Sabina
GOLD & SILVER CORP.

The BACK RIVER PROJECT

Freshwater Environment

Volume 6



Prepared by:

Rescan™
an ERM company

December 2013

Document Structure

MAIN VOLUME

Back River Project
Draft Environmental Impact Statement (DEIS)

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

- Overall Environmental Management Plan
- Individual Plans

VOLUME 11

Type A Water Licence Application

- Type A Application and Support Documents
- Geochemistry
- Tailings Management Alternatives
- TIA Water Quality Predictions

VOLUME 12

Other Approvals (NWB, KIA, AANDC, DFO, TC)

Sabina GOLD & SILVER CORP.

Rescan an ERM company

Back River Project Fact Sheet

December 2013

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

- Six mining areas within the Goose and George Properties. Three locations at the Goose Property (Goose, Umwelt, and Llama) and three locations at the George Property (Locale 1, Locale 2, and LCP North).

Site Preparation and Construction Phase

- Site preparation may begin in 2014 (winter roads, fuel depots, laydown areas)
- Full construction of the project could commence as early as 2016 – two years to complete construction
- Approximately $605 M initial capital investment

Operational Phase

- Goose Property: open pit at Llama, Umwelt and Goose deposits; underground at Umwelt deposit
- George Property: Open pits at Locale 1, Locale 2, LCP North

Production

- Production Rate (Ore): 15.0 million tonnes of mill feed for life of mine
- Projected annual 300,000 ounces of gold for about up to 10 years

Processing

- 5,000 tonnes per day
- Standard gravity separation and cyanide leaching circuit
- Tailings facility at Goose Property

Transport

- Gold doré bars shipped out by aircraft

Access Roads

- All-weather roads within George and Goose properties
- Winter road between George and Goose properties
- Winter road to link properties to the Marine Laydown Area at Bathurst Inlet
- Short term winter road link to Tibbett-Contwoyto Winter Road

Re-supply

- Marine supply via open water seasonal shipping (max of 10 ships, average of 3 to 5 per year)
- Year-round by aircraft
- Winter road to the Marine Laydown Area
- Winter road connection to Yellowknife (short term)

Environment

- Extensive baseline studies including terrestrial environment, wildlife (particularly caribou), marine environment, freshwater environment, air quality and resource utilization
- Traditional knowledge information collected and analyzed through an Inuit owned major study - Naonaiyaotit Traditional Knowledge Project
- 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 1200 person years over a two year period
- Direct operations employment up to 4442 person years for 10 years

Social and Economic Benefits

- Inuit Impact Benefits Agreement with the Kitikmeot Inuit Association
- 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 sufficient to verify that reclamation has successfully met closure and reclamation objectives

BACK RIVER PROJECT

DRAFT ENVIRONMENTAL IMPACT STATEMENT
Supporting Volume 6:
Freshwater Environment

December 2013
Project #0194096-0040

Citation:
Rescan. 2013. *Back River Project: Draft Environmental Impact Statement Supporting Volume 6: Freshwater Environment*. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd., an ERM company.

Prepared for:

Sabina Gold & Silver Corp.

Prepared by:

Rescan Environmental Services Ltd., an ERM company
Vancouver, British Columbia

Executive Summary

Rescan™
an ERM company

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 composed of three main areas: the Goose Property, the George Property, and a Marine Laydown Area (MLA) situated along the western shore of southern Bathurst Inlet. Sabina has prepared an Environmental Impact Statement (EIS) to identify and assess potential environmental and social effects resulting from the Project, and is consistent with the requirements outlined in the Nunavut Land Claim Agreement (NCLA) 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 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 2012) 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 noted in the EIS guidelines (NIRB 2013) is included in this volume.

Potential effects on VECs were evaluated spatially within Local Study Areas (LSA) for each of the Goose and George Properties and larger Regional Study Areas (RSA) that contained each of the LSAs. The Goose Property LSA covered 365 km^2 and included the Goose Property Potential Development Area (PDA) and followed the boundaries of the Propeller and Big watersheds. The Goose Property RSA covered 6,815 km^2 and included parts of the Ellice River Watershed and encompassed the Goose Property PDA and the LSA. The George Property LSA covered 105 km^2 and included the George Property PDA, and followed the boundaries of the Dragon, George, McCoy, and Lower Long watersheds. The George Property RSA covered 4,034 km^2 and included part of the Western River Watershed and encompassed the George Property PDA and LSA. All potential Project effects were assessed during the Site Preparation, Construction, Operations, Reclamation and Closure, and Post-closure Project 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 used in the water and sediment quality assessments.

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

Surface Hydrology

Baseline hydrology data are available for the Goose Property LSA from 2010 to 2013 and for the George Property LSA from 2012 and 2013. 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 the 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.

Potential Project effects on the hydrology VEC included water use, site water management activities, and winter roads. The potential effects from these activities were assessed using three indicators which were quantity of water used, streamflows, and lake volumes. The mitigation and management measures designed to eliminate or reduce the potential effects on surface hydrology included: the design of maximum water use volumes for key waterbodies in order to protect critical fish habitat, following DFO protocols for winter water withdrawal, confinement of infrastructure to local watersheds, and following winter road construction and maintenance DFO operational statements.

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 PDAs or LSAs. 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. Project residual effects are anticipated to be confined to the freshwater LSA. The closest proposed project that could potentially interact with the Project residual effects is the proposed BIPR project, which has a small section of all-weather road proposed at the northwest edge of the George Property freshwater RSA. The small section of proposed all-weather road is not anticipated to result in any effects to hydrology, and given that the Project residual effects were confined to the LSA, there are no expected cumulative effects on hydrology. As the Project residual effects were confined to the freshwater LSA, which resides entirely within 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, which is thawed during the summer only, 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 through-taliks beneath large lakes, such as those below Goose and George lakes. Structural features in the bedrock, such as the northwest-southeast trending faults commonly found at the Goose and George properties, 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 (lakes which overlie through taliks) to lower elevation large lakes, therefore the flow direction can be inferred from the surface elevation of the large lakes that overly through taliks. Site-specific groundwater data were

collected in 2012 and 2013 within the Goose and George Property PDAs. Thermistor strings, vibrating wire piezometers, borehole packer testing, and a Westbay well have been used to characterise 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. Groundwater quality indicated by the Westbay well will be representative of water that will seep in to the Umwelt underground 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, with extensive baseline studies focusing on the Goose Property LSA in 2010 and 2011, and on both the George and Goose property LSAs in 2012 and 2013. 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 George and Goose LSAs since 1994, with extensive water sampling programs being carried out from 2010 to 2013. The results showed that the lakes and streams in the freshwater LSAs 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, chorine, and cyanide. 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 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, three residual effects were identified: sediment introduction to surface waters as a result of site preparation, construction, and decommissioning, water quality changes due to site contact water, and water quality changes due to mine contact water. The magnitude of the anticipated residual effects is expected to be low, the duration short to medium term (confined to the life of the Project), sporadic in nature, and confined to within the freshwater 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) and the Aquatic Effects Management Plan (AEMP; Volume 10, Chapter 19), the significance of residual effects for freshwater water quality is predicted to be **Not Significant**.

A potential cumulative effects assessment was conducted because residual Project effects were predicted. Project residual effects are anticipated to be confined to the freshwater LSA. The closest proposed project that could potentially interact with the Project residual effects is the proposed BIPR project, which has a small section of all-weather road proposed at the northwest edge of the George Property freshwater RSA. The small section of proposed all-weather road is not anticipated to result in residual effects to water quality, and given that the Project residual effects were confined to the LSA, there are no expected cumulative effects on freshwater water quality. As the Project residual effects were confined to the freshwater LSA, which resides entirely within Nunavut, there was no potential for transboundary effects.

Freshwater Sediment Quality

Baseline freshwater sediment quality data have been collected in the George and Goose LSAs since 2007, with the most continuous sampling conducted from 2010 to 2013. The results show that the lakes in both the Goose and George LSAs are comprised of fine materials such as silts and clays (>89% composition) with generally low levels of organic matter. Steams are composed of coarser materials with the sediments at both property LSAs made up mainly of sand (43-53%), with small proportions of gravel- and silt-sized particles (22-29%). Lakes and streams in the George Property LSA tend to have greater sediment metal concentrations than those found in the George Property LSA. Arsenic, cadmium, chromium, copper and zinc concentrations are naturally greater than CCME sediment quality guideline levels at several lakes and streams within the George LSA. Arsenic and copper sediment concentrations are naturally above CCME sediment quality guidelines at several lakes and streams within the Goose Property LSA.

Potential Project-related 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, three residual effects were identified: sediment introduction to freshwater sediments as a result of site preparation, construction, and decommissioning, sediment quality changes due to site contact water, and sediment quality changes due to mine contact water. The magnitude of the anticipated residual effects is expected to be low, the duration short to medium term (confined to the life of the Project), sporadic in nature, and confined to within the freshwater 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) and the Aquatic Effects Management Plan (AEMP; Volume 10, Chapter 19), the significance of residual effects for freshwater sediment quality is predicted to be **Not Significant**.

A potential cumulative effects assessment was conducted because residual Project effects were predicted. Project residual effects are anticipated to be confined to the freshwater LSA. The closest proposed project that could potentially interact with the Project residual effects is the proposed BIPR project, which has a small section of all-weather road proposed at the northwest edge of the George Property freshwater RSA. The small section of proposed all-weather road is not anticipated to result in residual effects to sediment quality, and given that the Project residual effects were confined to the LSA, there are no expected cumulative effects on freshwater sediment quality. As the Project residual effects were confined to the freshwater LSA, which resides entirely within 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 and George Property LSAs from 2010 to 2013. More than 30 streams have been characterized in the Goose Property LSA, and more than 20 in the George Property LSA.

Within the Goose LSA, there are permanent barriers to fish migration along the stream between Pond A and Giraffe Lake (where the TIA has been located) 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 Outflow within the stream 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.

Within the George LSA, the stream/pond system between George Lake and Komatic Lake is characterized by low gradient habitat featuring glides and occasional pools and riffles, typical of beaded tundra streams. The portion of the stream system between George Lake and Lytle Lake features boulder fields that may become impassable at low water due to subsurface flow. However, spawning and rearing habitat for Arctic grayling is fair to good in reaches downstream of Sleigh Lake.

Large lakes such as Propeller, Goose and George 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 LSAs. 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 Project-related 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 habitat due to lake dewatering, development of open pits, water withdrawal for domestic and process use, and winter road construction. Stream habitat may also be lost due to the construction of mine infrastructure. 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 TIA 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 George lakes. Unavoidable losses of fish habitat (e.g. loss of Llama Lake due to Llama Open Pit) will be compensated

through the implementation of a Conceptual 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 effects that could act cumulatively with other projects. Therefore no cumulative effects or transboundary effects are expected.

Freshwater Fish Communities

The freshwater fish communities in the Goose and George Property LSAs are characteristic of Arctic freshwater ecosystems and include freshwater and anadromous species. Baseline studies have been conducted from 2010 to 2013 within the LSAs. 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 LSAs include Burbot (*Lota lota*) and Lake Whitefish (*Coregonus clupeaformis*). No Arctic Char (*Salvelinus alpinus*) have been captured within either of the Goose or George LSAs, although they are likely present within the freshwater RSAs.

Potential Project-related effects on the VEC freshwater fish community focused on the two abundant freshwater or anadromous fish species in the LSAs, 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 TIA 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 George lakes. Unavoidable losses to these freshwater fish species (e.g. loss of Llama Lake due to Llama Open Pit) will be further mitigated through the implementation of a Conceptual Fish Offsetting Plan.

Following the application of mitigation and management measures, one residual effect was identified: the possible reduction in Arctic Grayling populations as a result of the loss of Llama Lake and local drainages. Umwelt Outflow serves as spawning and rearing habitat for Arctic Grayling, and the reduction in flow in this system could adversely affect Arctic Grayling populations. The residual effect is expected to be of moderate magnitude, be of medium duration (confined to the lifetime of the Project), continuous, confined to the LSA, and potentially reversible if watershed inputs are restored during closure. Overall, the significance of residual effects for Arctic Grayling is predicted to be **Not Significant**. 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), no residual effects for Lake Trout are anticipated.

A potential cumulative effects assessment was conducted because a residual Project effect was predicted. The Project residual effect is anticipated to be confined to the freshwater LSA. The closest proposed project that could potentially interact with the Project residual effect is the proposed BIPR project, which has a small section of all-weather road proposed at the northwest edge of the George Property freshwater RSA. The small section of proposed all-weather road is not anticipated to result in residual effects to the freshwater fish community, and given that the Project residual effect was confined to the LSA, there are no expected cumulative effects on freshwater fish community/Arctic Grayling. As the Project residual effect was confined to the freshwater LSA, which resides entirely within Nunavut, there was no potential for transboundary effects.

ᐊᐅᓪᓛᔨᑦ ᑐᑭᓯᐊᖏᑎᑎᕆᔨᒋᑎᖅ ᓇᐃᓇᖅᓯᒪᔨᖅ

ᐅᓇ ᖃᓚᐊᖅ ᑯᖅᖢ ᓴᐟᓂᖅᓱᔨᖅ ᐱᓪᓚᐊᖅᓱᔨᖅ (ᐅᓇ ᐱᓪᓚᐊᖅᓱᔨᖅ) ᑐᓯᕆᖅᓯᒪᖅᓯᑦ ᖃᐟᓄᕆᖅ ᔪᑕ ᐱᓪᓚᐊᖅ ᑕᕆᑯᖅᓱᑦ ᓴᐃᓇᓚᓪᓕᑦ ᑯᓘᓐᓃᑦ. (ᓴᐃᓇ) ᐃᑐᐊᓂ ᐱᓇᖅᓇᖅᓂ ᖃᑎᖅᑎᐅᑦ ᓄᓇᖅᓂ ᓄᓇᐅᓪᒥ. ᐅᓇ ᐱᓪᓚᐊᖅᓱᔨᖅ ᑕᕆᑯᖅᓱᔨᑦ ᐱᖅᓯᓯᓂᑦ: ᔪᓴ ᔪᑐᖅᑲᖅᑐᖅ, ᔨᐊᔭ ᔪᑐᖅᑲᖅᑐᖅ, ᐊᓚᒪᑐ ᒪᓱᖅ ᑕᐃᑕᐅᓇ ᓄᓇᖅᓂ ᑕᐅᖅᓂ ᐱᓇᖅᓇᖅᓂ ᓯᓴᒥ ᓂᒋᐊᓂ ᖃᐅᖅᓱᓚᖅ. ᓴᐃᓇ ᑎᑎᕋᖅᓯᓚᔨᖅ ᐊᖅᑎᕐᕋᑎᓂᓄ ᐊᖅᑐᐃᑐᖅ ᐊᓚᒪᑐ ᐃᓕᓴᕐᕕᖅᑐᓄ ᐅᖅᖃᖅᓯᓚᔨᑦ ᓇᓗᓇᐃᖅᓯᔪᑎᑕᒋᑦ ᐊᖅᑎᕐᕋᑎᓂᓄ ᐊᓚᒪᑐ ᖃᐅᔨᔪᖅᑕᐅᓇᖅᑐᑦ ᐱᓕᕆᔨᑦ ᐃᓗᐊᓂᖅᑐᑦ ᐊᓚᒪᑐ ᓄᓇᐅᓪᒥ ᐱᓚᖅᓱᖅᑐᑦ ᐃᓚᖅᑕᐃᓕᓴᕐᕕᖅᑐᑦ ᐱᓚᖅᓱᖅᑐᑦ ᐃᓚᖅᑕᐃᓕᓴᕐᕕ

ᐊᕐᓕᕐᓂᓱᒪᓕᕆᔨᑦ ᐃᓕᓴᒪᓕᐅᕕᓱᓕᕆᓂᖅ 4,034 ᑭᓪᓗᒍ ᐊᒻᒪᓗ ᐃᓕᓴᐅᑎᓱᒪᓕᐊᓘᖅ ᐃᓕᖅᑐᓂᒃ ᑲᓇᖅᑐᖅ ᑯᓇᖅᑐᖅ ᑯᓇᖅᑐᖅ ᐊᒥᓕᖅᑎᒃ ᔪᐊᕐᓗᒋᑦ ᐃᓕᓴᐅᕕᓱᓕᕆᓂᖅ ᐊᒻᒪᓗ ᓄᓇᓕᕐᓂᑦ ᐃᓕᓴᐅᕕᓱᓕᕆᓂᖅ. ᑕᒪᖅᑭᑐ ᐱᓕᕐᓂᐊᕐᓇᖅᑐᓂ ᐊᕐᑭᐊᓇᖅᓯᓂᖅ ᖃᐅᔨᓴᕕᐊᓱᓕᔪ ᑕᐃᒃᓂ ᐃᓂᖅᓱᖅᑐᓂ, ᓴᓇᔨᕕᑦ, ᐊᕕᓕᕐᑎᓂᓂ, ᐃᓂᑐᖅᑲᖅᓯᓂ ᕕᑎᓴᖅᑎᖅᓴᕕᓂᖅᓱᖅᑐᓂ ᐊᒻᒪᓗ, ᐊᒻᒪᓗ ᒪᑐᐃᓂᖅᓱᖅᑐᓂ ᐱᓕᕐᓂᐊᖅᓴᓂ ᓯᖏᖅᑎᓕᕐᓂᐊᓂᐊᖅᓯᖅ. ᓇᓕᓕᐊᖅ ᒪᓕᑦᓴᖅ ᐃᓱᒪᕐᕉᓱᓕᔪᖅ ᑕᐃᒃᓂ ᓯᖏᐃᖅᓱᓇᓱᖅᓯᓂ ᐃᓕᓴᐅᕕᓱᓕᔪᖅ ᐃᓕᑎᕐᕕᓂᓗᓂᖅ ᐅᑯ ᐃᖅᑲᓇᕐᓂᐊᕕᑯᓂ ᐊᒻᒪᓗ ᐅᒪᓕᖅᑐᓂᒃ ᐃᓕᓴᐅᕕᓱᓕᔪᖅ ᐊᑦᑕᓇᖅᑐᖅᑎᑦᑕᖅᑐᓂ ᐱᓇᓱᖅᓯᓂᖅ. ᐅᖃᐅᕕᐳ ᑲᑎᒪᔨᖏᑦ ᑕᒧᑯᓯᖓᓂᑦ ᐊᖅᑭᑎᓂᓂᐊᕕᑯᓂ ᐃᓕᒪᒍ ᐊᒻᒪᓗ ᐃᓂᖅᓱᑦᑕᓗᓂ ᑐᑭᓯᒪᔭᕐᓂᖅ ᐱᓇᓱᖅᓯᓂᖅ. ᐊᕐᓕᕐᓂᐊᓂᐊᖅᓯᓂ ᐊᒻᒪᓗ ᐅᒪᓕᖅᑐᓂᒃ ᐃᓕᖅᑐᓂᒃ, ᐊᒻᒪᓗ ᐊᑦᑕᓇᖅᑐᑦᑕᖅᑐᓂ ᐊᑦᑕᓇᖅᑐᖅᑎᑦᑕᖅᑐᓂ ᐱᓇᓱᖅᓯᓂᖅ ᐃᓕᓴᐅᕕᓱᓕᔪᖅ ᐊᑦᑕᓇᖅᑐᖅᑎᑦᑕᖅᑐᓂ

ᑕᒪᐃᓇᐅᓪᓚᕆᖅᑎᑦᑕᒍ ᐅᖅᑐᑕᐅᓪᓗᐊᖅᑕᐃᓕᓪᓚᑎᑎᕐᑎᓴᕐᑕᐅᓪᓕᑦ ᐊᒻᒪᓗ ᐊᐅᓪᓚᕆᑎᓴᕐᑕᐅᑐᓴᖅᑐᑦ, ᒪᕐᕉᒃᖠᕐᕋᖅᑐᑦ ᐊᐅᑐᐃᓐᓇᖅᑐᑦ ᐃᓕᓴᕐᓂᕐᐊᓂᖅᓚᕋ ᐊᐅᖅᑐᑦ ᑕᐃᓕᖅᑎᑦ. ᐊᖏᕐᓂᖅᐸᐅᓇᓂᕆᐅᕙᖅ ᓂᓚᐅᑎᕆᐅᕙᖅ ᐃᓕᓴᐸᓪᓕᐊᓂᖅᓚᒃ ᐊᐅᖅᑐᑦ ᐊᕿᑎᑐᐅᐊᖏᖅᑐᑦ, ᐊᑯᓂᐅᑎᑕᖅ ᐊᐳᓪᓗᐊᖏᓪᓕᓪᓗᓂ ᒥᓂᐅᓚᐅᖅ (ᐃᑲᓗᓇᓂᐊᖅᑕᖏᓚᓂ ᐱᓕᓇᐊᖓᙵᙵᖅ), ᑲᙵᓗᓇᓪᓗᓂ ᑕᐃᒪᓇᐅᑦᑐᖅᒥ, ᐊᒻᒪᓗ ᐃᓗᐊᑲᓪᓗᓂ ᐱᖓᓕᓪᓗᐊᖅᑐᕐᓂᖅᓯᒪᙵᙵ6 ᐅᖏᖓᔪᓐᓂ ᓄᓇᓕᒫᑦ ᐃᓕᓴᕐᑎᑦᑕᒍ. ᐅᓇ ᐃᓴᖃᓪᓕᓴᕐᑕᐃᓕᓪᓚᑎᑎᕐᑎᓴᕐᑕᐅᓪᓚᒃ ᐸᑎᓕᕐᓴᖅᑐᑦ. ᑎᓪᓕᖃᓇᓐᓂᕐᑎᑦ ᐊᑐᕐᓴᕐᑕᐅᓪᓚᑎᑦᑎᓂᖅᓯᒪᓂᖅ ᐅᑯᐊ ᐊᐅᖅᑐᑦᑕᐃᓕᓪᓚᑎᑎᕐᑎᓴᕐᑕᐅᓪᓚᒃ ᑎᑎᕋᖅᓯᒪᔪᑦ ᐃᓗᐊᓂᖅᓚᒃ ᐊᐅᖅᑐᑦᑕᐃᓕᓪᓚᑎᑎᕐᑎᓴᕐᑕᐅᓪᓚᒃ ᐊᐅᖅᑐᑦ ᐊᑐᐅᓪᓚᕆᐊᖃᖅᑐᑦ

ᐃᓕᑦᑐᐃᒍ ᑕᒪᐃᓐᓄᑦ ᐃᓂᖅᓯᓂ ᐃᓂᖅᓯᓂ ᐃᒋᑦ ᒥᐊᓂᓱᐅᓂᖅᓴᓕᐅᓂᐊᖅᑐᑦ ᐊᖏᓪᓕᐊᑦ ᐊᐅᓪᓚᕐᓴᐅᑕᐅᓂᐊᖅᑐᐃᓄᑦ <ᖁᓇᐅᑎᑦ (ᑎᑎᕋᖅᓭᓪᓕᔪᑦ 10, ᐊᖏᑦ 7).

<u>ᑕᓭᓪᓂᖅ ᐊᖏᓪᓕᐊᑦ ᐃᓕᐅᐸᑦ ᐃᑎᓂᖅᓯᒪ</u>

ᑕᓭᓪᓂᖅ ᐊᖏᓪᓕᐊᑦ ᐃᓕᐅᐸᑦ ᐃᑎᓂᖅᓯᒪ ᖃᑉᐸᑎᕈᖅᓯᓚᖅᓯᑦ ᓄᐅᑕᐅᓪᓕᐅᖅᑐᑦ ᐱᓪᓚᐊᖅᓱᐊᕐᒥ ᑕᐃᓕᖅᓯᓂ 1994, ᐅᖅᓯᕐᓚᐊᖅᓭᓪᓕᔪᓐᓇ ᐱᑎᐊᖅᓴᐃᖅᓯᓂ ᐃᓪᓕᑕᐅᓇᓗᖅᑐᑦ ᑕᐃᑲᓂ ᔪᓐᓇᖃᖅᑐᑦ ᓄᓇᓕᖅᑎᔪᓂ ᐃᓪᓕᑕᐅᓇᓗᓭᓪᓕᒋᓐᓇᑲ ᑕᐃᑲᓂ 2010 ᐊᖏᓪᓕᐊᑦ 2011, ᐊᖏᓪᓕᐊᑦ ᑕᓕᕎᒃ ᔨᐊᐅᓕ ᐊᖏᓪᓕᐊᑦ ᔪᓐᓇ ᔪᓐᓇᐊᖅᑐᑦ ᓄᓇᓕᖅᑎᔪᓂ ᐃᓪᓕᑕᐅᓇᓗᓭᓪᓕᒋᓕᓪᓚᓐᓇᑲ ᑕᐃᑲᓂ 2012 ᐊᖏᓪᓕᐊᑦ 2013. ᑕᓯᑦ ᒥᑭᔨᖅᑐᑐᖅᓴᐅᓪᓚᑦ ᐊᖏᓪᓕᐊᑦ ᐃᑲᓪᓕᓂᑲ, ᑕᓪᓕᓐᓂ 5 ᐊᖏᓪᓕᐊᑦ 500 ᐃᑎᑎᒋᓂᖅᓱᒍ ᖃᑲᓱᓂ ᐊᖏᓪᓕᐊᑦ ᐊᑕᓐᓂ 10 ᒋᑕ ᐃᑎᓂᖅᓴᐅᖅᑐᖅ. ᑕᓯᑦ ᐃᖅᑲᑦ 2 ᒋᑕ ᖃᐅᐊᖅᓯᐃᓐᓇᐅᓴᓪᓚᖅᑐᑦ ᐊᑎᓕᓪᓕᕐᓂᓕᓂᑦ ᓄᐅᓯ ᐊᑕᓪᓚᐃᒍ ᐅᑭᐅᖅᓯᐅᑦ. ᑕᓯᑦ ᐃᓕᖅᑲᖅᑕᕐᖅᑐᑦ ᖃᑲᓱᓂ ᑕᓱᓐᓱᑲ ᐃᖅᑲᓱᓇ ᐃᓕᐅᑦᔪᓐᓇ ᑕᐃᓕᓐᓄᐃᓐᓇᐅᑦᓯᓪᓚᓇ ᓯᓗ ᐊᓄᑦᖅᑕᕐᓯᓐᓱᓇ. ᐃᓪᓕᖅᑎᓂᑦ ᐃᓪᓕᒋᖅᑕᕐᖅᑐᑦ ᓂᐅᓪᓯᓂᓐᓱᒍᔪᓂ ᐊᖏᓪᓕᐊᑦ ᐃᓱᐊᓂᓐᓱᒍᔪᓂ ᑕᓯᑦ ᐃᑎᓂᖅᓴᐅᖅᑐᑦ ᐅᖃᓪᓚᒋᖅᑕᐅᓂᐊᖅᑐᑦ ᓯᑯᓯᒪᓕᓪᓚᓯᑦ ᑕᓯᑦ ᐅᑭᐅᖅᓯᐅᑦ, ᑕᐃᓕᓐᓄᐃᓐᓇᐅᑦᓯᓪᓚᖅᑐᑦ. ᐃᒥᖅ ᐃᖅᑲᓱᓂ ᑕᑯᓂᖅᓴᐅᓂᐊᖅᑐᑦᓯᓪᓚᖅᑐᑦ, ᐊᓄᑦᖅᑕᕐᖅᑐᑦᓭᓪᓕᔪᓐᓇ ᐃᑕᓐᓄᐃᓐᓇᐅᑦᓯᓪᓚᖅᑐᑦ ᐃᓕᓴᕐᓂᐊᓕᓂᑦ ᐃᖅᑲᓱᓂ. ᐃᓕᓱᑕ ᐅᕐᓯᑲᖅᑕᕐᖅᑐᑦ ᐊᖏᓪᓕᐊᑦ ᐃᓕᓴᕐᓂᐊᓕᓂᑦ ᑕᓯᑦ ᐃᓕᓐᓄᐃᓐᓇᐅᑦᓯᓪᓚᖅᑐᑦ ᐅᑭᐅᖅᓯᐅᑦ, ᐊᓄᑦᖅᑕᕐᖅᑐᑦᓭᓪᓕᔪᓐᓇ ᐃᓕᓴᕐᓂᐊᓕᓂᑦ ᐃᓕᓐᓄᐃᓐᓇᐅᑦᓯᓪᓚᖅᑐᑦ

ᐱᓴᓪᓕᐅᕐᖓᓐᓄᑦ ᐅᖅᑐᑕᐅᔪᓂ ᐊᖅᑐᐃᓐᐊᖃᖅᑕᐃᓕᓚᑎᑕᑎᕐᕕᑕᐅᔪᓂ ᐊᒻᒪᓗ ᐊᐅᓪᓚᕆᕐᕕᐅᔪᓂ, ᐱᓕᕐᓂ ᐱᓴᖏᑦᑐᓪᓗᐊᖏᑐᑦ ᓇᓗᓇᐃᖅᑕᐅᓪᓚᕐᕕᐅᖅᑐᑦ: ᐃᖃᓗᓐᓄ ᐱᑎᐊᖅᑐᖅ ᖃᓄᖅᓱᓄ ᐃᒪᐅᐸ ᐃᓕᓴᐅᓄ ᐊᖏᔪᖅᑕᐅᓪᓚᕐᓂᓐᓄ, ᓴᓇᓴᐅᓐᓄ, ᐊᒻᒪ ᐱᓴᖅᑕᐅᓂᐊᕐᒥᓐᓄ, ᐃᒪᓕᒐ ᓴᓕᔪᑕᓕᖅᑐᓕᒐ ᐃᓕᓴᐅᓂᐊᖅᑐᖅ ᐃᓕᓴᐅᓂᐊᖅᑐᖅ ᐃᓕᓴᐅᓂᐊᖅᑐᖅ

ᓴᓗᒪᖅᓴᐅᑕᐅᔪᓂᑦ, ᐊᒻᒪᓗ ᓱᓕᔪᐊᑐᐃᓐᓇᕆᔨᓂᖅᓄᑦ ᐄᕆᖅᑐᖅ. ᐊᐅᑐᐃᓗᐊᖅᑕᐃᓕᓕᒫᑎᓕᕆᔨᑕᐅᔪᓂ ᐊᒻᒪᓗ ᐊᐅᓕᕐᓂᔪᑕᐅᔪᓂ ᐃᓂᕆᖅᑎᔪᐊᖅᑐᑦ ᐊᐅᓕᑕᐅᓗᑐᐃᑦ ᐊᐅᓕᑕᐅᓗᑐᐃᑦ ᐃᓕᓴᕐᓂᖅᑕᐅᔪᖅ ᐊᑎᖅᑕᕐᓂᐊᕐᓂᖅ ᐊᓕᕐᓇᖅᑐᑎᓕᓴᐃᓗᓂᖅ ᐊᓕᕐᓇᖅᑐᑎᓕᓴᐃᓗᓂᖅ ᐊᓕᕐᓇᖅᑐᑎᓕᓴᐃᓗᓂᖅ ᐊᐅᓕᑕᐅᓗᑐᐃᑦ ᐃᓕᓴᕐᓂᖅᑕᐅᔪᖅ ᐊᐅᓕᑕᐅᓗᑐᐃᑦ

ᐃᓗᐊᓂ ᔪᑦ ᓄᓇᓕᖅᓂ ᐃᓕᑕᐅᓇᓯᒪᔪᐊᑎᒍ, ᐊᔪᓕᑕᐅᓂᐊᖅᑐᖅ ᐃᖅᑲᓗᐃᑦ ᓄᑲᑕᓚᐊᕐᓴᖅᑎᑦ ᑕᒪᓂ ᑯᐊᓪᓴᕐᑯᑦ ᐊᐖᑲᓂ ᑕᓯᕋᓪᓚ A ᐊᓪᒪᓗ ᔪᐖᕕ ᑕᓯᖅ (ᑕᐃᑲᓂ TIA ᓇᓂᐅᐅᓯᒪᔪᖅ) ᐊᓪᒪᓗ ᑕᒪᐅᓪᓚ ᑯᐊᓂᐃᑦ ᐊᐖᑲᓂ ᐊᓪᒧᐃᑦ ᑕᓯᖅ ᐊᓪᒪᓗ ᔪᑦ ᑕᓯᖅ. ᐃᓂᖅᑲᖅᑐᑦ ᖃᑐᐖᕐᐅᐅᖅᑐᑦ ᐊᓪᒪᓗ ᖃᑐᐖᕐᐅᐅᖅᑐᑦ ᓯᓗᖅᐸᐅᓪᓕ ᐱᐅᓪᒍᔪᖅ ᑎᑭᐅᑎᑭᓐᓇᖅᑐᑦ ᖃᐅᔪᒪᑦ ᐊᓪᒪᓗ ᐊᓪᒧᑦ ᑕᓯᖅᑎᒍᑦ. ᐊᒥᓯᐃᓗᖓᓂ ᐃᓂᖅᑲᖅᑐᑦ ᑕᐃᑲᓂ ᐅᓪᓴᐃᑦ ᑯᐊᓂᐃᓯᓂᒃᑯᑦ ᐊᐖᑲᓂ ᐅᓪᓴᐃᑦ ᐃᓂᓪᓕᒍᒪᔪᑦ ᑲᑎᒪᓂᖅ ᐊᑐᖅᑐᑦ ᐅᓪᓴᐃᑦ ᐃᓂᓪᓕᒍᒪᔪᑦ ᐅᑭᐅᖅᑕᕐᓂᖅ ᐃᓂᓪᓕᒍᒪᔪ

ᐃᒪᖅᐱᐊᓂᒃ ᐃᖃᓗᐃᑦ ᐃᖃᓗᓯᖏᑎᓂᓪᓗ

ᐅᑯᐊ ᐃᒪᖅᐱᐊᓂᒃ ᐃᖃᓗᐃᑦ ᑕᐃbᓂ ᔪᑦ ᐊᒻᒪᓗ ᓴᐊᕕ ᔪᓗᐊᖅᑐᑦ ᓄᓇᓕᖅᓂ ᐃᓕᑕᐅᓴᕐᓯᒪᔪᑦ ᑕᒪᖏᐅᑦ ᐅᑭᐅᖅᑕᖅᑐᒥ ᐃᒪᖅᐱᐊᓂᒃ ᐅᒪᓕᖅ ᐊᐋᑎᑕᒫᓂᖅᓗᓂᓪᓗ ᐊᒻᒪᓗ ᒪᓴᐊᖅᑎᓂᑕᑦ ᐅᒪᓴᐊᓂᒃ. ᐃᓂᖅᑎ ᐃᓕᑕᐅᓴᕐᓯᒪᔪ ᑕᐃᒪᖏᓂᖅ 2010 ᑎᑭᓪᓗᒍ 2013 ᐃᓗᐊᓂ ᓄᓇᓕᖅᓂ ᐃᓕᑕᐅᓴᕐᓯᒪᔪᑎᒍᑦ. ᐃᒪᖅᐱᐊᓂᒃ ᐃᖃᓗᐃᑦ ᓄᓇᒋᑦ, ᐃᒪᖅᓴᖅᑕᖅᑐᑦ ᐊᐃᑲᑐᖅᓯᒪᔪᖏᓐᓂᒃ bᓇᑕᐅᑦ ᐅᑭᐅᖅᑕᖅᑐᐊᓂ. ᐃᓕᑎᕆᐃᑦ ᐅᓄᒋᓪ ᐅᒪᓕᖅᓂ, ᑕᒪᖅᑯᓂᖅᑐᑎᒃ bᐃᓴᓪᓕ, bᓇᔪᖅ, ᐊᒻᒪᓗ ᐃᖃᓗᐃᑦ. ᐊᓴᖏᑦ ᐅᒪᓕᖅᓂ ᓇᓂᖅᐅᐅᖅᑐᑦ ᐃᓗᐊᓂ ᓄᓇᓕᖅᓂ ᐃᓕᑕᐅᓴᕐᓯᒪᔪ ᑕᒪᖅᑯᓂ ᑎᑎᑦᑕᐅᑦ ᐊᑕᖅᑐᑦ ᐃᓗᐊᓂ ᐃᓕᑕᐅᓴᕐᓯᒪᔪᓂ, ᐱᑕᖅᑐᑦ ᐅᒪᓕᖅᓂ ᐃᓕᑕᐅᓴᕐᓯᒪᔪᓂ ᐃᓗᐊᓂ ᐃᓐᓇᐅᑉᐸᑦ ᐊᑐᖅᑐᑦ ᐃᓗᐊᓂ ᐃᓐᓇᐅᑉᐸᑦ ᐊᒻᒪᓗ ᐃᖃᓗᐃᑦ ᐅᓄᒋᓪ ᐃᓐᓇᐅᑉᐸᑦ ᐊᒻᒪᓗ ᓴᐃᖅᑕᖅᑐᑦ ᑕᒪᖅᑯᓂ ᐃᓐᓇᐅᑉᐸᑦ ᐊᒻᒪᓗ ᐃᖃᓗᐃᑦ ᐅᓄᒋᓪ

ᐋᓱᖏᑦᑐᓪᓗᐊᓂᖅᓴᒃ ᐅᖅᓯᒪᖅᓴᒪ ᓄᓇᓕᖅᓵᑦ ᐃᓕᐊᓂ ᐃᓕᑕᐅᓇᓯᑐᑦ, ᓂᕆᐅᓇᖅᓴᕐᑕᖅ ᐊᒃᑐᖅᑕᐅᐃᖅᓂᐊᓕᐊᒃᖏᖅᓴᒃ ᐃᒪᓕᕆᐊᒧᒃ ᐃᖏᓄᖅᓴᓂᒃ ᐊᓚᒪᓄ ᓯᓄᒃᐸᐅᑦᖅ ᐊᖅᒪᓕᕐᓂ. ᐅᓇ ᐱᑕᕆᐊᖅᓱᖅᖅ ᓄᖅᐸᖏᑕᓯᐊᕐᑎᓄᑐ ᐊᒃᑐᐃᓂᐊᖅᓴᕐᑕᖅ ᐃᒪᓕᕆᐊᒧᖅᓱᓂ ᓄᓇᓕᖅᓂ ᐃᑕᑕᐅᓇᓯᒪᔪᓂᑦ, ᐅᑯᐊᓗ ᐃᓂᖏᓄᑐᖅ ᑕᒪᐃᖅᓂ ᓄᓇᕐᒥᒥ, ᐱᑕᖏᓂᐊᖅᓴᕐᑕᖅ ᐊᓯᕆᖅᓂᑦ ᑎᑭᑕᑐᓂᒃ ᐊᒃᑐᖅᑕᐅᓗᓂ.

