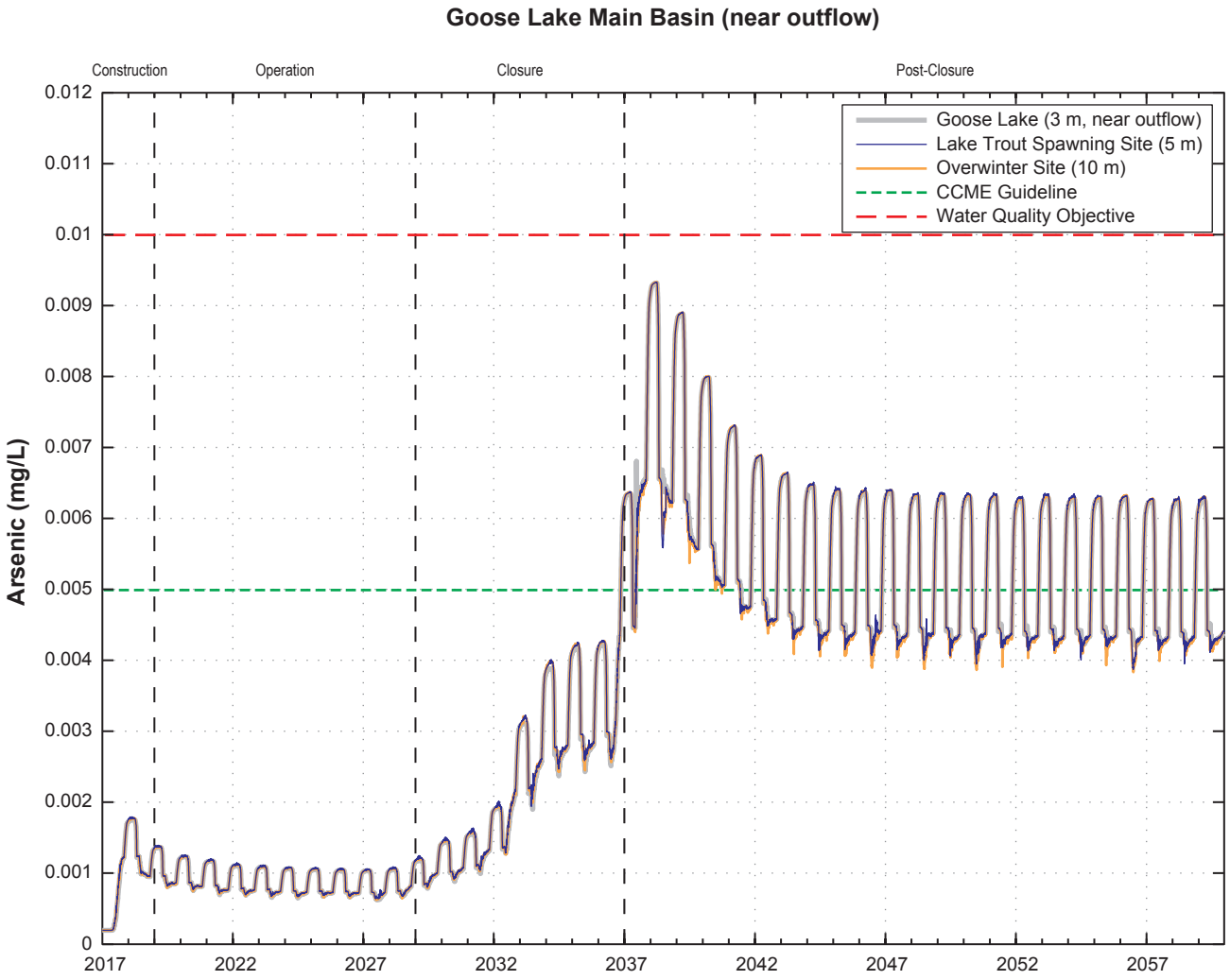

Figure 4.5-1

Predicted Arsenic Concentrations for Goose Lake with Time

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Table 4.5-8. Summary of Predicted Water Concentration of Parameters of Potential Concern in Llama Outflow Upstream, Goose Lake Tributary.

Parameter	Phase	Baseline Concentration (mg/L)[1]	CCME Guideline (mg/L)	Median Predicted Concentration (mg/L)	Maximum Predicted Concentration (mg/L)	Frequency of Predicted Values above Guideline
Arsenic	Construction	0.00020	0.005 (WQO=0.01 mg/L)	0.00020	0.00020	0
	Operations			0.00020	0.00020	0
	Closure			0.012	0.019	29
	Post-closure			0.013	0.016	138
Chloride	Construction	1	150	1	1	0
	Operations			1	1680	6
	Closure			99	295	14
	Post-closure			11	55	0
Copper	Construction	0.0014	0.002[2] (WQO=0.0042 mg/L)	0.0014	0.0014	0
	Operations			0.0014	0.0014	0
	Closure			0.0024	0.0028	29
	Post-closure			0.0025	0.0028	138
Iron	Construction	0.014	0.3	0.014	0.014	0
	Operations			0.014	0.014	0
	Closure			0.22	0.35	8
	Post-closure			0.087	0.18	0

[1] *Modelled baseline.*
[2] *Hardness-dependent guideline for soft water (hardness less than 80 mg/L) baseline.*

Table 4.5-9. Summary of Predicted Water Concentrations of Parameters of Potential Concern in Echo Outflow, Goose Lake Tributary.

Parameter	Phase	Baseline Concentration (mg/L)[1]	CCME Guideline (mg/L)	Median Predicted Concentration (mg/L)	Maximum Predicted Concentration (mg/L)	Frequency of Predicted Values above Guideline
Aluminum	Construction	0.011	0.005[2]	0.017	0.017	12
	Operations			0.014	0.049	60
	Closure			0.039	0.049	48
	Post-closure			0.036	0.039	138
Arsenic	Construction	0.00020	0.005 (WQO=0.01 mg/L)	0.0014	0.0014	0
	Operations			0.00091	0.010	4
	Closure			0.0067	0.010	48
	Post-closure			0.0058	0.0064	138
Nitrite (as N)	Construction	0.001	0.06	0.077	0.11	8
	Operations			0.0063	0.11	4
	Closure			0.011	0.093	7
	Post-closure			0.00091	0.0031	0

[1] *Modelled baseline.*
[2] *pH-dependent guideline, based on the mean baseline pH value of 6.2).*

Table 4.5-10. Summary of Predicted Water Concentration of Parameters of Potential Concentration in Goose Inflow Southeast, Goose Lake Tributary.

Parameter	Phase	Baseline Concentration (mg/L)[1]	CCME Guideline (mg/L)	Median Predicted Concentration (mg/L)	Maximum Predicted Concentration (mg/L)	Frequency of Predicted Values above Guideline
Aluminum	Construction	0.011	0.100[2]	0.012	0.012	0
	Operations			0.012	0.012	0
	Closure			0.012	0.113	2
	Post-closure			0.034	0.102	1
Arsenic	Construction	0.0002	0.0050 (WQO=0.01 mg/L)	0.00038	0.00040	0
	Operations			0.00037	0.00040	0
	Closure			0.00037	0.023	3
	Post-closure			0.0058	0.021	138
Copper	Construction	0.0014	0.0020[3] (WQO=0.0042 mg/L)	0.0014	0.0014	0
	Operations			0.0014	0.0014	0
	Closure			0.0014	0.0041	3
	Post-closure			0.0019	0.0037	23
Mercury	Construction	0.00001	0.00002	0.000010	0.000010	0
	Operations			0.000010	0.000010	0
	Closure			0.000010	0.000024	2
	Post-closure			0.000012	0.000022	1
Nitrite (as N)	Construction	0.001	0.060	0.014	0.020	0
	Operations			0.0020	0.010	0
	Closure			0.0010	0.36	4
	Post-closure			0.00099	0.31	20

[1] *Modelled baseline.*
[2] *pH-dependent guideline, based on the mean baseline pH value of 6.2).*
[3] *Hardness-dependent guideline for soft water (hardness less than 80 mg/L) baseline.*

4.5.4.3.5 Aluminum

The predicted aluminum concentration was greater than applicable CCME water quality guidelines in Echo OF and Goose IF SE (Tables 4.5-9 and 4.5-10). The residual effects from the changes in aluminum concentrations were predicted to be mediated by the natural background (Echo OF) or by the short duration of concentrations greater than guidelines (Goose IF SE). Aluminum concentrations in Echo OF in the baseline sampling program averaged 0.12 mg/L (*n* = 13, minimum = 0.067 mg/L, maximum = 0.163 mg/L). The predicted concentrations were less than observed background concentrations. The concentration of aluminum at Goose IF SE was predicted to be greater than CCME guidelines for a short period: two months during the Closure Phase and one month at the beginning of the Post-closure Phase (Table 4.5-10). The predicted concentrations were modestly greater than the guideline (maximum predicted concentration = 0.11 mg/L). Once these tributaries reach Goose Lake, these concentrations will be immediately reduced by dilution, and no residual effects were predicted beyond the tributaries.

The residual effect to water quality from aluminum in mine contact water was predicted to be *low* in magnitude because predicted values were within natural variability or at CCME guidelines and restricted to the PDA and *short term* in duration.

4.5.4.3.6 Arsenic

A hydrodynamic model was developed for predicting arsenic concentrations in Goose Lake (see Rescan 2015d, Volume 6, Appendix V6-4A). For the Goose Lake hydrodynamic model, arsenic concentrations were predicted over the temporal scale of all Project phases and the spatial scale of all of Goose Lake (all depths and locations). Both open-water (May to October) and under-ice (November to April) seasons were included in the modelling (Rescan 2015d, Volume 6, Appendix V6-4A).

Results from the hydrodynamic model indicate that predicted arsenic concentrations remain low and below the CCME guideline during the Construction and Operations phases. During the Closure phase, predicted concentrations start to rise, with concentrations peaking during the beginning of the Post-Closure phase (see Figure 4.5-1 above).

The elevated concentrations at the beginning of the Post-Closure phase are mainly due to the input of arsenic from the overflow of the closed Goose Main Pit and the closure of the upstream tailings facility/ waste rock storage area (via the Goose SE Inflow stream). The Llama/Umwelt system also continues to contribute to arsenic loading during this time. Peak concentrations in the main basin are predicted to be above the CCME guideline for the protection of freshwater aquatic life (0.005 mg/L), but below the site specific WQO for Goose Lake (0.01 mg/L).

During Post-Closure, predicted arsenic concentrations decline each year, with concentrations stabilizing approximately six years after the peak year. Once the input sources have stabilized, predicted arsenic concentrations remain at or below the CCME guideline for the majority of the year, but temporarily increase during the winter months due to cryoconcentration.

Please refer to the *2015 Goose Lake Hydrodynamic Modelling Report: Arsenic Predictions* for figures illustrating arsenic concentrations throughout the lake for each Project phase (Rescan 2015d, Volume 6, Appendix V6-4A). These figures clearly illustrate the areas within the lake where arsenic concentrations are predicted to be elevated over baseline concentrations.

For the inflow streams where the arsenic loading is arising, arsenic concentrations are predicted to be greater than concentrations in Goose Lake during the Closure Phase and the first two-to-three years of the Post-Closure Phase (Tables 4.5-8 and 4.5-10, Project Water and Load Balance Report, Volume 2, Appendix V2-7H; 2015 Goose Lake Hydrodynamic Modelling Report: Arsenic Predictions, Appendix V6-4A).

The magnitude of the residual effects from increases in arsenic concentrations in Goose Lake and its tributaries was determined to be *moderate* because predicted arsenic concentrations were near or greater than the site-specific water quality objective during the Closure and Post-Closure phases. The mitigation and management measures were predicted to ensure arsenic concentrations were below the water quality objective during the Construction and Operations phases, and the long-term arsenic concentration in Goose Lake was predicted to be below the water quality objective and at or below the CCME guideline, and therefore *low* in magnitude. Effects to aquatic life were not predicted because arsenic concentrations were predicted to be substantially less than identified toxicological thresholds for primary producers, aquatic invertebrates, and fish.

The duration of the effects was concluded to be *medium term*, because of the predicted increases of arsenic concentration during two project phases, but *local* in spatial extent because the expected increases in arsenic will remain within the LSA. The aquatic environment was predicted to be resilient to the predicted increases in arsenic concentrations because natural phytoplankton communities have a demonstrated resiliency to increased arsenic concentrations (Knauer, Behra, and Hemond 1999), and because arsenic concentrations were predicted to be near or below the site-specific water quality

objective. The residual effects from changes in arsenic concentrations were predicted to be *reversible*, because of the decrease in arsenic concentrations with time during post-closure.

4.5.4.3.7 Chloride

Residual effects from chloride were predicted downstream of the groundwater-storing Saline Water Pond (formerly Umwelt Lake), once that infrastructure is re-connected to natural drainage networks. Mine contact water enters the aquatic receiving environment at the Llama OF Upstream site, and chloride concentrations were predicted to be greater than guidelines for 20 months at the end of the Operations Phase and the beginning of the Closure Phase (Table 4.5-8). However, the chloride was predicted to be rapidly diluted in Llama OF. Maximum chloride concentrations decreased from 1,680 mg/L at the Llama OF US site to 184 mg/L at the Llama OF, which are less than 2 km apart (Table 4.5-7).

The residual effects from chloride were restricted to the section of Llama OF between the inflow from the Umwelt catchment and the inflow to Goose Lake. The magnitude of the residual effects from chloride on water quality was concluded to be *moderate* in magnitude, because concentrations were predicted to be greater than CCME guidelines. The residual effects were predicted to be restricted to the PDA and to be *short term* in duration.

4.5.4.3.8 Copper

Copper concentrations were predicted to be greater than the CCME water quality guideline for copper in soft waters (0.002 mg/L) in the Llama OF and Goose IF SE tributaries during the Closure and early-Post-Closure phases (Tables 4.5-7, 4.5-8, and 4.5-10). However, as copper is naturally abundant in Goose Lake and its tributaries, a site-specific WQO was developed of 0.0042 mg/L.

No predicted copper concentrations were greater than the site-specific water quality objective of 0.0042 mg/L. Although some predicted copper concentrations in Goose Lake tributaries were greater than the generic CCME water quality guideline (0.002 mg/L), the predicted copper concentrations were expected to be within the natural variation in the receiving environment. Therefore, the magnitude of the residual effects from copper on water quality was concluded to be *low*. The duration of the residual effects of copper, based on the quantitative modelling results, was *short term*, because the long-term median concentrations of copper in the Post-Closure Phase were close to baseline concentrations and less than the site-specific water quality objective and the generic CCME water quality guideline.

4.5.4.3.9 Iron

Increased concentrations of iron were predicted downstream of the Umwelt catchment during the Closure Phase. At the Llama OF US node, the maximum predicted concentration of iron was 0.35 mg/L, which was greater than the CCME long-term guideline of 0.3 mg/L (Table 4.5-8). Iron concentrations were predicted to be greater than CCME guidelines at the Llama OF US location for 8 months. As was observed for chloride, dilution in the Llama OF stream was predicted to reduce iron concentrations to 0.14 mg/L (Project Water and Load Balance, Volume 2, Appendix V2-7H). The residual effects from increased iron concentrations were predicted to be restricted to the PDA, *moderate* in magnitude, and *short term* in duration.

4.5.4.3.10 Mercury

Mercury concentrations were predicted to be slightly above guidelines for two months at the end of the Closure Phase and one month at the end of the Post-Closure Phase in the Goose IF SE stream (Table 4.5-10). The mercury in the Goose IF SE stream was predicted to be immediately diluted in

Goose Lake—the residual effects from mercury were predicted to be restricted to the Goose IF SE stream only. Therefore, the residual effects from mercury were predicted to be *moderate* in magnitude, *short term*, and restricted to the PDA.

4.5.4.3.11 Summary

Mine contact water may interact with the freshwater environment during all Project phases. In order to assess potential effects, a hydrodynamic model for Goose Lake was developed to predict arsenic concentrations in the lake, and site specific WQOs were developed for arsenic and copper. Increased concentrations of aluminum, arsenic, chloride, copper, iron, and mercury were predicted for some waterbodies in the LSA. The magnitude of residual effects for these water quality parameters was *low* to *medium* as they remained close to or below CCME guidelines or WQOs. The effects were predicted to be *local* as they would remain within the LSA, and *short term* to *medium* term in duration. The freshwater environment was predicted to be resilient and the effects were predicted to be *reversible* since the concentrations of all parameters were predicted to decrease with time. The probability of occurrence was estimated to be *high* due to the quantitative basis of the load balance model and the Goose Lake hydrodynamic model, and confidence was *high* because of the quantitative input from the baseline environmental data, the confidence in the mitigation and management strategies, and the quantitative water quality modelling.

The residual effect of mine contact water on the VEC freshwater water quality is predicted to be Not Significant.

4.5.4.4 Explosives

The quantitative water quality modelling included terms for nitrite, nitrate, and ammonia in blasting residues (Project Water and Load Balance Report; Volume 7, Appendix V2-7H). The predicted concentrations of blasting residues were screened against CCME long-term water quality guidelines, and nitrite concentrations were predicted to be greater than the CCME guideline in the Echo Outflow and the Goose Inflow SE stream (Tables 4.5-8 to 4.5-10). The timing of the predicted increases in nitrite concentrations depended on planned changes to the water management infrastructure (Project Water and Load Balance, Volume 2, Appendix V2-7H). Increased nitrite concentrations in Echo OF were predicted during the Mobilization and Construction Phase, Operations Phase, and the beginning of the Closure Phase (Table 4.5-9 and Project Water and Load Balance, Volume 2, Appendix V2-7H). In contrast, the increased nitrite concentrations in the Goose IF SE stream were predicted during the end of the Closure Phase and the beginning of the Post-Closure Phase (Table 4.5-10). The residual effects of nitrite, therefore, were predicted to be *short term* in duration, *local* in spatial extent because the elevated nitrite concentrations were predicted to be restricted to the Echo and Goose IF SE streams and the immediate dilution area in Goose Lake, and *sporadic* because nitrite would be mobilized only during snowmelt and large precipitation events. The freshwater environment was predicted to be resilient to the elevated nitrite concentration because nitrite is an active component of the nitrogen biogeochemical cycle. Furthermore, the residual effects from increased nitrite concentrations were predicted to be *fully-reversible* because of the natural nitrogen biogeochemical cycle.

The residual effect of explosives on the VEC freshwater water quality was predicted to be Not Significant.

4.5.5 Significance of Residual Effects

Four residual effects for the VEC freshwater water quality were assessed and resulted in the following significance ratings:

- construction and decommissioning activities – rated Not Significant;

- site contact water – rated Not Significant;
- mine contact water – rated Not Significant; and
- explosives – rated Not Significant.

The criteria used in the determination of the significance of each residual effect is detailed in Section 4.5.4 and summarized in Table 4.5-11.

4.6 POTENTIAL CUMULATIVE EFFECTS ASSESSMENT

4.6.1 Methodology Overview

The potential for cumulative effects arises when residual effects of the Project affect (i.e., overlap and interact with) the same resource/receptor that is affected by the residual effects of other past, existing or reasonably foreseeable projects or activities. When residual effects were identified for the Project, the Cumulative Effects Assessment (CEA) followed the process detailed in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1) and is comprised of the following steps:

1. Undertaking a scoping exercise to identify the potential for Project-related residual effects to interact with residual effects from other human activities and projects within a specified CEA boundary. For freshwater water quality, the boundary is the freshwater environment RSA.
2. Identifying and predicting potential cumulative effects that may occur and implementing additional mitigation measures to minimize the potential for cumulative effects where possible.
3. Identifying cumulative residual effects after the implementation of mitigation measures.
4. Determining the significance of any cumulative residual effects.

The cumulative residual effects were analyzed using the same criteria as the Project-related effects assessment (Section 4.5.1): direction, magnitude, duration, frequency, geographic extent, reversibility, probability of occurrence, and confidence in the analyses and conclusions. The magnitude of potential cumulative effects applied the same criteria as the Project-related effects assessment (Table 4.5-1). Using a weight of evidence and relative ranking approach, combined with best professional judgement, the cumulative residual effect was characterized as either significant (S), not significant (N), or positive (P) in the same manner as the Project-related effects assessment (Table 4.5-2).

Past, existing, and reasonably foreseeable major projects with potential residual effects that occur within the RSA for the VEC freshwater water quality were considered and are listed in Table 3.4-1 in the Effects Assessment Methodology (Volume 9, Chapter 1). The list includes projects within Nunavut and the Northwest Territories to consider the outermost spatial boundary, and reflects a comprehensive evaluation of potential interactions. As per the EIS guidelines (NIRB 2013a), the list of projects considered conforms to the requirement to consider a larger spatial boundary for the CEA as well as a longer temporal scale.

Table 4.5-11. Summary Table of Predicted Residual Effects and Overall Significance Rating

Description of Residual Effects	Project Phase	Significance Criteria			Likelihood of Occurrence			Overall Significance Rating		
		Direction	Magnitude	Duration	Frequency	Extent	Reversibility	Probability	Confidence	Significance
Construction and Decommissioning Activities	Mobilization and Construction	Negative	Low	Short term	Sporadic	Local	Reversible	Moderate	Medium	Not Significant
Site Contact Water	Mobilization and Construction	Negative	Low	Short term	Sporadic	Local	Reversible	Moderate	Medium	Not Significant
Mine Contact Water	Mobilization and Construction, Reclamation and Closure, and Post-closure	Negative	Low to Moderate	Short to Medium term	Sporadic	Local	Reversible	High	High	Not Significant
Explosives	Mobilization and Construction, Operations, Closure, and Post-closure	Negative	Moderate	Short term	Sporadic	Local	Reversible	High	High	Not Significant

The expected timing and duration of Project-related residual effects was compared with that of residual effects from other past, existing, and future human activities to identify temporal overlap. As identified in the EIS guidelines (NIRB 2013a), a longer timeline than the development and operations phases of the Project was considered.

4.6.2 Potential Interactions of Residual Effects with Other Projects

The following residual Projects effects on freshwater water quality were identified:

- construction and decommissioning activities;
- site contact water;
- mine contact water; and
- explosives.

The spatial boundary of the CEA was the Freshwater RSA (see Section 4.4.1). The temporal boundary for the CEA was any past, present, or reasonably foreseeable future projects (see list of projects in Volume 9, Chapter 1).

No past, present, or foreseeable projects that could potentially interact with the residual effects of the Back River Project lie within the Back River Project Freshwater RSA. Given that the Project residual effects were confined to the LSA, there are no expected cumulative effects on the VEC freshwater water quality.

4.7 TRANSBOUNDARY EFFECTS

As outlined in Section 4 of Volume 9 (Chapter 1), the potential for transboundary effects of the Project were determined based on whether residual Project effects could operate cumulatively with effects of projects in other jurisdictions. Transboundary effects can occur when VECs or the zone of influence of a project moves across jurisdictional borders external to the Nunavut Settlement Area (NSA). The non-significant Project residual effects for freshwater water quality are expected to remain confined to the LSA, which lies entirely within the Nunavut Settlement Area. As the Project residual effects were confined to Nunavut, there was no potential for transboundary effects.

4.8 MITIGATION AND ADAPTIVE MANAGEMENT

Mitigation and management measures will be used to eliminate or minimize Project effects on the VEC freshwater water quality. The measures include mitigation by Project design, conformity to existing regulations and guidelines, BMP, and the application of monitoring and adaptive management plans. The specific mitigation and management measures for freshwater water quality are shown in Table 4.8-1. Mitigation and management measures for other aspects of the Project, such as air quality and site water management, are detailed in Volume 10 of the FEIS, and detailed in the following plans:

- Risk Management and Emergency Response Plan (Volume 10, Chapter 3);
- Fuel Management Plan (Volume 10, Chapter 4);
- Spill Contingency Plans (Volume 10, Chapter 5);
- Mine Waste Rock Management Plan (Volume 10, Chapter 9);
- Waste Management Plan (Volume 10, Chapter 10);
- Incineration Management Plan (Volume 10, Chapter 11);
- Hazardous Materials Management Plan (Volume 10, Chapter 12);

- Explosives Management Plan (Volume 10, Chapter 13);
- Road Management Plan (Volume 10, Chapter 14);
- Borrow Pits and Quarry Management Plan (Volume 10, Chapter 16);
- Air Quality Monitoring and Management Plan (Volume 10, Chapter 17);
- Conceptual Fish Offsetting Plan (Volume 10, Chapter 21);
- Tailings Management Plan (Volume 10, Chapter 22); and
- Mine Closure and Reclamation Plan (Volume 10, Chapter 29).

Table 4.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Water Quality

Mitigation Category	Mitigation Measures
1. Mitigation by Project Design	
	Only geochemically suitable rock quarries and borrow sources will be used to construct roads, pads, and structures.
	Contact water will be directed to the water management infrastructure and tailings storage facilities.
	Infrastructure will be located, whenever feasible, on competent bedrock or appropriate base material that will limit permeability and transport of potentially poor quality water into the active layer and ultimately to the freshwater environment.
	The design of haul roads has been optimized to minimize the distance travelled, which will reduce dust deposition (and hence potential influence on water and sediment quality) associated with construction and operation.
	The Project has been designed to use winter ice road only access corridors thereby limiting dust emissions, limiting stream crossings, and instream works, and hence the potential influence on water and sediment quality.
	Erosion potential will be reduced by working during periods of low runoff as much as possible.
	Diversion of water will only occur at approved sources licensed for this function and during the temporal limits of the licence.
	Water will be recycled / reused where possible.
	Outlets will have a diffuser or be located in an area not subject to erosion from outflows.
2. Regulatory Requirements	
	MAC code/guidelines for design construction, operation, inspection/auditing of tailings management facilities
	The operation of incinerators will comply with Nunavut standards, Canada-Wide Standards for Dioxins and Furans and Canada-Wide Standards for Mercury emissions. Modern incineration equipment will be installed to minimize airborne contaminant loading of polycyclic aromatic hydrocarbons.
	Culvert maintenance will be conducted following the DFO Nunavut Measures to Avoid Causing Harm to Fish and Fish Habitat for Culvert Maintenance (Fisheries and Oceans Canada 2013a).
	In-water work will be conducted during approved timing windows presented in the DFO Nunavut Measures to Avoid Causing Harm to Fish and Fish Habitat for Timing Windows (Fisheries and Oceans Canada 2013b).
	Site road crossings will be constructed according to the the DFO Nunavut Measures to Avoid Causing Harm to Fish and Fish Habitat (Fisheries and Oceans Canada 2013a).
	Temporary stream crossings will be constructed according to the the DFO Nunavut Measures to Avoid Causing Harm to Fish and Fish Habitat (Fisheries and Oceans Canada 2013a).
	Winter ice road construction will follow the DFO Nunavut Measures to Avoid Causing Harm to Fish and Fish Habitat for Ice Bridges and Snow Fills (Fisheries and Oceans Canada 2013a).
	Water withdrawal will follow permit conditions.

(continued)

Table 4.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Water Quality (continued)

Mitigation Category	Mitigation Measures
3. Best Management Practices	
	Clean water and snow will be managed such that they do not contribute to potentially poor quality water and will be diverted to maintain natural drainage networks as much as possible.
	Potentially poor quality site water (runoff from waste rock storage areas, ore stockpiles, mine contact water) will be directed during operations to the water management infrastructure and tailings storage facilities.
	Sewage will be treated and not discharged to the receiving environment.
	Bulk fuel storage areas, hazardous materials storage areas, and explosives storage facilities will be bermed and lined with impermeable barriers to minimize leaks and spills reaching the freshwater environment.
	Modern incineration equipment will be installed to minimize airborne contaminant loading of dioxins, furans, and polycyclic aromatic hydrocarbons.
	Non-contact water will be diverted around infrastructure, as much as feasible, and directed to natural downstream drainage networks.
	Oily water treatment plants at equipment maintenance facilities will be used to minimize water and surface hydrocarbon contaminants.
	Disposal of excavated material will be in a location above the high water mark to ensure that this material does not enter the watercourse.
	Efforts shall be made to minimize the duration of any instream works and minimize disturbance of riparian vegetation at stream crossings.
	Prevent the release of sediment or sediment laden water into water frequented by fish.
	Regular inspections will be conducted to ensure erosion and sediment control measures are functioning properly; all necessary repairs and adjustments will be conducted in a timely manner.
	The dewatering of Llama Lake, or other waterbody, will follow an approved dewatering plan whereby water will not be discharged to the receiving environment if it does not meet approved criteria. Any poor quality water will be retained, discharged to a tailings storage facility or other appropriate holding facility.
	Exposed landscape surfaces will be protected, where possible, by the installation of covering material like riprap, aggregate, or rolled erosion control products.
	If water held in control devices is turbid but chemically-unaltered, it may infiltrate to the ground rather than storing it in an excavation.
	Runoff will be controlled where applicable by a combination of measures, which include: • slope texturing/grading to slow runoff and reduce effect slope lengths; • installation of synthetic permeable barriers and/or fibre rolls to reduce runoff velocities and retain sediments; and • check dams, gabions, and energy dissipation structures to reduce flow velocities in channels.
	Sediment loading in runoff may be minimized by the application of measures to intercept TSS before it reaches the freshwater environment. Sediment control measures may include: • preservation of riparian zones to trap sediment and to reduce flow velocities; and • stockpiles will be located away (>31 m) from watercourses.
	Visual monitoring will be conducted by the Environmental personnel on a regular basis to ensure drainage and erosion controls are effective.
	Construct ice bridge and snow fill approaches using clean, compacted snow and ice to a sufficient depth to protect banks of lakes, rivers or streams.

(continued)

Table 4.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Water Quality (completed)

Mitigation Category	Mitigation Measures
3. Best Management Practices (cont'd)	
	Vehicular access across a watercourse or waterbody will be by road or bridge, or other acceptable method according to DFO Measures to Avoid Serious Harm to Fish and Fish Habitat (Fisheries and Oceans Canada 2013a).
	All temporary works, silt curtains, construction material or debris, etc. are to be completely removed from the waterway when work is completed.
	Appropriate secondary containment systems will be used for petroleum product storage tanks to prevent spills and releases to water. This includes prevention of diesel release from pickups carrying tidy-tanks.
	Refueling and maintenance activities will not occur within 30 m of a watercourse or waterbody except where required due to equipment breakdown or approved activities near water.
	Refueling will occur at a refueling point with drainage capture/collection installed; in the event that refueling occurs elsewhere, drip trays will be used under vehicles and equipment.
4. Adaptive Management	
	The need for any corrective actions to on-site management or installation of additional control measures will be determined on a case-by-case basis. Indications of the need for corrective actions and additional control measures may include: • if results from the Surveillance Network monitoring program (which will be outlined in the future Type A Water Licence) show non-compliance; or • if results from the Aquatic Effects Monitoring Program, which will monitor the receiving environment around the mine infrastructure and activities, show negative effects to the freshwater environment.
5. Monitoring	
	An Aquatic Effects Management Plan will be in place that outlines the Aquatic Effects Monitoring Program (AEMP) that will be carried out during all phases of the Project. The AEMP will include the following: • monitoring a network of lakes and streams within the Goose Property Area at locations potentially affected by the Project and at reference areas well away from Project activities; • monitoring lake and stream water quality, sediment quality, and aquatic biology; • monitoring fish populations and fish tissues; and • if effluent (as defined in MMER regulations; SOR/2002-222) is discharged to the environment, then additional sampling for MMER requirements will be conducted (effluent characterization, acute toxicity testing, site characterization studies (including surface hydrology), sublethal toxicity testing).
	Regular inspections of water management facilities will be conducted by Environmental Personnel.
	There will be a Site Surveillance Network Monitoring Program that will be outlined in the future Type A Water Licence. This Program will consist of all of the site compliance monitoring that will be required for managing/moving and releasing water from all potential containment areas.

4.9 PROPOSED MONITORING PROGRAMS

4.9.1 Aquatic Effects Management Plan

The Aquatic Effects Management Plan describes the specific measures that will be taken to minimize or eliminate potential negative effects on the freshwater environment. The Plan includes the following components:

- planning and implementation processes for the Plan, including personnel and their responsibilities;

- mitigation and adaptive management measures;
- a detailed fish-out program
- the Aquatic Effects Monitoring Program (AEMP); and
- processes for adaptive management, checking, recordkeeping, reporting, and QA/QC.

The AEMP will monitor the receiving aquatic environment around Project infrastructure and activities. Results from the AEMP will be used to determine if existing mitigation and management measures are adequate and will provide an opportunity for adaptive management on an annual basis. It is anticipated that the AEMP will be a requirement of the future Type A Water Licence for the Project. The AEMP has also been designed to meet the requirements of Environmental Effects Monitoring (EEM) guidelines as required by the Metal Mining Effluent Regulations (MMER) in case of discharges from the water management infrastructure into the freshwater receiving environment.

4.10 IMPACT STATEMENT

Ten potential effects were identified for the VEC freshwater water quality as a result of the Project: construction and decommissioning activities; winter ice roads; site contact water; mine contact water; water use; quarries and borrow pits; explosives; fuels, oils, and PAH; treated sewage discharge; and dust deposition.

Potential effects were characterized using key indicators and quantitative thresholds as well as experience from other Northern projects and best professional judgement. Mitigation and management measures were described and their effectiveness was evaluated in the process of identifying residual effects. Four residual effects were identified after mitigation and management:

- construction and decommissioning activities;
- site contact water;
- mine contact water; and
- explosives.

Using the thresholds identified for the key indicators, each of these residual effects were rated with either a *low* or *moderate* magnitude and ultimately were rated as Not Significant because of the limited spatial extent of residual effects, and the implementation of the mitigation and management measures outlined in the Aquatic Effects Management Plan (Volume 10, Chapter 19), the Site Water Monitoring and Management Plan (Volume 10, Chapter 7), and other management plans in Volume 10. All residual effects to freshwater water quality were predicted to be restricted to the LSA. The freshwater environment was predicted to be resilient to the predicted residual Project effects.

No cumulative effects were predicted to occur as no interactions between other projects and the Back River Project freshwater water quality residual effects were expected because the effects were confined to the LSA. Similarly, as the Project residual effects were confined to Nunavut, there was no potential for transboundary effects.

4.11 SUPPORTING AND SUPPLEMENTAL INFORMATION

This section provides information requested in the EIS guidelines (NIRB 2013a) relating to water quality that was not included in the previous sections of this chapter. The EIS guidelines requested in Section 8.1.7.2:

> *…For any water sources identified as being current or future drinking water sources, compare concentrations of contaminants to relevant territorial drinking standards/guidelines and/or Health Canada Drinking Water Guidelines* (NIRB 2013a).

4.11.1 Drinking Water Baseline

Drinking water for the Project could come from either Goose Lake or Big Lake. The existing exploration camps are currently using Goose and George lakes as potable water sources, and have not experienced any drinking water quality issues. Current water quality data are available for all three lakes. Potable water is currently treated prior to use for human consumption. This procedure will continue throughout the mine life. Drinking water for the MLA camp will come from a desalination unit using Bathurst Inlet water. The desalinization plant will be operated according to the manufacturers requirements and the produced potable water will meet drinking water standards.

Table 4.11-1. Drinking Water Sources for Back River Project

Project Area	Proposed Drinking Water Source
Goose Property Area	Goose Lake or Big Lake
Marine Laydown Area	Bathurst Inlet (desalinated water)

All available water quality baseline data for Goose Lake and Big Lake are summarized in Table 4.11-2 along with the Canadian drinking water quality guidelines (Norecol Dames and Moore 1993, 1997; Health Canada 2012; Rescan 2012, 2013a, 2013b).

The mean baseline concentrations of all guideline metals were below the Canadian drinking water quality guidelines (Table 4.11-2). Therefore, the drinking water sources that are currently being used and may be used in the future will continue to provide safe drinking water for the proposed Project.

Table 4.11-2. Baseline Metal Concentrations in Lakes Used as Drinking Water Source

			Goose Lake[2]		Big Lake[3]	
Metals	Drinking Water Guidelines[1] (mg/L)	Detection Limits (mg/L)	Mean Baseline Total Concentration (mg/L)	95th Percentile of Baseline Concentration (mg/L)	Mean Baseline Total Concentration (mg/L)	95th Percentile of Baseline Concentration (mg/L)
Aluminum	0.1	0.003-0.02	0.0236	0.0694	0.019	0.021
Antimony	0.006	0.00005-0.002	<0.002	<0.002	<0.00005	<0.00005
Arsenic	0.010	0.00005-0.0004	<0.0004	<0.0004	0.00042	0.00046
Barium	1	0.00005	0.00808	0.0137	0.0044	0.0057
Beryllium	-	0.00001-0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Bismuth	-	0.0005-0.002	<0.002	<0.002	<0.0005	<0.0005
Boron	5	0.005	0.00606	0.0151	0.0054	0.0071
Cadmium	0.005	0.00001	<0.00001	0.0000273	<0.00001	<0.00001
Calcium	-	0.02	3.89	6.50	2.07	2.66
Chromium	0.05	0.0001-0.0005	<0.0005	0.000730	0.00022	0.00028
Cobalt	-	0.0001-0.0004	<0.0004	<0.0004	0.00069	0.0012
Copper	1	0.0001-0.0005	0.00203	0.00375	0.0019	0.0020
Iron	0.3	0.01	0.0340	0.0703	0.068	0.110
Lead	0.010	0.00005-0.0003	<0.0003	0.000421	<0.00005	<0.00005
Lithium	-	0.005	<0.005	<0.005	<0.005	<0.005
Magnesium	-	0.005	1.81	2.91	1.32	1.56
Manganese	0.05	0.00005	0.00394	0.00876	0.020	0.037
Mercury	0.001	0.00001-0.00005	<0.00005	<0.00005	<0.00001	<0.00001
Molybdenum	-	0.00005-0.0004	<0.0004	<0.0004	<0.00005	<0.00005
Nickel	-	0.001	0.00494	0.00792	0.0036	0.0047
Phosphorus	-	0.3	0.00485	0.150	0.0043	0.0053
Potassium	-	0.05	0.452	0.685	0.41	0.47
Selenium	0.01	0.00005-0.0002	<0.0002	0.000213	<0.0001	<0.0001
Silver	-	0.00001	<0.00001	<0.00001	<0.00001	<0.00001

(continued)

Table 4.11-2. Baseline Metal Concentrations in Lakes Used as Drinking Water Source (completed)

Metals	Drinking Water Guidelines[1] (mg/L)	Detection Limits (mg/L)	Goose Lake[2]		Big Lake[3]	
			Mean Baseline Total Concentration (mg/L)	95th Percentile of Baseline Concentration (mg/L)	Mean Baseline Total Concentration (mg/L)	95th Percentile of Baseline Concentration (mg/L)
Sodium	-	0.01	0.855	1.28	0.77	0.94
Strontium	-	0.0001-0.0002	0.0210	0.0363	0.0094	0.012
Thallium	-	0.00005-0.003	<0.003	<0.003	<0.00005	<0.00005
Tin	-	0.0001-0.002	<0.002	<0.002	<0.0001	<0.0001
Titanium	-	0.0003-0.01	<0.01	<0.01	<0.01	<0.01
TSS	-	3-4	<4	<4	<3	<3
Uranium	0.02	0.00001	<0.00001	0.0000110	0.000011	0.000014
Vanadium	-	0.00005	0.000190	0.000500	0.00014	0.00033
Zinc	5	0.001-0.003	<0.003	0.00485	0.0022	0.0035

Notes:

[1] Health Canada (2012). Guidelines for Canadian Drinking Water Quality Summary Table. Maximum acceptable concentrations and other values.

[3] Goose Lake sites (n = 26): Camp, Centre, Neck, South, Tail New, Tail Old.

*[3] Big Lake sites (*n = *3): Central and West.*

Baseline lake data collected in 1993, 1997, 2011, 2012, 2013 (Norecol Dames and Moore 1993, 1997; Rescan 2012, 2013a, 2013c).

(-) = no value

< DL = concentration was less than the method detection limits for that parameter

Samples where the concentration was below the detection limit were replaced with values of half the detection limit for calculation purposes.

Shaded values indicate concentrations above Health Canada guidelines.

5. Freshwater Sediment Quality

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5. Freshwater Sediment Quality

5.1 EXISTING ENVIRONMENT AND BASELINE INFORMATION

5.1.1 Overview and Regional Setting

The Back River Project (the Project) is located in western Nunavut in the continuous permafrost zone of the continental Canadian Arctic. The Project is composed of two main areas, the Goose Property Area and the Marine Laydown Area (MLA), which will be connected by winter ice roads (Figure 5.1-1). The majority of proposed infrastructure at the Goose Property lies within the regional Ellis River Watershed, which flows to the north and enters the Queen Maud Gulf (see Federal Watershed map in Chapter 1 of this Volume). The Back River Watershed lies to the south and east of the majority of proposed infrastructure and flows to the east eventually entering the Arctic Ocean south of Gjoa Haven.

The freshwater environment Regional Study Area (RSA; see Section 5.4.1 for definition) is characterized by extensive networks of lakes and streams within a hummocky landscape with low elevation relief and exposed bedrock uplands. Winter is characterized by extreme cold (mean monthly temperatures -33°C) and ice cover is present on lakes between October and July. Air temperatures are highest in July, reaching a mean monthly temperature of 14°C. Regional meteorological stations report total annual precipitation between 125 mm (2009) to 344 mm (2007) for the interval 2006 to 2012 (see Volume 4, Chapter 3 for additional information). Ice depths on waterbodies are typically 1.5 to 2 m thick and shallow waterbodies (< 1.5 m) freeze to the bottom (Rescan 2011, 2012a, 2013a, 2013b).

Hydrology in the Back River Project area is snowmelt dominated, with peak flows occurring from early May to mid-June in most watersheds. Occasional rainfall-driven high flow events may occur between June and September. The climate and the presence of permafrost results in one major flood period (freshet) in the June followed by a rapid return to base flow, and peak flow events throughout the rest of the summer and early fall periods in response to storms. Winter flow is absent as streams are frozen to the sediment bed and because of negligible groundwater reserves outside of the permafrost. Streams in the Project area are generally small and shallow and during summer tend to have low flow and low water levels. Many streams are ephemeral, flowing only during freshet.

Mean annual temperatures may increase in Canada's North by approximately 2.0ºC for the climate normal period for the years 2010 to 2030 (Volume 4, Chapter 3). Over the same time period, projections suggest that total annual precipitation could increase from 5 to 8% (Lemmen et al. 2008). The projected increase in mean annual air temperatures would lead to effects on the regional cryosphere. This would likely include alterations to sea, river, and lake ice regimes and winter snow pack, especially during the shoulder seasons of spring and fall, and to permafrost conditions. Studies of Arctic freshwater systems in the context of climate change conclude that ice-free seasons will be longer resulting in increased evaporation and water temperatures, increased lake stratification, and reduced permafrost (Prowse et al. 2006).

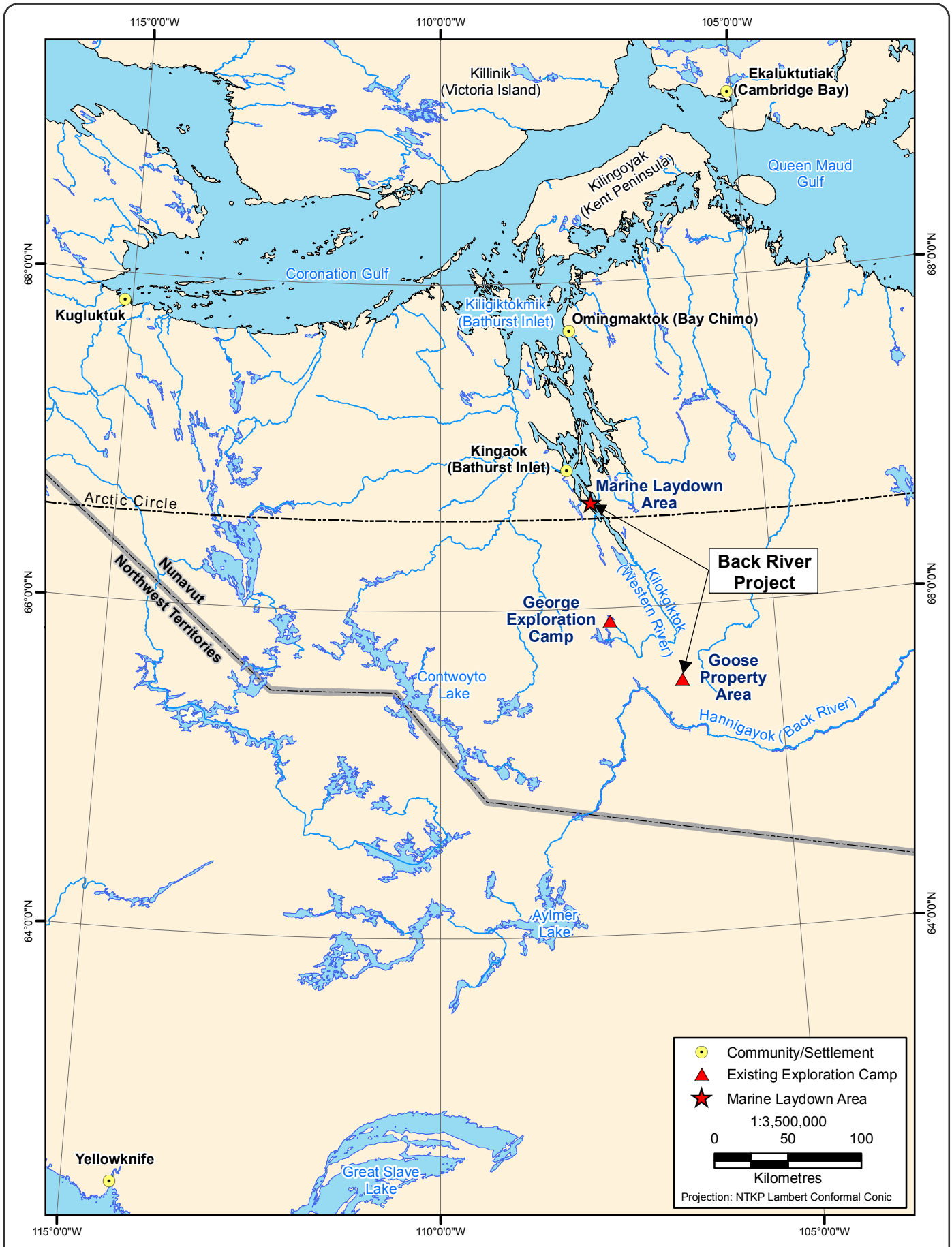

Figure 5.1-1

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Project Location

5.1.2 Proximity to Designated Environmental Areas

No existing or proposed parks or conservation areas are near the proposed Project. The nearest conservation area is the Queen Maud Gulf Migratory Bird Sanctuary approximately 100 km east of Bathurst Inlet on the far side of the Kent Peninsula. The Draft Nunavut Land Use Plan has no designated environmental areas within the RSA, and the proposed Project resides within the area designated as a High Mineral Potential area (Nunavut Planning Commission 2012). The proposed Hiukitak River Cultural Area is on the eastern shore of Bathurst Inlet outside of the RSA, and is approximately 60 km northeast of the proposed Marine Laydown Area (MLA). A key bird habitat site has been identified in the northern end of Bathurst Inlet, approximately 150 km north of the proposed MLA. The Back River is currently the only waterbody within the RSA to be considered as a heritage river. While no formal nomination for the Back River has been put forward thus far, the Project has been designed to avoid impacts to the Back River water system.

5.1.3 Baseline Study Area

Freshwater sediment quality baseline studies have been conducted in the streams and lakes in the Back River Project area from 2007 to 2015, with the most continuous sampling conducted by Rescan from 2010 to 2013. Sampling conducted near the MLA is covered in the Marine Environment Volume (Volume 7). Figure 5.1-2 shows the Goose Property Local Study Area (LSA) with the proposed Project infrastructure and baseline studies program.

5.1.4 Baseline Studies

5.1.4.1 Information Sources

The baseline data on freshwater sediment quality were compiled from recent site-specific surveys in the Project area. The primary sources of baseline sediment quality information used in the EIS were the following reports:

- *Back River Project: 2010 Lake Water and Sediment Quality Baseline Report* (Rescan 2011; Appendix V6-3A);
- *Back River Project: 2011 Freshwater Baseline Report* (Rescan 2012a; Appendix V6-3B);
- *Back River Project: 2012 Freshwater Baseline Report* (Rescan 2013a; Appendix V6-3C); and
- *Back River Project: 2013 Freshwater Baseline Report* (Rescan 2013b; Appendix V6-4B).

An additional source of supplementary sediment quality data used in this section was:

- *Field Report — Back River Project Freshwater Aquatic Resources 2007* (Gartner Lee Ltd. 2008).

5.1.4.2 Baseline Study Methods

Lakes

Baseline sediment quality data were collected from 19 lakes and ponds between 2007 and 2015 (Table 5.1-1; Gartner Lee Ltd. 2008; Rescan 2011, 2012a, 2013a, 2013b). All sediment samples were collected using an Ekman grab, although the number of sediment grabs combined to create a single replicate varied among sampling years. Replicates were spaced roughly 10 to 40 m apart. Each sediment sample was carefully transferred into a rinsed white plastic tray and the top 2 cm of sediment was scraped into a bowl, homogenized, and transferred to Whirl-Pak bags. All samples were refrigerated in darkness until shipment to ALS Environmental Services Ltd. (ALS; Burnaby, BC) for analysis. Baseline sampling methodologies and sampling locations are presented in Table 5.1-1; sampling locations are shown on Figure 5.1-2.

Table 5.1-1. Summary of Lake Sediment Quality Sampling Conducted for the Back River Project

Year	2007	2010	2011	2012	2013	2015
Sampling month	August	August	August	August	July	August
Sampling agency	Gartner Lee Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	ERM
Sampling method	Ekman grab	Ekman grab	Ekman grab	Ekman grab	Ekman grab	Ekman grab
Analytical lab	ALS Environmental	ALS Environmental	ALS Environmental	ALS Environmental	ALS Environmental	ALS Environmental
Data collected	Chemistry and particle size	Chemistry and particle size	Chemistry and particle size	Chemistry and particle size	Chemistry and particle size	Chemistry and particle size
Lakes sampled	Goose Lake	Llama Lake Umwelt Lake Chair Lake Mam Lake Reference B Lake	Llama Lake Umwelt Lake Giraffe Lake Goose Lake Propeller Lake Reference B Lake	Giraffe Lake Rabbit Lake Fox Lake Echo Lake Rascal Lake Goose Lake Propeller Lake Pond 19 Big Lake Del Lake	Wasp Lake Leaf Lake Giraffe Lake Umwelt Lake Rascal Lake Goose Lake Propeller Lake Reference B Lake	Echo Lake Stony Pond
Number of replicates per site	n = 1	n = 3, two sites sampled in deeper lakes	n = 3, two sites sampled in deeper lakes	n = 3 or n = 6 depending on lake depth and sampling plan	n = 3, with some lakes having multiple sampling stations	n = 3
Composition of a single replicate	composite of three pooled grabs	single grab	composite of two pooled grabs	single grab	single grab	single grab

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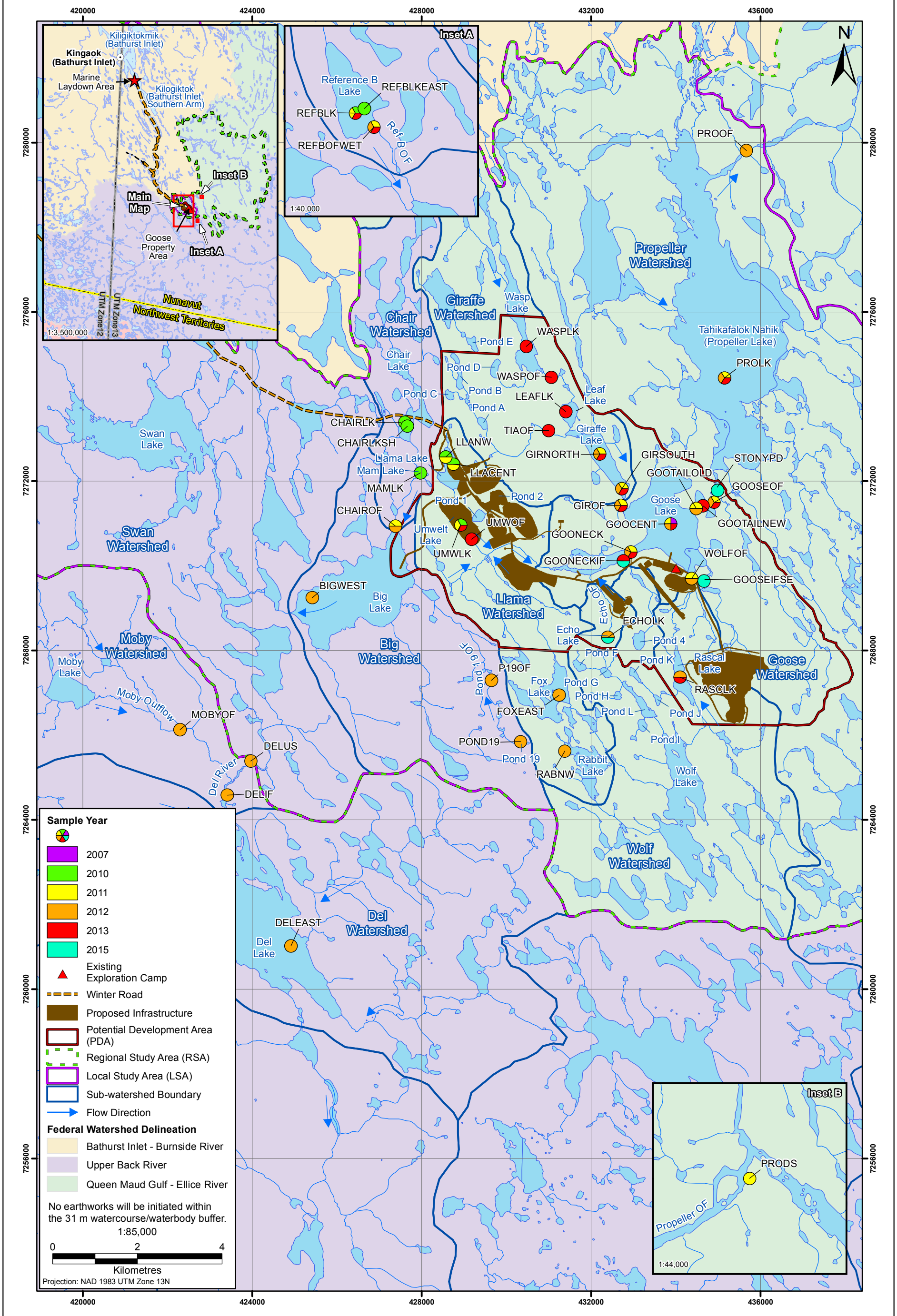

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Locations of Baseline Lake and Stream Sediment Quality, Goose Property Area, 2007 to 2015

Figure 5.1-2

Rescan an ERM company

Streams

Baseline sediment quality data were collected from 16 stream sites between 2011 and 2015 (Rescan 2012a, 2013a, 2013b). All sediment samples were collected using a plastic bowl and spoon, homogenized, and transferred to Whirl-Pak bags. All samples were refrigerated in darkness until shipment to ALS (Burnaby, BC) for analysis. Baseline sampling methodologies and sampling locations are presented in Table 5.1-2; sampling locations are shown on Figure 5.1-2.

Table 5.1-2. Summary of Stream Sediment Quality Sampling Conducted for the Back River Project

Year	2011	2012	2013	2015
Sampling month	August	August	July	August
Sampling agency	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	ERM
Sampling method	Bowl and spoon	Bowl and spoon	Bowl and spoon	Bowl and spoon
Analytical lab	ALS Environmental	ALS Environmental	ALS Environmental	ALS Environmental
Data collected	Chemistry and particle size	Chemistry and particle size	Chemistry and particle size	Chemistry and particle size
Streams sampled	Giraffe OF Wolf OF Goose OF Propeller D/S Chair OF Reference B OF	Giraffe OF Wolf OF Goose OF Propeller OF Chair OF Pond 19 OF Del US Moby OF Del IF Reference B OF	Wasp OF Giraffe IF Giraffe OF Umwelt OF Goose Neck IF Goose OF Reference B OF	Goose Neck IF Goose IF SE
Number of replicates per site	n = 3	n = 3	n = 3	n = 3
Composition of a single replicate	composite of sediment from a single reach	composite of sediment from a single reach	composite of sediment from a single reach	composite of sediment from a single reach

Sediment Quality QA/QC

The sediment quality QA/QC program included the use of chain of custody forms for all samples and the collection of three replicate sediment samples at all sites to account for within-site variability.

5.1.5 Lake Physical and Chemical Sediment Quality Parameters

Sediment quality is important for freshwater life as many freshwater organisms live in or on the sediments or feed on benthic organisms. The Canadian Council of Ministers of the Environment (CCME) has established interim guidelines for metal concentrations in sediments to protect freshwater life from acute and chronic toxicity (CCME 2015). Additionally, the particle size composition of sediments is a valuable parameter for predicting the type and variety of resident benthic organisms and for estimating the metal adsorption potential and organic carbon content of the sediments. Fine sediments composed of silt and clay particles tend to have greater metal and organic matter content due to particle surface adsorption, increased deposition rates, and longer residence times and often host distinct biological communities.

Natural sediment deposition rates in Arctic lakes tend to be small due to the relatively low flux of material from the landscape into the freshwater environment. Estimates for sedimentation rates average 113 mg/dm^2/30 days (ranged from 36 to 352 mg/dm^2/30 days; Hermanson 1990; Muir et al. 1996). The composition of the sediments observed in the baseline sampling program were consistent with low sedimentation rates (Rescan 2011, 2012a, 2013a, 2013b).

5.1.5.1 Lake Sediment Particle Size Composition

Lake sediment composition samples were collected from 19 sites between 2007 to 2015 (Table 5.1-1). The 2015 baseline sampling results will be available in a future report (Rescan 2015). Lake sediments were mainly comprised of silt or sand, with a combined mean of 90% silt and sand (Table 5.1-3). Pond 19 sediments had the greatest levels of coarser material, with a mean gravel content of 18% (Rescan 2013a).

Table 5.1-3. Summary of Lake Sediment Particle Size Composition in the LSA, 2007 to 2013

	Min	Mean	Max
% Gravel	0.05	1.4	23
% Sand	0.64	27	95
% Silt	2.3	62	92
% Clay	0.11	9.0	75

Note: This table used all available sediment quality data. Where data was less than the detection limit (DL), 0.5×DL was used to calculate metrics. The values were calculated from 130 samples collected throughout the LSA in the baseline program.

5.1.5.2 Lake Sediment Total Organic Carbon

Coarser sediments composed of gravel and sand often have lower concentrations of organic carbon and metals. Mean TOC in baseline lake sediment samples from the LSA ranged from 0.27% to 15.2% (Table 5.1-4), with the greatest proportions observed in Echo Lake (13.2%, 2012), Giraffe Lake North (11.6%; 2011 to 2013), and Goose Lake Neck (14.2%, 2011; Rescan 2012a, 2013a, 2013b).

Table 5.1-4. Summary of Lake Sediment Total Organic Carbon Concentrations in the LSA, 2007 to 2013

	Min	Mean	Max
TOC (%)	0.27	6.2	15.2

Note: This table used all available sediment quality data. Where data was less than DL, 0.5×DL was used to calculate metrics. The values were calculated from 156 samples collected throughout the LSA in the baseline program.

5.1.5.3 Lake Sediment Metals

The analysis of lake sediment metal concentrations was informed by the CCME guidelines. The CCME guidelines are conservative empirical thresholds that are meant to be protective of all forms of aquatic life and all aspects of aquatic cycles, including the most sensitive species over the long term (CCME 1999, 2015). The Interim Sediment Quality Guidelines (ISQG) are conservative empirical thresholds below which no effects on aquatic life are predicted to occur. The CCME Probable Effects Level (PEL) thresholds describe the sediment concentration at which biological effects are likely to occur.

Table 5.1-5 presents a summary of the total metal concentrations with CCME guidelines in the sediments of the LSA lakes surveyed between 2010 and 2013. Metals data from 2007 were not used due to high analytical detection limits.