Atanguyan Naetomik Okaohen

Hanigayokmi Havaak (Havaak) kulmik oyagaktakveoyomayok nanminigiyaoyok Sabina-konin Oyagakheoktinin iloani Oalikheani Kitikmeot, Nunavumi. Havaak pikahuyun havakveoloagumayun: Goose-mi Oyagaktakvik, George-mi Oyagaktakvik, Umiyalo Uheyakvikhaan (MLA-goyok) inikaktok oalikheani hinaani hivugaani Kigaom. Sabina-kon ihoakhaehimayun Avataoyomik Aktoknigagun Okaohikmik (EIS-mik) tikoakhiyaagani ilitokhaklogilo aktokneolaktun avataoyomun inuknulo Havaamin, taemaeginakhonilo atogeakakniginik okaotaoyonik Nunavumi Nunataknikun Agikatigegutaoyomi (NLCA-mi) Nunavumilo Avatilikiyin Katimayinin (NIRB-konin) Maligoakoyaenik Ihoakhakniginik Avataoyomik Aktoknigagun Okaohikmik Hanigayokmi Havaamin (NIRB-koni Titikam Napaa 12MN036; NIRB-koni 2013-mi). Una ataotimeoyun EIS-mi piyotikaktok ilitokhakniginik aktogutaolaktonik avataoyomun hilaenakmik piyotikaktonik Havaami hulilogagutinin kigoagun atulikmata ihoakhaotin monagiyotilo havaan.

Naonaeyaknigin piyotaolaktonik Atokloaklotin Manikami Pikaknigin (VEC-goyun) piyotaoyok Sabina-konin kitulika okakaktigiyaagani, atokniginik Igilgaa Kaoyimayaenik (TK-mik), maligoagakhaleoktin okakatigiyaagani maligoagakhaniklo ihomagiyaoyukhanik ila ilipkamaenageagani angutikhavaloen ilagelunen, atulikoyaeniklo okaotaoyun NIRB-kon EIS-giyani maligoagakhan (NIRB-kon 2013-mi). *Inoen Igilgaan Kanoyimayaenik Sabina-kon Hanigayokmi Havaaga, Naonaeyaotit Igilgaa Kaoyimayaenik Havaak Unipkaak (*KIA-kon 2012-mi) okaotaokhaaktun TK-mik hivonikhiyotikhani. Atokata ukoa ihoakotin, Ukoa imagiknigin imigakhan tikaoktaoyun VEC-nik: kaaganetun imavaloen, imagiknigin, imigakhan natkani halomanigin, tatini ikaloen umayulo nunagiyaen, tatinilo ikalokaknigin. Nunami imakaknigin, tikvani imavaloen, itinigilo ihomagiyaoyun Okaotaoyageakakniginik tamaetalo piyageakaktun hivonikhiyotikhanik okaotaoyonik EIS-mi maligoagakhani (NIRB-kon 2013-mi) ilaoyun uvani ataotomeoyoni makpigaani.

Aktoknigilaaktaen VEC-goyun ilitokhagaoyun kanoginiginik iloani Ilitokhagaoyum Nunam (LSA-goyum) atuni Goose-mi George-milo Iglukpakakvikni aginikhamilo Kanitoani Ilitokhagaoyumi Nunami (RSA-mi) pikaktun atuni LSA-ni. Goose-mi Iglukpakakvik LSA-giya ilakaktok 365 kilamitamik avatiknun ilakakhonilo Goose-mi Iglukpakakvikmi Pivaleaniganik Nunanmi (PDA-goyok) maligoakhogilo kikligin Propeller, Big-lo imakaknigin. Goose-mi Iglukpakakvikmi RSA-ga 6,815 kilamitaoyok avatiknun ilagivlogolo Kunayum Imakakniga avaluleotivlogolo Goose-mi Iglukpakakvikmi PDA-ga LSA-galo. George-mi Iglukpakakvikmi LSA-ga 105 kilamitaoyok avatiknun ilakakhonilo George-mi Iglukpakakvikmi PDA-ganik, maligoakhogolo kikligin Dragon, George, McCoy, Atpanetulo imakaknigin. George-mi Iglukpakakvikmi RSA-ga 4,034 kilamitaoyok avatiknun ilagivlogolo Olalikheani Kukam Imakakniga avaluleotivlogolo George-mi Iglukpakakvikmi PDA-ga LSA-galo. Tamaeta Havaamin aktutaolaktun ilitokhaktaoyun Inigiyaoyukhak Ihoakhaktaotilogo, Hanayaotilogo, Aolaveotilogo, Utiktitaoneaktilogolo Ilitkuheanun Umiktiknigalo, Umiktaakan Havaaguyukhan. Maligoagakhaloen ihomagiyaoyun ilitokhaktaotilogo ilakaktun *Ikalolikinikun Maligakyaok* unalo *Umayun Ihomaloknaktun Maligakyaok* (SARA-goyok). Kanatami Katimayin Havakveoyun Avatilikinikun (CCME-kon) imagikniga heogaleavlo kanoginigagun maligoakhan moangiyaagani imiktaakhani umayovaleon atoktaohimayun imagiknigagun heogavaloelo kanoginigagun ilitokhaotini.

Ukoa naetomik okaotaoyun taya avataoyomik, Havaami hulilogagutikhanik nahogiyaoyonik aktogutaolaktun imiktaakhani VEC-gin, ihoakhaotikhan, aktoknigagun ilitokhaotin, atulakalo, ataotimukpaleanigin aktokniginik ilitokhaotin atuni imiktaakhani VEC-gin.

Nunam Kaagani Imakaknigin

Hivoani imakaknigagun naonaepkotin kahaktun Goose-mi Iglukpakakvikmi LSA-gani 2010-min 2013-mun George-milo Iglukpakakvikmi LSA-ga 2012-min 2013-mun. Nunam kagani imakakniga maligoagakaktok Ukeoktaktomi umeaktuktun piyuhenik ila kugiknikaktun upingaami, hila unakpaleatilogo kikaegaagan. Mikiyoni tahikani, ukoa kugiknikaktun ikitoni uploni. Kugiknikaktun hikeoyaligaagan tatini ikigahaknilo, ila mikinikhanik tahikani. Nuna kikumakman, mikiyun kunoen imayoetun nunan iloanin, kugoekneagunakhiyun ukunaga tahikanin maniktiktaakan aoyami nipalikan kiheani. Kukan aginikhan, kugiknigin kiguvakneagunakhiyok imakakpalagitpan nuna aputin kigiknikhanin imakaknigani kuktukman oeguligeni kunoani. Nipaloknigin nugulikan aoyak ukeakhalihaakalo kugikhitiyotilaktok, kiheani una mikitkiyaoyok kukniga maniktikniganin nunam. Ikigahaen hikovaleavaktun nuguligaagan October atulihalikalo November. Mikitkiyani kuvalokni, imavaloen kikivaktun natkanun, kuktokagitok ukeomi. Imakaknikni agitkiyanilo tatini, kuknigin immalvo aolaniga kukvigiyaolaktun paaginilo taman hikoyoetun.

Havaamin aktogutaolaktun imakakniginik VEC-ni ilakaktok imaknik atokniginik, iglukpakakvikmi imaknik monagiyotinun hulilogaagutin, ukeomilo apkotin. Aktoknigilaktaen ukunanga hulilogaagutinin ilitokhagaoyun atokhotik pigahunik naonaeyaotinik kanogaalok atokniginik imaknik, kuknigin, takilo imakaknigin. Ihoakhiyotinun monagiyotinulo piyotaoyun atogeageagani mikhivaaligeaganilunen atoknigilaktaen nunam kaagani imakaknigin ukoagoyun: ihoakhakniga aginikhamik imaknik atoknigin imakaknikloagini monagiyaagani ikaloen nunagiyaen, malikhogin DFO-kon pikoyaen ukeomi imiktakniginik, iloaneginageaganilo pikotin inigiyaoyomi imakaknigini, malikhogilo ukeomi apkotin hanayaonigin monaginigilo DFO-kon aolanikun okaohenik.

Maligoaklogin atoknigin ihoakhaotin monagiyotilo atoktun, malguk kigoani aktoknigik tikaoktaoyuk: aalaguknigin kuktun, tatilo imakaknigin. Kanogaalok nahogiyaoyok kigoani aktoknigin mikaoneaknahogiyaoyok, hivitoniga tayaenak (ilaoneneak havakveotilogo Oyagaktakvik), atonakneaktok ilitkohigaloagatun, iloanelonilo PDA-goyun LSA-nilo. Kigaogun aktoknigin nahogiyaoyulo kikloanun aolaligeagani. Atokata atokpaleanigin ihoakhaotinun piyotin okaotaoyun Inigiyaoyomi Imaknik Amigiyotinun Monagiyotinulo Opalogaeyaon (Makpigaami 10, Titigaknigani 7), takukhaoniga kigoagun aktoknigin imakakniginik nalaotagaoyok **Ihomaloknaeniganik.**

Ataotimukpalealaktun aktokniginik ilitokhakniganik havaagiyaoyok ila kigoagun Havaak aktoknigin nalaotagaokmata. Havaamin kigoagun aktoknigin nahogiyaoyun iloaneginakniginik imiktaakhani LSA-mi. Kaninikhak havaagiyaoyomayok ilaolaktok Havaami kigoagun aktoknigini una BIPR-mik havaagiyaoyomayok, pikakman naetomik ukeogaalok apkotikhamik tunungani oalikheani kikligata George-mi Iklukpakakveom imiktaakhanik RSA-gani. Netok apkotaoyukhak nahogiyaogitok aktoknikaknihaagun imavaloknik, Havaamilo kigoagun aktoknigin iloanetmata LSA-mi, nahogigitun ataotimukpaleayonik aktokniginik imavaloen. Havaamin kigoagun aktoknigin iloanenmata imiktaakhani LSA-mi, inikaktok tamaan Nunavumi, pilimagitok tiktaonigin anokimin aktoknigin.

Nunam Iloani Imak

Havaak inikaktok iloani kikumaenaktum nunam nunakyoami Kanataom Ukeoktaktoani, talvuna imakaktok nunami ataani kikumaenakniganin (ila > 400-metamik ataani kaganin). Imakaktok aoktokataktomi kaagani kikomaniganin, aoktukpakman aoyamenak, ilaolaktun nunam kagani imavalokni. Mikiyomik ilaonikaktok nunam kaganin aoktoenakpaktum unanigaalok nunami imaoyun kuknigin pikaktukman hiliktoni aoktukpalaayoetoni kikomaniganik. Unanigaalok ataani kikomanigata imakaknigin nunan kukniginin ilaoyun nunam kagani imavaloknik aoktokataktuvlo nunam kumnigitigun natkani agiyun tatin, imaetoni natkani Goose-mi George-milo tatini. Kanoginigin kaektoni, ukununatun tunungani kivalikheani-hivugaani kivalikheani kumnigin kaektoni takukhaovaktun Goose-mi George-milo iglukpakakvikni, kukvigiyaolaktun nunam iloanin imavaloknik ataani nunam kikomaniganin. Kumnigin

naniyaovaktun Goose-mi George-milo iglukpakakvikni, kukveolagunakhiyun nunam iloani imavaloknin ataani kikomaneom nunam. Imaetuginaktok, nunam iloani imavaloen kukpaktun kigiknikhanin agiyonin tahiknin (tatin kaaganetun kumnigin) atpanetonun agiyonun tatinun, talvuna kuknikalaktok nunam kaaganin aginikhanin tatinin kaaginetun kikomanigata nunam iloani aomaniginin. Iglukpakakvikmi nunam iloani imakaknigin naonaepkotin katitiktaoyun 2012-mi 2013-milo iloani Goose-mi George-milo Iglukpakakvikni PDA-gani. Unaktaknigagun naonaeyaotin, hayuktun alguyan immam hakogikniganin kunmun, ikutaganik himikhiyotin ilitokhaknigin, nunamilo iloanin imiktakvik atoktaohimayun naonaeyageagani nunami imavaloen kanoginiginik. Imiktakvik nunamin, iliyaohimayok hanigaani oyagaktakvikham 2013-mi, atoktaohimayok nunam ilaoni imagikniginik naonaeyagaoyok. Hivoani kanoginigin nunam iloani imakaknigin naonaegutoayok unanegaalok nunami imak takyokakloatkiyaoyok takyomin, tamaeta avugivaleaniga ima 47,000 mg/L-mik aginikhamiklo, chloride-kaktuvlonilo havivalokniklo. Nunam iloani imagikniga naonaegutaoyok Westbay-mi imiktakvikmi nunamin taemaeyotineaktok imaknik kukloaktun avatigiyaoyomi nunam ilaonun monagiyaolonilo ilagani tamaeni Iglukpakakvikmi Imakakniganik Amigiyotini Monagiyotinulo Opalogaeyaonmi (Makpigaak 10-mi, Oegoani 7).

Taheoyun Imakaknigin Natkanetulo

Tahivaloen itiniginiklo hivonikhiyutin katitikhimayun Havaam haneanin 1994-min, iloengaomayonik ilitokhaotinik ihomagiloakhogo Goose-mi Oyagaktakvik LSA-mi 2010-mi 2011-milo, tamaknilo George-mi Goose-milo iglukpakakvini LSA-gini 2012-mi 2013-milo. Tatin mikiyuginaktun ikatutiklo, agitilaagin talimanin 500 ha-nun kaagini agitilaagin ikatkiyaovlotiklo 10-metamik itinikhakmik. Tattin ikatkiyan 2-metamik hikuvaktun natkanun ukeomi. Tattin akutaovaktun kaaginin natkanun aoyami anokimin. Ilagini aalatkektun unaknigin takukhaoheoknigilo natka pilaktok itinikhani tattini hikukaktonilunen tattini ukeomi, una taemaekatagitkalaoktilogo. Imagiknigin tattin agiyok, anukimin akutaoneagaloakhotik heogakaknigan. Imavaloen unaknigin tattini kuvaloknilo maligoaginakuktun Ukeoktaktomi unakniganik, unatkiyaoyonik August-mi kutiknikhaani naetum aoyam

Imiktaagakhan Halomanigin

Naonaeyaotaolgaktun imagiknigagun naonaepkotin katitikhimayun George-mi Goose-milo LSA-ni 1994-min, amihonik imaknik ilitokhaeyotini havaagiyaoyun 2010-min 201mun. Kanoginigin naonaegutoayun tattin kuvaloelo imiktaakhani LSA-ni taemaeginaktun Ukeoktaktomi imikhakvikhan atoktun. Kaganetun imavaloen pikakpalagitun ilaleotihimayonik naptoyonik havivalokniklo, taemaetonakhovuk nunan kanoginigani talvani. Tatin kuvaloelo aolavalayoetun avataelo ihoagitun, pH-gilo heknaktuyaaktun kanogigitotiklo. Tatin kuvaloelo heogakakpalaagitu halomateaktun. Ilaleotinigin anikhaguminaktun ila atoktavun amigaetun kuvalokni tatinilo, kiheani ilagin avataoyun pikaktun anikhaguminaktonik mikinikhanik CCME-mi imaoyun halomaniginik maligoagakhani imavaloen aolanikakpalagoegaagata ataani hikum (tatini) imakoginigilo kuktun aoyami (kuvaloen). Taemataok, aolagikhiyotin akitun amigaenikhalo tatin kuvaloelo naohimayokakpalagitotik mikiyonik naonikaktonun. Havivalokaknigin tatin kuvaloelo mikiyun, kiheani amigaekpatkun huminiganin havivalokakneom kanitoani nunami. Inmini havivalokakniganik aolavalaaginigilo imaoyun tatini kuvaloknilo, cadmium-kakniga kanoyakniklo agitkiyaook CCME-mi imaoyun halomaniginik maligoagakhani hapumiyaagani imiktaagakhani umayovaloen.

Havaamin aktugutaolaktun imiktaagakhanik imagikniganik VEC-ni ilakaktok Havaami hulilogagutinik aalaguktilaktanik ukoa naonaepkotin imagiknigagun: pH-mik, TSS-mik, aolagigutikhanik, havivaloknik, paovaloknik, BOD-mik, chorine-mik, cyanide-miklo. Aktoknigilaktaen Havaamin hulilogagutinin ilitokhagaoyun atokhogin ilaolilaktonik aolaniginik imiktaagakhalo inigiyaen, kuknigilo mahaktikneom, imaektitpaleaniginik, halomaktikhimayun kuktitaoyun, hilaenakulo katakpaleayun. Ihoakhaotin monagiyotilo atuktukhan inigekhimaneaktun monagiyaagani ukoa aolanigin, talvuna mikinikhaoyaagani pikagitaaganilunen Havaamin aktokniginik imiktaagakhanik imagiktonik VEC-ni. Iglukpakakvikmi Imaknik

Amigiyotinun Monagiyotinulo Opalogaeyaon (Makpigaami 10, Oegoani 7) ukoalo Havaami kanoginikhaenik ila kinitpan oyakan namaenageagani atoklotik apkotini tungaviknilo takukhaohoektineagaa mikhipkaklogolunen aktogutaolaktun imiktaakhanik imagikniganik.

Kigoani atolikniganik ihaokhaotin monagiyotilo, pigahun kigoagun aktoknigin tikoaktaohimayun: heokakpaleaniga nunam kaagani imavaloen ila iglukpakakvikhak ihoakhaktaotilogo, hanayaotilogo, agiptiktaotilogilo, imagikniga aalagukpaktun iglukpakakvikmi aktoknikaagami imaknik, imagiknigalo aalagukpaktok oyagaktakvikmin aktokhigumi imavaloen. Agitilaagani kigoagun aktoknigiyaoneaknahogiyaan mikaoneaknahogiyaan, hivitoniga naeloni takivalaagilonilo (oyagaktakveoginaktilogo Havaak), taemaekatalimagitok, ilaoneginaklonilo imiktaakhani LSA-mi. Kigoagun aktoknigin nahogiyaoyun kikloagulakniganik. Pihimakpan atokpaleaniganik ihoakhaotin okaotaoyun Iglukpakakvikmi Imaknik Amigiyotinun Monagiyotinulo Opalogaeyaonmi (Makpigaak 10-mi, Oegoani 7) Imakmilo Umayovaloen Aktokniginik Monagiyotinun Opalogaeyaon (AEMP-goyok; Makpigaami 10, Oegoani 19), pikakniga kigoagun aktokniginik imiktaakhanik imagiknigagun **Ihomalutaovalaagitok**.

Ataotimuktun aktoknigilaktaenik ilitokhaknik piyimayok kigoagun Havaamin aktoknigin nahogiyaokmata. Havaamin kigoagun aktoknigin nahogiyaoyun imiktaakhaneginageagani LSA-ni. Kaninikhak havaagiyaoyomayok ilaleotilaktok Havaami kigaogun aktokniginin atuligumayaoyok una BIPR-goyuk havaak, mikiyomik ukeogaalok akotikakveoyomayok tunungani oalikheani kikligata George-mi Iglukpakakveom imiktakvikhaani RSA-mi. Naetok ukeogaalok apkotaoyomayok nahogiyaogitok kigoagun aktoknikageagani imagikniginik, ila Havaami kigoagun aktoknigin ilaonenmata LSA-goyum, nahogiyaogitun ataotimukpaleaniginik aktokniginik imiktakvikhan imagikniganik. Havaami kigoagun aktoknigin ilaonenmata imiktakvikhan LSA-mi, inikaktokn tamaan Nunavumi, pikalimagitok nutpaleayonik aktokniginik.

Imiktakvikhani Heogavaleon Halomanigin

Naonaeyagan imiktaakhani heogalean halomanigignik naonaeptkotin katitigikimayun George-mi Goose-milo LSA-mi 2007-min, ilitokhaeginakhotik pihimayun 2010-min 2013-mun. Kanoginigin naonaegutaoyun ukoa tattin tamakni Goose-mi George-milo LSA-gani pikaktun heogaloeanik makluyaaktun (>89%-mik ilagenik) neoteanoakagitonik. Kuvaloen heogaleakaktun agitkiyanoanik maklukniko tamakni iglukpakakvikni LSA-mi heogaleanik (43-min 53%-mun), mikiyoniklo oyagaleanik (22-min 29%-mun). Tattin kuvaloelo George-mi Iglukpakakvikmi LSA-mi amigaetkiyan heogalean havivalokaktun ukunanga naniyaohimayonin George-mi Iglukpakakvikmi LSA-mi Arsenic-goyok, cadmium-lo, chromium-lo, kanoyaklo havivaloklo pikaknigin amigaetkiyan CCME-min heogalean halomaniginik maligoagakhani kanoginigin malgukni tattikni kuknilo iloani George-mi LSA-mi. Arsenic-mik kanoyakmiklo pikaktun heogalean amigaetkiyaoginaktun CCME-mi heogaleanik halomaniginik maligoagakhani malgukni tattikni kuknilo iloani Goose-mi Iglukpakakvikmi LSA-gani.

Havaamin aktogutaolaktun imiktakvikhani heogalean halomaniginik VEC-ni ilakaktok Havaamin hulilogagutinik aalagugutilaktok ukoa naonaegutin heogalean halomaniginik: heokan agitilaaginik, aolagikhiyotin mikanoelo paovaloen, havivaloen, paovaloelo. Aktoknigilaktean Havaami hulilogagutin ilitokhakhimayun atokhogin ilaleotilaknigin apkotaoyun imiktaakhalo inigiyaeni, kuvaleolo, imaektitpaleanigin, halomaktigaoyok kuktitaoyun, hilaenakmilo tutpaleayun. Ihoakhaotin monagiyotilo iliyaoneaktun monagiyaagani ukoa apkotaen, mikhivaaligutaoneaktun takuhaogilotiklunen Havaamin aktoknigin imiktaakhani heogalean halomanigini VEC-ni. Iglukpakakvikmi Imakni Amigiyotinun Monagiyotinulo Opalogaeyaon (Makpigaami 10, Oegoani 7) ukoalo ihaokhaotin atoktukhan hinaa nutgutpaleagitaagani tattin takunaeneaktok mikhivaaliklonilunen aktoknigilaktaen imiktaakhani heogalean halomaniginik.

Kigoagun atokniganik ihoakhaotin monagiyotilo, pigahun kigoagun aktoknigin tikaoktaoyun: heogavaleon tutpaleanigin imiktakvikhani heogaleanun iglukpakakvik ihoakhaktaotilogo, hanayoatilogo, agiptiktaotilogolo, heogalean halomaniginik aalaguknigin iglukpakakvikmi imakakniganin, heogalealo halomaniginik aalaguknigin oyagaktakvikmin imakakniganin. Agitilaagan nahogiyaoyum kigoagun aktokniginik mikineaknahogiyaoyok, hivitogilonilo (oyagakgakveotilogo Havaak), katutugaagalo, iloaneginaklonilo imiktaakhani LSA-mi. Kigoagun aktoknigin nahogiyaoyulo kikloagulakniginik. Piyotikaktok atokniganik ihoakhiyotin okaotaoyun Iglukpakakvimi Imiktaakhan Amiginiginun Monaginiginulo Opalogaeyaonmi (Makpigaami 10-mi, Oegoani 7) Imakmeotalo Aktokniginik Monagiyotinun Opalgoaeyaon (AEMP-mi; Makpigaami 10-mi, Oegoa 19), takuhaoniga kigoagun aktoniganik imitakvikhani heogavaloen halomaniganik nalaotagaoyok **Ihomalutoaginiganik.**

Ataotimuktun aktoknigilaktaenik ilitokhaknik pihimayok ila kigoagun Havaamin aktoknigin nahogiyaokmata. Havaamin kigoagun aktoknigin nahogiyaoyun iloaneginakneaktun imiktaakhani LSA-mi. Kaninihak havaagiyaoyomayok ilagiyaolaktok Havaami kigoagun aktokniginik una BIPR havaagiyaoyomayok, naetomik ukeogaalok apkotileokvigiyomayaan nahogiyaogitok kigoani aktoknikaniganik heogalean halomaniginik, Havaami kigoagun aktoknigin ilaoneaginakneaktilogin LSA-mi, nahogiyaogitun ataotimukpaleaniginik aktokniginik imiktakvihani heogalean halomaniginik. Havaami kigoagun aktoknigin ilaoniginakneakmata imiktakvikhanik LSA-mi, inikaktok taman Nunavumi, nutpaleayukhanik aktonikalimagitok.

Imiktakvikhani Ikaloen Umayonoelo Nunagiyaen

Imiktakvikhani Ikaloen/imakmeotalo nunagiyaen pikaktun tamaknik nunagiyaen naovaleayonoelo ihoakotin hatkigutoaginakneaktok imiktakvikhani ikalovaloknik aalatkekniginiklo imiktakvikhani ikaloen nunagiyaen. Naonaepkotikhaloen ilitokhagaoyun imiktakvikhani ikalonik umayonoanilo nunagiyaoyun ukoaguyun tamangnik nunagiyaen umayunoelo ihoakotin umayutigiyaen imiktakvikhani ikaloen aalatken ilalo aalatkeknigilo imiktakvikhani ikaloen. Tamatkeomayun naonaeyaotin imiktakvikhani ikaloknik imakmilo nunagiyaoyun pihimayun Goose-mi George-milo Iglukpakakvikni LSA-mi 2010-min 2013-mun. Amigaetkiyan 30-nin kunoen naonaeyagaoyun Goose-mi Iglukpakakvikmi LSA-mi, amigaetkiyalo 20-nin George-mi Iglukpakakvikmi LSA-mi.

Ilaoni Goose-mi LSA-gani, pikaktok aolalimagitomik kitpavigilimagitaen ikaloen avanmuktaktun kunoami akungani Tahikam A Giraffe Lake-milo (atagukvik inikakveani) kunoamilo akungani Umwelt Lake-min Goose-milo. Nunagiyaoyun halomanigin ikalokan agiklitikven iglikaknigilo Hulukpaogan nakunikhan akeaguyanoani kunoani kulaani atpanilo kunoani tahiknin. Nunagiyaotektun uknani Rascal-mi Kukami akunani Rascal, Goose-lo tatik. Una kunoak mikiyonik oyagalealik heogaleaniklo Hulukpaogan igligiyaen ikalogakakhotiklo, kitpavigivlogolo akungani tattin ukeomi ikaloen kitpavigiyaen.

Iloani George-mi LSA-gani, kunoen tahikalo akungani George-mi Tahikmin Lytle-mun Tahikmun oyagalokaktun anigulimagitun imaektihimatilogo ikaloknin nunam ilaogun kuktukmata. Kiheani iglikakven ikalogakaktulo Hulukpaoganik nakuyun akeaguyanoani atpani Sleigh-mi Tahikin.

Agiyun tattin Propeller-tun, Goose-tulo George-tulo ikalokaenaktun ukeogaalok amigaetuvlotiklo aalatken ikaloen ila Ihun, Hulukpaogalo ilaoni LSA-goyum. Ukoa itiyun tattin umavigivagaen ikalogaaloen hikuhimatilogo ukeomi. Aheanitaok, ikatun tattin 2-metamik itinikaktun kunoelo hikuvaktun natkanun ukeomi atoktaolimagitulo ukeomi ikalonin nunagiyaoyaagani.

Ilitokhakniga Havaamin piyotikaktun aktoknigilaktaen imiktakvikhani ikaloknin umayonoanilo nunagiyaoyun ilakaktun aktoknigiyaanin Havaami hulilogagutin nunagiyaeni imiktakveoyukhani ikaloen. Aktogutaolaktun okaotaoyun ilagani imiktakvikhan imagiknigini heogalealo halomaniginik ilitokhaotini. Havaamin hulilogagutin aktoknilaktun imiktakvikhani ikaloknik umayonoelo nunagiyaenik ilakaktun atogoekniginik tattini nunagiyaoyun tahik imaeyaktaoneakman, pivaleaniga oyagaktakvikham anmukpalealotik, imiktakveoyukhaklo inoen atoktakhaenik oyakikiyotikhanulo, ukeomilo apkotileokata.

Kunoelo nunagiyaoyun atogeakneagunakhiyun hanayaolikan oyagaktakvikmi pikotinik. Ihoakhaotaoloaktukhak atugitaagani aktoknigilaktaen imiktakvikhani ikaloen umayunoelo nunagiyaen Havaami ihoakhakniga ileogageagani pikotin kahagitaagani imiktakvikhani ikaloen nunagiyaen akitovalaagitpan. TIA-goyok ikagoniklo oyagaktaanik tutkuktigivik inikhaleoktaoyok aktokhigitaagani ikalokaktun imavaloen. Ihoakhaotaokmiyoklo inikhimaniganik aginikhanik imaknik atokniginik piyotikaktomik apumiyaagani ikalokan agiklitikven Goose-mi, Propeller-mi, George-milo tattini. Atoginiga ayoknaktok aheoniginik ikaloen nunagiyaenik (ila atogeokniga Llama Tattimik Oyagaktakveoneakman) himaotikakneaktok atokpaleanigagun umiga Ihomagiyaoyok Ikaloknik Aheaguknikhaagun Opalogaeyaon. Talvuna kigaogun aktoknigin nahogiyaogitun VEC-ni imiktakvikhani ikaloen umayonoelo nunagiyaenik.

Havaamin kigoagun aktoknikaginiga nahogiyaoyok, pikagitok aktoniginik ataotimukpaleayonik ahenin havaanin. Talvuna ataotimukpaleayun aktoknigin nutpaleayulunen aktoknigin nahogiyaogitun.

Imiktakvikhani Ikalokaknigin

Imiktakvikhani ikaloen Goose-mi George-milo Iglukpakakvikni LSA-gini ayikutaen Ukeoktaktomi imiktakvikhan tattin kanoginiginik ilakaktoklo imiktakvikhanik umayunoaniklo. Ilitokhaotiloan pihimayun 2010-min 2013-mun ilaoni LSA-goyum. Imiktakvikhani ikalokaknigin taemaetun tikvani nunami, kukveoyun nunan Kanatami Ukeoktaktomi. Ihun amigaenikhan ikalokni, Kapihilen tukleovlotik, Hulukpaogan, Kanayun, Ukatun itulo. Aalat ikaloen naniyaoyun LSA-mi ukoa Kaligalen Tahikmilo Kapihilen. Ikalokpiktokakhimagitok iloani ukoa Goose-mi George-milunen LSA-gini, pikagunakhiyugaloak imiktakvikhan RSA-gani.

Havaamin aktokhiyotaolaktun VEC-nik imiktakvikhani ikalokaknigin ihomagiyakaktun malguknik amigaetun imiktakvikhani utiktaktulunen ikaloen tattinin takyumun utimulo LSA-mi, Ihun Hulukpaogalo. Havaamik aktoknigutaolaktok ukuniga ikaloknik tokogakniginik ikiklivaleaneaktulo. Una Havaami hulilogagutinin ilageagutaolaktok tukugakniginik ikiklivaleaniginiklo Ihun Hulukpaogalo: tahik imaeyaktaokpan, ukeomi apkotileokniginin, hanayaolikan Havaam inigiyakhaa, imiktaktun inoen atoktakhaenik oyakikivikmilo ukeomilunen apkotileokata, kagaktitaeyulo kagaktitaotinun. Ihoakhaotaoloaktukhak atugitaagani aktoknigilaktaen Ihunik Hulukpaoganiklo Havaam kanoginiga inikaktilogin pikotin aktogilogin imikhakvikhani ikaloen nunagiyaen akitovalaagitpan. TIA-goyuk oyagaktaaniklo ikakukvik atulimagitonik inikaktitaoyuk aktoktaelivlotik ikalokaktonik imavaloknik. Ihoakhaotaokmiyoklo inikhimaniga aginikhanik imaknik atokniganik piyotikaktomik hapumiyaagnai ikalokan nunagiyaen Goose-mi, Propeller-mi, George-milo tahikni. Atoginiga ayoknaktok aheoniginik ikaloen nunagiyaenik (ila atogeokniga Llama Tattimik Oyagaktakveoneakman) himaotikakneaktok atokpaleanigagun umiga Ihomagiyaoyok Ikaloknik Aheaguknikhaagun Opalogaeyaon.

Kigoagun atokpaleaniganik ihaokhaotin monagiyotilo, ataohik kigoagun aktoniga tikaoktaoyok: ikiklivaleanikhaen Hulupaogan atogeakniganin Llama Taheoyum haneanilo kukniginin ahinun. Umwelt-mi Kuktok iglikakveoyok ikalokanilo nunagiyaoyok Hulukpaoganin, kugigoekniganiklo uma kukam ihoetomik aktolaktaen Hulukpaogan amigaeniginik. Kigoagun aktoknigin nahogiyaoyok agivalaaginiganik, hivitovalaagitonilo (oyagaktakveotilogo Havaak), atoenaktok, ilaoneginaktoklo LSA-goyum, kikloagulagunakhiyoklo imakaknigin utiktitaokpata umiktaokpan. Tamaeni, agitilaagan kigoagun aktoknigin Hulukpaoganik **Ihomalutaovalaagitok.** Piyotikaktok atokniganik ihoakhiyotin okaotaoyun Iglukpakakvimi Imiktaakhan Amiginiginun Monaginiginulo Opalogaeyaonmi (Makpigaami 10-mi, Oegoani 7) Imakmeotalo Aktokniginik Monagiyotinun Opalgoaeyaon (AEMP-mi; Makpigaami 10-mi, Oegoa 19), takuhaoniga kigoagun aktoniganik ihunik nahogiyaogitok.

Ataotimukpaleayun aktoknigilaktaenik ilitokhaknik pihimayok ila kigoagun Havaamin aktokniga nahogiyaokman. Havamin kigoagun aktokniga nahogiyaoyok ilaoneginakloni imiktakvikhanik LSA-mi. Kaninikhak havaagiyaoyomayok ilaleotilaktok Havaami kigaogun aktokniginin atuligumayaoyok una

BIPR-goyuk havaak, mikiyomik ukeogaalok akotikakveoyomayok tunungani oalikheani kikligata George-mi Iglukpakakveom imiktakvikhaani RSA-mi. Naetok ukeogaalok apkotaoyomayok nahogiyaogitok kigoagun aktoknikageagani imiktakvikhani ikalokakniginik, ila Havaami kigoagun aktoknigin ilaonenmata LSA-goyum, nahogiyaogitun ataotimukpaleaniginik aktokniginik imiktakvihani ikalokakniginik Hulukpaoganik. Havaami kigoagun aktoknigin ilaonenmata imiktakvikhan LSA-mi, inikaktokn tamaan Nunavumi, pikalimagitok nutpaleayonik aktokniginik.

Table of Contents

Rescan™
an ERM company

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

Table of Contents

Executive Summary i

Table of Contents xxv

List of Figures xxxiii

List of Tables xxxvi

List of Appendices xli

Acronyms and Abbreviations xliii

1. Surface Water 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 1-2

1.1.1.4 Annual Runoff and Seasonal Distribution 1-10

1.1.1.5 Peak Flows 1-14

1.1.1.6 Low Flows 1-14

1.1.2 Local Setting 1-14

1.1.2.1 Goose Property Area 1-19

1.1.2.2 George Property Area 1-24

1.1.2.3 Marine Laydown Area 1-26

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

1.1.3.1 Changes to the Active Layer and its Hydrologic Impacts 1-30

1.1.3.2 Changes to Runoff 1-30

1.1.3.3 Changes to Winter Flow 1-31

1.1.3.4 Hydrologic Impacts of Extreme Weather Events 1-31

1.1.3.5 Changes to Other Hydrologic Variables 1-31

1.2 Incorporation of Traditional Knowledge (TK) 1-32

1.2.1 Incorporation of TK for Existing Environment and Baseline Information 1-32

1.2.2 Incorporation of TK for VEC and VSEC Selection 1-33

1.2.3 Incorporation of TK for Spatial and Temporal Boundaries 1-33
1.3 Valued Components 1-33
1.3.1 Potential Valued Components and Scoping 1-33
1.3.2 Valued Components Included in Assessment 1-33
1.4 Spatial and Temporal Boundaries 1-34
1.4.1 Spatial Boundaries 1-34
1.4.1.1 Local Study Area 1-39
1.4.1.2 Regional Study Area 1-39
1.4.2 Temporal Boundaries 1-40
1.4.2.1 Site Preparation and Construction 1-40
1.4.2.2 Operations 1-41
1.4.2.3 Reclamation and Closure, and Post-closure 1-41
1.4.2.4 Maximum Footprint Conditions 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 1-44
1.5.3 Identification of Mitigation and Management Measures 1-44
1.5.4 Characterization of Residual Effects 1-45
1.5.4.1 Goose Property 1-46
1.5.4.2 George Property 1-48
1.5.5 Significance of Residual Effects 1-49
1.6 Potential Cumulative Effects Assessment 1-51
1.6.1 Methodology Overview 1-51
1.7 Transboundary Effects 1-52
1.8 Mitigation and Adaptive Management 1-52
1.9 Impact Statement 1-53

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 Area 2-10
2.1.2.3 George Property Area 2-19
2.1.2.4 Marine Laydown Area and Winter Road Corridors 2-28
2.2 Incorporation of Traditional Knowledge (TK) 2-28
2.2.1 Incorporation of TK for Existing Environment and Baseline Information 2-28
2.2.2 Incorporation of TK for Spatial and Temporal Boundaries 2-30
2.2.3 Incorporation of TK for Mitigation and Adaptive Management 2-30

2.3 Valued Components 2-30
2.3.1 Potential Valued Components and Scoping 2-30
2.3.2 Valued Components Included in Assessment 2-30
2.4 Supporting and Supplemental Information 2-30
2.4.1 Interaction of Groundwater with the Project 2-30
2.4.2 Numerical Groundwater Models and Groundwater Budget 2-31
2.4.3 Supporting Documents 2-31

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 3-7
3.1.4.1 Information Sources 3-7
3.1.4.2 Baseline Study Methods 3-7
3.1.5 Lake Limnology and Bathymetry 3-8
3.1.5.1 Lake Limnology 3-8
3.1.5.2 Lake Bathymetry 3-13
3.1.6 Stream Temperatures 3-14
3.2 Incorporation of Traditional Knowledge (TK) 3-17
3.2.1 Incorporation of TK for Existing Environment and Baseline Information 3-17
3.2.2 Incorporation of TK for Valued Ecosystem Component (VEC) Selection 3-18
3.3 Valued Components 3-18
3.3.1 Potential Valued Components and Scoping 3-18
3.3.2 Valued Components Included in Assessment 3-18

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 4-17
4.1.5.1 General Lake Parameters 4-17
4.1.5.2 Lake Total Suspended Solids and Turbidity 4-18
4.1.5.3 Lake Dissolved Oxygen 4-18
4.1.5.4 Lake Nutrients 4-20
4.1.5.5 Lake Metals 4-21
4.1.5.6 Lake Cyanide 4-23

4.1.6 Stream Water Quality 4-24
4.1.6.1 General Stream Parameters 4-24
4.1.6.2 Stream TSS and Turbidity 4-25
4.1.6.3 Stream Dissolved Oxygen 4-26
4.1.6.4 Stream Nutrients 4-26
4.1.6.5 Stream Metals 4-27
4.1.6.6 Stream Cyanide 4-29
4.2 Incorporation of Traditional Knowledge (TK) 4-30
4.2.1 Incorporation of TK for Existing Environment and Baseline Information 4-30
4.2.2 Incorporation of TK for Valued Ecosystem Component Selection 4-31
4.2.3 Incorporation of TK for Spatial and Temporal Boundaries 4-31
4.2.4 Incorporation of TK for Effects Assessment 4-31
4.2.5 Incorporation of TK for Mitigation and Adaptive Management 4-31
4.3 Valued Components 4-31
4.3.1 Valued Components Included in Assessment 4-31
4.4 Spatial and Temporal Boundaries 4-32
4.4.1 Spatial Boundaries 4-32
4.4.1.1 Local Study Area 4-32
4.4.1.2 Regional Study Area 4-32
4.4.2 Temporal Boundaries 4-35
4.5 Potential Project-Related Effects Assessment 4-35
4.5.1 Methodology Overview 4-35
4.5.1.1 Water Quality Indicators 4-36
4.5.2 Identification and Characterization of Potential Interactions with Project 4-38
4.5.2.1 Site Preparation, Construction, and Decommissioning Activities 4-43
4.5.2.2 Winter Roads 4-43
4.5.2.3 Site Contact Water 4-44
4.5.2.4 Mine Contact Water 4-44
4.5.2.5 Water Use 4-44
4.5.2.6 Quarries and Borrow Pits 4-44
4.5.2.7 Explosives 4-45
4.5.2.8 Fuels, Oils, and PAH 4-45
4.5.2.9 Treated Sewage Discharge 4-45
4.5.2.10 Dust Deposition 4-45
4.5.3 Identification of Mitigation and Management Measures 4-46
4.5.3.1 Site Preparation, Construction, and Decommissioning Activities 4-46
4.5.3.2 Winter Roads 4-48
4.5.3.3 Site Contact Water 4-49
4.5.3.4 Mine Contact Water 4-49
4.5.3.5 Water Use 4-50
4.5.3.6 Quarries and Borrow Pits 4-50

4.5.3.7 Explosives 4-51
4.5.3.8 Fuels, Oils, and PAH 4-52
4.5.3.9 Treated Sewage Discharge 4-53
4.5.4 Characterization of Residual Effects 4-53
4.5.4.1 Site Preparation, Construction, and Decommissioning Activities 4-53
4.5.4.2 Site Contact Water 4-54
4.5.4.3 Mine Contact Water 4-55
4.5.5 Significance of Residual Effects 4-56
4.6 Potential Cumulative Effects Assessment 4-56
4.6.1 Methodology Overview 4-56
4.6.2 Potential Interactions of Residual Effects with Other Projects 4-58
4.7 Transboundary Effects 4-58
4.8 Mitigation and Adaptive Management 4-58
4.9 Proposed Monitoring Programs 4-62
4.9.1 Conceptual Aquatic Effects Management Plan 4-62
4.10 Impact Statement 4-62
4.11 Supporting and Supplemental Information 4-63
4.11.1 Drinking Water Baseline 4-63

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 5-9
5.1.5.1 Lake Sediment Particle Size Composition 5-10
5.1.5.2 Lake Sediment Total Organic Carbon 5-10
5.1.5.3 Lake Sediment Metals 5-11
5.1.6 Stream Physical and Chemical Sediment Quality Characteristics 5-14
5.1.6.1 Stream Sediment Composition 5-14
5.1.6.2 Stream Sediment Total Organic Carbon 5-15
5.1.6.3 Stream Sediment Metals 5-15
5.2 Incorporation of Traditional Knowledge (TK) 5-17
5.2.1 Incorporation of TK for Existing Environment and Baseline Information 5-17
5.2.2 Incorporation of TK for VEC Selection 5-17
5.3 Valued Components 5-18
5.3.1 Valued Components and Scoping 5-18
5.4 Spatial and Temporal Boundaries 5-18
5.4.1 Spatial Boundaries 5-18

5.4.1.1 Local Study Area 5-18
5.4.1.2 Regional Study Area 5-21
5.4.2 Temporal Boundaries 5-21
5.5 Potential Project-related Effects Assessment 5-21
5.5.1 Methodology Overview 5-21
5.5.1.1 Sediment Quality Indicators 5-23
5.5.2 Identification and Characterization of Potential Interactions with Project 5-24
5.5.2.1 Site Preparation, Construction, and Decommissioning Activities 5-28
5.5.2.2 Site Contact Water 5-28
5.5.2.3 Mine Contact Water 5-28
5.5.2.4 Quarries and Borrow Pits 5-29
5.5.2.5 Explosives 5-29
5.5.2.6 Fuels, Oils, and PAH 5-29
5.5.2.7 Treated Sewage Discharge 5-30
5.5.2.8 Dust Deposition 5-30
5.5.3 Identification of Mitigation and Management Measures 5-30
5.5.3.1 Site Preparation, Construction, and Decommissioning Activities 5-31
5.5.3.2 Site Contact Water 5-33
5.5.3.3 Mine Contact Water 5-33
5.5.3.4 Quarries and Borrow Pits 5-33
5.5.3.5 Explosives 5-34
5.5.3.6 Fuels, Oils, and PAH 5-35
5.5.3.7 Treated Sewage Discharge 5-36
5.5.4 Characterization of Residual Effects 5-36
5.5.4.1 Site Preparation, Construction, and Decommissioning Activities 5-36
5.5.4.2 Site Contact Water 5-37
5.5.4.3 Mine Contact Water 5-38
5.5.5 Significance of Residual Effects 5-39
5.6 Potential Cumulative Effects Assessment 5-39
5.6.1 Methodology Overview 5-39
5.6.2 Potential Interactions of Residual Effects with Other Projects 5-41
5.7 Transboundary Effects 5-41
5.8 Mitigation and Adaptive Management 5-41
5.9 Proposed Monitoring Programs 5-45
5.9.1 Conceptual Aquatic Effects Management Plan 5-45
5.10 Impact Statement 5-45

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 6-9
6.1.5.1 Information Sources 6-9
6.1.5.2 Baseline Study Methods — Lakes and Ponds 6-10
6.1.5.3 Baseline Study Methods — Streams 6-18
6.1.5.4 Fish/Aquatic Habitat QA/QC 6-30
6.1.6 Setting — Lake Habitat 6-30
6.1.6.1 Fish Habitat — Physical Characteristics 6-30
6.1.6.2 Fish Habitat — Biological Resources 6-35
6.1.7 Setting — Stream Habitat 6-38
6.1.7.1 Fish Habitat — Physical Characteristics 6-38
6.1.7.2 Fish Habitat — Biological Resources 6-43
6.1.8 Synthesis of Existing Environment and Baseline Information 6-46
6.2 Incorporation of Traditional Knowledge (TK)..... 6-46
6.2.1 Incorporation of TK for Existing Environment and Baseline Information 6-46
6.2.2 Incorporation of TK for VEC and VSEC Selection 6-48
6.2.3 Incorporation of TK for Spatial and Temporal Boundaries 6-49
6.2.4 Incorporation of TK for Mitigation and Adaptive Management 6-49
6.3 Valued Components 6-49
6.3.1 Potential Valued Components and Scoping 6-49
6.3.2 Valued Components included in Assessment 6-49
6.4 Spatial and Temporal Boundaries..... 6-50
6.4.1 Spatial Boundaries..... 6-50
6.4.1.1 Local Study Area 6-50
6.4.1.2 Regional Study Area 6-53
6.4.2 Temporal Boundaries 6-53
6.5 Potential Project-Related Effects Assessment 6-53
6.5.1 Methodology Overview 6-53
6.5.1.1 Determining the Magnitude and Significance of Residual Effects .. 6-54
6.5.2 Potential Interactions with Project and Characterization 6-54
6.5.2.1 Loss of Fish Habitat: Project Infrastructure Footprint 6-56
6.5.2.2 Loss of Fish Habitat: Water Use 6-62
6.5.2.3 Deposition of Deleterious Substances 6-63
6.5.3 Identification of Mitigation and Management Measures 6-63
6.5.3.1 Loss of Fish Habitat: Project Infrastructure Footprint 6-63
6.5.3.2 Loss of Fish Habitat: Water Use 6-64
6.5.3.3 Deposition of Deleterious Substances 6-65
6.5.4 Characterization of Residual Effects..... 6-67
6.5.5 Significance of Residual Effects..... 6-67

6.6 Potential Cumulative Effects Assessment 6-67
6.6.1 Methodology Overview 6-67
6.6.2 Potential Interactions of Residual Effects with Other Projects 6-67
6.7 Transboundary Effects 6-67
6.8 Mitigative and Adaptive Management 6-67
6.9 Proposed Monitoring Programs 6-71
6.9.1 Aquatic Effects Monitoring Plan 6-71
6.9.2 Conceptual Fish Offsetting Plan 6-71
6.10 Impact Statement for Fish/Aquatic Habitat 6-72

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 7-3
7.1.2.1 The Fisheries Act 7-3
7.1.2.2 Metal Mining Effluent Regulations 7-4
7.1.3 Proximity to Designated Environmental Areas 7-5
7.1.4 Baseline Study Area 7-5
7.1.5 Baseline Studies 7-5
7.1.5.1 Information Sources 7-5
7.1.5.2 Baseline Study Methods 7-16
7.1.6 Fish Community Setting – Lakes and Ponds 7-18
7.1.7 Fish Community Setting - Streams 7-25
7.1.8 Metals in Fish Tissues 7-27
7.2 Incorporation of Traditional Knowledge (TK) 7-28
7.2.1 Incorporation of TK for Existing Environment and Baseline Information 7-28
7.2.2 Incorporation of TK for VEC and VSEC selection 7-30
7.2.3 Incorporation of TK for Spatial and Temporal Boundaries 7-31
7.2.4 Incorporation of TK for Mitigation and Adaptive Management 7-31
7.3 Valued Components 7-31
7.3.1 Potential Valued Components and Scoping 7-31
7.3.2 Valued Components included in Assessment 7-31
7.4 Spatial and Temporal Boundaries 7-32
7.4.1 Spatial Boundaries 7-32
7.4.1.1 Local Study Area 7-32
7.4.1.2 Regional Study Area 7-32
7.4.2 Temporal Boundaries 7-32
7.5 Potential Project-related Effects Assessment 7-35
7.5.1 Methodology Overview 7-35
7.5.2 Potential Interactions with Project and Characterization 7-36
7.5.2.1 Project Infrastructure Footprint 7-37
7.5.2.2 Water Use 7-38

7.5.2.3 Blasting 7-39
7.5.3 Identification of Mitigation and Management Measures 7-39
7.5.3.1 Project Infrastructure Footprint 7-40
7.5.3.2 Water Use 7-41
7.5.3.3 Blasting 7-42
7.5.4 Characterization of Residual Effects 7-44
7.5.5 Significance of Residual Effects 7-44
7.6 Potential Cumulative Effects Assessment 7-44
7.6.1 Methodology Overview 7-44
7.6.2 Potential Interactions of Residual Effects with Other Projects 7-44
7.7 Transboundary Effects 7-46
7.8 Mitigation and Adaptive Management 7-46
7.8.1 Mitigation by Project Design 7-46
7.8.2 Best Management Practices 7-46
7.8.3 Monitoring 7-47
7.9 Proposed Monitoring Programs 7-49
7.9.1 Aquatic Effects Monitoring Plan 7-49
7.9.2 Conceptual Fish Offsetting Plan 7-50
7.10 Impact Statement 7-50

References R-1

List of Figures

FIGURE **PAGE**

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 1-13

Figure 1.1-7. Ratio of Annual Runoff with Different Recurrence Periods to Mean Annual Runoff 1-15

Figure 1.1-8. Regional Regression Analysis between Instantaneous Peak Flow and Drainage Area 1-16

Figure 1.1-9. Regional Regression Analysis between June to September 7-Day Low Flow and Drainage Area 1-17

Figure 1.1-10. Study Area Drainage Basins – Goose Property Area 1-21

Figure 1.1-11. Annual Unit Hydrographs of Hydrometric Monitoring Stations – Goose Property Area 1-23

Figure 1.1-12. Study Area Drainage Basins – George Property Area 1-27

Figure 1.1-13. Annual Unit Hydrographs of Hydrometric Monitoring Stations – George Property Area .. 1-29

Figure 1.4-1. Spatial Boundaries of the Surface Water Hydrology Effects Assessment and Assessment Points within the Local Study Area and Regional Study Area 1-35

Figure 1.4-2. Surface Water Hydrology Assessment Points within the Local Study Area 1-37

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 Area as Determined by Air Photo Interpretation 2-12

Figure 2.1-6. Groundwater Level Observations at the Goose Property Area 2-13

Figure 2.1-7. Hydraulic Conductivity Measurements at the Goose Property Area 2-16

Figure 2.1-8. Hydrogeologic Conceptual Model of the Goose Property Area: Cross-Section A-A' Llama Deposit Area 2-20

Figure 2.1-9. Hydrogeologic Conceptual Model of the Goose Property Area: Cross-Section B-B' Umwelt Deposit Area 2-21

Figure 2.1-10. Hydrogeologic Conceptual Model of the Goose Property Area: Cross-Section C-C' Main Deposit Area 2-22

Figure 2.1-11. Geologic Structures at the George Property Area as Determined by Exploration Drilling . 2-23

Figure 2.1-12. Groundwater Level Observations at the George Property Area..... 2-25

Figure 2.1-13. Hydrogeologic Conceptual Model of the George Property Area: Cross-Section D-D' Locale 1 Deposit Area..... 2-29

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. Limnology and Bathymetry Sampling Conducted in the George Property Area for the Back River Project, 2006 to 2013.....3-5

Figure 3.1-4. Temperature Profiles of Goose Lake (Central Site), George Lake (Central Site), and Llama Lake in Ice-covered (April) and Open-water (August) Seasons, 2011 and 2012 3-12

Figure 3.1-5. Bathymetry of Goose Lake, Goose Property Area..... 3-15

Figure 3.1-6. Bathymetry of George Lake, George Property Area 3-16

Figure 4.1-1. Project Location 4-2

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

Figure 4.1-3. Waterbodies in the George Property Area 4-7

Figure 4.1-4. Locations of Baseline Lake and Stream Water Quality, Goose Property Area, 1993 to 2013.....4-9

Figure 4.1-5. Locations of Baseline Lake and Stream Water Quality, George Property Area, 1997 to 2013..... 4-11

Figure 4.1-6. Dissolved Oxygen Concentrations in Lakes in Under-ice and Open-water Conditions in the Goose and George Property Areas, 2010 to 2013..... 4-19

Figure 4.4-1. Local Study Area and Regional Study Area for Freshwater Water Quality..... 4-33

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 2013.....5-5

Figure 5.1-3. Locations of Baseline Lake and Stream Sediment Quality, George Property Area, 2007 to 2013.....5-7

Figure 5.1-4. Sediment Arsenic Concentrations in Goose and George Property Area Lakes, Back River Project, 2007 to 2012 5-12

Figure 5.4-1. Local Study Area and Regional Study Area for Freshwater Sediment Quality..... 5-19

Figure 6.1-1. Project Location 6-2

Figure 6.1-2. Lake/Pond Fish Habitat Baseline Data (2010 – 2013) for the Goose Property Area.....6-5

Figure 6.1-3. Lake/Pond Fish Habitat Baseline Data (2010 – 2013) for the George Property Area 6-7

Figure 6.1-4. Lake/Pond Fish Habitat – Aquatic Resources Baseline Data (1997 – 2013) for the Goose Property Area 6-13

Figure 6.1-5. Lake/Pond Fish Habitat – Aquatic Resources Baseline Data (2007 – 2013) for the George Property Area..... 6-15

Figure 6.1-6. Stream Fish Habitat Baseline Data (2010 – 2013) for the Goose Property Area 6-21

Figure 6.1-7. Stream Fish Habitat Baseline Data (2010 – 2013) for the George Property Area 6-23

Figure 6.1-8. Stream Fish Habitat – Aquatic Resources Baseline Data (1997 – 2013) for the Goose Property Area 6-25

Figure 6.1-9. Stream Fish Habitat – Aquatic Resources Baseline Data (2012 - 2013) for the George Property Area 6-27

Figure 6.4-1. Local Study Area and Regional Study Area for Freshwater Fish/Aquatic Habitat 6-51

Figure 6.5-1. Infrastructure Layout and Locations of Potential Habitat Loss, Goose Property Area .. 6-57

Figure 6.5-2. Infrastructure Layout and Locations of Potential Fish Habitat Loss, George Property Area 6-59

Figure 6.5-3. Daily Discharge and Wetted Depth at Goose Lake Outflow 6-66

Figure 7.1-1. Lake/Pond Fish Community Baseline Data (2010 to 2013), Goose Property Area 7-7

Figure 7.1-2. Lake/Pond Fish Community Baseline Data (2011 to 2013), George Property Area 7-9

Figure 7.1-3. Stream Fish Community Baseline Data (2011 to 2013), Goose Property Area 7-11

Figure 7.1-4. Stream Fish Community Baseline Data (2012 to 2013), George Property Area 7-13

Figure 7.1-5. Baseline Relative Abundance by Gillnet, Goose Property Area..... 7-20

Figure 7.1-6. Baseline Relative Abundance by Beach Seine, Goose Property Area 7-21

Figure 7.1-7. Baseline Relative Abundance by Gillnet, George Property Area 7-23

Figure 7.1-8. Baseline Relative Abundance by Beach Seine, George Property Area..... 7-24

Figure 7.4-1. Local Study Area and Regional Study Area for Lake Trout and Arctic Grayling..... 7-33

Figure 7.5-1. Daily Discharge and Wetted Depth at Goose Lake Outflow 7-43

List of Tables

TABLE **PAGE**

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

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 Annual Runoff (mm) based on Frequency Analysis for Regional Hydrometric Stations 1-12

Table 1.1-4. Estimated Instantaneous Peak Flows at Regional Hydrometric Stations..... 1-18

Table 1.1-5. Estimated 7-Day Low Flows during June to September at Regional Hydrometric Stations . 1-18

Table 1.1-6. Hydrometric Monitoring Stations in the Goose Property Area 1-20

Table 1.1-7. Peak Flows and Low Flows in the Goose Property Area 1-24

Table 1.1-8. Annual Runoff and Seasonal Distribution in the Goose Property Area 1-25

Table 1.1-9. Hydrometric Monitoring Stations in the George Property Area 1-25

Table 1.1-10. Peak Flows and Low Flows in the George Property Area..... 1-26

Table 1.1-11. Annual Runoff and Seasonal Distribution in the George Property Area 1-26

Table 1.3-1. Surface Water Hydrology Valued Ecosystem Component Indicators..... 1-34

Table 1.4-1. Effect Assessment Points within the Local Study Area and Regional Study Area 1-39

Table 1.4-2. Proposed Water Withdrawal Volumes from Goose, Propeller, and George Lake..... 1-40

Table 1.5-1. Surface Water Hydrology VEC Indicators and Magnitude Categories 1-42

Table 1.5-2. Effects of the Project on Streamflows and Lake Volumes (Percent Change from Baseline Conditions) at Assessment Points within the LSA and RSA 1-47

Table 1.5-3. Summary of Residual Effects on Surface Water Hydrology and Overall Significance Rating..... 1-50

Table 1.8-1. Surface Water Hydrology Mitigation and Management Measures 1-52

Table 2.1-1. Common Regional Overburden Materials and Their 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 Sub-permafrost Monitoring System..... 2-17

Table 2.1-4. Overburden Materials Common at the George Property and their Hydrogeologic Properties..... 2-24

Table 2.1-5. Hydraulic Conductivity Measurements at the George Property Area..... 2-27

Table 3.1-1. Baseline Lake Limnology Sampling Conducted for the Back River Project 3-9

Table 3.1-2. Baseline Stream Temperatures Collected for the Back River Project..... 3-11

Table 3.1-3. Summary of Secchi Depths in George and Goose Property Area Lakes, Back River Project .. 3-13

Table 3.1-4. Summary of Lake Morphologies in George and Goose Property Areas, Back River Project ... 3-13

Table 3.1-5. Summary of Stream Water Temperatures in the George and Goose Property Areas, 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 2013..... 4-13

Table 4.1-2. Baseline Stream Water Quality Sampling Conducted for the Back River Project, 1993 to 2013..... 4-15

Table 4.1-3. Summary of Lake Water Chemistry in the Goose and George Property Areas, 1993 to 2013..... 4-17

Table 4.1-4. Summary of Lake Water TSS and Turbidity in the Goose and George Property Areas, 1993 to 2013..... 4-18

Table 4.1-5. Summary of Lake Water Nutrient Concentrations in the Goose and George Property Areas, 1994 to 2013 4-20

Table 4.1-6. Distribution of Samples from Waterbodies by CCME Total Phosphorus Trigger Ranges, 1993 to 2013 4-21

Table 4.1-7. Summary of Lake Water Metal Concentrations in the Goose Property Area, 1993 to 2013..... 4-22

Table 4.1-8. Summary of Lake Water Metal Concentrations in the George Property Area, 1994 to 2013 4-22

Table 4.1-9. Water Quality Parameters with Sample Concentrations Greater than CCME Guideline Values in Goose Property Lakes, 1997 to 2013 4-23

Table 4.1-10. Water Quality Parameters with Sample Concentrations Greater than CCME Guideline Values in George Property Lakes, 1997 to 2013 4-24

Table 4.1-11. Summary of Lake Water Free Cyanide Concentrations (mg/L) in the Goose and George Property Areas, 1997 to 2013 4-24

Table 4.1-12. Summary of Stream Water Chemistry in the Goose and George Property Areas, 1993 to 2013 4-25

Table 4.1-13. Summary of Stream Water TSS and Turbidity in the Goose and George Property Areas, 1993 to 2013 4-25

Table 4.1-14. Stream Sites with Water Dissolved Oxygen Concentrations Less than the CCME Guideline for Early Life Stages in the Goose and George Property Areas, 1994 to 2013 .. 4-26

Table 4.1-15. Summary of Stream Water Nutrient Concentrations in the Goose and George Property Areas, 1994 to 2013 4-26

Table 4.1-16. Distribution of Samples from Streams by CCME Total Phosphorus Trigger Ranges, 1993 to 2013 4-27

Table 4.1-17. Summary of Stream Water Metal Concentrations in the Goose Property Area, 1993 to 2013 4-28

Table 4.1-18. Summary of Stream Water Metal Concentrations in the George Property Area, 1997 to 2013 4-28

Table 4.1-19. Water Quality Parameters with Sample Concentrations Greater than CCME Guideline Values in Goose Property Area Streams, 1993 to 2013 4-29

Table 4.1-20. Water Quality Parameters with Sample Concentrations Greater than CCME Guideline Values in George Property Area Streams, 1997 to 2013 4-30

Table 4.1-21. Summary of Stream Water Free Cyanide Concentrations (mg/L) in the Goose and George Property Areas, 1997 to 2013 4-30

Table 4.5-1. Rating Criteria for Evaluating the Magnitude of Residual Effects on Freshwater Water Quality VEC 4-36

Table 4.5-2. Definitions of Significance Ratings for Freshwater Water Quality VEC 4-36

Table 4.5-3. Freshwater Water Quality Indicators for Effects Assessment 4-37

Table 4.5-4. Indicators and Thresholds Used for Magnitude Characterization for Residual Effects Analysis on the VEC Freshwater Water Quality 4-37

Table 4.5-5. Definition of the Components of the Project's Interactions with the VEC Freshwater Water Quality 4-40

Table 4.5-6. Key Indicators of Project Activity Interactions with the Freshwater Environment for Effects Assessment 4-42

Table 4.5-7. Summary Table of Predicted Residual Effects and Overall Significance Rating 4-57

Table 4.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Water Quality 4-59

Table 4.11-1. Drinking Water Sources for Back River Project 4-63

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 5-9

Table 5.1-3. Summary of Lake Sediment Particle Size Composition in the Goose and George LSA, 2007 to 2013..... 5-10

Table 5.1-4. Summary of Lake Sediment Total Organic Carbon Concentrations in the Goose and George LSA, 2007 to 2013..... 5-11

Table 5.1-5. Summary of Lake Sediment Metal Concentrations in the Goose LSA, 2010 to 2013 5-11

Table 5.1-6. Goose LSA Lakes with Sediment Metal Concentrations Greater than CCME Sediment Quality Guidelines, 2010 to 2013 5-13

Table 5.1-7. Summary of Lake Sediment Metal Concentrations in the George LSA, 2010 to 2013..... 5-13

Table 5.1-8. George LSA Lakes with Sediment Metal Concentrations Greater than CCME Sediment Quality Guidelines, 2010 to 2013 5-14

Table 5.1-9. Summary of Stream Sediment Particle Size Compositions in the Goose and George LSA, 2011 to 2013 5-15

Table 5.1-10. Summary of Stream Sediment Total Organic Carbon Concentrations in the Goose and George LSA, 2011 to 2013 5-15

Table 5.1-11. Summary of Stream Sediment Metals Concentrations in the Goose LSA, 2011 to 2013.. 5-16

Table 5.1-12. Goose LSA Streams with Metal Concentrations Greater than CCME Sediment Quality Guidelines, 2011 to 2013..... 5-16

Table 5.1-13. Summary of Stream Sediment Metal Concentrations in the George LSA, 2011 to 2013 . 5-17

Table 5.1-14. George LSA Streams with Sediment Metal Concentrations Greater than CCME Sediment Quality Guidelines, 2010 to 2013 5-17

Table 5.5-1. Rating Criteria for Magnitude of Freshwater Sediment Quality Residual Effects 5-22

Table 5.5-2. Definitions of Significance Ratings of Residual Effects on the VEC Freshwater Sediment Quality 5-22

Table 5.5-3. The VEC Freshwater Sediment Quality Indicators for Effects Assessment 5-23

Table 5.5-4. Indicator Thresholds for the VEC Freshwater Sediment Quality 5-23

Table 5.5-5. Definition of the Components of the Project's Interactions with the VEC Freshwater Sediment Quality 5-25

Table 5.5-6. Key Indicators of Project Activity Interactions with the Freshwater Environment for Effects Assessment 5-27

Table 5.5-7. Summary Table of Predicted Residual Effects on the VEC Freshwater Sediment Quality and Overall Significance Rating 5-40

Table 5.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Sediment Quality 5-42

Table 6.1-1. Summary of Baseline Lake Phytoplankton Sampling Conducted at George and Goose Property Areas 6-11

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

Table 6.1-3. Summary of Baseline Lake Benthos Sampling Conducted at the Goose and George Property Areas 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..... 6-29

Table 6.1-7. Summary of Fish Habitat Quality in Goose Property Area Lakes and Ponds Surveyed between 2010 and 2013 6-32

Table 6.1-8. Summary of Fish Habitat Quality in George Property Area Lakes, 1990 and 2012..... 6-33

Table 6.1-9. Summary of Habitat Quality in Goose Property Area Streams, 1996 to 2012..... 6-40

Table 6.1-10. Summary of Habitat Quality in George Property Area Streams, 1990 to 2013 6-41

Table 6.5-1. Magnitude Rating for Evaluating Residual Effects on the VEC Freshwater Fish/Aquatic Habitat..... 6-54

Table 6.5-2. Definitions of Significance Ratings for the VEC Freshwater Fish/Aquatic Habitat..... 6-55

Table 6.5-3. Potential Interactions with the VEC Freshwater Fish/Aquatic Habitat 6-55

Table 6.5-4. Project activities and Phases interacting with the VEC Freshwater Fish/Aquatic Habitat..... 6-56

Table 6.5-5. Volume Limits to Water Use 6-64

Table 6.8-1. Mitigation and Management Measures Summary 6-69

Table 7.1-1. Life History Periodicity of Fish Species in the Back River Project Area 7-2

Table 7.1-2. Summary of Lakes Where Fish Sampling Occurred, 1990 to 2013..... 7-15

Table 7.1-3. Summary of Tissue Metal Samples and Locations, 2011 to 2013 7-17

Table 7.1-4. Fish Bearing Lakes and Ponds in the Goose Property LSA, 1997 to 2013 7-18

Table 7.1-5. Fish Bearing Lakes in the in the George Property, 1990 to 2013..... 7-22

Table 7.1-6. Summary of Fish Species Captured in Goose Property Streams, 2006 to 2013 7-26

Table 7.1-7. Summary of Fish Species Captured in George LSA Streams, 1990 to 2013 7-26

Table 7.5-1. Rating Criteria for Evaluating the Magnitude of Residual Effects on the VECs Lake Trout and Arctic Grayling 7-35

Table 7.5-2. Definitions of Significance Ratings for the VECs Lake Trout and Arctic Grayling 7-36

Table 7.5-3. Potential Interactions for Freshwater Fish Community VECs Lake Trout and Arctic Grayling 7-36

Table 7.5-4. Summary of Potential Interactions between Freshwater Fish Community and the Project . 7-37

Table 7.5-5. Volume Limits for Water Use 7-41

Table 7.5-6. Summary of Residual Effects and Significance Ratings for the VECs Lake Trout and Arctic Grayling 7-45

Table 7.6-1. Interaction of Freshwater Fish Community Residual Effects from the Back River Project . 7-45

Table 7.8-1. Summary of Mitigation and Management Measures for Lake Trout and Arctic Grayling . 7-48

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. Investigating Impacts of the Proposed Development and Withdrawal at the Goose Property on Umwelt Lake Volume and Outflows

Appendix V6-1D. Investigating Impacts of the Proposed Development and Withdrawal at the Goose Property on Goose Lake Volume and Outflows

Appendix V6-1E. Investigating Impacts of the Proposed Development and Withdrawal at the Goose Property on Propeller Lake Volume and Outflows

Appendix V6-1F. Investigating Impacts of the Proposed Development and Withdrawal at the George Property on George Lake Volume and Outflows

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 V6-6A. 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

Acronyms and Abbreviations

Rescan™
an ERM company

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
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 Water Hydrology

Rescan™
an ERM company

1. Surface Water 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 infrastructure for the Goose Property area is within the Ellice River Watershed and infrastructure for the George Property area is within the Western 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 Western River drains an area of 4,034 km^2 north to Bathurst Inlet approximately 80 km from the MLA. 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.

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
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 LittleCrapeau 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	1978-2011
10RA002	Baillie River near the mouth	65°00'38" N	104°29'26" W	14,500	1978-2011
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*	64°36'33" N	110°50'27" W	185	1995-2011
n/a	Vulture-Polar Stream*	64°44'24" N	110°32'56" W	7.2	1997-2011

** from Ekati Project (Rescan 2013b)*

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 significant, 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 sub-surface flows.