Table 5.1-5. Summary of Lake Sediment Metal Concentrations in the LSA, 2010 to 2013

	Concentration (mg/kg)			% of Samples with Concentrations greater than ISQG*	% of Samples with Concentrations greater than PEL*
	Min	Mean	Max		
Arsenic	2.7	18	140	77	31
Cadmium	0.025	0.30	1.4	7	0
Chromium	6.8	26	56	12	0
Copper	8.5	70	170	80	0
Lead	1.7	4.8	11	0	0
Mercury	0.0025	0.052	0.12	0	0
Zinc	11	69	200	4	0

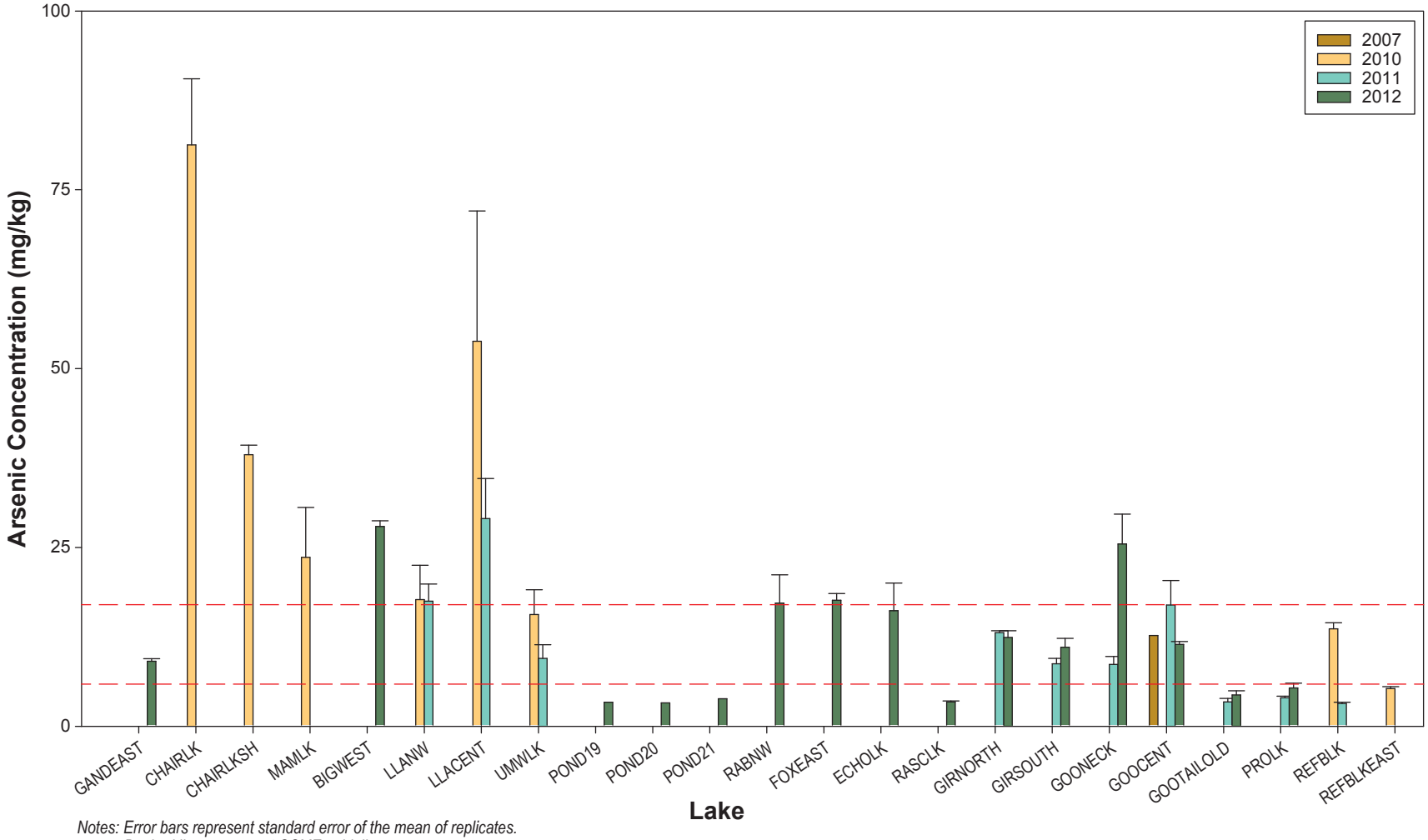
Note: This table excluded the 2007 metals data, which had higher detection limits than the 2010-2013 data. Where data was less than DL, 0.5×DL was used to calculate summary statistics. 129 samples were included in the analysis.
** CCME sediment quality guidelines for the protection of aquatic life (CCME 2015).*

The LSA lake sediment samples had naturally elevated baseline metal concentrations, with concentrations frequently greater than CCME guidelines for arsenic and copper and occasionally for cadmium, chromium, and zinc (Tables 5.1-5 and 5.1-6). Of the 129 historical and baseline samples collected between 2007 and 2013 from the LSA area, 46% had arsenic concentrations greater than the CCME ISQG and 31% had concentrations greater than the CCME PEL (Figure 5.1-3). Chair Lake had the most metals that were greater than CCME guidelines and the greatest arsenic concentrations, with mean concentrations 4.8 times greater than the CCME PEL (Rescan 2013a). Mean concentrations for all other metals were less than the CCME PEL. Most lakes in the LSA had mean sediment copper concentrations greater than the CCME ISQG, and some lakes had sediments with mean metal concentrations that were greater than the cadmium, chromium, and zinc CCME ISQG.

Table 5.1-6. LSA Lakes with Sediment Metal Concentrations Greater than CCME Sediment Quality Guidelines, 2010 to 2013

Lake	Dominant Particle Type	Metals Greater than ISQG*	Metals Greater than PEL*
Wasp Lake	sand	As, Cu	As
Leaf Lake	sand	As	As
Giraffe Lake	silt; silt and sand	As, Cu	-
Llama Lake	silt	As, Cu	As
Umwelt Lake	silt and sand	As, Cu	-
Rabbit Lake	silt	As, Cu	As
Fox Lake	silt	As, Cu	As
Echo Lake	silt	As, Cu	-
Rascal Lake	silt and sand	Cu	-
Goose Lake	silt; sand	As, Cd, Cu	As
Propeller Lake	silt	Cu	-
Chair Lake	silt	As, Cr, Cu, Zn	As
Mam Lake	silt	As, Cu	As
Big Lake	silt	As, Cu	As
Del Lake	silt	As, Cr	-
Reference B Lake	sand; silt and sand	As	-

Note: Exceedances are listed if the mean for all available samples was greater than the CCME guidelines. As = arsenic, Cr = chromium, Cd = cadmium, Cu = copper, Zn = zinc. '-' indicates that no metals had concentrations greater than guideline values.
** CCME Sediment Quality Guidelines for the Protection of Aquatic Life (CCME 2015).*



Notes: Error bars represent standard error of the mean of replicates.
Dashed lines represent CCME guidelines.
The arsenic interim sediment quality guideline is 5.9 mg/kg and the probable effect level is 17 mg/kg.

Figure 5.1-3

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Sediment Arsenic Concentrations in Goose Property Area Lakes, Back River Project, 2007 to 2012

Figure 5.1-3

5.1.6 Stream Physical and Chemical Sediment Quality Characteristics

5.1.6.1 Stream Sediment Composition

Baseline sediment quality samples were collected from 15 stream sites in the LSA between 2011 and 2015 (Table 5.1-2). The 2015 stream baseline sediment quality data will be presented in a future report (Rescan 2015). Stream sediments were mainly comprised of sand, with small proportions of gravel- and silt-sized particles, and smaller proportions of clay (Table 5.1-7).

Table 5.1-7. Summary of Stream Sediment Particle Size Compositions in the LSA, 2011 to 2013

	Min	Mean	Max
% Gravel	0.05	23	77
% Sand	1.4	53	93
% Silt	0.05	22	91
% Clay	0.05	2.6	19

Note: This table used all available sediment quality data. Where data was < DL, 0.5 DL was used to calculate metrics. The values were calculated from 65 samples collected throughout the LSA in the baseline program.

5.1.6.2 Stream Sediment Total Organic Carbon

Stream sediment organic carbon content is determined by processes occurring across the landscape and within the stream. Runoff can bring organic material into the stream environment and in-stream flow processes can move material into depositional environments. In-stream primary production by algae or aquatic plants can also add to the organic carbon pool. Sediments comprised of finer particles, like silt and clay, can bind and immobilize organic carbon.

Mean TOC in LSA stream sediments ranged from 0.05 to 29%, with the greatest percentage occurring in Reference B Outflow sampling site (Table 5.1-8; Rescan 2012a, 2013a).

Table 5.1-8. Summary of Stream Sediment Total Organic Carbon Concentrations in the LSA, 2011 to 2013

	Min	Mean	Max
TOC (%)	0.05	6.1	29

Note: This table used all available sediment quality data. Where data was < DL, 0.5 DL was used to calculate metrics. The values were calculated from 65 samples collected throughout the LSA in the baseline program.

Substantial annual variation in sediment TOC concentrations were observed, particularly at the Giraffe Outflow site (15.9% in 2011, 0.3% in 2012, and 0.5% in 2013) and the Goose Outflow site (23% in 2011, 0.3% in 2012, and 0.4% in 2013; Rescan 2012a, 2013a, 2013b).

5.1.6.3 Stream Sediment Metals

LSA stream sediments had naturally elevated metal concentrations, though to a lesser extent than lake sediments. This difference between streams and lakes may be related to smaller proportions of fine sediments in streams. Stream sediments in the LSA were occasionally greater than CCME guidelines for arsenic and copper, and infrequently for chromium and cadmium (Table 5.1-9 and Table 5.1-10). Mean arsenic concentrations in sediments were greater than the CCME ISQG at eight of the 15 stream sites sampled; mean arsenic concentrations at Propeller Outflow (25.1 mg/kg) were 1.5 times greater than the CCME PEL (17 mg/kg; Rescan 2013a, 2013b). No other metal had mean concentrations greater than the CCME PEL in any stream. Chromium concentrations in Propeller Outflow sediments were greater

than the CCME ISQG, whereas copper concentrations were greater than CCME ISQG in the Wasp OF and Reference B Outflow sediments (Table 5.1-10; Rescan 2012a, 2013a).

Table 5.1-9. Summary of Stream Sediment Metals Concentrations in the LSA, 2011 to 2013

Metal	Metal Concentration (mg/kg)			% of Samples with Concentrations Greater than ISQG*	% of Samples with Concentrations Greater than PEL*
	Min	Mean	Max		
Arsenic	1.3	12	210	41	15
Cadmium	0.025	0.11	0.71	3	0
Chromium	5.7	21	75	8	0
Copper	3.2	22	130	22	0
Lead	1.1	3.2	16	0	0
Mercury	0.0025	0.022	0.13	0	0
Zinc	9.7	30	87	0	0

Note: This table used all available sediment quality data. Where data was < DL, 0.5 DL was used to calculate metrics. 65 samples were included in this analysis.
** CCME sediment quality guidelines for the protection of aquatic life (CCME 2015).*

Table 5.1-10. LSA Streams with Metal Concentrations Greater than CCME Sediment Quality Guidelines, 2011 to 2013

Stream	Dominant Particle Type	Metals Greater than ISQG*	Metals Greater than PEL*
Del US	sand	As	-
Chair OF	sand	As	-
Wasp OF	silt	As, Cu	As
Giraffe OF	gravel and sand	As	-
Goose OF	silt	As	As
Goose OF	gravel and sand	As	-
Propeller OF	gravel	As, Cr	As
Reference B OF	sand (2012) and silt (2013)	As, Cu	As

Note: Exceedances are listed if the mean for all available samples was greater than the CCME guidelines. As = arsenic, Cr = chromium, Cu = copper. '-' indicates that no metals had concentrations greater than guideline values.
** CCME Sediment Quality Guidelines for the Protection of Aquatic Life (CCME 2015).*

5.2 INCORPORATION OF TRADITIONAL KNOWLEDGE (TK)

The effects assessment relies on the information collected from Inuit-led TK information, public scoping, focus group meetings, government engagement, and scientific knowledge. To the extent possible, available TK was incorporated into the evaluation of the potential effects of the Project on the environment. The following reports were reviewed for TK specific information related to (VEC or VSEC) features:

- Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP) (KIA 2012; Appendix V3-3A of FEIS);
- Naonaiyaotit Traditional Knowledge Project - Hannigayok (Sabina Gold & Silver Corp. Proposed Back River Project). Results from Data Gaps Workshops, Final Report (June 2014) (KIA 2014; Appendix V3-3B of FEIS); and
- Back River Project: Existing and Publically Available Traditional Knowledge from Selected Aboriginal Groups in the Northwest Territories (Appendix V3-3C of FEIS).

5.2.1 Incorporation of TK for Existing Environment and Baseline Information

Available Traditional Knowledge from the *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* report (KIA 2012) was reviewed for information on freshwater sediment quality (see Volume 3, Chapter 3 of the EIS). TK information documented in the NKTP report included observations of many changes in the freshwater environment over the past few decades. These included shallower lakes and rivers, reductions in river flow, and smaller fish spawning runs (KIA 2012). Inuit have observed changes in water quality over the past few decades, but little information was available on sediment quality.

5.2.2 Incorporation of TK for VEC Selection

The results of the Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP) report (KIA 2012) were used for scoping and refining the potential Valued Ecosystem Component (VEC)/Valued Socio-Economic Component (VSEC) list (see Volume 9, Chapter 1). The TK report presents clear maps of valued animal species, environmental components, and traditional land use activities. This information was used to determine whether these valued aspects potentially interacted with the proposed Project and, if so, they were included in the initial VEC/VSEC list. This information, along with information from public consultation, consultation with regulatory agencies, and regulatory considerations, was used to determine the final VEC/VSEC list. The final list was submitted to NIRB on April 8, 2013 and posted on the NIRB ftp site. As part of this process, freshwater sediment quality was selected as a VEC.

5.3 VALUED COMPONENTS

5.3.1 Valued Components and Scoping

Surface freshwater sediment quality was identified as a potential VEC from a comprehensive list in the EIS guidelines (Section 7.6.1; NIRB 2013a) and was identified as potentially interacting with the Project during the scoping process (see Volume 9, Chapter 1). Few comments regarding surface freshwater sediment quality were expressed in consultations with communities, but moderate regulatory considerations were identified. As a result of the scoping process, surface freshwater sediment quality was selected as a VEC for the EIS.

5.4 SPATIAL AND TEMPORAL BOUNDARIES

The spatial and temporal boundaries for the VEC freshwater sediment quality were defined as the maximum spatial and temporal extent within which the environmental assessment was conducted. The boundaries were determined by the criteria specified in the EIS guidelines (NIRB 2013a) and outlined in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1).

5.4.1 Spatial Boundaries

The spatial boundary used for the assessment of the VEC freshwater sediment quality included the Goose Property Potential Development Area (PDA), the Goose Property Local Study Area (LSA), and an overall Freshwater Regional Study Area (RSA). The MLA is a narrow strip of land on the west side of southern Bathurst Inlet. Most streams in this area flow directly to Bathurst Inlet to west and these streams are not within the MLA PDA. Project infrastructure and activities were not expected to interact with any streams. Potential effects related to the MLA are addressed in the Marine Environment Volume (Volume 7) and are not considered further in the freshwater sediment quality assessment.

5.4.1.1 Local Study Area

The LSA includes areas where there exists the reasonable potential for immediate effects due to Project activities, ongoing normal activities, or to possible abnormal operating conditions (NIRB 2013b). The LSA used for the assessment of effects on the VEC freshwater sediment quality for the Goose Property is 365 km^2 and includes the PDA and the boundaries of the Propeller and Big watersheds (Figure 5.4-1). The PDA includes an area that encompasses planned infrastructure.

5.4.1.2 Regional Study Area

The freshwater RSA includes the PDA, the LSA, and additional areas within which there is the potential for indirect or cumulative effects. The RSA used for the assessment of effects on the VEC freshwater sediment quality is 6,815 km^2 and encompasses the PDA and LSA. The RSA includes small sections of the Ellice and Back River Watersheds, and includes the upper ~80 km of the Ellice Watershed.

5.4.2 Temporal Boundaries

The temporal boundaries used for the effects assessment on the VEC freshwater sediment quality are as described in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1). The temporal boundaries used for the assessment were aligned with the Project phases and were defined as follows:

- Mobilization and Construction Phase: 4 years;
- Operations Phase: 10 years;
- Reclamation and Closure Phase: 8 years;
- Post-closure Monitoring Phase: 5 years;
- Other potential phases:
  - Temporary Closure: less than 2 years,
  - Care and Maintenance Phase: 2 to 10 years,
  - Exploration: included in Construction and Operations phases.

The temporal boundaries used for the VEC freshwater sediment quality were defined in relation to planned activities over the lifetime of the Project within which a reasonable expectation of interaction with components of the freshwater environment can be predicted.

5.5 POTENTIAL PROJECT-RELATED EFFECTS ASSESSMENT

5.5.1 Methodology Overview

The Project-related effects assessment for the VEC freshwater sediment quality followed the process detailed in the Methodology for Project Effects Assessment (Volume 9, Chapter 1):

1. Identification of potential interactions of the Project with freshwater sediment quality;
2. Characterization of potential effects;
3. Identification of mitigation and management measures to be taken that would eliminate or reduce potential effects;
4. Characterization of residual effects using the primary attributes of direction (i.e., positive, neutral, or negative), magnitude, reversibility, confidence, and probability, and the secondary attributes of extent, frequency, and duration; and
5. Determination of the significance of the residual effects.

PROJECT #0194096-0002 GIS # BAC-01-053_S August 31 2015

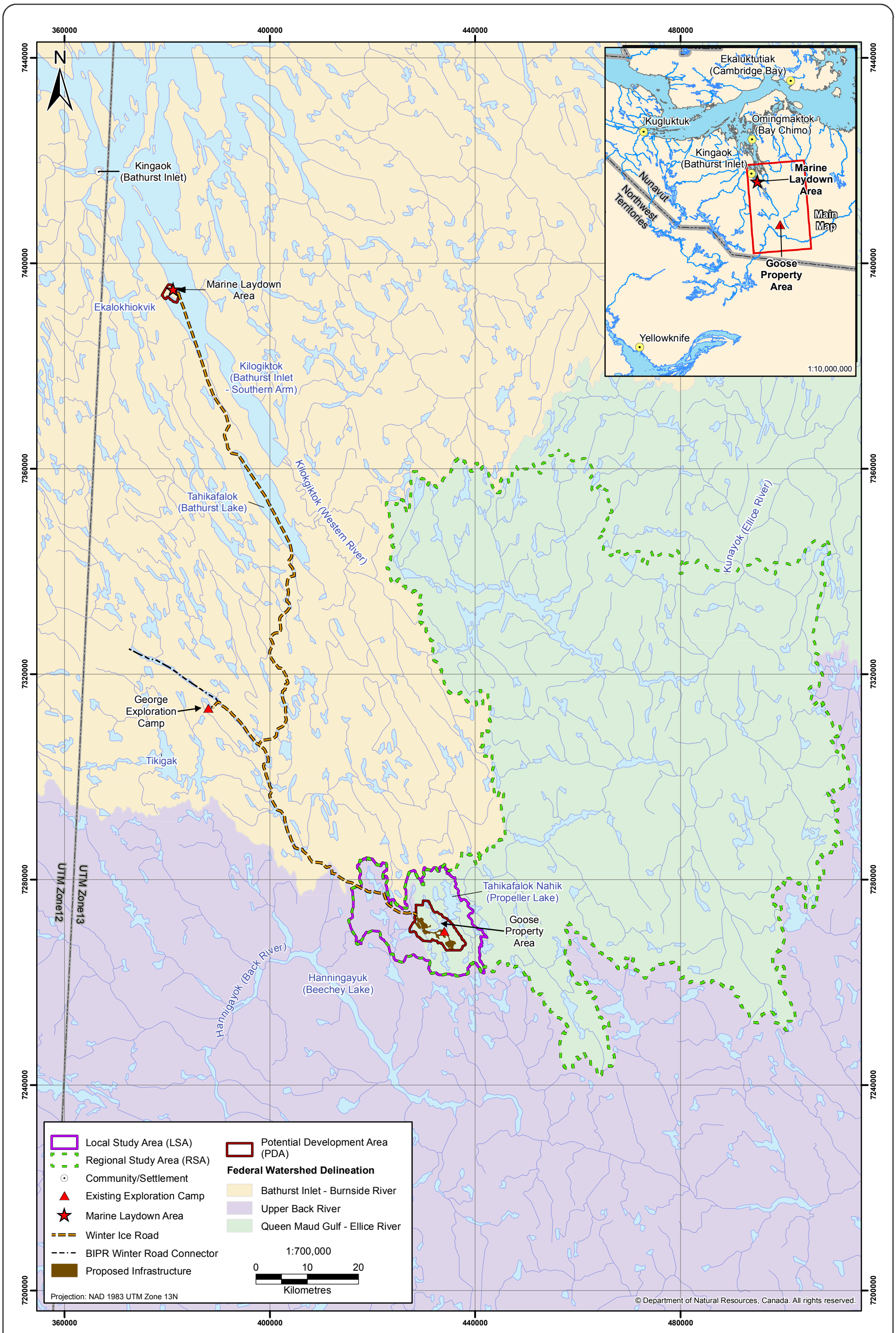

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Figure 5.4-1

Local Study Area and Regional Study Area for Freshwater Sediment Quality

If mitigation and management measures were considered entirely effective, potential Project-related effects to the VEC freshwater sediment quality were deemed negligible and were not identified as residual effects. The rating criteria for the attributes used to characterize residual effects (i.e., direction, magnitude, reversibility, confidence, probability, extent, frequency, and duration) are provided in tables in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1). Table 5.5-1 presents the ratings specific for the magnitude of residual effects to the VEC freshwater sediment quality. The CCME guidelines for sediment quality were used, when available, in addition to existing baseline conditions as the threshold for determining the magnitude of residual effects because they are designed to be protective of all forms of aquatic life and all aspects of aquatic cycles, including the most sensitive species over the long term (CCME 1999, 2015). Under these rating criteria, residual effects from Project activities classified in the *Low* magnitude would result in changes in freshwater sediment quality that would be less than the CCME guidelines or within the natural variation observed in the baseline studies. Naturally elevated sediment concentrations of metals were observed in the baseline studies (Sections 5.1.5.3 and 5.1.6.3), for example, and the magnitude ratings criteria were designed to account for this natural variation. *Low* magnitude residual effects would, therefore, be predicted not to result in any effects on aquatic organisms because of the conservative design of the CCME guidelines (CCME 1999). If the concentration of a metal was naturally greater than CCME guidelines (e.g., arsenic), then a *Low* magnitude effect would apply as long as the concentration was within the 90% percentile of baseline values. Combined with the probability that the effect will occur, the significance of the effect was rated as positive, not significant, or significant (Table 5.5-2). For example, residual effects receive a rating of 'Not Significant' if typically they are expected to be one of the following: negligible or low magnitude, confined to LSA, moderate to high reversibility, or short duration (Volume 9). However, given the qualitative nature of the assessment, these ratings are evaluated for biophysical VECs on a case by case basis.

Table 5.5-1. Rating Criteria for Magnitude of Freshwater Sediment Quality Residual Effects

Rating	Classification
Negligible	No change from baseline values
Low	Within the CCME ISQG guideline, *or* less than the 90% percentile of baseline values if indicator is naturally greater than threshold *Less than threshold*
Moderate	Greater than CCME ISQG guideline, *or* greater than the 90% percentile of baseline values if indicator is naturally greater than threshold *Less than 10× threshold*
High	Greater than CCME ISQG guideline, *or* greater than the 90% percentile of baseline values if indicator is naturally greater than threshold *Greater than 10× threshold*

5.5.1.1 Sediment Quality Indicators

Sediment quality is a complex of multiple parameters and indicators, as discussed in the Existing Environment (Section 5.1). Project activities will interact with the freshwater environment along a number of pathways and may change any of these indicators to outside of natural ranges, which therefore represent changes to sediment quality. For example, discharge from a sewage treatment plant may introduce additional organic matter into the freshwater environment and subsequently cause increases in the organic matter content of the sediments. The sediment quality effects assessment was based on the analysis of four sediment quality indicators that represent the most probable and significant potential interactions between Project activities and the freshwater environment (Table 5.5-3).

Table 5.5-2. Definitions of Significance Ratings of Residual Effects on the VEC Freshwater Sediment Quality

Significance	Descriptor of Significance
Positive	Effect could result in improvements in freshwater sediment quality, relative to the baseline, within the RSA into the foreseeable future.
Significant	Effect is expected to result in a decline in freshwater sediment quality that is long-lasting or permanent within the zone of influence of the Project, relative to reference conditions; levels may be variable or stable over years, but significantly lower on average than the natural variation of sediment quality and compared to reference sites elsewhere. Regional management actions such as research, monitoring, and recovery initiatives may be required should changes to freshwater sediment quality be deemed above acceptable risk thresholds.
Not Significant	Effect may result in a decline in freshwater sediment quality within the zone of influence of the Project relative to reference conditions during the life of the project, but sediment quality should return to baseline conditions in the shorter-term after Project closure. Monitoring may be initiated to confirm the ratings of the effects assessment.

Table 5.5-3. The VEC Freshwater Sediment Quality Indicators for Effects Assessment

Indicator	Description	Project Interactions	Pathway
Particle Size	Addition of material to sediments, changes the composition of the sediments	Contribute particles to freshwater environment (siltation) or disturb sediments	In-water works, runoff, aerial deposition, discharge
Nutrients and Organic Carbon	Chemical compounds that may enhance aquatic plant and algal growth, or alter community structure	Contribute nutrients and organic material to freshwater sediments in in runoff and discharge	Runoff, discharge
Metals	Metals adsorbed to sediment particles or dissolved in interstitial water	Contribute metals in runoff, discharge, and aerial deposition	Runoff, aerial deposition, discharge
Hydrocarbons	Petroleum hydrocarbon compounds	Contribute hydrocarbons in runoff, discharge, and aerial deposition	Runoff, aerial deposition, discharge

It is important to note that the key indicators of the VEC freshwater sediment quality outlined in Table 5.5-3 are subject to natural variation, but guidelines have been established to protect aquatic life (CCME 2015). For the purposes of this assessment, the contaminants of potential concern (COPC) identified in the CCME sediment quality guidelines were used as indicators. The thresholds for the residual effects analysis were based on the CCME guidelines and existing background concentrations and detailed in Table 5.5-4.

Table 5.5-4. Indicator Thresholds for the VEC Freshwater Sediment Quality

		CCME Guideline Concentration	
Indicator	**Parameter**	**ISQG[†]**	**PEL[†]**
Particle Size	Sediment composition	No regulatory threshold value; threshold set to 90th quantile of baseline values	
Nutrients and Organic Carbon	Nutrient and organic carbon	No regulatory threshold value; threshold set to 90th quantile of baseline values	
Metals	Arsenic	5.9 mg/kg	17 mg/kg
	Cadmium	0.6 mg/kg	3.5 mg/kg
	Chromium	37.3 mg/kg	90 mg/kg
	Copper	35.7 mg/kg	197 mg/kg
	Lead	35.0 mg/kg	91.3 mg/kg

(continued)

Table 5.5-4. Indicator Thresholds for the VEC Freshwater Sediment Quality (completed)

Indicator	Parameter	CCME Guideline Concentration	
		ISQG[†]	PEL[†]
Metals *(cont'd)*	Mercury	0.17 mg/kg	0.486 mg/kg
	Zinc	123 mg/kg	315 mg/kg
Hydrocarbons	Petroleum hydrocarbons	*range of guidelines for petroleum hydrocarbon compounds (CCME 2015)*	

[†] *CCME sediment quality guidelines for the protection of aquatic life (CCME 2015).*

5.5.2 Identification and Characterization of Potential Interactions with Project

Project activities have the potential to affect the VEC freshwater sediment quality. Potential interactions between the Project and the VEC freshwater sediment quality were based on the initial matrix provided in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1) and further refined using the EIS guidelines (NIRB 2013a) and professional judgement based on extensive experience at other similar projects in Nunavut and the Northwest Territories. Activities that will occur throughout the duration of the Project were considered for their potential interactions with the freshwater environment.

Some Project interactions with the freshwater environment are likely to occur through non-point source pathways (e.g., runoff and deposition). Non-point source pathways were assessed within the LSA for the Project as a whole, rather than considering the effects on each individual receiving environment. Many of these pathways have the potential to vary substantially in timing and magnitude during the life of the Project. A qualitative effects assessment approach using conservative assumptions of Project effects was generally used for the effects assessment. The effects of dust deposition were assessed quantitatively in the Environmental Risk Assessment (Volume 8, Chapter 5), with the results applied to this assessment of Project effects on the VEC freshwater sediment quality.

The interactions of Project activities and the VEC freshwater sediment quality were grouped by related Project activities (termed Project interaction group), shared pathways to the freshwater environment, and shared key sediment quality indicators for the effects assessment (Table 5.5-5). For example, the construction of water crossings and the clearing of surfaces for pad construction were grouped into the *Construction and Decommissioning* Activities Project Interaction Group because both activities will be occurring during similar stages of Project development and both activities have the potential to contribute to erosion and deposition of suspended material into freshwater receiving environments through the shared pathway of runoff. The identified Project interaction groups are:

- *Construction and Decommissioning Activities* - Project activities that include the clearing of overburden, earthworks, and construction activities for pads and infrastructure.
- *Site Contact Water* - the runoff from Project infrastructure including pad areas, laydown areas, roads, and airstrips.
- *Mine Contact Water* - water that contacts mine surfaces and operations, including runoff from waste rock storage areas (WRSA) and ore storage areas, as well as drilling water for exploration activities.
- *Quarries and Borrow Pits* - activities related to the operation of quarries and borrow pits.
- *Explosives* - Project activities related to the transport, manufacture, storage, and use of explosives.
- *Fuels, Oils, and PAH (Polycyclic aromatic hydrocarbons)* - Project activities related to the storage of fuels, fueling and maintenance operations, and the combustion of waste.
- *Treated Sewage Discharge* - discharge from domestic water treatment facilities.
- *Dust Deposition* - Project activities that generate dust, including vehicle traffic, mining operations, and milling, that can then be deposited in freshwater receiving environments.

Table 5.5-5. Definition of the Components of the Project's Interactions with the VEC Freshwater Sediment Quality

Project Phase	Project Activity	Project Interaction Group							
		Construction and Decommissioning Activities	Site Contact Water	Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
Mobilization and Construction	Camp and mill facility construction, local site roads, airstrip, equipment laydown areas, pad areas	X							
	Quarry development				X				
	Dam or dyke construction for water management facilities and dewatering activities	X							
	Pit pre-stripping, waste rock pile construction, head-frame and underground development	X							
	Machinery and vehicle refueling; fuel storage and handling						X		
	Sewage treatment plant and discharge							X	
	Landfill construction and solid waste management	X	X						
	Chemical and hazardous material storage and management		X						
	Explosives storage and handling					X			
Operations	Open pits: drilling, blasting, and excavation			X		X			X
	Underground: drilling, blasting, and excavation			X		X			X
	Waste rock storage areas			X					X
	TSFs operation			X					X
	In-pit and surface water management			X					

(continued)

Table 5.5-5. Definition of the Components of the Project's Interactions with the VEC Freshwater Sediment Quality (completed)

		Project Interaction Group							
Project Phase	**Project Activity**	**Construction and Decommissioning Activities**	**Site Contact Water**	**Mine Contact Water**	**Quarries and Borrow Pits**	**Explosives**	**Fuels, Oils, and PAH**	**Treated Sewage Discharge**	**Dust Deposition**
Operation *(cont'd)*	Road and airstrip use and maintenance		X		X				X
	Sewage treatment and discharge							X	
	Equipment maintenance and fuel storage and handling		X				X		
	Chemical and hazardous material storage and management		X						
	Explosives storage and handling					X			
Reclamation and Closure	Open pits			X					
	Underground mines			X					
	TSFs			X					
	Waste rock storage areas			X					
	Road reclamation of site roads	X							
	Airstrip reclamation	X							
	Landfill closure	X							
	Quarry decommissioning	X			X				
	Marine Laydown Area reclamation	X							

In some cases, the pathways and interactions would change between locations or Project phases, and those changes were considered in the effects assessment. For example, once the site water management infrastructure is completed, site contact water (e.g., runoff from laydown areas) will be diverted to the water management facilities and not directly reach the freshwater environment. The assessment of potential effects from site contact water during the Operations phase, when the site water management infrastructure is in operation, was therefore different than the period during the Construction phase before the completion of the water management infrastructure.

Pathway was used to describe the linkage between each Project interaction group and the VEC freshwater sediment quality. The four identified pathways for interactions between Project activities and the freshwater environment are:

- *runoff* - describes the transport of material or compounds from the terrestrial environment into the freshwater environment by precipitation or snowmelt.
- *water withdrawals* - describes the influence that changes in volume and flow may have on freshwater waterbodies.
- *discharge* - the direct input of Project water into freshwater waterbodies.
- *aerial deposition* - the direct input of material and chemical compounds from the air into the freshwater environment.

The pathway(s) for each Project interaction group were identified (Table 5.5-6) and then used to describe potential effects, identify mitigation and management measures, and characterize the potential for residual effects from Project activities.

Table 5.5-6. Key Indicators of Project Activity Interactions with the Freshwater Environment for Effects Assessment

Project Activity	Pathway	Indicators	Project Phases
Construction and decommissioning activities	Runoff, discharge	particle size, nutrients, metals, hydrocarbons	Mobilization and Construction, Operations, Reclamation and Closure
Site contact water	Runoff	particle size, nutrients, metals, hydrocarbons	Mobilization and Construction, Operation, Temporary Closure, Care and Maintenance, Reclamation and Closure, Post-closure
Mine contact water	Runoff, discharge	particle size, nutrients, metals	Mobilization and Construction, Operation, Temporary Closure, Care and Maintenance, Reclamation and Closure, Post-closure
Quarries and borrow pits	Runoff	particle size, nutrients, metals	Mobilization and Construction
Explosives	Runoff, aerial deposition	nutrients, hydrocarbons	Mobilization and Construction, Operations, Reclamation and Closure
Fuels, Oils, and PAH	Runoff, aerial deposition	particle size, hydrocarbons	Mobilization and Construction, Operation, Reclamation and Closure
Treated Sewage Discharge	Discharge	nutrients, hydrocarbons	Mobilization and Construction, Operations, Reclamation and Closure
Dust deposition	Aerial deposition	particle size and metals	Mobilization and Construction, Operations

The potential effects for each of the Project activities identified in Tables 5.5-5 and 5.5-6 were characterized in Sections 5.5.2.1 to 5.5.2.8. The potential effects assessment considered the proposed Project activities (Volume 2) and the pathway(s) linking the Project activities to the freshwater environment. The potential effects were identified and characterized in the absence of mitigation or management measures.

5.5.2.1 Construction and Decommissioning Activities

Ground preparation for Project infrastructure, including buildings, roads, and mine works, would occur during the Mobilization and Construction phase throughout the PDA in the LSA. Construction would involve vegetation clearing, the removal and relocation of surficial materials, and the construction of pad areas from surficial material, borrow material, and quarried rock. The construction activities would also include the construction of the water management infrastructure, such as ditches and berms. The decommissioning and reclamation of Project infrastructure will similarly require the disturbance, transport, and relocation of surficial materials, as well as the disturbance and removal of vegetation and ground cover. The production of methylmercury will be negated by stripping and stockpiling organic material as part of mobilization and construction activities.

Landscape disturbance and the removal of vegetation have the potential for effects on the VEC freshwater sediment quality. The primary pathway for these potential effects would be runoff (i.e., the transport of material in overland flow into the freshwater environment). Runoff would occur primarily during snowmelt and freshet in the spring, during precipitation events in the summer and fall, and would be absent in the winter. Some in-water or near-water activities required during Mobilization and Construction and Reclamation and Closure phases also have the potential for effects on sediment quality. Additional effects may occur via dust deposition, which are presented separately in Section 5.5.2.8.

Llama Lake and Umwelt Lake will be dewatered as part of the development of the Project. The primary pathway of potential effects will be through the discharge of water into nearby receiving environments during dewatering activities.

Runoff from prepared and decommissioned areas could affect the VEC freshwater sediment quality by changing sediment particle size composition (siltation from eroded material) and by contributing metals, nutrients, organic matter, and hydrocarbons (from use of fuels and oils) into the freshwater environment.

5.5.2.2 Site Contact Water

Site contact water was defined as the runoff from snowmelt and precipitation events that interacts with site surfaces including roads, laydown areas, and buildings. The interaction between runoff and Project infrastructure could transport suspended material (siltation), metals, nutrients, organic matter, or hydrocarbons into the freshwater environment if not managed or mitigated. The potential for effects from site contact water could occur during all phases of the Project.

5.5.2.3 Mine Contact Water

Mine contact water was defined as the underground water removed from mine works; the runoff from mine surfaces, WRSA, water management structures (e.g. Saline Water Pond) and ore stockpiles; drilling fluids from ongoing exploration activities; mill process water; and water in the TSF. The pathways of interaction between mine contact water and the freshwater environment are runoff and discharge. The majority of mine workings, including both open pit and underground, will occur in permafrost, throughout their depth, and no groundwater inflow will occur. The underground works at

the Umwelt deposit have a predicted maximum inflow of 596 m^3/d, and other predicted groundwater sources were the Llama underground, Llama Pit, and Goose Main underground works (Water and Load Balance Report; Volume 2, Appendix V2-7H). Overburden, waste rock, and tailings may also be in contact with surface water. The majority of mine contact water will occur from precipitation (Project Description, Volume 2).

Potential effects from mine contact water may occur during all phases of the Project. Mine contact water, including water interacting with overburden, waste rock, and tailings, could affect the VEC freshwater sediment quality by contributing suspended material (siltation), metals, nutrients (contact with blasting residues), and hydrocarbons (use of fuel, oil, and grease) into the freshwater environment.

5.5.2.4 Quarries and Borrow Pits

Quarries and borrow pits would be developed to supply material for construction and maintenance during the Mobilization and Construction and Operations phases. The pathway of interaction between quarries and the freshwater environment is through runoff, which can transport suspended material and/or metals into freshwater receiving environments. The potential effects from the use of explosives and dust associated with quarries and borrow pits were assessed separately. These transported materials can change the composition of sediments (siltation) or increase sediment metal concentrations.

5.5.2.5 Explosives

Ammonium nitrate (AN) and fuel oil (FO) will be used as the explosive for quarries and mine development and production. Ammonium nitrate and fuel oil will be shipped and stored on site in bulk bags and bulk liquid fuel. The ANFO explosive would then be mixed on site. Both components of the ANFO explosive have the potential for effects on the VEC freshwater sediment quality: AN disassociates in water into ammonia and nitrate and FO is a mixture of petroleum hydrocarbons. The pathways of interaction between explosives and the freshwater environment are runoff and aerial deposition, and the potential effects may occur during Mobilization and Construction and Operations phases. The VEC freshwater sediment quality can be affected by the runoff and deposition of explosives (and blasting residues). Runoff or deposition of those compounds can increase the sediment concentrations of ammonia, nitrate, and petroleum hydrocarbons.

5.5.2.6 Fuels, Oils, and PAH

The Fuels Project interaction group was defined as the Project activities that involve the handling, storage, and use of petroleum hydrocarbons. These activities include the storage and transport of fuels, fueling, and maintenance operations. The activities in this interaction group have the potential for introducing hydrocarbons into the environment. Included in this group is the incineration of waste, which has the potential for creating PAHs by incomplete combustion. The primary pathways of interaction between these sources of hydrocarbons and the freshwater environment are runoff and aerial deposition. Activities at facilities, laydown areas, fuel storage areas, and waste management areas can deposit hydrocarbons compounds such as oil and grease that can subsequently be transported into freshwater environments in runoff.

The potential effects from fuels and other hydrocarbons may occur during the Mobilization and Construction, Operations, and Reclamation and Closure phases.

5.5.2.7 Treated Sewage Discharge

Treated sewage from domestic water treatment facilities will be discharged to Llama Lake during the Mobilization and Construction phase and the TSF during the Operation phase. Therefore, the pathway

of interaction between treated sewage and the freshwater environment is discharge. Discharge of sewage effluent could affect the VEC freshwater sediment quality by contributing nutrients or organic compounds and influencing the oxygen demand (and subsequently reducing oxygen concentrations) in receiving freshwater environments. The potential effects from treated sewage discharge may occur during all Project phases.

5.5.2.8 Dust Deposition

Dust can be generated by a variety of Project activities, including vehicle traffic, blasting activities, quarry operations, rock processing, and mining activities in open pits. Areas cleared for infrastructure (i.e., laydown areas) can also be sources of dust. The aerial deposition of the Project-generated dust is the primary pathway of interaction. Dust deposition into the freshwater environment could affect the VEC freshwater sediment quality by introducing suspended material and associated metals and nutrients into surrounding waterbodies. The potential effects from dust deposition may occur during all phases of the Project. No residual effects from dust deposition were predicted in the Environmental Risk Assessment (Volume 8, Chapter 6), so no further assessment of potential dust deposition effects on the VEC freshwater sediment quality was conducted.

5.5.3 Identification of Mitigation and Management Measures

The following section details the mitigation and management measures designed to enhance Project benefits and reduce or eliminate negative Project effects. If mitigation and management measures were considered entirely effective, potential Project-related effects to the VEC freshwater sediment quality were deemed *negligible* and not identified as residual effects. Once these are taken into account, any remaining residual Project effects on the VEC freshwater sediment quality are characterized in Section 5.5.4.

The proposed mitigation and management measures would be actions to prevent, avoid, minimize, offset, or restore the VEC freshwater sediment quality within the spatial and temporal boundaries of the Project. Mitigation and management measures—to eliminate or reduce Project effects on the VEC freshwater sediment quality—include design and planning, engineered structures, the application of control technologies, best management practices, regulatory requirements, monitoring, and adaptive management. The relevant mitigation and management measures, including the spatial and temporal boundaries of the proposed actions, are considered and described for each Project activity in Sections 5.5.3.1 to 5.5.3.7. All mitigation and management measures will be applied, when applicable, throughout the life of the Project. The Site Water Monitoring and Management Plan (Volume 10, Chapter 7) is the key plan for site and mine contact water. The Aquatic Effects Management Plan (Volume 10, Chapter 19) details the mitigation and management measures for the receiving freshwater environment. The following environmental management plans relevant to the VEC freshwater sediment quality will be applied during the Project:

- Risk Management and Emergency Response Plan (Volume 10, Chapter 3);
- Fuel Management Plan (Volume 10, Chapter 4);
- Spill Contingency Plan (Volume 10, Chapter 5);
- Mine Waste Rock Management Plan (Volume 10, Chapter 9);
- Waste Management Plan (Volume 10, Chapter 10);
- Incinerator Management Plan (Volume 10, Chapter 11);
- Hazardous Materials Management Plan (Volume 10, Chapter 12);

- Explosives Management Plan (Volume 10, Chapter 13);
- Road Management Plan (Volume 10, Chapter 14);
- Borrow Pits and Quarry Management Plan (Volume 10, Chapter 16);
- Air Quality Monitoring and Management Plan (Volume 10, Chapter 17);
- Fish Offsetting Plan (Volume 10, Chapter 21);
- Tailings Management Plan (Volume 10, Chapter 22); and
- Mine Closure and Reclamation Plan (Volume 10, Chapter 29).

5.5.3.1 Construction and Decommissioning Activities

The primary pathway of interaction between the Project activities in the Construction interaction group and the freshwater environment is runoff. The proposed mitigation and management measures will minimize the potential for erosion and the transportation of material in runoff (Aquatic Effects Management Plan, Volume 10, Chapter 19). The Project will minimize runoff and the transport of material into the freshwater environment by the following planning and design measures:

- Infrastructure and waste rock storage areas will be confined to the local watersheds where the deposits are located to limit potential effects on sediment quality to local drainage areas;
- Infrastructure will be located, whenever feasible, on competent bedrock or appropriate base material that will limit permeability and the transport of potentially lower quality water into the active layer and ultimately to the freshwater environment;
- The Project infrastructure will be designed to minimize the footprint area, such as being located near the deposits; and
- Restoration of the landscape will occur as soon as possible to minimize erosion potential.

The Project will use Best Management Practices (BMP) drawn from governmental organizations and specific Arctic experience to minimize erosion and reduce the entrainment of potential chemical compounds into runoff. Project activities near water will follow the DFO Nunavut Measures to Avoid Causing Harm to Fish and Fish Habitat (Fisheries and Oceans Canada 2013a). In-water work will be conducted during approved timing windows (Fisheries and Oceans Canada 2013b). Only geochemically suitable rock quarries and borrow sources that provide non-potentially acid-generating rock will be used to construct roads, pads, and structures (Mine Waste Management Plan, Volume 10, Chapter 9; Tailings Management Plan, Volume 10, Chapter 22). Exposed landscape surfaces will be protected, where possible, by the installation of covering material like riprap, aggregate, or rolled erosion control products. Runoff flow may be controlled by a combination of measures, including:

- slope texturing/grading to slow runoff and reduce effect slope lengths;
- installation of synthetic permeable barriers and/or fibre rolls to reduce runoff velocities and retain sediments; and
- check dams, gabions, and energy dissipation structures to reduce flow velocities in channels.

Sediment levels in runoff will be minimized, where applicable, by intercepting sediment before it reaches the freshwater environment. In addition to measures aimed at controlling runoff flow, the quantity of transported material in runoff may be controlled by measures including:

- preservation of riparian zones to trap sediment and to reduce flow velocities;

- installation of synthetic permeable barriers, fibre rolls, and/or silt fences as required;
- installation of check dams, gabions, and sediment basins to reduce flow velocities and encourage sediment deposition;
- stockpiles being located away from watercourses; and
- Refuelling and maintenance activities not occurring, were possible, within 30 m of a watercourse or waterbody except where required due to equipment breakdown or approved activities near water.

The potential effects from dewatering on freshwater sediment quality will be mitigated as outlined in the Lake Dewatering Plan (Site Water Monitoring and Management Plan, Volume 10, Chapter 7). Dewatering will be staged to seasonal flows, when possible, to minimize adverse effects to water quality and quantity. Acceptable volumes of water transferred to the receiving environment will be determined to avoid effects associated with water level fluctuations in the receiving environment. Clean water transferred to the receiving environment will remain within 10% of base flow or water levels if possible.

Depending on the volume of clean water to be discharged to the receiving environment, lake dewatering may be conducted in the fall when there is some ice cover on the shore that will limit resuspension of lakebed sediments. This would help allow for the maximum amount of clean water to be transferred by keeping the TSS levels low in the lake to be dewatered longer. However, the fall is also when base flows are at their lowest, so the amount of clean water that could be transferred may be limited depending on the receiving environment location.

Clean lake water will be transferred and monitored for turbidity and total suspended solids (TSS), until the TSS threshold is reached (Site Water Monitoring and Management Plan (Volume 10, Chapter 7). Water transferred during dewatering activities will meet a TSS or turbidity threshold equivalent to the MMER limit for TSS (15 mg/L). Water that does meet established criteria will be retained or transferred to a suitable water management facility, such as the TSF.

Changes to sediment and water quality during construction, and decommissioning activities will be monitored under the Site Water Monitoring and Management Plan (Volume 10, Chapter 7) and the Aquatic Effects Monitoring Plan (Volume 10, Chapter 19) to ensure drainage and erosion controls are effective. Previously designed and executed Aquatic Effects Management Plans have been shown to be effective at monitoring preconstruction and construction activities of other Arctic projects (Rescan 2012b). Necessary repairs and adjustments to operations will be conducted as needed to ensure sediment quality does not surpass the CCME guidelines for sediment quality parameters in fish-bearing receiving waters and is maintained within baseline variability (Table 5.5-3; CCME 2015). The need for any corrective actions to on-site management or installation of additional control measures will be determined on a case-by-case basis. Indications of the need for corrective actions and additional control measures may include:

- if results from the Site Water Monitoring Program (Volume 10, Chapter 7; to be outlined in the future Type A Water Licence) show non-compliance; or
- if results from the Aquatic Effects Monitoring Program (Volume 10, Chapter 19), which will monitor the receiving environment around the mine infrastructure and activities, show negative effects to the freshwater environment.

There is a potential for residual effects on freshwater sediment quality from construction and decommissioning activities.

5.5.3.2 Site Contact Water

Runoff is the interaction pathway for site contact water. The key mitigation measure will be to intercept and divert site contact water before it reaches the freshwater environment (Site Water Monitoring and Management Plan; Volume 10, Chapter 7). Infrastructure will be designed such that its footprint is minimized to limit the changes to local drainage patterns. Non-contact water will be diverted around infrastructure, as much as is feasible, and directed to natural downstream drainage networks to maintain local drainage patterns. Site contact water will be directed to water management and tailings storage facilities and will not contact the surrounding freshwater environment. Clean water and snow will be managed such that they do not contribute to potentially poor quality water and will be diverted to maintain natural drainage networks as much as possible. Clean water and snow will be managed such that they do not contribute to potentially poor quality water and will be diverted to maintain natural drainage networks as much as possible.

Monitoring and adaptive management will be used to ensure the goals of the Site Water Monitoring and Management Plan and Aquatic Effects Management Plan are met (Volume 10, Chapters 7 and 19). During construction, all contact water will be monitored and treated to meet CCME guidelines or approved site specific water quality objectives prior to contact with fish-bearing receiving environments. Regular inspections of water management facilities will be conducted by Environmental Personnel under the Site Water Monitoring and Management Plan (Volume 10, Chapter 7). The need for any corrective actions to on-site management or installation of additional control measures will be determined on a case-by-case basis. Residual effects on freshwater sediment quality from site contact water may occur.

5.5.3.3 Mine Contact Water

Mine contact water will interact with the VEC freshwater sediment quality through the runoff and discharge pathways. The primary mitigation and management measure will be to divert all mine contact water away from the freshwater environment (Site Water Monitoring and Management Plan; Volume 10, Chapter 7). All mine contact water from runoff and inflow sources will be collected and directed to water management and tailings storage facilities as soon as the water management infrastructure is completed in the Construction Phase. The plan to mitigate mine contact water includes runoff from WRSAs, ore stockpiles, water management facilities, and tailings stored in the tailings storage facilities, which will be managed under the Mine Waste Rock Management Plan and the Tailings Management Plan (Volume 10, Chapters 9 and 22). Discharge of mine contact water occurs after specific sections of Project infrastructure are decommissioning and water management structures are breached and re-connected to existing drainage networks (Water and Load Balance Report; Volume 2, Appendix V2-7H). For example, the Echo WRSA pond is reconnected to the Goose Lake tributary Echo OF in Project Year 10 at the end of the Operations Phase. There is the potential for residual effects from mine contact water on freshwater sediment quality.

5.5.3.4 Quarries and Borrow Pits

Quarries will interact with the VEC freshwater sediment quality through the runoff pathway. Mitigation and management measures for the construction and operation of quarries and borrow pits will be focused on minimizing the material and compounds potential transported in runoff, and minimizing the runoff reaching the freshwater environment (Site Water Monitoring and Management Plan, Volume 10, Chapter 7; Borrow Pits and Quarry Management Plan, Volume 10, Chapter 16). The materials and compounds in quarry runoff will be minimized by the following measures:

- quarries will be developed using only geochemically suitable material (Mine Waste Rock Management Plan and Tailings Management Plan; Volume 10, Chapter 9 and 22); and

- machinery will be fuelled, maintained, and repaired to avoid potential leaks of fuels and petroleum hydrocarbons (Fuel Management Plan; Volume 10, Chapter 4);

The effects of runoff from quarries will be minimized by the following measures:

- local drainage patterns will be maintained and the flow of water into the quarry minimized by the diversion of non-contact water around quarries; and
- quarries and borrow pits will have water collection and control infrastructure (Borrow Pits and Quarry Management Plan; Volume 10, Chapter 16). If the runoff is turbid but chemically-unaltered, it will be allowed to infiltrate into the ground.

Runoff will be monitored and managed to ensure fish-bearing receiving environments will meet water quality objectives. Adjacent waterbodies will be monitored for water and sediment quality through the Aquatic Effects Management Plan (Volume 10, Chapter 19) and the Site Water Monitoring and Management Plan (Volume 10, Chapter 7). Therefore, no residual effects from quarries and borrow pits were predicted on the VEC freshwater sediment quality because of the proposed mitigation and management measures, including monitoring and adaptive management of quarry runoff.

5.5.3.5 Explosives

Potential effects from explosives will interact with the freshwater environment through the runoff and aerial deposition pathways. Deposition of explosives and blasting residues on surfaces, with the subsequent possibility of transport in runoff to freshwater environments, will be mitigated and managed by:

- storing explosive products on site in accordance with Territorial and Federal regulations (1990; C.R.C., c. 599);
- contracting a licensed operator to handle and manufacture the explosives;
- intercepting and collecting runoff from explosive storage and manufacture facilities before it reaches the freshwater environment (Mobilization and Construction Phase) or diverting it to the tailings storage facilities (Operations Phase); and
- adopting BMPs for the blasting and handling of explosives to avoid spillage and minimize ammonium and nitrate residues after blasting.

The BMPs for explosives use will manage dust and excess blasting residues (Explosives Management Plan; Volume 10, Chapter 13). Blasting residues will be monitored in Project lakes through the Aquatic Effects Management Plan (Volume 10, Chapter 19).

Some residual effects from blasting residues were predicted during the Mobilization and Construction phase due to runoff prior to the completion of water management infrastructure, and during the re-connection of water management infrastructure in the Closure phase. Therefore, residual effects from explosives in runoff were predicted on the VEC freshwater sediment quality.

However, no effects were predicted from the storage, manufacture, and transport of explosives during the Operations of the Project because of the mitigation and management measures. Explosives will be used during the Operations phase primarily for mining operation, with minor quarry and borrow pit activities for maintenance materials and potential closure activities. All contact water will be diverted to the water management facilities and therefore any blasting residues will be diverted to these facilities and not to the freshwater environment.

The effects from blasting residues on sediment quality through the aerial deposition pathway was predicted to be negligible due to the mitigation and management measures for explosives use and air quality (Volume 10, Chapters 13 and 17). The quantity of explosives will be designed to minimize the generation of dust and further dust management measures will minimize the transport of any generated dust particles. Therefore, no residual effects from the aerial deposition of blasting residues were predicted.

5.5.3.6 Fuels, Oils, and PAH

The fuels, oils, and PAH Project interaction group activities will interact with the freshwater environment through runoff and aerial deposition (for PAH). The mitigation and management measures for runoff are focused on preventing hydrocarbons from being transported in runoff and may consist of the follow measures:

- machinery will be routinely inspected for leaks and refuelling will occur, when feasible, at a designated refuelling point with drainage capture/collection installed. In the event that refuelling occurs elsewhere, drip trays may be used under vehicles and equipment;
- appropriate secondary containment systems will be used for petroleum product storage tanks to prevent spills and releases to water, including the prevention of diesel release from pickups carrying tidy-tanks;
- bulk fuel storage areas and hazardous materials storage areas will be bermed and lined with impermeable barriers to minimize leaks and spills; and
- oily water treatment plants at equipment maintenance facilities will be used to minimize water and surface hydrocarbon compounds.

In the event that hydrocarbons are transported in runoff, runoff from camp pads, laydown areas, and waste management areas will be directed to the water management structures and will not be discharged into the freshwater environment. Prior to the completion of the water management infrastructure during the Mobilization and Construction phase, runoff will be collected in sumps and discharged only if it meets water quality standards. Fuels, oils, and PAHs will be managed under the Fuel Management Plan (Volume 10, Volume 4) and the Hazardous Materials Management Plan (Volume 10, Chapter 12).

For the aerial deposition pathway, the primary mitigation measure will be the efficient operation of the incinerator (Incineration Management Plan; Volume 10, Chapter 11). The operation of the incinerator will comply with Nunavut guidelines (Government of Nunavut 2012), Canada-Wide Standards for Dioxins and Furans (CCME 2001), and Canada-Wide Standards for Mercury Emissions (CCME 2000). Management measures will include the following:

- a waste segregation program will be implemented (i.e., materials that are unsuitable for incineration, e.g., chlorinated plastics, will be diverted to alternate waste disposal facilities);
- personnel will be properly trained in incinerator operations; and
- stack testing during commissioning and adaptive management to ensure compliance with standards.

Project activities related to fuels and other petroleum hydrocarbons were predicted to have negligible effects on the VEC freshwater sediment quality through the runoff and aerial deposition pathways because of the extensive proposed mitigation and management measures. No hydrocarbon compounds or sediments from Project activities in the camps, laydown areas, fuel areas, or waste storage areas were predicted to reach the freshwater environment because of the BMPs for machinery operation,

maintenance, and fueling, and the direction of runoff carrying potential compounds to the water management facilities. The incinerator will be operated according to guidelines and standards, and therefore negligible aerial deposition of PAH into the freshwater environment were predicted. Therefore, no residual effects from fuels, oils, and PAHs are predicted on the VEC freshwater sediment quality.

5.5.3.7 Treated Sewage Discharge

The pathway of interaction between treated sewage and the freshwater environment is discharge. No sewage effluent will be discharged to the freshwater environment during any phase of the Project (Waste Management Plan; Volume 10, Chapter 10). Instead, treated sewage effluent will be discharged to Llama Lake prior to dewatering and then to the tailings management facilities during the Operations and Closure phases (Water and Load Balance Report; Volume 2, Appendix V2-7H). Water from Llama Lake will be discharged to Goose Lake prior to dewatering, but this water will be treated and will meet permit requirements. Thus, there will be no residual effects from treated sewage discharge on the VEC freshwater sediment quality.

5.5.4 Characterization of Residual Effects

In Section 5.5.3, seven potential effects were evaluated for whether they would result in residual effects after mitigation. Residual effects are those effects predicted to remain after the application of mitigation and management. Four of these potential effects were identified as residual effects: 1) *construction and decommissioning activities*, 2) *site contact water*, 3) *mine contact water*, and 4) *explosives*. The significance of these residual effects is evaluated below. Each residual effect is described in this section in terms of eight descriptors (Volume 9; Chapter 1), including: direction, magnitude, duration, frequency, geographic extent, reversibility, probability, and confidence. The magnitude for each residual effect was evaluated by using the information in Table 5.5-1. Table 5.5-2 provides a description of the significance ratings used for residual effects.

5.5.4.1 Construction and Decommissioning Activities

The mitigation and management measures were predicted to be effective at minimizing potential effects from runoff associated with construction and decommissioning activities. The use of only geochemically suitable material for construction of roads and pads will eliminate the potential for acid-rock drainage (Mine Waste Rock Management Plan, Volume 10, Chapter 9; and Tailings Management Plan, Volume 10, Chapter 22). The proposed mitigation and management measures will minimize the quantity of material transported in runoff (e.g., TSS and metals) and the likelihood of runoff reaching the freshwater environment. Some runoff into nearby waterbodies could be possible during the early stages of the mobilization and construction phase before water management structures are fully operational (e.g., TSFs, sediment ponds, and diversion ditches). Once the water management structures are in place, any runoff from cleared areas is expected to be fully mitigated.

Water transferred during dewatering activities will meet a TSS or turbidity threshold equivalent to the MMER limit for TSS (15 mg/L). This threshold is less than the CCME water quality guideline for TSS and any increase in the TSS due to the discharge of water during dewatering would be transient and restricted to the PDA. In addition, any increases in sediment concentrations from the construction of retention dykes would likely be transient and restricted to the PDA. No significant effects to sediment quality were predicted because of the adherence to limits on the suspended sediment in discharge from dewatering activities.

Only small amounts of runoff would be expected to reach the surrounding waterbodies while the water management features are being constructed. The extensive mitigation and management measures incorporating design, BMPs, and adaptive management were predicted to minimize the transport of

sediments through runoff into the freshwater environment. Project activities were not anticipated to affect sedimentation rates. There are no planned discharges to receiving waters that would be sediment-laden. The potential effect of suspended sediments or other soil/sediment materials from construction activities is included in this assessment. No significant increases in the rate and distribution of sedimentation in waterbodies in the LSA were predicted. Sediment loading will be minimized by the BMPs outlined in Section 5.5.3.1, and lake dewatering activities will be managed to avoid the discharge of sediment-laden water. Sediment dispersion models were not required because no significant interactions were anticipated between Project activities and sedimentation processes in the freshwater environment after the application of the mitigation and management measures.

The predicted magnitude of the residual effect was *low*. The magnitude of the residual effect was evaluated in the context of the final receiving environment for fish-bearing waters with respect to the thresholds given by the CCME sediment quality guidelines. Upstream sources close to construction and decommissioning activities may have higher TSS concentrations, but the residual effects were evaluated for the nearby fish-bearing environments. Baseline freshet flows in the Project area had TSS concentrations ~10 mg/L greater than average TSS concentrations (~1.8 mg/L; Section 4.1.7.2), which suggest that periodic high-sediment conditions are a feature of the freshwater environment during periods of significant overland runoff. Therefore, the effects on the VEC freshwater sediment quality from construction and decommissioning activities were predicted to be within natural variation and will not have any significant effects on the indicators of sediment quality.

The effects were predicted to be within the footprint (within the PDA) or *local* (restricted to the LSA), *short-term* in duration, and *sporadic* as runoff would only occur during snowmelt and episodic large precipitation events. The freshwater environment has the capacity to recover and the effects were predicted to be fully *reversible*. The probability of occurrence was estimated to be *moderate* due to the uncertainties related to precipitation, and confidence was *high* because of the quantitative baseline environmental data, the predictable nature of the potential effects, and the confidence in the mitigation and management strategies.

The residual effect of site construction on the VEC freshwater sediment quality, which describes the disturbance of the landscape due to the construction and reclamation of Project infrastructure, is predicted to be Not Significant.

5.5.4.2 Site Contact Water

The mitigation and management measures were predicted to be effective and minimize the potential effects from runoff associated with site contact water. Once the site water management infrastructure is complete (Site Water Monitoring and Management Plan; Volume 10, Chapter 7), all site contact water will be diverted to the water management facilities and will not contact the freshwater environment. Therefore, no residual effects on the VEC freshwater sediment quality from site contact water were predicted during the Operations, Temporary Closure, and Care and Maintenance phases. However, Project activities will occur when the site water management infrastructure is not fully operational (e.g., before commissioning during the Mobilization and Construction Phase, or after the re-connection to natural drainage networks during the Closure Phase). Some runoff into nearby waterbodies could be possible during this period; therefore, residual effects from site contact water are predicted on the VEC freshwater sediment quality during the Mobilization and Construction, Reclamation and Closure, and Post-Closure phases when the water management features are inactive.

In the event that site contact water did contact the freshwater environment, the water quality indicators were predicted to be within the range of natural variation (as discussed in Section 4.5.5.1), and were not predicted to result in changes to sediment quality indicators beyond the CCME guideline thresholds.

Therefore, the predicted magnitude of the residual effect was *low*. The effects were predicted to be footprint (within the PDA) or *local* (restricted to the LSA), *short-term* in duration (confined to the Mobilization and Construction Phase), and *sporadic* as runoff would only occur during snowmelt and episodic large precipitation events. The freshwater environment was predicted to be resilient and the effects were predicted to be fully *reversible*. The probability of occurrence was estimated to be *moderate* due to the uncertainties related to precipitation, and confidence was *high* because of the quantitative baseline environmental data and the confidence in the mitigation and management strategies.

The residual effect of site contact water on the VEC freshwater sediment quality is predicted to be Not Significant.

5.5.4.3 Mine Contact Water

The mitigation and management measures were predicted to be effective and minimize the potential effects from runoff and discharge associated with mine contact water during the Operations Phase. Once the site water management infrastructure is complete (Site Water Monitoring and Management Plan; Volume 10, Chapter 7), mine contact water, including underground water and runoff from WRSAs, Saline Water Pond, and ore piles, will be diverted to the water management facilities and will not contact the freshwater environment. However, Project activities will occur when the site water management infrastructure is not fully operational (e.g., before commissioning during the Mobilization and Construction Phase and after decommissioning in the Reclamation and Closure Phase and Post-Closure Phase).

The quantitative Water and Load Balance (Volume 2, Appendix V2-7H) identified the following parameters of potential concern resulting from mine contact water: aluminum, arsenic, chloride, copper, iron, and mercury.

For the assessment of residual effects to sediment quality from potential Project-related increases in these parameters, the analysis was focused on parameters with existing sediment quality thresholds and that also had water quality predicted increases that were longer than a few months (e.g., arsenic and copper). The other parameters (i.e., aluminum, chloride, iron) do not have CCME sediment quality guidelines for the protection of aquatic life, with the exception of mercury. The predicted increases in water concentrations of these parameters were short-term in duration and located close to the point of contact between the mine contact water and the freshwater environment (Water and Load Balance Report, Volume 2, Appendix V2-7H; Section 4.5.4.3, Volume 6, Chapter 4). The predicted concentrations for mercury were near the CCME guideline for only a two month duration. The short duration of the predicted increases in water concentrations of these parameters was predicted to have minor interactions with the sediments, and negligible long-term changes in the concentrations of aluminum, chloride, iron, and mercury in sediments in the immediate receiving environment.

<u>Arsenic</u>

Arsenic concentrations were predicted to increase downstream of WRSAs and the TSF in the Llama Lake Outflow (Llama OF) and Goose SE IF tributaries to Goose Lake, as well as in Goose Lake itself (Water and Load Balance Report, Volume 2, Appendix V2-7H; 2015 Goose Lake Hydrodynamic Modelling Report: Arsenic Predictions, Appendix V6-4A). The residual effects to water quality from these Project-related increases in arsenic were assessed in the freshwater water quality chapter, under the 'mine contact water' section (Volume 6, Chapter 4), and were concluded to be not significant when the duration, spatial extent, and magnitude of the residual effects to water quality were considered.

For the assessment of the residual effects of predicted water arsenic concentrations on sediment quality, the natural background concentrations of arsenic in the receiving environment were considered.

The baseline sampling program found naturally elevated concentrations of arsenic in lake and stream sediments throughout the LSA, including Goose Lake. Weathering and runoff of particulate and dissolved arsenic are the natural sources of arsenic in aquatic sediments, and the baseline program indicated that substantial quantities of arsenic have been mobilized into the aquatic environment. Once deposited in the aquatic sediments, arsenic is incorporated into iron and sulphur minerals (Kneebone et al. 2002; O'Day et al. 2004). The sediments in Goose Lake and its tributaries are expected to have these typical processes of arsenic binding and burial. These natural processes are mediated by micro-organisms (Oremland and Stolz 2003), and are coupled to redox conditions and iron- and sulphur-cycling. Although water column concentrations of arsenic in Goose Lake are relatively low (Sections 4.1.5.5, Volume 6, Chapter 4), the substantial concentrations of arsenic in the sediments of Goose Lake indicate that arsenic binding and burial processes are an active biogeochemical process in the sediment environment. The processes of arsenic sequestration in the sediments are not expected to be affected by Project activities. Overall, Goose Lake is predicted to have water arsenic concentrations close to or below the CCME guideline for the protection of freshwater aquatic life (0.005 mg/L) for the long-term (See the freshwater water quality chapter, this volume, Chapter 4, Figure 4.5-1).

For the assessment of the residual effect of predicted water arsenic concentrations on sediment quality, the magnitude of the effect was concluded to be *moderate* because the increased arsenic water concentrations were predicted to increase arsenic sediment concentrations through natural arsenic binding and burial processes. The effect was predicted to be *local* (confined to localized areas in Goose Lake and/or tributaries) and remain within the PDA, and *medium term* in duration because of the medium term predicted increases in water arsenic concentrations.

Copper

Like arsenic, copper water concentrations were predicted to increase in the Llama OF and Goose SE IF tributaries of Goose Lake downstream from WRSAs and mine infrastructure once those areas are re-connected to natural draining networks. However, the predicted increases in water concentrations were modest (e.g., less than 25%) compared to the natural background copper concentrations and the background sediment concentrations of copper were substantial and greater than CCME sediment quality guidelines in Goose Lake. In the baseline sampling program, naturally elevated copper concentrations were observed in most sediment samples characterized by silt- or clay-sized particles. Copper, like many metals, adsorbs readily to silt and clay particles.

The modest predicted increases in copper concentrations due to mine contact water was not predicted to substantially change sediment copper concentrations because of the low magnitude of the predicted water concentration change and the high background concentrations of copper in the receiving environment. In the Llama OF and Goose SE IF stream environments, copper was not predicted to accumulate in sediments because of the low abundance of silt- and clay-sized particles in those lotic environments. Once in Goose Lake, the Project-derived copper was predicted to be naturally sequestered to the sediments and could result in modest increases in sediment copper concentrations. Assuming equal dilution throughout Goose Lake, the Post-Closure water copper concentration is 0.0019 mg/L (Water and Load Balance Report, Volume 2, Appendix V2-7H), which is within the range of natural variation (Section 4.5.4.3, Volume 6, Chapter 4). Sediment copper concentrations may therefore increase, due to the increased copper concentrations in water, but the increase in sediments were predicted to be similar in magnitude to the changes in the water concentrations. Sediment copper concentrations were predicted, on this basis, to be within the 90% quantile of baseline concentrations. The magnitude of the residual effects from copper on sediment quality, therefore, was predicted to be *low*. The duration of the residual effects from copper on sediment quality would be *short term* because of the relatively short (e.g., less than 4 years) duration of elevated copper concentrations in Goose Lake tributaries (Water and Load Balance Report, Volume 2, Appendix V2-7H).

Mine contact water may interact with the freshwater environment during the Mobilization and Construction, Reclamation and Closure, and Post-closure phases. The predicted magnitude of the residual effect to the VEC freshwater sediment quality was *low* for the residual effects from elevated copper concentrations and *moderate* for the residual effect from elevated arsenic concentrations in mine contact water. The effects were predicted to be *local* (restricted to the LSA), *short* to *long term* in duration (for copper and arsenic respectively), and *sporadic* as runoff or discharge would only occur during or after snowmelt and large precipitation events. The freshwater environment was predicted to be resilient and the effects were predicted to be *partially-reversible* because the Project was not predicted to modify significant biogeochemical processes. The probability of occurrence was estimated to be *moderate* due to the uncertainties related to precipitation, and confidence was *medium* because of the quantitative baseline environmental data, the quantitative water quality modelling, and the confidence in the mitigation and management strategies.

The residual effect of mine contact water on the VEC freshwater sediment quality was predicted to be Not Significant.

5.5.4.4 Explosives

The mitigation and management measures for explosives were assumed to be effective, but some blasting residues were predicted to contact the freshwater receiving environment during the Mobilization and Construction Phase and during the Reclamation and Closure Phase when natural drainage networks are re-established. Increased water concentrations of inorganic nitrogen species (e.g., nitrite, nitrate, and ammonia) were predicted downstream of WRSAs and infrastructure in the Llama OF, Echo OF, and Goose SE IF tributaries to Goose Lake (Water and Load Balance, Volume 2, Appendix V2-7H). Increased water concentrations of inorganic nitrogen species may result in increased sediment nitrogen concentrations, either through the direct deposition and adsorption of nitrogen compounds to the sediments, or the indirect incorporation of nitrogen in organic matter. However, the short term (e.g., less than 4 years) increases in water nitrogen concentrations in the Goose Lake tributaries would not be predicted to result in long-term changes in sediment nitrogen concentrations. Nitrogen is a required nutrient for microbial metabolism, and any additional nitrogen deposited in the sediments as a result of blasting residues was predicted to be processed and dispersed throughout the aquatic ecosystem. Therefore, the residual effect from blasting residues was predicted to be *low* in magnitude, *short term* in duration, and *local* in spatial extent. The natural biogeochemical processes in the nitrogen cycle were expected to reverse any Project-related changes in sediment nitrogen concentrations and the receiving environment was predicted to be resilient. Therefore, the residual effect of explosives on the VEC freshwater sediment quality is predicted to be Not Significant.

5.5.5 Significance of Residual Effects

Four residual effects for the VEC freshwater sediment quality were assessed and resulted in the following significance ratings:

- Construction and Decommissioning Activities – rated Not Significant;
- Site Contact Water – rated Not Significant;
- Mine Contact Water – rated Not Significant; and
- Explosives – rated Not Significant.

The criteria used in the determination of the significance of each residual effect is detailed in Section 5.5.4 and summarized in Table 5.5-7.

Table 5.5-7. Summary Table of Predicted Residual Effects on the VEC Freshwater Sediment Quality and Overall Significance Rating

Description of Residual Effects	Project Phase	Significance Criteria			Likelihood of Occurrence			Overall Significance Rating		
		Direction	Magnitude	Duration	Frequency	Extent	Reversibility	Probability	Confidence	Significance
Construction	Mobilization and Construction, Reclamation and Closure	Negative	Low	Short term	Sporadic	Local	Reversible	Moderate	Medium	**Not Significant**
Site Contact Water	Mobilization and Construction, Reclamation and Closure	Negative	Low	Short term	Sporadic	Local	Reversible	Moderate	Medium	**Not Significant**
Mine Contact Water	Mobilization and Construction, Reclamation and Closure, Post-Closure Monitoring	Negative	Low to Moderate	Short to Long term	Sporadic	Local	Partially-Reversible	Moderate	Medium	**Not Significant**
Explosives	Mobilization and Construction, Reclamation and Closure	Negative	Low	Short term	Sporadic	Local	Reversible	Moderate	Medium	**Not Significant**

5.6 POTENTIAL CUMULATIVE EFFECTS ASSESSMENT

5.6.1 Methodology Overview

The potential for cumulative effects arises when residual effects of the Project affect (i.e., overlap and interact with) the same resource/receptor that is affected by the residual effects of other past, existing or reasonably foreseeable projects or activities. When residual effects were identified for the Project, the Cumulative Effects Assessment (CEA) followed the process detailed in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1) and was comprised of the following steps:

1. Undertaking a scoping exercise to identify the potential for Project-related residual effects to interact with residual effects from other human activities and projects within a specified CEA boundary.
2. Identifying and predicting potential cumulative effects that may occur and implementing additional mitigation measures to minimize the potential for cumulative effects where possible.
3. Identifying cumulative residual effects after the implementation of mitigation measures.
4. Determining the significance of any cumulative residual effects.

The cumulative residual effects were analyzed using the same criteria as the Project-related effects assessment (Section 5.5.1): direction, magnitude, duration, frequency, geographic extent, reversibility, probability of occurrence, and confidence in the analyses and conclusions. The magnitude of potential cumulative effects applied the same criteria as the Project-related effects assessment (Table 5.5-1). Using a weight of evidence and relative ranking approach, combined with best professional judgement, the cumulative residual effect was characterized as either significant (S), not significant (N), or positive (P) in the same manner as the Project-related effects assessment (Table 5.5-2).

Past, existing, and reasonably foreseeable major projects with potential residual effects that occur within the RSA for the VEC freshwater sediment quality were considered and are listed in Table 3.4-1 in the Effects Assessment Methodology (Volume 9, Chapter 1). The list includes projects within Nunavut and the Northwest Territories to consider the outermost spatial boundary, and reflects a comprehensive evaluation of potential interactions. As per the EIS guidelines (NIRB 2013a), the list of projects considered conforms to the requirement to consider a larger spatial boundary for the CEA as well as a longer temporal scale.

The expected timing and duration of Project-related residual effects was compared with that of residual effects from other past, existing, and future human activities to identify temporal overlap. As identified in the EIS guidelines (NIRB 2013a), a longer timeline than the development and operations phases of the Project were considered.

5.6.2 Potential Interactions of Residual Effects with Other Projects

The following residual Projects effects on freshwater sediment quality were identified:

- Construction and decommissioning activities;
- Site contact water;
- Mine contact water; and
- Explosives.

The spatial boundary of the CEA was the Freshwater RSA (see Section 5.4.1). The temporal boundary for the CEA was any past, present, or reasonably foreseeable future projects (see list of projects in Volume 9, Chapter 1).

No past, present, or foreseeable projects that could potentially interact with the residual effects of the Back River Project lie within the RSA. Given that the Project residual effects were confined to the LSA, there are no expected cumulative effects on the VEC freshwater sediment quality.

5.7 TRANSBOUNDARY EFFECTS

As outlined in Section 4 of Volume 9 (Chapter 1), the potential for transboundary effects of the Project were determined based on whether residual Project effects could operate cumulatively with effects of projects in other jurisdictions. Transboundary effects can occur when VECs or the zone of influence of a project moves across jurisdictional borders external to the Nunavut Settlement Area (NSA). The non-significant Project residual effects for freshwater sediment quality are expected to remain confined to the LSA, which lies entirely within the Nunavut Settlement Area. As the Project residual effects were confined to Nunavut, there was no potential for transboundary effects.

5.8 MITIGATION AND ADAPTIVE MANAGEMENT

Mitigation and management measures will be used to eliminate or minimize Project effects on the freshwater environment. The measures include mitigation by Project design, conformity to existing regulations and guidelines, BMP, and the application of monitoring and adaptive management plans. The specific mitigation and management measures for freshwater sediment quality are shown in Table 5.8-1.

Table 5.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Sediment Quality

Mitigation Category	Mitigation Measures
1. Mitigation by Project Design	
	Only geochemically suitable rock quarries and borrow sources will be used to construct roads, pads, and structures.
	Contact water will be intercepted and managed.
	Infrastructure and waste rock storage areas at the Goose Property have been confined to the local watersheds where the deposits are located, thereby confining potential influence on water and sediment quality to the local drainage areas.
	Infrastructure will be located, whenever feasible, on competent bedrock or appropriate base material that will limit permeability and transport of potentially poor quality water into the active layer, and ultimately to the freshwater environment.
	The design of haul roads has been optimized to minimize the distance travelled which will reduce dust (and hence potential influence on water and sediment quality) associated with construction and operation.
	The Project has been designed to use winter ice road only access corridors thereby limiting dust emissions, limiting stream crossings, and instream works, and hence the potential influence on water and sediment quality.
	Erosion potential will be reduced by working during periods of low runoff as much as possible.
	Diversion of water will only occur at approved sources licensed for this function and during the temporal limits of the licence.
	Water will be recycled / reused where possible.
	Outlets will have a diffuser or be located in an area not subject to erosion from outflows.

(continued)

Table 5.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Sediment Quality (continued)

Mitigation Category	Mitigation Measures
2. Regulatory Requirements	
	MAC code/guidelines for design construction, operation, inspection/auditing of tailings management facilities.
	The operation of incinerators will comply with Nunavut standards, Canada-Wide Standards for Dioxins and Furans and Canada-Wide Standards for Mercury emissions (CCME 2000, 2001). Modern incineration equipment will be installed to minimize airborne contaminant loading of polycyclic aromatic hydrocarbons.
	Culvert maintenance will be conducted following the DFO Nunavut Measures to Avoid Causing Harm to Fish and Fish Habitat for Culvert Maintenance (Fisheries and Oceans Canada 2013a).
	In-water work will be conducted during approved timing windows presented in the DFO Nunavut Measures to Avoid Causing Harm to Fish and Fish Habitat for Timing Windows (Fisheries and Oceans Canada 2013b).
	Site road crossings will be constructed according to the the DFO Nunavut Measures to Avoid Causing Harm to Fish and Fish Habitat (Fisheries and Oceans Canada 2013a).
	Temporary stream crossings will be constructed according to the the DFO Nunavut Measures to Avoid Causing Harm to Fish and Fish Habitat (Fisheries and Oceans Canada 2013a).
	Winter ice road construction will follow the DFO Nunavut Measures to Avoid Causing Harm to Fish and Fish Habitat for Ice Bridges and Snow Fills (Fisheries and Oceans Canada 2013a).
	Water withdrawal will follow permit conditions.
3. Best Management Practices	
	Clean water and snow will be managed such that they do not contribute to potentially poor quality water and be diverted to maintain natural drainage networks as much as possible.
	Potentially poor quality site water (runoff from waste rock storage areas, ore stockpiles, mine contact water) will be directed during operations to the Goose Property Area water management infrastructure.
	Sewage will be treated, and treated sewage effluent will be discharged to tailings storage facilities.
	Bulk fuel storage areas, hazardous materials storage areas, and explosives storage facilities will be bermed and lined with impermeable barriers to minimize leaks and spills reaching freshwater environment.
	Modern incineration equipment will be installed to minimize airborne contaminant loading of dioxins, furans, and polycyclic aromatic hydrocarbons.
	Non-contact water will be diverted around infrastructure, as much as feasible, and directed to natural downstream drainage networks.
	Oily water treatment plants at equipment maintenance facilities will be used to minimize water and surface hydrocarbon contaminants.
	Disposal of excavated material will be in a location above the high water mark to ensure that this material does not enter the watercourse.
	Efforts shall be made to minimize the duration of any instream works and minimize disturbance of riparian vegetation at stream crossings.
	Prevent the release of sediment or sediment laden water into water frequented by fish.
	Regular inspections will be conducted to ensure erosion and sediment control measures are functioning properly; all necessary repairs and adjustments will be conducted in a timely manner.
	The dewatering of Llama Lake, or other waterbody, will follow an approved dewatering plan, whereby water will not be discharged to the receiving environment if it does not meet approved criteria. Any poor quality water will be retained, discharged to the TSF or other appropriate holding facility.

(continued)

Table 5.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Sediment Quality (continued)

Mitigation Category	Mitigation Measures
3. Best Management Practices *(cont'd)*	
	Exposed landscape surfaces will be protected, where possible, by the installation of covering material like riprap, aggregate, or rolled erosion control products. If water held in control devices is turbid but chemically unaltered, it may infiltrate to the ground rather than storing it in an excavation. Runoff will be controlled where applicable by a combination of measures, which include: • slope texturing/grading to slow runoff and reduce effect slope lengths; • installation of synthetic permeable barriers and/or fibre rolls to reduce runoff velocities and retain sediments; and • check dams, gabions, and energy dissipation structures to reduce flow velocities in channels. Sediment loading in runoff may be minimized by the application of measures to intercept TSS before it reaches the freshwater environment. Sediment control measures may include: • preservation of riparian zones to trap sediment and to reduce flow velocities; and • stockpiles will be located away (>31 m) from watercourses. Visual monitoring will be conducted by the Environmental personnel on a regular basis to ensure drainage and erosion controls are effective. Construct ice bridge and snow fill approaches using clean, compacted snow and ice to a sufficient depth to protect banks of lakes, rivers or streams. All temporary works, silt curtains, construction material or debris, etc. are to be completely removed from the waterway when work is completed. Appropriate secondary containment systems will be used for petroleum product storage tanks to prevent spills and releases to water. This includes prevention of diesel release from pickups carrying tidy-tanks. Refuelling and maintenance activities will not occur, when feasible, within 30 m of a watercourse or waterbody except where required due to equipment breakdown or approved activities near water. Refuelling will occur at a refuelling point with drainage capture/collection installed, in the event that refuelling occurs elsewhere, drip trays may be used under vehicles and equipment.
4. Adaptive Management	
	The need for any corrective actions to on-site management or installation of additional control measures will be determined on a case-by-case basis. Indications of the need for corrective actions and additional control measures may include: • if results from the Surveillance Network monitoring program (which will be outlined in the future Type A Water Licence) show non-compliance; or • if results from the Aquatic Effects Monitoring Program, which will monitor the receiving environment around the mine infrastructure and activities, show negative effects to the freshwater environment.
5. Monitoring	
	An Aquatic Effects Management Plan will be in place that outlines the Aquatic Effects Monitoring Program (AEMP) that will be carried out during all phases of the Project. The AEMP will include the following: • monitoring a network of lakes and streams within the Goose Property at locations potentially affected by the Project and at reference areas away from Project activities; • monitoring lake and stream water quality, sediment quality, and aquatic biology; • monitoring fish populations and fish tissues; and

(continued)

Table 5.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Sediment Quality (completed)

Mitigation Category	Mitigation Measures
5. Monitoring *(cont'd)*	• if effluent (as defined in MMER regulations) is discharged to the environment, then additional sampling for MMER requirements will be conducted (effluent characterization; acute toxicity testing; site characterization studies (including surface hydrology); sublethal toxicity testing). Regular inspections of water management facilities will be conducted by Environmental Personnel. There will be a Site Surveillance Network Monitoring Program that will be outlined in the future Type A Water Licence. This Program will consist of all of the site compliance monitoring that will be required for managing/moving and releasing water from all potential containment areas.

Mitigation and management measures for other aspects of the Project, such as air quality and site water management, are detailed in Volume 10 of the EIS, and detailed in the following plans:

- Risk Management and Emergency Response Plan (Volume 10, Chapter 3);
- Fuel Management Plan (Volume 10, Chapter 4);
- Spill Contingency Plan (Volume 10, Chapter 5);
- Mine Waste Rock Management Plan (Volume 10, Chapter 9);
- Waste Management Plan (Volume 10, Chapter 10);
- Incinerator Management Plan (Volume 10, Chapter 11);
- Hazardous Materials Management Plan (Volume 10, Chapter 12);
- Explosives Management Plan (Volume 10, Chapter 13);
- Road Management Plan (Volume 10, Chapter 14);
- Borrow Pits and Quarry Management Plan (Volume 10, Chapter 16);
- Air Quality Monitoring and Management Plan (Volume 10, Chapter 17);
- Fish Offsetting Plan (Volume 10, Chapter 21);
- Tailings Management Plan (Volume 10, Chapter 22); and
- Mine Closure and Reclamation Plan (Volume 10, Chapter 29).

5.9 PROPOSED MONITORING PROGRAMS

5.9.1 Aquatic Effects Management Plan

The Aquatic Effects Management Plan describes the specific measures to minimize or eliminate potential effects on the freshwater environment (presented in Volume 10, Chapter 19). The Plan describes and presents the following components:

- The planning and implementation processes for the Plan, including the personnel and their responsibilities;
- The mitigation and adaptive management measures;
- The Aquatic Effects Monitoring Program (AEMP); and

- The processes for adaptive management, checking, recordkeeping, reporting, and QA/QC.

The AEMP will monitor the receiving aquatic environment around Project infrastructure and activities. Results from the monitoring will be used to determine if existing mitigation and management measures are adequate and provide an opportunity for adaptive management on an annual basis. It is anticipated that the AEMP will be a requirement of the future Type A Water Licence for the Project. The AEMP has also been designed to meet the requirements of mining Environmental Effects Monitoring (EEM), as required by the Metal Mining Effluent Regulations (MMER) under the *Fisheries Act* (1985), in the eventuality of discharges from the water management infrastructure into the freshwater receiving environment.

5.10 IMPACT STATEMENT

Eight potential effects were identified for the VEC freshwater sediment quality as a result of the Project: construction and decommissioning; site contact water; mine contact water; quarries and borrow pits; explosives; fuels, oils, and PAH; treated sewage discharge; and dust deposition. Potential effects were characterized using key indicators and quantitative thresholds for potential effects as well as experience from other Northern projects and best professional judgement. Mitigation and management measures were described and their effectiveness was evaluated in the process of identifying residual effects. Four residual effects were identified after mitigation and management:

- construction and decommissioning activities;
- site contact water;
- mine contact water; and
- explosives.

Using the thresholds identified for the key indicators, each of these residual effects were rated with *low* magnitude (with the exception of *medium* magnitude for mine contact water arsenic concentrations) and ultimately were rated as *not significant* because of the implementation of the extensive mitigation and management measures outlined in the Aquatic Effects Management Plan (Volume 10, Chapter 19) and in other management plans in Volume 10. All residual effects to freshwater sediment quality were predicted to be restricted to the LSA. Residual effects are expected to be reversible with sediment quality returning to baseline conditions because of the resiliency of the freshwater environment to the predicted residual Project effects.

No cumulative effects were predicted to occur as no interactions between other projects and the Back River Project freshwater sediment quality residual effects were expected because the effects were confined to the LSA. Similarly, as the Project residual effects were confined to Nunavut, there was no potential for transboundary effects.

6. Freshwater Fish / Aquatic Habitat

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6. Freshwater Fish/Aquatic Habitat

6.1 EXISTING ENVIRONMENT AND BASELINE INFORMATION

6.1.1 Overview and Regional Setting

The Back River Project (the Project) is located in the Kitikmeot region of western Nunavut in the continuous permafrost zone of the continental Canadian Arctic. The Project is composed of two main areas, the Goose Property Area and the Marine Laydown Area (MLA), which will be connected by winter ice roads (Figure 6.1-1). The majority of proposed infrastructure at the Goose Property lies within the regional Ellis River Watershed, which flows to the north and enters the Queen Maud Gulf (see Federal Watershed map in Chapter 1 of this Volume). The Back River Watershed lies to the south and east of the majority of proposed infrastructure and flows to the east eventually entering the Arctic Ocean south of Gjoa Haven.

The region containing the Project is characterized by extensive networks of lakes and streams within a hummocky landscape with low elevation relief and exposed bedrock uplands. Winter is characterized by extreme cold (mean monthly temperatures -33°C), and ice cover is present on lakes between October and July. Air temperatures are highest in July, reaching a mean monthly temperature of 14°C (Rescan 2012b). Regional meteorological stations report total annual precipitation between 125 mm (2009) to 344 mm (2007) for the interval 2006 to 2012 (see Volume 4, Chapter 3 for additional information). Ice depths on waterbodies are typically 1.5 to 2 metres thick, and shallow waterbodies (< 1.5 m) freeze to the bottom (Rescan 2011, 2012c, 2013b).

Hydrology in the Project area is snowmelt dominated, with peak flows occurring from early May to mid-June in most watersheds. Occasional rainfall-driven high flow events may occur between June and September.

The Goose Property is in the headwater region of its watershed and has relatively small upstream catchments. A few deep lakes provide the majority of year-round fish habitat, while shallow and ephemeral lakes and ponds provide seasonal habitat. Year-round habitat quality in lakes is primarily limited by depth, since overwintering by fish is only possible in lakes that do not freeze to the bottom or retain sufficient dissolved oxygen levels during ice cover. Streams in the Project area are generally small and shallow and do not provide overwintering fish habitat. Over the course of the summer, these streams tend to have low flow and low water levels. Many streams are ephemeral, flowing only during freshet, while others feature seasonal barriers such as boulder fields and subsurface seepages.

6.1.2 Regulatory Framework

6.1.2.1 Fisheries Act

Fish and fish habitat are protected under the *Fisheries Act* (1985), as well as other federal regulatory acts and principles. In 2012, the *Fisheries Act* was amended to establish into legislation the federal government's direction to focus efforts on protecting the productivity of commercial, recreational, and Aboriginal fisheries (CRA fisheries); to institute enhanced compliance and protection tools that are more easily enforceable; to provide clarity, certainty, and consistency of regulatory requirements; and to enable enhanced partnerships with stakeholders.

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Project Location

Figure 6.1-1

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The changes to the *Fisheries Act* include a prohibition against causing serious harm to fish that are part of or support a CRA fishery (Section 35), provisions for flow and passage (Sections 20 and 21), and a framework for regulatory decision-making (Sections 6 and 6.1).

The new Purpose section states that the fisheries protection provisions of the *Fisheries Act* aim to provide for the sustainability and ongoing productivity of CRA fisheries.

The four factors in Section 6 and 6.1 to be taken into account by the Minister in decision-making (e.g., issuing authorizations) or making regulations are:

- the contribution of the relevant fish to the ongoing productivity of CRA fisheries;
- fisheries management objectives;
- whether there are measures and standards to avoid, mitigate, or offset serious harm to fish that are part of a CRA fishery; and
- the public interest.

For the purposes of the *Fisheries Act*, serious harm to fish includes the death of fish or any permanent alteration to, or destruction of, fish habitat (PAD). The *Fisheries Act* defines fish habitat as "spawning grounds and any other areas, including nursery, rearing, food supply, and migration areas, on which fish depend directly or indirectly in order to carry out their life processes." The term "fish" includes parts of fish; shellfish, crustaceans, marine animals, and any parts of shellfish, crustaceans, or marine animals; and the eggs, sperm, larvae, spat, and juvenile stages of fish, shellfish, crustaceans, and marine animals.

On November 1, 2013, The Fisheries Protection Policy Statement (DFO 2013a) was issued and replaced the earlier Policy for the Management of Fish Habitat (DFO 1986). Although the new policy statement does not include the "no net loss" principle, as outlined in the earlier policy, application of this NNL principle provides some useful guidance when considering "serious harm to fish". In addition, the direction found within the 2013 scientific guidance document (Koops et al. 2013; Randall et al. 2013) has been consulted and followed.

Any project or activity that causes a serious harm to fish that are part of, or support, a CRA fishery requires an authorization from DFO. Regulations have been developed to guide the application for this authorization: Applications for Authorization under Paragraph 35(2)(b) of the *Fisheries Act* Regulations. DFO has issued additional guidance in the "The Fisheries Protection Program Operational Approach".

6.1.2.2 Metal Mining Effluent Regulations

In 1996, Environment Canada undertook an assessment of the aquatic effects of mining in Canada. This assessment provided recommendations regarding the review and amendments of the Metal Mining Liquid Effluent Regulations, currently titled the Metal Mining Effluent Regulations (MMER; SOR/2002-222), and the design of a national Environmental Effects Monitoring (EEM) program for metal mining. The MMER, under the *Fisheries Act*, instruct metal mines to conduct EEM as a condition governing the authority to deposit effluent (MMER, Part 2, section 7).

The MMER (SOR/2002-222) permit the deposition of mine effluent into water containing fish if the effluent pH is within a defined range, if the concentrations of the MMER deleterious substances in the effluent do not exceed authorized limits, and if the effluent is demonstrated to be non-acutely lethal to Rainbow Trout (*Oncorhynchus mykiss*). These discharge limits were established to be minimum national standards based on best available technology economically achievable at the time that the

MMER were promulgated. To assess the adequacy of the effluent regulations for protecting the aquatic environment, the MMER include EEM requirements to evaluate the potential effects of effluents on fish, fish habitat, and the use of fisheries resources.

Regulations Amending the MMER were published in the Canada Gazette, Part II, in October 2006 (Canada Gazette 2006). The purpose of these amendments was to clarify the regulatory requirements by addressing matters related to the interpretation and clarity of the regulatory text that had emerged from the implementation of the Regulations.

Additional amendments to the MMER were published in the Canada Gazette, Part II, in March 2012 (Canada Gazette 2012). The following changes were made to improve the EEM provisions of the MMER:

- modifications to the definition of an "effect on fish tissue" in order to be consistent with the Health Canada fish consumption guidelines and to clarify that the concentration of total mercury in tissue of fish from the exposure area must be statistically different from and higher than its concentration in fish tissue from the reference area;
- addition of selenium and electrical conductivity to the list of parameters required for effluent characterization and water quality monitoring;
- exemption for mines, other than uranium mines, from monitoring radium 226 as part of the water quality monitoring, if 10 consecutive test results showed that radium 226 levels are less than 10% of the authorized monthly mean concentration (subsection 13(2) of the Regulations; SOR/2002-222);
- change to the time frame for the submission of interpretative reports for mines with effects on the fish population, fish tissue, and benthic invertebrate community from 24 to 36 months;
- change to the time frame for the submission of interpretative reports for magnitude and geographic extent of effects, and for investigation of cause of effects, from 24 to 36 months; and
- minor changes to the wording for consistency within Schedule 5.

6.1.3 Proximity to Designated Environmental Areas

No existing or proposed parks or conservation areas are located near the proposed Project. The nearest conservation area is the Queen Maud Gulf Migratory Bird Sanctuary approximately 100 km east of Bathurst Inlet on the far side of the Kent Peninsula. The Draft Nunavut Land Use Plan (Nunavut Planning Commission 2012, 2014) has no designated environmental areas within the Freshwater Regional Study Area (RSA), and the proposed Project resides within the area designated as a High Mineral Potential area. The proposed Hiukitak River Cultural Area is on the eastern shore of Bathurst Inlet outside of the Freshwater RSA, and is located approximately 60 km northeast of the proposed Marine Laydown Area (MLA). A key bird habitat site has been identified in the north end of Bathurst Inlet, approximately 150 km to the north of the proposed MLA. The Back River is currently the only waterbody within the RSA to be considered as a heritage river. While no formal nomination for the Back River has been put forward thus far, the Project has been designed to avoid impacts to the Back River water system.

6.1.4 Baseline Study Area

Freshwater fish/aquatic habitat baseline studies were undertaken from 2010 to 2013 in the Back River Project area. Figure 6.1-2 shows the Goose Local Study Area (LSA), along with waterbodies where baseline fish habitat studies were conducted.

GIS # **BAC-06-260**

October 1, 2015

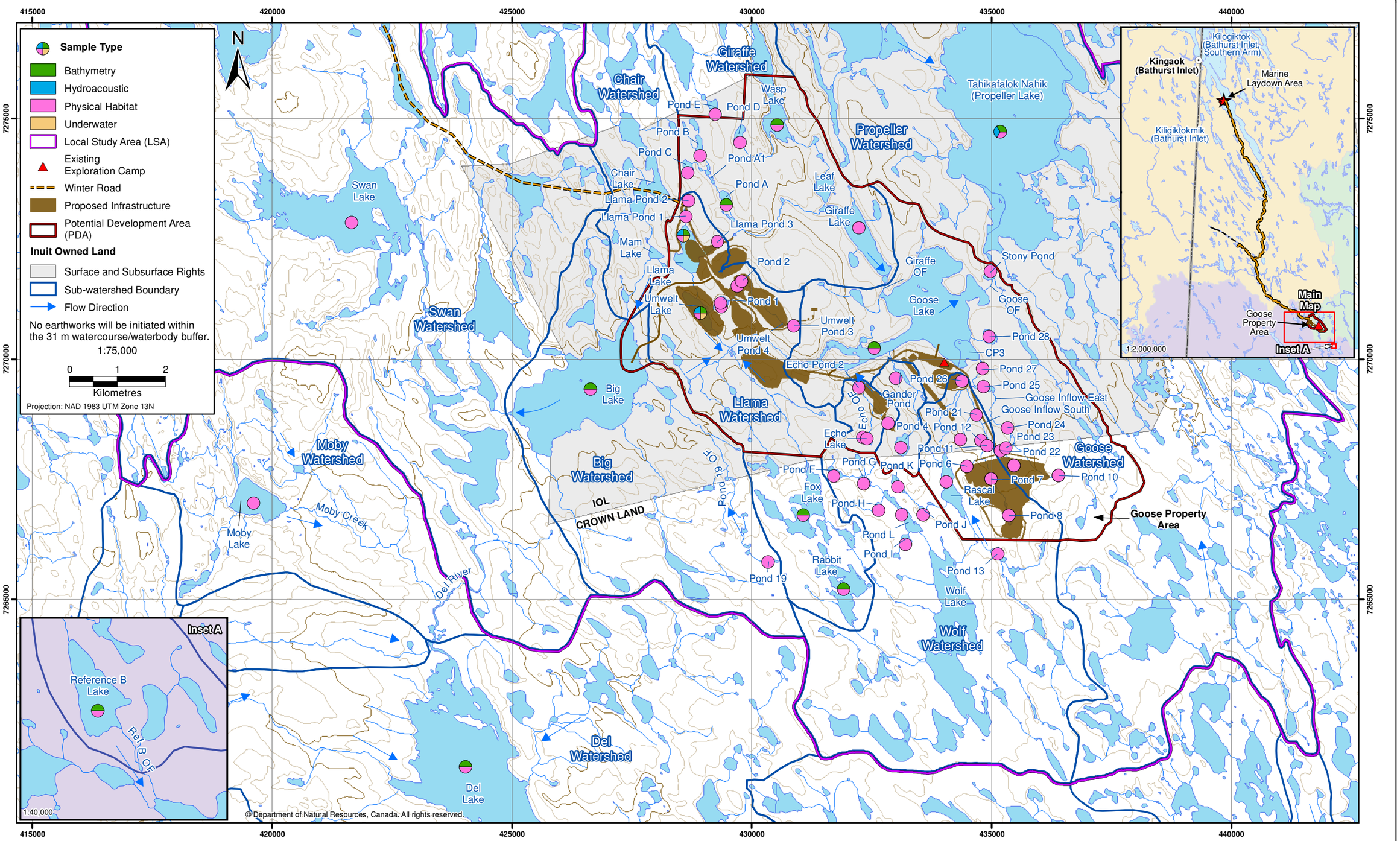

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Figure 6.1-2

Lake/Pond Fish Habitat Baseline Data (2010 – 2015) for the Goose Property Area

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6.1.5 Baseline Studies

6.1.5.1 Information Sources

Comprehensive baseline fish habitat and aquatic habitat data are available for the Goose Property from 2010 to 2015 (Rescan 2010, 2012a, 2012c, 2012d, 2012e, 2013a, 2013b, 2014, 2015). Supplemental historical data are also available prior to 2010. The following provides a summary of the available baseline data from 2010 to 2015.

2010 Baseline Studies

- Fish Habitat Baseline (Rescan 2010, Appendix V6-6A):
  - Characterize fish habitat in Llama, Umwelt, and Reference B lakes via hydroacoustic methods, underwater video, and visual observation.

2011 Baseline Studies

- Fish Habitat Baseline (Rescan 2012a, Appendix V6-6B):
  - Pond Assessments:
    Describe the type of fish habitat (substrate composition and cover in the littoral areas); and
    Assess ponds for their ability to support perennial fish habitat.
  - Lake Assessments:
    Characterize fish habitat quality in Goose, Llama, Umwelt, and Reference B lakes through visual observation.
- Freshwater Baseline (Rescan 2012c, Appendix V6-3B):
  - Lake Assessments:
    Collect baseline August phytoplankton, zooplankton, and benthos density and community composition data in Giraffe, Llama, Goose, Umwelt, Propeller, and Reference B lakes.
  - Stream Assessments:
    Collect baseline August periphyton and benthos density and community composition data in Chair Outflow, Llama Outflow, Echo Outflow, Giraffe Outflow, Wolf Outflow, Goose Outflow, Propeller Outflow, Propeller Downstream, and Reference B Outflow.

2012 Baseline Studies

- Fish Habitat Baseline (Rescan 2012d, Appendix V6-6C):
  - Assess fish habitat at stream crossings near potential site roads; and
  - Assess fish habitat that could be affected by potential mine development at the Goose Property.
- Freshwater Baseline (Rescan 2012e, Appendix V6-3C):
  - Lake Assessments:
    Collect baseline August phytoplankton, zooplankton and benthos density and community composition data in 14 lake sites in the Goose Property.
  - Stream Assessments:
    Collect baseline August periphyton, and benthos density and community composition data in 12 stream sites in the Goose Property.

2013 Baseline Studies

- Fish Habitat Baseline (Rescan 2013b, Appendix V6-6D):
  - Collect baseline fish habitat information in Giraffe, Propeller, and Wasp lakes;
  - Conduct detailed habitat surveys on streams that could be affected by development of mine infrastructure and compensation, including Giraffe Inflow, Llama Outflow, Rascal Outflow, and Echo Inflow.
- Freshwater Baseline (Rescan 2013a, Appendix V6-6D):
  - Lake Assessments:

    Collect baseline August phytoplankton, zooplankton and benthos density and community composition data in 18 lake sites in the Goose Property.
  - Stream Assessments:

    Collect baseline August periphyton, and benthos density and community composition data in nine stream sites in the Goose Property.

2014 Baseline Studies

- Fish Habitat Baseline (Rescan, 2014, Appendix V6-6E):
  - Collect baseline fish habitat and fish distribution information from nine stream sites and eight ponds within and downstream of the proposed Tailings Storage Facility.

2015 Baseline Studies

- Fish Habitat Baseline (Rescan, 2015c):
  - Collect baseline fish habitat and fish distribution information from 18 stream sites and 15 ponds within and downstream of the proposed Tailings Storage Facility.
  - Conduct habitat and fish distribution surveys on 11 ponds.
- Freshwater Baseline (Rescan, 2015b):
  - Lake Assessments:

    Collect baseline August benthos density and community composition data from one pond site in the Goose Property.
  - Stream Assessments:

    Collect baseline August periphyton, and benthos density and community composition data in two stream sites in the Goose Property.

Supplemental Historical Information

Additional information on the freshwater environment came from studies conducted in the Back River region between 1990 and 2007. These data were used to supplement baseline information and to give a longer temporal range for some information. These studies included:

- *Field Report — Back River Project Freshwater Aquatic Resources 2007* (Gartner Lee Ltd. 2008): collected phytoplankton biomass data from two lake sites in the Goose Property Area.

6.1.5.2 Baseline Study Methods — Lakes and Ponds

Freshwater Fish Habitat — Physical Characteristics

Fish habitat — the region and physical resources essential for fish to carry out life processes — was assessed in lakes and ponds within the Goose Property Area between 2010 and 2015. Shoreline habitat was assessed at each site to determine the substrate composition, abundance of aquatic cover, and extent of the littoral zone (generally defined as the depth to which the bottom remained visible from the surface). Maximum depth measurements were estimated using hand-held depth sounders at most sites, exceptions being those sites where bathymetric surveys were performed (Figure 6.1-2). In addition to bathymetry, bottom habitat typing was performed with a hydroacoustic echosounder at several lakes including: Umwelt, Llama, Reference B and Propeller. Figure 6.1-2 presents the locations and types of physical habitat surveys conducted between 2010 and 2015 in the Goose Property Area.

Freshwater Fish Habitat — Biological Resources

Phytoplankton

Baseline data on phytoplankton — organisms that form the base of pelagic food chains leading to fish — are available for 14 lakes collected in 2007, 2011, 2012, 2013, and 2015 (Rescan 2012c; 2012e [Appendix V6-3B, V6-3C]; 2013a; Figures 6.1-3 and Table 6.1-1).

Table 6.1-1. Summary of Baseline Lake Phytoplankton Sampling Conducted at the Goose Property Area

Year	2007	2011	2012	2013
Sampling Month(s)	August	August	April (chl *a* only), August	April (chl *a* only), August
Sampling Agency	Gartner Lee	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.
Data Collected	Chl *a**	Chl *a*, phytoplankton taxonomy and density	Chl *a*, phytoplankton taxonomy and density	Chl *a*, phytoplankton taxonomy and density
Sampling Method	Grab samples	GO-FLO sample from 1 m depth; 0.45 µm filters	Sample from 1 m depth (or 1 m below ice-water interface)†; 0.45 µm filters	Sample from 1 m depth (or 1 m below ice-water interface)†; 0.45 µm filters
Taxonomists	-	Bio-limno Research and Consulting Inc, Halifax NS	EcoAnalysts, Moscow ID, USA	EcoAnalysts, Moscow ID, USA
Analytical Lab (for chl *a*)	ALS Environmental, Edmonton, AB	ALS Environmental, Burnaby BC	ALS Environmental, Burnaby BC	ALS Environmental, Burnaby BC
Lake(s) Sampled	Goose Property Goose Lake Propeller Lake	Goose Property Goose Lake Llama Lake Giraffe lake Umwelt Lake Reference B Lake	Goose Property Goose Lake Propeller Lake Giraffe Lake Rabbit Lake Fox Lake Rascal Lake Big Lake Moby Lake Del Lake	Goose Property Goose Lake Propeller Lake Giraffe Lake Umwelt Lake Reference B Lake Rascal Lake Leaf Lake Wasp Lake
Number of Replicates per Site	n = 1	n = 3	n = 1 (April) n = 3 (August)	n = 1 (April) n = 3 (August)

** Note all chlorophyll a data was below detection limit in 2007 (< 1 µg/L).*

† Under-ice sampling in April.

Phytoplankton are free-floating photosynthetic microorganisms that use inorganic nutrients and sunlight to produce organic matter. They play an important ecological role in many aquatic systems as primary producers and food for higher trophic levels. In ponds and lakes, for example, phytoplankton are the main source of food for zooplankton, which are consumed directly by planktivorous fish. Zooplankton are also consumed by certain pelagic and benthic invertebrates, which constitute important food resources for insectivorous and omnivorous species of fish.

Phytoplankton biomass (as chlorophyll *a*) and taxonomy samples were collected using Niskin sampling bottles (ice-covered sampling) or GO-FLO sampling bottles (open-water sampling). All samples were transferred into 1 L plastic bottles and stored in a cool, dark cooler until return to camp. Once at camp, the biomass samples were filtered onto 0.45 µm filters that were wrapped in aluminum foil and stored frozen. Chlorophyll samples were analyzed at ALS laboratories in Burnaby, BC. Taxonomy samples were preserved with Lugol's iodine solution once back at camp. These samples were sent immediately a qualified taxonomist for enumeration and identification.

Zooplankton

Baseline data on zooplankton — secondary producers composing a key dietary resource for fish — have been collected from 11 lakes between 2011 and 2012 (Rescan 2012c; 2012e; Figures 6.1-4 and 6.1-5 and Table 6.1-2). Zooplankton are small aquatic organisms that feed on bacteria, phytoplankton, other zooplankton, and particulate organic matter, and are prey for larger organisms including other zooplankton and fish.

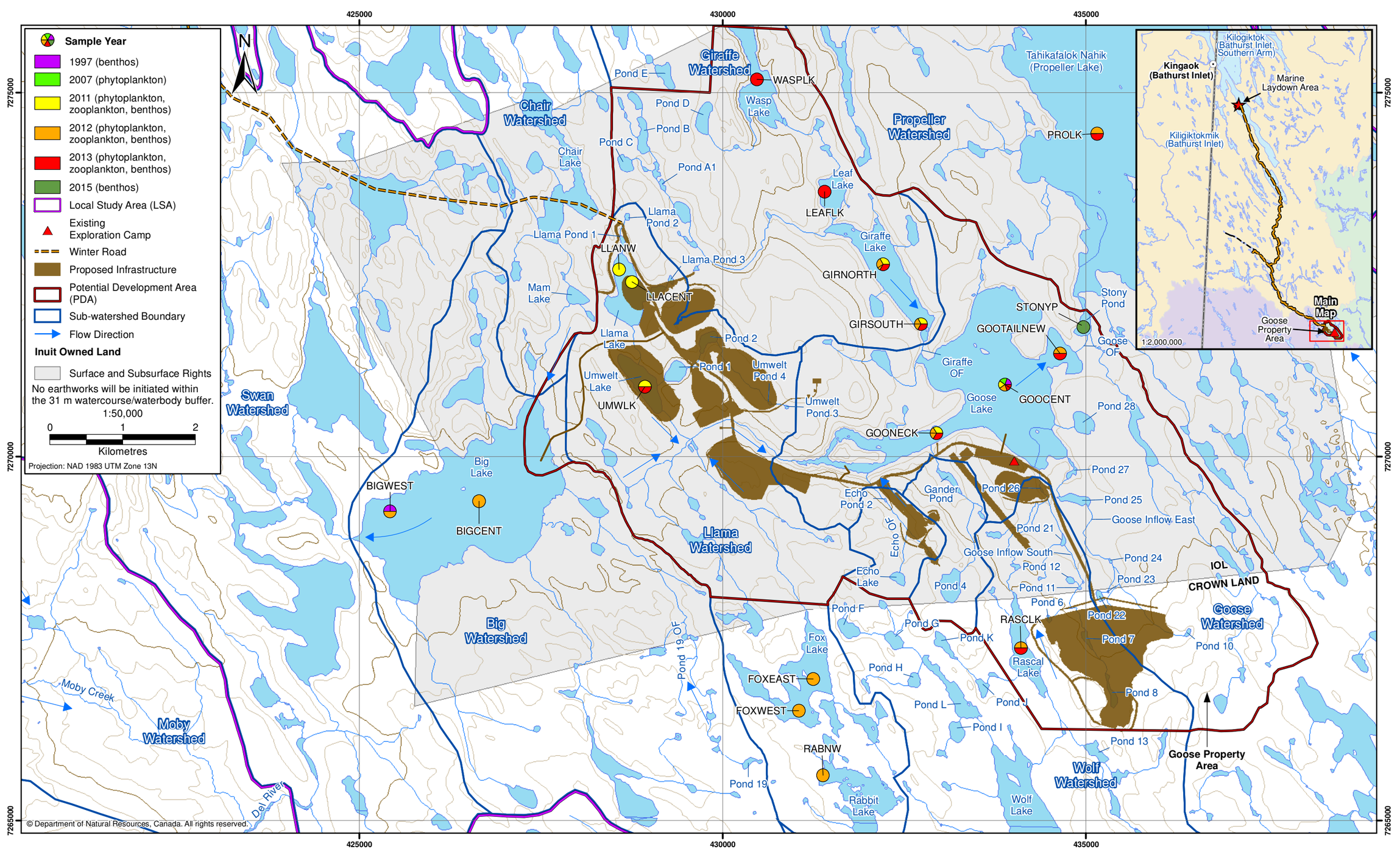
Zooplankton data were collected from both Giraffe and Goose lakes in 2011 and 2012. Zooplankton density and taxonomy samples were collected at each lake site, with three replicate vertical hauls conducted at each site using plankton net fitted with a 118 µm mesh. The net was lowered to 1 m above the sediment and brought to the surface at a speed of 0.5 m/s. An internally-mounted flow meter was used to record the volume of water passing through the net during all hauls. Zooplankton samples were preserved with 10% buffered formalin and sent to a qualified taxonomist for enumeration and identification.

Benthic Invertebrates

Baseline data on benthic invertebrates — the most important prey for adult invertivorous (e.g., insectivorous) fish and juvenile piscivorous fish — have been collected from 21 lakes during the summers of 1997 (Norecol Dames & Moore 1997), 2011, 2012, 2013, and 2015 (Rescan 2012c, 2012e; 2013a; Table 6.1-3; Figures 6.1-4 and 6.1-5, Rescan 2015b).

Benthic invertebrates are a diverse group of organisms that live on or in the sediments, making up an important component of lake ecosystems. Crustaceans, insects, and molluscs compose the bulk of this resource pool, which is also referred to as benthos. These organisms feed on algae, bacteria, detritus, and other invertebrates and are an important pathway for energy and nutrients to move between primary producers and upper trophic levels, for example from the lake bottom to the open water column and eventually into fish species like Lake Trout (*Salvelinus namaycush*) and Arctic Grayling (*Thymallus arcticus*).

Replicate samples of benthic invertebrates were collected from lake sediments at each site. Replicates within sites were collected approximately 20 to 50 m apart from one another. Once recovered, each sediment sample was transferred into a 500 µm sieve bucket and was rinsed with site-specific water until free of sediments. The material retained within the sieve was then placed into a labelled plastic jar and filled with 10% buffered formalin. All benthos samples were sent to a qualified taxonomist for enumeration and identification. Density of benthic invertebrates was calculated by dividing the total count of each benthic invertebrate species (or taxon) by the surface area of the sediment sampler. These methods, employed for all of the Rescan collections, differed from those used previously by Norecol Dames & Moore (1997) see Table 6.1-3.



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Lake/Pond Fish Habitat - Aquatic Resources Baseline Data (1997 - 2015) for the Goose Property Area

Figure 6.1-3

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GIS # **BAC-06-262**

October 1, 2015

Survey Location
- 2010 - 2011
- 2012
- 2013
- 2014
- 2015
- Local Study Area (LSA)
- Existing Exploration Camp
- Winter Road
- Proposed Infrastructure
- Potential Development Area (PDA)
- Sub-watershed Boundary
- Flow Direction

Inuit Owned Land
- Surface and Subsurface Rights

No earthworks will be initiated within the 31 m watercourse/waterbody buffer.

1:55,000

0 1 2 Kilometres

Projection: NAD 1983 UTM Zone 13N

N

420000 425000 430000 435000

7275000 7270000

Swan Watershed
Swan Lake
Chair Watershed
Chair Lake
Giraffe Watershed
Propeller Watershed
Tahikafalok Nahik (Propeller Lake)
Llama Watershed
Big Watershed
Moby Watershed
Goose Watershed
Mam Lake
Llama Lake
Leaf Lake
Giraffe Lake
Big Lake
Moby Lake
Moby Creek
Echo Lake
Gander Pond
Wolf Lake
Rascal Lake
Fox Lake
Rabbit Lake
Stony Pond
Goose Lake
Goose OF
Giraffe OF
Echo OF
Pond 19 OF
Wasp Lake

Pond E, Pond D, Pond B, Pond C, Pond A1, Llama Pond 2, Llama Pond 1, Llama Pond 3, Llama-1, Llama-2, Llama-3, Pond 1, Pond 2, Umwelt Pond 4, Umwelt Pond 3, Umwelt-2, Pond F, Pond G, Pond K, Pond H, Pond J, Pond L, Pond I, Pond 4, Pond 19, Pond 10, Pond 13, Pond 25, Pond 26, Pond 27, Pond 28

131, 130, 132, 103, 142, 143, 101, 102, 100, 104, 107, 106, 108, 109, 110, 111, 112, 114, 127, 141, 126, 113, 134, 138, 137, 136, 133, 117, 120, 118

Goose Inflow South, Goose Inflow East

Inset A

139, Pond 21, R8-1, R13-1, Pond 24, R8-2, R8-3, R14-1, R15-1, Pond 12, Pond 22, Pond 11, R8-4, Pond 23, R9-2, R9-1, R15-2, R10-1, R11-1, R14-2, R14-3, R14-4, R15-3, R10-2, R11-2E, R11-2W, Pond 6, Pond 7, R15-4, R15-5, R12-1, R12-2, R12-3E, R12-3W

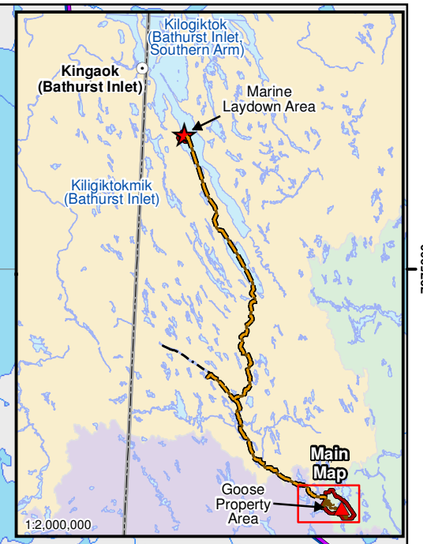
1:25,000

AS-1, AS-2, AS-3, AS-4

See Inset A

IOL CROWN LAND

Goose Property Area



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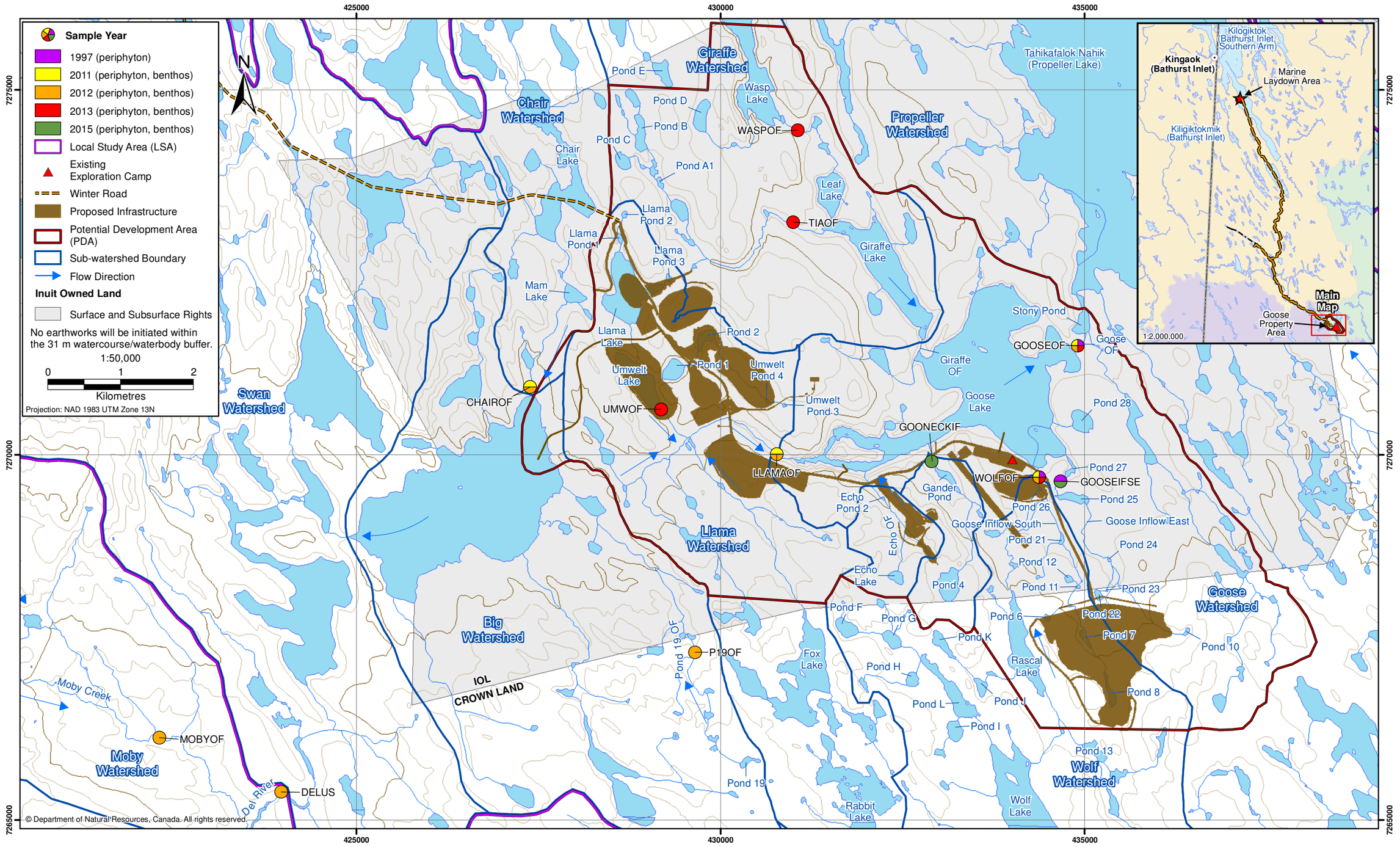
Stream Fish Habitat Baseline Data (2010 - 2015) for the Goose Property Area

Figure 6.1-4

Rescan an ERM company



Sabina GOLD & SILVER CORP.