Compared to non-permafrost regions, permafrost watersheds tend to have higher peak flow and lower base flow (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). Base flow is low, and is supported primarily by inputs from the shallow upper active layer of the soil profile, which is the only portion of the soil profile that thaws in the summer months.

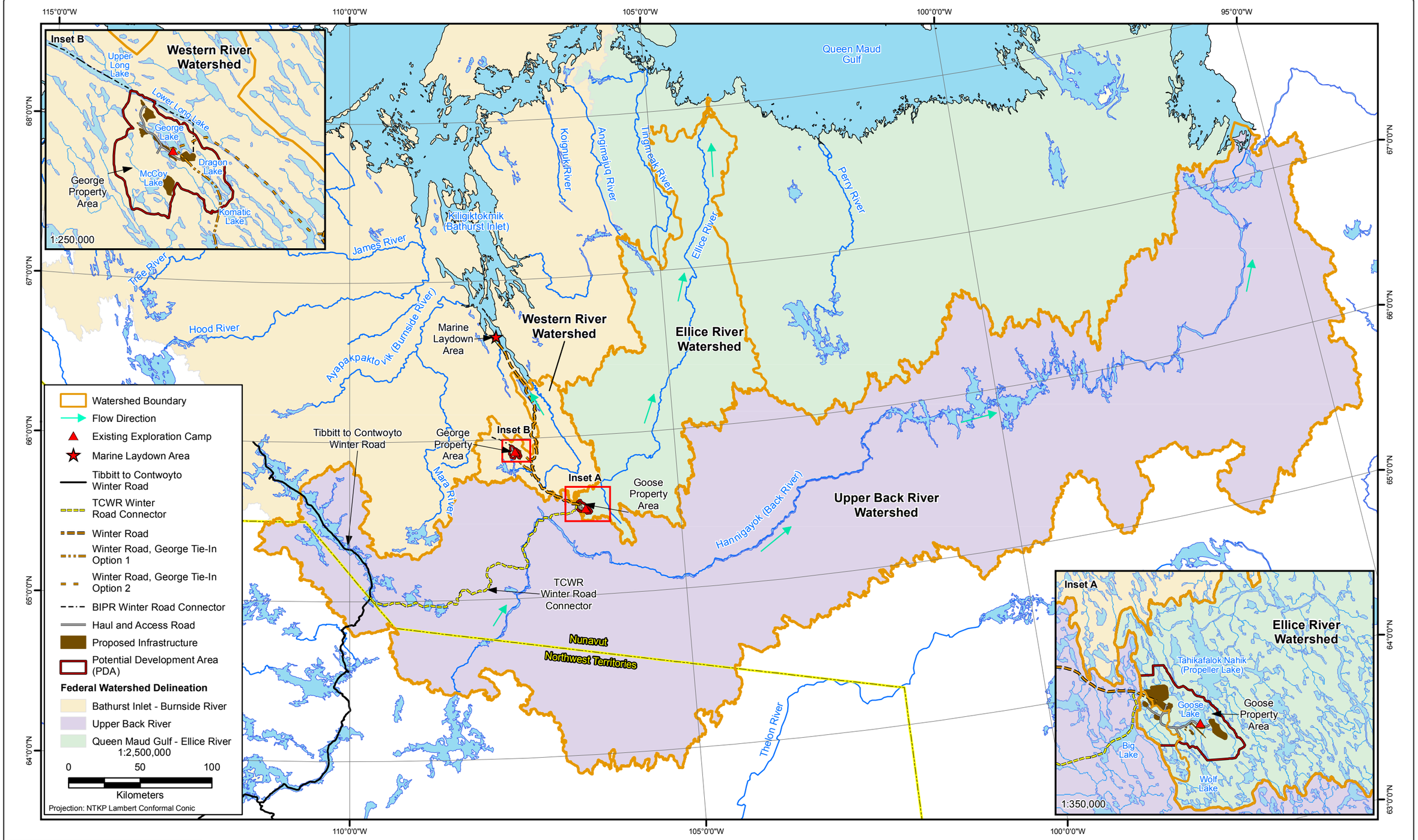
Channel freeze-up typically occurs between late October and early November. In smaller drainage basins, stream channels typically freeze to their bottom, with zero flow occurring in winter. In very large catchments, and larger lake outlets, flow energy and water turbulence may be sufficient to maintain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

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 physiographic setting is 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 upstream 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).

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

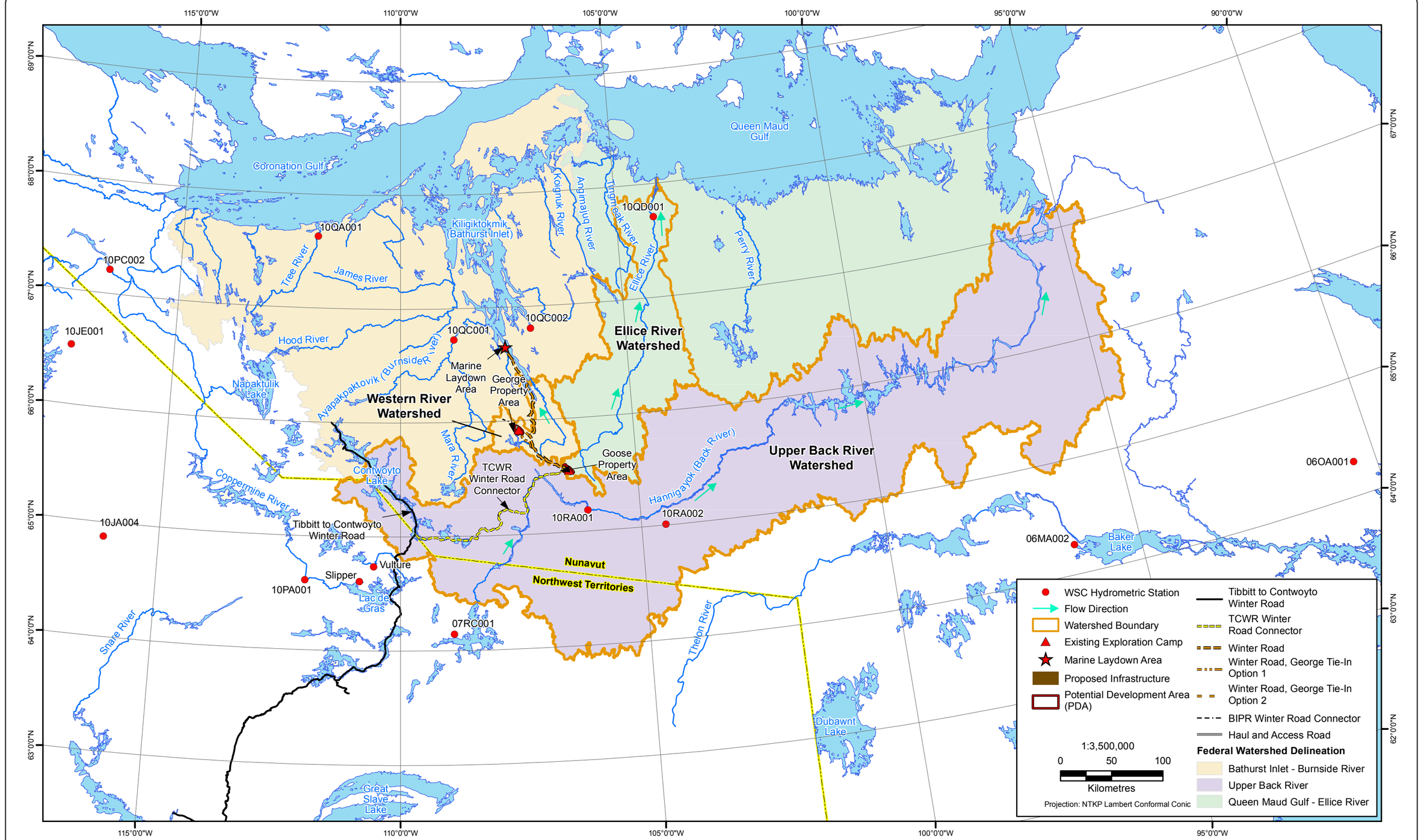
- *Amount of snowpack in spring*. Snowpack depth is dependent on the amount of snowfall during the previous winter and the amount of snow remaining in each watershed prior to freshet. Snow can be lost or redistributed due to sublimation, melting, or wind.



Sabina GOLD & SILVER CORP. Rescan an ERM company

Figure 1.1-1

Regional Watersheds of the Back River Project



Sabina GOLD & SILVER CORP.

Rescan an ERM company

Figure 1.1-2

Regional Hydrometric Stations Relevant to the Study Area

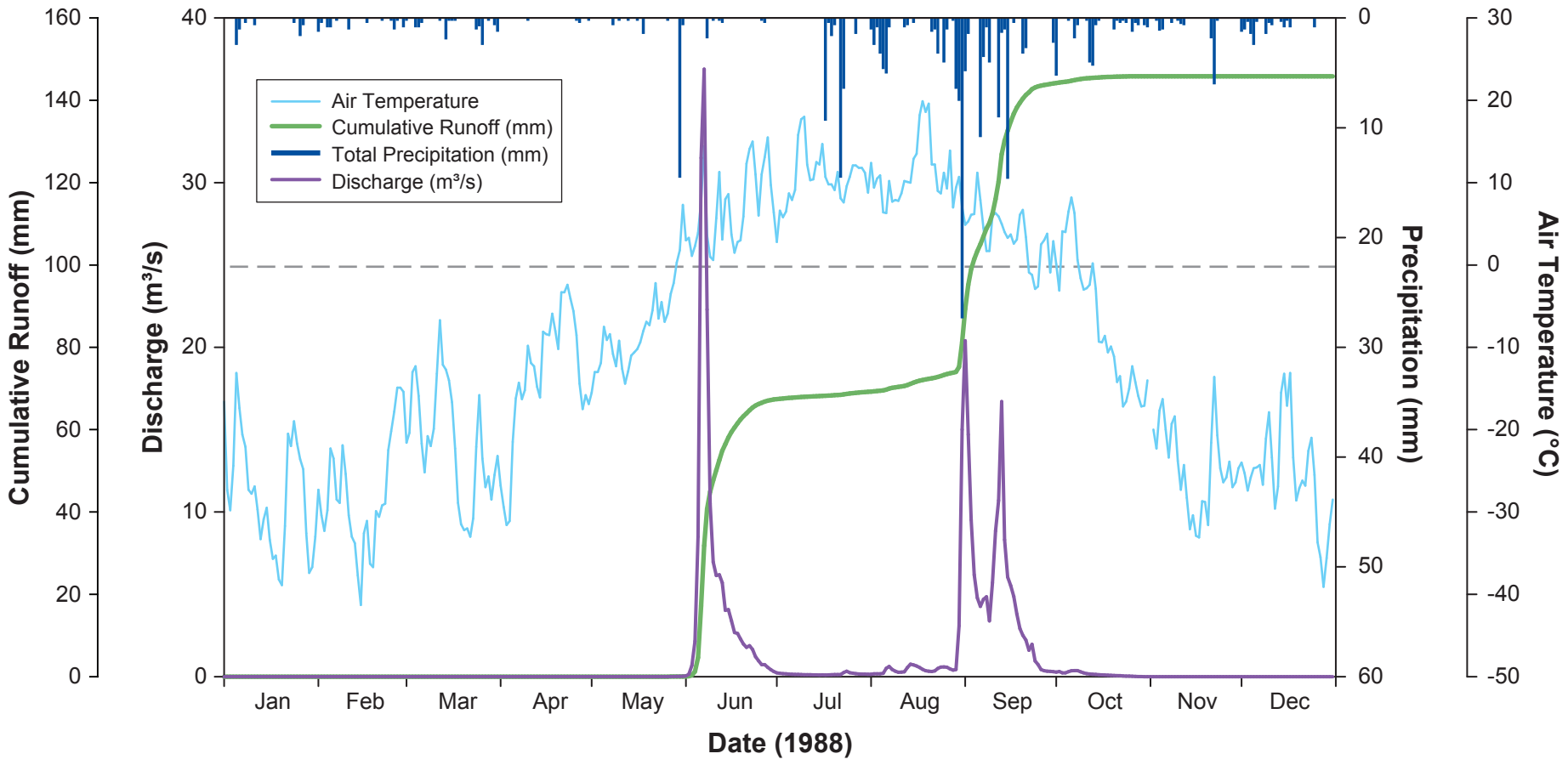


Figure 1.1-3

Sabina GOLD & SILVER CORP.

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

Rescan Engineers & Scientists

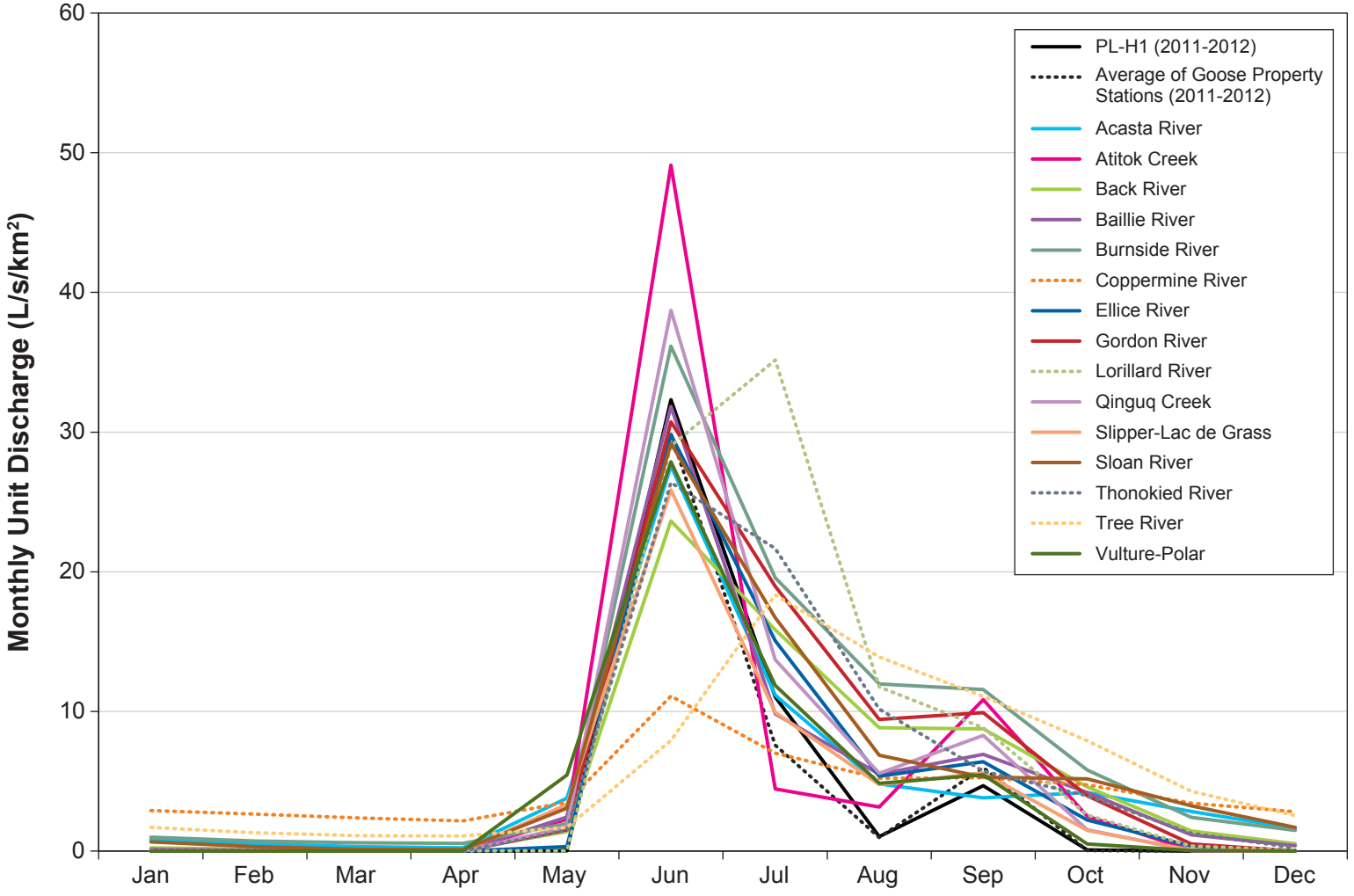


Figure 1.1-4

Sabina GOLD & SILVER CORP.

Historical Mean Monthly Unit Discharge Hydrographs of Regional and Project Stations

Figure 1.1-4

Rescan Engineers & Scientists

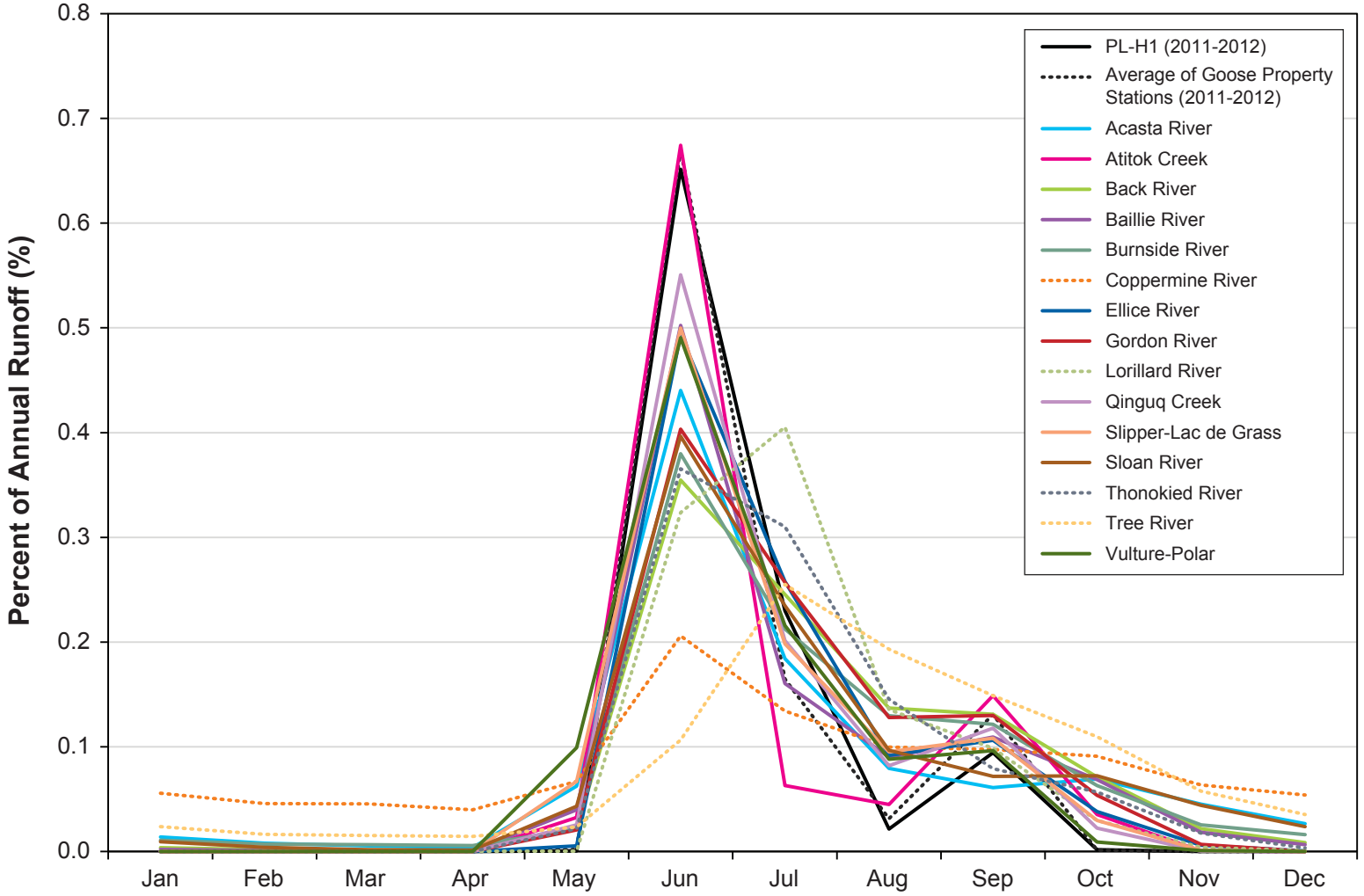


Figure 1.1-5

Sabina GOLD & SILVER CORP.

Monthly Distribution of Annual Runoff at Regional and Project Stations

Figure 1.1-5

Rescan Engineers & Scientists

- *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 significant 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). To characterize the applicability of data from these regional stations to the Project area, monthly unit discharge (Figure 1.1-4) and monthly distribution of annual runoff (Figure 1.1-5) at these stations are compared to those of the Project stations. 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.

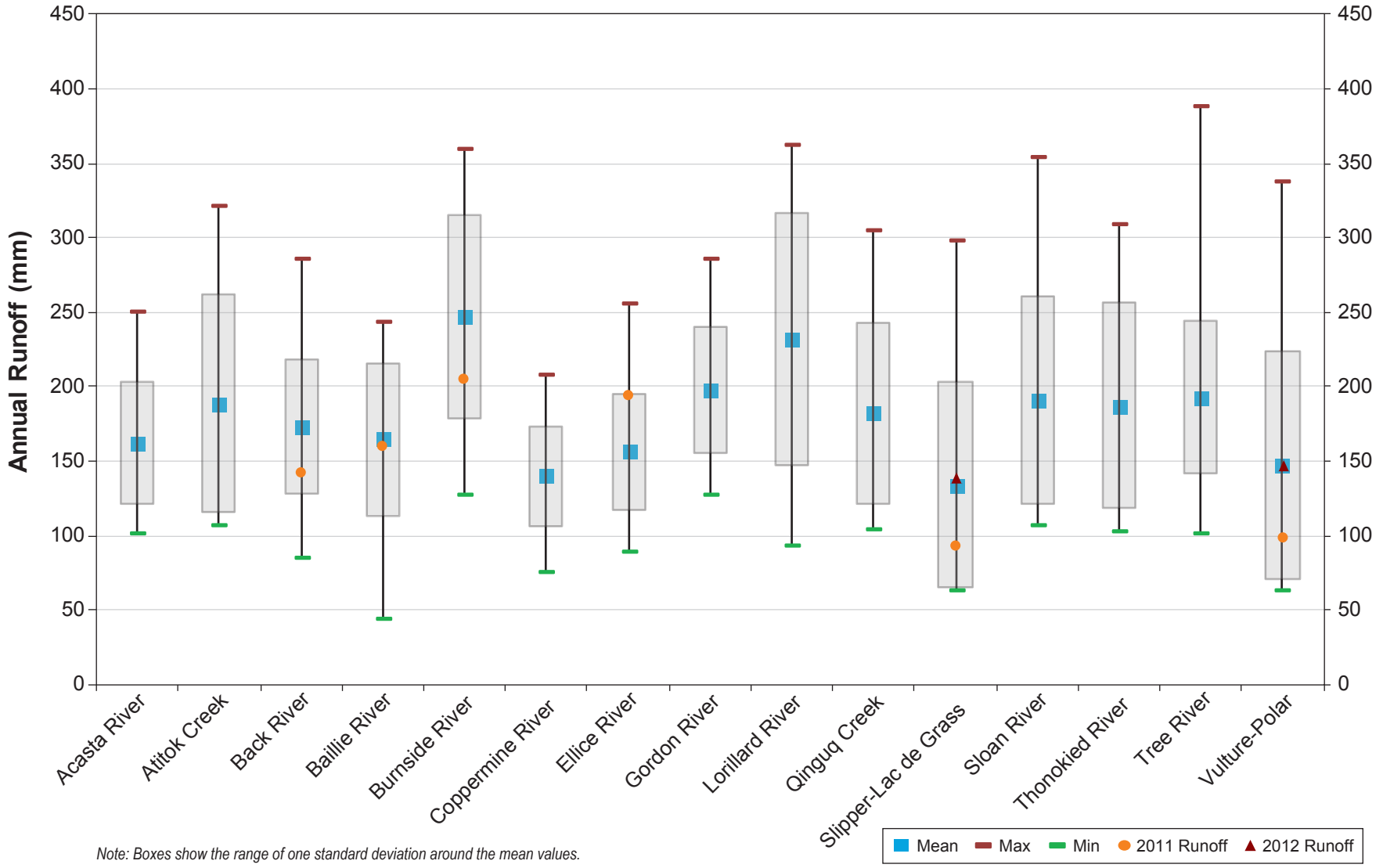
In order to provide estimates of annual runoff variability, statistical frequency analyses were performed on annual runoff at each of the regional stations. The annual runoff data were analyzed using HYFRAN-PLUS statistical software for the available period of record. The software contains a Decision Support System (DSS) which is designed to test independence (Wald-Wolfowitz test), stationarity (Kendall test), and homogeneity (Wilcoxon test) of the sample data, and help with the selection of the most appropriate class of distributions. There are eighteen statistical distributions available in HYFRAN-PLUS. Annual runoff frequency results are summarized in Table 1.1-3. The mean value represents runoff at a cumulative probability of 0.5 (50% of years are greater and less than this value, respectively) and is associated with a two-year recurrence interval. Dry years are represented by cumulative probabilities less than 0.5, while wet years have cumulative probabilities greater than 0.5.

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

Table 1.1-3. Estimated Annual Runoff (mm) based on Frequency Analysis for Regional Hydrometric Stations

Station	Drainage Area (km^2)	Annual Runoff (mm)	Wet Years					Mean	Dry Years				
			100-yr	50-yr	20-yr	10-yr	5-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100-yr
Acasta River	2,280	162.4	306	285	264	236	215	192	156	129	118	109	101
Atitok Creek	217	188.7	394	373	349	314	283	246	182	128	104	86.7	69.8
Back River	19,600	172.8	290	279	266	248	231	211	173	135	115	98.4	79.8
Baillie River	14,500	164.3	352	325	297	260	231	201	156	122	108	97.5	86.9
Burnside River	16,800	246.8	400	390	377	356	335	307	248	188	158	135	111
Ellice River	16,900	156.6	274	260	246	225	207	188	153	124	110	99.6	88.8
Gordon River	1,530	197.5	327	311	294	271	252	230	194	162	148	137	125
Qinguq Creek	432	182.3	366	346	323	290	262	231	176	131	110	95.3	80.3
Slipper-Lac de Gras	185	134.1	381	346	310	262	223	183	122	78.1	61.2	49.6	38.9
Sloan River	2,040	190.8	416	387	357	315	280	243	182	134	113	97.7	82.7
Thonokied River	1,780	187.2	400	374	347	308	275	239	179	131	110	94.2	78.9
Vulture-Polar	7.2	147.4	412	375	338	286	244	200	133	85.5	66.7	53.9	42



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

Figure 1.1-6

Sabina GOLD & SILVER CORP.

Long-term Annual Runoff at Regional Hydrometric Stations

Figure 1.1-6

Rescan Engineers & Scientists

For the regional stations with approved 2011 and 2012 annual runoff values, these data are plotted in Figure 1.1-6 along with long-term runoff estimates (i.e., mean, standard deviation, minimum, and maximum). It is seen that the 2011 annual runoff ranges between 66% of the mean annual runoff (MAR) at Vulture Polar Stream (equivalent to a 5 to 10-year dry) to 123% of the MAR at Ellice River (equivalent to a 5-year wet). On average the 2011 runoff is 87% of the MAR at these stations (equivalent to a 5-year dry). By plotting the ratio of wet and dry annual runoff to mean annual runoff values (Figure 1.1-7), a trend between these ratios and the drainage area of regional stations is evident.

1.1.1.5 Peak Flows

Peak flows at regional stations were estimated by examining flood frequencies for different return periods (Table 1.1-4). 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. Similar to annual runoff frequency analysis, data were tested for independence, stationarity, and homogeneity before distribution functions were fitted. Data from Burnside River Station failed to pass the Wald-Wolfowitz independence test, and therefore was excluded from further analysis. The maximum daily discharge frequency results were then converted to instantaneous peak values with a 20% increase factor, which is representative of both regional and Project stations. These results are summarized in Table 1.1-4. A strong correlation between the instantaneous peak flows with different recurrence periods and the drainage area is seen in Figure 1.1-8. The regression equations in Figure 1.1-8 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). It was noticed that selecting these stations, instead of using all regional stations, would result in a more conservative estimate of peak flows at the Project stations.

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 in regional stations. More severe low flow events associated with 5, 10, and 20 year return periods (7-day Q_5, Q_{10}, and Q_{20}) were also estimated here. The low flow frequency analysis was based on recorded 7-day low flows during June to September in the regional hydrometric stations. The 7-day low flow data were analyzed using HYFRAN-PLUS statistical software for the available period of record. Data were tested for independence, stationarity, and homogeneity before fitting distribution functions. Results of the frequency analysis are summarized in Table 1.1-5.

By plotting the 7-day low flow values with different recurrence periods (Figure 1.1-9), a trend between these values and the drainage area of regional stations is evident. Data from Back River, Gordon River, and Qinguq Creek stations were excluded in Figure 1.1-9, because the unusually large number of zero-valued low flows reported at these stations would result in more scattered data and less strong coefficients of determination.

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 more than 20 hydrometric monitoring stations in 2010, 2011, 2012, and 2013 within the Project area (Appendices V6-1A, Rescan 2012a; Appendix V6-1B, Rescan 2012b; Rescan n.d.).

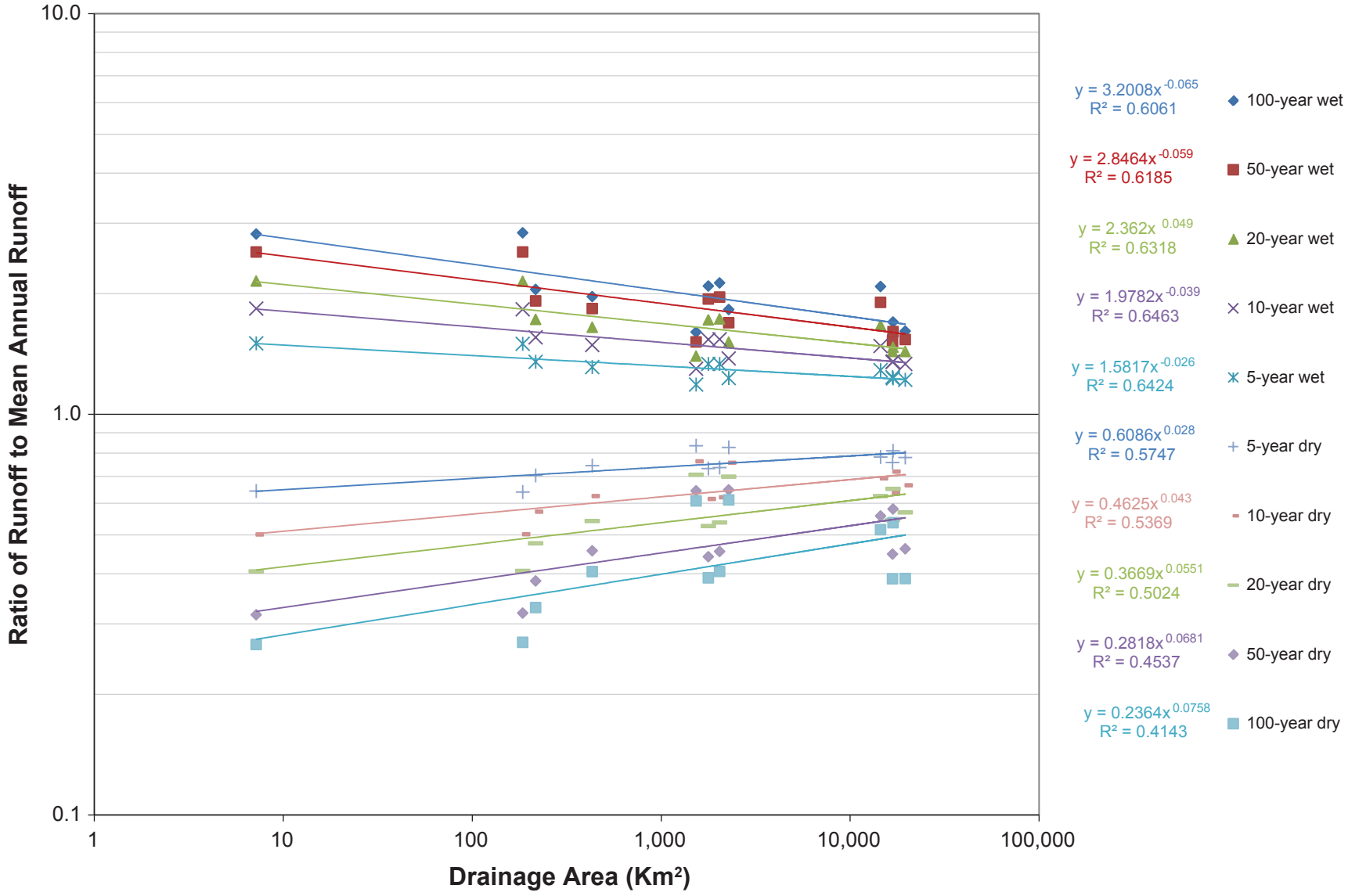


Figure 1.1-7

Sabina GOLD & SILVER CORP.

Ratio of Annual Runoff with Different Recurrence Periods to Mean Annual Runoff

Figure 1.1-7

Rescan Engineers & Scientists

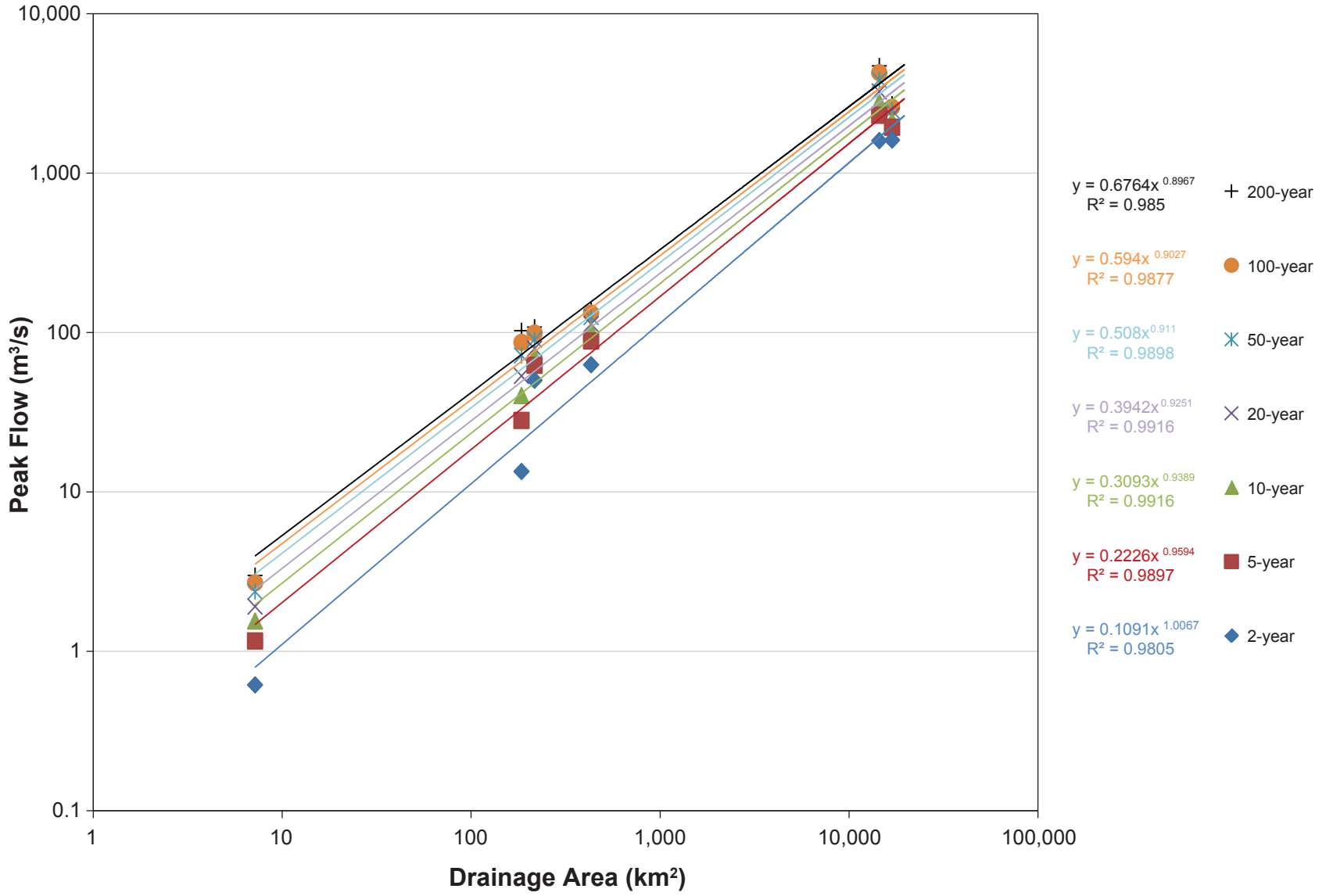


Figure 1.1-8

Sabina GOLD & SILVER CORP.