Figure 6.1-5

Stream Fish Habitat - Aquatic Resources Baseline Data (1997 - 2015) for the Goose Property Area

Rescan an ERM company

Table 6.1-2. Summary of Baseline Lake Zooplankton Sampling Conducted at the Goose Property Area

Year	2011	2012
Sampling Month(s)	August	August
Sampling Agency	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.
Data Collected	Zooplankton taxonomy and density	Zooplankton taxonomy and density
Sampling Methods	Horizontal/vertical tows depending on site depth; 118 µm mesh net, 0.3 m diameter; Flow meter	Horizontal/oblique/vertical tows depending on site depth; 118 µm mesh net, 0.3 m diameter
Taxonomist	Applied Technical Services, Victoria, BC	EcoAnalysts, Moscow, ID, USA
Lake(s) Sampled	Goose Property	Goose Property
	Goose Lake	Goose Lake
	Giraffe Lake	Giraffe Lake
	Llama Lake	Big Lake
	Reference B Lake	Del Lake
	Umwelt Lake	Fox Lake
		Rabbit Lake
Number of Replicates per Site	n = 3	n = 3

Table 6.1-3. Summary of Baseline Lake Benthos Sampling Conducted at the Goose Property Area

Year	1997	2011	2012	2013	2015
Sampling Month(s)	August	August	August	July	August
Sampling Agency	Norecol Dames and Moore	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.
Data Collected	Benthos taxonomy and density*	Benthos taxonomy and density	Benthos taxonomy and density	Benthos taxonomy and density	Benthos taxonomy and density
Sampling Method	Ponar grab (0.0232 m^2); sieve size unknown	Ekman (0.0225 m^2); 500 µm sieve bucket	Ekman (0.0225 m^2); 500 µm sieve bucket	Ekman (0.0225 m^2); 500 µm sieve bucket	Ekman (0.0225 m^2); 500 µm sieve bucket
Analytical Lab	ECCON Environmental, unknown location	Dr. Jack Zloty, Summerland, BC	EcoAnalysts, Moscow ID, USA	EcoAnalysts, Moscow ID, USA	Biologica Environmental Services Victoria, BC
Lake(s) Sampled	Goose Property	Goose Property	Goose Property	Goose Property	Goose Property
	Goose Lake	Goose Lake	Goose Lake	Goose Lake	Stony Pond
	Big Lake	Giraffe Lake	Giraffe Lake	Giraffe Lake	

(continued)

Table 6.1-3. Summary of Baseline Lake Benthos Sampling Conducted at the Goose Property Area (completed)

Lake(s) Sampled *(cont'd)*		Llama Lake Umwelt Lake Reference B Lake	Rascal Lake Big Lake Fox Lake Propeller Lake Rabbit Lake Pond 19 Del Lake	Rascal Lake Umwelt Lake Reference B Lake Propeller Lake Leaf Lake Wasp Lake	
Number of Replicates	n = 5 per site	n = 5 or n = 10 depending on lake depth	n = 5 or n = 10 depending on lake depth	n = 5 or n = 10 depending on lake depth	n = 3
Composition of a Single Replicate	Assume each replicate is from a single pull, although this is not stated in methods	Each replicate a composite of three pulls	Each replicate a composite of three pulls	Each replicate a composite of three pulls	Each replicate is a composite of three pulls
Area Sampled per Replicate (m^2)	0.0232	0.0675	0.0675	0.0675	0.0675

** Note: raw densities are unavailable, only summed densities/sample with no clarity on what organisms were included or excluded.*

6.1.5.3 Baseline Study Methods — Streams

Freshwater Fish Habitat — Physical Characteristics

Fish habitat in streams was surveyed using methods based on the Fish Habitat Assessment Procedures (FHAP; Johnston and Slaney 1996). Representative sections of each reach were chosen for assessment and individual habitat units were measured with respect to length, bankfull and wetted width, depth, substrate composition, residual pool depth, bank stability, bank height, and instream cover. Barriers to fish migration were also noted and measured, where appropriate. Habitat suitability for spawning, rearing, and overwintering was described and an overall habitat quality ranking was applied (Table 6.1-4).

All streams within proposed infrastructure areas were ground-truthed, mapped, and the habitat was assessed through the implementation of the Sensitive Habitat Inventory Mapping (SHIM) protocol. The SHIM method is intended as a standard for watercourse and fish habitat mapping in British Columbia (Mason and Knight 2001) and was adapted for use in Arctic streams by Rescan. This method attempts to ensure the collection and mapping of reliable, high quality, current, and spatially accurate information about fish habitats and watercourses. The habitat data collected was similar to that collected during FHAP surveys; however, it was geo-referenced to the stream using a highly accurate GPS.

Figure 6.1-4 presents the locations of stream fish habitat surveys conducted between 2010 and 2013 in the Goose Property Area.

Table 6.1-4. Overall Habitat Quality Rankings and Criteria

	Habitat Quality Ranking		
	High	**Medium**	**Low**
Definition	Habitat that is necessary to sustain an Aboriginal, commercial, or recreational fishery, any species at risk*, or because of the habitat's relative rareness, productivity, and/or sensitivity.	Habitat that is used by fish for feeding, growth, and migration but is not deemed to be essential. This category of habitat usually contains a large amount of similar habitat that is readily available to the fishery.	Habitat that has low productive capacity and contributes marginally to fish production.
Indicators	The presence of high-value spawning or rearing habitat (e.g., locations with an abundance of suitably sized spawning gravels, deep pools, undercut banks, or stable debris, which are necessary to the population), or the presence of any *SARA*-listed species*, its residence, or its critical habitat.	Migration corridors, the presence of suitable spawning habitat, habitat with moderate rearing potential for the fish species present.	The absence of suitable spawning habitat, and habitat with low rearing potential (e.g., locations with a distinct absence of deep pools, undercut banks, or stable debris, and with little or no suitably sized spawning gravels for the fish species present).

*Notes: *terrestrial or aquatic red- and blue-listed species, those designated by the Committee on the Status of Endangered Wildlife in Canada, or those SARA-listed species.*

Freshwater Fish Habitat — Aquatic Resources

Periphyton

Baseline data on periphyton — an important base to the food chains upon which many stream fish rely — are available for 18 stream sites and were collected during 1997, 2011, 2012, and 2013 (Rescan 2012c, 2012e; 2013a; Figure 6.1-5; Table 6.1-5). Samples were also collected in 2015 (Rescan 2015b). Periphyton communities consist of algae that grow on the surfaces of rocks or larger plants, and are an important source of food and nutrients for many benthic invertebrates, which are, in turn, prey for fish.

Table 6.1-5. Summary of Baseline Stream Periphyton Sampling Conducted for the Back River Project

Year	1997	2011	2012	2013	2015
Sampling Month(s)	August	August	August	July	August
Sampling Agency	Norecol Dames and Moore	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.
Data Collected	Chl *a*, periphyton taxonomy (data currently unavailable)	Chl *a*, periphyton taxonomy and density	Chl *a*, periphyton taxonomy and density	Chl *a*, periphyton taxonomy and density	Chl *a*, periphyton taxonomy and density
Sampling Method	Instantaneous – rock scrapping	Instantaneous – rock scrapping	Instantaneous – rock scrapping	Instantaneous – rock scrapping	Instantaneous – rock scrapping
Taxonomists	Unknown	Bio-limno Research and Consulting Inc, Halifax, NS	EcoAnalysts, Moscow, ID, USA	EcoAnalysts, Moscow, ID, USA	Biologica Environmental Services Victoria, BC

(continued)

Table 6.1-5. Summary of Baseline Stream Periphyton Sampling Conducted for the Back River Project (completed)

Analytical Lab (for chl *a*)	Unknown	ALS Environmental, Burnaby, BC	ALS Environmental, Burnaby, BC	ALS Environmental, Burnaby, BC	ALS Environmental Burnaby, BC
Stream(s) Sampled	Goose Property	Goose Property	Goose Property	Goose Property	Goose Property
	Goose OF	Goose OF	Goose OF	Goose OF	Stony Pond
	Goose IF (SE)	Giraffe OF	Giraffe OF	Giraffe OF	
	Wolf OF	Propeller D/S	Propeller OF	Propeller OF	
		Reference B OF	Reference B OF	Reference B OF	
		Chair OF	Chair OF	Former TIA OF	
		Llama OF	Llama OF	Wasp OF	
		Wolf OF	Wolf OF	Umwelt OF	
			Del IF		
			Del US		
			Moby OF		
			Pond 19 OF		
Number of Replicates per Site	n = 1	n = 3	n = 3	n = 3	n = 3
Composition of a Single Replicate	Each replicate is a composite of 5 scrapped areas	Each replicate is a composite of 6 scrapped areas (collected from two rocks)	Each replicate is a composite of 6 scrapped areas (collected from two rocks)	Each replicate is a composite of 6 scrapped areas (collected from two rocks)	Each replicate is a composite of 6 scrapped areas (collected from two rocks)
Area Sampled per Replicate (m^2)	0.0125	0.0095	0.0095	0.0095	0.0095

** Komatic Inflow had no rocks so periphyton were collected from sediment surface using modified methods.*

Available data from 1997 is limited to chlorophyll *a* concentrations and a list of species found at the three sites sampled. For the 2011, 2012, and 2013 samples, a circular template with a foam base was used to seal a known area of rock from the rest of that rock (see Table 6.1-5). Periphyton attached to the rock inside this circular area was collected using tweezers, a modified toothbrush, a syringe, and distilled water. For each replicate, two rocks were selected with flat upper surfaces suitable for periphyton sampling. All constituents of the attached periphyton community were sampled from three circular areas on each of the two rocks for each replicate (i.e., a total of six circular areas per replicate).

Benthic Invertebrates

Baseline data on benthic invertebrates (benthos) — organisms that live on or in the stream sediments and serve as food for many fish inhabiting running water — were collected from 19 stream sites during the summer of 1997 (Norecol Dames & Moore 1997), 2011, 2012, and 2013 (Rescan 2012c, 2012e; 2013a; Figure 6.1-5; Table 6.1-6). Samples were also collected in 2015 (Rescan 2015b). Benthic invertebrates inhabiting streams feed on algae, bacteria, and detritus and are an important pathway for energy and nutrients to move into higher trophic levels, particularly fish.

Table 6.1-6. Summary of Baseline and Historical Stream Benthos Sampling Conducted for the Back River Project, 1997 to 2013

Year	1997	2011	2012	2013	2015
Sampling Month(s)	August	August	August	July	August
Sampling Agency	Norecol Dames and Moore	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	ERM
Data Collected	Benthos taxonomy and density*	Benthos taxonomy and density	Benthos taxonomy and density	Benthos taxonomy and density	Benthos taxonomy and density
Sampling Method	Waters and Knapp sampler (30 cm diameter, 30 cm height); sieve mesh size unknown	Hess Sampler (0.096 m^2); 500 µm mesh size	Hess Sampler (0.096 m^2); 500 µm mesh size	Hess Sampler (0.096 m^2); 500 µm mesh size	Hess Sampler (0.096 m^2); 500 µm mesh size
Analytical Lab	ECCON Environmental, unknown location	Dr. Jack Zloty, Summerland, BC	EcoAnalysts, Moscow, ID, USA	EcoAnalysts, Moscow, ID, USA	Biologica Environmental Services Victoria, BC
Stream(s) Sampled	Goose Property	Goose Property	Goose Property	Goose Property	Goose Property
	Wolf Outflow	Chair Outflow	Moby Outflow	WASP OF	Stony Pond
	Goose SE IF	Llama Outflow	Del Inflow	Former TIA OF	
	Goose Outflow	Giraffe Outflow	Del US	Giraffe OF	
		Wolf Outflow	Pond 19 Outflow	Umwelt OF	
		Goose Outflow	Chair Outflow	Goose OF	
		Propeller Outflow	Giraffe Outflow	Propeller OF	
		Propeller D/S	Wolf Outflow	Reference B OF	
		Reference B Outflow	Goose Outflow		
			Propeller Outflow		
			Reference B Outflow		
Number of Replicates per Site	n = 5	n = 5	n = 5	n = 5	n = 3
Composition of a Single Replicate	Assume each replicate is from a single sample although this is not stated in methods	Each replicate a composite of 3 pooled samples	Each replicate a composite of 3 pooled samples	Each replicate a composite of 3 pooled samples	Each replicate a composite of 3 pooled samples
Area Sampled per Replicate (m^2)	0.0701 (based on above assumption)	0.288	0.288	0.288	0.288

** Note: raw densities are unavailable, only summed densities/sample with no clarity on what organisms were included or excluded.*

Data collection methods in 1997 differed from those in 2011, 2012, and 2013, which prevented comparisons between these time periods, with the exception of species presence and absence (see Table 6.1-6). The slow flow velocities and low water levels that occur in streams in late summer created some challenges for sampling stream benthos; however, these dry conditions were generally consistent between streams and years. Sampling methodologies are presented in Table 6.1-5, and sampling locations are shown in Figure 6.1-5.

6.1.5.4 Fish/Aquatic Habitat QA/QC

Quality assurance and quality control was implemented at several stages of the fish habitat field programs in order to ensure accurate data collection and analysis. In the field, practice sessions were held with crew leaders at the beginning of each sampling trip to ensure that sampling and data collection was being conducted in a standard manner. Scales and electronic measuring devices (conductivity and pH meters) were calibrated prior to the beginning of the field trip. Upon entry of the data into databases, data was checked against field cards to verify the accuracy of data entry and to check for transcription errors.

Chain of custody forms were used for all aquatic resource samples. All sampling involved replication; triplicate samples were taken for chlorophyll *a* (phytoplankton biomass), phytoplankton taxonomy, periphyton taxonomy, and zooplankton taxonomy. A higher degree of replication was employed for benthos samples (i.e., n = 5). Additional QA/QC measures were used by the benthic invertebrate taxonomist to ensure consistent and accurate sorting of benthos samples.

As part of the QA/QC program, the re-sorting of benthic sample residues was conducted on a randomly selected subsample (10%) of the benthos samples to determine the level of sorting efficiency. The criterion for acceptable sorting was that more than 90% of the total number of organisms found in both the initial and QA/QC sort were recovered during the initial sort, as required by Environment Canada for invertebrate community surveys (Environment Canada 2002). Any sample not meeting this 90% removal criterion was re-sorted a third time. During this step of the QA/QC program, 90% minimum efficiency was attained for all benthos samples.

6.1.6 Setting — Lake Habitat

6.1.6.1 Fish Habitat — Physical Characteristics

Goose Property Area

The Goose Property contains many lentic waterbodies that range in size from large lakes to small ponds and wetlands. Most lakes in the region feature littoral habitat well suited for northern fish species, i.e., shorelines dominated by mixed rock, with occasional outcrops of bedrock (Rescan 2010); Figure 6.1-2; Plate 6.1-1). However, deeper lake areas (> 2.5 m depth), which serve as fish overwintering habitat, are uncommon in the Goose Property and may limit fish population sizes in many lakes and ponds (Rescan 2012d). The maximum depth of most lakes averages between 4 and 6 m. Most of the lakes surveyed support fish spawning, rearing, and feeding, with fewer supporting overwintering (Table 6.1-7).

Umwelt Lake is in the Llama watershed, upstream of Goose Lake and downstream of Llama Lake. The lake is relatively shallow, with a maximum depth of 3.0 m that limits the potential area for fish overwintering as much of the lake freezes to the bottom during winter. Mixed rock shorelines may provide spawning and rearing habitat for Arctic Grayling, and fish may use the lake for summer spawning, rearing and feeding. The limited connection and low flow between Umwelt Lake to Llama and Goose lakes late in summer indicates that Arctic Grayling do use Umwelt to overwinter. The deeper areas of the lake are dominated by sandy substrate. In many places, the transition between rocky shoreline substrate and sandy lake bottom is abrupt (Plate 6.1-2).

Plate 6.1-1. Boulder-dominated shoreline typical of lakes in the Goose Property. Big Lake, August 2012.

Plate 6.1-2. Abrupt transition between rocky shoreline substrate and muddy benthic substrate at Umwelt Lake, Goose Property. August 2012.

Table 6.1-7. Summary of Fish Habitat Quality in Goose Property Area Lakes and Ponds Surveyed between 2010 and 2015

Waterbody	Data Source	Surface Area (ha)	Maximum Depth (m)	Overall Fish Habitat	Spawning Habitat		Summer Rearing and Feeding Habitat	Overwintering Habitat
					Lake-spawning Salmonids	Forage Fish **		
Goose Property								
Goose Lake	2,3	320.2	16.5	Medium	Good	Poor	Good	Good
Llama Lake***	1,2,3	36.7	13.6	Important	Good	Fair	Good	Good
Umwelt Lake****	1,2,3,4	20.2	3	Medium	Poor	Fair	Good	Poor
Big	3	403.8	5.6	Medium	Good	Poor	Good	Fair
Fox	3	72	6.9	Medium	Fair	Fair	Fair	Fair
Rabbit	3	59.6	4	Medium	Fair	Poor	Fair	Fair
Moby	3	59.4	12.5*	Medium	Good	Poor	Good	Good
Rascal	3	28.2	4*	Medium	Fair	Fair	Fair	Fair
Swan	3	408.3	6*	Medium	Good	Poor	Good	Fair
Pond 1	2	6.3	3*	Low	Poor	Fair	Poor	Poor
Pond 2	2	4.1	< 2*	Low	Poor	Fair	Poor	None
Pond 3	2	2.6	< 2*	Low	Poor	Poor	Poor	None
Pond 4	2	9.8	4*	Low	Poor	Fair	Poor	Fair
Pond 5	2	3.5	1.5*	Low	Poor	Fair	Poor	None
Pond 6	5,6	0.5	1*	Low	Poor	Fair	Fair	None
Pond 7	5,6	1.66	< 1*	Poor	Poor	Fair	Fair	None
Pond 8	5,6	2.7	2*	Important	Good	Good	Good	Fair
Pond 9	5,6	0.22	0.4*	Low	Poor	Poor	Poor	None
Pond 10	5,6	0.56	>3*	Important	Poor	Good	Good	Good
Pond 11	5,6	0.86	< 1*	Low	Poor	Fair	Fair	None
Pond 12	5,6	0.24	< 1*	Low	Poor	Fair	Fair	None
Pond 13		No data	>3*	Important	Poor	Fair	Good	Good
Pond 19	3	1.8	< 1*	Low	Poor	Fair	Poor	None
Pond 20	6	0.19	< 2*	Low	Poor	Fair	Poor	None
Pond 21	6	0.73	0.68	Medium	Low	Fair	Fair	None
Pond 22	6	1.18	1.03	Low	Poor	Fair	Fair	None
Pond 23	6	0.07	0.35	Low	Poor	Fair	Poor	None
Pond 24	6	0.22	0.69	Low	Poor	Fair	Fair	None

(continued)

Table 6.1-7. Summary of Fish Habitat Quality in Goose Property Area Lakes and Ponds Surveyed between 2010 and 2015 (completed)

Waterbody	Data Source	Surface Area (ha)	Maximum Depth (m)	Overall Fish Habitat	Spawning Habitat		Summer Rearing and Feeding Habitat	Overwintering Habitat
					Lake-spawning Salmonids	Forage Fish **		
Pond 25	6	4.2	0.4	Medium	Poor	Fair	Fair	None
Pond 26	6	0.19	0.87	Low	Poor	Fair	Fair	None
Pond 27	6	1.56	Too deep	Medium	Poor	Fair	Fair	Fair
Echo Pond 1	6	No data	No data	Low	Poor	Poor	Poor	None
Echo Pond 2	6	No data	0.41	Low	Poor	Poor	Poor	None
Pond A	2	4.8	3*	Low	Poor	Poor	Poor	Poor
Pond B	2	5.8	1.5*	Low	Fair	Fair	Fair	None
Pond C	2	3.6	4*	Low	Poor	Fair	Fair	Fair
Pond D	2	6.8	4*	Low	Poor	Fair	Fair	Fair
Pond E	2	9.3	< 2*	Low	Fair	Fair	Fair	None
Pond F	2	5.4	< 2*	Low	Poor	Fair	Poor	None
Pond G	2	4.2	< 2*	Low	Poor	Fair	Poor	None
Pond H	2	2.8	< 2*	Low	Poor	Fair	Poor	None
Pond I	2	4.7	< 2*	Low	Poor	Poor	Fair	None
Pond J	2	2.7	< 2*	Low	Poor	Poor	Poor	None
Pond K	2	4.4	< 2*	Low	Poor	Fair	Fair	None
Pond L	2	15.2	2.5*	Medium	Fair	Poor	Good	Poor
Llama Pond 1	6	0.71	> 3	Medium	Fair	Fair	Fair	Fair
Llama Pond 2	6	No data	< 2	Medium	Fair	Fair	Fair	None
Llama Pond 3	6	0.57	< 1*	Low	Poor	Fair	Fair	None
Stony Pond	6	No data	2.5*	Good	Fair	Fair	Good	Good
Unwelt Pond 3	6	0.2	0.75*	Low	Poor	Fair	Fair	None
Unwelt Pond 4	6	No data	1*	Low	Poor	Fair	Fair	None
Reference Sites								
Reference B Lake	1,2,3	36	5.1	Medium	Good	Fair	Good	Fair

** Maximum depth was estimated; ** Forage fish include species such as Ninespine Stickleback and Slimy Sculpin.*** Llama Lake overall score was medium in baseline report, upgraded to important as it bears the majority of overwintering habitat in the norther arm of the Llama watershed; **** Umwelt Lake overall score was low in baseline report, upgraded to medium as it bears some overwintering habitat in the norther arm of the Llama watershed;*
[1] Rescan (2010); [2] Rescan (2012a); [3] Rescan (2012d); [4] Rescan (2013a); [5] Rescan (2014); [6] Rescan (2015c).

Llama Lake is upstream of Umwelt Lake and is connected in the summer months to Umwelt Lake by a short stream. The substrate of Llama Lake is dominated by mixed rock, particularly around the shorelines and in shallow areas. Deeper water areas are dominated by silt. The maximum depth of Llama Lake is 13.6 m, which allows sufficient depth and oxygen levels for fish overwintering. The deeper sections of Umwelt and Llama Lake provide overwintering habitat to Lake Trout and Round Whitefish (*Prosopium cylindraceum*) in the sub-watershed.

Pond habitat in the Goose Property is generally shallow and many of the ponds featured ephemeral inflows or outflow that would limit fish migration into and out of these waterbodies (Rescan 2012a). Owing to their shallow depths, these ponds freeze all the way to the bottom in winter, making them unsuitable for overwintering habitat. However, ponds 8 and 10, lying south of Goose Lake, have sufficient depth and likely harbour Ninespine Stickleback (*Pungitius pungitius*) in over winter.

Of the ponds surveyed, most did not provide year-round fish habitat due to their shallow depth and poorly defined inflows and outflows (Plate 6.1-3). The surface area of the ponds surveyed ranged from 2.6 to 15.2 ha, and the maximum depth ranged, on average, from 1.5 to 4.5 m. Ponds are dominated by fine sediments (e.g., Pond A, Pond H) and some provide seasonal habitat for forage species such as Ninespine Stickleback and Slimy Sculpin (*Cottus cognatus*). However, the depth of most ponds precludes fish overwintering and, when coupled with ephemeral flows provides marginal to poor fish habitat. Ponds dominated by rocky substrates (e.g., Pond L, Pond E) may be suitable for Arctic Grayling spawning and rearing. But again, use of these ponds is likely limited by access to suitable overwintering habitat and ephemeral connections to deeper lakes (Table 6.1-7).

Plate 6.1-3. Typical shoreline of small ponds in the Goose Property, featuring organic substrate and aquatic vegetation. Pond A, July 2011.

6.1.6.2 Fish Habitat — Biological Resources

Phytoplankton

Goose Property Area

In general, phytoplankton biomass was low, lakes were ultra-oligotrophic and taxonomic richness and diversity was variable among lakes, but moderate to high in value.

Goose Property lake communities had low phytoplankton biomass and densities. All lakes surveyed had mean chl *a* concentrations (and total phosphorous, TP, concentrations, see Volume 6, Chapter 4) that would class them as ultra-oligotrophic (< 2 µg/L; (Vollenweider and Kerekes 1982), with an overall mean biomass of 0.34 µg chl *a*/L. Lakes had mean phytoplankton densities ranging from 243,000 cells/L (Big Lake Central, under ice) to 1,900,000 cells/L (Big Lake West, open water), with an overall mean of 880,000 cells/L. Lakes had lower phytoplankton densities in under-ice than in open-water conditions.

Lake phytoplankton communities were mainly composed of cyanobacteria (Myxophyceae), flagellated algae (Cryptophyceae), green algae (Chlorophyceae), golden algae (Chrysophyceae) and diatoms (Bacillariophyceae). Abundant phytoplankton genera in the Goose Property Area samples included the cyanobacteria *Leptolyngbya*, *Merismopedia*, *Aphanocapsa*, and *Limnothrix*, and the cryptophytes *Komma* and *Cryptomonas*, and the green algae *Elakatothrix* and *Monoraphidium*.

Lake phytoplankton communities were moderately diverse and had variable genus richness. Genera diversity levels ranged from a mean of 0.40 (Simpson's index) at Rascal Lake (2012 under ice) to a mean of 0.92 at Goose Lake Central and Neck (2011 open water). The number of genera present per sample ranged from a mean of 8 (Rascal Lake 2012, under ice) to 28 (Goose Lake Central 2012, open water).

Zooplankton

Goose Property Area

In general, zooplankton density was low, but variable among years and lakes in the Goose Property. Taxonomic richness and diversity of zooplankters was variable among lakes.

Zooplankton densities in the Goose Property lakes ranged from a mean of 6,360 adults/m^3 (Reference B) to 83,000 adults/m^3 (Del Lake). Inter-annual variability in zooplankton density can be high, for example densities were approximately three times higher in 2012 than in 2011 in the two lakes sampled in both 2011 and 2012 (Goose and Giraffe lakes).

Adult zooplankton communities tended to be composed of rotifers and crustaceans, with common taxa including the rotifers *Conochilus* and *Kellicottia*, the copepods *Leptodiaptomus* and *Cyclops*, and the Daphniidae ("water flea") genera *Holopedium*. Zooplankton densities in Del Lake were considerably higher in 2012 than in other lakes (mean: 83,000 individuals/m^3) and over 95% were the rotifer species *Conochilus unicornis* and *Kellicottia longispina*. The zooplankton genera found in the Goose Property lakes appear to be typical of small Arctic to sub-arctic lakes (O'Brien, Buchanan, and Haney 1979; O'Brien et al. 2004; Rautio and Vincent 2006; Symons, Arnott, and Sweetman 2012).

Adult zooplankton richness and diversity varied among lakes. Overall, lakes ranged from a mean genus richness of 3.0 genera/sample to 10.7 genera/sample and from a mean genus diversity of 0.24 at Reference B Lake to 0.67 (Simpson's index) at Big Lake. Note that sample volume was variable between lakes and years depending on site depth and random sampling effects (ranging from 0.22 to 0.69 m^3).

Benthic Invertebrates

Goose Property Area

At the Goose Property, benthos density was low, but variable among years and lakes. Taxonomic richness and was low and variable among lakes. Benthos diversity was moderate, but also varied among lakes.

Average benthos densities measured in the Goose Property lakes ranged from 1,140 individuals/m^2 at the Llama Lake in 2011, to a mean of 10,540 individuals/m^2 in Goose Lake 2012. For the sites sampled in both (Table 6.1-3), densities varied considerably with no consistent trend spatially or temporally. Benthos densities at these sites were higher in one year than the other year by a factor of 1.8 to 3.3.

Benthic communities were largely composed of true flies (dipterans) and bivalves, with ringed worms (annelids) and crustaceans (mainly ostracods) also prevalent. Common and abundant taxa observed include the small "pea" clam (genus *Psidium*), and the dipterans from the genera *Zalutschia*, *Tanytarsus,* and *Pagastiella*.

Lakes at the Goose Property had low to moderately diverse benthic invertebrate communities. Baseline benthos richness and diversity varied between the Goose Property lakes. Taxonomic richness ranged from a mean of 4.4 families/sample at Giraffe Lake in 2011 to a mean of 7.2 families/sample at Goose Lake in 2011. Diversity at the family level ranged from a mean of 0.17 at Pond 19 in August 2012 to 0.60 at Giraffe Lake in August 2012. At the lake sites sampled in both 2011 and 2012 (Table 6.1-3), there was no obvious pattern between diversity and richness between the years.

6.1.7 Setting — Stream Habitat

6.1.7.1 Fish Habitat — Physical Characteristics

Goose Property Area

Stream sites were surveyed in the Goose Property Area in 2011, 2012, 2014 and 2015. Most of the surveyed sites were at potential mine site road crossings and under TSF infrastructure, but lake inflows and outflows were also surveyed. Of these, nine sites were determined to be non-classified drainages with no defined channel, overland or sub-surface flow, and little to no fish habitat potential.

Most of the streams surveyed featured poorly defined channels with multiple flow paths and shallow depths (Plate 6.1-4). Substrates were dominated by boulders and fines and little to no in-stream vegetation was present. There were frequent patches of overland flow and boulder fields which are likely barriers to fish migration during low flow periods. Permanent barriers to fish migration were observed: a 4 m cascade on the stream connecting Umwelt Lake to Goose Lake (Plate 6.1-5), and several cascades and boulder fields along the stream connecting Pond A to Giraffe Lake (Plate 6.1-6; Figure 6.1-2).

Habitat quality for rearing and spawning Arctic Grayling was generally best in the reaches immediately upstream and downstream of lakes, and poor in reaches further from deep waterbodies. For example, in the Goose Inflow South (GIS) and East (GIE) streams, Artic Grayling were only captured or observed in the lower reaches downstream of ponds 21 (in GIS) and 24 (in GIE). The remainder of the channels upstream of these ponds were ephemerally connected and only Ninespine Stickleback was present. Table 6.1-9 summarizes the habitat quality at each stream site surveyed in 2011 and 2012, as well as streams surveyed historically.

Plate 6.1-4. Typical stream in the Goose Property, with multiple, poorly defined channels and shallow flow. Wasp Inflow, June 2013.

Plate 6.1-5. Rock cascade feature on Umwelt Outflow, Goose Property, looking upstream. June 2012.

Plate 6.1-6. Boulder field feature on Giraffe inflow, Goose Property, looking upstream. June 2013.

Rascal Stream East (RSE) flows from Rascal to Goose lakes and connects with GIS prior to entering Goose Lake. RSE and the lower reaches of GIS and GIE were all categorized as high quality habitat. These sections of stream contain small cobble and gravel that supports Arctic Grayling spawning and rearing, as well as providing a migratory corridor between lakes with overwintering habitat (Table 6.1-8).

6.1.7.2 Fish Habitat — Biological Resources

Periphyton

Goose Property Area

Baseline periphyton biomass and taxonomy samples were collected from thirteen stream sites in the Goose Property Area during August 2011 and 2012. Periphyton samples were also collected from Goose South East Inflow and from Wolf Outflow in 1997.

In general, stream periphyton biomass was low to moderate, streams were oligotrophic and taxonomic richness and diversity was moderate to high.

Mean periphyton biomass levels, as chl *a*, were lower than 2.5 µg/cm^2 at all sites during all years. Most streams would be classified as oligotrophic during their sampling, based on the scheme by Dodds, Jones, and Welch (1998) i.e., TP < 2.0 µg/cm^2). Mean periphyton densities varied considerably between stream sites and years, ranging from 180,000 cells/cm^2 at the Reference B Outflow sampling site in 2012 to 7,060,000 cells/cm^2 at Giraffe Outflow in 2011. In both 2011 and 2012, Giraffe Outflow had the highest periphyton densities. For the stream sites sampled in both years (Table 6.1-5), all had mean densities at least two times greater in 2011 than in 2012 suggesting large natural variability can exist between years.

Table 6.1-8. Summary of Habitat Quality in Goose Property Area Streams, 1996 to 2015

Stream Name	Source	Site	Habitat Type	Overwintering Habitat	Spawning Habitat Quality		Rearing Habitat Quality	Overall Habitat Quality
					Arctic Grayling	Forage Fish		
Creek 1	1	N/A	Stream	None	None	Poor	Poor	Low
Creek 3	1	N/A	Stream	None	None	Poor	Poor	Low
Creek 5	1	N/A	Stream	None	None	Poor	Poor	Low
Unnamed	2	AS-1	NCD	None	None	None	None	None
Airstrip Stream (Creek 4)	1,2	AS-2	Stream	None	Poor	Poor	Fair	Low
Airstrip Stream (Creek 4)	1,2	AS-3	Stream	None	Poor	Poor	Fair	Low
Unnamed	2	AS-4	Stream	None	Poor	Poor	Poor	Low
Unnamed	3	100	NCD	None	None	None	None	None
Umwelt Outflow	3	101	Stream	None	Poor	None	Fair	Low
Fox Outflow	3	102	Stream	None	Fair	Fair	Fair	Low
Llama Outflow	3	103	Stream	None	Fair	Good	Good	Medium
Fox Outflow	3	104	Stream	None	Poor	Poor	Fair	Low
Unnamed	3	105	NCD	None	None	None	None	None
Unnamed	3	106	NCD	None	None	None	None	None
Unnamed	3	107	NCD	None	None	None	None	None
Unnamed	3	108	Stream	None	Fair	Good	Fair	Low
Unnamed	3	109	NCD	None	None	None	None	None
Unnamed	3	110	NCD	None	None	None	None	None
Unnamed	3	111	NCD	None	None	None	None	None
Unnamed	3	112	NCD	None	None	None	None	None
Goose Inflow (Creek 2)	1, 3	113	Stream	None	Good	Fair	Good	High
Reference B Outflow	3	125	Stream	None	Fair	Good	Fair	Medium
Rascal Outflow/Rascal Stream East	3	126	Stream	None	Good	Poor	Good	High
Rabbit Outflow/Rascal Stream East	3	127	Stream	None	Fair	Good	Fair	Medium

(continued)

Table 6.1-8. Summary of Habitat Quality in Goose Property Area Streams, 1996 to 2015 (continued)

Stream Name	Source	Site	Habitat Type	Overwintering Habitat	Spawning Habitat Quality		Rearing Habitat Quality	Overall Habitat Quality
					Arctic Grayling	Forage Fish		
Data from 2013								
Unnamed	4	100-2013	NCD	None	None	None	None	None
Gander Outflow/Rascal Stream West	4	101-2013	Stream	None	Fair	Fair	Good	Medium
Unnamed	4	102-2013	Stream	None	None	None	Fair	Low
Unnamed	4	103-2013	Stream	None	Fair	Fair	Good	Medium
Unnamed	4	105-2013	NCD	None	None	None	None	None
Giraffe Inflow	4	200-2013	Stream	None	None	None	None	None
Wasp Inflow	4	215-2013	Stream	None	Fair	Good	Good	Medium
Unnamed	4	500-2013	Stream	None	Fair	Good	Good	Medium
Unnamed	4	303-2013	Stream	None	Good	Good	Good	High
Gander Inflow/Rascal Stream West	4	804-2013	Stream	None	Fair	Fair	Good	Medium
Propeller Inflow	4	814-2013	Stream	None	Good	Fair	Good	High
Umwelt Outflow	4	Reach 6, 7	Stream	None	Fair	Good	Good	High
Llama Outflow	4	Reach 1, 2	Stream		Fair-Good	Good	Good	High
Goose Inflow East (Lower Watershed)	4	Main Goose Pit Stream Reach 4, 5, 6	Stream	None	None - Good	Good	Poor - Good	Marginal - High
Goose Inflow South (Lower Watershed)	4	Rascal - Goose Reaches 1 and 2; Main Goose Pit Stream Reach 7	Stream	None	Good	Good	Good	High
Rascal Stream East	4	Rascal – Goose Reaches 3 through 7, Main Goose Pit Reaches 2 and 3	Stream	None	Good	Good	Good	High

(continued)

Table 6.1-8. Summary of Habitat Quality in Goose Property Area Streams, 1996 to 2015 (completed)

Stream Name	Source	Site	Habitat Type	Overwintering Habitat	Spawning Habitat Quality		Rearing Habitat Quality	Overall Habitat Quality
					Arctic Grayling	Forage Fish		
Data from 2014								
Goose Inflow East (Upper Watershed)	5	Main Goose Pit Stream Reaches 13, 14, 15	Stream and NCD	None	None - Fair	None - Fair	Poor - Good	Low - High
Goose Inflow South (Upper Watershed)	5	Main Goose Pit Stream Reaches 8, 9, 19, 11, and 12	Stream	None	Poor	Fair	Poor to Fair	Low
Data from 2015								
Big Lake Outlet	6		Stream	Good	Good	Good	Good	High
Llama Pond 1 Outlet	6		Stream	None	None	Poor	Poor	Low
Umwelt inflow from Pond 1	6		Stream	None	None	Good	Fair	Medium

Notes: N/A = not applicable; NCD = non-classified drainage
[1] Norecol Dames & Moore (1997); [2] Rescan (2012a); [3] Rescan (2012c), [4] Rescan (2013a), [5] Rescan (2014), [6] Rescan (2015),

Stream periphyton communities tended to be dominated by cyanobacteria (Myxophyceae) and diatoms (Bacillariophyceae), with green algae (Chlorophyceae) also present. Common genera observed in 2011 and 2012 were the pennate diatoms *Achnanthidium* and *Tabellaria* (also noted as dominant in all 1997 sites), and the cyanobacteria *Aphanocapsa*.

Periphyton genera richness and diversity varied by year and by stream. Overall, a mean of 21 genera/sample was observed for all samples from all streams in all years. Periphyton diversity at the genus level was moderate to high, with mean diversity of 0.8 on the Simpson's index. The boulder field at Llama Outflow had the lowest periphyton diversity and richness at 0.61 (Simpsons Index) and 18 genera/sample, respectively.

Benthic Macroinvertebrates

Goose Property Area

Baseline benthic taxonomy samples were collected from thirteen stream sites in the Goose Property Area during August 2011 and 2012. In general, stream benthos density was variable among years and locations, and taxonomic richness and diversity was low to moderate.

Benthos densities varied within and between stream sites, with the lowest densities at the shallow cobble Giraffe Outflow in 2012 (mean: 570 individuals/m^2) and the greatest densities at the boulder field Llama Outflow in 2011 (mean: 4,370 individuals/m^2). For streams sampled in both years, there was no clear trend in densities between 2011 and 2012 benthic samples.

Stream benthic communities were largely composed of dipterans (true flies), with other taxa present including oligochaete/annelid worms, ostracods (seed shrimp) and acari (water mites). Hydra, bivalves, gastropods (snails) and coleopterans (beetles) made up a small proportion of communities at some stream sites. Additionally, the pollution sensitive taxa Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), known collectively as EPT, were found at all streams. EPT made up between 0.4% and 13% of the mean benthic community at Goose Property streams, with the lowest proportions being at Reference B Outflow (< 0.5 %; 2011) and the greatest proportions being at Goose Outflow (13%; 2012).

Often a few genera were particularly abundant, suggesting benthos communities were dominated by a few groups and diversity was low. At most streams, the most abundant genus made up over 15% of the total benthic community, and the three most abundant genera made up over 20% of the total benthic community. These dominant genera varied between streams, although the dipterans *Paratanytarsus, Thienemannimyia, Polypedilum* and *Psectrocladius* were among the three most abundant genera at more than five stream sampling sites during each of the 2011 or 2012 sampling events.

Richness and diversity in Goose Property stream benthic communities tended to be low to moderate. Stream samples ranging from a mean of 6.4 families/sample at Wolf Outflow to 14.6 families/sample at Propeller Downstream, while diversity ranged from 0.20 at the small Pond 19 Outflow to 0.70 at Goose Outflow (Simpson's index).

6.1.8 Synthesis of Existing Environment and Baseline Information

In general, the streams, ponds, and lakes in the Project area exhibited physical and ecological characteristics that are typical of many freshwater aquatic ecosystems in the Arctic, though some of the measured characteristics proved variable, as noted above. For instance, ice is a physical habitat characteristic that has a strong influence on all Arctic freshwater communities. The ice scour that occurs as a result of the yearly freeze-melt cycle prevents the build-up of periphyton-derived biomass

in streams, and of vegetated areas in the littoral zones of ponds and lakes (Vincent and Hobbie 2000). This key climatological limitation on freshwater fish habitat structure and aquatic food web inputs was reflected in the low periphyton abundance and the absence of inshore aquatic vegetation in Project area waterbodies. In addition, common aquatic resource characteristics that were observed across the Project area included low autochthonous (i.e., within-system) primary productivity, arising from periphyton in streams or phytoplankton and periphyton in ponds and lakes. Waterbodies in the Project area were often classified as oligotrophic or ultra-oligotrophic, which are common attributes of many freshwater systems in the Arctic (Hobson and Welch 1995; Prowse et al. 2006; Vincent, Hobbie, and Laybourn-Parry 2008). In addition, freshwater Arctic ecosystems generally contain simplified communities of animals, plants, and microbes (Vincent and Hobbie 2000; Power, Reist, and Dempson 2008). This was particularly true for freshwater fish in the Project area, which were invariably characterized by low diversity and abundance. However, the fish species that were sampled in the LSA are widely distributed in many waterbodies throughout the RSA, and they are also known to inhabit large geographic ranges outside the RSA (Walters 1955; Ellis 1962; Scott and Crossman 1973).

6.2 INCORPORATION OF TRADITIONAL KNOWLEDGE (TK)

The effects assessment relies on the information collected from Inuit-led TK information, public scoping, focus group meetings, government engagement, and scientific knowledge. To the extent possible, available TK is incorporated into the evaluation of the potential effects of the Project on the environment. The following reports were reviewed for TK specific information related to Valued Ecosystem Component (VEC) features:

- *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* (KIA 2012) (Appendix V3-3A of FEIS);
- *Naonaiyaotit Traditional Knowledge Project - Hannigayok (Sabina Gold & Silver Corp. Proposed Back River Project). Results from Data Gaps Workshops, Final Report (June 2014)* (KIA 2014) (Appendix V3-3B of FEIS); and
- *Back River Project: Existing and Publically Available Traditional Knowledge from Selected Aboriginal Groups in the Northwest Territories* (Appendix V3-3C of FEIS).

6.2.1 Incorporation of TK for Existing Environment and Baseline Information

Available TK on important fish species and Aboriginal fishery locations was obtained through the Kitikmeot Inuit Association's (KIA's) Naonaiyaotit Traditional Knowledge Project (NTKP) database. This is summarized in the report entitled *Inuit Traditional Knowledge of Sabina Gold & Silver Corp. Back River (Hannigoyok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* report (KIA 2012).

Maps presented in Figures 30–32 in Chapter 7 of the 2012 *NTKP* report (hereafter, 2012 TK report) specifically indicate the presence of important freshwater fishing locations for Arctic Char (*Salvelinus alpinus)* and Arctic Grayling (*Thymallus arcticus*) in the Western River (*Kilokgiktok*). In addition, the maps in the 2012 TK report indicate that, outside the Goose Property RSA, other freshwater fishing sites of value to the Inuit occur in and around Beechey Lake, just south of the Goose Property RSA.

Pertinent information on Aboriginal fisheries resources was also obtained from Land Use Focus Group Sessions, which were held in November of 2012; these sessions included Inuit hunters and trappers from Kugluktuk, Cambridge Bay, Omingmaktok, and Bathurst Inlet (see Chapter 4, Land Use, in Volume 8: Human Environment). The Focus Group participants from Bathurst Inlet and Omingmaktok described and mapped a contemporary travel route that leads from Bathurst Inlet (community) south past Bathurst Lake and George Lake, down to the Beechey Lake and Goose Lake areas (Figure 4.1-2 in Chapter 4, Volume 8). These participants also indicated that Bathurst Lake is fished, specifically for Lake Trout (*Salvelinus namaycush*). The participants also indicated that hunting and fishing take place along the length of this

route. Focus group participants reported that they stay near Beechey Lake while hunting, trapping, and fishing in the area. Goose Lake, located in the LSA, was also identified as an area where fishing may occur while staying near Beechey Lake. While Goose Lake may be fished by traditional land users, it is not known to be a destination or key location for fishing (Volume 8, Chapter 4).

In the 2012 TK report (KIA 2012), the Inuit note that fish are present throughout the landscape surrounding and including the Project Area. They further note that freshwater fishing primarily takes place in the Back River Watershed, along the Western River, and nearby Bathurst Inlet. Lake Trout are found in lakes throughout the region; however, they are also found in rivers where large, deep pools do not freeze in winter. Whitefish and Lake Cisco are also found in such lakes. Arctic Grayling are fished in several lakes, rivers, and streams in the Back River Watershed and along the Western River. The Inuit observe that Arctic Grayling spawn over shallow boulder fields, and that the juvenile fish are commonly found in shallow, sandy streams (KIA 2012). The following information is included in the TK report:

> *... This river (Hiukkittak) has a really strong current and they used to have a weir back then on it right by this bend (near the mouth). There is also another weir around here. I remember we restored the stones and used that ancient weir for spearing fish...*
>
> *... The fish go further up into the lakes using the rivers. All kinds of fish do this. They also use the same river to go down to the ocean.*
>
> *Sometimes the fish will winter in the lakes because the rivers get too shallow for the fish to go down river. In the spring they start to migrate down river...*
>
> *When the fish went up the river (Arctic Charr fall migration) at Hiukkittak... Inuit speared them or used baskets to scoop them up.*
>
> *... There would be lots of fish at Hiukkittak, Kugyoak and around Kangihoakyok (waters feeding into Kangihoakyok) during the spring. Even in the summer when the fish were ready to go up river, there was lots of fish...*
>
> *Inuit jigged for fish where the fishing was good. They fished in the lakes.... They fished these places using hooks during the spring or winter and sometimes they used nets.*
>
> *... The people from Kingaok and Omingmaktok must know about that river (Hiukkittak). It is really sandy from all the way up here (at the mouth) downstream... People fish the ocean at the mouth of the river. I have nets at Ehokhikhiovik (initial river section of Hiukkittak)... I usually have nets at this place...*
>
> *Inuit fished anywhere in the rivers. They fished the river when the fish were going downriver and upriver, when they needed food. (We fished at Hakvaktok (south coast of Melville Sound), Naoyak and Etibliakyok, Kolgayok (Tingmeak River), Kunayok (Ellice River). Hiukkittak, Aniakhiokvik (Fishing Creek), Kingaok, Daniel Moore Bay (Kangihoakyok) and all along the coast of Victoria Island up to Wellington Bay (including Paatlik or Byron Bay)...*
>
> *These areas (coastal Parry Bay, Etibliakyok (Kent Peninsula isthmus), Kolgayok (Tingmeak River, and an area east of Fishing Creek) are fishing places. They have charr and trout... and cisco whitefish...*
>
> *Lake trout, charr, whitefish and grayling are found in lakes.*

When we were young, the fishing areas were identified by our parents. You should mark that place (mouth of Burnside River (Ayapakpaktokvik)) because people still go there to fish. Our parents taught us these things, even about tomcod fishing.

The lake is where we would have nets in the winter. Inukholik (near Hiukkittak) is where they would set nets in the winter...

... At the rivers (mouth of Hannigayok (Back River) at Beechey Lake and stream on north-central shore of Beechey Lake) they liked to net for fish, for... lake trout and whitefish.

They net fish near Kingaok every fall Ayapakpaktokvik (Burnside River). This lake (Ekalokhiokvik (Tahikafalok Lake)) has a small river to the ocean (Aniakhiokvik (Fishing Creek)). That is another area that they mainly fish, I know this because my grandfather liked fishing there...

... Inuit fished along the shore... at Kingaok (northwest of Fishing Creek). Over here at Kingaok (stream leading into and south of Ayapakpaktokvik (Burnside River) near its mouth) Inuit have fished for a long time. That river has charr and whitefish...

... They would jig for fish in the lakes around here (north of Beechey Lake) when they were traveling to see the white people (to the trading post at Kingaok). They jigged for fish in the lakes as they were traveling, when they camped... They fished when they stopped so they could have fresh food, I remember. I was following them that time.

... These parts of the Jakes (narrows)... are called 'kongunik' (pl.) and that is why this is called 'konngok' (sf.). This narrow spot (at the narrows of Hanningayuk (Beechey Lake)) never freezes all winter. That is why they tell Inuit who are traveling to be careful because this narrow spot doesn't freeze. We call those narrow parts of the Jakes 'kongunik'. We know about that konngok where Inuit set fish nets because it doesn't freeze all winter. You have to be careful when you travel through there...

Those rivers where Inuit mostly fish (Ayapakpaktokvik and Hivogahik) and where they hunted the caribou near the mouth of the lakes are important. Some of these areas where they mostly fished during the winter don't freeze that well. These areas sometimes are scary (dangerous places for traveling).

In the fall we used gill nets to catch a lot of fish for the dogs, and for dry fish too. All these places where we had our nets have inokhok or rock pile markers. On our trap Jines too we fished. We did a lot of fishing especially on the days that were stormy. We did a lot of fishing to pass the time...

In the Bathurst Inlet area C51 mapped Tagionoak (Goulburn Lake), Swan Lake (Tagionuak), and a lake west of Amagok as good for fishing.

This is a good spot for fishing too (at the mouth of Ayappappaktokvik). This long arm in here, it's a good spot for fishing. When I was there in February, it was good, a good fishing spot there...

There is a river there as well Kokiviayok. It's small but there are a lot of fish.

Additional TK on the locations of camps used for fishing, on fish species occurrence and habitat use as well as on the types of fish preferred as food sources by Inuit was obtained through information summarized in the report entitled *Naonaiyaotit Traditional Knowledge Project - Hannigayok (Sabina*

Gold & Silver Corp. Proposed Back River Project). Results from Data Gaps Workshops, Final Report (June 2014) (KIA 2014).

Maps presented in Figure 3 in Chapter 4 and Figure 12 in Chapter 11 of the 2014 *NTKP* report (hereafter, 2014 TK report) specifically indicate the presence of Inuit fishing places and important areas for freshwater fish including Arctic Char, Lake Trout, Broad Whitefish (*Coregonus nasus*), Arctic Cisco (*Coregonus autumnalis*) and Arctic Grayling. The maps in the 2014 TK report indicate freshwater fishing sites of value to the Inuit occur outside of the Freshwater RSA. Bathurst Lake, which is located approximately 40 km southeast of the MLA, was identified as a winter gathering place with edible fish.

The 2014 TK report (KIA 2014), mapped major fishing areas but indicated that fishing occurred everywhere and that the Inuit fished whenever they were on the land. All the lakes and rivers that flow into Bathurst Inlet were described as important for fishing and many of the rivers had ancient stone weirs at locations that were also important fish camps. In particular, the mouth of Hiukkittak (river) was used extensively for fishing. Near Bathurst Inlet, Goulburn Lake was a major fishing area while Fishing Lake was the local fishing spot. Lakes further south including Bathurst Lake, Kenyon Lake and Beechey Lake were also identified as important fishing locations.

The 2014 TK report described TK related to the occurrence and habitat of freshwater fish. Lake Trout habitat is described as any lake and many small ponds, depending on their depth. Lake Trout also occur in large rivers and though they are known to go to the ocean, when they do they remain near river mouths and streams. Broad Whitefish occur in lakes as well as in streams and rivers that drain into lakes. Broad Whitefish and Arctic Cisco are abundant at river mouths and sections of rivers that contain rapids. Streams are considered Arctic Grayling areas. Burbot are considered a good food fish that occur in freshwater systems anywhere on the land. The following information is included in the 2014 TK report (KIA 2014):

<u>Traditional Camps and Fish Camps</u>

> *Bathurst Lake, it's one of the places that our elders talk about lots. Lakes like this tend to be used mainly for freshwater lakes, where they can winter, where they can gather for the winter, being closer to the ocean. They can go down there for a day or so and come back at the end of the day. It's because there was freshwater there. It's a bigger lake with fish edible fish for the winter.*
>
> *When we were little, we used to stay there and my dad used to have his nets (Kangilialok on Banks Peninsula). There is really big trout in there…*
>
> *This is also a lake with small trout. There are lots of small trout in there, there are millions of them. Charr too. Even this one here, these kind of narrows, there's charr in there and trout. (Tagionoak (Goulburn Lake on Banks Peninsula); narrows to Bathurst Inlet)*
>
> *(There are) charr and whitefish*
>
> *Kukiviakyok... is an old fishing camp. There used to be a great big fish weir in there but it's all gone now, from dis-use. It's not being used, or kept up anymore… It's a fishing area. There used to be tons of families in there, fishing.*
>
> *Summer camps (on a travel route going to Bathurst). All these places are summer camping areas. The whole area is a summer camping area. Each side of the inlet (Bathurst), all the way to the bottom.*

Somewhere in here there is a weir (between Charr Lake and Bathurst Inlet). They used to be winter camps in here as well in this area… That's only one of the areas where they had winter camps. There were quite a few of them; I can't recall where they all are.

Lakes and Rivers

Nunamiut fished for over-wintering and land-locked charr, but the main lake and river fish were ehok (lake trout, anakheek (broad whitefish), kapihillik (arctic cisco) and hulukpaugan (grayling).

Some of these big lakes you could go charr fishing by jigging

You could wait around for lake trout. Anywhere there is an outlet on the lake, where the ice is thin… That's where people go to fish. These areas you don't have to chop through two or three feet of ice. Most year-round these rivers, any outlet on the lake, or inlet, you find fish, charr, year-round.

Some parts are really narrow, in the creeks, but there is fish there. Some parts can be really skinny narrow little creeks, when the charr, the big charr are going up, and you can just grab them. (About a fishing place, a small stream between the large Goulburn Lake and a tiny lake to the north)

Interviewer: *Are there any areas that were more preferred for fishing by Inuit?*

Hanningayuk area (was preferred for fishing).

I'm not exactly sure where, but our elders, they talk about Hanningayuk (Beechey Lake) area too. Long ago before fishing nets ever came out, there used to be stone weirs there, along these rivers too…

When you start to think about the fishing season, when it's time to make dry meat or whatever in the fall time, they start to be more in the rivers, in the rapids. Not in the middle of the lake, when it starts to get cooler, in the springtime too, they stay near the rapids.

Right around Bathurst Lake

(There are) stories about Bathurst Lake and surrounding areas. It's not a great big humongous lake by any means, but still it's a large lake. Because it's very deep our elders have said there are fish there that could actually eat caribou.

They talk about ekalakpauk, very large fish. Ekalakpauk are giant fish. They are (not trout), they are something else. I always think about, what always comes to mind is a freshwater shark or something like that.

What I've heard is when they saw a wave coming; these lakes don't have very big waves all the time, but when they saw a huge wave coming they would run inland because they knew there was a big fish that was making that make wave. So they would go inland.

It's the same way those killer whales go after the seals, they come right up on the shore.

Ehok (Lake Trout) and Ekalok (Charr)

Ehok (lake trout), they go to the ocean but mostly they stay by the river mouth or stream. In the ocean they mostly stick around the river mouth. In the study area there will be lots of charr.

(There are lots of charr) in the main part of the river systems. In Hannigayok (Back River) it will be all lake trout. Any lake, any little pond there too, you wouldn't think that there would be ehok (lake trout) there too, but depending on how deep they are, there's always ehok in there. It could be a small little lake. You'd never think there would be fish in there but ehok are common in those areas too.

Those are big rivers. You will have lots there.

Lots and lots of lake trout.

In that area (Banks Peninsula), when the charr start going up in fall time, there will be lots of charr there too.

Kapihillik (Arctic Cisco), Anakheek (Broad Whitefish) and Hulukpaugan (Grayling)

Anywhere. There are lots and lots (of arctic cisco).

There will be whitefish there. In summertime they will be at the coast. Then they will go back to the lakes and the river systems… (In the ocean) they mostly will stick around the coasts.

Little streams too.

All these little streams and rivers that drain into the lakes. There is more concentration in some parts of the lakes.

The large lake whitefish, you can find them just about anywhere you find lake trout, in rivers, where there are fresh water rivers. Kogluk (meaning fast rapids) has lots and lots of anakheek (broad whitefish), especially at the mouth of the rivers. Every river has kogluks. So if you fish any river with rapids, you will likely catch anakheek and kapihillik (arctic cisco).

They are just about anywhere you find lake trout, ehok, or anakheek, anywhere you find those, you also find lots and lots of whitefish in the lakes. In areas, these fish, for some reason, I don't know why that is, they stick to areas where there is less copper in the lakes.

For some reason, even though there's lots of copper around that area, there are lots and lots of whitefish for some reason. But once you get further up on the mainland, like around High Lake area, where there is lots of copper content in the lakes… You find some lakes on the sides of the hills, on the shoreline with steep cliffs, you can see this copper coming down into those lakes.

People don't find those whitefish around there. And for some reason over here there are a lot less whitefish on the west side because of the copper content. That's what I've noticed where I go fishing. For some reason, always fish that are not predatory fish, they don't breed in those copper areas.

And grayling, yes. If there is copper content in those lakes, there will be no lake whitefish or grayling. There are none of those where there is lots of copper content in the water.

All these streams here are considered grayling areas. Where it's further west you go you won't find whitefish or grayling. Closer to the ocean more, but further inland you go, you start to get more and more copper fields.

Tiktalik (Burbot)

They (burbot) stay in freshwater systems.

First time I caught it, a really big one, I was really young. I told my dad I caught a really, really ugly fish.

Anywhere on the land of I've caught them. We have caught many of them in Contwoyto, Pellatt Lake… People do eat them but I consider them looking more like cod to me so I don't eat them. I'm allergic to cod. I can eat just about everything else alright but for some reason, cod, and everything that eats cod, I have an allergic reaction to, such as seals or polar bears.

First time my wife see tiktalik (burbot), she asked 'what kind of fish is this?' It's a really good fish but it looks funny. They're good, they're really good, that tiktalik.

They are something like barracuda but they're small. They are silver.

The Back River Project: Existing and Publically Available Traditional Knowledge from Selected Aboriginal Groups in the Northwest Territories (Appendix V3-3C of DEIS/FEIS) report identifies the traditional, asserted, and settled land claim territories of NWT Aboriginal groups and describes traditional land use and harvesting activities. In this report, the fishing activities of the Akaitcho Dene, Tłı̨chǫ Dene and North Salve Metis are described. Freshwater fish harvest was identified by most groups in multiple seasons with Trout, Whitefish, Burbot, Inconnu, Arctic Grayling, Lake Herring, and Northern Pike identified as freshwater species specifically targeted by Akaitcho Dene. Traditional land use (including fishing activities) of the selected groups was identified in the Yellowknife River area, in Great Slave Lake and Great Bear Lake and throughout the barrenlands extending as far Contwoyto Lake. All fishing areas and activities referenced in this report are located far south of the Freshwater RSA.

6.2.2 Incorporation of TK for VEC and VSEC Selection

The results of the TK Report (KIA 2012) were reviewed for refining the potential VEC/VSEC list (see Volume 9, Chapter 1). Clear maps of valued fisheries species are presented in Chapter 7 of the 2012 TK report (Figures 31 and 32)(KIA 2012), consequently, fish habitat was assigned as a VEC. In addition, valued, freshwater fish species, Lake Trout and Arctic Grayling, were assigned as VECs and are treated individually within the Freshwater Fish Community Chapter (Volume 6, Chapter 7).