Regional Regression Analysis between Instantaneous Peak Flow and Drainage Area

Figure 1.1-8

Rescan Engineers & Scientists

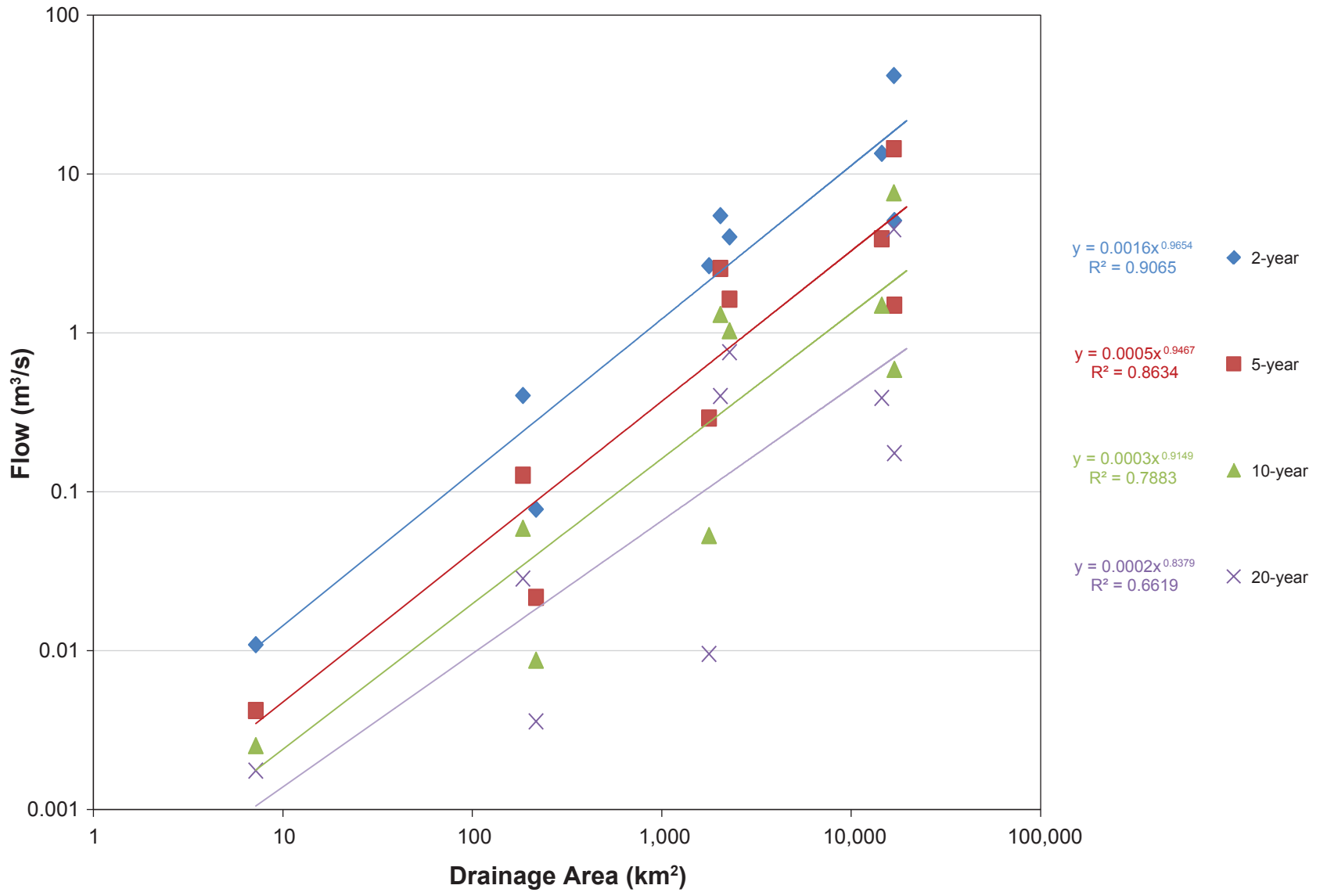


Figure 1.1-9

Sabina GOLD & SILVER CORP.

Regional Regression Analysis between June to September 7-Day Low Flow and Drainage Area

Figure 1.1-9

Rescan Engineers & Scientists

Table 1.1-4. 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 1.1-5. 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)	June-September 7-Day Low Flows (m^3/s)			
				2-yr	5-yr	10-yr	20-yr
Acasta River	2,280	**162.4**	11.7	4.02	1.63	1.03	0.76
Atitok Creek	217	**188.7**	1.3	0.077	0.022	0.009	0.004
Back River	19,600	**172.8**	107.4	18.65	0.32	0.01	0.00
Baillie River	14,500	**164.3**	75.5	13.49	3.90	1.49	0.39
Burnside River	16,800	**246.8**	131.5	41.54	14.41	7.61	4.49
Ellice River	16,900	**156.6**	83.9	5.09	1.49	0.59	0.17
Gordon River	1,530	**197.5**	9.6	0.511	0.008	0.000	0.000
Qinguq Creek	432	**182.3**	2.5	0.0122	0.0001	0.0000	0.0000
Slipper-Lac de Gras	185	**134.1**	0.8	0.40	0.13	0.06	0.03
Sloan River	2,040	**190.8**	12.3	5.45	2.54	1.31	0.40
Thonokied River	1,780	**187.2**	10.6	2.64	0.29	0.05	0.01
Vulture-Polar	7.2	**147.4**	0.03	0.011	0.004	0.003	0.002

This includes:

- continuous stream water level (stage) measurements during the open-water season;
- more than 200 manual stream discharge measurements and water level surveys;
- development of stage-discharge rating curves and annual hydrographs at each of the monitoring locations;
- analysis of flow duration and 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 12 winter snow course survey in 2012, 8 within the Goose Property and 4 within the George property. Many bathymetric surveys have also been completed in the Project 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). Discharge measurements were completed on a monthly basis 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 (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.

1.1.2.1 Goose Property Area

The Goose Property local study area (LSA) 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 in the Goose Property area consisted of two stations in 2010, and was expanded to 9 stations in 2011, 12 stations in 2012 and 17 stations in 2013. (Table 1.1-6 and Figure 1.1-10). 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 2012 were used for the following sections. The 2013 data will be available in early 2014. The monitoring drainage areas range from 1.4 km^2 at EL-H1 to 204.4 km^2 at PL-H1, covering a total drainage area of 391.3 km^2.

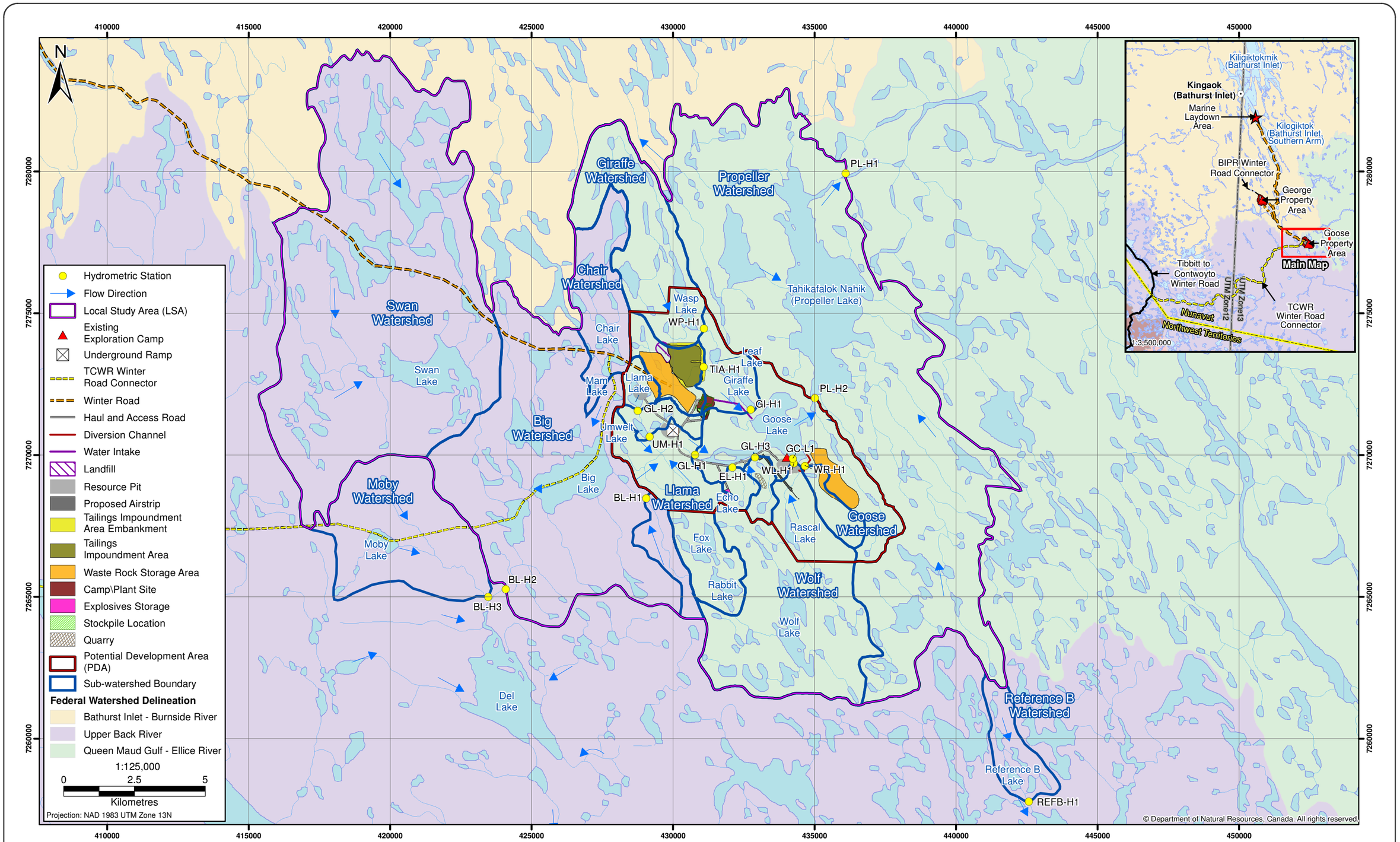
Unit discharge was calculated using daily discharge for the twelve hydrometric monitoring stations that were operated in 2011 and 2012 (Figure 1.1-11). The hydrologic regime in the Project area is characterized by the Arctic nival flow regime. Instantaneous and daily peak flows occurred in early to mid-June 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. At PL-H1, high flows (i.e., flows greater than 8.1 m^3/s) occurred during June 16 to 18. Hourly variations of the high flows during this period resulted in occurrence of

instantaneous and daily peak flows on different dates (Table 1.1-7). 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).

Table 1.1-6. Hydrometric Monitoring Stations in the Goose Property Area

Hydrometric Station	Location	Geographic Coordinates*		Drainage Area (km^2)	Lake Coverage (%)	Period of Operation
		Easting	Northing			
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-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
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
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
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	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	Wolf Drainage outflow	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
WP-H1	Wasp Lake outflow	431,086	7,274,468	17.6	14.0	Jun 5 to Sep 12, 2013
WR-H1		434,687	7,269,635	2.7	2.4	Jun 1 to Sep 15, 2013

** UTM, Datum NAD 83, Zone 13 W*

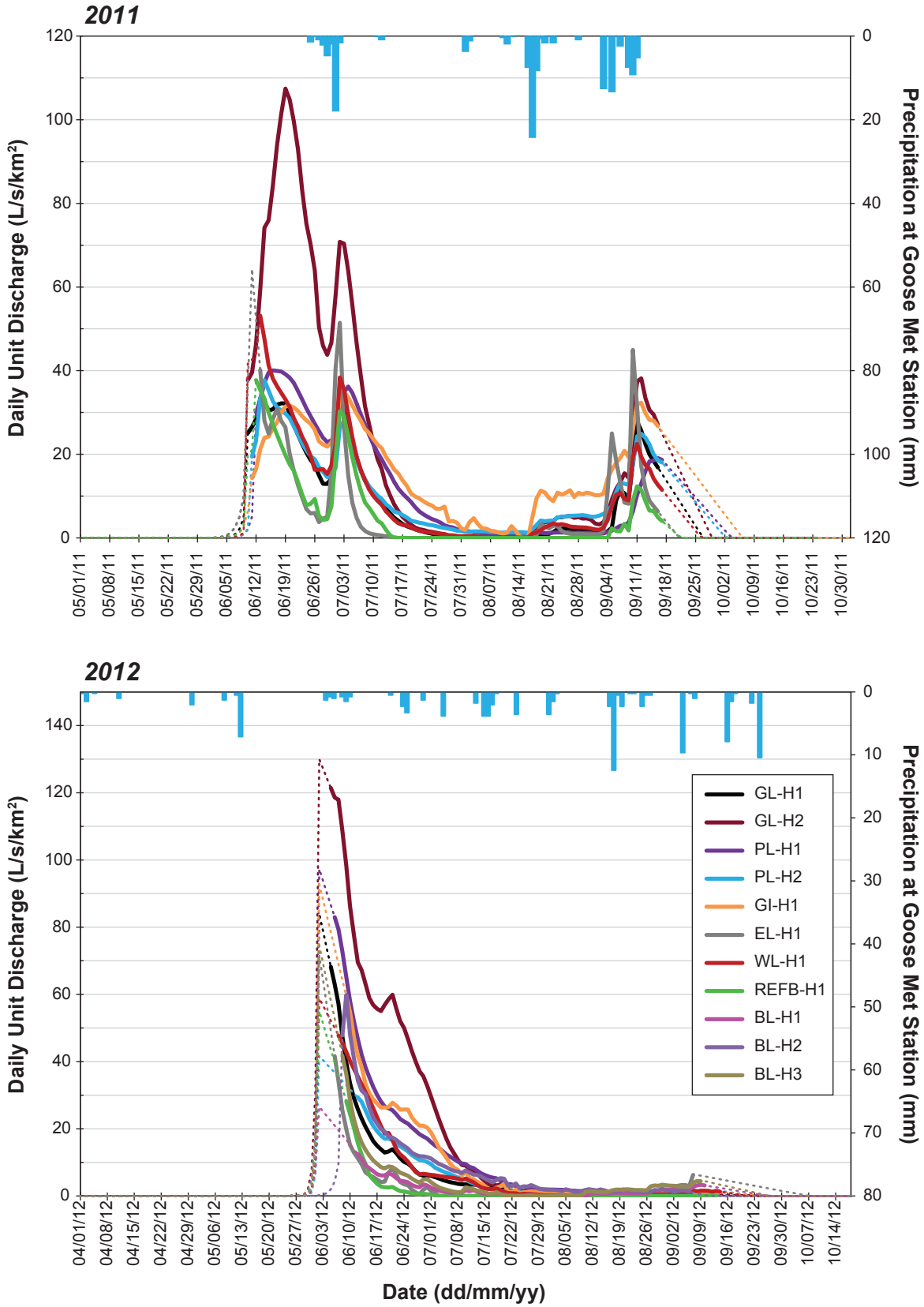


Sabina GOLD & SILVER CORP.

Rescan an ERM company

Figure 1.1-10

Study Area Drainage Basins - Goose Property Area



Sabina GOLD & SILVER CORP.

Annual Unit Hydrographs of Hydrometric Monitoring Stations - Goose Property Area

Figure 1.1-11

Rescan™ Engineers & Scientists

Table 1.1-7. 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
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
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
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
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
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
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
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
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
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
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-H3	21.4	2012	*2.08*	*1.59*	*Jun 2*	0	Jul 21 – Aug 9

Note: Estimated values are italicized
** Dry channel conditions between the indicated dates*

Most streams experienced zero or extreme low flow conditions in August during the open-water period (Table 1.1-7). Flow duration analysis demonstrated that, on average, there was streamflow during 30% of the year for most of the monitored streams.

Over the 2011-2012 monitoring period, annual runoff values ranged from a low of 36 mm at station BL-H1 in 2012 to a high of 227 mm at station GL-H2 in 2011 (Table 1.1-8). The majority of seasonal runoff occurred in June at all stations. The runoff in June accounted for a low of 29% of the annual total at station GI-H1 in 2011 and a high of 92% at station GL-H3 in 2012. A very low annual runoff occurred at station BL-H1 (Table 1.1-8; Figure 1.1-11).

1.1.2.2 George Property Area

The George Property local study area (LSA) has approximately 16% lake coverage, an average ground slope of 2.8%, and a total relief of 177 m. This area has higher relief than the Goose Property, with ridges of bedrock and esker deposits separating well-defined glacial valleys. The gauged streams on the George Property are deep and narrow and meander within the over-widened valleys created by glaciers.

Table 1.1-8. 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
GL-H1	2011	95	0	48	24	2	26	0	0
	2012	81	0	90	9	1	0	0	0
GL-H2	2011	227	0	58	22	2	18	0	0
	2012	206	0	90	10	0	0	0	0
GL-H3	2011	-	-	-	-	-	-	-	-
	2012	216	1	92	7	0	1	0	0
PL-H1	2011	123	0	45	33	2	20	0	0
	2012	134	0	84	14	2	0	0	0
PL-H2	2011	108	0	40	23	7	30	0	0
	2012	72	0	83	12	2	3	0	0
GI-H1	2011	157	0	29	29	10	32	1	0
	2012	126	0	85	11	2	1	0	0
EL-H1	2011	77	0	54	17	3	26	0	0
	2012	55	1	80	0	0	18	1	0
WL-H1	2011	104	0	54	23	3	20	0	0
	2012	82	0	88	9	1	2	0	0
REFB-H1	2011	56	0	59	28	0	13	0	0
	2012	40	1	99	0	0	0	0	0
BL-H1	2012	36	1	78	6	5	11	0	0
BL-H2	2012	69	0	72	21	6	1	0	0
BL-H3	2012	71	0	82	4	5	8	0	0

The hydrometric monitoring network in the George Property area consisted of three stations that were installed in 2012, and was expanded to 8 stations in 2013 (Table 1.1-9 and Figure 1.1-12). Data from 2012 were used for the following sections. The 2013 data will be available in early 2014. The monitoring drainage areas ranged from 9.47 km^2 at REFC-H1 to 24 km^2 at KL-H1, monitoring a total drainage area of 33.47 km^2.

Table 1.1-9. Hydrometric Monitoring Stations in the George Property Area

Hydrometric Station	Location	Geographic Coordinates*		Drainage Area (km^2)	Lake Coverage (%)	Period of Operation
		Easting	Northing			
KL-H1	Komatic Lake inflow	390,592	7,309,400	24	19.7	Jun 10 to Sep 12,2012 Jun 4 to Sep 17, 2013
KL-H2	George Lake outflow	386,687	7,314,673	9.7	24.6	Jun 10 to Sep 12, 2012 Jun 11 to Sep 14, 2013
LG-H1	Long Lake outflow	394,280	7,305,113	271.3	17.0	Jun 11 to Sep 9, 2013
LY-H1	Lytle Lake outflow	387,171	7,313,490	10.6	23.4	Jun 10 to Sep 14, 2013
MC-H1	McCoy Lake	385,983	7,310,950	10.8	12.6	Jun 10 to Sep 14, 2013
MC-H2	McCoy Lake outflow	385,070	7,310,204	15.8	11.6	Jun 9 to Sep 17, 2013
REFC-H1	Reference Lake C outflow	396,495	7,335,612	9.47	17	Jun 11 to Sep 11, 2012
SL-H1	Sleigh Lake outflow	388,273	7,312,297	13.0	23.2	Jun 9 to Sep 17, 2013

** UTM, Datum NAD 83, Zone 13 W*

Annual unit discharge hydrographs were produced for the three hydrometric monitoring stations (Figure 1.1-13). As in the Goose Property, the hydrologic patterns in the George Property area are also characterized by the Arctic nival flow regime.

During the 2012 monitoring period, instantaneous peak flows within the George Property ranged from 0.73 m^3/s at KL-H2 to 2.16 m^3/s at KL-H1. All streams experienced zero low or extreme low flow conditions in August (Table 1.1-10). Flow duration analysis revealed that on average, there was streamflow at the stations during 31% of the year.

Table 1.1-10. Peak Flows and Low Flows in the George 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
REFC-H1	9.47	2012	0.569	0.440	June 2	0	Aug 22 – Sep 11
KL-H1	24.0	2012	2.16	1.74	June 2	0	Jul 30 – Aug 9
KL-H2	9.66	2012	0.728	0.644	June 2	0	Aug 2 -4

Note: Estimated values are italicized

Annual runoff values ranged from a low of 62 mm at station REFC-H1 to a high of 143 mm at stations KL-H1 and KL-H2 (Table 1.1-11). The majority of seasonal runoff in the George Property occurs in June. The runoff in June accounted for a low of 67% of the annual total at station BL-H1 in 2012 and a high of 86% at station REFC-H1.

Table 1.1-11. Annual Runoff and Seasonal Distribution in the George Property Area

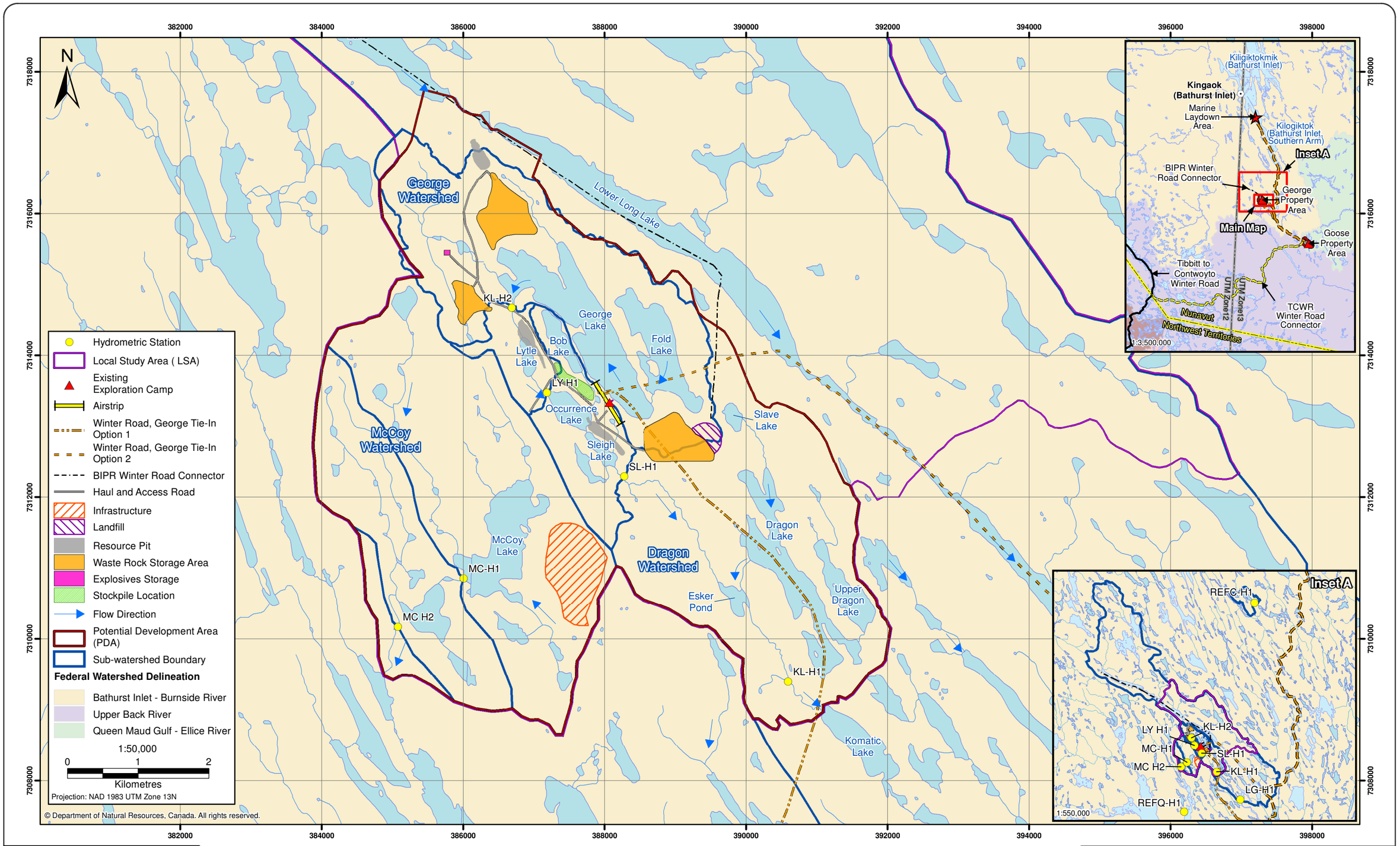
Hydrometric Station	Year	Annual (mm)	Seasonal Distribution (%)						
			Jan-May	Jun	Jul	Aug	Sep	Oct	Nov-Dec
REFC-H1	2012	62	0	86	14	0	0	0	0
KL-H1	2012	143	0	67	15	3	9	5	0
KL-H2	2012	143	0	69	23	4	4	0	0

1.1.2.3 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 Anticipated Global Climate Change and its Hydrologic Impacts

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. Over the same time periods, precipitation could increase from 5 to 8% and 15 to 30%, respectively (see Volume 4, Chapter 3).

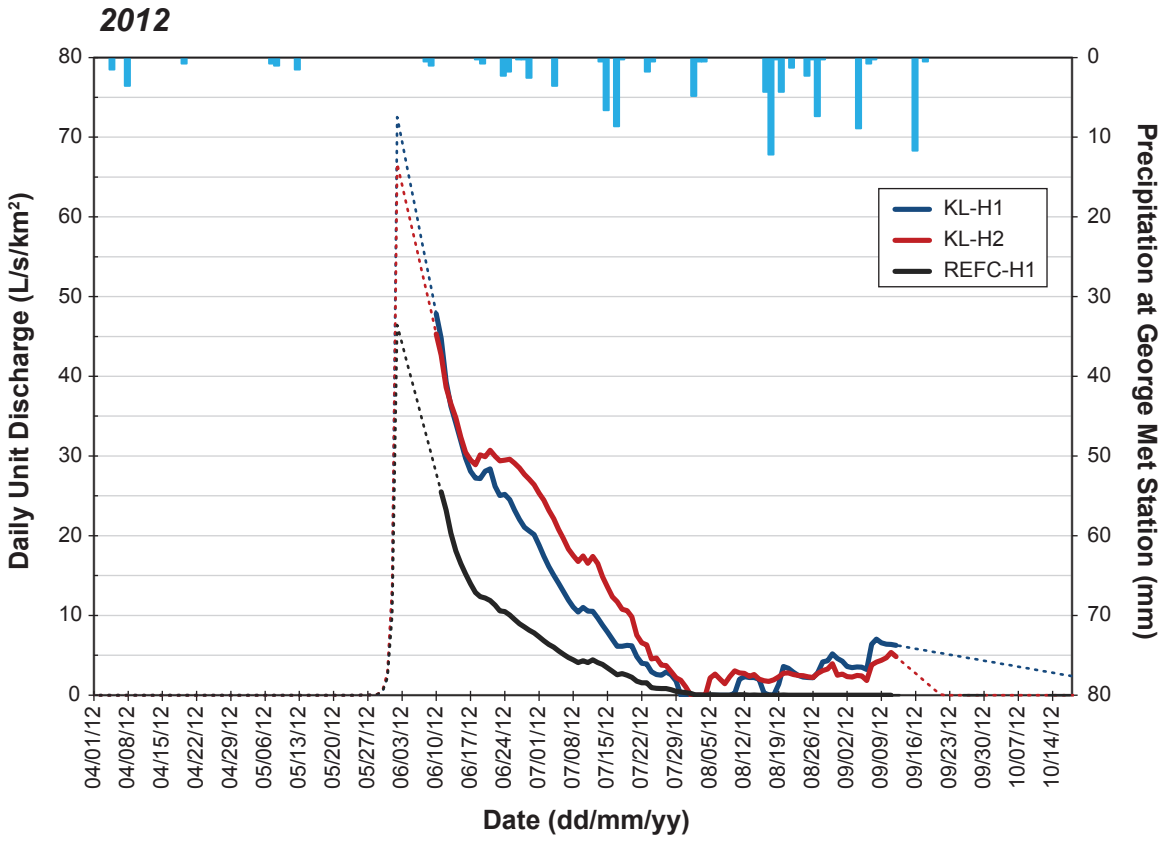


© Department of Natural Resources, Canada. All rights reserved.

Sabina GOLD & SILVER CORP. Rescan an ERM company

Figure 1.1-12

Study Area Drainage Basins - George Property Area



Sabina GOLD & SILVER CORP.

Annual Unit Hydrographs of Hydrometric Monitoring Stations - George Property Area

Figure 1.1-13

Rescan™ Engineers & Scientists

The expected duration of the Back River Project is currently 24 years (2 years site preparation, 2 years construction, 10 years operations, and 10 years closure). Therefore, the summary below focuses on the likely impacts of climate change on hydrology 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 limited number of Arctic hydrologic modelling studies that examine climate change impacts, much of the discussion below is qualitative, and is based on anticipated changes to hydrologic processes.

1.1.3.1 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 base flow, 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 base flows, 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.

1.1.3.2 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 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. 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). GCM's predict increases in snowfall, and in 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 GCMinputs (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 Laird 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.

1.1.3.3 Changes to Winter Flow

Winter flows are also expected to markedly increase in this area. For a 6°C warming in the Laird River Watershed, winter flows are expected to increase by 31% (Thorne 2011). Flow under ice may also extend in duration under warmer climate scenarios. 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. It is also considered unlikely that anticipated warming during the Project lifespan would lead to winter flow in the Project area.

1.1.3.4 Hydrologic Impacts of Extreme Weather Events

More precipitation is expected to fall in extreme events (Pohl, Marsh, and Bonsal 2007; Lewis and Lamoureux 2010; Thorne 2011). From a hydrologic perspective, this 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, and avulsion, and extreme flows have the potential to impact engineering structures.

1.1.3.5 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)

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 in inland compared to coastal areas.

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 did 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 current DEIS 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 DEIS.

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 DEIS.

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, three specific indicators were selected to assess the surface water hydrology VEC (Table 1.3-1). These include:

- *Quantity of water used by the Project*. This quantity reflects the legal requirements of the Project (i.e., compliance with the future Type A water licence).
- *Streamflows*. Integrity of fish/aquatic habitat is dependent on streamflows. Reduction in streamflows 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
Quantity of water used	Reflects the legal requirements of the Project (i.e., compliance with the future Type A water licence)
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 boundaries of the surface water hydrology effects assessment (Figure 1.4-1) include the baseline watershed boundaries and have considered watersheds over a range of spatial scales from local (i.e., immediately downstream of the Project infrastructure) to regional (i.e., Ellice River and Western River). The spatial boundaries have been divided into a Local Study Area (LSA) and a Regional Study Area (RSA), which will be discussed further below. The locations of assessment points within the LSA and RSA can be seen in Figures 1.4-1 and 1.4-2, and Table 1.4-1.

PROJECT #0194096-0040 GIS # BAC-10-079 October 17 2013

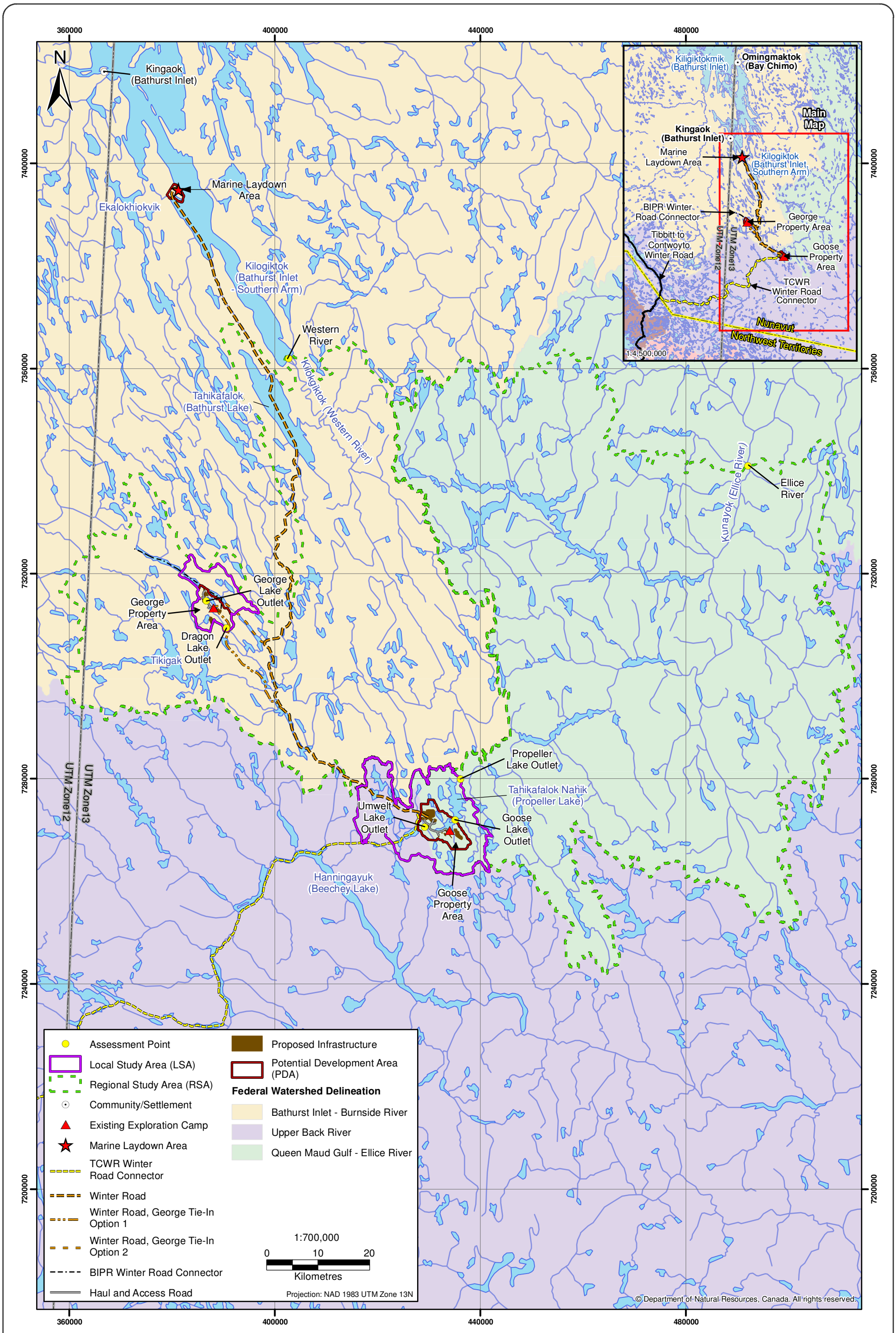


Figure 1.4-1

Sabina GOLD & SILVER CORP.

Spatial Boundaries of the Surface Water Hydrology Effects Assessment and Assessment Points within the Local Study Area and Regional Study Area

Figure 1.4-1

Rescan an ERM company

PROJECT #0194096-0040 GIS # BAC-10-081 October 17 2013

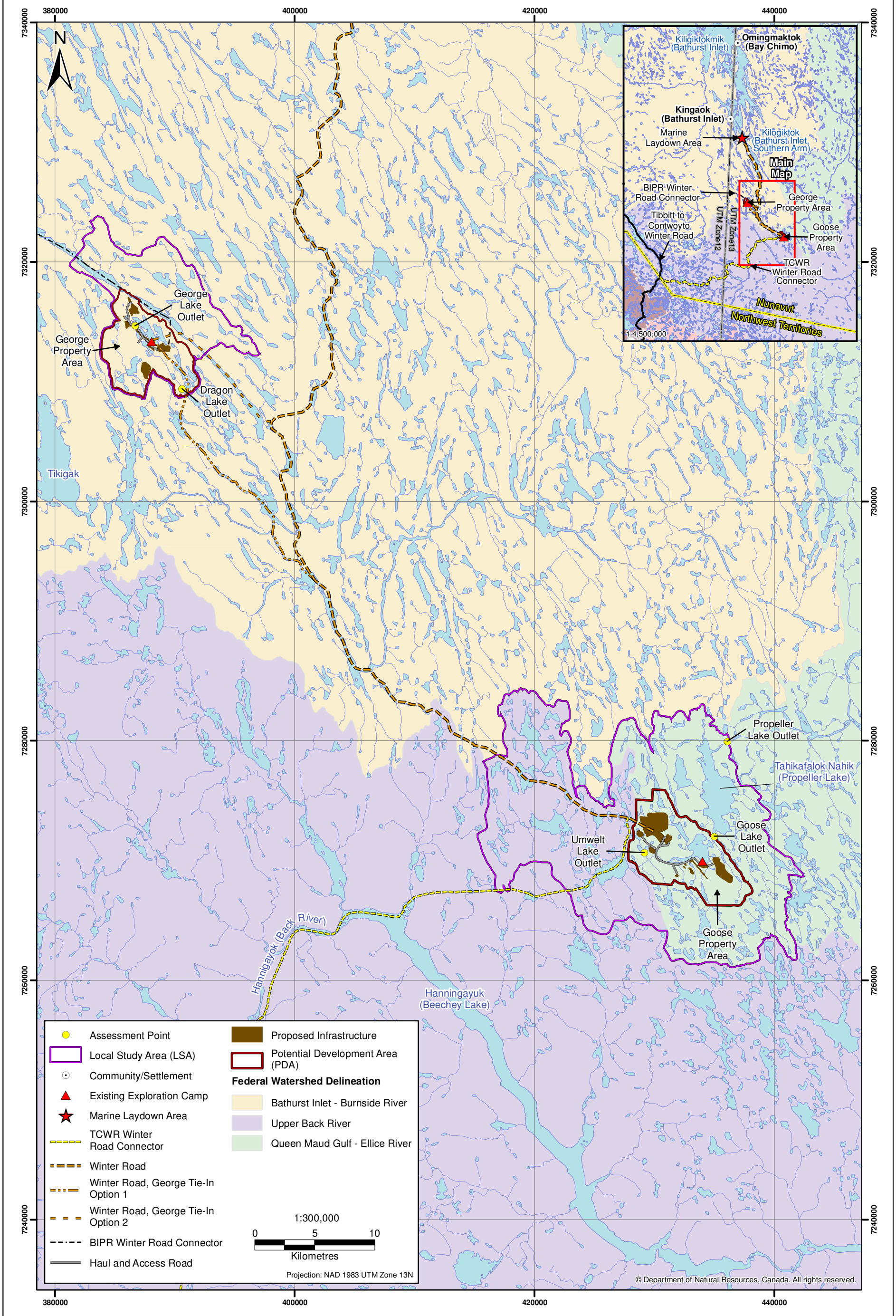


Figure 1.4-2

Sabina GOLD & SILVER CORP.

Surface Water Hydrology Assessment Points within the Local Study Area

Figure 1.4-2

Rescan an ERM company

Table 1.4-1. Effect Assessment Points within the Local Study Area and Regional Study Area

	Goose Property				George Property		
	LSA			RSA	LSA		RSA
Assessment Point	Umwelt Lake	Goose Lake	Propeller Lake	Ellice River	George Lake	Dragon Lake	Western River
Catchment Area of the Assessment Point (km^2)	4.1[1]	101[2]	205[3]	6,655[4]	10[5]	24[6]	4,034[7]

[1] *At Umwelt Lake outlet*
[2] *At Goose Lake outlet, i.e., hydrometric station PL-H2*
[3] *At Propeller Lake outlet, i.e., hydrometric station PL-H1*
[4] *At the most downstream point within the Goose Property RSA*
[5] *At George Lake outlet, i.e., hydrometric station KL-H2*
[6] *At Dragon Lake outlet, i.e., hydrometric station KL-H1*
[7] *At the most downstream point within the George Property RSA*

1.4.1.1 Local Study Area

The surface water hydrology LSA (Figures 1.4-1 and 1.4-2) is based on the proposed Project footprint and activities that could affect surface water hydrology. 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 surface water hydrology effects assessment is divided into two regions:

- At the Goose Property, the LSA boundary (365 km^2) includes the Potential Development Area (PDA) and matches with the boundaries of Propeller Lake and Big Lake watersheds at hydrometric stations PL-H1 and BL-H2 (Figure 1.1-10; Figure 1.4-2).
- At the George Property, the LSA (105 km^2) boundary includes the PDA, the George Lake, Dragon Lake, and McCoy Lake watersheds, and part of the Long Lake Watershed (Figure 1.1-12; Figure 1.4-2).

1.4.1.2 Regional Study Area

The surface water hydrology RSA (Figure 1.4-1) includes the LSA plus additional area within which there is the potential for indirect or cumulative effects. The RSA encompasses the following watersheds:

- The RSA boundary for the Goose Property (6,815 km^2) includes part of the Ellice River Watershed and encompasses the PDA and the LSA. All Project infrastructure at Goose Property resides within the Ellice River Watershed. The upper 80 km of the watershed was included rather than the entire watershed (Figure 1.4-1). It is approximately 18 times greater than the LSA (365 km^2) and 126 times greater than the PDA (54 km^2).
- The RSA boundary for the George Property includes the Western River Watershed (drainage area 4,034 km^2). All Project infrastructure at Goose Property resides within the Ellice River Watershed. The upper portion of the watershed that drains into the southern tip of Bathurst Inlet is included in the RSA (Figure 1.4-1). The RSA is approximately 37 times greater than the LSA (105 km^2) and 94 times greater than the PDA (42 km^2).

Only the potential changes to the above watersheds have been addressed in this assessment. Potential effects related to the Marine Laydown Area (MLA) are addressed in Volume 7.

1.4.2 Temporal Boundaries

Temporal boundaries for the surface water hydrology assessment are aligned with the phases of the Project (see Volume 9, Chapter 1). Project phase durations used are as follows:

- Site Preparation and Construction: 4 years;
- Operations: 10 years;
- Reclamation and Closure: 10 years; and
- Post-closure: 5 years.

The following assumptions were made for the assessment.

1.4.2.1 Site Preparation and Construction

Goose Property

Water management infrastructure will be built upstream of Goose Lake to divert contact water and a portion of non-contact water, which would naturally report to the Project infrastructure, to the TIA. At the end of this phase, flows from 11.3 km^2 of Goose Lake catchment areas will be diverted to the TIA (Appendix V6-1D).

Up to 210 m^3/day of water is planned to be withdrawn from Goose Lake for domestic use, as well as 70 m^3/day for industrial use, for a maximum water use of 280 m^3/day (Table 1.4-2).

Table 1.4-2. Proposed Water Withdrawal Volumes from Goose, Propeller, and George Lake

Project Phase	Goose Lake		Propeller Lake		George Lake	
	Year-round Withdrawal (m^3/day)	Additional Withdrawal in June (m^3/day)	Year-round Withdrawal (m^3/day)	Additional Withdrawal in June (m^3/day)	Year-round Withdrawal (m^3/day)	Additional Withdrawal in June (m^3/day)
Site Preparation and Construction	280	n/a	n/a	n/a	115	n/a
Operations	1,000	1,000	1,510	1,000	115	n/a
Reclamation and Closure	1,000[1]	1,000[1]	1,510[1]	1,000[1]	115[1]	n/a[1]
Maximum Footprint Conditions[2]	**1,000**	**1,000**	**1,510**	**1,000**	**115**	**n/a**

[1] *Water use volumes for reclamation and closure were assumed to be the maximum water use volumes for operations*
[2] *Maximum water use volumes during all phases of the Project*

George Property

No water diversion infrastructure is planned at the George Property; however, the natural runoff coefficient (47%) is expected to decrease to 30% at waste rock storage areas (Appendix V6-1F).

Up to 45 m^3/day of water is planned to be withdrawn from George Lake for domestic use, as well as 70 m^3/day for industrial use for a maximum water use of 115 m^3/day (Table 1.4-2).

1.4.2.2 Operations

Goose Property

Water management infrastructure will be the same in the operational phase as at the end of the construction phase. That is, flows from 11.3 km^2 of Goose Lake catchment areas will be diverted to the TIA (Appendix V6-1D).

Up to 210 m^3/day of water is planned to be withdrawn from Goose Lake for domestic use. During operations, the mill will require fresh make-up water and industrial water withdrawal could go up to 790 m^3/day from Goose Lake, as well as 1,300 m^3/day from Propeller Lake, throughout the year. In June, an additional 1,000 m^3/day of water could be withdrawn from each of Goose Lake and Propeller Lake, i.e., a total of 2,000 m^3/day from Goose and Propeller lakes (Table 1.4-2).

George Property

Similar to the construction phase, no water diversion infrastructure is planned at the George Property during the operational phase. Natural runoff coefficient (47%) is expected to decrease to 30% at waste rock storage areas (Appendix V6-1F).

Up to 45 m^3/day of water is planned to be withdrawn from George Lake for domestic use, as well as 70 m^3/day for industrial use, for a maximum water use of 115 m^3/day (Table 1.4-2).

1.4.2.3 Reclamation and Closure, and Post-closure

The reclamation and closure plan is still in a conceptual phase (see Volume 10, Chapter 29). For the purpose of this assessment, the water use volumes for closure were assumed to be the maximum water use volumes for operations (Table 1.4-2).

1.4.2.4 Maximum Footprint Conditions

The maximum water use values shown in Table 1.4-2 were used for assessment even though actual water use volumes could be less and will likely vary inter annually.

1.5 POTENTIAL PROJECT-RELATED EFFECTS ASSESSMENT

The EIS guidelines (NIRB 2013) state that the DEIS 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	Quantity of water used	Negligible	Meets the requirements of the future Type A water licence
		Low	n/a[1]
		Moderate	n/a[1]
		High	Does not meet the requirements of the future Type A water licence
	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[2]
		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
	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[3]
		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] *No low or moderate affect category were considered. Any violation of the water licence requirements were considered as high magnitude effects.*
[2] *Established by fish habitat requirements (DFO 2013)*
[3] *For winter volumes the 10% threshold is based on the DFO protocol for winter water withdrawal (DFO 2010). For summer volumes, although no standard available, 10% was considered as the threshold.*

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 three surface water hydrology indicators are summarized in Table 1.5-1.

Compliance with the future Type A water licence was used as the criterion to assess the magnitude of potential effects on the quantity of water used. That is, if the quantity of water used is within the limits that are identified by the future Type A water licence, no effect was assumed to occur. Otherwise, the magnitude of the effects was assumed to be high.

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). In assessing the streamflow effects, a variation of 10% from baseline conditions was assumed to be within the natural variability of the riverine system. That is, if the streamflows are changed less than 10% from the baseline conditions, the effect on streamflows are assumed to be of low magnitude (Table 1.5-1). This is in agreement with recommendations from the Science Advisory, Fisheries and Oceans Canada (DFO 2013), 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 over-wintering 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; Appendices 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. However, in this study the 10% volume change threshold was used for the summer months, too (Table 1.5-1). Similar to streamflows, a 50% threshold was assumed to identify high magnitude effects (Table 1.5-1).

Effects of the Project components on streamflows and lake volumes were estimated at several assessment points within Local Study Area (LSA) and Regional Study Area (RSA). These include Umwelt Lake, Goose Lake, Propeller Lake, George Lake, and Dragon Lake within the LSA, and Ellice River and Western River, within the RSA (Table 1.4-1).

Collected data from the 2011 and 2012 hydrometric monitoring program (see Section 1.1.2 and Rescan 2012a, 2012b) 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).

For the effect assessment, a monthly time-step was used. Given the length and quality of hydrometric data and the proposed Site Water Monitoring and Management Plan (Volume 10, Chapter 7), a monthly time-step is sufficient to assess the effects of the Project. An assessment based on a shorter time-step would not provide more accurate results.

The Mine Closure and Reclamation Plan (Volume 10, Chapter 29) is still in a conceptual phase with many possible alternatives. Closure was addressed in this assessment by assuming the same maximum water use volumes as during operations. Further details on closure will be available for the FEIS.

In this effect assessment study, conservative assumptions were made. Examples of conservative assumptions include:

- wherever the Site Water Monitoring and Management Plan (Volume 10, Chapter 7) was not finalized, a conservative portion of the watershed was assumed to be diverted from the natural streams. For example, it was assumed that water from all catchment areas that would naturally drain into the waste rock storage areas at the Goose Property, will be diverted to the TIA;
- if the volume-outflow relation for lakes was not known (e.g., for George Lake and Propeller Lake), it was conservatively assumed that a Q m^3/day upstream runoff reduction and lake water withdrawal would result in Q m^3/day reduction from the lake outflow, as well as Q m^3/day reduction from the lake volume; and
- for Propeller Lake where the volume-outflow relation for the lake was not known, and flow data was available for 2011 and 2012, average flows during 2011 and 2012 were used to estimate the baseline conditions. Data from regional hydrometric stations show that the average of 2011 and 2012 would represent a year that is dryer than normal (see Section 1.1.1).

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 the quantity of water used, streamflows, and lake volumes.

Potential Interactions during Site Preparation, Construction, and Operations

- *Water Use*. Water withdrawals from Goose, Propeller, and George lakes for domestic and industrial uses are planned during the site preparation, construction, and operations (Table 1.4-2). These activities could affect the quantity of water used, streamflows, and lake volumes.
- Site Water Management Activities:
  - *Water Diversions*. At the Goose Property area, water management infrastructure upstream of Goose Lake will divert contact water and a portion of non-contact water, which would naturally report to the Project infrastructure, to the TIA. These activities could affect the streamflows, and lake volumes.
  - *Modification of Natural Drainage*. At both the Goose Property and George Property areas, the natural runoff coefficient is expected to be less than the baseline conditions at waste rock storage areas. Reduced runoff coefficients could affect the streamflows, and lake volumes.
  - *Lake Dewatering*. Dewatering of lakes or portions of lakes may 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.
- *Winter Road Construction and Maintenance*. Use of water to annually build and maintain the winter roads could affect the streamflows, and lake volumes.

Potential Interactions during Reclamation and Closure

The reclamation and closure plan is still in a conceptual phase (see Volume 10, Chapter 29). For the purpose of this assessment, the potential interactions with the Project components and activities during the reclamation and closure were assumed to be similar to those during the operations.

A watershed-based approach was used to systematically characterize the potential effects of the Project on surface water hydrology, That is, the Project components and activities, listed above, were considered collectively.

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.

Water Use

Water withdrawal will follow DFO's Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut (DFO 2010) and DFO's Operational Statement on Mineral Exploration Activities (DFO 2009). That is, the quantity of water used will be within the thresholds identified in these DFO documents.

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.

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

Locations of infrastructure, waste rock storage areas, and the TIA at the Goose Property have been selected to be confined to the local watersheds where the deposits are located (Site Water Monitoring and Management Plan, Volume 10, Chapter 7). These watersheds are not within the regional Upper Back River Watershed, thereby confining potential changes to water quantity (hydrology) to the local drainage areas. For example, an alternative site for the TIA, 10 km from the property, was rejected, because it would be located in the Moby Watershed that lies within the regional Upper Back River Watershed.

Winter Road Construction and Maintenance

Winter road construction will follow the required mitigation and management measures (Road Management Plan, Volume 10, Chapter 14). Several regulatory requirements will be considered during road construction and maintenance, including culverts and other stream crossings. These include:

- winter road construction will follow the DFO Nunavut Operational Statement for Ice Bridges and Snow Fills (DFO 2007a);
- site road crossings will be constructed according to the DFO Nunavut Operational Statement for Clear Span Bridges (DFO 2007b);
- culvert maintenance will be conducted following the DFO Nunavut Operational Statement for Culvert Maintenance (DFO 2007c); and
- temporary stream crossings will be constructed according to the DFO Nunavut Operational Statement for Temporary Stream Crossings (DFO 2007d).

Water use for winter road construction and maintenance will be in conformance with regulatory requirements, above. The mitigation measures are expected to eliminate all potential effects of the road construction and maintenance on surface water hydrology.

1.5.4 Characterization of Residual Effects

Analyses undertaken to support this assessment (Appendices V6-1C to V6-1F) shows that after consideration of the mitigation and management measures, the future Type A water licence requirements will be met. However, there will be some residual effects on streamflows and on lake volumes. That is, the mitigation measures will:

- eliminate the effects on the quantity of water used (no further assessment required);
- reduce the effects on streamflows (potential residual effects to be characterized); and
- reduce the effects on lake volumes (potential residual effects to be characterized).

Therefore, among the three potential effects of the Project on surface water hydrology indicators, the potential residual effects on streamflows and lake volumes are characterized in the following section.

For residual effects on surface water hydrology, after implementation of the proposed mitigation measures (Section 1.5.3), standard ecological risk assessment frameworks that categorize the levels of detail and quality of the data required for the effect assessment were used. 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) were used to characterize the baseline conditions;
- statistical modelling was performed to estimate regional hydrologic indices using data collected from regional hydrometric stations;
- a watershed-based approach was used to quantify the effects of the Project on surface water hydrology. That is, effects of all Project-related activities in Section 1.5.2, which were not eliminated by mitigation measures (Section 1.5.3), were assessed collectively (Appendices V6-1C to V6-1F); and
- 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.

The Project components and activities (e.g., water use and water diversion) interact with each other, and with surface water hydrology. A watershed-based approach was used to systematically characterize the potential effects of the Project on surface water hydrology, That is, the effects of Project components and activities were considered collectively.

Effects were estimated at several assessment points within the LSA and RSA. These include Umwelt Lake, Goose Lake, Propeller Lake, George Lake, and Dragon Lake within the LSA, and Ellice River and Western River, within the RSA (Table 1.4-1; Figure 1.4-1). Residual effects on streamflows and lake volumes at assessment points within the Goose Property and George Property are characterized in the following sections.

1.5.4.1 Goose Property

Umwelt Lake

Umwelt Lake drainage area during the baseline conditions is 4.1 km^2. During the maximum footprint condition of the Project, natural runoff from 2.0 km^2 of this area is planned to be diverted to the TIA. This includes 1.7 km^2 catchment area of Llama Lake, and 0.3 km^2 that would naturally drain to Umwelt Pit (Appendix V6-1C). That is, 49% of the Umwelt Lake drainage area will be diverted to the TIA. Therefore, it is expected that the Umwelt Lake outflows will be reduced by 49% compared to the baseline conditions.

Residual effects of the project on Umwelt Lake outflow and volume are summarized in Table 1.5-2 (see Appendix V6-1C for details). Given the available dataset, the residual effects of the Project on Umwelt Lake volume cannot be quantified. However, it is known that Llama Lake, which is located within the Umwelt Lake Watershed, will be dewatered during the Project. Therefore, in the effect assessment process, the residual effect of the Project on the Umwelt Lake Watershed was assumed to be high.

Table 1.5-2. Effects of the Project on Streamflows and Lake Volumes (Percent Change from Baseline Conditions) at Assessment Points within the LSA and RSA

Assessment Point	Drainage Area (km^2)	Reduction in Lake Outflow		Reduction in Lake Volume	
		Average Outflow Reduction	Maximum Monthly Outflow Reduction	Maximum Reduction in Winter[1] Volume	Maximum Reduction in Summer[2] Volume
Umwelt Lake	4	49%	49%	0%[3]	High[4]
Goose Lake	102	21%	23%	5%	1%
Propeller Lake	205	10%	27%	1%	6%
Ellice River	6,655	< 1%	< 1%	n/a[5]	n/a[5]
George Lake	10	10%	14%	1%	2%
Dragon Lake	24	4%	6%	n/a[6]	n/a[6]
Western River	4,034	< 1%	< 1%	n/a[5]	n/a[5]

[1] *October to May*
[2] *June to September*
[3] *No water withdrawal from the lake is proposed.*
[4] *Further information was required to be quantified. The magnitude of the effect was assumed to be high in the effect assessment process.*
[5] *Assessment point is not a lake.*
[6] *Only streamflow changes were assessed. Lake volume changes are not significant because no withdrawal from the lake is planned.*

Goose Lake

An analysis was undertaken to assess the effects of diverting 11.6 km^2 of Goose Lake catchment area, and the year-round water withdrawal of 1,000 m^3/day from Goose Lake (with additional 1,000 m^3/day withdrawal in June), on Goose Lake outflows and water levels (Appendix V6-1D). Such diversion and water withdrawal values would result in 10 cm drawdown in Goose Lake water levels compared to the baseline conditions during the winter. During the summer, the maximum water level drawdown, compared to the baseline conditions, was 6 cm which would occur in June. These drawdown effects would result in maximum lake volume reductions of 6% and 1%, during the winter and summer (Table 1.5-2).

Goose Lake outflows would decrease by 21, 16, 23, and 18% during June, July, August, and September (Appendix V6-1D). On average, during the open-water season (i.e., June to September), Goose Lake outflows are predicted to decrease by 21% (Table 1.5-2).

Sabina is applying for a Type A water licence to withdraw up to 2,000 m^3/day from Goose Lake in June, and up to 1,000 m^3/day during the rest of the year. That is, the water use will not violate the requirements of the water licence.

Propeller Lake

An analysis was performed to assess the effects of water diversions and withdrawals on Propeller Lake (Appendix V6-1E). Similar to the Goose Lake analysis, above, it was assumed that 11.6 km^2 of the catchment areas that would naturally drain to Goose Lake will be diverted to the TIA. However, in the absence of accurate lake bathymetry and lake volume-outflow relation data, conservative assumptions were considered. For example, it was assumed that if the upstream runoff reduction and the lake water withdrawal add up to Q m^3/day, the lake outflow and the lake volume will be reduced by Q m^3/day. A year-round water withdrawal of 1,000 m^3/day (with additional 1,000 m^3/day withdrawal in June) from Goose Lake and a year-round water withdrawal of 1,510 m^3/day (with additional 1,000 m^3/day

withdrawal in June) from Propeller Lake were considered. Based on this analysis, Propeller Lake outflows would decrease by 10, 6, 27, and 13% during June, July, August, and September (Appendix V6-1E). On average, during the open-water season (i.e., June to September) Propeller Lake outflows would decrease by 10% (Table 1.5-2).

Maximum lake volume reduction of 6% (in the summer), and 1% (in the winter), compared to lake volumes at baseline conditions, was estimated to occur (Table 1.5-2).

Sabina is applying for a Type A water licence to withdraw up to 2,510 m^3/day from Propeller Lake in June, and up to 1,510 m^3/day during the rest of the year. That is, the water use will not violate the requirements of the water licence.

Ellice River

The assessment point on Ellice River within the RSA (Figure 1.4.1) covers a drainage area of 6,815 km^2. From this drainage area, 160 km^2 lies within the Big Lake Watershed (a tributary of the Back River Watershed) and will not be affected by the proposed diversion and water withdrawal activities. The remaining 6,655 km^2 catchment area includes the Propeller Lake Watershed (205 km^2), the effects of the Project on which was presented above. Based on this proportion of catchment areas (i.e., 34:1) and the aforementioned quantified effects on Propeller Lake outflows, it is expected that the effects the Project on Ellice River (i.e., the RSA assessment point) will be less than 1% (Table 1.5-2).

1.5.4.2 George Property

George Lake

Development of the waste rock areas at the George Property will decrease the natural runoff coefficient of 1.8 km^2 of the George Lake catchment area from 47% to 30% (Appendix V6-1F). Such a development, as well as the 115 m^3/day water withdrawal from George Lake would affect George Lake outflow and volume. In the absence of lake volume-outflow relation data, conservative assumptions were considered. That is, it was assumed that if the upstream runoff reduction and the lake water withdrawal add up to Q m^3/day, the lake outflow and the lake volume will be reduced by Q m^3/day. With this assumption, the lake water levels were estimated to drawdown 8 cm during the summer, and 2 cm during the winter (Appendix V6-1F). These drawdown effects would result in maximum lake volume reductions of 2% and 1%, during the summer and winter (Table 1.5-2).

George Lake outflows would decrease by 10, 8, 13, and 14% during June, July, August, and September (Appendix V6-1F). On average, during the open-water season, George Lake outflows would decrease by 10% (Table 1.5-2).

The proponent is applying for a Type A water licence to withdraw up to 115 m^3/day from George Lake throughout the year. That is, the water use will not violate the requirements of the water licence.

Dragon Lake

The Dragon Lake outflow assessment point covers a drainage area of 24 km^2 that includes the 10 km^2 watershed areas of the George Lake assessment point, above. Based on this proportion of catchment areas (i.e., 2.4:1) and the aforementioned quantified effects on George Lake outflows, it is expected that the average streamflows at Dragon Lake outflows, within the George Property LSA, will be reduced by 4% (Table 1.5-2).

Western River

The assessment point on Western River within the RSA (Figure 1.4.1) covers a drainage area of 4,034 km^2 that includes the 105 km^2 areas within the LSA. Based on this proportion of catchment areas (i.e., 38:1) and the aforementioned quantified effects on George Lake outflows, it is expected that the effects the Project on Western River (i.e., the RSA assessment point) will be less than 1% (Table 1.5-2).

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 1.5-3.

Direction

Only the negative effects of the Project are discussed in this assessment. That is, streamflow and lake volume reduction in Table 1.5-2 are negative effects.

Magnitude

- Streamflows: at the RSA scale, effects of the Project on streamflows are less than 1% which is rated as negligible based on Table 1.5-1. At the LSA scale, the magnitudes of residual effects vary within the LSA.
  - At the Goose Property area, Umwelt Lake outflows (drainage area of 4 km^2) are expected to be reduced by 49% (magnitude may be classified as moderate to high). However, when evaluated at the downstream assessment points of the LSA, the effects were low or moderate. Goose Lake outflows (drainage area of 102 km^2) are expected to be reduced by 21% (magnitude classified as moderate) and Propeller Lake outflows (drainage area of 205 km^2) are estimated to be reduced by 10% (magnitude classified as low). That is, the magnitude of the effects was moderate at the boundary of the PDA (Goose Lake outlet), and low at the boundary of the LSA (Propeller Lake outlet).
  - At the George Property area, changes in streamflows at both George Lake and Dragon Lake outflows were less than 10%. That is, the magnitude of effects on streamflows were rated low.

  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 Goose Property area, the effects were of low to moderate magnitudes at the downstream assessment points of the Goose Property area. At the boundaries of Goose and George LSAs (i.e., Propeller Lake and Dragon Lake), 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 were estimated to be of low magnitude (less than the 10% threshold in Table 1.5-1) at all assessment points except at Umwelt Lake, where it was conservatively assumed to be high. 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 within the Goose Property PDA, the effects were of low magnitude at the boundaries of Goose and George LSAs (i.e., Propeller Lake and Dragon Lake). Therefore, the overall magnitude was estimated to be low.

Table 1.5-3. Summary of Residual Effects on Surface Water Hydrology and Overall Significance Rating

Description of Residual Effects	Significance Criteria			Likelihood of Occurrence			Overall Significance Rating		
	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*

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 the site preparation construction, operations, and closure. Therefore, 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 Goose Property 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 Umwelt Lake assessment point).

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 1.5-3, 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 following residual Project effects were identified and are thus included in a cumulative effects assessment:

- streamflows, and
- lake volumes.

1.6.1 Methodology Overview

The spatial boundary for the surface water hydrology potential cumulative effects assessment was the RSA (Figure 1.4-1). The temporal boundary was past, present, and foreseeable future project timescales as described in Volume 9, Chapter 1.

The only project that could interact with the residual effects of the Back River Project is the Bathurst Inlet Port and Road (BIPR) project, as a small portion of the proposed road route lies within the Back River Project potential cumulative effects study area (the RSA). However, the residual effects of the Back River Project were confined within the LSA.

The BIPR project would involve an all-weather road, which would not affect water use or sustained flow volumes within the Back River Project RSA. It is therefore concluded that there are no residual cumulative effects on surface water hydrology.

1.7 TRANSBOUNDARY EFFECTS

All residual Project effects were confined to the LSAs, which are fully contained within Nunavut. Hence, there are no 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 (Volume 10, Chapter 7), Road Management Plan (Volume 10, Chapter 14), Aquatic Effects Management Plan (Volume 10, Chapter 19), and Mine Closure and Reclamation Plan (Volume 10, Chapter 29). 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
1. Mitigation by Project Design	
Infrastructure, waste rock storage areas, and the TIA at the Goose Property have been confined to the local watersheds where the deposits are located, and have stayed out of the regional Upper Back River Watershed, thereby confining potential changes to water quantity (hydrology) to the local drainage areas.	
The preferred Tailings Impoundment Area (TIA) location is located within the local watersheds where the main infrastructure will be located (compared to the alternative site in the Moby Watershed that lies within the regional Upper Back River Watershed).	
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 TIA, thereby reducing the amount of water required from local natural surface waters.	
2. Regulatory Requirements	
Winter road construction will follow the DFO Nunavut Operational Statement for Ice Bridges and Snow Fills (DFO Nunavut Operational Statement: Ice Bridges and Snow Fills, version 3.0 [2007]).	
Water withdrawal will follow DFO's Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut and DFO's Operational Statement on Mineral Exploration Activities (DFO Nunavut Operational Statement: Mineral Exploration Activities, version 1.0 [2009]).	
Site road crossings will be constructed according to the DFO Nunavut Operational Statement for Clear Span Bridges (DFO Nunavut Operational Statement: Clear Span Bridges, version 3.0 (2007]).	
Culvert maintenance will be conducted following the DFO Nunavut Operational Statement for Culvert Maintenance (DFO Nunavut Operational Statement: Culvert Maintenance, version 3.0 [2007]).	
Temporary stream crossings will be constructed according to the DFO Nunavut Operational Statement for Temporary Stream Crossings (DFO Nunavut Operational Statement: Temporary Stream Crossing, version 1.0 [2007]).	
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.	
Clean water and snow will be diverted to maintain natural drainage networks as much as possible.	

(continued)

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

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, or the Fish Offsetting Monitoring Program, show adverse effects to fish or fish habitat due to water quantity issues.

1.9 IMPACT STATEMENT

The Project has the potential to affect surface water hydrology by altering streamflows and lake volumes. Assessment of these effects is detailed in Section 1.5, and summarized in Table 1.5-3.

Although changes of potentially high magnitudeare experienced within the Project footprint (e.g., Umwelt Lake assessment point), the extent of these effects is not beyond the boundaries of the LSA. Further, the effects do not extend to locations at the downstream extent of the LSAs (e.g., Propeller Lake). Therefore, based on the analysis done, the overall residual effects are **Not Significant.**

2. Groundwater

Rescan™
an ERM company

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) are found to the north of the George Property Area (underlying the Marine Laydown Area (MLA) and northern reaches of the Winter 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 Their 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 (refer to Supporting Volume 5 Chapter 2 for a discussion of the permafrost environment). Two groundwater flow regimes are present in the continuous permafrost context: shallow flow in the active layer and open taliks (which are present beneath waterbodies with depths greater than two-thirds mean annual ice thickness) above the

permafrost, and deep flow beneath the base of the permafrost. The shallow and deep flow regimes are connected where through taliks exist beneath large surface waterbodies. 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 baseflow 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 snow melt. 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 fall freeze-up. Additional recharge throughout the active layer is provided by precipitation.

Where through-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 sub-permafrost groundwater throughout the Project footprint is inferred to flow generally northward towards the Arctic Ocean (Figure 2.1-2). Groundwater beneath the Goose Property Area is expected to flow northeastward, trending towards and along the Ellice River within the Queen Maud Gulf (Ellice River) Watershed. Groundwater beneath the George Property Area and the Winter Road alignments is expected to flow trending northward towards Bathurst Inlet. Large lakes in the immediate vicinity of the George Property Area suggest that flow follows the topography southeastward then eastward prior to trending northward, towards then along the Western River.

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 sub-permafrost groundwater quality in Canada's North has been slowly 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.

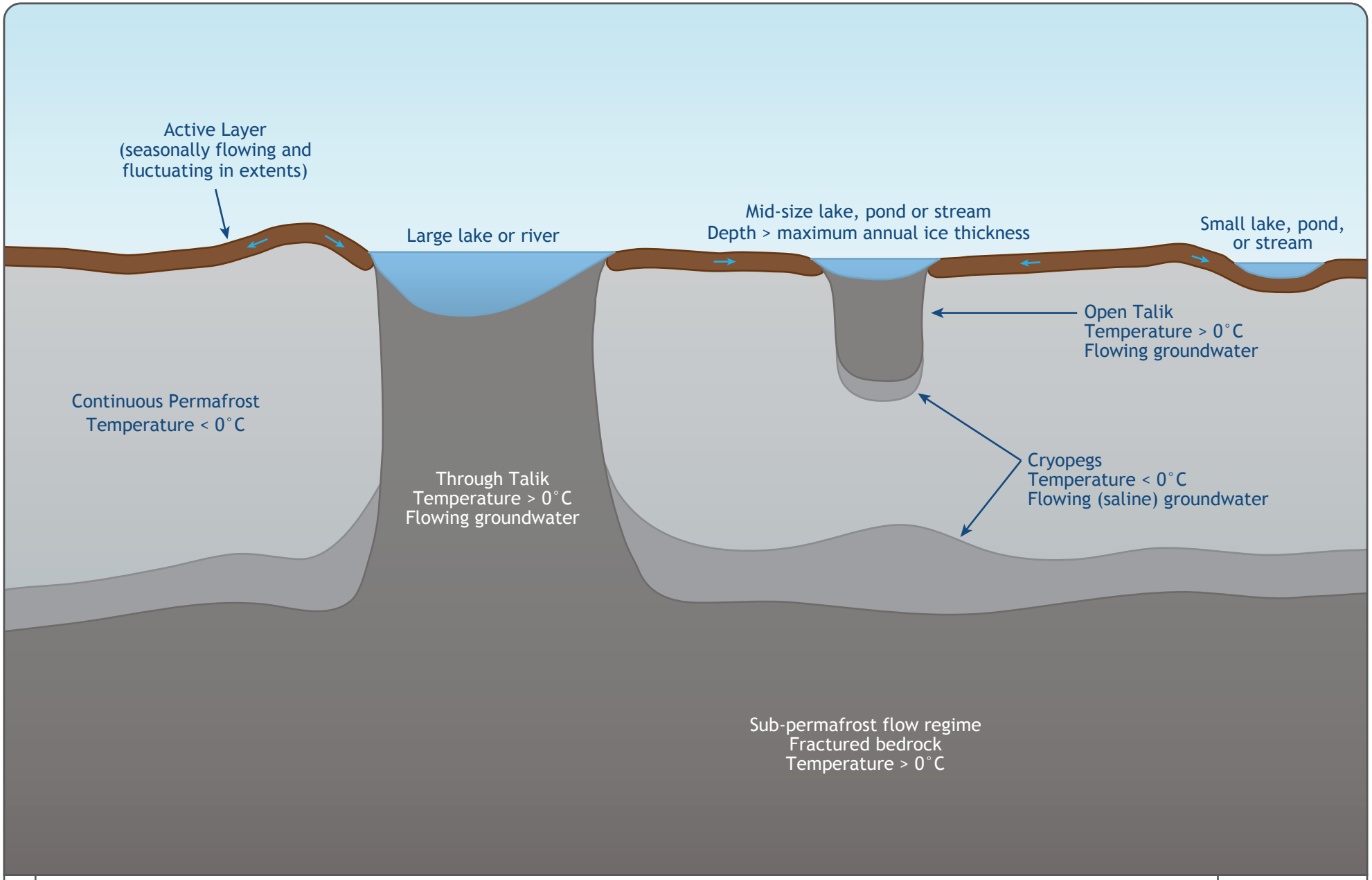


Figure 2.1-1

Sabina GOLD & SILVER CORP.