6.2.3 Incorporation of TK for Spatial and Temporal Boundaries

The results of the TK Reports were reviewed for spatial and temporal boundaries (KIA 2012, 2014). According to Figures 31 and 32 within Chapter 7 of the 2012 TK report (KIA 2012) and Figure 12 of the 2014 TK report (KIA 2014), the PDA, LSA, or freshwater RSA do not overlap with Inuit fishing locations.

6.2.4 Incorporation of TK for Mitigation and Adaptive Management

As a result of information obtained from the *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* report (KIA 2012) and *Naonaiyaotit Traditional Knowledge Project - Hannigayok (Sabina Gold & Silver Corp. Proposed Back River Project). Results from Data Gaps Workshops, Final Report (June 2014)* (KIA 2014), the mitigation and management of fish habitat focuses on habitat for three freshwater fish species: Arctic Grayling, Lake Trout, and Arctic Char. The TK reports included the mapped distribution of each of these species, as well as areas important for fishing. The Project has been designed such that infrastructure will not be located on important freshwater fishing habitat. Additional mitigation of Project-related effects may be achieved by a Conceptual Fish Offsetting Plan, which also considers TK.

6.3 VALUED COMPONENTS

6.3.1 Potential Valued Components and Scoping

Valued Ecosystem Components (VECs) are specific attributes of the biophysical environment that are regarded as crucial to the scientific, economic, or cultural heritage of a location. The determination of freshwater VECs and potential effects for inclusion in this effects assessment considered and was informed by:

- the EIS Guidelines (NIRB 2013);
- the public, during public consultation and open house meetings held in the Kitikmeot communities;
- local land users, during focus group and mapping sessions with residents of Kugluktuk, Cambridge Bay, Omingmaktok, and Bathurst Inlet;
- meetings with regional Inuit groups (for example, the KIA);
- Kitikmeot Community Advisory Group (CAG) meetings comprised of local stakeholders (e.g., Hunters and Trappers Organization [HTO] representatives).

The freshwater aquatic environment was identified as a potential VEC that encompassed the habitat, aquatic ecology and aquatic biota supporting CRA fisheries (NIRB 2013). Each of these selections was recognized as belonging to one of two broader categories of VECs: 1) fish/aquatic habitat; and 2) fish community, each of which encapsulates the moderate to significant concerns identified in the TK report and through community consultation (Volume 9, Chapter 1).

6.3.2 Valued Components included in Assessment

The VECs selected to assess the potential effects of the Project on freshwater fisheries species in the LSA and RSA include:

- Fish/aquatic habitat; and
- Fish community (Lake Trout and Arctic Grayling).

This chapter assesses Project effects on the VEC of fish/aquatic habitat. These include only the *direct* effects of Project infrastructure and activity on the physical aspects of the aquatic environment that provide distinct habitat for fisheries species. Chapter 7 of this volume (Volume 6) assesses Project effects on the fish community VECs, Lake Trout and Arctic Grayling.

The fish/aquatic habitat VEC comprises both the physical habitat and the biological resources that are essential to the productivity of fish species. This chapter evaluates the *direct* effects of Project

activities the physical habitat of fish, but excludes the assessment of *indirect* effects of Project activities on biological resources. Biological resources, as defined here and informed by the EIS Guidelines (NIRB 2013), includes the primary producers (phytoplankton, diatoms, and periphyton) and the secondary producers (benthic invertebrates and zooplankton) that make up the lower trophic levels which form the base of fish dietary resources. The exclusion, from this chapter, of Project-related *indirect* effects on biological resources is rationalized through the following logic:

1. Potential Project-related effects on fish habitat are mediated *indirectly* through trophic interactions between fish and their biological/dietary resources (primary and secondary producers).
2. Potential Project-related effects on primary and secondary producers arise *indirectly* from changes to water and sediment quality.
3. Potential Project-related effects on water and sediment quality arise *directly* from Project activities and are assessed individually, as the VECs Water Quality (Volume 6, Chapter 4) and Sediment Quality (Volume 6, Chapter 5).
4. No significant residual effects are predicted for Water and Sediment Quality after mitigation, management and monitoring measures are considered (Volume 6, Chapters 4 and 5 respectively).

Water and sediment quality also form part of the aquatic ecology of fish and may, therefore, be considered under the fish/aquatic habitat VEC. However, as stated above for biological resources, water and sediment quality are treated independently in separate chapters and no significant residual effects are predicted (Volume 6, Chapters 4 and 5).

6.4 SPATIAL AND TEMPORAL BOUNDARIES

The freshwater fish/aquatic habitat VEC spatial and temporal boundaries were defined as the maximum limits within which the assessment was conducted. The boundaries were determined by the criteria specified in the EIS guidelines (NIRB 2013), and outlined in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1).

6.4.1 Spatial Boundaries

The spatial boundary used for the assessment of the VEC freshwater fish/aquatic habitat included the Goose Property Potential Development Area (PDA), the Goose Property Local Study Area (LSA), and an overall Freshwater Regional Study Area (RSA). The Marine Laydown area (MLA) is a narrow strip of land on the west side of southern Bathurst Inlet. Most streams in this area flow directly to Bathurst Inlet on the west side. At the MLA, Project infrastructure does not interact with any streams or freshwater within its associated LSA or PDA.

6.4.1.1 Local Study Area

The LSA includes areas where there exists the reasonable potential for immediate effects due to Project activities, ongoing normal activities, or to possible abnormal operating conditions (NIRB 2013). The LSA used for the assessment of effects on the VEC freshwater fish/aquatic habitat for the Goose Property is 365 km^2 and includes the PDA and the boundaries of the Propeller and Big watersheds (Figure 6.4-1). The PDA includes an area that encompasses planned infrastructure.

6.4.1.2 Regional Study Area

The freshwater RSA includes the PDA, the LSA, and additional areas within which there is the potential for indirect or cumulative effects. The freshwater RSA used for the assessment of effects on the VEC freshwater fish/aquatic habitat assessment is 6,815 km^2 and encompasses the PDA and LSA. The RSA

includes small sections of the Ellice and Back River Watersheds, and includes the upper ~80 km of the Ellice Watershed.

6.4.2 Temporal Boundaries

The temporal boundaries used for the assessment of effects on the VEC freshwater fish/aquatic habitat align with the duration of Project phases as described in Volume 9, Chapter 1, as follows:

The temporal boundaries for the Project phases were defined as follows:

- Mobilization and Construction phase – 4 years;
- Operation phase – 10 years;
- Reclamation and Closure phase – 8 years;
- Post-closure Monitoring phase - 5 years;
- other potential phases:
  - Temporary Closure – less than 2 years;
  - Care and Maintenance Phase – 2 to 10 years; and
  - Exploration: included in Construction and Operations phases.

6.5 POTENTIAL PROJECT-RELATED EFFECTS ASSESSMENT

6.5.1 Methodology Overview

The Project-related effects assessment for the VEC freshwater fish/aquatic habitat followed the process detailed in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1):

1. Project activities were grouped on the basis of shared interaction pathways and by the timing and magnitude of the interactions with the freshwater environment.
2. The potential effects were then evaluated on the nature of the interaction, the magnitude and frequency of the Project activities, and the biophysical characteristics of the receiving freshwater environment; site-specific data from the Existing Environment and Baseline was synthesized and applied to understand the natural variation within, and resiliency of the environment.
3. The effects of mitigation and management measures to eliminate or reduce the potential effects were considered.
4. Residual effects were determined as the potential effects that would remain after the application of mitigation and management measures.
5. The significance of the residual effects was determined by the direction (i.e., positive, neutral, or negative), magnitude, confidence, and probability.

6.5.1.1 Determining the Magnitude and Significance of Residual Effects

The significance of residual effects on the VEC freshwater fish/aquatic habitat was determined using the ratings and classifications described in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1, Table 2.4-3). First, the direction of a residual effect was determined to be positive, neutral, or negative. Negative effects were then assessed according to several criteria. The magnitude of the effect (Table 6.5-1) and reversibility were used as the primary criteria; the extent, duration, and frequency of the effect as secondary criteria; and the certainty and probability of an event used as qualifying criteria.

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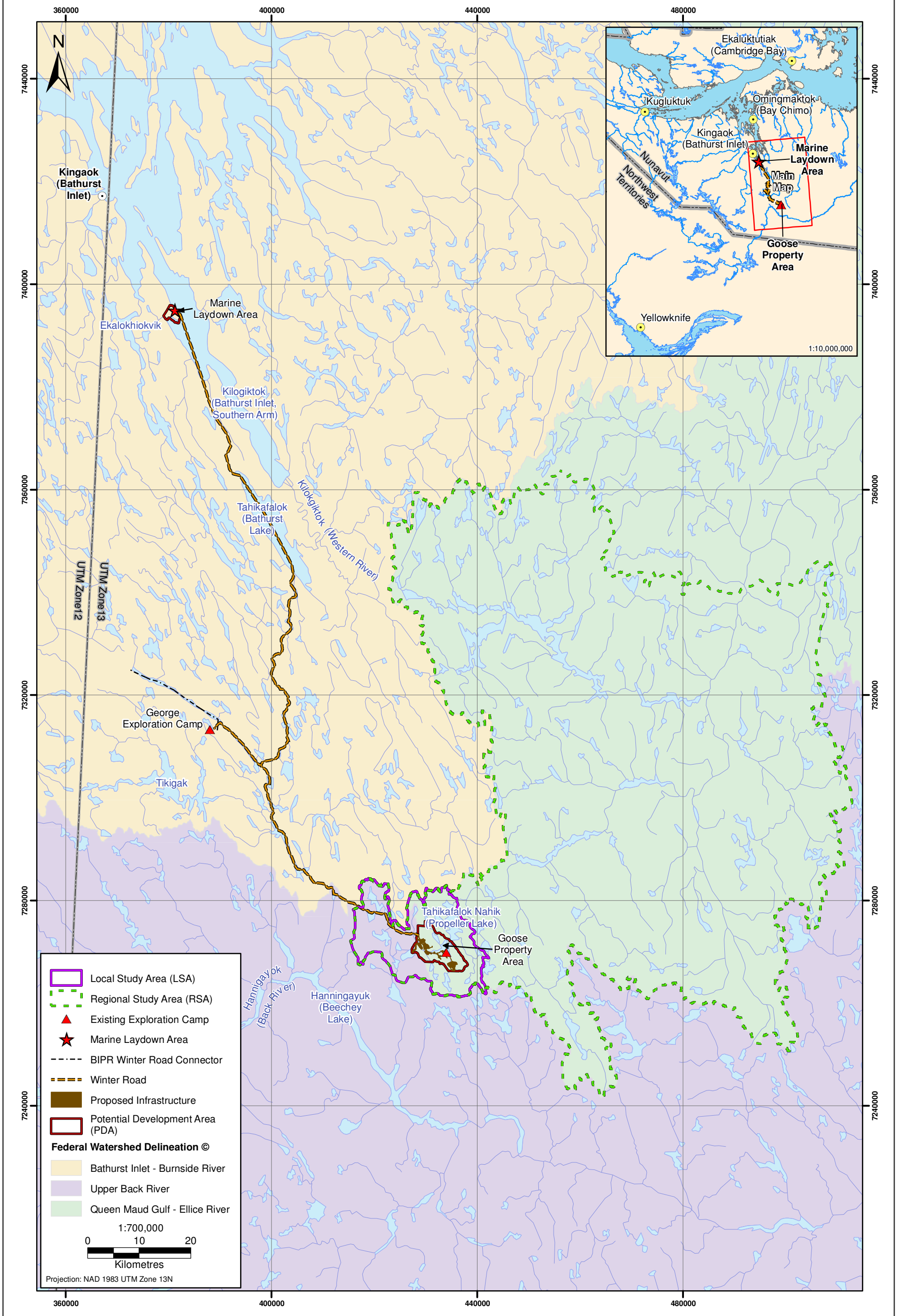

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Figure 6.4-1

Local Study Area and Regional Study Area for Freshwater Fish/Aquatic Habitat

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Table 6.5-1. Magnitude Rating for Evaluating Residual Effects on the VEC Freshwater Fish/Aquatic Habitat

Criteria	Classification	
Magnitude	Negligible	Habitat changes are unlikely to have an effect on productive capacity that is distinguishable from natural variation.
	Low	Habitat changes affect less than 10% of the waterbody area, and resulting reductions in productive capacity are unlikely to affect the entire fish population of a waterbody.
	Moderate	Habitat changes affect up to 20% of the available habitat area in a waterbody, such that resulting reductions in productive capacity may affect fish populations in the entire waterbody.
	High	Habitat changes are expected to affect more than 20% of the waterbody area and may result in changes to the productive capacity of habitat within and beyond the waterbody, affecting an entire fish population or more than one fish population.

If the magnitude of a residual effect was determined to be greater than *Low* in magnitude after mitigation and management (i.e., distinguishable from natural variation and potentially greater than regulated or threshold values), then the conservative assumption of at least *Moderate* magnitude was applied for the remainder of the effects assessment process. Furthermore, only residual effects with a high degree of confidence in mitigation and management would be given a *Low* or *Negligible* in magnitude.

Determining Significance of Residual Effects

The significance of a residual effect was rated as Positive, Not Significant, or Significant (Table 6.5-2). For example, residual effects receive a rating of 'Not Significant' if typically they are expected to be one of the following: negligible or low magnitude, confined to LSA, moderate to high reversibility, or short duration (Volume 9). However, given the qualitative nature of the assessment, these ratings are evaluated for biophysical VECs on a case by case basis.

Table 6.5-2. Definitions of Significance Ratings for the VEC Freshwater Fish/Aquatic Habitat

Significance	Descriptor of Significance
Positive	Effect could result in an increase in fish/aquatic habitat, relative to the baseline within the RSA into the foreseeable future.
Significant	Effect is expected to result in a decrease in fish/aquatic habitat that is not mitigated through Project design and management, and is long-lasting or permanent within the Project zone of influence relative to reference condition.
Not Significant	Effect may result in a decrease in fish/aquatic habitat, but one that is fully mitigated through Project design and management, or fully reversible to baseline conditions in the shorter-term after Project closure.

6.5.2 Potential Interactions with Project and Characterization

The potential interactions of Project activity with the VEC freshwater fish/aquatic habitat were determined using the initial matrix provided in the Project Description, and further refined using the EIS guidelines, professional judgement, and experience at other projects in Nunavut and the Northwest Territories.

Freshwater fish/aquatic habitat may interact and be affected by Project activities in two ways: serious harm occurring through a loss or reduction of fish habitat by permanent alteration or destruction

(PAD), or through changes to water and sediment quality arising from the deposition of deleterious substances (Table 6.5-3).

Table 6.5-3. Potential Interactions with the VEC Freshwater Fish/Aquatic Habitat

Potential Interaction/Effect	Cause	Description	General Project Activity	Regulation
Loss of fish/aquatic habitat*	Permanent alteration or destruction (PAD) of habitat	Loss or damage of fish habitat through encroachment of infrastructure or water withdrawal	1. Project Infrastructure Footprint 2. Water Use	*Fisheries Act* (1985) Section 35(2)
Changes in water and sediment quality resulting in: 1. Direct fish mortality or reduction in fish health** 2. Indirect reduction in biological resources of fish through trophic interactions***	Deposition of deleterious substances	Mine effluent, hydrocarbon contaminants, increased nutrient loading, introduced sediment (increased TSS or deposition in spawning areas)	1. Management of Contact Water, Effluent, and Dust	Metal Mining Effluent Regulations (SOR/2002-222)

** this chapter: Vol. 6, Chapter 6.*
*** see Vol. 6, Chapter 7.*
**** see Vol. 6, Chapters 4 and 5.*

A PAD is a *direct* loss or reduction of fish habitat area potentially incurred through planned construction (e.g., encroachment of infrastructure on existing fish habitat), or accidents and malfunctions (e.g., slope failures, spills). Accidents and malfunctions are addressed in Volume 9, Chapter 3.

The introduction of deleterious substances could alter fish habitat *directly* by reducing water and sediment quality to the extent that fish health decreases and mortality occurs, or *indirectly*, through trophic interactions with biological resources used by fish. The direct effect on fish health and mortality potentially caused by the introduction of deleterious substances in water is assessed in in Volume 6, Chapter 7. The *indirect* effect on fish/aquatic habitat potentially resulting from the introduction of deleterious substances into water and sediment is assessed in two chapters: Volume 6, Chapters 4 and 5 for water and sediment quality respectively. Table 6.5-4 describes the specific Project activities that link to potential interactions with the VEC freshwater fish/aquatic habitat identified in Table 6.5-3.

6.5.2.1 Loss of Fish Habitat: Project Infrastructure Footprint

Project infrastructure has the potential to interact with the VEC freshwater fish/aquatic habitat wherever the locations overlap with freshwater (Figures 6.5-1 and 6.5-2). Potential effects on the VEC freshwater fish/aquatic habitat are anticipated during all phases of the Project, beginning in Construction when the building of most infrastructure will take place and occurring through Post Closure.

Lakes

In fish bearing lakes, a direct loss of habitat will occur in Llama Lake as the result of construction of the Llama Pit and at Umwelt Lake as a result of Saline Water Pond construction (Figures 6.5-1 and 6.5-2). These habitat losses will result from draining each of the lakes during the Construction Phase and will persist in perpetuity.

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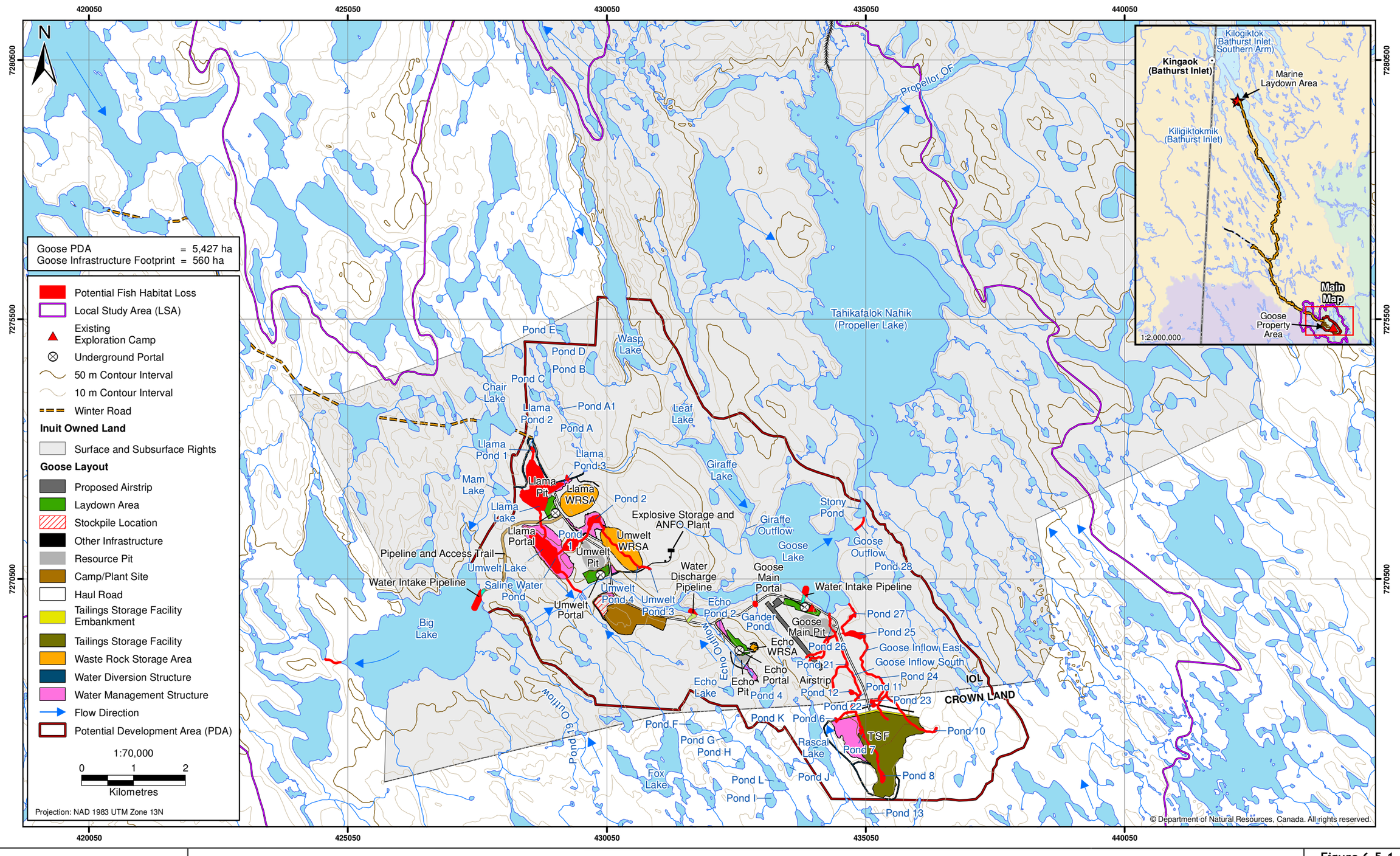

Figure 6.5-1

Infrastructure Layout and Locations of Potential Fish Bearing Habitat Loss, Goose Property Area

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Goose PDA = 5,427 ha
Goose Infrastructure Footprint = 560 ha

- Fish Presence Assumed
- Fish Presence Confirmed
- Fish Absence Confirmed
- Local Study Area (LSA)
- Existing Exploration Camp
- Underground Portal
- 50 m Contour Interval
- 10 m Contour Interval
- Winter Road

Inuit Owned Land

- Surface and Subsurface Rights

Goose Layout

- Proposed Airstrip
- Laydown Area
- Stockpile Location
- Other Infrastructure
- Resource Pit
- Camp/Plant Site
- Haul Road
- Tailings Storage Facility Embankment
- Tailings Storage Facility
- Waste Rock Storage Area
- Water Diversion Structure
- Water Management Structure
- Flow Direction
- Potential Development Area (PDA)

1:70,000

0 1 2

Kilometres

Projection: NAD 1983 UTM Zone 13N

420050 425050 430050 435050 440050

7275500 7270500 7265500

Tahikafalok Nahik (Propeller Lake)
Wasp Lake
Pond E
Pond D
Pond C
Pond B
Chair Lake
Llama Pond 2
Pond A1
Pond A
Leaf Lake
Llama Pond 1
Llama Pond 3
Giraffe Lake
Mam Lake
Llama Pit
Llama WRSA
Pond 2
Llama Lake
Explosive Storage and ANFO Plant
Stony Pond
Giraffe Outflow
Llama Portal
Pond 1
Umwelt WRSA
Goose Lake
Goose Outflow
Pond 28
Pipeline and Access Trail
Umwelt Pit
Umwelt Lake
Umwelt Pond 3
Water Discharge Pipeline
Goose Main Portal
Water Intake Pipeline
Water Intake Pipeline
Saline Water Pond
Umwelt Pond 4
Echo Pond 2
Pond 27
Umwelt Portal
Big Lake
Gander Pond
Goose Main Pit
Pond 26
Pond 25
Echo Outflow
Echo WRSA
Pond 21
Goose Inflow South
Goose Inflow East
Echo Portal
Pond 12
Airstrip
Pond 24
IOL
Echo Pit
Pond 4
Echo Lake
Pond 22
Pond 11
CROWN LAND
Pond 10
Pond K
Pond 6
Pond 23
Pond F
TSF
Pond G
Pond H
Rascal Lake
Pond 7
Pond 9
Pond 8
Fox Lake
Pond L
Pond J
Pond I
Pond 13
Pond 19
Rabbit Lake
Wolf Lake
Del River

Kingaok (Bathurst Inlet)
Kilogiktok (Bathurst Inlet, Southern Arm)
Marine Laydown Area
Kiligiktokmik (Bathurst Inlet)
Main Map
Goose Property Area
1:2,000,000

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Fish Bearing Status within the LSA, Goose Property Area

Figure 6.5-2

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Table 6.5-4. Project activities and Phases interacting with the VEC Freshwater Fish/Aquatic Habitat

General Project Activity	Specific Project Activity	Project Phase
Project Infrastructure Footprint	1. Locations of TSF, WRSAs, open pits, mill, camp, quarries and borrow pits, road and airstrip water crossings 2. Lake dewatering	1. All phases 2. Mobilization and Construction
Water Use	1. Water withdrawal (camp, mill and winter ice roads)	1. Mobilization and Construction, Operation, Reclamation and Closure
Water, Effluent, and Dust Management	1. Contact water 2. Treated water and sewage discharge 3. Road and airstrip use and maintenance 4. Explosives storage and use 5. Dust deposition 6. Camps, waste management, fuel	1. All phases 2. Mobilization and Construction, Operation 3. All phases 4. Mobilization and Construction, Operation 5. All phases 6. Mobilization and Construction, Operation.

At Llama Lake, the entire basin will be drained in preparation for the construction of the Llama Pit, which represents a complete loss of 36.59 ha of habitat used by Lake Trout, Arctic Grayling, Round Whitefish, and Slimy Sculpin (Figure 6.5-1; Table 6.5-5). The majority of the area of the lake is composed of shallow water (less than 4 m), with large, boulder-cobble substrate, followed by deep water areas (greater than 4 m) with fine substrates, and nearshore areas (less than 2.5 m deep) with fine substrates. Llama Lake was categorized as high quality habitat overall as it provides the majority of deepwater overwintering habitat in the northern section of the Llama Watershed and spawning habitat for Lake Trout and Round Whitefish. Llama Pit will be decommissioned during Operations, when it will be used as a contact water storage facility (Llama Reservoir). From this point onwards, all saline groundwater from the Saline Water Pond will be pumped to the bottom of the partially flooded Llama Reservoir to create a meromictic lake. Llama Reservoir is predicted to overtop during the Reclamation and Closure phase, with water from the reservoir discharging towards the south and into the reclaimed Saline Water Pond catchment (formerly Umwelt Lake).

Umwelt Lake will be drained to construct a Saline Water Storage Pond, which represents a complete loss of 19.4 ha of habitat used by Lake Trout, Arctic Grayling, and Round Whitefish and likely Slimy Sculpin (Figure 6.5-1; Table 6.5-5). The majority of the area of the lake is composed of shallow water (less than 2 m) with mixed cobble and boulder and fine substrates, followed by a small area of slightly deeper water habitat (maximum depth 3 m). Umwelt Lake was categorized as medium quality habitat overall as it provides mainly summer rearing habitat with limited deep water areas for overwintering Arctic Grayling. The Saline Water Pond will begin to be drained into Llama Reservoir during Operations. After draining is complete, the berms of the Saline Water Pond will be breached during the Reclamation and Closure Phase. After the Saline Water Pond closure and reclamation is complete, the diversion berms around the Llama Reservoir will be breached, and the reservoir will be allowed to fill with non-contact water. Details regarding the closure and reclamation of the area around the Saline Water Pond are presented in the Mine Closure and Reclamation Plan (Volume 10, Chapter 29).

The installation of water intake and discharge pipes during the Construction Phase in Goose Lake will result in a total loss of 5,065 m^2 of fish bearing habitat (Figure 6.5-1; Table 6.5-5). In southeast Goose Lake, the dimensions of the in-water construction zone for the intake pipe are anticipated to be a maximum of 15 m wide by 129 m long for an approximate footprint of 3,563 m^2. In western Goose Lake, the dimensions of the in-water construction zone for the discharge pipe are anticipated to be a maximum of 15 m wide by 64 m long for an approximate footprint of 1,502 m^2. The natural substrate types found

under both construction zones are common within Goose Lake and consist of predominantly cobble and boulder at the intake pipe location and predominantly boulder and bedrock at the discharge location. Construction of the intake and discharge pipelines will consist of placing the 4 inch pipe on the substrate surface, covering the pipe and construction zone with clean non-acid generating boulder/cobble rip rap, and daylighting the end of pipe at approximately 5 m water depth. The pipes will be decommissioned by cutting to the substrate level and capping; rip rap will be permanently left in place.

The installation of a water intake pipe at the eastern shore of Big Lake during the Construction Phase will result in a loss of approximately 5,227 m^2 of fish bearing habitat (Figure 6.5-1; Table 6.5-5). The dimensions of the in-water construction zone are anticipated to be a maximum of 20 m wide by 304 m long. The natural substrate type found under the intake pipe construction zone is common within Big Lake and consists of predominantly cobble and boulder. To construct the intake pipeline, a 4 inch pipe will be placed on the substrate surface then the pipe will be covered to the extent of the construction zone with clean non-acid generating boulder/cobble rip rap. The end of the pipe will be daylighted at approximately 5 m water depth. The pipes will be decommissioned by cutting at the substrate level and capping; rip rap will be permanently left in place.

Ponds

Several small, fish bearing ponds located in the Llama Watershed (associated with the Llama and Umwelt Pits) and the Goose and Wolf watersheds (both associated with the TSF) will be lost to infrastructure (Figure 6.5-1), representing a total wetted area loss of 22.6 ha (Figure 6.5-1; Table 6.5-5).

Within the Llama Watershed, Llama ponds 1 (0.71 ha north of Llama Lake) and 3 (0.57 ha east of Llama Lake) likely serve primarily as summer rearing habitat for juvenile fish from Llama Lake and will be indirectly lost through isolation by the placement of water management structures. Both ponds are ephemerally connected to Llama Lake by short streams which dry up in summer and are dominated by boulders nearshore and fine substrates in deeper regions. Llama Pond 1 may provide some overwintering habitat as it is estimated to be approximately 4 m deep, whereas Llama Pond 3 is less than 1 m deep and provides no overwintering capacity. These habitat losses will be initiated during the Construction Phase and persist in perpetuity.

Pond 1 (located east of Umwelt Lake; Figure 6.5-1) will also be indirectly lost from the Llama Watershed due to disconnection and isolation from Umwelt Lake for the construction of the Saline Water Pond. Pond 1 provides approximately 6.3 ha of low quality rearing habitat for forage fish (Slimy Sculpin and Ninespine Stickleback) which may overwinter within its 3 m depth. This habitat loss will be initiated during the Construction Phase and persist in perpetuity.

Fifteen ponds within the Goose and Wolf watersheds will be lost due to the placement of infrastructure: four within the boundary of the TSF (5.1 ha: ponds 6, 7, 8 and 9), ten due to the loss of catchment discharge downstream of the TSF (9.4 ha: ponds 11, 12, 20, 21, 22, 23, 24, 25, 26, 27) and one by isolation from connected waterbodies (0.56 ha: pond 10). Within the planned TSF boundary, ponds 6, 7 and 9 are shallow (less than 1 m maximum depth) and consist predominantly of boulder and fine substrate. Given their shallow nature, fish use of these ponds is limited to the summer. Within the potential TSF location overwintering habitat only exists in Pond 8. Pond 10, potentially isolated on the eastern side of the TSF, is also sufficiently deep to provide potential overwintering habitat to forage fish along with summer rearing habitat. The remainder of the ponds downstream of the TSF are split into two groups based on seasonal connectivity; those ponds lower in the watershed that have good connectivity to Goose Lake throughout the summer, and those ponds higher in the watershed that have only ephemeral connectivity to Goose Lake during the spring freshet. Those ponds lower in the watershed (ponds 21, 25, 26, 27) provide medium quality summer rearing habitat for Arctic Grayling

and forage fish. Ponds located higher in the watershed (11, 12, 20, 22, 23, 24) provide low quality summer rearing habitat for forage fish. In dry years, fish may become trapped and perish in ponds higher in the watershed if low in-stream flow conditions in the fall prevent fish from accessing viable overwintering habitat. Pond habitat losses will be initiated during the Construction Phase and the loss of ponds directly underneath the TSF (ponds 6, 7, 8 and 9) will persist in perpetuity. All remaining ponds may receive an increase in discharge and potentially a return to fish bearing condition once the TSF is breached and decommissioned in Post Closure. However, for the establishment of a fisheries offsetting plan, all ponds are considered losses in perpetuity.

Streams

Several small, fish bearing streams will be lost to infrastructure (Figures 6.5-1 and 6.5-2) and are located in three watersheds, the Llama watershed (associated with the Llama and Umwelt Pits), the Goose watershed (associated with the TSF) and the Wolf watershed (associated with airstrip construction, the Goose Pit and the TSF), representing a total wetted area loss of 3.2 ha (Table 6.5-5). The predicted scenarios for stream discharge loss, including cross sections, are not presented as stream habitat described below is considered a complete loss and the balance of this loss will be included in the Conceptual Fish Offsetting Plan.

Within the Llama Watershed, four stream reaches will be lost totalling 0.6 ha of fish bearing habitat. Two streams are associated with the construction of the Llama Pit and the associated water management structures (Llama Inflow from Llama Pond 1 and Llama Outflow) and two streams are associated with the construction of the Saline Water Pond (Umwelt Inflow from Pond 1 and Umwelt Outflow). Llama Inflow from Llama Pond 1 contains overall medium quality habitat but offers good connectivity between Llama Lake and Llama Pond 1 for rearing Lake Trout and forage fish. Llama Outflow habitat is high quality overall, consisting of fair to good quality spawning habitat for Arctic Grayling, good spawning habitat for forage fish and good quality juvenile rearing habitat. Umwelt Inflow from Pond 1 is of fair quality overall with good connectivity between Umwelt Lake and Pond 1 and fair to good rearing and spawning habitat for forage fish only. Umwelt Outflow habitat is high quality overall, consisting of fair quality spawning habitat for Arctic Grayling, good spawning habitat for forage fish and good quality habitat for juvenile rearing fish. All streams will experience a complete, or very nearly complete reduction of discharge from upstream waterbodies and will provide little to no habitat for fish. In addition, there is a potential for small amounts of runoff along the Umwelt Outflow providing the opportunity for fish to become stranded in its lower reaches. These habitat losses will be initiated during the Construction Phase when Llama and Umwelt lakes are drained. The loss of the upstream catchment will persist through operations and closure, after which the discharge will resume along the natural stream route. For the establishment of a fisheries offsetting plan, all ponds are considered losses in perpetuity.

Within the Goose and Wolf Watersheds, three streams will be lost, or partially lost totalling an approximate 2.6 ha of fish bearing habitat (Table 6.5-5). Two streams will be lost due to the construction of the TSF and the loss upstream catchment area (Goose Inflow East [GIE: 1.6 ha loss] and Goose Inflow South [GIS: 0.6 ha loss]), whereas Rascal Stream East (RSE: 0.5 ha loss) will be partially lost due to development of the airstrip and associated water management infrastructure (Figure 6.5-1).

The Goose Inflow East and South streams can be generally classified into two habitat types based on seasonal connectivity: sections lower in the watershed maintain good connectivity to Goose Lake throughout the summer and provide habitat for Arctic Grayling and forage fish (sections downstream of Pond 24 in GIE, and of Pond 21 In GIS; Figure 6.5-1), whereas sections higher in the watershed have only ephemeral connectivity to Goose Lake during the spring freshet and provide habitat only for forage fish. In sections of GIS and GIE lower in the watershed, the habitat is rated as high quality,

providing good spawning and rearing habitat for Arctic Grayling and forage fish from Goose Lake and direct connection to overwintering habitat in Goose Lake. The lower section of GIS also provides part of the corridor that Arctic Grayling use to migrate between Goose and Rascal lakes (Figure 6.5-1). In sections of GIS and GIE higher in the watershed, the habitat is generally rated as low, with fair spawning and rearing habitat for forage fish, but often a discontinuous connection between ponds, of which only two provide overwintering capability (Pond 8 and 10). Stream habitat losses in GIE and GIS will be initiated during the Construction Phase and the loss of higher watershed sections directly underneath the TSF will persist in perpetuity. All remaining downstream sections of GIE and GIS will receive reduced flows because of lost upstream catchment area resulting in channel discontinuity, increased periods of dry channel and fewer flow days. Reduced flow in these channels may be sufficient to allow fish to enter and become stranded, perish or to spawn and strand eggs. GIE and GIS may return to baseline discharge and potentially a return to fish bearing condition once the TSF is breached and decommissioned in Post Closure. However, for the establishment of a fisheries offsetting plan, the entire length of GIE and GIS are considered losses in perpetuity.

The Rascal Stream East (RSE) was surveyed in 2012 and 2013 (Rescan 2012e), and is characterized by a heavily braided channel that is dominated by glide and riffle habitat. Boulders dominate the substrate, punctuated by patches of gravel and cobble substrate. The stream is heavily utilized by Arctic Grayling (Rescan 2012e), and contains good quality spawning, rearing, and foraging habitat. The 1.1 km section of RSE upstream of the airstrip culverts, nearest Rascal Lake, will remain undisturbed and provide approximately 0.7 ha of habitat available for spawning, rearing and foraging Arctic Grayling and forage fish from Rascal Lake. Stream habitat losses in RSE will be initiated during the Construction Phase when the culverts for the airstrip are installed and a culvert diverting flow to GIE is established to realign discharge in RSE around the Goose Pit and under a haul road. The habitat losses will continue through Post Closure, when the entire volume of RSE is diverted into the Goose TF to reduce filling time for the Goose Pit Lake. Once the Goose TF is full, the pit lake will be breached to allow flow to Goose Lake along the natural RSE alignment. Thus, the RSE will have habitat losses under two culverted areas and reduced flows during the filling of the Goose Pit. Reduced flow in the RSE may be sufficient to allow fish to enter and become stranded, perish or to spawn and strand eggs. RSE may return to baseline discharge and potentially a return to fish bearing condition once the culverts are removed and the Goose Pit Lake is breached in Post Closure. However, for the establishment of a fisheries offsetting plan, the length of RSE downstream of the airstrip culverts are considered habitat losses in perpetuity.

Fish habitat loss related to Project infrastructure will also be incurred in Gander Outflow, which will be culverted during site road construction and result in the loss of 21 m^2 of fish bearing habitat underneath the culvert footprint. This section of Gander Outflow includes fair spawning and good rearing habitat for Arctic Grayling and was rated as important overall. Habitat loss may occur if crossing structures are improperly sized or installed. In addition, in-water construction may mobilize sediment, destabilize stream banks, and alter streambeds. At stream crossing sites, these impacts could reduce or eliminate spawning, rearing and feeding habitat for Arctic Grayling (Stewart et al. 2007). The Gander Outflow crossing will be culverted with a closed bottom corrugated metal pipe designed to maintain Arctic Grayling passage by keeping water velocities under 1.5 m/s (Site Water Monitoring and Management Plan (Volume 10, Chapter 7). The habitat loss will be initiated during the Construction Phase and persist until decommissioned in Post Closure.

Table 6.5-5. Fish-bearing Waterbodies Affected by Project Infrastructure

Waterbody	Name	Watershed	Project Effect	Loss Type	Area (m^2)	Maximum Depth	Length (m^2)	Width (m^2)[a]	Species Captured[b]	Data Source
Lakes and Ponds	Llama Lake	Llama	Infrastructure (Llama Pit)	Total	365,900	13.6	-	-	LKTR, RDWF, NSSB	1,2,3
	Llama Pond 1	Llama	Infrastructure (Water Diversion Structure)	Total	7,119	>3	-	-		6
	Llama Pond 3	Llama	Infrastructure (Llama Pit)	Total	5,731	0.8	-	-		6
	Umwelt Lake	Llama	Infrastructure (Saline Water Pond)	Total	193,603	3.0	-	-	LKTR, ARGR, RDWF	1,2,3,4
	Pond 1	Llama	Infrastructure (Isolation)	Total	62,507	3.0	-	-	SLSC, NSSB	2
	Pond 6	Wolf	Infrastructure (TSF)	Total	4,974	1.0	-	-		5,6
	Pond 7	Wolf	Infrastructure (TSF)	Total	16,636	<1	-	-		5,6
	Pond 8	Wolf	Infrastructure (TSF)	Total	27,042	2.0	-	-	NSSB	5,6
	Pond 9	Goose	Infrastructure (TSF)	Total	2,183	0.4	-	-		5,6
	Pond 10	Goose	Infrastructure (Isolation from connected waterbodies)	Total	5,624	>3	-	-		5,6
	Pond 11	Wolf	Infrastructure (Downstream of TSF loss of catchment)	Total	8,642	<1	-	-		5,6
	Pond 12	Wolf	Infrastructure (Downstream of TSF loss of catchment)	Total	2,365	<1	-	-	NSSB	5,6
	Pond 20	Wolf	Infrastructure (Downstream of TSF loss of catchment)	Total	1,900	NA	-	-		5,6
	Pond 21	Wolf	Infrastructure (Downstream of TSF loss of catchment)	Total	7,325	0.7	-	-	NSSB	5,6
	Pond 22	Wolf	Infrastructure (Downstream of TSF loss of catchment)	Total	11,774	1.0	-	-		5,6
	Pond 23	Goose	Infrastructure (Downstream of TSF loss of catchment)	Total	701	0.4	-	-	NSSB	5,6
	Pond 24	Goose	Infrastructure (Downstream of TSF loss of catchment)	Total	2,209	0.7	-	-	NSSB	5,6
	Pond 25	Goose	Infrastructure (Downstream of TSF loss of catchment)	Total	41,974	0.4	-	-	NSSB	5,6
	Pond 26	Wolf	Infrastructure (Downstream of TSF loss of catchment)	Total	1,870	0.9	-	-		5,6
	Pond 27	Goose	Infrastructure (Downstream of TSF loss of catchment)	Total	15,554	>2	-	-	ARGR, SLSC, BURB, NSSB	5,6
	Portion of Goose Lake	Goose	Infrastructure (Water Intake and Discharge Pipes)	Partial	5,065	16.5	-	-	LKTR, ARGR, RDWF, BURB, SLSC, NSSB	2,3
	Portion of Big Lake	Big	Infrastructure (Water Intake Pipe)	Partial	5,227	5.6	-	-	LKTR, ARGR, RDWF, LKWF, BURB, SLSC	3
Streams	Goose Inflow East	Goose	Infrastructure (TSF and Downstream loss of catchment)	Total	15,548	-	3,887	4	ARGR, SLSC, BURB, NSSB	5,6
	Goose Inflow South	Wolf	Infrastructure (TSF and Downstream loss of catchment)	Total	6,349	-	3,527	1.8	ARGR, SLSC, BURB, NSSB	4,5,6
	Rascal Stream East[c]	Wolf	Infrastructure (Airstrip and reaches downstream to Goose Inflow South)	Partial	4,544	-	1,228	3.7	ARGR, SLSC, BURB, NSSB	4
	Llama Inflow from Llama Pond 1	Llama	Infrastructure (Water Diversion Structure)	Total	179	-	99	1.8		6
	Umwelt Inflow from Pond 1	Llama	Infrastructure (Isolation from connected waterbodies)	Total	129	-	129	1.0		6
	Llama Outflow	Llama	Infrastructure (Llama Pit dewatering; loss of catchment)	Total	786	-	436	1.8	ARGR, RDWF, SLSC, NSSB	6
	Umwelt Outflow	Llama	Infrastructure (Saline Water Pond dewatering; loss of catchment)	Total	4,406	-	551	8.0	ARGR, NSSB	6
	Gander Outflow	Wolf	Infrastructure (Culvert for Haul Road)	Partial	21	-	30	0.7	ARGR, NSSB	4

[a] *average bankfull width across all reaches within the stream system*

[b] *LKTR - Lake Trout, ARGR - Arctic Grayling, RDWF - Round Whitefish, LKWF - Lake Whitefish, SLSC - Slimy Sculpin, BURB - Burbot, NSSB - Ninespine Stickleback, where no species has been captured, fish presence assumed due to direct connectivity (no barriers) with fish bearing habitat*

[c] *this stream has been renamed Rascal Stream East: original data from Rescan 2013 and includes the Main Pit Stream Reaches 2 and 3, and 538 m of the Rascal - Goose Stream Reach 4.*

Data Sources: 1. Rescan (2010), 2. Rescan (2012a), 3. Rescan (2012d), 4. Rescan (2013a), 5. Rescan (2014), 6. Rescan (2015c)

6.5.2.2 Loss of Fish Habitat: Lake Dewatering

Dewatering of Llama and Umwelt lakes will be required in order to construct the Llama open pit and the Saline Water Pond. Dewatering will result in direct loss of fish habitat as described above, but may also cause the suspension of sediments within the waterbody being drained (due to bank slumping and substrate disturbance). The suspension and deposition of sediments during lake dewatering would potentially result in an *indirect* loss of fish habitat through water and sediment quality effects on primary and secondary producers. The assessment of Project effects and mitigation measures applied to water and sediment quality are completed individually in Volume 6, Chapters 4 and 5.

6.5.2.3 Loss of Fish Habitat: Water Use

Water Withdrawal

Water for domestic and process use will be drawn from Goose and/or Big lakes and is anticipated to occur during all phases of the Project with the possible exception of post-closure.

Water withdrawal from lakes has the potential to affect fish/aquatic habitat through multiple pathways, including a reduction in available fish habitat, changes to primary and secondary producers and a reduction in discharge volume at lake outflows. For example, water withdrawal from large, ice-covered lakes may cause a decrease in the amount and suitability of overwintering habitat available for fish or potentially expose overwintering eggs of Lake Trout to air (Cott 2007). Reduction in discharge at lake outflow streams can influence the ability for fish passage through a decrease the number of days stream habitat is accessible and increase the duration of sensitive periods (flow less than 30% Mean Annual Discharge; DFO 2013b). Lastly, water withdrawal has the potential to modify water and sediment quality such that shifts in lower trophic level prey communities (invertebrates) are altered. Smaller, shallow lakes and ponds are more susceptible to habitat changes due to water withdrawals than large lakes.

Water withdrawal for winter ice road construction may also occur at select lakes and ponds along the proposed winter ice road corridors when required. Connection between the two Project areas will be established via a winter ice road constructed during the winter months as needed during the life of the Project.

In addition to the potential effects of water withdrawal on the VEC freshwater fish/aquatic habitat listed above, water draw for winter ice roads has the potential to restrict the temporal availability of fish habitat in streams. For example, improper decommissioning of winter ice road crossings may result in temporary barriers to fish passage by increasing erosion and bank instability during spring flooding (DFO 2007).

The construction and presence of winter ice roads over streams in the Project footprint is most likely to affect Arctic Grayling, which rely on stream habitat for spawning in the spring, and for juvenile rearing throughout the summer (Stewart et al. 2007). Temporary barriers to fish passage resulting from ice and snow crossings may block access to spawning areas during the spring spawning season, and erosion of stream banks may increase sedimentation, smothering spawning gravels and increasing suspended sediment loads in the water column.

Winter ice roads also have the potential to affect lake shores. If improperly constructed, winter ice roads may lead to shoreline erosion and increased suspended sediment and sediment deposition. Sediment eroded from shorelines and stream crossings may settle along the rocky shorelines of lakes, possibly affecting the quality of Lake Trout spawning habitat (Marcus, Hubert, and Anderson 1984). The suspension and deposition of sediments during lake dewatering would also potentially result in an *indirect* loss of fish habitat through water and sediment quality effects on primary and secondary producers.

The assessment of Project effects on water and sediment quality are completed individually in Volume 6, Chapters 4 and 5, and left out of this assessment as outlined in Section 6.3.2.1 of this chapter.

6.5.2.4 Deposition of Deleterious Substances

Potential effects of Project activities on the VEC freshwater fish/aquatic habitat may occur through the deposition of deleterious substances. As justified in Section 6.3.2.1, Project activities that affect biological resources through the deposition of deleterious substances result from *indirect* trophic level interactions which are ultimately due to changes in water and sediment quality. The assessment of Project effects on water and sediment quality were completed separately and independently in Volume 6, Chapters 4 and 5. Please refer to Section 6.3.2.1 for the rationalization to exclude the water and sediment quality in the effects assessment for the VEC freshwater fish/aquatic habitat. The deposition of deleterious substances is not carried forward into subsequent sections of the assessment of the VEC freshwater fish/aquatic habitat.

6.5.2.5 Local and Regional Context for Project Interactions

When considering the extent of potential Project effects there are three important themes to emphasize: losses at the landscape level, the type of habitat losses, and the distribution of the species affected.

The sum of potential interactions of the Project with fish habitat results in a permanent loss of approximately 83 ha of fish bearing waterbodies (lakes, ponds and streams). The predicted loss in fish bearing habitat represents a small area when compared to the Project footprint, local and regional study areas: approximately 11.5% of the available fish bearing habitat within the PDA, 1.2 % within the LSA, and 0.09% of that available within the Freshwater RSA. The calculation of fish bearing habitat in the PDA, LSA and RSA was completed using the proportion of fish bearing habitat to non-fish bearing habitat classified during baseline studies within the LSA (equal to 0.98 or 98%). This proportion was then multiplied by the total wetted habitat in the PDA, LSA and RSA to estimate the total fish bearing habitat area within each. Total wetted habitat was 732 ha in the PDA, 7,000 ha in the LSA and 96,363 ha in the RSA. The percentage of loss for each area was calculated as 100 multiplied by the amount of fish habitat lost (83 ha) divided by the estimated fish bearing habitat in the PDA, LSA and RSA.

This affected fish habitat is located primarily in the upstream reaches of watersheds resulting in highly localized habitat losses that will not disconnect migration routes between lakes for fish species. The loss of Llama and Umwelt lakes and their associated ponds and streams in the northern arm of Llama Watershed, in addition to GIE and GIS and their associated ponds within the Goose and Wolf watersheds, are all located in the most upstream ends of the respective watersheds and will not disrupt fish migration. The partial loss of RSE may disrupt the main arm of the Arctic Grayling migration route between Goose and Rascal lakes during the Project phases, however the Rascal Stream West through Gander Pond is also used by Arctic Grayling to connect these two lakes.

The fisheries habitat losses within the PDA affect fish species commonly encountered throughout waters located within Nunavut and the Canadian Arctic, namely Lake Trout, Arctic Grayling, Lake Whitefish and forage species (Slimy Sculpin and Ninespine Stickleback). None of the affected species are listed under SARA or COSWEIC and localized losses are minimal when considering the total amount of habitat available to these abundant Arctic species within the LSA and RSA.

All fish bearing habitat losses will be balanced in an approved fisheries offsetting plan, which is summarized in section 6.5.3.4 and detailed in Volume 10, Chapter 21.

6.5.3 Identification of Mitigation and Management Measures

Mitigation measures will be in place to avoid or minimize the potential effects of the Project on the VEC freshwater fish/aquatic habitat. Mitigation measures are supplemented by the use of additional management. For example, alternative siting locations may be identified along with changes in Project design and the use of best management practices. The mitigation and management measures presented in this chapter are considered to be technically, environmentally, and economically feasible.

6.5.3.1 Loss of Fish Habitat: Project Infrastructure Footprint

Locations of Project Infrastructure

The majority of Project infrastructure has been sited to avoid fish bearing water and, wherever possible, to avoid encroaching on freshwater fish habitat by adhering to a 31 m setback from all water. The WRSAs have all been sited to avoid fish-bearing water and have been confined to local watersheds close to the main mine infrastructure.

Additional mitigation to avoid adverse effects on fish is required for streams predicted to experience reduced discharge that will potentially result in an increase in fish and egg stranding. These streams include Umwelt Outflow in the Llama Watershed, GIE in the Goose Watershed and GIS and RSE in the Wolf Watershed (section 6.5.2.1). In each of these streams, all potential fish use (migration, spawning, rearing and egg) will be prevented by creating fish barriers at all migratory pathways into the channel prior to ice melt during the Construction phase. This includes barriers constructed at the following locations:

- Umwelt Outflow at the limit of the southern flowing downstream end where the stream connects to eastern flows toward Goose Lake;
- GIE and GIS at the downstream limit where each stream enters Goose Lake; and
- RSE upstream of the airstrip culverts.

Blocking fish access to the GIE, GIS and RSE streams may involve the construction of a permeable or semi-permeable gravel berm dug into the streambed. Once flows are re-established in GIE, GIS and RSE in Post Closure, barriers may be removed to allow fish passage into the systems. Blocking fish access to Umwelt Outflow may involve creating a permanent impassable fall or cascade barrier. This may be done to prevent fish access to upstream water management areas if required during post-closure.

The construction and maintenance of stream crossings, roads and berms will follow DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat. These include the following mitigation measures to guide these processes and to ensure that fish and aquatic habitat are not adversely affected by development:

- Design and plan in-water works such that loss or disturbance to aquatic habitat is minimized and sensitive spawning habitats are avoided;
- Where possible, approaches will be designed to be perpendicular to the watercourse to minimize loss or disturbance to riparian vegetation;
- Instream activities will be undertaken in isolation of open or flowing water, or when frozen, to maintain the natural flow of water downstream and avoid introducing sediment into the watercourse;
- Effective erosion and sediment control measures will be installed before starting work to prevent sediment from entering the waterbody;

- Site isolation measures (e.g., silt boom or silt curtain) will be used to contain suspended sediment where in-water work is required;
- Regular inspection and maintenance of erosion and sediment control measures and structures will be conducted during the course of construction;
- Repairs to erosion and sediment control measures and structures will be promptly completed if damage occurs;
- Removal of non-biodegradable erosion and sediment control materials will be completed once site is stabilized;
- Clearing of riparian vegetation will be kept to a minimum to avoid disturbance to the riparian vegetation and prevent soil compaction;
- All construction materials will be removed from the construction site upon project completion;
- Machinery will be in a clean condition and maintained free of fluid leaks, invasive species and noxious weeds;
- Whenever possible, machinery will be operated on land above the high water mark or on ice in a manner that minimizes disturbance to the banks and bed of the waterbody;
- Whenever possible, machine fording of a watercourse will be limited to a one-time event (i.e., over and back), and only if no alternative crossing method is available. If repeated crossings of the watercourse are required, a temporary crossing structure will be constructed; and
- Service machinery will be washed, refueled and fuel and other materials for the machinery stored in such a way as to prevent any deleterious substances from entering the water.

For the fish bearing crossing at Gander Outflow which will continue to serve as a migration corridor between Goose and Rascal lakes, the culvert was sized to keep maximum water velocities below 1.5 m/s such that it does not present a velocity barrier to migrating Arctic Grayling. In addition, the culvert will be embedded to a depth of 0.4 m and filled with streambed material to promote fish passage and habitat suitability.

Timing of in-water construction activities will conform, when possible, to Nunavut timing windows for the protection of fish and their habitat. For stream activities, the window is in place to avoid the spring spawning time for Arctic Grayling from May 1 to July 15. For lake activities, this window is meant to avoid fall spawning species within the LSA (Lake Trout and Whitefish) and is from September 1 to June 30.

Where fish habitat loss is expected through the placement of infrastructure, mitigation for lost habitat has been incorporated into the Fish Offsetting Plan (Volume 10, Chapter 21). The objective of the Fish Offsetting Plan is to compensate for the alteration or destruction of fish-bearing habitat by creating or modifying fish habitat elsewhere on the landscape (see section 6.5.3.4).

As a result of mitigation and balancing fisheries losses with fisheries offsetting, there are no residual effects anticipated on the VEC freshwater fish/aquatic habitat due to Project infrastructure. Unavoidable habitat losses due to Project infrastructure will be restricted to within the LSA, specifically in the Llama, Goose and Wolf watersheds. All habitat losses related to Project Infrastructure will be offset by increasing the productivity of CRA species considered to be of high value to stakeholders. The detailed description of fisheries offsetting can be found in the Fish Offsetting Plan.

Lake Dewatering

Any dewatering of lakes will be in accordance with a Lake Dewatering Plan and fishout protocol, found in both the Site Water Monitoring and Management Plan (Volume 10, Chapter 7) and the Aquatic Effects Management Plan (Volume 10, Chapter 19). Fisheries offsetting is planned where lake dewatering is expected to result in the loss of fish habitat, and no residual effects on the VEC freshwater fish/aquatic habitat are anticipated.

6.5.3.2 Loss of Fish Habitat: Water Use

Water Withdrawal

The primary mitigation measure for the VEC freshwater fish/aquatic habitat is to protect habitat necessary for life stages of freshwater fish by limiting the amount of water withdrawn from each waterbody (Table 6.5-6). In addition, water will be recycled where possible to reduce the demand for water withdrawals. As a result of mitigation measures, there are no residual effects anticipated on the VEC freshwater fish/aquatic habitat due to water use.

Table 6.5-6. Volume Limits to Water Use

	Goose Lake		Big Lake
Project Phase	**Year-round Withdrawal (m^3/day)**	**Additional June to October Withdrawal (m^3/day)**	**Year-round Withdrawal (m^3/day)**
Construction	400	n/a	350
Operations	900	400	350
Reclamation and Closure	400	n/a	350
Post-Closure	n/a	n/a	n/a

To protect essential fish habitat in Goose Lake and downstream in Propeller Lake, the maximum volume limit for year round water withdrawal was set at 900 m^3/day during Operations phases. An additional 400 m^3/day could be withdrawn during peak flow periods (June to October) during Operations and Closure phases, such that the maximum amount of water withdrawn during any peak usage will be 1,300 m^3/day.

At the maximum limit to withdrawal volumes shown above, the water level and outflow volume of Goose Lake is expected to decrease, but remain within the range of natural variation to protect fish habitat (Appendix V6-1E; DFO 2009, 2010). The limit to water drawdown will prevent water levels in Goose Lake from decreasing more than 0.06 m. The maximum drop in lake level is reached during late winter under ice. This anticipated reduction in water level in Goose Lake is considered negligible and therefore within DFO guidelines (DFO 2009, 2010) as ice thickness in Goose Lake varies up to 0.2 m among years and locations and water level fluctuates more than 0.3 m during the open-water period (Rescan 2012c, 2012e).

Maximum limits to water withdrawal volume from Goose Lake would also affect outflow volume (discharge rate) at the Goose Outflow stream — a wide, shallow connection between Goose and Propeller lakes. The primary potential effects on Goose Outflow would be due to a reduction in flow (discharge) and the number of usable flow days throughout the open water season resulting from winter and summer withdrawal from Goose Lake. The number of usable flow days is quantified using DFO's ecological flow guidelines (DFO 2013), where the usable days are considered any day in which the stream is discharging above 30% Mean Annual Discharge (MAD; see Appendix V6-1E for the full hydrological analysis).

The outflow discharge in Goose Lake is anticipated to remain within the range of natural variation to protect fish habitat. During the open water season, the limit to water drawdown will prevent discharge from decreasing more than 13.3% from average baseline outflow volume, and up to 17.4% in a 1-in-20-dry year. Baseline flow and water level in Goose Outflow are marginal to insufficient for fisheries production during sensitive periods (flow less than 30% Mean Annual Discharge; DFO 2013b; Figure 6.5-3) and the estimated 13.3% reduction in discharge due to maximum water withdrawal does not alter the date or duration of the vulnerable period when Goose Outflow is marginal for fish use (Figure 6.5-3; Appendix V6-1E). Moreover, the stream becomes impassable to fish at low flows late in summer due to the presence of a boulder garden (Norecol Dames & Moore 1997).

In addition, the results of hydrological modeling (Appendix V6-1E) indicate that the total number of flow days in Goose Outflow will decrease by a total of 10 days, equal to 6.8% of the flow period (Baseline flow days = 147, Reduced flow days as a result of maximum water withdrawal by Project = 137). The predicted reduction of 10 flow days in Goose Outflow results from first, a delay of 6 days for the onset of flow above 30% MAD during freshet (Baseline = May 25, Project = May 31) due to winter withdrawal, and second, an earlier date of onset of flow below 30% MAD due to summer withdrawal (2 days: Baseline = Oct 19, Project = Oct 15). Again, this reduction appears to be within the range of natural variation in flow days during baseline studies. During the course of three years of data collection at Goose Outflow (Hydrometric Station GI-H1), the range of natural variability in peak freshet is 4 days and the onset of low flow is 7 days. Note that this analysis used a conservative approach by comparing baseline discharge and flow days to predictions of Project discharge for a 1 in 20 dry year. This is conservative because in dry years, when water levels are at their lowest, less habitat would be available for fish use when compared to an average or wet year. Thus, the predicted reduction in number of flow days during a 1-in-20 dry year will be greater than that in an average year.

Water withdrawal from Goose Lake also has the potential to affect the outflow volume of the nearest lake downstream, Propeller Lake. Hydrological modeling indicates that the flow reduction at Propeller Outflow is anticipated to be 6.2% (0.06 m^3/s) on average and 8.2% (0.04 m^3/s) for a 1 in 20 dry year (Appendix V6-1E). Thus, the maximum reduction in discharge volume for Propeller Lake is expected to be below the 10% maximum permissible withdrawal volume to protect fish habitat (DFO 2009, 2010).

Water withdrawal from Big Lake has been designed to avoid impacts to fish habitat. Maximum withdrawal for Big Lake was set below 10% of the outflow volume, below the maximum permissible withdrawal volume to protect fish habitat (DFO 2009, 2010). Hydrologic modelling (Appendix V6-1E) predicts a reduction of 2.3% (average) and 4.5% (1 in 20 dry year). A maximum of 350 m^3/day of water will be withdrawn throughout the year.

Mitigation measures applied during the construction and operation of the intake and discharge pipelines follow DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat. These include the following:

- Screen water intakes or outlet pipes to prevent entrainment or impingement of fish;
- Screens should be located in areas and depths of water with low concentrations of fish throughout the year;
- Screens should be located away from natural or artificial structures that may attract fish that are in migrating, spawning, or rearing habitat;
- The screen face should be oriented in the same direction as the flow;
- Ensure openings in the guides and seals are less than the opening criteria to make "fish tight";

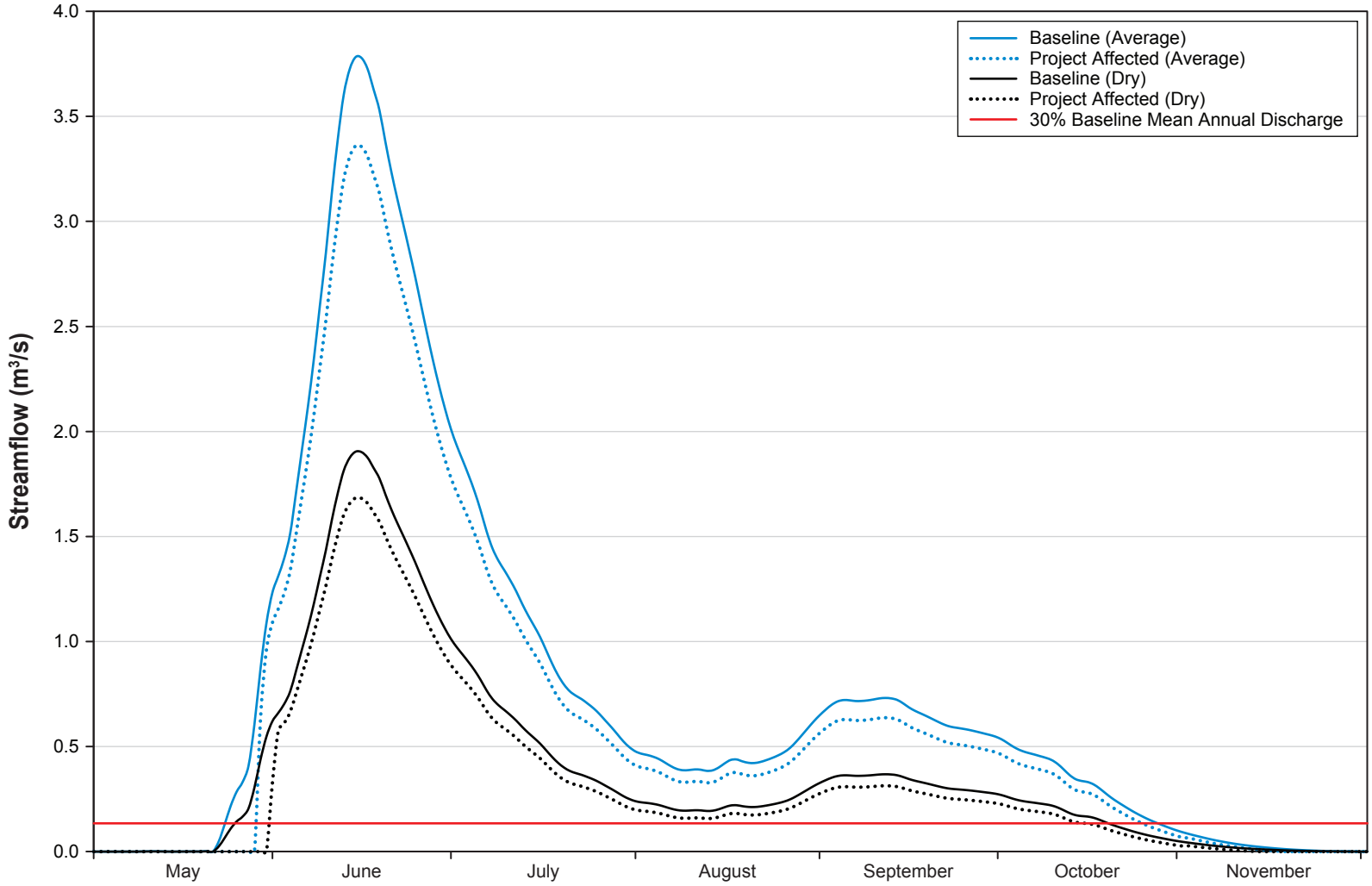

Figure 6.5-3

Sabina GOLD & SILVER CORP.

Baseline and Project-affected Flows at Goose Outflow

Figure 6.5-3

Rescan an ERM company

- Screens should be located a minimum of 300 mm (12 in.) above the bottom of the watercourse to prevent entrainment of sediment and aquatic organisms associated with the bottom area;
- Structural support should be provided to the screen panels to prevent sagging and collapse of the screen;
- Large cylindrical and box-type screens should have a manifold installed in them to ensure even water velocity distribution across the screen surface. The ends of the structure should be made out of solid materials and the end of the manifold capped;
- Heavier cages or trash racks can be fabricated out of bar or grating to protect the finer fish screen, especially where there is organic debris loading. A 150 mm (6 in.) spacing between bars is typical;
- Provision should be made for the removal, inspection, and cleaning of screens;
- Screen mesh size should be a maximum of 2.54 cm;
- Ensure regular maintenance and repair of cleaning apparatus, seals, and screens is carried out to prevent debris-fouling and impingement of fish; and
- Pumps should be shut down when fish screens are removed for inspection and cleaning.

Winter Ice Road Construction and Use

Winter ice road construction will adhere to the measures above and the following DFO guidelines based upon the Nunavut *Operational Statement for Ice Bridges and Snow Fills* (DFO 2007):

- Use existing trails or winter ice roads wherever possible as access routes to limit unnecessary clearing of additional vegetation and prevent soil compaction;
- Construct approaches and crossings perpendicular to the watercourse wherever possible;
- Construct ice bridge and snow fill approaches using clean, compacted snow and ice to a sufficient depth to protect the banks of the lake, river or stream;
- The use of material other than ice or snow to construct a temporary crossing over any ice-covered stream is prohibited under section 11 of the Northwest Territories Fishery Regulations, unless authorized by a Fishery Officer;
- Install sediment and erosion control measures before starting work to prevent the entry of sediment into the watercourse. Inspect them regularly during the course of construction and decommissioning activities and make all necessary repairs if any damage occurs;
- Operate machinery on land or on ice and in a manner that minimizes disturbance to the banks of the lake, river or stream.
  - Machinery is to arrive on site in a clean condition and is to be maintained free of fluid leaks;
  - Wash, refuel and service machinery and store fuel and other materials for the machinery away from the water to prevent any deleterious substance from entering the water or spreading onto the ice surface;
  - Keep an emergency spill kit on site in case of fluid leaks or spills from machinery; and
  - Restore banks to original condition if any disturbance occurs.
- Ensure that the intakes are sized and adequately screened to prevent debris blockage and fish mortality. Mesh size will not be larger than 2.54 mm;

- Crossings do not impede water flow at any time of the year;
- When the crossing season is over and where it is safe to do so, create a v-notch in the centre of the ice bridge to allow it to melt from the centre and also to prevent blocking fish passage, channel erosion and flooding. Compacted snow should be removed from snow fills prior to the spring freshet;
- Stabilize any waste materials removed from the work site to prevent them from entering the lake, river, or stream. This could include covering spoil piles with biodegradable mats or tarps; and
- The site should be stabilized using effective sediment and erosion control measures. In areas with permafrost, care should be exercised to ensure these measures do not cause thawing or frost heave.

Water withdrawal for the construction of winter ice roads will adhere to the measures above and the following DFO guidelines taken from the *Protocol for Winter Water Withdrawal from Ice-Covered Waterbodies in the Northwest Territories and Nunavut* (DFO 2010):

- In one ice-covered season, total water withdrawal from a single waterbody is not to exceed 10% of the available water volume;
- In cases where there are multiple users withdrawing water from a single waterbody, the total combined withdrawal volume is not to exceed 10% of the available water volume; and
- Only waterbodies with maximum depths that are ≥1.5 m than their corresponding maximum expected ice thickness should be considered for water withdrawal.

The construction of ice bridges and snow fill approaches at the land-water interface will utilize only clean, compacted snow and ice to a sufficient depth to protect the shoreline. Speed limits will be enforced to prevent ice scour along shorelines.

Temporary Stream Crossings

Temporary crossings will adhere to the measures above and the following DFO guidelines:

- If there are any activities with the potential to disrupt sensitive fish life stages (e.g., fording of the watercourse by machinery) the appropriate fisheries timing widows will be adhered to;
- Machinery fording a flowing watercourse to bring equipment required for construction to the opposite side is limited to a one-time event (over and back) and is to occur only if an existing crossing at another location is not available or practical to use;
  - If minor rutting is likely to occur, stream bank and bed protection methods (e.g., swamp mats, pads) should be used, provided they do not constrict flows or block fish passage;
  - Grading of the stream banks for the approaches should not occur;
  - If the stream bed and banks are steep and highly erodible (e.g., dominated by organic materials and silts) and erosion and degradation are likely to occur as a result of equipment fording, then a temporary bridge should be used in order to protect these areas;
  - The one-time fording should adhere to fisheries timing windows;
  - Fording should occur under low flow conditions, and not when flows are elevated due to local rain events or seasonal flooding;

- For temporary bridges also employ the following measures:
  - Use only clean materials (e.g., rock or coarse gravel fill, wood, or steel) for approaches to the bridge (i.e., not sand, clay or organic soil) and install in a manner that avoids erosion and sedimentation;
  - Design temporary bridges to accommodate any expected high flows of the watercourse during the construction period;
  - Restore the bank and substrate to pre-construction condition;
  - Completely remove all materials used in the construction of the temporary bridge from the watercourse following the equipment crossing, and stabilize and re-vegetate the banks;

Culvert Maintenance

Measures to Protect Fish and Fish Habitat when Maintaining Culverts will adhere to the measures above and the following DFO guidelines:

- Existing trails, roads, or cut lines will be used wherever possible to avoid disturbance to the riparian vegetation;
- The removal of vegetation should be kept to a minimum;
- Unless accumulated material (i.e., vegetation, ice build-up, etc.) is preventing the passage of water and/or fish through the structure, material and debris removal will be completed according to the Nunavut In-Water Construction Timing Windows. Any proposal to conduct such work under ice covered conditions, with the exception of ice build-up removal, requires prior review by DFO;
- DFO will be notified if emergency debris removal is required. Emergencies include situations where carrying out the project immediately is in the interest of preventing damage to property or the environment, or is in the interest of public health or safety;
- Effective sediment and erosion control measures will be installed before starting work to prevent sediment from entering the watercourse. Regular inspections will be completed during the course of construction and make all necessary repairs if any damage occurs;
- The removal of accumulated material will be limited to the area within the culvert, immediately upstream of the culvert and to that which is necessary to maintain culvert function and fish passage;
- Accumulated material and debris will be removed slowly to prevent downstream flooding and reduce the amount of sediment-laden water going downstream and reduce the potential for stranding fish in upstream areas;
- Machinery will be operated on land (from outside of the water) in a manner that minimizes disturbance to the banks of the watercourse.
  - Machinery is to arrive on site in a clean condition and is to be maintained free of fluid leaks;
  - Washing, refueling and servicing of machinery and fuel storage will be completed away from the water to prevent any deleterious substance from entering the water;
  - An emergency spill kit will be kept on site in case of fluid leaks or spills from machinery;
  - Banks will be restored to original condition if any disturbance occurs.

- If replacement rock reinforcement/armouring is required to stabilize eroding inlets and outlets, the following measures should be incorporated:
  - Appropriately-sized, clean rocks will be placed into the eroding area;
  - Only clean, non-acid generating rocks will be used. Rocks will not be obtained from below the ordinary high water mark of any waterbody;
  - Rock will be installed at a similar slope to maintain a uniform stream bank and natural stream alignment;
  - Rocks installed will be done so as to not interfere with fish passage or constrict the channel width;
- Waste materials removed from the work site will be stabilized to prevent them from entering the watercourse;

As a result of mitigation, there are *no residual effects* anticipated on the VEC marine fish/aquatic habitat due to winter ice road construction and use.

6.5.3.3 Deposition of Deleterious Substances

The mitigation and management measures to avoid potential Project effects on the VEC freshwater fish/aquatic habitat can be found in the assessment of Project effects on water and sediment quality in Volume 6, Chapters 4 and 5. As justified in Section 6.3.2.1, Project activities that affect biological resources through the deposition of deleterious substances result from *indirect* trophic level interactions which are ultimately due to changes in water and sediment quality. Please refer to Section 6.3.2.1 for the rationalization to exclude the water and sediment quality in the effects assessment for the VEC freshwater fish/aquatic habitat.

The assessment of residual effects on the VECs freshwater Water Quality and Sediment Quality can be found in Volume 6, Chapters 4 and 5.

6.5.3.4 Fisheries Offsetting

The purpose of the Fish Offsetting Plan (Volume 10; Chapter 21), as per the guiding policies of Fisheries and Oceans Canada (DFO), is to maintain or improve the productivity of the CRA fishery. The Fish Offsetting Plan is the result of continued community and regulatory engagement associated with the Project. The outcome of engagement activities identified an offsetting measure or option focused on improving the productivity of an Arctic Char fishery at Bernard Harbour (the Hingittok Lake-Nulahugyuk Creek system), which is located approximately 100 km directly north of the hamlet of Kugluktuk, Nunavut, along the south coast of the Dolphin and Union Strait. Bernard Harbour was once the site of a traditional domestic fishery for Arctic Char.

The rationale for Bernard Harbour as a suitable offsetting option for the Project begins with reports by local harvesters in the 1990s that the traditional fishery is in decline. Follow-up investigations concluded that conditions of the creek may be deteriorating because of natural causes (e.g., changes in climate, resulting in low water levels, and boulder barriers), affecting the upstream migration of adult char to spawning areas in Hingittok Lake. During 2014 to 2015, a TK study combined with environmental monitoring provided a better understanding of the Arctic char fishery at Bernard Harbour (and related historic and contemporary environmental conditions). The baseline studies, all of which included Kugluktuk Hunters and Trappers Organization as full partners, demonstrated how the proposed approach to stream remediation is grounded in historic Aboriginal fisheries management strategies that have been used at Bernard Harbour (i.e. seasonal stream channel manipulation and rock

weir construction). Thus, the approach to offsetting for Project losses aims to integrate local community benefits while satisfying regulatory requirements.

To estimate the potential benefits of the offsetting option to fisheries production (as a surrogate of fisheries productivity), changes in migration success were estimated and then related to changes in the biomass of adult Arctic Char in Nulahugyuk Creek. The predicted gains in biomass following remediation may be substantial, magnifying over time when Arctic Char offspring return as adults (by offsetting year 8 or 9). It is also predicted that gains in biomass at Bernard Harbour will exceed all losses in fisheries production resulting from Project activity.

The Conceptual Fish Offsetting Plan will be finalized and presented as a Final Fisheries Offsetting Plan during the permitting phase of the Project and submitted as part of the Application for Authorization under the *Fisheries Act*. The plan would be approved by DFO as a condition of the Authorization required for the development of the Back River Project.

6.5.4 Characterization of Residual Effects

After considering the mitigation measures and fisheries offsetting and monitoring plans there are no anticipated residual effects on the VEC freshwater fish/aquatic habitat from the Project.

6.5.5 Significance of Residual Effects

After considering the mitigation measures and fisheries offsetting and monitoring plans there are no anticipated residual effects on the VEC freshwater fish/aquatic habitat from the Project.

6.6 POTENTIAL CUMULATIVE EFFECTS ASSESSMENT

6.6.1 Methodology Overview

The potential for cumulative effects arises when residual effects of *the Project* affect (i.e., overlap and interact with) the same resource/receptor that is affected by the residual effects of other past, existing or reasonably foreseeable projects or activities. When residual effects are present, the Cumulative Effects Assessment (CEA) followed the process detailed in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1).

6.6.2 Potential Interactions of Residual Effects with Other Projects

After considering mitigation measures and the fisheries offsetting and monitoring plans, no residual effects of Project activities on the VEC freshwater fish/aquatic habitat were predicted. Thus, there exists no potential for interactions with Projects — past, existing, or in the foreseeable future — for the VEC freshwater fish/aquatic habitat.

There are no anticipated residual effects on the VEC freshwater fish/aquatic habitat due to the Project. Therefore, there are no potential effects on fish habitat from the Back River Project that could act additively or synergistically with other projects. A CEA was not conducted (see CEA Methodology; Volume 9; Chapter 1).

6.7 TRANSBOUNDARY EFFECTS

As outlined in Section 4 of Volume 9 (Chapter 1), the potential for transboundary effects of the Project were determined based on whether residual Project effects could operate cumulatively with effects of projects in other jurisdictions. Transboundary effects can occur when VECs or the zone of influence of a project moves across jurisdictional borders external to the Nunavut Settlement Area (NSA).

After considering mitigation measures and the fisheries offsetting and monitoring plans there are no anticipated residual effects on the VEC freshwater fish/aquatic habitat for the Back River Project. Thus, no transboundary effects on the VEC freshwater fish/aquatic habitat are expected to occur.

6.8 MITIGATIVE AND ADAPTIVE MANAGEMENT

Numerous mitigation or management plans will be in place to eliminate or minimize the potential effects on the VEC freshwater fish/aquatic habitat. These plans can be found in Volume 10 and include:

- Fish Offsetting Plan;
- Aquatic Effects Management Plan;
- Environmental Management Plan;
- Environmental Protection Plan;
- Fuel Management Plan;
- Spill Contingency Plans;
- Oil Pollution Emergency Plan;
- Site Water Monitoring and Management Plan;
- Waste Management Plan;
- Incineration Management Plan;
- Explosives Management Plan;
- Road Management Plan ;
- Borrow Pits and Quarry Management Plan;
- Air Quality Monitoring and Management Plan; and
- Mine Closure and Reclamation Plan.

Best Management Practices

The Project will be constructed and managed following government guidelines and industrial best management practices as much as possible to avoid unnecessary impacts to fish/aquatic habitat. Government guidelines to avoid harm to fish/aquatic habitat include DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat, federal and territorial guidelines to preserve water and air quality, and federal and territorial environmental protection regulations. In addition, standard industrial best management practices will be developed, and much of this is featured in the Site Water Monitoring and Management Plan (Volume 10, Chapter 7). Detailed information on all best management practices are presented in Table 6.8-1.

Monitoring

Monitoring of construction activities and environmental compliance will be achieved through a Site Surveillance Network Monitoring Program that will be outlined in the future Type A Water Licence. This program will consist of all of the site compliance monitoring that will be required for managing/moving and releasing water from all potential containment areas.

Table 6.8-1. Mitigation and Management Measures Summary

Mitigation Category	Mitigation Measures
1. Mitigation by Project Design	
	Where possible, infrastructure, waste rock storage areas, and the camp and plan site have been located outside of fish bearing water;
	A Final Fish Offsetting Plan will be in place that has been approved by DFO and in consultation with the KIA, and other interested parties, to offset or enhance the permanent alteration or destruction of fish habitat. Freshwater offsetting will include a community supported Arctic Char fishery enhancement at Bernard Harbour.
	Efforts will be made during the final design stage to have the right-of-way cross each stream as close to perpendicular as possible to minimize the amount of riparian vegetation that may need to be disturbed during construction;
	Where pumps are used in fish-bearing watercourses or where fish salvage has not occurred, the intakes will be screened following DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (see section 6.5.3.1);
	Where water will be withdrawn from fish-bearing lakes, reduction in water level and discharge will be kept within 10% of the measured outflow volume, or below a threshold determined to have no significant residual effects on fish and fish habitat.
2. Regulatory Requirements	
	All in water activity will be conducted during approved timing windows following DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat. This includes: Culvert maintenance; Timing windows; Building and maintaining site road crossings; Temporary stream crossings; Winter ice road construction; and Water withdrawal. See section 6.5.3 for detailed mitigation methods.
3. Best Management Practices	
	Efforts shall be made to minimize the duration of any instream works and minimize disturbance of riparian vegetation at stream crossings;
	Prevent the release of sediment or sediment laden water into water frequented by fish;
	The dewatering of Llama and Umwelt lakes will follow an approved dewatering plan, whereby water will not be discharged to the receiving environment if it does not meet approved criteria;
	Machinery fording a watercourse to bring equipment required for construction to the opposite side is limited to a one-time event (over and back) and shall occur only if an existing crossing at a nearby location is not available or practical to use;
	Vehicular access across a watercourse or waterbody will be by road or bridge, or other acceptable method according to DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (see section 6.5.3.2);
	All temporary works, silt curtains, construction material or debris, etc. are to be completely removed from the waterway when work is completed;
	Fish removal from Llama and Umwelt lakes prior to or during dewatering will follow the DFO's General Fish-Out Protocol for Lakes and Impoundments in the Northwest Territories and Nunavut (Tyson et al. 2011).

(continued)

Table 6.8-1. Mitigation and Management Measures Summary (completed)

Mitigation Category	Mitigation Measures
4. Adaptive Management	
	The need for any corrective actions to on-site management or installation of additional control measures will be determined on a case-by-case basis. Indications of the need for corrective actions and additional control measures may include: • if results from the Surveillance Network monitoring program (which will be outlined in the future Type A Water Licence) show non-compliance; • if results from the Aquatic Effects Monitoring Program, which will monitor the receiving environment around the mine infrastructure and activities, show adverse effects to the freshwater environment; or • if results from the Fish Offsetting Monitoring Program show that the offsetting program is not successful.
5. Monitoring	
	There will be an approved Fish Offsetting Monitoring Program for the Project. The Fish Offsetting Monitoring Program may consist of the following components: • fish presence/habitat use; • local density or population size estimates for fish species; • habitat stability monitoring of constructed habitat; • assessment of primary productivity; and • assessment of benthic invertebrate community.

In addition, an Aquatic Effects Monitoring Program (AEMP; Volume 10, Chapter 19) will be carried out during all phases of the Project. The AEMP will include the following:

- monitoring a network of lakes and streams in and around the Goose Property area at locations potentially affected by the Project and at reference areas well away from Project activities;
- monitoring lake and stream water quality, sediment quality, and aquatic biology;
- monitoring fish populations and fish tissues; and
- if effluent as defined in the MMER, is discharged to the environment, then additional sampling for MMER requirements will be conducted.

Finally, a monitoring program will be developed to monitor the effectiveness of the Fish Offsetting Plan. The monitoring program will be developed in conjunction with regulatory agencies and the KIA, and will assess the effectiveness of the offsetting activities over time in reference to specific performance objectives. These performance objectives may include:

- stability of constructed habitat;
- primary productivity;
- benthic invertebrate community;
- fish presence/habitat use; and
- local density or population size estimated for fish species.

Adaptive Management

The need for any corrective actions to on-site emission management or installation of additional control measures will be determined on a case-by-case basis. Triggers for developing adaptive management measures may include:

- non-compliance results from the Surveillance Network Monitoring Program;
- adverse effects on fish/aquatic habitat as suggested by AEMP results; and
- adverse results from the Fish Offsetting Monitoring Program.

6.9 PROPOSED MONITORING PROGRAMS

6.9.1 Aquatic Effects Monitoring Plan

The AEMP will monitor various aspects of the freshwater environment, including:

- monitoring a network of lakes and streams in and around the Goose Property Area at locations potentially affected by the Project and at reference areas well away from Project activities;
- monitoring lake and stream water quality, sediment quality, and aquatic biology;
- monitoring fish populations and fish tissues; and
- if effluent (as defined in the MMER, SOR/2002-222) is discharged to the environment, then additional sampling for MMER requirements will be conducted (effluent characterization; acute toxicity testing; site characterization studies [including surface hydrology]; sublethal toxicity testing).

6.9.2 Fish Offsetting Plan

The Fish Offsetting Plan will address all potential serious harm to CRA fish by creating compensatory fish habitat elsewhere in the landscape. The monitoring of fish offsetting may include estimating the potential benefits of the offsetting option to fisheries production (as a surrogate of fisheries productivity), changes in migration success and changes in the biomass of adult Arctic Char in Nulahugyuk Creek. It is also predicted that gains in biomass at Bernard Harbour will exceed all losses in fisheries production resulting from Project activity.

6.10 IMPACT STATEMENT FOR FISH/AQUATIC HABITAT

The VEC freshwater fish/aquatic habitat comprises both the physical habitat and the biological resources that are necessary for the productivity of fisheries species. This chapter evaluates the *direct* effects of Project activities on the physical habitat of fish. Project activities can only affect the biological resources of fish (primary and secondary producers) through *indirect* trophic-level interactions stemming from changes to freshwater water and sediment quality. The effects assessment of Project activities on the VECs freshwater water quality and sediment quality is completed in separate chapters (Volume 6, Chapters 4 and 5).

The VEC freshwater fish/aquatic habitat may be affected by Project activities in two ways: 1) serious harm occurring through a loss or reduction of fish habitat by permanent alteration or destruction (PAD); or 2) through changes to water and sediment quality arising from the deposition of deleterious substances. PADs occur whenever there is loss or damage of fish habitat through encroachment of infrastructure or water withdrawal. The direct loss of fish bearing habitat will amount to 83 ha due to the placement of pits, water management structures (e.g. Saline Storage Pond), waste rock storage areas, a tailing storage facility, water intake and discharge pipes, and road crossings. This equates to approximately 11.5% of the fish bearing habitat within the PDA, 1.2% of the Goose Property LSA and 0.09% of the freshwater RSA. Fish bearing habitat losses are predicted to occur in the Llama Watershed (Llama Lake, Umwelt Lake, associated streams and three ponds), the Goose Watershed (Goose Inflow East and seven associated ponds), the Wolf Watershed (538 m of Rascal Stream East, Goose Inflow East, eight Ponds, and a culvert at Gander Pond Outflow) and the placement of intake/ discharge pipes in

Goose Lake and an intake pipe in Big Lake. Water withdrawal from Goose and Big lakes also has the potential to affect freshwater fish/aquatic habitat through a decrease in the amount and suitability of overwintering habitat available for fish, or by potentially exposing overwintering eggs to air.

As a result of mitigation, management, and balancing all fish bearing habitat losses with the Fish Offsetting Plan, there are no residual effects anticipated on the VEC freshwater fish/aquatic habitat due to Project infrastructure. The primary mitigation measures are setting maximum limits to water withdrawal to protect sensitive fish habitat and siting Project infrastructure to avoid fish-bearing water.

As no Project residual effects are anticipated, there are no potential residual effects that could act cumulatively with other project potential effects. Therefore no cumulative effects or transboundary effects are expected on the VEC freshwater fish/aquatic habitat.

7. Freshwater Fish Community

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7. Freshwater Fish Community

7.1 EXISTING ENVIRONMENT AND BASELINE INFORMATION

7.1.1 Overview and Regional Setting

The Back River Project (the Project) is located in western Nunavut in the continuous permafrost zone of the continental Canadian Arctic. The Project is composed of two main areas, the Goose Property Area and the Marine Laydown Area (MLA), which will be connected by winter ice roads (Figure 7.1-1). The majority of proposed infrastructure at the Goose Property lies within the regional Ellis River Watershed, which flows to the north and enters the Queen Maud Gulf (see Federal Watershed map in Chapter 1 of this Volume). The Back River Watershed lies to the south and east of the majority of proposed infrastructure and flows to the east eventually entering the Arctic Ocean south of Gjoa Haven. Fish distribution in the Goose Property Area is typical of inland, headwater regions of the Canadian Arctic. Lake Trout (*Salvelinus namaycush*), Round Whitefish (*Prosopium cylindraceum*), Arctic Grayling (*Thymallus arcticus*), Slimy Sculpin (*Cottus cognatus*), and Ninespine Stickleback (*Pungitius pungitius*) are the dominant freshwater fish species in the Project area. Other species reported in the study area include Burbot (*Lota lota*) and Lake Whitefish (*Coregonus clupeaformis*). No Arctic Char (*Salvelinus alpinus*) have been captured at the Goose Property; however, they have been captured nearer Bathurst Inlet approximately 76 km to the north. Table 7.1-1 presents a summary of the life history periodicity of species captured within the Back River Project Area.

Lake Trout spawn in lakes over cobble and rubble substrates at depths of less than 12.2 m in the fall (Scott and Crossman 1973). Eggs and alevins remain in the substrate for several months, with hatching occurring around June. Consequently, to avoid mortality, Lake Trout lay eggs at a depth deep enough to avoid freezing in winter (ice can reach depths of up to 2 m). Juvenile Lake Trout generally remain in shallow water and may briefly venture into streams, while adult Lake Trout generally remain in lakes, utilizing deep water habitat. Exceptions occur in larger rivers, where Lake Trout may be found in large, deep pools that do not freeze in winter, and at deep river mouths (KIA 2012). Lake trout are generally apex predators with a diverse diet ranging from zooplankton to fish to small mammals (Scott and Crossman 1973).

Round Whitefish are also lake spawners and lay their eggs in the fall over gravel substrates, often near river mouths (Scott and Crossman 1973). Some populations may undergo a spawning migration to reach preferred spawning grounds. Hatching occurs in the spring and juvenile and adults generally live in lakes, although they may also be found in streams, rivers, and brackish water. They are an important food source for Lake Trout. Round whitefish are primarily bottom-feeders, with diets composed of benthic invertebrate, fish eggs, and small molluscs (Scott and Crossman 1973).

Arctic Grayling spawn in the spring, usually in small streams around the period of ice break-up (Scott and Crossman 1973). Grayling generally prefer to spawn over gravel or coarse sand substrates; however, they have been observed to spawn over substrates ranging from mud to boulder (Bishop 1971; Hubert et al. 1985). Some Inuit reported that grayling spawn over shallow boulder fields (KIA 2012). Once spawning is complete, adults migrate back to lakes and larger rivers while juveniles remain in small streams to rear. Overwintering occurs in lakes and larger rivers that do not freeze to the bottom (Scott and Crossman 1973). Juvenile grayling feed mainly on zooplankton, switching to aquatic insects as they grow. Adults consume mainly aquatic insects, but may also feed on small fish, fish eggs, and zooplankton (Scott and Crossman 1973). Ninespine Stickleback are summer spawners, and usually use shallow waters with fine or mud substrates and aquatic vegetation for spawning (Scott and Crossman 1973). Sticklebacks may occupy a variety of habitats, including small streams and deep lakes. They are an important food source for Lake Trout. Stickleback feed primarily on small aquatic insects and plankton (Scott and Crossman 1973).

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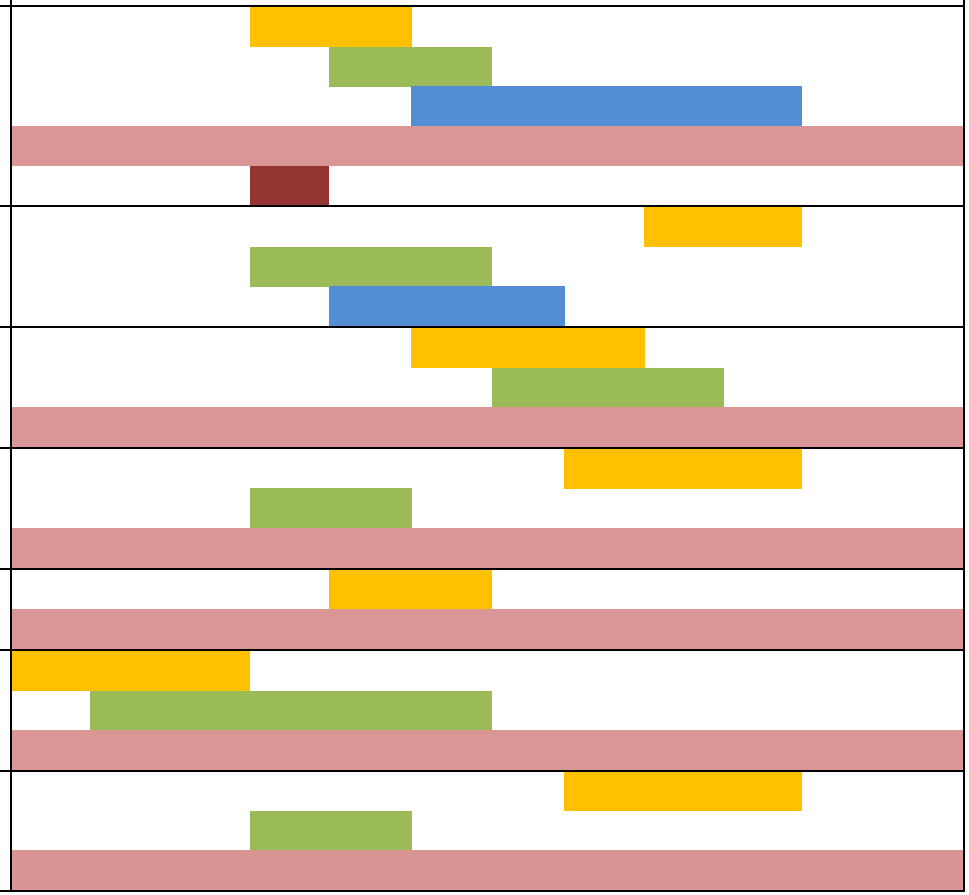
Figure 7.1-1

Project Location

Table 7.1-1. Life History Periodicity of Fish Species in the Back River Project Area

Species	Life stage	Habitat	Month
			Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Arctic Grayling	Spawning	Streams/Rivers	
	Hatching	Streams/Rivers	
	Fry rearing/migration	Streams/Rivers	
	Rearing/overwintering	Rivers/Lakes	
	Adult migration	Streams/Rivers	
Lake Trout	Spawning	Lakes	
	Hatching	Lakes	
	Fry emergence	Lakes	
Ninespine Stickleback	Spawning	Streams/Lakes	
	Hatching	Streams/Lakes	
	Rearing/overwintering	Streams/Lakes	
Round Whitefish	Spawning	Lakes	
	Hatching	Lakes	
	Rearing/overwintering	Lakes	
Slimy Sculpin	Spawning	Streams/Lakes*	
	Rearing/overwintering	Streams/Lakes*	
Burbot	Spawning	Lakes/Rivers	
	Hatching	Lakes/Rivers	
	Rearing/overwintering	Lakes	
Lake Whitefish	Spawning	Lakes	
	Hatching	Lakes	
	Rearing/overwintering	Lakes	



Information compiled from Scott and Crossman (1973) and from field observations.
** Very little is known about the life history of the Slimy Sculpin in the Arctic.*

Slimy Sculpin are also summer spawners (Scott and Crossman 1973); however, little is known about their habitat use and habits throughout the Arctic. They appear to be ubiquitous throughout the Project area, occupying a variety of habitat types in lakes, ponds, and streams. Slimy sculpin are bottom-feeders, with a diet composed mainly of aquatic insects and other benthic invertebrates (Scott and Crossman 1973).

Burbot generally inhabit deep waters in lakes; however, they migrate into the shallow littoral zones to spawn in the winter (Scott and Crossman 1973). Burbot in northern Canada often spend the early summer feeding in river channels, along lake shorelines, and sometimes in weedy tributary streams. By July, most Burbot have returned to the deepest portions of the lakes. Adult Burbot are apex predators, with a diet similar Lake Trout (Scott and Crossman 1973; Cott, Johnston, and Gunn 2011). Juvenile Burbot feed on aquatic insects and crustaceans, while adults feed primarily on fish (Scott and Crossman 1973).

Lake Whitefish are fall spawners. Eggs are typically deposited randomly in shallow waters at depths of less than 8 m. In early spring eggs hatch and larvae form aggregations along steep shorelines. Young lake whitefish move to deeper, cooler, waters by early summer. Adults follow a similar pattern, moving to shoals in the spring to feed and back to deep water as warming occur. Classified primarily as bottom feeders, Lake Whitefish typically feed on a wide variety of benthic invertebrates, planktonic crustaceans, and small fish, however, have been known to also eat insects at the surface of the water (Scott and Crossman 1973).

7.1.2 Regulatory Framework

7.1.2.1 The Fisheries Act

Fish and fish habitat are protected under the *Fisheries Act* (1985), as well as other federal regulatory acts and principles. In 2012, the *Fisheries Act* was amended to establish into legislation the federal government's direction to focus efforts on protecting the productivity of commercial, recreational, and Aboriginal fisheries (CRA fisheries); to institute enhanced compliance and protection tools that are more easily enforceable; to provide clarity, certainty, and consistency of regulatory requirements; and to enable enhanced partnerships with stakeholders.

The changes to the *Fisheries Act* include a prohibition against causing serious harm to fish that are part of or support a CRA fishery (*Fisheries Act* Section 35), provisions for flow and passage (*Fisheries Act* Sections 20 and 21), and a framework for regulatory decision-making (*Fisheries Act* Sections 6 and 6.1).

The new Purpose section states that the fisheries protection provisions of the *Fisheries Act* aim to provide for the sustainability and ongoing productivity of CRA fisheries.

The four factors in Section 6 and 6.1 to be taken into account by the Minister in decision-making (e.g., issuing authorizations) or making regulations are:

- the contribution of the relevant fish to the ongoing productivity of CRA fisheries;
- fisheries management objectives;
- whether there are measures and standards to avoid, mitigate, or offset serious harm to fish that are part of a CRA fishery; and
- the public interest.

For the purposes of the *Fisheries Act*, serious harm to fish includes the death of fish or any permanent alteration to, or destruction of, fish habitat (PAD). The *Fisheries Act* defines fish habitat as "spawning grounds and any other areas, including nursery, rearing, food supply, and migration areas, on which fish depend directly or indirectly in order to carry out their life processes." The term "fish" includes parts of fish; shellfish, crustaceans, marine animals, and any parts of shellfish, crustaceans, or marine animals; and the eggs, sperm, larvae, spat, and juvenile stages of fish, shellfish, crustaceans, and marine animals.

On November 1, 2013, The Fisheries Protection Policy Statement (DFO 2013a) was issued and replaced the earlier Policy for the Management of Fish Habitat (DFO 1986). Although the new policy statement does not include the "no net loss" principle, as outlined in the earlier policy, application of this NNL principle provides some useful guidance when considering "serious harm to fish". In addition, the direction found within the 2013 scientific guidance document (Koops et al. 2013; Randall et al. 2013) has been consulted and followed.

Any project or activity that causes serious harm to fish that are part of, or support, a CRA fishery requires an authorization from DFO. Regulations have been developed to guide the application for this authorization: Applications for Authorization under Paragraph 35(2)(b) of the *Fisheries Act* Regulations. DFO has issued additional guidance in "The Fisheries Protection Program Operational Approach".

7.1.2.2 Metal Mining Effluent Regulations

In 1996, Environment Canada undertook an assessment of the aquatic effects of mining in Canada. This assessment provided recommendations regarding the review and amendments of the Metal Mining Liquid Effluent Regulations, currently titled the Metal Mining Effluent Regulations (MMER; SOR/2002-222), and the design of a national Environmental Effects Monitoring (EEM) program for metal mining. The MMER, under the *Fisheries Act*, instruct metal mines to conduct EEM as a condition governing the authority to deposit effluent (MMER, Part 2, section 7).

The MMER (SOR/2002-222) permit the deposition of mine effluent into water containing fish if the effluent pH is within a defined range, if the concentrations of the MMER deleterious substances in the effluent do not exceed authorized limits, and if the effluent is demonstrated to be non-acutely lethal to Rainbow Trout (*Oncorhynchus mykiss*). These discharge limits were established to be minimum national standards based on best available technology economically achievable at the time that the MMER were promulgated. To assess the adequacy of the effluent regulations for protecting the aquatic environment, the MMER include EEM requirements to evaluate the potential effects of effluents on fish, fish habitat, and the use of fisheries resources.

Regulations Amending the MMER were published in the Canada Gazette, Part II, in October 2006 (Canada Gazette 2006). The purpose of these amendments was to clarify the regulatory requirements by addressing matters related to the interpretation and clarity of the regulatory text that had emerged from the implementation of the Regulations.

Additional amendments to the MMER were published in the Canada Gazette, Part II, in March 2012 (Canada Gazette 2012). The following changes were made to improve the EEM provisions of the MMER:

- modifications to the definition of an "effect on fish tissue" in order to be consistent with the Health Canada fish consumption guidelines and to clarify that the concentration of total mercury in tissue of fish from the exposure area must be statistically different from and higher than its concentration in fish tissue from the reference area;

- addition of selenium and electrical conductivity to the list of parameters required for effluent characterization and water quality monitoring;
- exemption for mines, other than uranium mines, from monitoring radium 226 as part of the water quality monitoring, if 10 consecutive test results showed that radium 226 levels are less than 10% of the authorized monthly mean concentration (subsection 13(2) of the Regulations; SOR/2002-222);
- change to the time frame for the submission of interpretative reports for mines with effects on the fish population, fish tissue, and benthic invertebrate community from 24 to 36 months;
- change to the time frame for the submission of interpretative reports for magnitude and geographic extent of effects, and for investigation of cause of effects, from 24 to 36 months; and
- minor changes to the wording for consistency within Schedule 5.

7.1.3 Proximity to Designated Environmental Areas

No existing parks or conservation areas are located near the proposed Project. The nearest conservation area is the Queen Maud Gulf Migratory Bird Sanctuary approximately 100 km east of Bathurst Inlet on the far side of the Kent Peninsula. The Draft Nunavut Land Use Plan (Nunavut Planning Commission 2012, 2014) has no designated environmental areas within the RSA, and the proposed Project resides within the area designated as a High Mineral Potential area. The proposed Hiukitak River Cultural Area is on the eastern shore of Bathurst Inlet outside of the RSA, and is located approximately 60 km northeast of the proposed Marine Laydown Area (MLA). A key bird habitat site has been identified in the north end of Bathurst Inlet, approximately 150 km to the north of the proposed MLA. The Back River is currently the only waterbody within the RSA to be considered as a heritage river. While no formal nomination for the Back River has been put forward thus far, the Project has been designed to avoid impacts to the Back River water system.

7.1.4 Baseline Study Area

Freshwater fish community baseline studies were undertaken annually between 2010 and 2015 in the Back River Project area. Figures 7.1-2 and 7.1-3 show the Goose Property Local Study Area (LSA), along with waterbodies where baseline fish community information is available.

7.1.5 Baseline Studies

7.1.5.1 Information Sources

Data used for the assessment of potential effects on fish community were collected from various data sources. The primary data sources were baseline studies conducted by Rescan between 2010 and 2014 in the Goose Property (Appendices V6-6A to V6-6E; Rescan 2010, 2012a, 2012c, 2014b, 2014a). Fish community studies were also undertaken in 2015, and results from these studies will be available in the future (Rescan 2015c). The following provides a summary of the 2010 to 2015 available baseline data:

<u>2010 Baseline Studies</u>

Fish and Fish Habitat Baseline (Rescan 2010, Appendix V6-6A):

- Characterize fish communities in Umwelt, Llama, and Reference B lakes using gillnetting, minnow trapping, and hydroacoustic methods; and
- Estimate absolute and relative abundances for each fish species in Llama and Umwelt Lakes.

Goose PDA = 5,427 ha
Goose Infrastructure Footprint = 560 ha

Survey Location
Hydroacoustic
Fish Community
Tissue Metals (Slimy Sculpin)
Tissue Metals (Lake Trout)
Existing Exploration Camp
Winter Road
Proposed Infrastructure
Potential Development Area (PDA)

Inuit Owned Land

Surface and Subsurface Rights
Sub-watershed Boundary
Flow Direction

1:90,000

0 2 4
Kilometres

Projection: NAD 1983 UTM Zone 13N

415050 420050 425050 430050 435050 440050 445050

7275500 7270500 7265500 7260500

Chair Watershed
Giraffe Watershed
Pond E
Pond D
Wasp Lake
Chair Lake
Pond B
Pond A1
Pond C
Giraffe Lake
Leaf Lake
Tahikafalok Nahik (Propeller Lake)
Propeller Watershed
Swan Lake
Llama Pond 2
Llama Pond 1
Pond A
Llama Pond 3
Mam Lake
Pond 2
Goose Watershed
Stony Pond
Goose OF
Llama Lake
Umwelt Pond 3
Goose Lake
Pond 26
Pond 28
Pond 27
Pond 25
Pond 21
Pond 20
Pond 11
Pond 24
Pond 12
Pond 23
Pond 22
Goose Inflow East
Pond 10
Pond 9
Pond 7
Goose Inflow South
Pond 8
Umwelt Lake
Pond 1
Swan Watershed
Gander Pond
Rascal Stream West
Rascal Stream East
Echo Pond 2
Echo Pond 1
Echo Outflow
Pond 4
Llama Watershed
Moby Watershed
Big Lake
Echo Lake
Pond G
Pond F
Pond 6
Moby Lake
Moby Creek
Big Watershed
Pond 19 OF
Fox Lake
Pond K
Pond H
Pond L
Pond J
Pond I
Rascal Lake
Pond 13
Rabbit Lake
Pond 19
Wolf Lake
Wolf Watershed
Del River
Del Lake
Del Watershed
Reference B Watershed
Reference B Lake
RefB OF
Hanningayuk (Beechey Lake)
IOL
CROWN LAND

N

Kilogiktok (Bathurst Inlet, Southern Arm)
Kingaok (Bathurst Inlet)
Marine Laydown Area
Kiligiktokmik (Bathurst Inlet)
Main Map
Goose Property Area
1:2,000,000

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Figure 7.1-2

Sabina GOLD & SILVER CORP.

Lake/Pond Fish Community Baseline Data (2010 to 2015), Goose Property Area

Rescan an ERM company

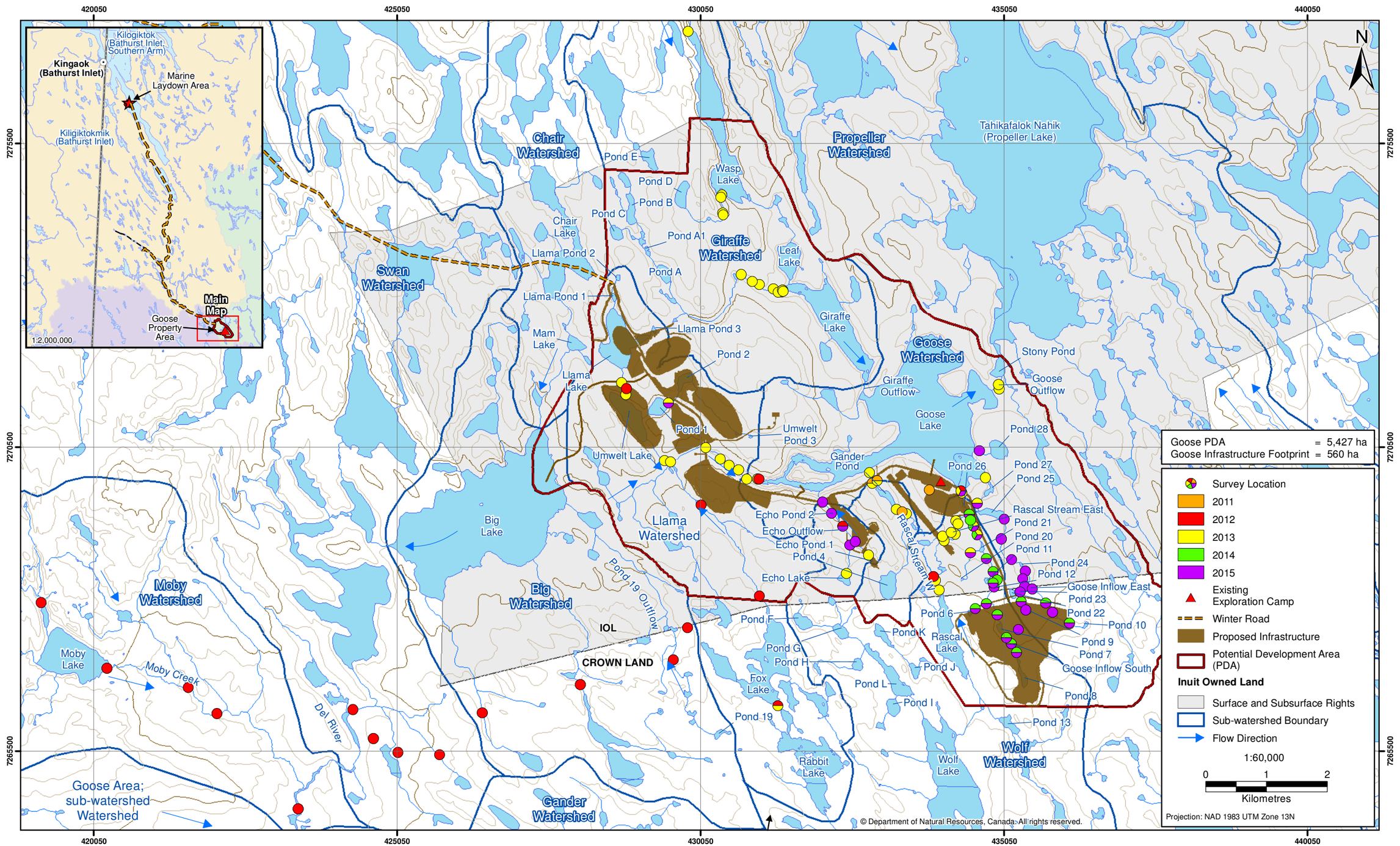

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Figure 7.1-3

Stream Fish Community Baseline Data (2011 to 2015), Goose Property Area

Rescan an ERM company

2011 Baseline Studies

Fish and Fish Habitat Baseline (Rescan 2012a, Appendix V6-6B):

- Characterize fish communities in Umwelt, Llama, Reference B, and Goose Lakes in terms of species composition, relative abundance, and other biological variables; and
- Collect detailed biological data, including tissue metal samples, on Lake Trout and/or Round Whitefish from Goose, Umwelt, Llama, and Reference B Lakes.

2012 Baseline Studies

Fish and Fish Habitat Baseline (Rescan 2012c, Appendix V6-6C):

- Assess fish presence at stream crossings associated with potential site roads;
- Assess fish community composition and habitat in lakes and streams in and around the proposed mine; and
- Collect baseline tissue metal samples and stomach content samples from Goose, Llama, Umwelt, and Gander Lakes.

2013 Baseline Studies

Fish and Fish Habitat Baseline (Rescan 2014a, Appendix V6-6D):

- Collect baseline fish community and habitat information in lakes and streams in and around the proposed mine;
- Collect tissue metal data from fish in Goose, Reference B, and Propeller Lakes using Lake Trout tissue plug and Slimy Sculpin whole body analyses;
- Confirm fish-bearing status in ponds and streams adjacent to proposed infrastructure;
- Conduct spawning surveys and fry surveys on Rascal-Goose Stream to confirm population size and high quality habitat locations; and,
- Conduct fish community surveys at proposed stream crossings along site roads.

2014 Baseline Studies

Fish and Fish Habitat Assessment of the Tailings Impoundment Area Alternative Site (Rescan 2014b, Appendix V6-6E):

- Collect baseline fish community and habitat information in ponds and streams underneath and downstream of the proposed Tailings Storage Facility (TSF).

2015 Baseline Studies

Fish and Fish Habitat Baseline (Rescan 2015c, Table 7.1-2):

- Collect an additional year of baseline data in ponds and streams underneath and downstream of the proposed Tailings Storage Facility (TSF);
- Sample lakes, ponds, and streams in the Echo, Llama, and Goose watersheds; and
- Collect tissue metal data from fish in Propeller Lake and from Goose Inflow East (GIE) downstream of the proposed TSF.

Table 7.1-2. Summary of Lakes Where Fish Sampling Occurred, 1990 to 2015

Waterbody	Norecol (1997)	Golder (2007)	Rescan (2010)	Rescan (2012a)	Rescan (2012b)	Rescan (2014a)	Rescan (2014b)	Rescan (2015)
Goose Property								
Goose Lake	X	X		X	X	X		
Llama Lake			X	X	X			
Umwelt Lake			X	X	X			
Reference B Lake			X	X	X	X		
Big Lake	X				X			
Fox Lake					X			
Rabbit Lake					X			
Rascal Lake					X			
Swan Lake					X			
Pond 19					X			
Gander Pond				X				
Giraffe Lake						X		
Wasp Lake						X		
Echo Lake				X		X		
Propeller Lake						X		
Pond 1				X		X		X
Pond 2				X				X
Pond 3				X				
Pond 4				X				X
Pond 6							X	X
Pond 7							X	X
Pond 8							X	X
Pond 9							X	X
Pond 10							X	X
Pond 11							X	X
Pond 12							X	X
Pond 13							X	
Pond 20								X
Pond 21								X
Pond 22								X
Pond 23								X
Pond 24								X
Pond 25								X
Pond 26								X
Pond 27								X
Pond 28								X
Pond A				X		X		
Pond A1				X		X		
Pond A2						X		

(continued)

Table 7.1-2. Summary of Lakes Where Fish Sampling Occurred, 1990 to 2015 (completed)

Waterbody	Norecol (1997)	Golder (2007)	Rescan (2010)	Rescan (2012a)	Rescan (2012b)	Rescan (2014a)	Rescan (2014b)	Rescan (2015)
Pond A3						X		
Pond B				X				
Pond C				X				
Pond D				X		X		
Pond E				X				
Pond F				X				
Pond G				X				
Pond H				X				
Pond I				X				
Pond J				X				
Pond K				X				
Pond L				X				

Historical Information

Historical data from studies conducted in the Back River Project region between 1990 and 2007 were used to supplement baseline information and to give a more complete assessment. These studies included:

Back River Project: Environmental Baseline Studies, September 2006 (Golder Associates Ltd. 2007).

- Focused sampling on George Lake, but Goose Lake was also sampled. Lake sampling was conducted by gillnetting and minnow trapping. Stream sampling via electrofishing was conducted on the Goose Lake outflow stream.

George Lake Project: 1997 Data (Norecol Dames and Moore 1997):

- Conducted fish habitat assessments on Goose Lake and Big Lake in 1996 near the current Goose Property. This included basic assessments of habitat quality on tributary streams and ponds surrounding both lakes. Additionally, they collected periphyton from three streams and benthos from the two lakes. Periphyton taxonomy data are missing but biomass data are available, and benthos data is limited to summed data and species lists.

In addition to these reports, traditional knowledge on fish species, fish distributions, and Inuit fishing areas were incorporated; see Section 7.2 for details.

7.1.5.2 Baseline Study Methods

Fish Sampling – Lakes and Ponds

Fish population studies varied in scope among waterbodies and years, with the most intensive sampling occurring in Llama, Umwelt, Goose, and Reference B lakes in the Goose Property. Fish populations in lakes were sampled using gillnets, minnow traps, beach seines, and by electrofishing. Catch-per-unit-effort (CPUE) was used as an indicator of fish density within lakes and relative abundance among lakes for each sampling method employed. Hydroacoustic methods were used on Llama and Umwelt Lakes to estimate fish population size and distribution. All fish surveys included analyses of fish population characteristics, as well as the size, condition, and age of the fish.

Tissue metal samples were collected from Lake Trout and Round Whitefish from selected lakes in the Goose Property, as well as from reference waterbodies, in 2011, 2012 and 2013. Additional samples were collected from Propeller Lake in 2015 (Rescan 2015c). Figure 7.1-2 shows the locations where fish sampling was done in lakes during baseline studies between 2010 and 2015.

Fish Sampling - Streams

Eighty-one stream sites on the Goose Property were sampled between 2011 and 2015 by electrofishing and visual observation. The primary objective of fish sampling in these streams was to determine presence/absence and species composition. CPUE was used as an indicator of fish density within streams and relative abundance among streams for each sampling method employed. Stream fish surveys included analyses of fish size, condition, and age. Figures 7.1-3 shows the locations where stream fish sampling was conducted during baseline studies between 2011 and 2015.

Fish Tissue Metals

Tissue metal samples were collected in 2011 and 2012 from Lake Trout and Round Whitefish, and in 2013 from Lake Trout and Slimy Sculpin from selected lakes in the Goose Property (Table 7.1-3). In 2011 and 2012, all fish tissue analysis was conducted on fillets collected from whole, sacrificed fish; while in 2013, tissue analysis was conducted on tissue plugs from live Lake Trout and on whole body samples of Slimy Sculpin. The change in species was meant to facilitate future non-lethal sampling of Lake Trout and to establish a small-bodied, sedentary species (Slimy Sculpin) as a sentinel for future monitoring.

Table 7.1-3. Summary of Tissue Metal Samples and Locations, 2011 to 2013

Year	2011		2012		2013	
Species	Lake Trout	Round Whitefish	Lake Trout	Round Whitefish	Lake Trout	Slimy Sculpin
Sample Method	Fillet	Fillet	Fillet	Fillet	Tissue plug	Whole body
Sample Locations	Goose LSA	Goose LSA	Goose LSA	Goose LSA	Goose LSA	Goose LSA
	Goose Lake	Umwelt Lake	Goose Lake	Llama Lake	Giraffe Lake	Goose Lake
	Llama Lake	Reference B Lake	Llama Lake	Reference B Lake		Propeller Lake
	Reference B Lake		Reference B Lake	Del Lake		Giraffe Lake
			Umwelt Lake			Reference B Lake

Note: additional tissue metal samples were collected from Propeller Lake and Goose Inflow East in 2015.

Lake Trout and Round Whitefish collected for tissue sampling in 2011 and 2012 were filleted, and the bones and skin were removed. Fillets were placed in sterile Whirl-Pak bags and frozen. In 2013, dermal punches were used to obtain tissue samples from Lake Trout without the need for sacrificing fish. Two to three dermal punches were taken from each fish, placed in sterile Whirl-Pak bags, and flash-frozen on dry ice to preserve moisture. Slimy Sculpin were collected, sacrificed, and frozen as whole-body samples due to their size. All tissue samples were sent to ALS Environmental Services in Burnaby, BC for analysis.

In the lab, tissue samples were homogenized and sub-sampled prior to hotblock digestion with nitric and hydrochloric acids, in combination with repeated additions of hydrogen peroxide. Analysis was by Inductively Coupled Plasma – Mass Spectrometry (ICPMS). Mercury concentrations were analyzed by atomic fluorescence spectrophotometry.

7.1.6 Fish Community Setting – Lakes and Ponds

Goose Property

The Goose Property LSA contains seven fish species: Lake Trout, Round Whitefish, Arctic Grayling, Slimy Sculpin, Burbot, Ninespine Stickleback, and Lake Whitefish. Lake Trout tend to dominate the species composition in most lakes in the LSA. Since Lake Trout are fall spawners and must overwinter in lakes, they were most commonly found in lakes with mean depths greater than 4 m. Some shallower lakes and ponds contained higher abundances of Arctic Grayling and Round Whitefish as compared to Lake Trout, particularly Llama Lake, Umwelt Lake and Pond L.

Several shallow ponds were sampled in 2011, 2013, 2014, and 2015 to determine fish distribution. Most of these did not contain any fish (Rescan 2012a, 2014a, 2014b, 2015c), which was attributed to their shallow depths (freezing to bottom) and ephemeral connections to large waterbodies. The most common species captured in ponds was the Ninespine Stickleback (Table 7.1-4). A small number of ponds with greater maximum depths (> 2 m) and/or connectivity to larger bodies of water were found to contain Arctic Grayling. Slimy Sculpin were also occasionally captured. Table 7.1-4 presents the fish species captured in Goose Property lakes and ponds between 1997 and 2015.