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, NWT. Brackish to saline water was observed at depths exceeding 300 mbg, 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.

Sub-permafrost 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 sub-permafrost 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 sub-permafrost groundwater quality data in Mainland Nunavut. Groundwater quality may be under greater influence from interactions with the surface water than other sites due to the relatively thin permafrost and frequent through taliks.

A Westbay sub-permafrost groundwater monitoring system was installed at the Meliadine Project site, as documented by Golder (2013). Water samples collected from a zone 454 mbg 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 sub-permafrost 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 sub-permafrost 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.

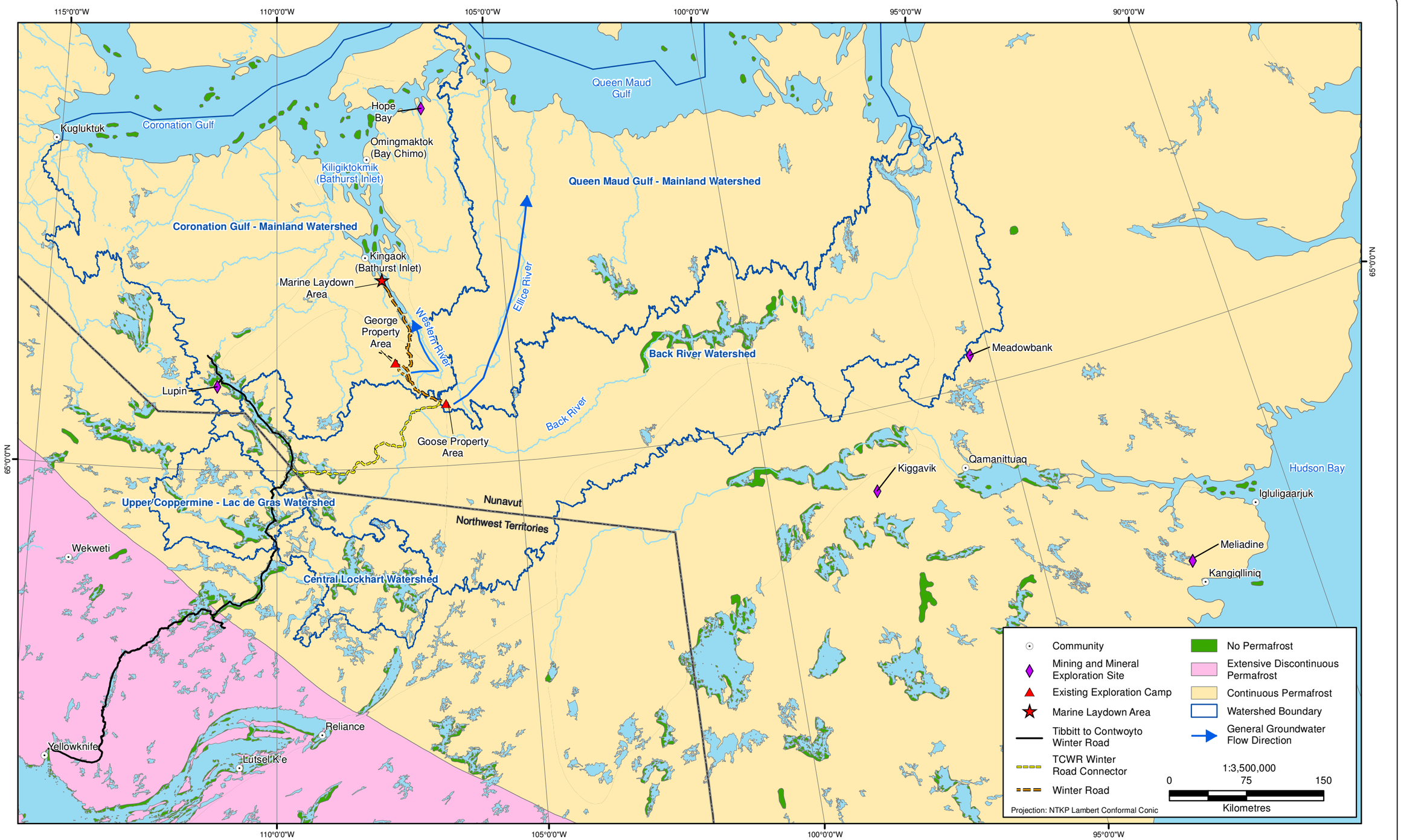
The available data suggest generally increasing TDS with depth. Concentrations on the scale of tens of grams per litre have been measured at depths of 500 mbg and deeper beneath continuous permafrost. Dominance of chloride among the anions is prevalent, with calcium and sodium dominating the cations. 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 Area and the George Property Area by three approaches, as follows.



Sabina Gold & Silver Corp.

Rescan an ERM company

Figure 2.1-2

Regional Groundwater Context

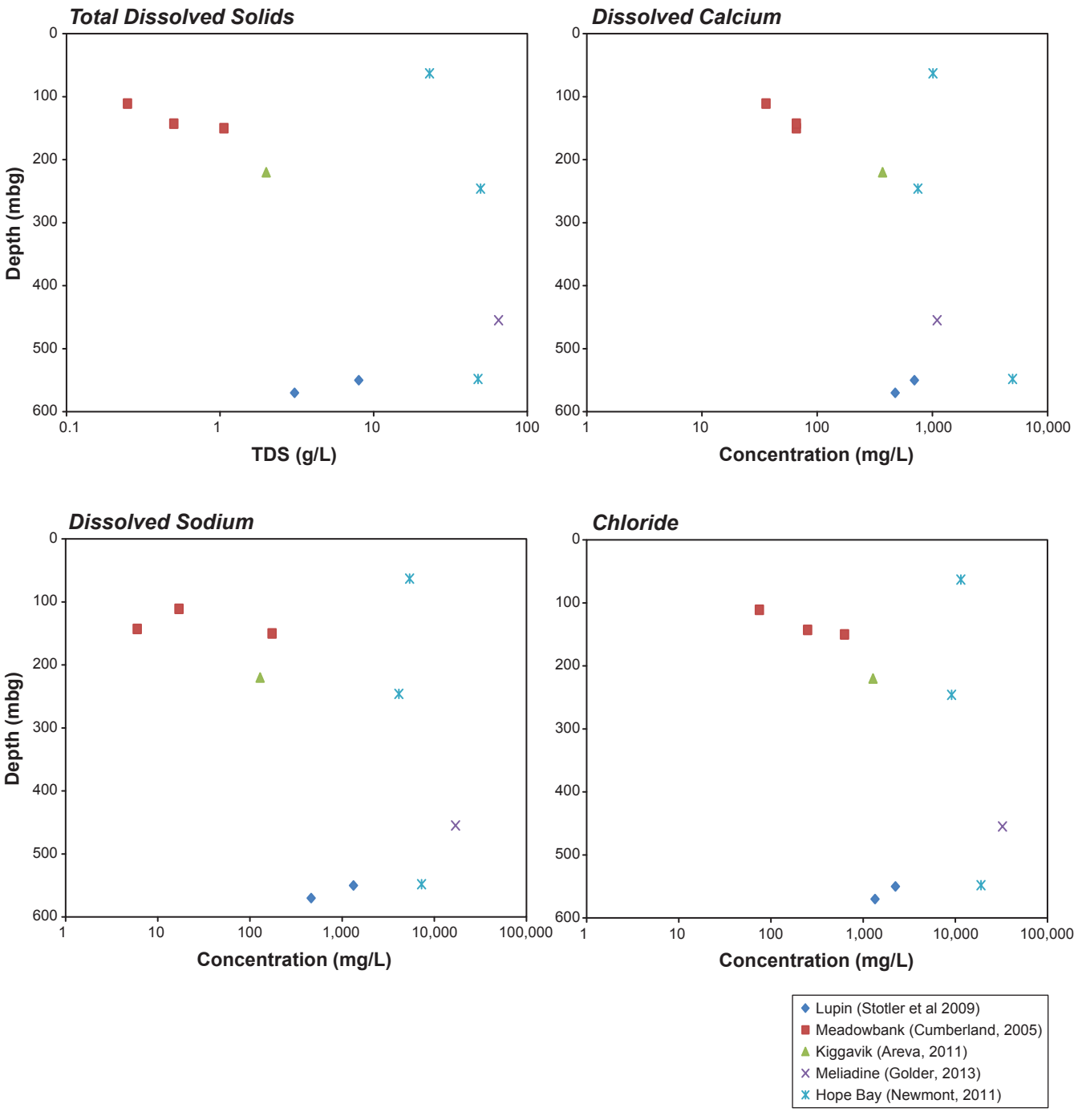


Figure 2.1-3

Regional Groundwater Total Dissolved Solids and Major Ion Concentrations

Sabina GOLD & SILVER CORP.

Rescan Engineers & Scientists

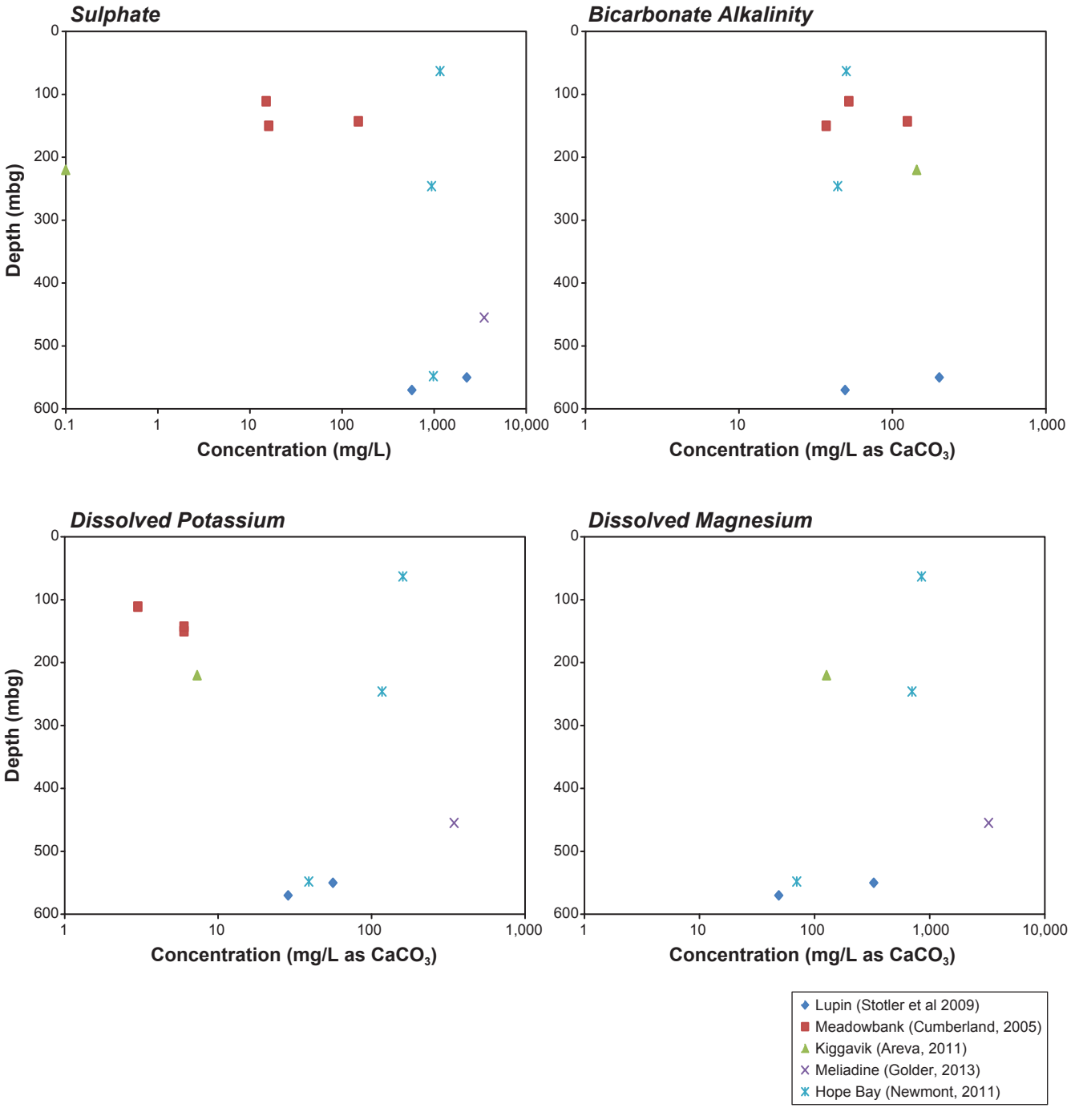


Figure 2.1-4

Regional Groundwater Major Ion Concentrations

Sabina GOLD & SILVER CORP.

Rescan Engineers & Scientists

Vibrating wire piezometers (VWPs) — Three VWPs were installed at the Goose Property in 2012 by SRK Consulting (SRK; Appendix V6-2C), as well as 13 by Knight Piésold Consulting (KP; 11 at the Goose Property, and 2 at the George Property) 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 Sub-permafrost 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 Through Taliks — One-dimensional steady-state analytical geothermal models were used to assess talik depths beneath a number of lakes in the Goose and George Property Areas (refer to Volume 5, Chapter 2: Permafrost). Lakes which present conditions predicted to result in through talik were identified. Through taliks present hydraulic connections between the surface water and sub-permafrost groundwater. Water surface elevations of those lakes predicted to overly through taliks provide evidence of the sub-permafrost water levels and flow directions.

Hydraulic Conductivities

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

Hydraulic conductivities were calculated for 16 injection packer tests conducted by SRK in 2012 at the Goose Property, and for 33 falling head packer tests conducted by KP in 2013 (22 at the Goose Property and 11 at the George Property). 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 from beneath the permafrost near the Umwelt Deposit using a Westbay Sub-permafrost 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 sub-permafrost 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 sub-permafrost zones was accounted for to estimate true sub-permafrost 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 methods and results are documents in Volume 5 Chapter 2 (Permafrost).

In Volume 5 Chapter 2 (Permafrost), One-dimensional analytical geothermal models were used to indicate the likelihood (low, moderate, or high) of through talik presence beneath lakes at the Goose and George Property Areas. In this chapter, through taliks are assumed to be present beneath lakes for-which the models indicated moderate to high likelihood of through talik presence.

2.1.2.2 Goose Property Area

Local Geologic Context

An overview of the local geologic setting at the Goose Property is provided in Volume 5, Chapter 1. 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 in the Goose Property Area (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 by air photo interpretation 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 found at the Goose Property, 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.

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

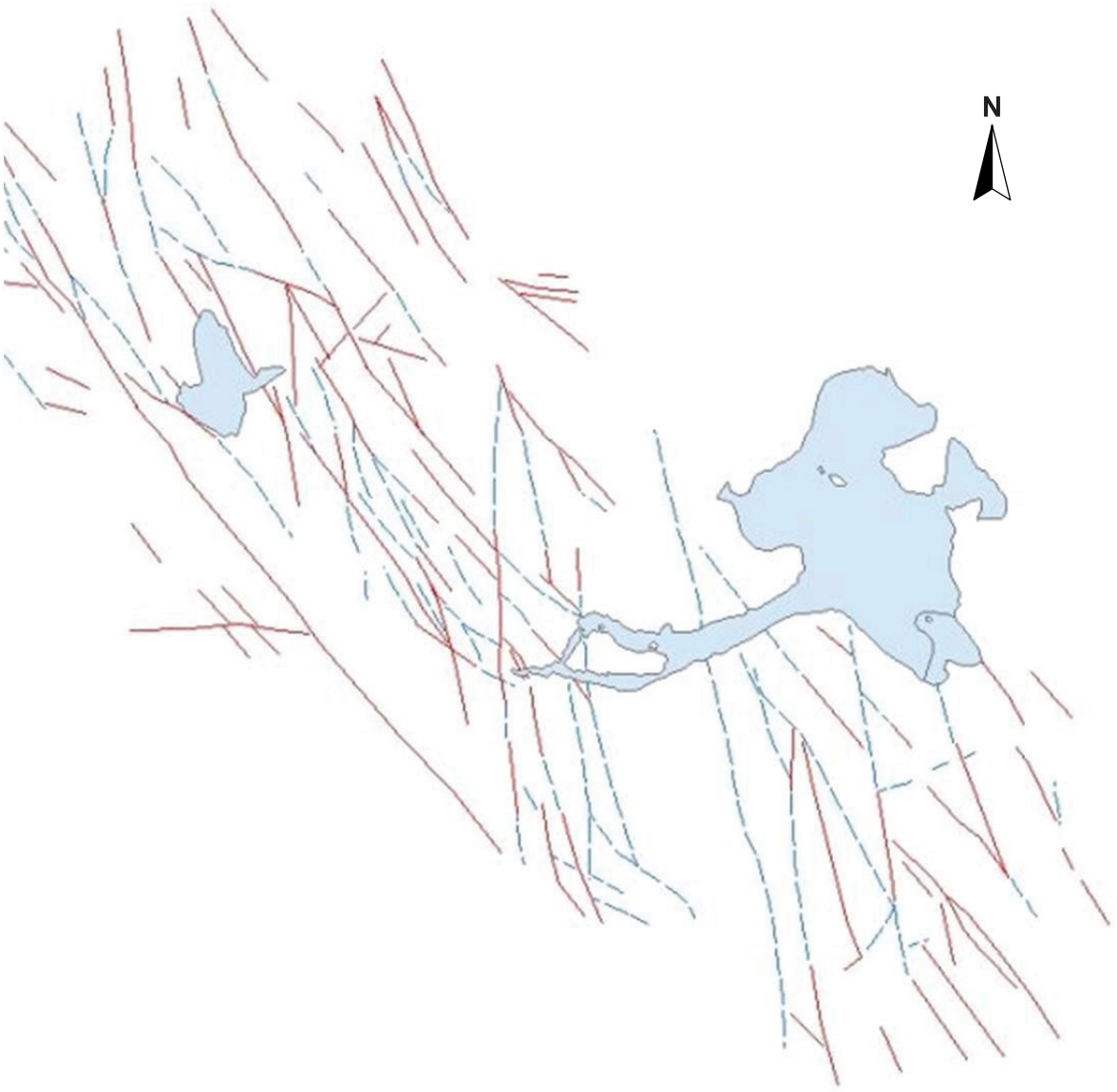
Surficial Material	Landscape Cover (%)[a]	Hydraulic Conductivity[b]	Topographic Setting[c]	Active Layer Depth[c,d]
Morainal	55.6	Low to moderate	Blankets > 1 m at lower slope and lowlands, veneers < 1m thick at upper slopes and crests	Low to moderate
Glaciofluvial	14.2	Moderate to high	Forming eskers or veneers over adjacent morainal deposits, slope grades up to 12%	High
Organics	7.2	Low to moderate	lowlands	Low
Weathered bedrock	2.8	Moderate to high	Highlands and upper slopes, highly variable slope grades	Low to high
Open Water	15.4	-	-	-

[a] *Obtained 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 Area. Propeller Lake has the lowest elevation of lakes predicted to overly through taliks, with higher lake water levels trending westward. Instruments installed beneath the permafrost indicate that the sub-permafrost groundwater behaves as a confined flow system, with pressures that exceed the elevation of the base of the permafrost. All groundwater pressures beneath the permafrost are lower than lake elevations, suggesting that lakes in the Goose Property Area behave as a source of recharge to the deep groundwater system.

Lakes overlying through taliks at lower elevations may receive water from the deep groundwater, but there is no evidence to indicate as such at the Goose Property Area. 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 much lower between Goose and Propeller Lakes, where the elevation difference is one metre.



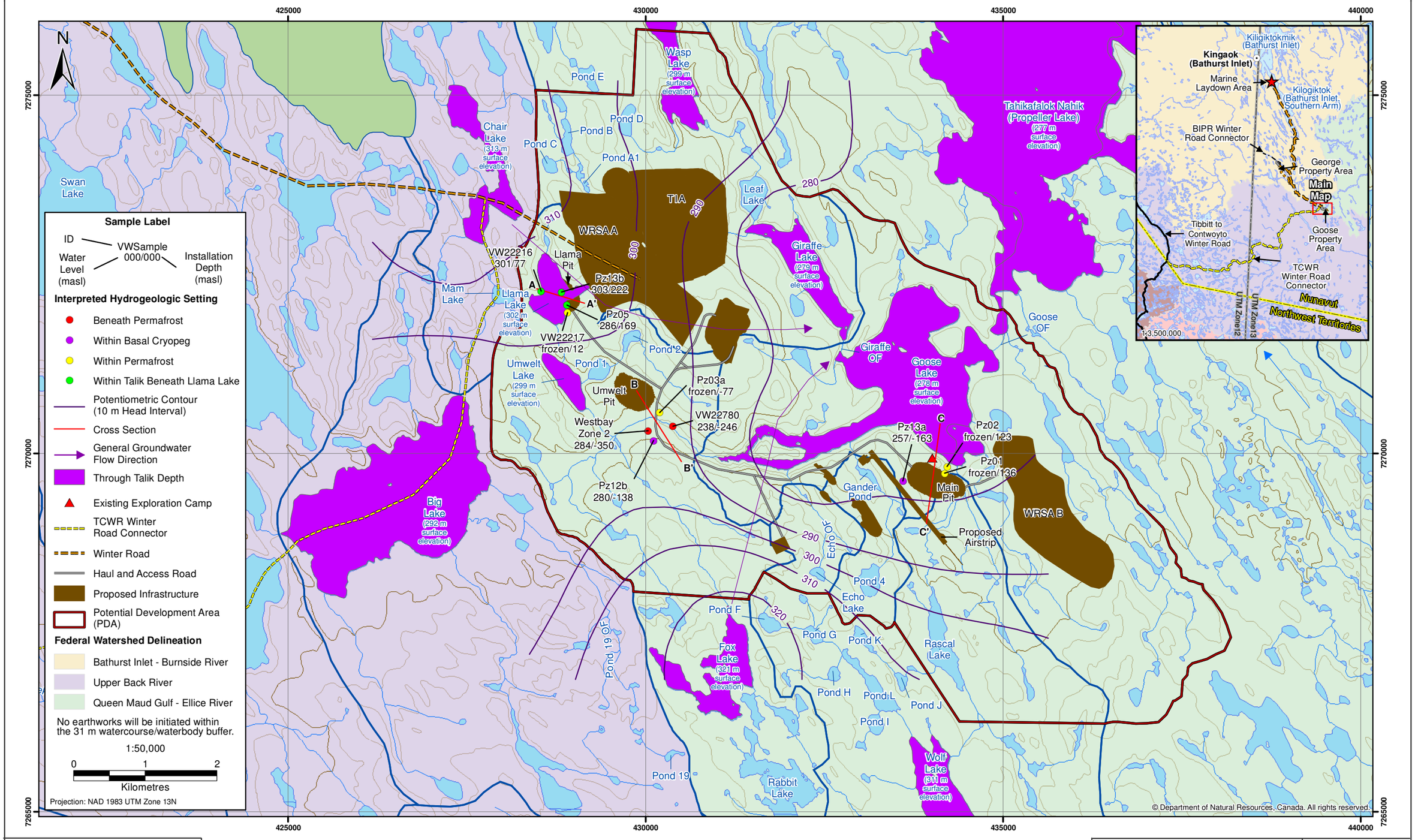
Source: SRK Consulting Inc (2012).

Figure 2.1-5

Geologic Structures at the Goose Property Area as Determined by Air Photo Interpretation

Sabina GOLD & SILVER CORP.

Rescan Engineers & Scientists



Sabina Gold & Silver Corp.

Rescan an ERM company

Figure 2.1-6

Groundwater Level Observations at the Goose Property Area

Groundwater in the active layer is expected to flow following surface topography and the surface water drainage network. The western reaches of the 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 Goose Property Area 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

A number of trends may be identified in the bedrock hydraulic conductivity results (Figure 2.1-7). Hydraulic conductivities generally decrease with depth. The shallow (less than 100 m deep) moderately fractured bedrock exhibits hydraulic conductivities with a geometric mean around 10^{-6} m/s (measurements varied from 10^{-9} m/s to nearly 10^{-5} m/s) within taliks. The presence of talik was indicated by temperature measurements, or inferred due to location of test interval beneath a large lake). At greater depths (50 to 150 mbg) within taliks, competent bedrock exhibits bulk hydraulic conductivities around 10^{-8} m/s (measurements were as low as 4E-10 m/s) and fracture zones exhibit hydraulic conductivities as high as 10^{-6} m/s. Hydraulic conductivities may be as high as 10^{-8} m/s within major faults and extensive fracture zones at depths exceeding 200 m within taliks and beneath the permafrost (measurements were as high as 2E-8 m/s). Outside of heavily fractures zones the deep bedrock typically exhibits a hydraulic conductivity of 10^{-9} m/s or less (measurements were as low as 4E-10 m/s). Measured hydraulic conductivities within the permafrost were less than 10^{-8} m/s regardless of depth. The permafrost is expected to be essentially impermeable to fresh water.

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.

Groundwater Quality

Two Westbay system sampling zones were purged adequately to determine concentrations of analytes in natural groundwater: zone 3 (620 mbg) and zone 5 (515 mbg). The results indicate that the groundwater is hyper-saline 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). Concentrations of fluoride, iron, arsenic, and zinc exceed CCME guidelines for the protection of freshwater aquatic life. 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. 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.

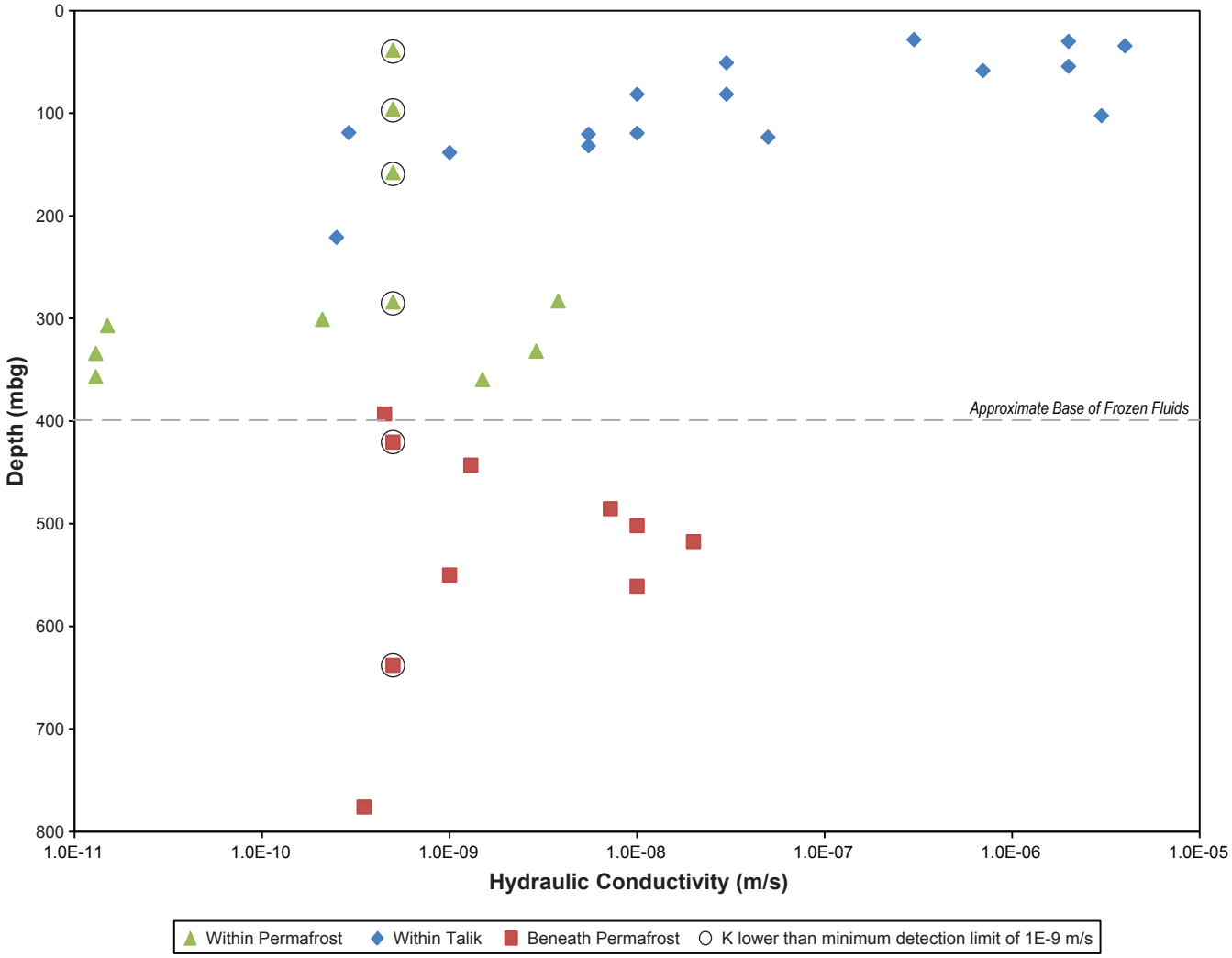


Figure 2.1-7

Hydraulic Conductivity Measurements at the Goose Property Area

Sabina GOLD & SILVER CORP.

Rescan Engineers & Scientists

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

Analyte[a]	Unit	CCME FWAL Guideline[e]	Sampling Zone 3 620 mbg	Sampling Zone 5 515 mbg
Charge Balance Error	-	-	+ 1.5%	- 1.7%
pH[b]	-	6.5 to 9.0	6.9	8.0
Total Dissolved Solids	mg/L	-	76,000	47,000
Hardness	mg/L as $CaCO_3$	-	47,000	31,000
Anions and Nutrients				
Total Alkalinity[c]	mg/L as $CaCO_3$	-	140	230
Ammonia, Total	mg/L as N	Zone 3 = 20; Zone 5 =2[n]	0.08	0.0
Bromide	mg/L	-	400	460
Chloride	mg/L	120	44,000	30,000
Fluoride	mg/L	0.12[f]	***0.7***	***0.5***
Nitrate	mg/L as N	13	< 0.50	< 0.50
Nitrite	mg/L as N	0.06	< 0.10[m]	< 0.10[m]
Total Kjeldahl Nitrogen	mg/L	-	2	0
Orthophosphate-Dissolved	mg/L as P	-	0	0.05
Phosphorus - Total	mg/L	[o]	0.2	0.2
Sulfate	mg/L	-	< 50	< 50
Dissolved Metals				
Aluminum	mg/L	0.1[g]	< 0.1	< 0.1
Antimony	mg/L	-	< 0.0050	< 0.005
Arsenic	mg/L	0.005	***0.008***	***0.008***
Barium	mg/L	-	9	3
Beryllium	mg/L	-	< 0.005	< 0.005
Bismuth	mg/L	-	< 0.05	< 0.05
Boron	mg/L	1.5	***3***	***4***
Cadmium	mg/L	Zone 3 = 0.007; Zone 5 = 0.005[h]	< 0.001	< 0.001
Calcium	mg/L	-	17,000	11,000
Chromium	mg/L	0.001 to 0.0089[i]	***< 0.01[m]***	***0.01***
Cobalt	mg/L	-	< 0.01	< 0.01
Copper	mg/L	Zone 3 = 2.3; Zone 5 = 1.6[j]	< 0.02	< 0.02
Iron	mg/L	0.3	***8***	***1***
Lead	mg/L	Zone 3 = 8; Zone 5 = 5[k]	< 0.005	< 0.005
Lithium[d]	mg/L	-	5	5
Magnesium	mg/L	-	1,100	900
Manganese	mg/L	-	3	2
Mercury	mg/L	-	< 0.00001	< 0.00001

(continued)

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

Analyte[a]	Unit	CCME FWAL Guideline[e]	Sampling Zone 3 620 mbg	Sampling Zone 5 515 mbg
Molybdenum	mg/L	0.073	0.03	0.03
Nickel	mg/L	Zone 3 = 10; Zone 5 = 8[l]	0.009	0.01
Potassium	mg/L	-	190	90
Selenium	mg/L	0.001	< 0.01[m]	< 0.01[m]
Silicon	mg/L	-	< 1	< 1
Silver	mg/L	0.0001	< 0.001[m]	< 0.001[m]
Sodium	mg/L	-	7,600	6,000
Strontium	mg/L	-	400	200
Thallium	mg/L	0.0008	< 0.005[m]	< 0.005[m]
Tin	mg/L	-	< 0.01	< 0.01
Titanium	mg/L	-	< 0.20	< 0.2
Uranium	mg/L	0.015	< 0.001	< 0.001
Vanadium	mg/L	-	< 0.05	< 0.05
Zinc	mg/L	0.03	0.6	0.5

Bold/Italicized values exceed corresponding CCME guideline
[a] Values determined based on laboratory tests (methods and results documented in Appendix V6-2A) unless specified otherwise
[b] Determined from field measurements using calibrated electronic probe
[c] Determined from field titration measurements
[d] Lithium used as indexing parameter to estimate groundwater concentrations from the series of mixed solutions.
[e] Guidelines for the protection of freshwater aquatic life published in CCME 2013
[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 10 $^{0.86[log10(hardness)]-3.2}$ µg/L
[i] Chromium Hexavalent 0.001 mg/L and Chromium Trivalent 0.0089 mg/L
*[j] Copper guideline concentration = $e^{0.8545[ln(hardness)]-1.465}$ * 0.2 µg/L*
[k] Lead guideline concentration = $e^{1.273[ln(hardness)]-4.705}$ µg/L
[l] Nickel guideline concentration = $e^{0.76[ln(hardness)]+1.06}$ µg/L
[m] Detection limits exceeds CCME guideline
[n] Ammonia (total) guideline pH and temperature dependent (tabulated by CCME 2013) and intended for fresh waters
[o] CCME (2013) publishes trigger ranges for total phosphorus in fresh waterbodies, the reported results would be classified as hyper-eutrophic

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 mbg) — 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 10^{-6} m/s. Flow trends downwards where taliks are connected to the sub-permafrost 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 mbg 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). Considerable heterogeneity exists, with bulk hydraulic conductivities ranging from 10^{-9} m/s within tight bedrock, to 10^{-6} m/s along major faults. Flow is concentrated along persistent faults, which strike predominantly to the northwest and dip steeply to the northeast (SRK 2012). Hydraulic gradients are downwards where the taliks are connected to the sub-permafrost 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 hyper-saline 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 Sub-permafrost — Fractured bedrock at depths exceeding 200 mbg in through taliks and beneath the permafrost (depths exceeding 400 mbg 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 major faults 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 hyper-saline 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 sub-permafrost hydrostratigraphic unit. By convention cryopegs are considered part of the permafrost.

Permafrost — The permafrost may be regarded as impermeable to fresh water, as it freezes shortly after exposure to temperatures below freezing. Hydraulic conductivities as high as 10^{-8} m/s have been measured with brine solutions. However, the solutions contained within the permafrost, except within cryopegs, are considered to be frozen and therefore immobile. 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. Fractures contain ice except in cryopegs.

Cross-sections A-A' (Figure 2.1-8), B-B' (Figure 2.1-9), and C-C' (Figure 2.1-10) depict the interpreted hydrogeologic conceptual model in close proximity to proposed infrastructure at the Goose Property Area. The locations of these cross-sections are shown on Figure 2.1-6.