Table 7.1-4. Fish Bearing Lakes and Ponds in the Goose Property LSA, 1997 to 2015

Waterbodies Sampled	Species						
	Lake Trout (*Salvelinus namaycush*)	**Round Whitefish** (*Prosopium cylindraceum*)	**Lake Whitefish** (*Coregonus clupeaformis*)	**Arctic Grayling** (*Thymallus arcticus*)	**Burbot** (*Lota lota*)	**Slimy Sculpin** (*Cottus cognatus*)	**Ninespine Stickleback** (*Pungitius pungitius*)
Lakes							
Goose Lake	X[1,3,4,5]	X[1,4,5]	-	X[1,4,5]	X[1]	X[1,4]	X[1,4]
Big Lake	X[1,4]	X[1,4]	X[1]	-	X[1]	X[1]	-
Umwelt Lake	X[4]	X[2,3]	-	X[2]	-	-	-
Llama Lake	X[2,3]	X[2,3]	-	-	-	-	X[2]
Fox Lake	X[4]	X[4]	-	-	-	-	-
Rabbit Lake	X[4]	-	-	X[4]	-	-	X[4]
Moby Lake	X[4]	-	-	-	-	-	X[4]
Rascal Lake	X[4]	-	-	-	-	-	-
Swan Lake	X[4]	X[4]	-	-	-	-	-
Echo Lake	-	-	-	-	-	-	-
Giraffe Lake	X[6]	X[6]	-	-	X[6]	X[6]	X[6]
Propeller Lake	X[6]	X[6]	-	X[6]	X[6]	X[6]	X[6]
Reference B Lake	X[2,3,4,6]	X[2,3,4,6]	-	-	X[6]	X[6]	X[6]
Pond 1	-	-	-	-	-	-	X[3,6,7]
Pond 8	-	-	-	-	-	-	X[7]
Pond 12	-	-	-	-	-	-	X[7]
Pond 21	-	-	-	-	-	-	X[7]
Pond 23	-	-	-	-	-	-	X[7]
Pond 24	-	-	-	-	-	-	X[7]
Pond 25	-	-	-	-	-	-	X[7]

(continued)

Table 7.1-4. Fish Bearing Lakes and Ponds in the Goose Property LSA, 1997 to 2015 (completed)

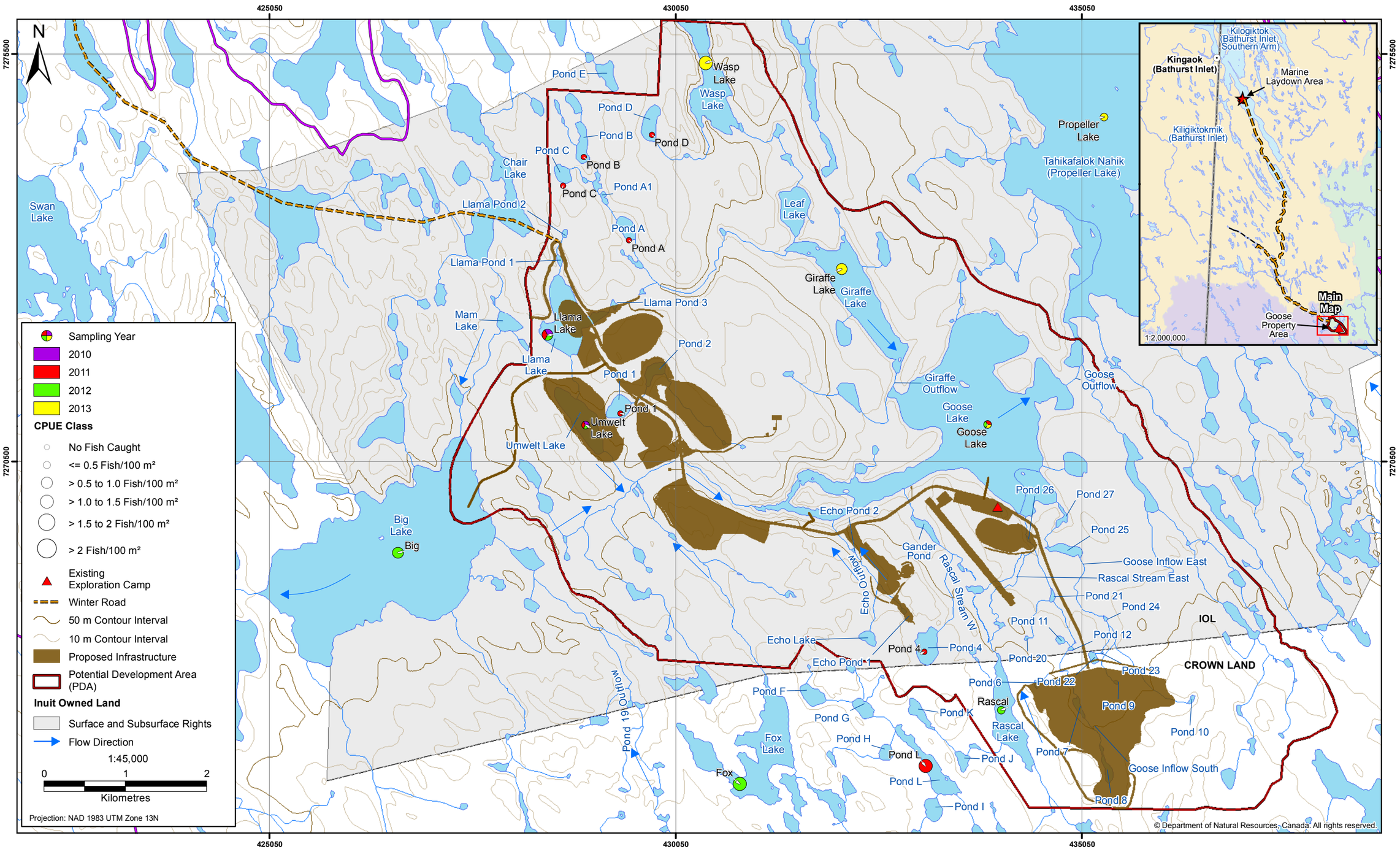
Waterbodies Sampled	Species						
	Lake Trout (*Salvelinus namaycush*)	Round Whitefish (*Prosopium cylindraceum*)	Lake Whitefish (*Coregonus clupeaformis*)	Arctic Grayling (*Thymallus arcticus*)	Burbot (*Lota lota*)	Slimy Sculpin (*Cottus cognatus*)	Ninespine Stickleback (*Pungitius pungitius*)
Pond 27	-	-	-	-	-	-	X[7]
Pond 28	-	-	-	-	-	-	X[7]
Pond "L"	-	-	-	X[3]	-	-	-
Pond "I"	-	-	-	X[3]	-	-	-
Pond "D"	-	-	-	-	-	X[3]	-
Stony Pond	-	-	-	X[7]	-	-	-
Gander Pond	-	-	-	X[7]	X[6]	X[6]	X[6]
26 Ponds*	-	-	-	-	-	-	-

*Dashes indicate that no fish were captured, [1] Hubert and Associates Ltd. (2004), [2] Rescan (2010), [3] Rescan (2012a) [4] Rescan (2012c), [5] Golder Associates Ltd. (2007) , [6] (Rescan 2014a), [7] Rescan (2015c); * the 26 fishless ponds include ponds: 2, 4, 19, A, A1, B, C, E, F, G, H, J, K, Umwelt Pond 3 and 4, Llama Pond 2, and Echo Pond 2; in addition the following ponds were determined fish-bearing but no catch was made: Ponds 6, 7, 9, 11, 12, 22, 26 and Llama Ponds 1 and 3. See figure 7.1-6 for fish-bearing status.*

In general, Lake Trout were the most common species caught in Goose Property lakes, but the relative abundance varied among lakes sampled. Exceptions to this pattern included Umwelt Lake and Pond L, which were generally dominated by Arctic Grayling. The highest abundance of fish (total gillnet CPUE of all species pooled) was recorded in Del Lake while the lowest (excluding ponds) was recorded in Propeller Lake (Figure 7.1-4). The mean CPUE in lakes sampled by gillnet at the Goose Property lakes ranged between 0.06 and 2.33 fish/100 m^2/h.

Mean total CPUE in lakes sampled by beach seine ranged from 0.10 to 6.84 fish/100 m^2 at the Goose Property. No fish were captured by beach seine in Pond 19; however, visual observations of fish confirmed this pond as fish-bearing. The abundance estimate from beach seine (i.e., beach seine CPUE) was the highest in Big Lake and the lowest in Swan Lake (Figure 7.1-5). Differences in relative abundance between capture methods arise because capture efficiency is often compromised by habitat type and quality (e.g., rocky or steep shorelines). The capture rate of beach seines is greatly influenced by habitat type and therefore less accurate than gillnetting when estimating the relative abundance of fish. The overall distribution of fish presence within the Project Area is represented in Figure 7.1-6.

Hydroacoustic gear was used to estimate fish abundance in Llama and Umwelt lakes in 2010. The total number of fish in each lake was estimated at 226 (95% CI 4 to 1,794) and 155 (95% CI 5 to 864), respectively. These estimates are considered to be conservative due to the limitations of using hydroacoustic gear in shallow water. Based on concurrent sampling conducted with gillnets, roughly 78% of the fish in Llama Lake were estimated to be Lake Trout, while 22% were Round Whitefish. Based on the same kind of concurrent sampling, approximately 77% of the fish in Umwelt Lake were estimated to be Arctic Grayling, while the remainder of the fish in that waterbody were presumed to be Round Whitefish. However, variation in species relative abundance was observed when taking into account all sampling years. For example, over all sampling years, Round Whitefish is the dominant species in Llama Lake, accounting for approximately 60% of the total number of fish, whereas Lake Trout make up most of the remaining 40% of individuals.



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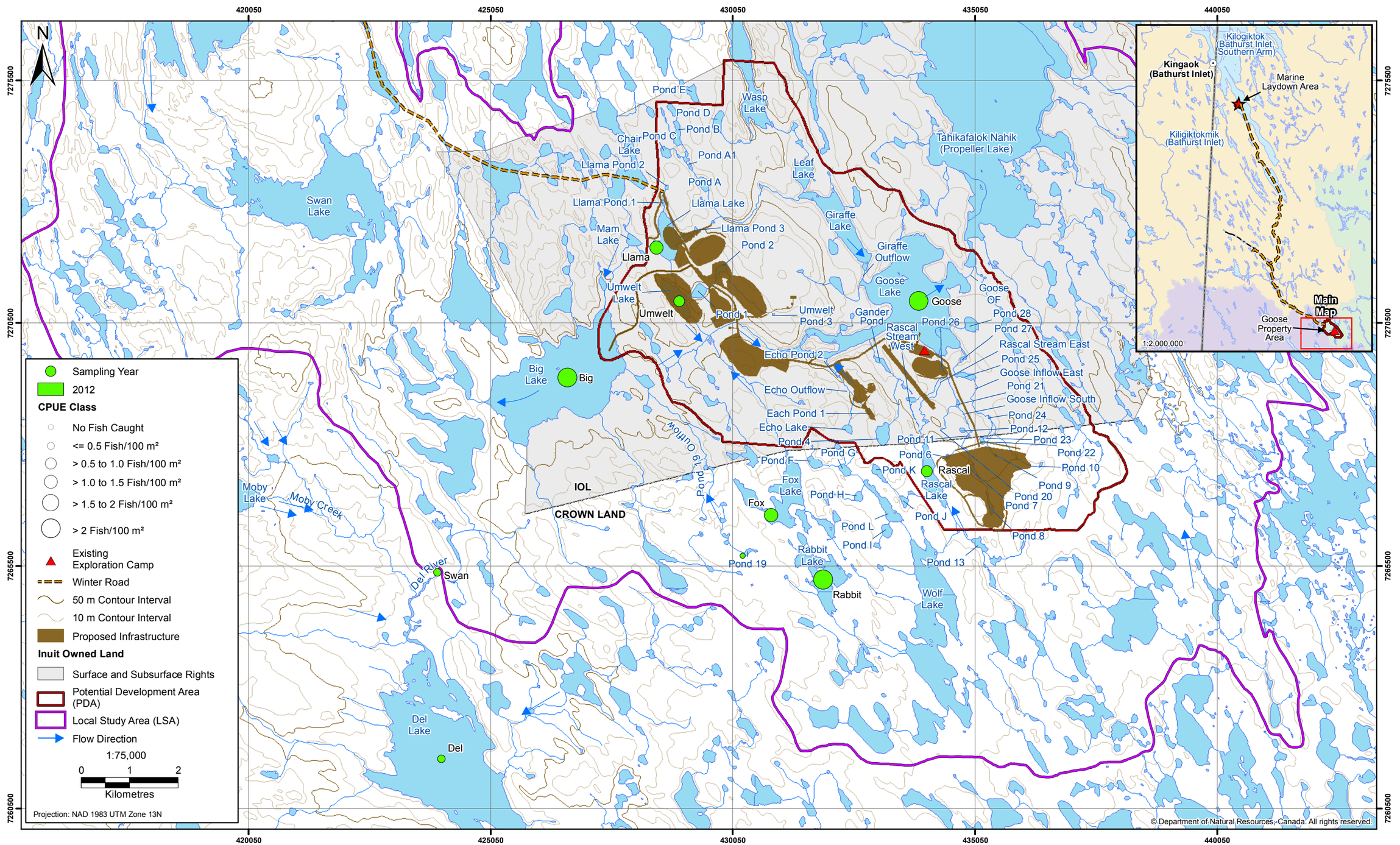
Baseline Relative Abundance by Gillnet
Goose Property Area

Figure 7.1-4

Rescan an ERM company

GIS # **BAC-06-060b**

November 4, 2015



Sabina GOLD & SILVER CORP.

Baseline Relative Abundance by Beach Seine
Goose Property Area

Figure 7.1-5

Rescan an ERM company

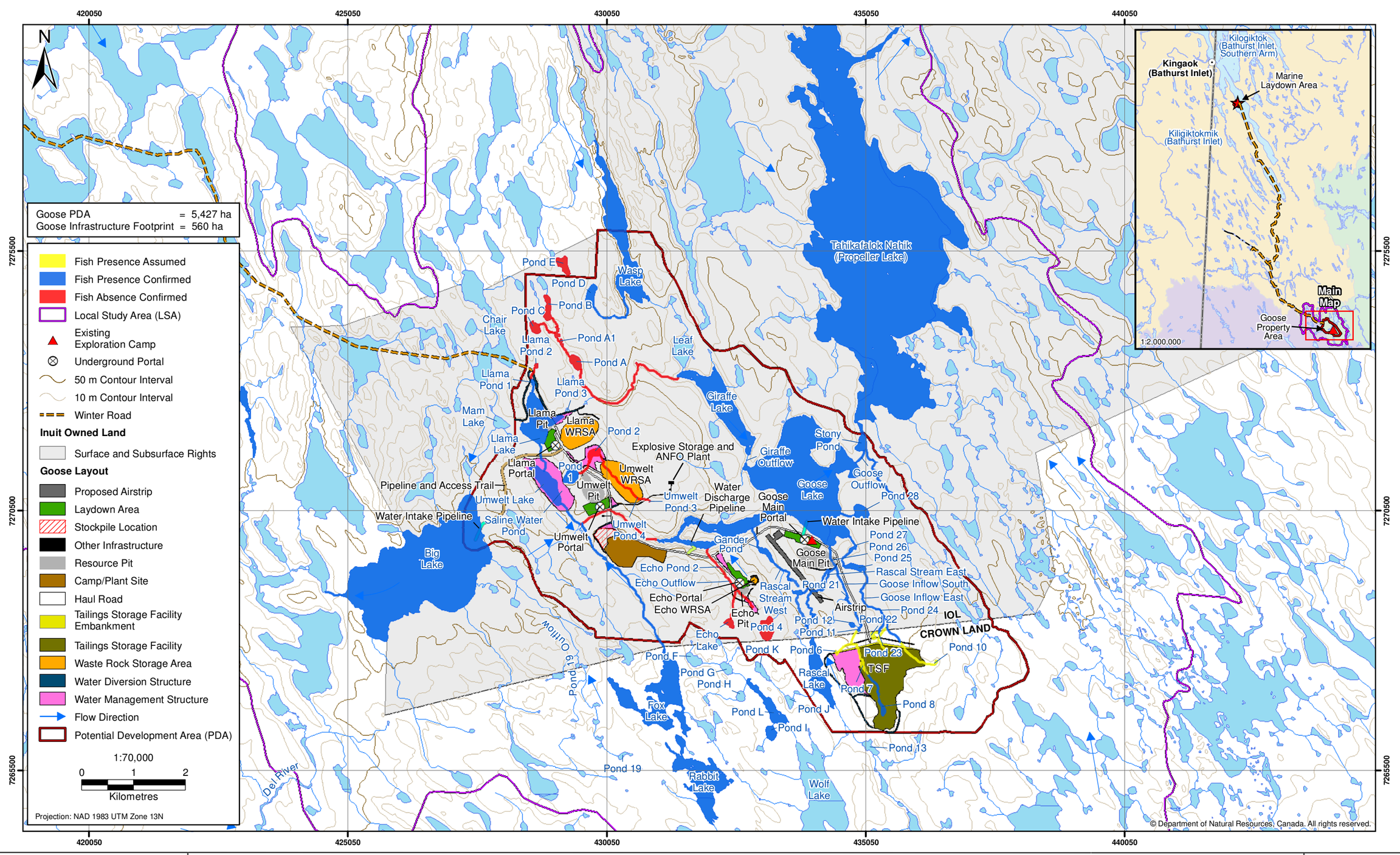


Figure 7.1-6

Fish Bearing Status within the LSA, Goose Property Area

Sabina GOLD & SILVER CORP.

Rescan an ERM company

The mean fork length of Lake Trout captured by gillnet ranged from 332 to 469 mm in the Goose Property. Lake Trout captured in Llama Lake tended to be small in comparison to other lakes, while Lake Trout from Goose Lake tended to be close to the median size for all lakes in the Goose Property. Few Lake Trout were captured in Umwelt Lake. The mean body condition of Lake Trout throughout the LSA ranged from 0.94 to 1.29 g/mm^3; most fish captured had condition factors that fell within the standard range for healthy salmonids (0.9 to 1.1). Lake Trout captured by gillnet ranged in age from 3 to 31 years, with the majority being between 9 and 11 years old. The diet of Lake Trout, as sampled as a snapshot from stomach contents, was dominated by chironomid larvae (bottom-dwelling fly larvae) and cladocerans (zooplankton).

Arctic Grayling captured by gillnet in Umwelt Lake had a mean fork length of 255 mm. The condition factor was similar for all adult grayling captured, ranging from 1.18 to 1.20 g/mm^3. Most of the Arctic Grayling captured by beach seine were juveniles, with mean fork lengths ranging from 45 mm in Umwelt Lake to 66 mm in Goose Lake. Arctic Grayling captured by gillnet ranged in age from 3 to 5 years, while grayling captured by beach seine ranged in age from 1 to 3 years.

Round Whitefish captured by gillnet in the Goose Property had a mean fork length that ranged from 154 to 391 mm, with the largest fish being captured in Reference B Lake, and the smallest in Swan Lake. The mean condition factor of Round Whitefish ranged from 0.79 g/mm^3 to 1.21 g/mm^3, with fish from Umwelt Lake tending to have poorer body condition than fish from other lakes and fish from Llama Lake tending to have higher condition relative to other lakes. Round Whitefish captured by beach seine ranged in age from 1 to 3 years. Whitefish captured by gillnet ranged in age from 3 to 23 years, with most individuals belonging to the 6, 7, or 8 year age class. Round Whitefish diet (stomach contents) was dominated by chironomid larvae.

7.1.7 Fish Community Setting - Streams

Goose Property

In general, Arctic Grayling and Slimy Sculpin were the most abundant species captured in streams, followed by Ninespine Stickleback, Burbot, Round Whitefish, and Lake Trout. The highest abundance of fish (CPUE) caught by electrofishing streams was recorded in the Rascal Stream East (RSE: connecting Rascal Lake to Goose Lake). Three stream sites in the Goose Property were sampled for fish in 2011, 13 sites were sampled in 2012, 16 sites were sampled in 2013, and Goose Inflow East (GIE) and Goose Inflow South (GIS) were sampled in 2014 and 2015. No fish were captured or observed at six of the sites sampled.

Juvenile Arctic Grayling were also observed in several streams late in the summer, including RSE, Rascal Stream West (RSW), GIS, Umwelt Outflow and Fox Outflow. The juvenile grayling were especially abundant around boulder fields, where many were stranded in isolated pools. These observations suggest that boulder fields may act as habitat sinks, resulting in mortality of juveniles when flow conditions are at their lowest. Similar effects have been observed in other streams, where stream flooding and juvenile displacement commonly results in mortality as fish are stranded in unsuitable habitat (Stewart et al. 2007b).

Table 7.1-5 presents a summary of the species captured in streams in the Goose Project area between 2006 and 2015.

Table 7.1-5. Summary of Fish Species Captured in Goose Property Streams, 2006 to 2015

Waterbodies Sampled	Site ID	Species					
		Lake Trout (*Salvelinus namaycush*)	Round Whitefish (*Prosopium cylindraceum*)	Arctic Grayling (*Thymallus arcticus*)	Burbot (*Lota lota*)	Slimy Sculpin (*Cottus cognatus*)	Ninespine Stickleback (*Pungitius pungitius*)
Goose Outflow	N/A	-	-	X[4]	X[3]	X[3,4]	-
Giraffe Inflow	N/A	-	-	-	-	X[4]	-
Wasp Inflow	N/A	-	-	X[4]	-	X[4]	-
Rascal Stream East (Airstrip Stream)	AS-1, AS-2	-	-	X[4]	X[4]	X[1,3,4]	X[4]
Rascal Stream West (Gander Pond outflow and inflow)		-	-	X[5]	X[4]	X[4]	X[4]
Umwelt Outflow	101	-	-	-	-	-	X[4]
Fox Outflow	102, 104	-	-	X[2]	-	X[2]	-
Llama Outflow	103	-	X[2]	X[2,4]	-	X[2,4]	X[4]
Unnamed	108	-	-	X[2]	-	-	-
Pond A Inflow	N/A	-	-	-	-	-	-
Goose Inflow (GIS and GIE)	113	-	X[4]	X[4]	-	X[2,4]	X[2,4]
Reference B Outflow	125	-	-	X[2]	X[2]	-	-
Rascal Outflow	126	-	-	-	-	-	-
Rabbit Outflow	127	-	-	X[2]	-	X[2]	-

Dashes indicate that no fish were captured, [1] Rescan (2012a), [2] Rescan (2012c), [3] Golder Associates Ltd. (2007), [4] Rescan (2014a), [5] Rescan (2015c)

7.1.8 Metals in Fish Tissues

Baseline data on metal concentrations in fish tissues are described below to provide information regarding fish health in Project areas. Fish tissue metal concentration is assessed in the Country Foods chapter (see Volume 8, Chapter 5).

Goose Property

In 2011 and 2012 samples of Lake Trout and Round Whitefish tissues were analyzed from Goose Lake, Llama Lake, Umwelt Lake, and Reference B Lake. Baseline fish tissue metal concentrations are also used in the assessment of Country Foods (see Volume 8, Chapter 5). Mercury concentrations in the tissue of Lake Trout from Goose Property lakes ranged from 0.04 to 0.45 mg/kg wwt, which is lower that the Health Canada guideline of 0.5 mg/kg wwt. This is consistent with results obtained from an earlier study of Goose Lake (Norecol Dames and Moore 1997), in which the Lake Trout inhabiting this waterbody were also found to have tissue concentrations of mercury below 0.5 mg/kg wwt. Norecol Dames and Moore (1997)also analyzed the concentrations of metals in the liver of Lake Trout and found that three trout from Goose Lake had liver concentrations ranging from 0.52 to 0.66 mg/kg wwt, slightly exceeding the Health Canada guideline.

In 2011 and 2012, concentrations of arsenic, selenium, and mercury in Lake Trout tissues differed among lakes. Concentrations of arsenic and selenium were generally higher in Llama Lake than Goose

Lake or Reference B Lake. Concentrations of mercury were generally higher in Goose Lake than in other Goose Property lakes.

In 2011 and 2012, Lake Trout were lethally sampled; however, due to concerns about the long-term impacts of lethal sampling on large-bodied fish populations, lethal sampling of Lake Trout was not repeated in 2013. Instead, non-lethal tissue biopsies were collected from Lake Trout from Giraffe Lake. Lethal tissue samples were collected from (small-bodied) Slimy Sculpin from Giraffe, Goose, Propeller and Reference Lake B lakes.

The concentration of most metals in Lake Trout tissue from Giraffe Lake were below relevant guidelines, with the exception of mercury, in which the baseline average concentration was above the Health Canada Guidelines (guideline value 0.50 mg/kg wwt, mean concentration 0.58 mg/kg wwt).

Mean mercury concentrations for Slimy Sculpin were below the Health Canada Guidelines (guideline value 0.50 mg/kg wwt) at all sites (range from to 0.0405 mg/kg wwt in Propeller Lake to 0.0795 mg/kg wwt in Giraffe Lake). In Giraffe Lake, the higher mercury concentration in Slimy Sculpin coincides with high mercury concentrations in Giraffe Lake Trout, and is likely a result of natural geological variation among the lakes.

In 2015, additional tissue metal samples will be collected from the stream between Pond 25 and 27 (Site CP3), and from near the inflow of Propeller Lake. Data for 2015 will be available in early 2016.

7.2 INCORPORATION OF TRADITIONAL KNOWLEDGE (TK)

The effects assessment relies on the information collected from Inuit-led Traditional Knowledge (TK) information, public scoping, focus group meetings, government engagement, and scientific knowledge. To the extent possible, available TK is incorporated into the evaluation of the potential effects of the Project on the environment. The following reports were reviewed for TK specific information related to Valued Ecosystem Component (VEC) features:

- *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* (KIA 2012) (Appendix V3-3A of FEIS);
- *Naonaiyaotit Traditional Knowledge Project - Hannigayok (Sabina Gold & Silver Corp. Proposed Back River Project). Results from Data Gaps Workshops, Final Report (June 2014)* (KIA 2014) (Appendix V3-3B of FEIS); and
- *Back River Project: Existing and Publically Available Traditional Knowledge from Selected Aboriginal Groups in the Northwest Territories* (Appendix V3-3C of FEIS).

7.2.1 Incorporation of TK for Existing Environment and Baseline Information

Available TK on important fish species and Aboriginal fishery locations was obtained through the Kitikmeot Inuit Association's (KIA's) Naonaiyaotit Traditional Knowledge Project (NTKP) database. This is summarized in the report entitled *Inuit Traditional Knowledge of Sabina Gold & Silver Corporation's Back River (Hannigoyok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP) Report* (KIA 2012).

Maps presented in Figures 30–32 in Chapter 7 of the 2012 *NTKP* report (hereafter, 2012 TK report) indicate that there are no traditional fishing grounds within the LSA. There are important freshwater fishing locations outside the RSA, including Arctic Char (*Salvelinus alpinus)* and Arctic Grayling (*Thymallus arcticus*) fishing in the Western River (*Kilokgiktok*) to the west of the RSA and for Lake Trout (*Salvelinus namaycush*) and Arctic Grayling around Beechey Lake, just south of the RSA.

Pertinent information on Aboriginal fisheries resources was also obtained from Land Use Focus Group Sessions, which were held in November of 2012; these sessions included Inuit hunters and trappers from Kugluktuk, Cambridge Bay, Omingmaktok, and Bathurst Inlet (see Chapter 4, Land Use, in Volume 8: Human Environment). The Focus Group participants from Bathurst Inlet and Omingmaktok described and mapped a contemporary travel route that leads from Bathurst Inlet (community) south past Bathurst Lake and George Lake, down to the Beechey Lake and Goose Lake areas (Figure 4.1-2 in Chapter 4, Volume 8). These participants also indicated that Bathurst Lake, located approximately 20 km west of the RSA, is fished, specifically for Lake Trout. The participants also indicated that hunting and fishing take place along the length of this route, where people may stop to take a break and hunt and/or fish. Focus group participants reported that they stay near Beechey Lake while hunting, trapping, and fishing in the area. Goose Lake, located in the LSA, was also identified as an area where fishing may occur while staying near Beechey Lake. While Goose Lake may be fished by traditional land users, it was not known to be a destination or key location for fishing (Volume 8, Chapter 4).

In the 2012 TK report (KIA 2012), the Inuit note that fish are present throughout the landscape surrounding and including the Project Area. They further note that freshwater fishing primarily takes place in the Back River Watershed, along the Western River, and nearby Bathurst Inlet. Lake Trout are found in lakes throughout the region; however, they are also found in rivers where large, deep pools do not freeze in winter. Whitefish and Lake Cisco are also found in such lakes. Arctic Grayling are fished in several lakes, rivers, and streams in the Back River Watershed and along the Western River. The Inuit observe that Arctic Grayling spawn over shallow boulder fields, and that the juvenile fish are commonly found in shallow, sandy streams (KIA 2012). The following information is included in the TK report:

> *... This river (Hiukkittak) has a really strong current and they used to have a weir back then on it right by this bend (near the mouth). There is also another weir around here. I remember we restored the stones and used that ancient weir for spearing fish...*
>
> *... The fish go further up into the lakes using the rivers. All kinds of fish do this. They also use the same river to go down to the ocean.*
>
> *Sometimes the fish will winter in the lakes because the rivers get too shallow for the fish to go down river. In the spring they start to migrate down river...*
>
> *When the fish went up the river (Arctic Charr fall migration) at Hiukkittak... Inuit speared them or used baskets to scoop them up.*
>
> *... There would be lots of fish at Hiukkittak, Kugyoak and around Kangihoakyok (waters feeding into Kangihoakyok) during the spring. Even in the summer when the fish were ready to go up river, there was lots of fish...*
>
> *Inuit jigged for fish where the fishing was good. They fished in the lakes.... They fished these places using hooks during the spring or winter and sometimes they used nets.*
>
> *... The people from Kingaok and Omingmaktok must know about that river (Hiukkittak). It is really sandy from all the way up here (at the mouth) downstream... People fish the ocean at the mouth of the river. I have nets at Ehokhikhiovik (initial river section of Hiukkittak)... I usually have nets at this place...*
>
> *Inuit fished anywhere in the rivers. They fished the river when the fish were going downriver and upriver, when they needed food. (We fished at Hakvaktok (south coast*

of Melville Sound), Naoyak and Etibliakyok, Kolgayok (Tingmeak River), Kunayok (Ellice River). Hiukkittak, Aniakhiokvik (Fishing Creek), Kingaok, Daniel Moore Bay (Kangihoakyok) and all along the coast of Victoria Island up to Wellington Bay (including Paatlik or Byron Bay)...

These areas (coastal Parry Bay, Etibliakyok (Kent Peninsula isthmus), Kolgayok (Tingmeak River, and an area east of Fishing Creek) are fishing places. They have charr and trout... and cisco whitefish...

Lake trout, charr, whitefish and grayling are found in lakes.

When we were young, the fishing areas were identified by our parents. You should mark that place (mouth of Burnside River (Ayapakpaktokvik)) because people still go there to fish. Our parents taught us these things, even about tomcod fishing.

The lake is where we would have nets in the winter. Inukholik (near Hiukkittak) is where they would set nets in the winter...

... At the rivers (mouth of Hannigayok (Back River) at Beechey Lake and stream on north-central shore of Beechey Lake) they liked to net for fish, for... Lake Trout and whitefish.

They net fish near Kingaok every fall Ayapakpaktokvik (Burnside River). This lake (Ekalokhiokvik (Tahikafalok Lake)) has a small river to the ocean (Aniakhiokvik (Fishing Creek)). That is another area that they mainly fish, I know this because my grandfather liked fishing there...

... Inuit fished along the shore... at Kingaok (northwest of Fishing Creek). Over here at Kingaok (stream leading into and south of Ayapakpaktokvik (Burnside River) near its mouth) Inuit have fished for a long time. That river has charr and whitefish...

... They would jig for fish in the lakes around here (north of Beechey Lake) when they were traveling to see the white people (to the trading post at Kingaok). They jigged for fish in the lakes as they were traveling, when they camped... They fished when they stopped so they could have fresh food, I remember. I was following them that time.

... These parts of the Jakes (narrows)... are called 'kongunik' (pl.) and that is why this is called 'konngok' (sf.). This narrow spot (at the narrows of Hanningayuk (Beechey Lake)) never freezes all winter. That is why they tell Inuit who are traveling to be careful because this narrow spot doesn't freeze. We call those narrow parts of the Jakes 'kongunik'. We know about that konngok where Inuit set fish nets because it doesn't freeze all winter. You have to be careful when you travel through there...

Those rivers where Inuit mostly fish (Ayapakpaktokvik and Hivogahik) and where they hunted the caribou near the mouth of the lakes are important. Some of these areas where they mostly fished during the winter don't freeze that well. These areas sometimes are scary (dangerous places for traveling).

In the fall we used gill nets to catch a lot of fish for the dogs, and for dry fish too. All these places where we had our nets have inokhok or rock pile markers. On our trap

> *Jines too we fished. We did a lot of fishing especially on the days that were stormy. We did a lot of fishing to pass the time...*
>
> *In the Bathurst Inlet area C51 mapped Tagionoak (Goulburn Lake), Swan Lake (Tagionuak), and a lake west of Amagok as good for fishing.*
>
> *This is a good spot for fishing too (at the mouth of Ayappappaktokvik). This long arm in here, it's a good spot for fishing. When I was there in February, it was good, a good fishing spot there...*
>
> *There is a river there as well Kokiviayok. It's small but there are a lot of fish.*

Additional TKon the locations of camps used for fishing, on fish species occurrence and habitat use as well as on the types of fish preferred as food sources by Inuit was obtained through information summarized in the report entitled *Naonaiyaotit Traditional Knowledge Project - Hannigayok (Sabina Gold & Silver Corp. Proposed Back River Project). Results from Data Gaps Workshops, Final Report (June 2014)* (KIA 2014).

Maps presented in Figure 3 in Chapter 4 and Figure 12 in Chapter 11 of the 2014 *NTKP* report (hereafter, 2014 TK report) specifically indicate the presence of Inuit fishing places and important areas for freshwater fish including Arctic Char, Lake Trout, Broad Whitefish (*Coregonus nasus*), Arctic Cisco (*Coregonus autumnalis*) and Arctic Grayling. The maps in the 2014 TK report indicate freshwater fishing sites of value to the Inuit that occur outside of the RSA including in Beechey Lake, just south of the RSA and throughout the Bathurst Inlet area, north of the RSA.

The 2014 TK report (KIA 2014), mapped major fishing areas but indicated that fishing occurred everywhere and that the Inuit fished whenever they were on the land. All the lakes and rivers that flow into Bathurst Inlet were described as important for fishing and many of the rivers had ancient stone weirs at locations that were also important fish camps. In particular, the mouth of Hiukkittak (river) was used extensively for fishing. Near Bathurst Inlet, Goulburn Lake was a major fishing area while Fishing Lake was the local fishing spot. Lakes further south including Bathurst Lake, Kenyon Lake and Beechey Lake were also identified as important fishing locations.

The 2014 TK report described TK related to the occurrence and habitat of freshwater fish. Lake Trout habitat is described as any lake and many small ponds, depending on their depth. Lake Trout also occur in large rivers and though they are known to go to the ocean, when they do they remain near river mouths and streams. Broad Whitefish occur in lakes as well as in streams and rivers that drain into lakes. Broad Whitefish and Arctic Cisco are abundant at river mouths and sections of rivers that contain rapids. Streams are considered Arctic Grayling areas. Burbot are considered a good food fish that occur in freshwater systems anywhere on the land. The following information is included in the 2014 TK report (KIA 2014):

> Traditional Camps and Fish Camps
>
> *Bathurst Lake, it's one of the places that our elders talk about lots. Lakes like this tend to be used mainly for freshwater lakes, where they can winter, where they can gather for the winter, being closer to the ocean. They can go down there for a day or so and come back at the end of the day. It's because there was freshwater there. It's a bigger lake with fish edible fish for the winter.*

When we were little, we used to stay there and my dad used to have his nets (Kangilialok on Banks Peninsula). There is really big trout in there…

This is also a lake with small trout. There are lots of small trout in there, there are millions of them. Charr too. Even this one here, these kind of narrows, there's charr in there and trout. (Tagionoak (Goulburn Lake on Banks Peninsula); narrows to Bathurst Inlet)

(There are) charr and whitefish

Kukiviakyok... is an old fishing camp. There used to be a great big fish weir in there but it's all gone now, from dis-use. It's not being used, or kept up anymore… It's a fishing area. There used to be tons of families in there, fishing.

Summer camps (on a travel route going to Bathurst). All these places are summer camping areas. The whole area is a summer camping area. Each side of the inlet (Bathurst), all the way to the bottom.

Somewhere in here there is a weir (between Charr Lake and Bathurst Inlet). They used to be winter camps in here as well in this area… That's only one of the areas where they had winter camps. There were quite a few of them; I can't recall where they all are.

Lakes and Rivers

Some of these big lakes you could go charr fishing by jigging

You could wait around for Lake Trout. Anywhere there is an outlet on the lake, where the ice is thin… That's where people go to fish. These areas you don't have to chop through two or three feet of ice. Most year-round these rivers, any outlet on the lake, or inlet, you find fish, charr, year-round.

Some parts are really narrow, in the creeks, but there is fish there. Some parts can be really skinny narrow little creeks, when the charr, the big charr are going up, and you can just grab them. (About a fishing place, a small stream between the large Goulburn Lake and a tiny lake to the north)

Interviewer: *Are there any areas that were more preferred for fishing by Inuit?*

Hanningayuk area (was preferred for fishing).

I'm not exactly sure where, but our elders, they talk about Hanningayuk (Beechey Lake) area too. Long ago before fishing nets ever came out, there used to be stone weirs there, along these rivers too…

When you start to think about the fishing season, when it's time to make dry meat or whatever in the fall time, they start to be more in the rivers, in the rapids. Not in the middle of the lake, when it starts to get cooler, in the springtime too, they stay near the rapids.

Right around Bathurst Lake

(There are) stories about Bathurst Lake and surrounding areas. It's not a great big humongous lake by any means, but still it's a large lake. Because it's very deep our elders have said there are fish there that could actually eat caribou.

They talk about ekalakpauk, very large fish. Ekalakpauk are giant fish. They are (not trout), they are something else. I always think about, what always comes to mind is a freshwater shark or something like that.

What I've heard is when they saw a wave coming; these lakes don't have very big waves all the time, but when they saw a huge wave coming they would run inland because they knew there was a big fish that was making that make wave. So they would go inland.

It's the same way those killer whales go after the seals, they come right up on the shore.

Ehok (Lake Trout) and Ekalok (Charr)

Ehok (Lake Trout), they go to the ocean but mostly they stay by the river mouth or stream. In the ocean they mostly stick around the river mouth. In the study area there will be lots of charr.

(There are lots of charr) in the main part of the river systems. In Hannigayok (Back River) it will be all Lake Trout. Any lake, any little pond there too, you wouldn't think that there would be ehok (Lake Trout) there too, but depending on how deep they are, there's always ehok in there. It could be a small little lake. You'd never think there would be fish in there but ehok are common in those areas too.

Those are big rivers. You will have lots there.

Lots and lots of Lake Trout.

In that area (Banks Peninsula), when the charr start going up in fall time, there will be lots of charr there too.

Kapihillik (Arctic Cisco), Anakheek (Broad Whitefish) and Hulukpaugan (Grayling)

Anywhere. There are lots and lots (of arctic cisco).

There will be whitefish there. In summertime they will be at the coast. Then they will go back to the lakes and the river systems… (In the ocean) they mostly will stick around the coasts.

Little streams too.

All these little streams and rivers that drain into the lakes. There is more concentration in some parts of the lakes.

The large lake whitefish, you can find them just about anywhere you find Lake Trout, in rivers, where there are fresh water rivers. Kogluk (meaning fast rapids) has lots and lots of anakheek (broad whitefish), especially at the mouth of the rivers. Every river has kogluks. So if you fish any river with rapids, you will likely catch anakheek and kapihillik (arctic cisco).

They are just about anywhere you find Lake Trout, ehok, or anakheek, anywhere you find those, you also find lots and lots of whitefish in the lakes. In areas, these fish, for some reason, I don't know why that is, they stick to areas where there is less copper in the lakes.

For some reason, even though there's lots of copper around that area, there are lots and lots of whitefish for some reason. But once you get further up on the mainland, like around High Lake area, where there is lots of copper content in the lakes… You find some lakes on the sides of the hills, on the shoreline with steep cliffs, you can see this copper coming down into those lakes.

People don't find those whitefish around there. And for some reason over here there are a lot less whitefish on the west side because of the copper content. That's what I've noticed where I go fishing. For some reason, always fish that are not predatory fish, they don't breed in those copper areas.

And grayling, yes. If there is copper content in those lakes, there will be no lake whitefish or grayling. There are none of those where there is lots of copper content in the water.

All these streams here are considered grayling areas. Where it's further west you go you won't find whitefish or grayling. Closer to the ocean more, but further inland you go, you start to get more and more copper fields.

Tiktalik (Burbot)

They (burbot) stay in freshwater systems.

First time I caught it, a really big one, I was really young. I told my dad I caught a really, really ugly fish.

Anywhere on the land of I've caught them. We have caught many of them in Contwoyto, Pellatt Lake… People do eat them but I consider them looking more like cod to me so I don't eat them. I'm allergic to cod. I can eat just about everything else alright but for some reason, cod, and everything that eats cod, I have an allergic reaction to, such as seals or polar bears.

First time my wife see tiktalik (burbot), she asked 'what kind of fish is this?' It's a really good fish but it looks funny. They're good, they're really good, that tiktalik.

They are something like barracuda but they're small. They are silver.

The Back River Project: Existing and Publically Available Traditional Knowledge from Selected Aboriginal Groups in the Northwest Territories (Appendix V3-3C of FEIS) report identifies the traditional, asserted, and settled land claim territories of NWT Aboriginal groups and describes traditional land use and harvesting activities. In this report, the fishing activities of the Akaitcho Dene, Tłı̨chǫ Dene and North Salve Metis are described. Freshwater fish harvest was identified by most groups in multiple seasons with Trout, Whitefish, Burbot, Inconnu, Arctic Grayling, Lake Herring, and Northern Pike identified as freshwater species specifically targeted by Akaitcho Dene. Traditional land use (including fishing activities) of the selected groups was identified in the Yellowknife River area, in Great Slave Lake and Great Bear Lake and throughout the barrenlands extending as far Contwoyto Lake. All fishing areas and activities referenced in this report are located far south of the RSA.

7.2.2 Incorporation of TK for VEC and VSEC selection

The results of the TK Report (KIA 2012) were reviewed for refining the potential VEC/VSEC list (see Volume 9, Chapter 1). Clear maps of valued fisheries species are presented in Chapter 7 of the 2012 TK Report (Figures 31 and 32), consequently, Lake Trout and Arctic Grayling were assigned as VECs.

In addition, freshwater fish habitat was assigned as a VEC and is treated individually within the Freshwater Fish/Aquatic Habitat Chapter (Volume 6, Chapter 6).

7.2.3 Incorporation of TK for Spatial and Temporal Boundaries

The results of the TK Reports were reviewed for spatial and temporal boundaries (KIA 2012, 2014). According to Figures 31 and 32 within Chapter 7 of the 2012 TK report and Figure 12 of the 2014 TK report, the Goose Property Potential Development Area (PDA), Local Study Area (LSA), or freshwater Regional Study Area (RSA) do not overlap with Inuit fishing locations.

7.2.4 Incorporation of TK for Mitigation and Adaptive Management

As a result of information obtained from the *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* report (KIA 2012) and *Naonaiyaotit Traditional Knowledge Project - Hannigayok (Sabina Gold & Silver Corp. Proposed Back River Project) Results from Data Gaps Workshops, Final Report (June 2014)* (KIA 2014), the mitigation and management of the freshwater fish community focuses on habitat for three freshwater fish species: Arctic Grayling, Lake Trout, and Arctic Char. The TK report included the mapped distribution of each of these species, as well as areas important for fishing. The Project has been designed such that infrastructure will not located on important freshwater fishing habitat. Additional mitigation of Project-related effects may be achieved by a Fish Offsetting Plan, which also considers TK. Ongoing consultation with DFO, and future engagement with the KIA and other stakeholders, regarding the further development of the Fish Offsetting Plan, including the development of additional or alternative options that could provide value to the local communities, is intended in conjunction with the Water Licencing process.

7.3 VALUED COMPONENTS

7.3.1 Potential Valued Components and Scoping

The freshwater fish community was identified as a potential VEC that encompassed the health, distribution and population of Aboriginal, recreational or commercial fisheries for which moderate to significant concerns were identified (Volume 9, Chapter 1). This information, along with public consultation, government engagement, regulatory consideration, and TK information, was used in the scoping process. As a result of the scoping process (Volume 9, Chapter 1), the freshwater fish community was identified as a VEC. This VEC was further broken down into two VECs, Lake Trout and Arctic Grayling, each chosen for their ecological importance and concern by Aboriginal groups.

7.3.2 Valued Components included in Assessment

The VECs selected to assess the potential effects of the Project on the freshwater fish community include:

- Lake Trout; and
- Arctic Grayling.

This chapter assesses the potential *direct* effects of the Project on the mortality and population abundance of the VECs Lake Trout and Arctic Grayling.

Individual fish health and *indirect* mortality could be potentially affected by the activity through the contamination of water or sediment as well as through contaminants bioaccumulating in fish through trophic interactions with primary and secondary producers (see Figure 6.4-8 in Volume 8, Chapter 6).

The potential for bioaccumulation in the VECs Lake Trout and Arctic Grayling is quantitatively assessed in the Human Health and Environmental Risk Assessment chapter (Volume 8; Chapter 6) and in the Country Foods chapter (Volume 8, Chapter 5). In addition, the potential for adverse effects to fish health due to changes in water and sediment quality is assessed in the VECs freshwater water and sediment quality (Volume 6, Chapters 4 and 5). Adverse effects to fish health were not predicted because changes in water and sediment quality were not predicted to significantly exceed thresholds based on applicable site-specific conditions and CCME guidelines for water and sediment quality for the protection of aquatic life (CCME 2015).

7.4 SPATIAL AND TEMPORAL BOUNDARIES

7.4.1 Spatial Boundaries

The spatial boundaries used for the assessment of effects on the VECs Lake Trout and Arctic Grayling include the Goose Property Potential Development Area (PDA), Goose Property Local Study Area (LSA) and an overall Freshwater regional study area (RSA). The Marine Laydown area (MLA) is a narrow strip of land on the west side of southern Bathurst Inlet. Most streams in this area flow directly to Bathurst Inlet on the west side. At the MLA, Project infrastructure does not interact with any streams or freshwater within its associated LSA or PDA.

7.4.1.1 Local Study Area

The LSA includes areas where there exists the reasonable potential for immediate effects due to Project activities, ongoing normal activities, or to possible abnormal operating conditions (NIRB 2013). The LSA used for the assessment of effects on the VEC freshwater fish community for the Goose Property is 365 km^2 and includes the PDA and the boundaries of the Propeller and Big watersheds (Figure 7.4-1). The PDA includes an area that encompasses planned infrastructure.

7.4.1.2 Regional Study Area

The freshwater RSA includes the PDA, the LSA, and additional areas within which there is the potential for indirect or cumulative effects. The RSA used for the assessment of effects on the VEC fish community is 6,815 km^2 and encompasses the PDA and LSA. The RSA includes small sections of the Ellice and Back River Watersheds, and includes the upper ~80 km of the Ellice Watershed (Figure 7.4-1).

7.4.2 Temporal Boundaries

The temporal boundaries used for the assessment of effects on the VEC freshwater fish/aquatic habitat align with the duration of Project phases as described in Volume 9, Chapter 1, as follows:

The temporal boundaries for the Project phases were defined as follows:

- Mobilization and Construction phase – 4 years;
- Operation phase – 10 years;
- Reclamation and Closure phase – 8 years;
- Post-closure Monitoring phase - 5 years
- other potential phases:
- Temporary Closure – less than 2 years;
- Care and Maintenance Phase – 2 to 10 years; and
- Exploration: included in Construction and Operations phases.

7.5 POTENTIAL PROJECT-RELATED EFFECTS ASSESSMENT

7.5.1 Methodology Overview

The Project-related effects assessment for the VEC freshwater fish/aquatic habitat followed the process detailed in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1).

1. Identify potential interactions between the Project and the VECs Lake Trout and Arctic Grayling.
2. Characterize the potential effects that could result from the interactions.
3. Identify mitgation or management measures that could be taken to eliminate or reduce the potential effects.
4. Characterize any residual effects (potential effects that would remain after mitigation and management measures have been applied).
5. Determine the significance of potential residual effects.

The significance of residual effects on the freshwater fish community VECs Lake Trout and Arctic Grayling was determined using the ratings and classifications described in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1, Table 2.4-3). Ratings are evaluated based on the Magnitude (set specifically for the VECs Lake Trout and Arctic Grayling; Table 7.5-1), Extent, Frequency, Duration, Reversibility, Certainty, and Probability.

Table 7.5-1. Rating Criteria for Evaluating the Magnitude of Residual Effects on the VECs Lake Trout and Arctic Grayling

Magnitude Rating	Classification
Negligible	Habitat changes are unlikely to have an effect on productive capacity that is distinguishable from natural variation.
Low	Habitat changes affect less than 10% of the waterbody area, and resulting reductions in productive capacity are unlikely to affect the entire fish population of a waterbody.
Moderate	Habitat changes affect up to 20% of the available habitat in a waterbody, such that resulting reductions in productive capacity may affect fish populations in the entire waterbody.
High	Habitat changes are expected to affect more than 20% of the waterbody area and may result in changes to the productive capacity of habitat within and beyond the waterbody, affecting an entire fish population or more than one fish population.

If the magnitude of a residual effect was qualitatively determined to be greater than *Low* after mitigation and management (i.e., distinguishable from natural variation and potentially greater than regulated or threshold values), then the potential effects was identified as a residual effect.

The significance of a residual effect was rated as Positive, Not Significant, or Significant (Table 7.5-2). For example, residual effects receive a rating of 'Not Significant' if typically they are expected to be one of the following: negligible or low magnitude, confined to LSA, moderate to high reversibility, or short duration (Volume 9). However, given the qualitative nature of the assessment, these ratings are evaluated for biophysical VECs on a case by case basis.

GIS # BAC-06-099

July 31 2015

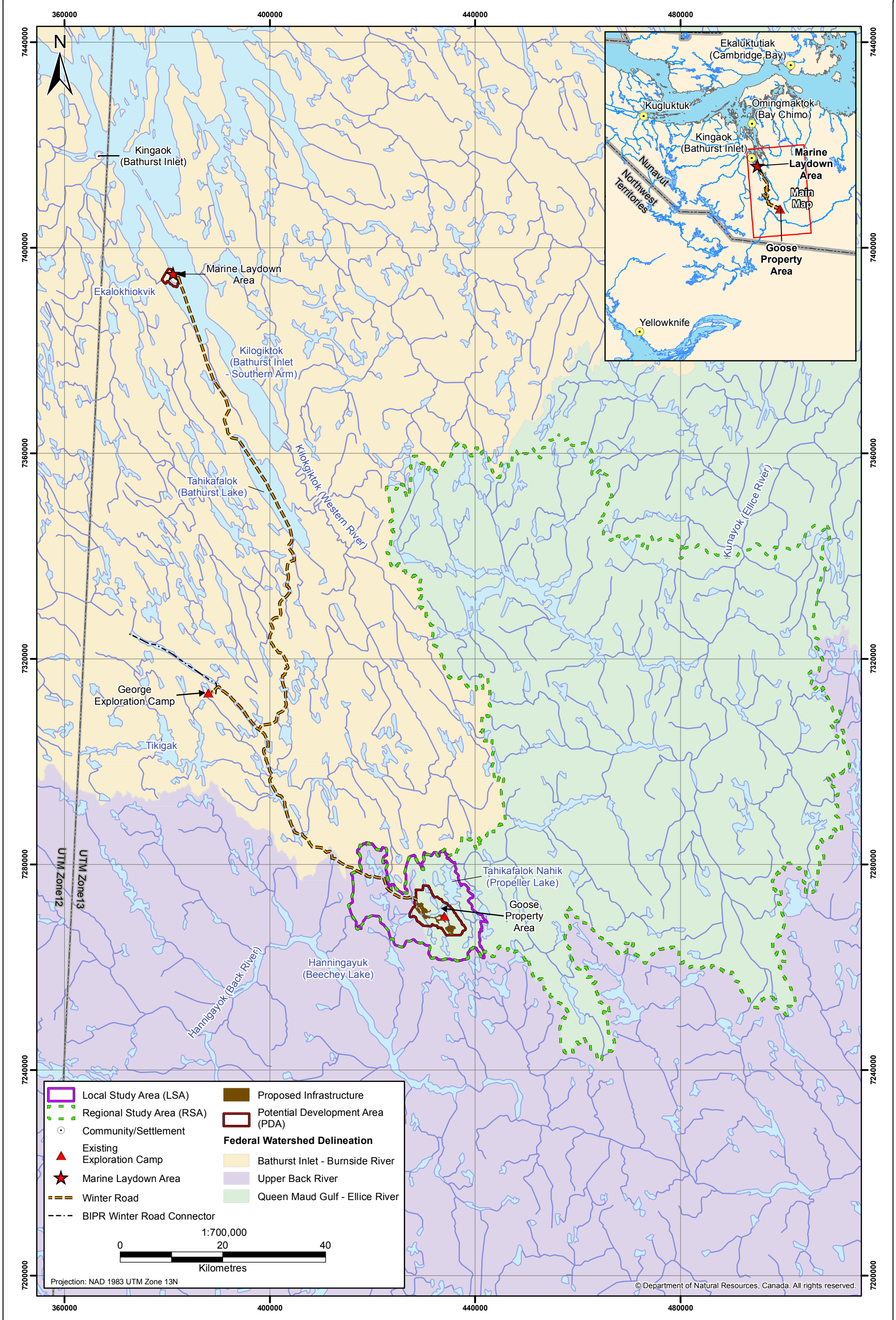


Figure 7.4-1

Local Study Area and Regional Study Area for Lake Trout and Arctic Grayling

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Table 7.5-2. Definitions of Significance Ratings for the VECs Lake Trout and Arctic Grayling

Significance	Descriptor of Significance
Positive	Effect could result in an increase in productive capacity of Lake Trout or Arctic Grayling, relative to the baseline within the RSA into the foreseeable future.
Significant	Effect is expected to result in a decrease in productive capacity of Lake Trout or Arctic Grayling that is not mitigated through Project design and management, and is long-lasting or permanent within the Project zone of influence relative to reference condition.
Not Significant	Effect may result in a decrease in productive capacity of Lake Trout or Arctic Grayling, but one that is fully mitigated through Project design and management, or fully reversible to baseline conditions in the shorter-term after Project closure.

7.5.2 Potential Interactions with Project and Characterization

Potential interactions between the Project and the Lake Trout and Arctic Grayling VECs were based on the initial matrix provided in the Project Description, and further refined using the EIS guidelines (NIRB 2013), professional judgement, and experience at other projects in Nunavut and the Northwest Territories. Activities throughout the duration of the Project were considered for their potential interactions with each fish community VEC. The freshwater fish community may be affected along two general pathways: Serious harm occurring through direct mortality and changes to population abundance; or through decreased health and indirect mortality (Table 7.5-3).

Table 7.5-3. Potential Interactions for Freshwater Fish Community VECs Lake Trout and Arctic Grayling

Fish Community Effects	Cause	Description	General Project Activity	Regulation
Direct mortality and population abundance	Water, withdrawal, blasting, fishing	Any impact that causes the death of fish directly (i.e., lake dewatering, fishing) or reduction in population abundance (i.e., stress effects on migration)	1. Water Use 2. Blasting 3. Project infrastructure footprint	*Fisheries Act* (1985), Sections 35, 36.
Reduction in water and sediment quality resulting in: 1. Indirect mortality* 2. Reduction in health *	Deposition of deleterious substances	Any impact that affects individual health and longevity, tissue quality, or parasite load.	1. Management of Contact Water, Effluent, Dust	Metal Mining Effluent Regulations (SOR/2002-222)

*Note: * Potential effects on the VECs Lake Trout and Arctic Grayling arising from the deposition of deleterious substances are assessed in the Human Health and Environmental Risk Assessment (Volume 8; Chapter 6) and VECs freshwater water and sediment quality (Volume 6; Chapters 4 and 5).*

This chapter focuses on the interactions and potential effects associated with the pathway of direct mortality and changes to population abundance.

For the pathway of decreased health and indirect mortality, potential changes in water quality and sediment quality could affect the VEC fish community. Arsenic was identified as a potential contaminant of concern, and as a result, a hydrodynamic model was developed in order to predict arsenic concentrations in Goose Lake (Rescan 2015d; Volume 6, Appendix V6-4A). The model included all areas of Goose Lake (all depths and locations) and predicted concentrations for the duration of all Project phases. Two specific key fish areas were included in the model, in order to predict arsenic concentrations at these known Lake Trout spawning sites and fish overwintering sites. Results are

presented in Figures 4.1-1 through 4.1-5 in the *2015 Goose Lake Hydrodynamic Modelling Report: Arsenic Perditions* (Rescan 2015d, Volume 6, Appendix V6-4A).

Details of the assessment of arsenic in Goose Lake are included in the Freshwater Water Quality Chapter (Volume 6, Chapter 4) under the 'mine contact water' sections. In summary, arsenic concentrations in Goose Lake are predicted to remain below the CCME guideline for the protection of freshwater aquatic life during the Construction and Operations phases, and during most of the Closure Phase. Arsenic concentrations are predicted to increase during late Closure/early Post-Closure to concentrations above the CCME guideline, but below the site specific water quality objective for arsenic in Goose Lake. In the long-term, arsenic concentrations are predicted to decrease to near or below the CCME guideline. All predicted arsenic concentrations were substantially less than identified toxicological thresholds for primary producers, aquatic invertebrates, and fish. Overall there are no anticipated significant adverse effects on the VEC fish community in Goose Lake as a result of predicted changes to water quality.

The potential for bioaccumulation in Lake Trout and Arctic Grayling is quantitatively assessed in the Human Health and Environmental Risk Assessment chapter (Volume 8; Chapter 6) and in the Country Foods chapter (Volume 8, Chapter 5).

Direct mortality and changes to population abundance of the VECs Lake Trout and Arctic Grayling may potentially be caused by lake dewatering and Project activities that physically harm fish (including fishing). For example, changes in the hydrologic regime of a stream may cause changes in the spawning run timing of a fish species, leading to potential effects on survival and reproduction.

Table 7.5-4 describes the specific Project activities that link to potential interactions with the freshwater fish community VECs identified in Table 7.5-3.

Table 7.5-4. Summary of Potential Interactions between Freshwater Fish Community and the Project

General Project Activity	Specific Project Activity	Project Phases
Project Infrastructure	1. Lake dewatering	1. Mobilization and Construction
	2. Winter road construction	2. Mobilization and Construction, Operation, Reclamation and Closure
	3. Project Footprint	3. All Phases
	4. Stream Crossings	4. Mobilization and Construction, Operation, Reclamation and Closure
Water Use	Water withdrawal (camp, mill, winter roads)	Mobilization and Construction, Operation, Reclamation and Closure
Blasting	Explosives Storage and Use	Mobilization and Construction, Operation

7.5.2.1 Project Infrastructure Footprint

Lake Dewatering

The Project Description includes the dewatering of Llama Lake to access the Llama Deposit, and the dewatering of Umwelt Lake to construct the Saline Water Pond (Figure 7.5-1).

GIS # **BAC-06-267**

November 4, 2015

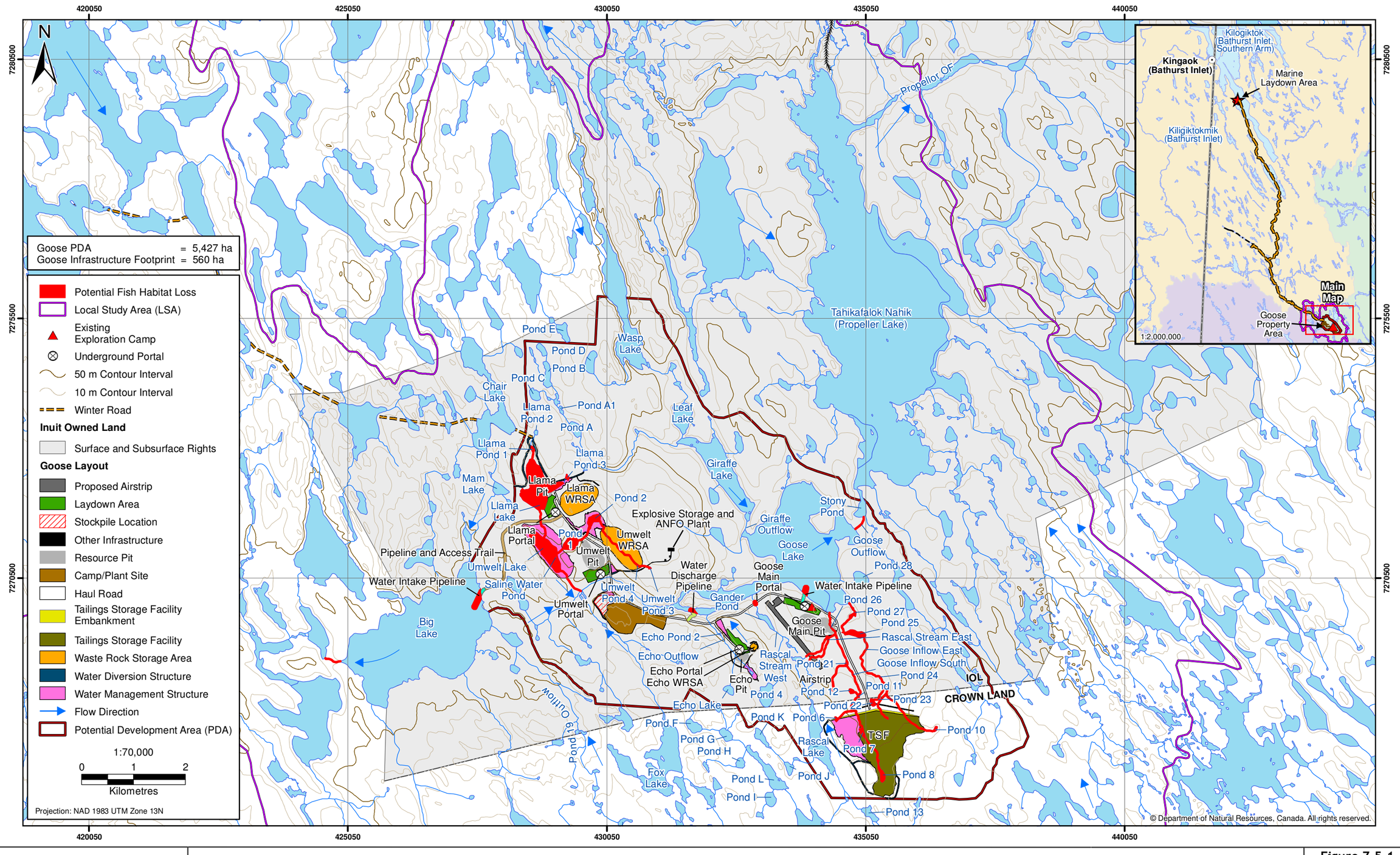

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Figure 7.5-1

Infrastructure Layout and Locations of Potential Fish Bearing Habitat Loss, Goose Property Area

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Lake Trout

Direct mortality of Lake Trout will occur as a result of the dewatering of Llama Lake for construction of Llama Pit. A fish-out program will be implemented to capture all fish from Llama Lake. A hydroacoustics survey estimated the total number of fish in Llama Lake to be approximately 226; however, the 95% confidence limits ranged from 4 to 1,794. The estimated proportion of the total number of fish that are Lake Trout varied across years. In 2012, 78% of those fish were estimated to be Lake Trout using hydroacousitics, while the remainder were Round Whitefish. Subsequent sampling suggested that Round Whitefish accounts for approximately 60% of the total number of fish, whereas Lake Trout make up most of the remaining 40%.

There is the potential for mortality of a very few Lake Trout to be incurred as a result of the dewatering of Umwelt Lake. Umwelt Lake is a small, shallow lake (maximum depth of 3.0 m), located just downstream of Llama Lake. Only a single Lake Trout has been caught in three years of sampling at Umwelt Lake and their presence appears to be incidental, likely migrating from Llama Lake during summer. A fish-out program will be implemented to capture all fish from Umwelt Lake.

Arctic Grayling

Direct mortality of Arctic Grayling resident in Umwelt Lake will occur as a consequence of the loss (dewatering) of Umwelt Lake. A fish-out program will be implemented to capture all fish from Umwelt Lake. The fish population of Umwelt Lake was estimated (using hydroacoustics) to be approximately 155 fish (95 % CI is 5 to 864 fish). Of these, approximately 77% were Arctic Grayling, while the remainder were Round Whitefish.

Lake Dewatering will result in the loss of fish habitat due to losses of downstream discharge; this has been described in Section 6.5.2.1 of Volume 6, Chapter 6. Arctic Grayling are present in the outflow streams from Llama and Umwelt lakes. The population of Arctic Grayling overwintering in Umwelt Lake, and possibly Llama Lake, use the Umwelt Llama outflow streams for spawning, rearing and foraging during all life history stages. The dewatering of Llama and Umwelt lakes removes all potential overwintering habitat available to Arctic Grayling in the northern arm of the Llama Watershed. The population of Arctic Grayling residing in these two lakes will no longer persist when the lakes are dewatered. Thus, the reduced/eliminated discharge downstream of the lakes will not result in further impact to the Arctic Grayling population.

Additional effects of lake dewatering will result in the complete isolation of the fish bearing Pond 1 and its outflow (Figure 7.5-1). Three years of sampling at Pond 1 (Rescan 2012a, 2014a, 2015c) indicates that only forage fish (Ninespine Stickleback) inhabit the waters, but must overwinter in either Umwelt or Llama Lake. Although the populations of forage fish may form part of the diet of Fish VECs (Lake Trout and Arctic Grayling) resident in Llama and Umwelt lakes, the complete loss of these VEC populations are accounted for in the dewatering of Llama and Umwelt lakes. Thus, the loss of forage fish in Pond 1 and its outflow will not incur additional losses to the VEC species Lake Trout and Arctic Grayling populations.

Winter Ice Roads

Winter road construction may occur over selected lakes, ponds, and streams along the proposed winter road corridors throughout Project phases. Connection between the Goose Property Area and the Marine Laydown Area will be established via winter roads constructed during the winter months as needed during the life of the Project.

Lake Trout

The potential effects of winter roads are likely to be more evident in streams than in lakes due to the necessity of constructing and decommissioning ice bridges and snow fills. Lake Trout are rarely found in streams, and will therefore not be affected by these activities.

Arctic Grayling

Arctic Grayling may be adversely affected by winter road development. Arctic Grayling spawn in streams and rivers early in the spring when the ice melts. Spawning success appears to be strongly affected by stream blockages (Stewart et al. 2007b). Improper decommissioning of ice bridges and snow fills could cause stream channels to become blocked to fish migration during the spring migration, which could in turn lead to grayling failing to spawn.

Other potential impacts on fish communities arising from the construction and use of winter roads arise from accidents and malfunctions, including spills and vehicle accidents. These potential impacts are covered under Accidents and Malfunctions (Volume 9; Chapter 3).

Project Footprint

Water management structures in Llama Watershed

The construction of water management structures for the Llama pit will result in the loss of fish habitat in Llama Pond 1 and its outflow, and Llama Pond 3 and its outflow, due to losses of downstream discharge and have been described in Section 6.5.2.1 of Volume 6, Chapter 6. The loss of upstream catchment discharge and the effects of dewatering Llama Lake will result in the complete isolation of these potentially fish bearing ponds and their respective outflows to Llama Lake (Figure 7.5-1). No fish have been caught in either pond (Rescan 2015c), however their close proximity to Llama Lake and good connectivity suggest they may be used by Lake Trout and possibly Arctic Grayling that reside in Llama Lake. Habitat assessments indicate neither pond is sufficiently deep to permit overwintering, therefore fish must overwinter in Llama Lake. The dewatering of Llama Lake removes all potential overwintering habitat available to fish in the northern arm of the Llama Watershed. The populations of Lake Trout and Arctic Grayling residing in these lakes will no longer persist when the lakes are dewatered. Thus, the predicted reduction in discharge downstream of water management structures will not result in further impact to these Lake Trout or Arctic Grayling populations.

TSF, Main Pit and Airstrip in the Goose and Wolf Watersheds

Two streams will be lost due to the construction of the TSF and the lost upstream catchment area (Goose Inflow East [GIE] and Goose Inflow South [GIS]), whereas Rascal Stream East (RSE) will be partially lost due to development of the airstrip and associated water management infrastructure (Figure 7.5-1). These three streams form the southern tributaries of Goose Lake. Fifteen ponds along the length of the GIE and GIS will also be lost due to the placement of infrastructure: four within the boundary of the TSF (ponds 6, 7, 8 and 9), ten due to the loss of catchment discharge downstream of the TSF (ponds 11, 12, 20, 21, 22, 23, 24, 25, 26, 27) and one by isolation from connected waterbodies (pond 10). Characterization of these habitat losses have been described in Section 6.5.2.1 of Volume 6, Chapter 6 and a description of the effects on the VEC's Lake Trout and Arctic Grayling are found below.

The Goose Inflow East and South streams, and their associated ponds, can be generally classified into two habitat types based on seasonal connectivity and fish species presence: sections lower in the watershed maintain good connectivity to Goose Lake throughout the summer and provide habitat for Arctic Grayling and forage fish (sections downstream of Pond 24 in GIE, and of Pond 21 In GIS; Figure 7.5-1), whereas sections higher in the watershed have only ephemeral connectivity to Goose Lake during the spring freshet and provide habitat only for forage fish.

Lake Trout

The potential for direct mortality of Lake Trout during the construction of the TSF, airstrip culverts, Main Pit, and associated infrastructure exists only if in-water work is completed outside of appropriate timing windows (section 7.5.3.1). In the absence of proposed mitigation, in-water work directly placed over foraging habitat has the potential to cause direct mortality of stranded fish. Lake Trout have not been captured in affected streams; however, juvenile Lake Trout may use lake inflows/outflows for rearing during the summer months. This potential effect only overlaps with stream habitat in lower reaches of the GIE and GIS, where flow is sufficient to allow fish to access habitat throughout the open water season.

Project infrastructure located within the RSE, GIS, and GIE streams also has the potential to result in reduced population abundance of Lake Trout due to the decreased availability of Arctic Grayling, which may serve as their prey. However, the diet of Lake Trout in Goose Lake is made primarily of invertebrates 88.3%), with 11.7% recognized as fish remains of unidentified species. Lake Trout preferentially feed upon whitefish and smaller forage fish rather than Arctic Grayling (Stewart et al. 2007a) and relative catch rates for Round Whitefish (1.9 fish/100 m^2) in Goose Lake indicate this prey item far exceeds the abundance of Arctic Grayling (0.06 fish/100 m^2). Forage fish (Ninespine Stickleback and Slimy Sculpin) are also plentiful (Rescan 2012c) in Goose Lake; therefore, no residual effect is anticipated as a result of potentially decreased availability of Arctic Grayling as prey for Lake Trout.

Arctic Grayling

The potential for direct mortality of Arctic Grayling during the construction of the TSF, airstrip culverts, Main Pit, and associated infrastructure exists only if in-water work is completed outside of appropriate timing windows (section 7.5.3.1). The RSE and the downstream sections of GIS and GIE provide spawning and rearing habitat for Arctic Grayling and forage fish, which will be present throughout the open water season at all life history stages. RSE was found to have the highest Arctic Grayling fry densities (1,467 fry; Table 7.5-5) in the Goose Property area. During the construction of Project infrastructure, natural discharge to known spawning habitat will become reduced and could potentially strand eggs, alevins, juveniles and adults resulting in direct mortality. In-water work directly placed over spawning habitat also has the potential to cause direct mortality of eggs and stranded fish of all ages if timing windows are not adhered to.

Table 7.5-5. Arctic Grayling Spawning and Rearing Habitat adjacent to Goose Lake

Stream	Length (m)	Fish Activity (*Number Obs.*)		Source within Rescan 2014a
		Spawning	Rearing	
Rascal Stream East (RSE; potential loss)	1,228	Yes (9)	Yes (251)	Figure 3.3-7; Figure 3.3-9; 538 m of Reach 4 in Table 3.3-1; Reaches 2, and 3 in Table 3.3-3
Goose Inflow South (GIS; potential loss)	644	Likely	Yes (211)	Reaches 1 and 2 in Table 3.3-1
Rascal Stream East (undisturbed section)	1,127	Likely	Yes (1,216)	264 m of Reach 4 and Reaches 5 and 6 in Table 3.3-1
Rascal Stream West (Gander Pond Outflow)	1,600	Yes (9)	Yes (99)	Figure 3.6-6; Reach 7 in Table 3.3-1 and Reaches 1 and 2 in Table 3.6-1
Goose - Propeller Outflow and Goose-Propeller Off-channel Area	728	Yes (1)	Yes (7)	Figure 3.6-5; Table 3.3-13; Section 3.6.1.2
Goose Inflow from Giraffe Lake	500*	Possible**	Possible**	
Goose Inflow from Umwelt Lake	Impassable Cascade	No	No	Table 3.3-5

*Notes: * approximate length as measured from Google Earth Imagery, ** Arctic Grayling were not caught in Giraffe Lake in 2013 baseline sampling. No further baseline fish sampling will be conducted in Giraffe Lake as this it is no longer a potential receiving environment.*

Project infrastructure located within the southern tributaries of Goose Lake (RSE, GIS, and GIE streams) has the potential to reduce population abundance of the Goose Lake Arctic Grayling population through a loss of access to spawning habitat (Figure 7.5-1). Approximately 32% of the available spawning habitat for this population is being lost to infrastructure placement (potential losses in RSE and GIS in Table 7.5-5). Spawning habitat losses are accounted for in Volume 6, Chapter 6 and in the Conceptual Fish Offsetting Plan (Volume 10, Chapter 21). However, the loss of spawning habitat will potentially decrease population abundance of Arctic Grayling in Goose Lake by increasing competition for fewer spawning sites, possibly resulting in the failure of some individuals to spawn over the Project phases (Construction to Post-Closure). This effect may be diminished by the continued availability of good spawning habitat in undisturbed streams connected to Goose Lake. Fry surveys indicate that the number of Arctic Grayling young of year found in potentially lost sections of RSE and GIS accounts for approximately 26% of all fry surveyed, with the majority of fry (68% totalling 1,216 fry) rearing in the undisturbed section of RSE upstream of the airstrip culverts (Table 7.5-5). After accounting for Project effects, Goose Lake Arctic Grayling will still have access to 0.7 ha of good quality spawning habitat in the upper RSE in addition to habitat in Goose Outflow (to Propeller Lake) and likely between Goose and Giraffe Lakes.

Migration of Arctic Grayling between Rascal and Goose Lakes will potentially be reduced due to Project infrastructure along the RSE and GIS streams from Construction through Post-Closure (Figure 7.5-1). The RSE and northern most reach of GIS (where it enters Goose Lake) are the main migratory corridor for Arctic Grayling moving between the Goose and Wolf watersheds throughout the open-water season and likely provides a pathway for fish migrating between summer and winter rearing habitat. The potential effect of reduced migration is the isolation and stranding of fish in the stream channel and direct mortality if fish are unable to migrate to adjacent overwintering habitat. Direct mortality of fish through stranding is unlikely as the connection between lakes and to overwintering habitat in Rascal and Goose Lake will continue through the undisturbed western arm of the stream (RSW). Connectivity will be re-established in RSE at Post-Closure.

Stream crossings

The potential for direct mortality of Arctic Grayling during the construction of the haul road culvert at Gander Pond Outflow on the RSW exists only if in-water work is completed outside of appropriate timing windows and if appropriate mitigation is not followed (section 7.5.3.1). In the absence of proposed mitigation, in-water work directly placed over fish habitat has the potential to cause direct mortality of fish and their eggs. In addition, improperly placed or sized culverts may result in the restriction of migration and access to spawning habitat in the RSW, or overwintering habitat in Goose and Rascal lakes.

7.5.2.2 Water Use

Water for domestic and process use will be drawn from Goose and Big Lakes in the Goose Property Area, and is anticipated to occur during all phases of the Project.

Water Withdrawal

Lake Trout

Lake Trout could be affected by water withdrawal from Goose Lake and Big Lake, as well as from lakes used to support the construction of winter roads (Figure 7.5-1). Water withdrawal has the potential to negatively affect Lake Trout population abundance by drawing down water and exposing spawning habitat. This could potentially cause the mortality of Lake Trout eggs, which are deposited in the fall and incubate over the winter. Lake Trout spawn over coarse substrates in lakes, at depths ranging from

0.15 to 55 m (Scott and Crossman 1973; Marcus, Hubert, and Anderson 1984). In Arctic environments, spawning must occur below the depth to which ice forms — typically 1.6 to 2 m in the LSA lakes.

Arctic Grayling

Water withdrawal may potentially result in a reduction in the population abundance of Arctic Grayling if it causes spawning habitat to become dewatered while eggs or alevins are incubating, or if it inhibits migration. Water withdrawals are anticipated to result in a reduction in outflow volume caused by lake water withdrawal at Goose Outflow and Big Outflow. There is also a potential for reduced discharge at Propeller Outflow arising from downstream effects of water withdrawal from Goose Lake.

Arctic Grayling spawn in streams in the early spring soon after ice-off (Stewart et al. 2007b). Eggs incubate for two to three weeks, and alevins remain the gravel for up to five days after hatching. Fry typically stay in small streams throughout the summer, migrating downstream to lakes in the late summer before freeze-up (Scott and Crossman 1973; Stewart et al. 2007b). These life history characteristics make juvenile grayling particularly susceptible to stranding during the summer. In addition, juvenile and adult grayling may become stranded in isolated habitats when water levels drop.

Direct harm to both Lake Trout and Arctic Grayling may also be caused by improper design and installation of pumps and piping systems to collect and pump water out of the lakes. Fish may become entrained in pumps or on debris screens if steps are not taken to control access to these features. Mitigation based upon DFO protocols will be followed to ensure that this does not happen (see section 7.5.3).

7.5.2.3 Blasting

Use of explosives within or adjacent to Lake Trout or Arctic Grayling habitat may cause mortality of incubating eggs, internal organ damage, and behavioural changes (Wright and Hopky 1998; Faulkner et al. 2006). Effects may be intensified in the presence of ice and hard substrates. These effects are most likely to be apparent where open pits encroach on Lake Trout or Arctic Grayling habitat at Llama Pit, Umwelt Pit, and Main Pit.

7.5.2.4 Local and Regional Context for Project Interactions

When considering the extent of potential Project effects there are three important themes to emphasize: losses at the landscape level, the type of losses, and the distribution of the species affected.

The sum of potential interactions of the Project with fish habitat results in a permanent loss of approximately 83 ha of fish bearing waterbodies (lakes, ponds and streams). The predicted loss in fish bearing habitat represents a small area when compared to the Project footprint, local and regional study areas: approximately 11.5% of the available fish bearing habitat within the PDA, 1.2 % within the Goose Property LSA, and 0.09% of that available within the RSA. The calculation of fish bearing habitat in the PDA, the LSA and RSA was completed using the proportion of fish bearing habitat to non-fish bearing habitat classified during baseline studies within the LSA (equal to 0.98 or 98%). This proportion was then multiplied by the total wetted habitat in the PDA, LSA and RSA to estimate the total fish bearing habitat area within each. Total wetted habitat was 732 ha in the PDA, 7,000 ha in the LSA and 96,363 ha in the RSA. Lastly, the percentage of loss for each area was calculated as 100 multiplied by the amount of fish habitat lost (83 ha) divided by the estimated fish bearing habitat in the PDA, LSA and RSA.

The affected fish populations are primarily in the upstream reaches of watersheds resulting in highly localized fisheries losses (within the PDA) and will not disconnect migration routes between lakes for fish species. The loss of populations of Lake Trout and Arctic Grayling from Llama and Umwelt lakes,

and their associated ponds and streams in the northern arm of Llama Watershed, in addition to GIE and GIS and their associated ponds within the Goose and Wolf watersheds, are at the most upstream ends of the respective watersheds. The partial loss of RSE may disrupt the main arm of the Arctic Grayling migration route between Goose and Rascal lakes during the Project phases, however the RSW stream through Gander Pond is also used by Arctic Grayling to connect these two lakes.

The fisheries productivity losses within the PDA affect fish species commonly encountered throughout waters located within Nunavut and the Canadian Arctic, namely Lake Trout, Arctic Grayling, Round Whitefish and forage species (Slimy Sculpin and Ninespine Stickleback). None of the affected species are listed under SARA or COSWEIC and localized losses are minimal when considering the total amount of habitat available to these abundant Arctic species within the LSA and RSA.

All fisheries productivity losses will be balanced in an approved fisheries offsetting plan, which is summarized in section 7.5.3.4 and detailed in Volume 10, Chapter 21.

7.5.3 Identification of Mitigation and Management Measures

Mitigation measures will be in place to avoid or minimize the potential effects of the Project on the freshwater fish community VECs Lake Trout and Arctic Grayling. Mitigation measures are supplemented by the use of additional management. For example, alternative siting locations may be identified along with changes in Project design and the use of best management practices. The mitigation and management measures presented in this chapter are considered to be technically, environmentally, and economically feasible.

The following mitigation and management measures are generally applicable to the entire freshwater fish community in the Project area including the VECs Lake Trout and Arctic Grayling. Thus, rather than splitting up the mitigation and management objectives for each VEC (Lake Trout and Arctic Grayling), measures are grouped by the effects and designed to prevent or reduce harm to fish communities.

7.5.3.1 Project Infrastructure Footprint

Lake Dewatering

Fish removal from Llama and Umwelt lakes prior to dewatering will follow the DFO's General Fish-Out Protocol for Lakes and Impoundments in the Northwest Territories and Nunavut (Tyson et al. 2011) outlined in the Conceptual Fish Offsetting Plan.

Fishing by mine staff will be banned within all Project areas and, thus, will not result in fish mortality.

Fish mortalities predicted to result from water pumps used for withdrawing water will be mitigated through the use of screened intakes in accordance with DFO’s Measures to Avoid Causing Harm to Fish and Fish Habitat. These include the following:

- Screen water intakes or outlet pipes to prevent entrainment or impingement of fish;
- Screens should be located in areas and depths of water with low concentrations of fish throughout the year;
- Screens should be located away from natural or artificial structures that may attract fish that are in migrating, spawning, or rearing habitat;
- The screen face should be oriented in the same direction as the flow;
- Ensure openings in the guides and seals are less than the opening criteria to make “fish tight”;

- Screens should be located a minimum of 300 mm (12 in.) above the bottom of the watercourse to prevent entrainment of sediment and aquatic organisms associated with the bottom area;
- Structural support should be provided to the screen panels to prevent sagging and collapse of the screen;
- Large cylindrical and box-type screens should have a manifold installed in them to ensure even water velocity distribution across the screen surface. The ends of the structure should be made out of solid materials and the end of the manifold capped;
- Heavier cages or trash racks can be fabricated out of bar or grating to protect the finer fish screen, especially where there is organic debris loading. A 150 mm (6 in.) spacing between bars is typical;
- Provision should be made for the removal, inspection, and cleaning of screens;
- Ensure regular maintenance and repair of cleaning apparatus, seals, and screens is carried out to prevent debris-fouling and impingement of fish; and
- Pumps should be shut down when fish screens are removed for inspection and cleaning.

As a result of mitigation and balancing of serious harm with fisheries offsetting, there are *no residual effects* anticipated on the VECs Lake Trout and Arctic Grayling due to lake dewatering. All mortalities of fish resulting from planned fish-out and dewatering activities will be restricted to the Project PDA and compensated fully through the Conceptual Fish Offsetting Plan.

Winter Ice Roads

Winter road construction will adhere to the measures above and the following DFO guidelines based upon the Nunavut *Operational Statement for Ice Bridges and Snow Fills* (DFO 2007):

- Use existing trails or winter roads wherever possible as access routes to limit unnecessary clearing of additional vegetation and prevent soil compaction;
- Construct approaches and crossings perpendicular to the watercourse wherever possible;
- Construct ice bridge and snow fill approaches using clean, compacted snow and ice to a sufficient depth to protect the banks of the lake, river or stream;
- The use of material other than ice or snow to construct a temporary crossing over any ice-covered stream is prohibited under section 11 of the Northwest Territories Fishery Regulations, unless authorized by a Fishery Officer;
- Install sediment and erosion control measures before starting work to prevent the entry of sediment into the watercourse. Inspect them regularly during the course of construction and decommissioning activities and make all necessary repairs if any damage occurs;
- Operate machinery on land or on ice and in a manner that minimizes disturbance to the banks of the lake, river or stream.
  - Machinery is to arrive on site in a clean condition and is to be maintained free of fluid leaks;
  - Wash, refuel and service machinery and store fuel and other materials for the machinery away from the water to prevent any deleterious substance from entering the water or spreading onto the ice surface;
  - Keep an emergency spill kit on site in case of fluid leaks or spills from machinery; and
  - Restore banks to original condition if any disturbance occurs.

- Ensure that the intakes are sized and adequately screened to prevent debris blockage and fish mortality. Mesh size will not be larger than 2.54 mm;
- Crossings do not impede water flow at any time of the year;
- When the crossing season is over and where it is safe to do so, create a v-notch in the centre of the ice bridge to allow it to melt from the centre and also to prevent blocking fish passage, channel erosion and flooding. Compacted snow should be removed from snow fills prior to the spring freshet;
- Stabilize any waste materials removed from the work site to prevent them from entering the lake, river, or stream. This could include covering spoil piles with biodegradable mats or tarps; and
- The site should be stabilized using effective sediment and erosion control measures. In areas with permafrost, care should be exercised to ensure these measures do not cause thawing or frost heave.

Water withdrawal for the construction of winter roads will adhere to the measures above and the following DFO guidelines taken from the Protocol for Winter Water Withdrawal from Ice-Covered Waterbodies in the Northwest Territories and Nunavut (DFO 2010):

- In one ice-covered season, total water withdrawal from a single waterbody is not to exceed 10% of the available water volume;
- In cases where there are multiple users withdrawing water from a single waterbody, the total combined withdrawal volume is not to exceed 10 % of the available water volume; and
- Only waterbodies with maximum depths that are ≥1.5 m than their corresponding maximum expected ice thickness should be considered for water withdrawal.

The construction of ice bridges and snow fill approaches at the land-water interface will utilize only clean, compacted snow and ice to a sufficient depth to protect the shoreline. Speed limits will be enforced to prevent ice scour along shorelines.

As a result of mitigation, there are *no residual effects* anticipated on the VECs Lake Trout and Arctic Grayling due to winter road construction or maintenance.

Project Footprint

The majority of Project infrastructure has been sited to avoid fish bearing water and, wherever possible, to avoid encroaching on freshwater fish habitat by adhering to a 31 m setback from all water. Waste rock storage areas (WRSA), and the camp and plan site have all been sited to avoid fish-bearing water and have been confined to local watersheds close to the main mine infrastructure.

Additional mitigation to avoid adverse effects on fish is required for streams predicted to experience reduced discharge that will potentially result in an increase in fish and egg stranding. These streams include Umwelt Outflow in the Llama Watershed, GIE in the Goose Watershed and GIS and RSE in the Wolf Watershed (section 6.5.2.1). In each of these streams, all potential fish use (migration, spawning, rearing and egg incubation) will be prevented by creating fish barriers at all migratory pathways into the channel prior to ice melt during the Construction phase. This includes barriers constructed at the following locations:

- Umwelt Outflow at the limit of the southern flowing downstream end where the stream connects to eastern flows toward Goose Lake;

- GIE and GIS at the downstream limit where each stream enters Goose Lake; and
- RSE upstream of the airstrip culverts.

Blocking fish access to the GIE, GIS and RSE streams may involve the construction of a permeable or semi-permeable gravel berm dug into the streambed. Once flows are re-established in GIE, GIS and RSE in Post Closure, barriers may be removed to allow fish passage into the systems. Blocking fish access to Umwelt Outflow may involve creating a permanent impassable fall or cascade barrier. This may be done to prevent fish access to upstream water management areas if required during post-closure.

Stream crossings

The construction and maintenance of stream crossings, roads and berms will follow DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat. These include the following mitigation measures to guide these processes and to ensure that fish and aquatic habitat is not adversely affected by development:

- Design and plan in-water activities and works such that loss or disturbance to aquatic habitat is minimized and sensitive spawning habitats are avoided;
- Where possible, approaches will be designed to be perpendicular to the watercourse to minimize loss or disturbance to riparian vegetation;
- Instream activities will be undertaken in isolation of open or flowing water, or when frozen, to maintain the natural flow of water downstream and avoid introducing sediment into the watercourse;
- Effective erosion and sediment control measures will be installed before starting work to prevent sediment from entering the water body;
- Site isolation measures (e.g., silt boom or silt curtain) will be used to contain suspended sediment where in-water work is required;
- Regular inspection and maintenance of erosion and sediment control measures and structures will be conducted during the course of construction;
- Repairs to erosion and sediment control measures and structures will be promptly completed if damage occurs;
- Removal of non-biodegradable erosion and sediment control materials will be completed once site is stabilized;
- Clearing of riparian vegetation will be kept to a minimum to avoid disturbance to the riparian vegetation and prevent soil compaction;
- If replacement rock reinforcement/armouring is required to stabilize eroding or exposed areas, appropriately-sized, clean rock will be installed at a similar slope to maintain a uniform bank/shoreline and natural stream/shoreline alignment;
- All construction materials will be removed from the construction site upon project completion;
- Machinery will be in a clean condition and maintained free of fluid leaks, invasive species and noxious weeds;
- Whenever possible, machinery will be operated on land above the high water mark or on ice in a manner that minimizes disturbance to the banks and bed of the waterbody;

- Whenever possible, machine fording of a watercourse will be limited to a one-time event (i.e., over and back), and only if no alternative crossing method is available. If repeated crossings of the watercourse are required, a temporary crossing structure will be constructed; and
- Service machinery will be washed, refueled and fuel and other materials for the machinery stored in such a way as to prevent any deleterious substances from entering the water.

For the fish bearing crossing at Gander Outflow which will continue to serve as a migration corridor between Goose and Rascal lakes, the culvert was sized to keep maximum water velocities below 1.5 m/s such that it does not present a velocity barrier to migrating Arctic Grayling. In addition, the culvert will be embedded to a depth of 0.4 m and filled with streambed material to promote fish passage and habitat suitability.

Temporary Stream Crossings

Temporary crossings will adhere to the measures above and the following DFO guidelines:

- If there are any activities with the potential to disrupt sensitive fish life stages (e.g., fording of the watercourse by machinery) the appropriate fisheries timing widows will be adhered to;
- Machinery fording a flowing watercourse to bring equipment required for construction to the opposite side is limited to a one-time event (over and back) and is to occur only if an existing crossing at another location is not available or practical to use;
- If minor rutting is likely to occur, stream bank and bed protection methods (e.g., swamp mats, pads) should be used, provided they do not constrict flows or block fish passage;
- Grading of the stream banks for the approaches should not occur;
- If the stream bed and banks are steep and highly erodible (e.g., dominated by organic materials and silts) and erosion and degradation are likely to occur as a result of equipment fording, then a temporary bridge should be used in order to protect these areas;
- Fording should occur under low flow conditions, and not when flows are elevated due to local rain events or seasonal flooding;
- For temporary bridges also employ the following measures:
- Use only clean materials (e.g., rock or coarse gravel fill, wood, or steel) for approaches to the bridge (i.e., not sand, clay or organic soil) and install in a manner that avoids erosion and sedimentation;
- Design temporary bridges to accommodate any expected high flows of the watercourse during the construction period;
- Restore the bank and substrate to pre-construction condition;
- Completely remove all materials used in the construction of the temporary bridge from the watercourse following the equipment crossing, and stabilize and re-vegetate the banks;

Culvert Maintenance

Measures to Protect Fish and Fish Habitat when Maintaining Culverts will adhere to the measures above and the following DFO guidelines:

- Unless accumulated material (i.e., vegetation, ice build-up, etc.) is preventing the passage of water and/or fish through the structure, material and debris removal will be completed according to the Nunavut In-Water Construction Timing Windows. Any proposal to conduct such

work under ice covered conditions, with the exception of ice build-up removal, requires prior review by DFO;

- DFO will be notified if emergency debris removal is required. Emergencies include situations where carrying out the project immediately is in the interest of preventing damage to property or the environment, or is in the interest of public health or safety;
- The removal of accumulated material will be limited to the area within the culvert, immediately upstream of the culvert and to that which is necessary to maintain culvert function and fish passage;
- Accumulated material and debris will be removed slowly to prevent downstream flooding and reduce the amount of sediment-laden water going downstream and reduce the potential for stranding fish in upstream areas;
- If replacement rock reinforcement/armouring is required to stabilize eroding inlets and outlets, the following measures should be incorporated:
  - Appropriately-sized, clean rocks will be placed into the eroding area;
  - Only clean, non-acid generating rocks will be used. Rocks will not be obtained from below the ordinary high water mark of any waterbody;
  - Rock will be installed at a similar slope to maintain a uniform stream bank and natural stream alignment;
  - Rocks installed will be done so as to not interfere with fish passage or constrict the channel width;
- Waste materials removed from the work site will be stabilized to prevent them from entering the watercourse;

Timing Windows

Timing of in-water construction activities will conform, when possible, to Nunavut timing windows for the protection of fish and their habitat. For stream activities, the window is in place to avoid the spring spawning time for Arctic Grayling from May 1 to July 15. For lake activities, this window is meant to avoid fall spawning species within the LSA (Lake Trout and Whitefish) and is from September 1 to June 30.

As a result of mitigation, there are *no residual effects* anticipated on the VEC Lake Trout and Arctic Grayling due to Project footprint. As with fish habitat losses (Volume 6, Chapter 6), the fisheries productivity losses — direct mortality in of Lake Trout and Arctic Grayling in Llama and Umwelt Lakes and population reduction of Arctic Grayling in Goose Lake — will be fully balanced by the proposed Arctic Char productivity enhancement project outlined in the Conceptual Fish Offsetting Plan.

7.5.3.2 Water Use

Water Withdrawal

The primary mitigation measure to avoid affecting mortality and population abundance of the VECs Lake Trout and Arctic Grayling is to limit the amount of water taken from each waterbody (Table 7.5-6). In addition, water will be recycled where possible to limit the demand for water withdrawals. As a result of mitigation measures, there are no residual effects anticipated on the VECs Lake Trout and Arctic Grayling due to water use.

Table 7.5-6. Volume Limits for Water Use

Project Phase	Goose Lake		Big Lake
	Year-round Withdrawal (m^3/day)	Additional June to October Withdrawal (m^3/day)	Year-round Withdrawal (m^3/day)
Construction	400	n/a	350
Operations	900	400	350
Reclamation and Closure	400	n/a	350
Post-Closure	n/a	n/a	n/a

To protect important habitat for Lake Trout and Arctic Grayling, the maximum volume limit for year round water withdrawal was set at 900 m^3/day during the Operations phase in Goose Lake. An additional 400 m^3/day will be withdrawn during peak flow periods (June to October) during Operations, such that the maximum amount of water that will be withdrawn during peak flow periods will be 1,300 m^3/day in Goose Lake. The maximum amount of water that will be withdrawn from Big Lake will be 350 m^3/day and will occur during Construction, Operations and Reclamation and Closure.

At the maximum limit to withdrawal volumes (Table 7.5-6), the water level and outflow volume of Goose Lake is expected to decrease, but remain within the range of natural variation to protect fish habitat (Appendix V6-1D; DFO 2009, 2010). The limit to water drawdown will prevent water level in Goose Lake from decreasing more than 0.06 m. The maximum drop in lake level is reached during late winter under ice. This anticipated reduction in water level in Goose Lake is considered negligible and therefore within DFO guidelines (DFO 2009, 2010) as ice thickness in Goose Lake varies up to 0.2 m among years and locations and water level fluctuates more than 0.3 m during the open-water period (Rescan 2012b, 2012d).

Maximum limits to water withdrawal volume from Goose Lake would also affect outflow volume (discharge rate) at the Goose Outflow stream — a wide, shallow connection between Goose and Propeller lakes. The primary potential effects on Goose Outflow would be due to a reduction in flow (discharge) and the number of usable flow days throughout the open water season resulting from winter and summer withdrawal from Goose Lake. The number of usable flow days is quantified using DFO's ecological flow guidelines (DFO 2013b), where the usable days are considered any day in which the stream is discharging above 30% Mean Annual Discharge (MAD; see Appendix V6-1E for the full hydrological analysis).

The outflow discharge in Goose Lake is anticipated to remain within the range of natural variation to protect fish habitat. During the open water season, the limit to water drawdown will prevent discharge from decreasing more than 13.3% from average baseline outflow volume, and up to 17.4% in a 1 in 20 dry year. Baseline flow and water level in Goose Outflow are marginal to insufficient for fisheries production during sensitive periods (flow less than 30% Mean Annual Discharge; DFO 2013b; Figure 6.5-3) and the estimated 13.3% reduction in discharge due to maximum water withdrawal does not alter the date or duration of the vulnerable period when Goose Outflow is marginal for fish use (Figure 7.5-2; Appendix V6-1E). Moreover, the stream becomes impassable to fish at low flows late in summer due to the presence of a boulder garden (Norecol Dames and Moore 1997).

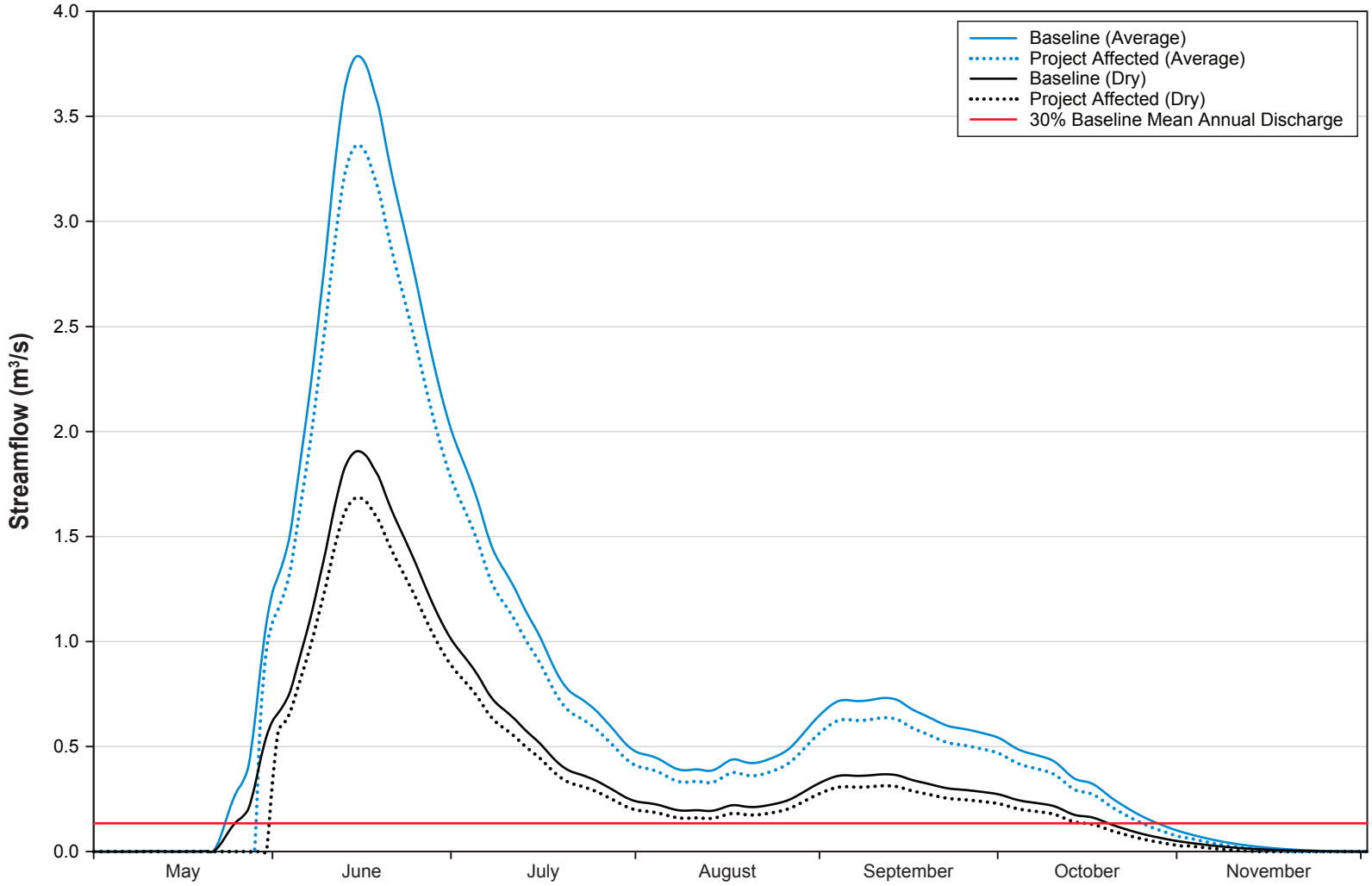

Figure 7.5-2

Sabina GOLD & SILVER CORP.

Baseline and Project-affected Flows at Goose Outflow

Figure 7.5-2

Rescan an ERM company

In addition, the results of hydrological modeling (Appendix V6-1E) indicate that the total number of flow days in Goose Lake Outflow will decrease by a total of 10 days, equal to 6.8% of the flow period (Baseline flow days = 147, Project = 137). The predicted reduction of 10 flow days in Goose Outflow results from first, a delay of 6 days the onset of flow above 3 % MAD during freshet (Baseline = May 25, Project = May 31) due to winter withdrawal, and second, an earlier date of onset of flow below 30% MAD due to summer withdrawal (2 days: Baseline = Oct 19, Project = Oct 15). Again, this reduction appears to be within the range of natural variation in flow days during baseline studies. During the course of three years of data collection at Goose Outflow (Hydrometric Station GI-H1), the range of natural variability in peak freshet is 4 days and the onset of low flow is 7 days. Note that this analysis used a conservative approach by comparing baseline discharge and flow days to predictions of Project discharge for a 1 in 20 dry year. This is conservative because in dry years, when water levels are at their lowest, less habitat would be available for fish use when compared to an average or wet years. Thus, the predicted reduction in number of flow days during a 1 in 20 dry year will be greater than that in an average year.

Water withdrawal from Goose Lake also has the potential to affect the outflow volume of the nearest lake downstream, Propeller Lake. Hydrological modeling indicates that the flow reduction at Propeller Outflow is anticipated to be 6.2% (0.06 m^3/s) on average and 8.2% (0.04 m^3/s) for a 1 in 20 dry year (Appendix V6-1E). Thus, the maximum reduction in discharge volume for Propeller Lake is expected to be below the 10% maximum permissible withdrawal volume to protect fish habitat (DFO 2009, 2010).

Water withdrawal from Big Lake has been designed to avoid impacts to fish habitat. Maximum withdrawal for Big Lake was set below 10% of the outflow volume, below the maximum permissible withdrawal volume to protect fish habitat (DFO 2009, 2010). Hydrologic modelling (Appendix V6-1E) predicts a reduction of 2.3% (average) and 4.5% (1 in 20 dry year). Withdrawals from Big Lake are anticipated to occur during the Construction and Operations phases. A maximum of 350 m^3/day of water will be withdrawn throughout the year.

Where pumps are used for withdrawing water in fish-bearing waters, the intakes will be screened in accordance with the DFO guidance found in the Lake Dewatering section above (section 7.5.3.1).

As a result of mitigation, there are *no residual effects* anticipated on the VECs Lake Trout and Arctic Grayling due to water withdrawal.

7.5.3.3 Blasting

When explosives are required to be used near fish bearing water, the potential for impacts to fish and fish habitat will be minimized by implementing the following measures based on DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat:

- In-water work requiring the use of explosives will adhere to appropriate fisheries timing windows prevent disruption of vulnerable fish life stages, including eggs and larvae;
- When necessary, the work site will be isolated to exclude fish from within the blast area by using bubble/air curtains (i.e., a column of bubbled water extending from the substrate to the water surface as generated by forcing large volumes of air through a perforated pipe/hose), cofferdams or aquadams;
- Any fish trapped within the isolated area will be removed and released unharmed beyond the blast area prior to initiating blasting;

- Blast charge weights will be minimized, possibly by subdividing each charge into a series of smaller charges in blast holes with a minimum 25 millisecond (1/1000 seconds) delay between charge detonations;
- Blast holes will be back-filled with sand or gravel to grade or to streambed/water interface to confine the blast;
- Blasting mats will be placed over top of holes to minimize scattering of blast debris around the area;
- Ammonium nitrate based explosives will not be used in or near water due to the production of toxic by-products;
- All blasting debris and other associated equipment/products will be removed from the blast area once compete.

Explosive use will employ the following additional guidelines for the use of explosives in or near waters taken from Wright and Hopky (1998):

- 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 100 kPa (14.5 psi) in the swimbladder of a fish.
  - 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 riverbed) that will ensure that explosive charges meet the 100 kPa overpressure guideline are shown in Table 1 of Wright and Hopkey (1998).
- No explosive is to be detonated that produces, or is likely to produce, a peak particle velocity greater than 13 mm/s in a spawning bed during the period of egg incubation.
  - For confined explosives, setback distances or burial depths from spawning beds that will ensure that explosive charges meet the 13 mm/s guideline criteria are shown in Table 2 of Wright and Hopkey (1998).
- For unconfined explosives, the appropriate DFO Regional/Area authorities will be contacted for further guidance.

Explosive products will be stored on site in accordance with Territorial and Federal regulations. The main storage of ammonium nitrate will be located at the Goose Property Area, with secondary storage areas at the MLA. The handling and manufacture of explosives will be contracted to a licensed operator. Emulsion plants for the manufacture of explosives will be built in the Goose Property Area, and will be stand-alone with dedicated waste management systems and truck washing facilities.

As a result of mitigation, there are *no residual effects* anticipated on the VECs Lake Trout and Arctic Grayling due to blasting.

7.5.3.4 Fisheries Offsetting

The purpose of the Conceptual Fish Offsetting Plan (Volume 10; Chapter 21), as per the guiding policies of Fisheries and Oceans Canada (DFO), is to maintain or improve the productivity of the CRA fishery. The Conceptual Offsetting Plan is the result of continued community and regulatory engagement associated with the Project. The outcome of engagement activities identified an offsetting measure or option focused on improving the productivity of an Arctic Char fishery at Bernard Harbour (the Hingittok Lake-Nulahugyuk Creek system), which is located approximately 100 km directly north of the

hamlet of Kugluktuk, Nunavut, along the south coast of the Dolphin and Union Strait. Bernard Harbour was once the site of a traditional domestic fishery for Arctic Char.

The rationale for Bernard Harbour as a suitable offsetting option for the Project begins with reports by local harvesters in the 1990s that the traditional fishery is in decline. Follow-up investigations concluded that conditions of the creek may be deteriorating because of natural causes (e.g., changes in climate, resulting in low water levels, and boulder barriers), affecting the upstream migration of adult char to spawning areas in Hingittok Lake. During 2014 to 2015, aTK study combined with environmental monitoring provided a better understanding of the Arctic char fishery at Bernard Harbour (and related historic and contemporary environmental conditions). The baseline studies, all of which included Kugluktuk Hunters and Trappers Organization (HTO) as full partners, demonstrated how the proposed approach to stream remediation is grounded in historic Aboriginal fisheries management strategies that have been used at Bernard Harbour (i.e. seasonal stream channel manipulation and rock weir construction). Thus, the approach to offsetting for Project losses aims to integrate local community benefits while satisfying regulatory requirements.

To estimate the potential benefits of the offsetting option to fisheries production (as a surrogate of fisheries productivity), changes in migration success were estimated and then related to changes in the biomass of adult Arctic Char in Nulahugyuk Creek. The predicted gains in biomass following remediation may be substantial, magnifying over time when Arctic Char offspring return as adults (by offsetting year 8 or 9). It is also predicted that gains in biomass at Bernard Harbour will exceed all losses in fisheries production resulting from Project activity.

The Conceptual Fish Offsetting Plan will be finalized and presented as a Final Fisheries Offsetting Plan during the permitting phase of the Project and submitted as part of the Application for Authorization under the Fisheries Act. The plan would be approved by DFO as a condition of the Authorization required for the development of the Back River Project.

7.5.4 Characterization of Residual Effects

After considering the mitigation measures, fisheries offsetting and monitoring plans there are no anticipated residual effects on the VECs Lake Trout and Arctic Grayling from the Project.

7.5.5 Significance of Residual Effects

After considering the mitigation measures, fisheries offsetting and monitoring plans there are no anticipated residual effects on the VECs Lake Trout and Arctic Grayling from the Project.

7.6 POTENTIAL CUMULATIVE EFFECTS ASSESSMENT

7.6.1 Methodology Overview

The potential for cumulative effects arises when residual effects of *the Project* affect (i.e., overlap and interact with) the same resource/receptor that is affected by the residual effects of other past, existing or reasonably foreseeable projects or activities. When residual effects are present, the Cumulative Effects Assessment (CEA) followed the process detailed in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1).

7.6.2 Potential Interactions of Residual Effects with Other Projects

After considering mitigation measures and the fisheries offsetting and monitoring plans, no residual effects of Project activities on the VECs Lake Trout and Arctic Grayling were predicted. Thus, there

exists no potential for interactions with Projects — past, existing, or in the foreseeable future — for the VEC freshwater fish community.

There are no anticipated residual effects on the VECs Lake Trout and Arctic Grayling due to the Project. Therefore, there are no potential effects on fish community from the Back River Project that could act additively or synergistically with other projects. A CEA was not conducted (see CEA Methodology; Volume 9; Chapter 1).

7.7 TRANSBOUNDARY EFFECTS

As outlined in Section 4 of Volume 9 (Chapter 1), the potential for transboundary effects of the Project was determined based on whether residual Project effects could operate cumulatively with effects of projects in other jurisdictions. Transboundary effects can occur when VECs or the Project zone of influence moves across jurisdictional borders external to the Nunavut Settlement Area (NSA).

After considering mitigation measures and the fisheries offsetting and monitoring plans there are no anticipated residual effects on the VEC freshwater fish community for the Back River Project. Thus, no transboundary effects on the VEC freshwater fish community are expected to occur.

7.8 MITIGATION AND ADAPTIVE MANAGEMENT

Numerous mitigation or management plans will be in place to eliminate or minimize the potential effects on the VECs Lake Trout and Arctic Grayling. These plans can be found in Volume 10 and include:

- Conceptual Fish Offsetting Plan;
- Aquatic Effects Management Plan;
- Environmental Management Plan;
- Environmental Protection Plan;
- Fuel Management Plan;
- Spill Contingency Plans;
- Oil Pollution Emergency Plan;
- Site Water Monitoring and Management Plan;
- Waste Management Plan;
- Incineration Management Plan;
- Explosives Management Plan;
- Road Management Plan ;
- Borrow Pits and Quarry Management Plan;
- Air Quality Monitoring and Management Plan; and
- Mine Closure and Reclamation Plan.

7.8.1 Mitigation by Project Design

The Project has been designed to avoid impacts on the VECs Lake Trout and Arctic Grayling where possible. The major aspects of mitigation by design include:

- Locating the WRSAs, mine site and plant to avoid fish bearing water;

- Locating infrastructure a minimum of 31 meters away from fish-bearing waterbodies; and
- Designing water use limits to avoid effects on habitat necessary for fish.

A full list of mitigation by Project design can be found in Table 7.8-1.

Table 7.8-1. Summary of Mitigation and Management Measures for Lake Trout and Arctic Grayling

Mitigation Category	Mitigation Measures
1. Mitigation by Project Design	
	Where possible, infrastructure, waste rock storage areas, and the camp and plant site have been located outside of fish bearing water;
	A Final Fish Offsetting Plan will be in place that has been approved by DFO, in consultation with the KIA and other interested parties, to offset or enhance for the permanent alteration or destruction of fish habitat. Freshwater offsetting includes a community supported Arctic Char fishery enhancement at Bernard Harbour.
	Efforts will be made during the final design stage to have the right-of-way cross each stream as close to perpendicular as possible to minimize the amount of riparian vegetation that may need to be disturbed during construction.
	Where pumps are used in fish-bearing watercourses or where fish salvage has not occurred, the intakes will be screened in accordance with the DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (see section 7.5.3.1; screens with openings no larger than 2.54 mm). Outlets will have a diffuser or be located in an area not subject to erosion from outflows.
	Where water will be withdrawn from fish-bearing lakes, reduction in water level and discharge will be kept within 10 % of the measured outflow volume, or below a threshold determined to have no significant residual effects on fish and fish habitat. These thresholds can be found in Table 7.5-6.
2. Regulatory Requirements	
	All in water activity will be conducted during approved timing windows following DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat. This includes:
	Culvert maintenance;
	Timing Windows;
	Building and maintaining site road crossings;
	Temporary stream crossings;
	Winter road construction; and
	Water withdrawal.
	See section 6.5.3 for detailed mitigation methods.
3. Best Management Practices	
	Efforts shall be made to minimize the duration of any instream works and minimize disturbance of riparian vegetation at stream crossings.
	Prevent the release of sediment or sediment laden water into water frequented by fish.
	The dewatering of Llama and Umwelt lakes will follow an approved dewatering plan, whereby water will not be discharged to the receiving environment if it does not meet approved criteria;
	Machinery fording a watercourse to bring equipment required for construction to the opposite side is limited to a one-time event (over and back) and shall occur only if an existing crossing at a nearby location is not available or practical to use;
	Vehicular access across a watercourse or waterbody will be by road or bridge, or other acceptable method according to DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (see section 7.5.3.1);

(continued)

Table 7.8-1. Summary of Mitigation and Management Measures for Lake Trout and Arctic Grayling (completed)

Mitigation Category	Mitigation Measures
3. Best Management Practices *(cont'd)*	
	All temporary works, silt curtains, construction material or debris, etc. are to be completely removed from the waterway when work is completed; Fish removal from Llama Lake prior to dewatering will follow the DFO's General Fish-Out Protocol for Lakes and Impoundments in the Northwest Territories and Nunavut (Tyson et al. 2011).
4. Adaptive Management	
	The need for any corrective actions to on-site management or installation of additional control measures will be determined on a case-by-case basis. Indications of the need for corrective actions and additional control measures may include: • if results from the Surveillance Network monitoring program (which will be outlined in the future Type A Water Licence) show non-compliance; • if results from the Aquatic Effects Monitoring Program, which will monitor the receiving environment around the mine infrastructure and activities, show adverse effects to the freshwater environment; or • if results from the Conceptual Fish Offsetting Monitoring Program show that the offsetting program is not successful.
5. Monitoring	
	There will be an approved Conceptual Fish Offsetting Monitoring Program for the Project. The Conceptual Fish Offsetting Monitoring Program may consist of the following components: • fish presence/habitat use; • local density or population size estimates for fish species; • habitat stability monitoring of constructed habitat; • assessment of primary productivity; and • assessment of benthic invertebrate community.

7.8.2 Best Management Practices

The Project will be constructed and managed following government guidelines and industrial best management practices as much as possible to avoid unnecessary impacts to fish communities. Government guidelines to avoid harm to fish communities include DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat, federal and territorial guidelines to preserve water and air quality, and federal and territorial environmental protection regulations. In addition, standard industrial best management practices will be developed, and much of this is featured in the Site Water Monitoring and Management Plan (Volume 10, Chapter 7). Detailed information on all best management practices are presented in Table 7.8-1.

7.8.3 Monitoring

Monitoring of construction activities and environmental compliance will be achieved through a Site Surveillance Network Monitoring Program that will be outlined in the future Type A Water Licence. This program will consist of all of the site compliance monitoring that will be required for managing/moving and releasing water from all potential containment areas.

In addition, an Aquatic Effects Monitoring Program (AEMP; Volume 10; Chapter 19) will be carried out during all phases of the Project. The AEMP will include the following:

- monitoring a network of lakes and streams within the Goose Property at locations potentially affected by the Project and at reference areas well away from Project activities;

- monitoring lake and stream water quality, sediment quality, and aquatic biology;
- monitoring fish populations and fish tissues; and
- if effluent (as defined in the Metal Mining Effluent Regulations [MMER], SOR/2002-222) is discharged to the environment, then additional sampling for MMER requirements will be conducted.

Finally, a Fish Offsetting Monitoring Program will be developed to monitor the effectiveness of the Fish Offsetting Plan. The monitoring program will be developed in consultation with regulatory agencies and the KIA, and will assess the effectiveness of the compensation activities over time in reference to specific performance objectives. These performance objectives may include:

- stability of constructed habitat;
- primary productivity;
- benthic invertebrate community;
- fish presence/habitat use; and
- local density or population size estimated for fish species.

Adaptive Management

The need for any corrective actions to on-site emission management or installation of additional control measures will be determined on a case-by-case basis. Triggers for developing adaptive management measures may include:

- non-compliance results from the Surveillance Network Monitoring Program;
- adverse effects on fish/aquatic habitat as suggested by AEMP results; and
- adverse results from the Fisheries Offsetting Monitoring Program.

7.9 PROPOSED MONITORING PROGRAMS

7.9.1 Aquatic Effects Monitoring Plan

The AEMP can be found in Volume 10, Chapter 19. The AEMP will monitor various aspects of the freshwater environment, including:

- monitoring a network of lakes and streams within the Goose Property at locations potentially affected by the Project and at reference areas well away from Project activities;
- monitoring lake and stream water quality, sediment quality, and aquatic biology;
- monitoring fish populations and fish tissues; and
- if effluent is discharged to the environment, then additional sampling for MMER requirements will be conducted (effluent characterization; acute toxicity testing; site characterization studies [including surface hydrology]; sublethal toxicity testing).

7.9.2 Fish Offsetting Plan

The Conceptual Fish Offsetting Plan will address all potential serious harm to CRA fish by creating compensatory fish habitat elsewhere in the landscape. The monitoring of fish offsetting may include estimating the potential benefits of the offsetting option to fisheries production (as a surrogate of fisheries productivity), changes in migration success and changes in the biomass of adult Arctic Char in

Nulahugyuk Creek. It is also predicted that gains in biomass at Bernard Harbour will exceed all losses in fisheries production resulting from Project activity.

7.10 IMPACT STATEMENT

This chapter assesses the potential *direct* effects of the Project on the mortality and population abundance of the VECs Lake Trout and Arctic Grayling. In addition to such *direct* effects, individual fish health and *indirect* mortality could be potentially affected by Project-related activities through the contamination of water or sediment, as well as through contaminants bioaccumulating in fish through trophic interactions with primary and secondary producers (Volume 8; Chapter 6). A hydrodynamic model was developed in order to predict arsenic concentrations in Goose Lake (Volume 6, Chapter 4). The modelling included important fish spawning and overwintering areas and led to the conclusion that no anticipated significant adverse effects on the fish community of Goose Lake are expected. Additional details are provided in the freshwater water quality chapter under the 'mine contact water' section (Volume 6, Chapter 4). The effects assessments for freshwater water quality and sediment quality identified non-significant residual effects, so no significant effects on the VEC fish community (Lake Trout and Arctic Grayling) are expected via the *indirect* pathway. The potential for bioaccumulation in the VECs Lake Trout and Arctic Grayling is quantitatively assessed in the Human Health and Environmental Risk Assessment chapter (Volume 8; Chapter 6) and in the Country Foods chapter (Volume 8, Chapter 5).

Direct mortality and population abundance of the freshwater fish community VECs (Lake Trout and Arctic Grayling) may be affected by Project activities through several routes: Project infrastructure (lake dewatering, winter roads, and Project footprint), water withdrawal, and blasting with explosives. Direct mortality of Lake Trout and Arctic Grayling is anticipated as result of lake dewatering for Project infrastructure in Llama and Umwelt lakes. Reduced population abundance of Arctic Grayling is anticipated for the population of Goose Lake as a result of lost spawning and rearing habitat in its southern tributaries.

As a result of mitigation, management, and balancing all fish bearing habitat losses with the Conceptual Fish Offsetting Plan, there are no residual effects anticipated on the VECs Lake Trout and Arctic Grayling. The primary mitigation measures are setting maximum limits to water withdrawal to protect sensitive fish habitat and siting Project infrastructure (WRSAs, camp and plant site) to avoid fish-bearing water. Where direct mortality is anticipated and population abundance declines are predicted, losses to fisheries productivity will be fully compensated by establishing a Final Fisheries Offsetting Plan. The plan would be approved by DFO as a condition of the Authorization required for the development of the Back River Project.

As no Project residual effects are anticipated, there are no potential residual effects that could act cumulatively with other project potential effects. Therefore no cumulative effects or transboundary effects are expected on the VEC freshwater fish community.

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Definitions of the acronyms and abbreviations used in this reference list can be found in the Acronyms and Abbreviations section.

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