2.1.2.3 George Property Area

Geologic Context

An overview of the local bedrock geologic setting is provided in Volume 5, Chapter 1. The dominant lithology at the George Property includes the Beechey Lake Group greywacke, mudstone, and banded iron formations. Ductile and brittle shearing has been observed, with fold axes trending northwest, and a major thrust fault striking northeast (Figure 2.1-11). A number of conjugate brittle faults dip steeply to the northeast (Cater 2010).

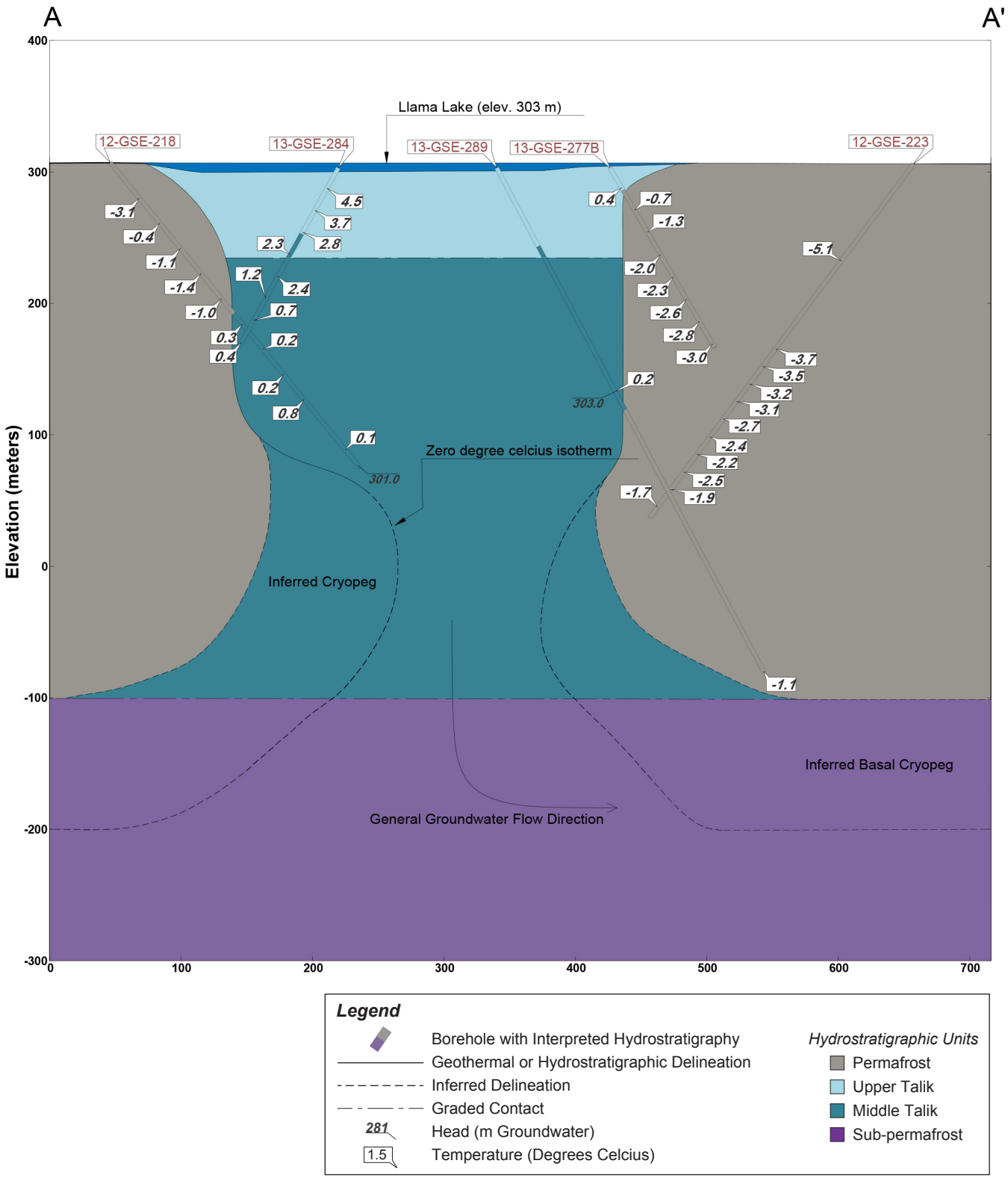
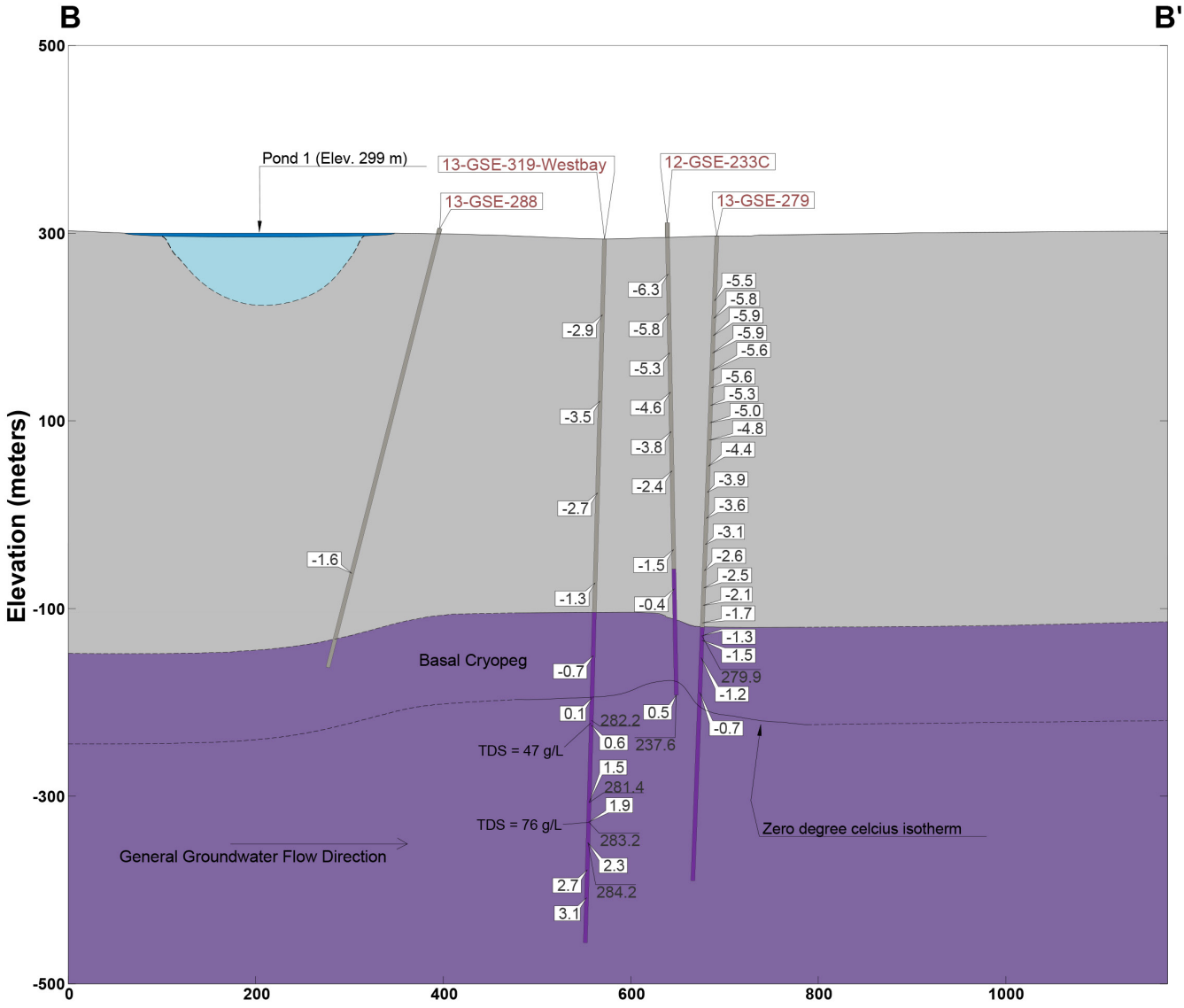


Figure 2.1-8

Hydrogeologic Conceptual Model of the Goose Property Area: Cross-Section A-A' Llama Deposit Area

Sabina GOLD & SILVER CORP.

Rescan an ERM company



Legend

- Borehole with Interpreted Hydrostratigraphy
- Geothermal or Hydrostratigraphic Delineation
- Inferred Delineation
- Graded Contact
- 281 Head (m Groundwater)
- 1.5 Temperature (Degrees Celcius)

Hydrostratigraphic Units

- Permafrost
- Upper Talik
- Middle Talik
- Sub-permafrost

Figure 2.1-9

Hydrogeologic Conceptual Model of the Goose Property Area: Cross-Section B-B' Umwelt Deposit Area

Sabina GOLD & SILVER CORP.

Rescan an ERM company

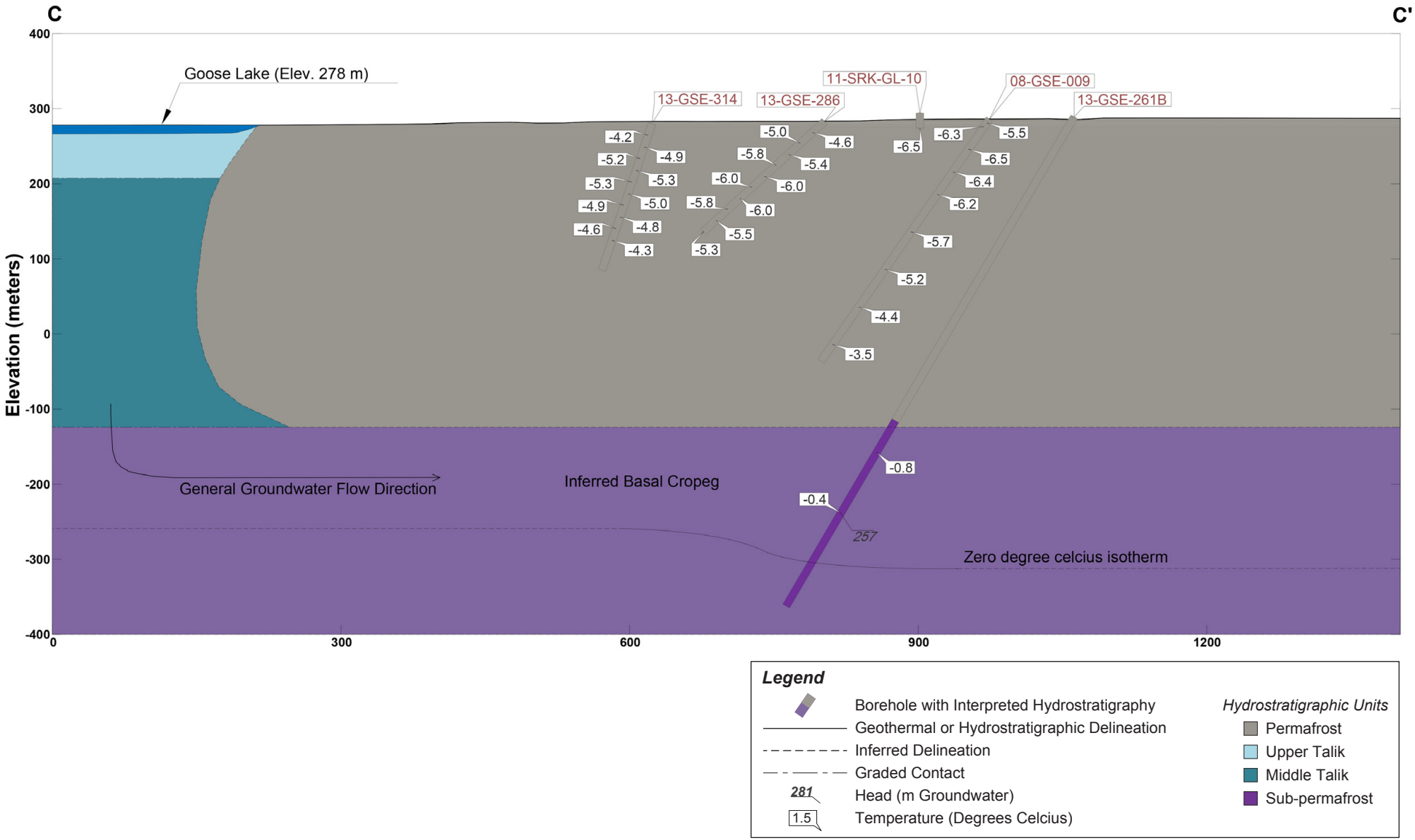


Figure 2.1-10

Sabina GOLD & SILVER CORP.

Hydrogeologic Conceptual Model of the Goose Property Area: Cross-Section C-C' Main Deposit Area

Figure 2.1-10

Rescan an ERM company

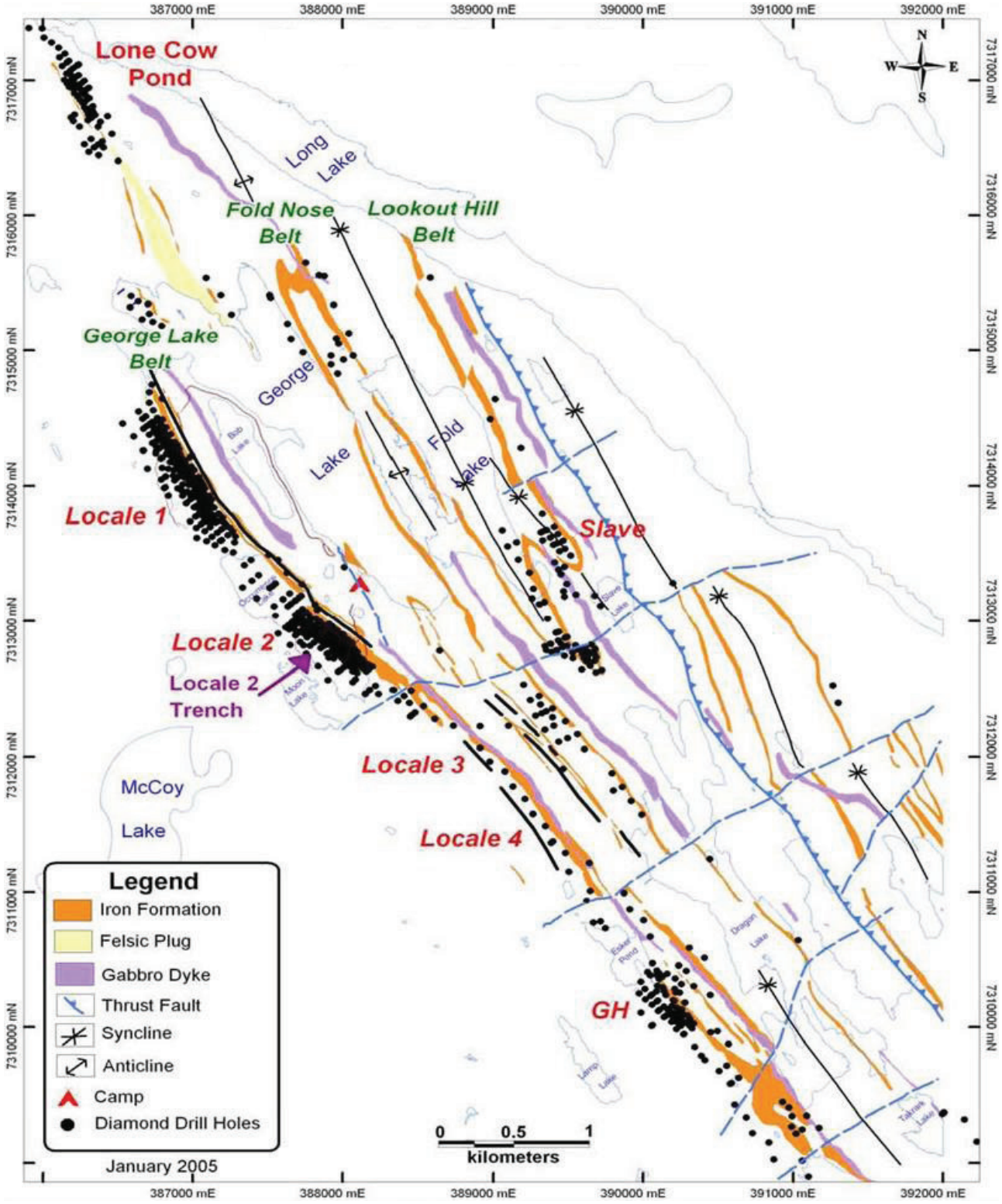


Figure 2.1-11

Geologic Structures at the George Property Area as Determined by Exploration Drilling

Sabina GOLD & SILVER CORP.

Rescan Engineers & Scientists

Overburden materials are characteristic of a post-glacial environment. At the George Property morainal sediments are dominant, covering nearly half the landscape. Other sediments commonly found include glaciofluvials, lacustrine, and organic deposits, and exposed weathered bedrock. Proportions of various sediments found at the George Property, and their hydrogeologic attributes, are provided in Table 2.1-4. Overburden thicknesses range up to 22 m (average of 4.5 m) and are generally thicker at topographic lows. A complete description of overburden geology is provided in Volume 5, Chapter 3.

Table 2.1-4. Overburden Materials Common at the George Property and their Hydrogeologic Properties

Surficial Material	Landscape Cover (%)[a]	Hydraulic Conductivity[b]	Topographic Setting[c]	Active Layer Depth[c,d]
Morainal	41.5	Low to moderate	Blankets > 1 m at lower slope and lowlands, veneers < 1m thick at upper slopes and crests	Low to moderate
Glaciofluvial	6.1	Moderate to high	Forming eskers or veneers over adjacent morainal deposits, slope grades up to 12%	High
Lacustrine and glaciolacustrine	5.5	Low	Lowlands and lower slopes, slope grade less than 1%	Low
Organics	7.3	Low to moderate	lowlands	Low
Weathered bedrock	9.3	Moderate to high	Highlands and upper slopes, highly variable slope grades	Low to high
Open Water	28.1	-	-	-

[a] *Obtained 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.*

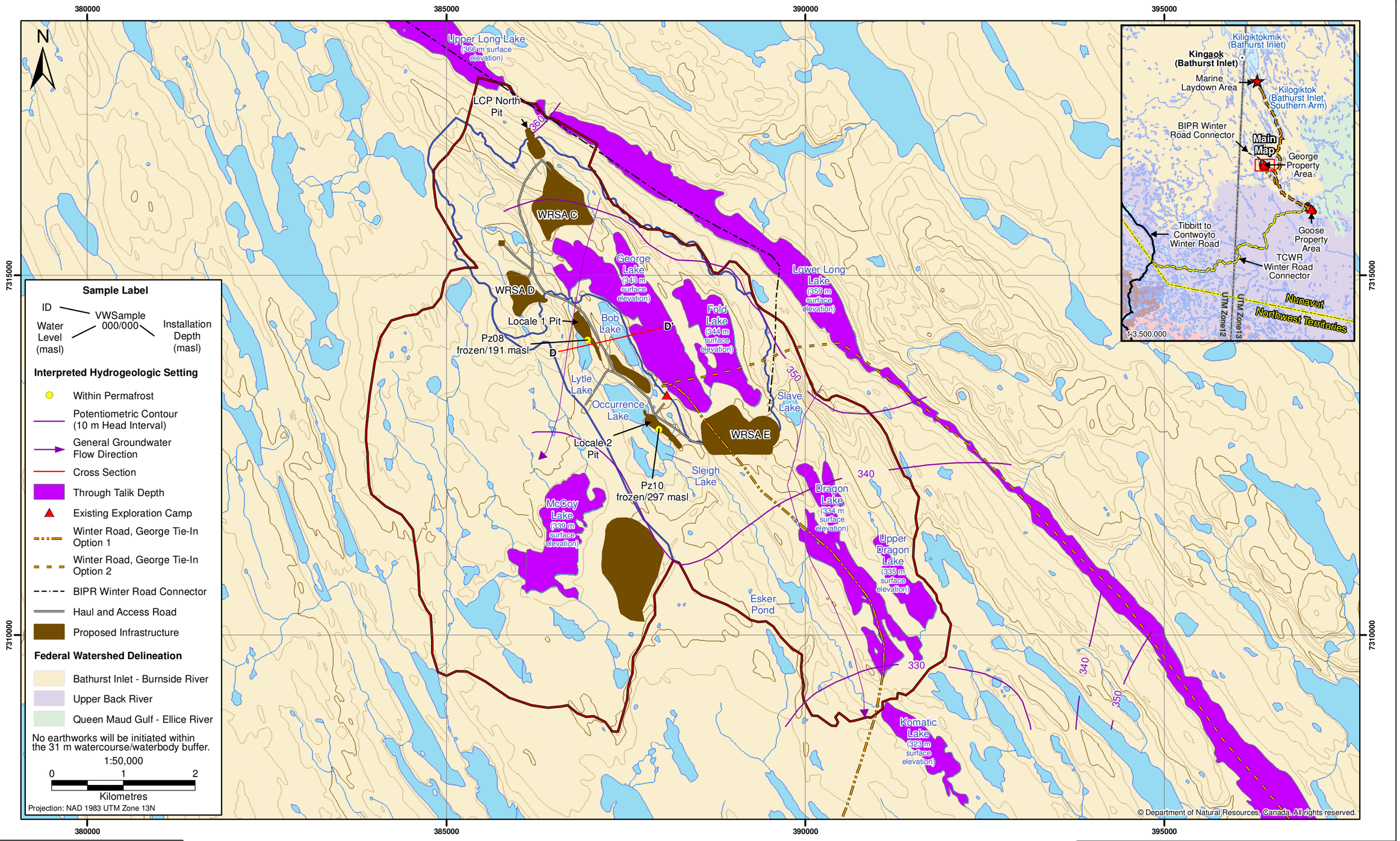
Groundwater Levels and Flow Directions

Lake elevations indicate a general sub-permafrost groundwater flow trend from north to south across the George Property Area (Figure 2.1-12). Komatic Lake has the lowest elevation of lakes expected to overlie a through talik, with higher lake water levels trending northward. Lower Long Lake provides head from the northeast along the length of the site. Lake elevation differences suggest lateral hydraulic gradients are likely to be 0.01 to 0.003 m/m. Both VWPs installed at the George Property are frozen within the permafrost.

Groundwater in the active layer is expected to flow following surface topography and the surface water drainage network. The northern reaches of the PDA drain towards George Lake. Western reaches drain towards McCoy Lake. Central and southeastern reaches drain towards Dragon lake and beyond to the southeast. Highland areas in the south and west of the PDA are expected to drain following freshet, due to the absence of recharge from large ponds or lakes. Other areas are expected to sustain a saturated zone through the summer until fall freeze-up.

Hydraulic Conductivity Measurements

Fractured bedrock hydraulic conductivities in the range of 10^{-9} m/s and lower have been measured at depths up to 250 mbg within the permafrost (Table 2.1-5). One shallow interval beneath Lytle Lake may be within a talik. Measurements within the permafrost in close proximity to the Locale 2 deposits were consistently less than the lower detection limit of the testing method (10^{-9} m/s).



Sabina GOLD & SILVER CORP.

Rescan an ERM company

Figure 2.1-12

Groundwater Level Observations at the George Property Area

Table 2.1-5. Hydraulic Conductivity Measurements at the George Property Area

Borehole Number	Test Interval				Reported Hydraulic Conductivity (m/s)	Interpreted Permafrost Context
	mbg		masl			
	Top	Bottom	Top	Bottom		
Locale 1 Area						
13GRL113	11	39	326	298	4.E-09	Talik beneath Lytle Lake or permafrost
	40	64	297	273	2.E-09	within Permafrost
	59	269	278	68	< 1E-9[a]	within Permafrost
13GRL115	13	33	324	304	2.E-09	within Permafrost
	32	54	305	283	2.E-09	within Permafrost
13GRL119	9	84	329	254	1.E-09	within Permafrost
13GRL121	26	72	314	268	< 1E-9[a]	within Permafrost
Locale 1 Area						
13GRL110	11	46	326	291	< 1E-9[a]	within Permafrost
	16	66	321	271	< 1E-9[a]	within Permafrost
13GRL129	12	250	334	96	< 1E-9[a]	within Permafrost
13GRL130	11	49	333	295	< 1E-9[a]	within Permafrost

[a] *Hydraulic conductivity was below test lower detection limit.*

Geologic and permafrost conditions at the George Property Area are similar to those at the Goose Property Area. The permafrost is expected to be somewhat more extensive and taliks somewhat smaller (discussed in Volume 5, Chapter 2) at the George Property. Bedrock units are similar: sedimentary and meta-sedimentary rock (greywacke, mudstone, siltstone, iron formation).

A number of (conjugate) faults strike perpendicular to the dominant folding and thrust fault structures, which is expected to result in anisotropy of the bulk hydraulic conductivity that differs from the Goose Property. Flow at oblique angles to the dominant hydraulic gradient is expected to be more common at the George Property, along the conjugate fault features.

The following general trends in bedrock hydraulic conductivity observed at the Goose Property Area are expected to be applicable at the George Property Area as well:

- hydraulic conductivities generally decrease with depth within the taliks and beneath the permafrost;
- hydraulic conductivities may be as high as 10^{-6} m/s within taliks in the shallow bedrock (less than 100 mbg);
- hydraulic conductivities may be as high as 10^{-6} m/s within fracture zones in taliks at depths exceeding 100 m. The widespread competent rock at depths exceeding 100 m has a considerably lower hydraulic conductivity (around 10^{-8} m/s);
- bedrock beneath the permafrost and at the base of taliks exhibits hydraulic conductivity of 10^{-9} m/s or less except along major faults. Hydraulic conductivities as high as 10^{-8} m/s may be present along major faults at these depths; and
- hydraulic conductivity within the permafrost is 10^{-9} m/s or less, and the permafrost is expected to be essentially impermeable to fresh water.

Permeabilities in the active layer are expected to be highly heterogeneous due to the abundance of glacial till (morainal deposits). High permeability is expected within the glaciofluvial deposits found within and adjacent to the esker that cross-cuts the PDA from the northwest to the southeast. These glaciofluvial materials are expected to behave as a preferential flow pathway within the active layer, as they are located along the dominant topographic drainage pathway from George Lake to Esker Pond, and they are frequently adjacent to low-permeability lacustrine deposits.

Groundwater Quality

Groundwater quality at the George Property is expected to resemble that at the Goose Property and other sites in Mainland Nunavut, as the geologic and permafrost settings are similar. The sub-permafrost groundwater is expected to be hyper-saline with a TDS of 70 g/L or greater, dominated by calcium chloride and sodium chloride salts. A trend of increasing salinity with depth is expected within taliks beneath lakes. No proposed infrastructure is expected to interact with the sub-permafrost or talik groundwater.

Site Conceptual Model

The site conceptual model for the George Property Area corresponds with that for the Goose Property Area. The permafrost is deeper at the George Property Area, thus the sub-permafrost groundwater is bounded deeper. A number of faults at the George Property strike at an oblique angle to the dominant flow direction, and thus the lateral component of flow is expected to be greater than that at Goose. Cross-section D-D' (Figure 2.1-13) depicts the interpreted hydrogeologic conceptual model in close proximity to the Locale 1 deposit, where thermistor strings have been installed. The location of this cross-section is shown in Figure 2.1-12.

2.1.2.4 Marine Laydown Area and Winter Road Corridors

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

The Marine Laydown Area is adjacent to an extensive through talik expected to be present beneath the seawater of Bathurst Inlet. Shallow groundwater is confined to the active layer within the Marine Laydown Area on-land. Marine sediments are the dominant overburden material found within the active layer, with secondary quantities of colluvium (poorly sorted sediments deposited at the base of slopes) (Rescan 2013). The active layer generally drains towards the sea water of Bathurst Inlet.

2.2 INCORPORATION OF TRADITIONAL KNOWLEDGE (TK)

In 2012, the Kitikmeot Inuit Association (KIA) completed a report which presented Traditional Knowledge (TK) for the region encompassing the proposed project using the Naonaiyaotit Traditional Knowledge Project (NTKP; KIA 2012). The TK cites "underground streams and cold water springs" as a traditional source of water.

2.2.1 Incorporation of TK for Existing Environment and Baseline Information

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.

Drinking water is addressed in the DEIS in Volume 6, Chapter 4 (Freshwater Water Quality).

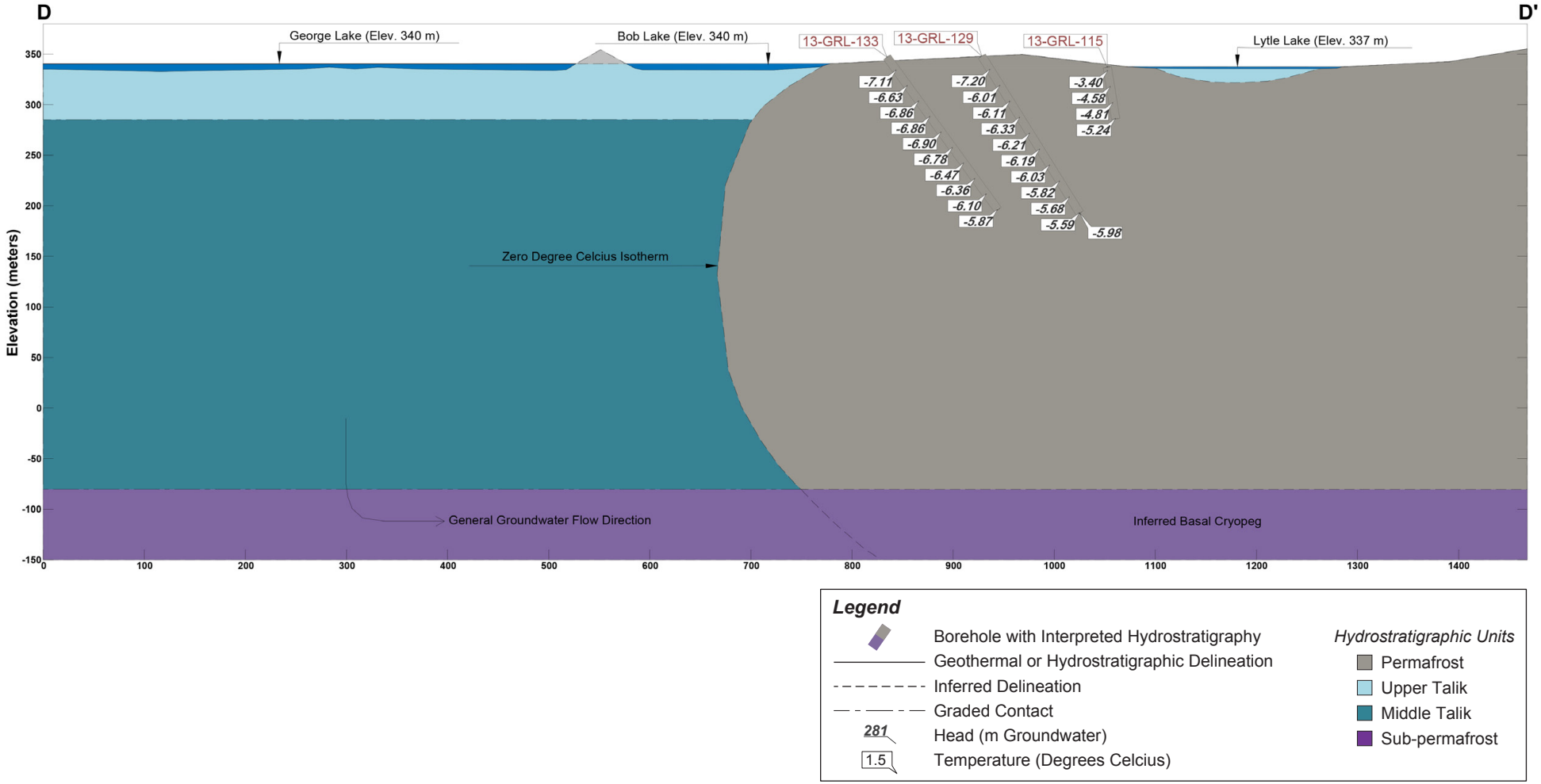


Figure 2.1-13

Sabina GOLD & SILVER CORP.

Hydrogeologic Conceptual Model of the George Property Area: Cross-Section D-D' Locale 1 Deposit Area

Figure 2.1-13

Rescan an ERM company

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 VEC/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 DEIS. All information requested in the NIRB-issued EIS guidelines related to Groundwater is included in this DEIS.

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 Project Areas is expected to limit interaction of the groundwater with the Project. However all components of the groundwater environment (active layer, talik, and sub-permafrost 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 new talik may form beneath the Tailing Impoundment Area (TIA), due to the introduction of a large pond. The extents of this talik 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 TIA is expected to 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 perimeter, and the presence of continuous permafrost around the facility perimeter beneath the active layer.

The existing talik beneath Llama Lake would freeze in response to the pit excavation and dewatering, due to 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 pit would result in resurgence of talik, and would isolate the exposed bedrock from further oxidation.

The Umwelt Underground Mine will penetrate through the permafrost and contact the groundwater in the basal cryopeg (approximately 400 to 500 mbg) and beneath the permafrost (greater than 500 mbg). A mine inflow study has been conducted (Appendix V11-3C). The Umwelt Underground is expected to behave as a local groundwater sink when being dewatered, with groundwater flow within the fractures radially towards the mine. No ML/ARD is expected to contact the groundwater while the Umwelt Underground is operational due to dewatering and the resulting radial-inward groundwater flow. Water extracted from the Umwelt Underground will be pumped into the TIA. Flooding of the mine would result in resurgence of talik, and would isolate the exposed bedrock from further oxidation.

2.4.2 Numerical Groundwater Models and Groundwater Budget

Numerical groundwater flow and solute transport modelling was not conducted, as the interaction of the Project with groundwater is expected to be limited. The Waste Rock Storage Facilities, landfills, TIA, and mine excavations will be isolated from the natural groundwater environment by permafrost or hydraulic containment.

A groundwater budget has not been developed, because groundwater resources will not be extracted for project use. However, inflow to the Umwelt Underground will be directed to the tailing impoundment area (TIA). Dewatering of the Umwelt Underground has been included as a component of the Site Water Monitoring and Management Plan (Volume 10, Chapter 7). 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;
- 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
- *2013 Terrain and Soils Baseline Report* prepared by Rescan Environmental Services Ltd. For Sabina Gold and Silver Corporation (Appendix V5-3A).

3. Limnology and Bathymetry

Rescan™
an ERM company

3. Limnology and Bathymetry

3.1 EXISTING ENVIRONMENT AND BASELINE INFORMATION

3.1.1 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. It is composed of three main areas: the Goose Property Area, the George Property, and the Marine Laydown Area (MLA; Figure 3.1-1). All areas would be connected by winter roads. All proposed infrastructure at the Goose Property lies within the Ellis River Watershed. The Ellis River Watershed flows to the northwest, and enters the ocean on the west side of Bathurst Inlet (see Federal Watershed map in Chapter 1 of this Volume). The Back River Watershed lies south of the proposed infrastructure in the Goose Property Area and flows to the east eventually entering the Arctic Ocean south of Gjoa Haven. Lakes and streams in the George Property Area drain into the Western River Watershed that flows north and enters Bathurst Inlet at its southernmost point.

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. 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. Baseline studies conducted in 2010 and 2011 focused on the Goose Property Area, while studies in 2012 and 2013 focused on both the George and Goose Property areas. Figures 3.1-2 and 3.1-3 show the George and Goose Property areas and their 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 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 special designation for the region surrounding the George and Goose Property areas, but the caribou calving grounds in the region have been designated PSE-R2 (Nunavut Planning Commission 2012). The proposed Hiukitak River Cultural Area is on the eastern shore of Bathurst Inlet, and is located 40 km east of Kingaok, 60 km north-east of the proposed Marine Laydown Area (MLA), and 140 km north of the George Property Area.

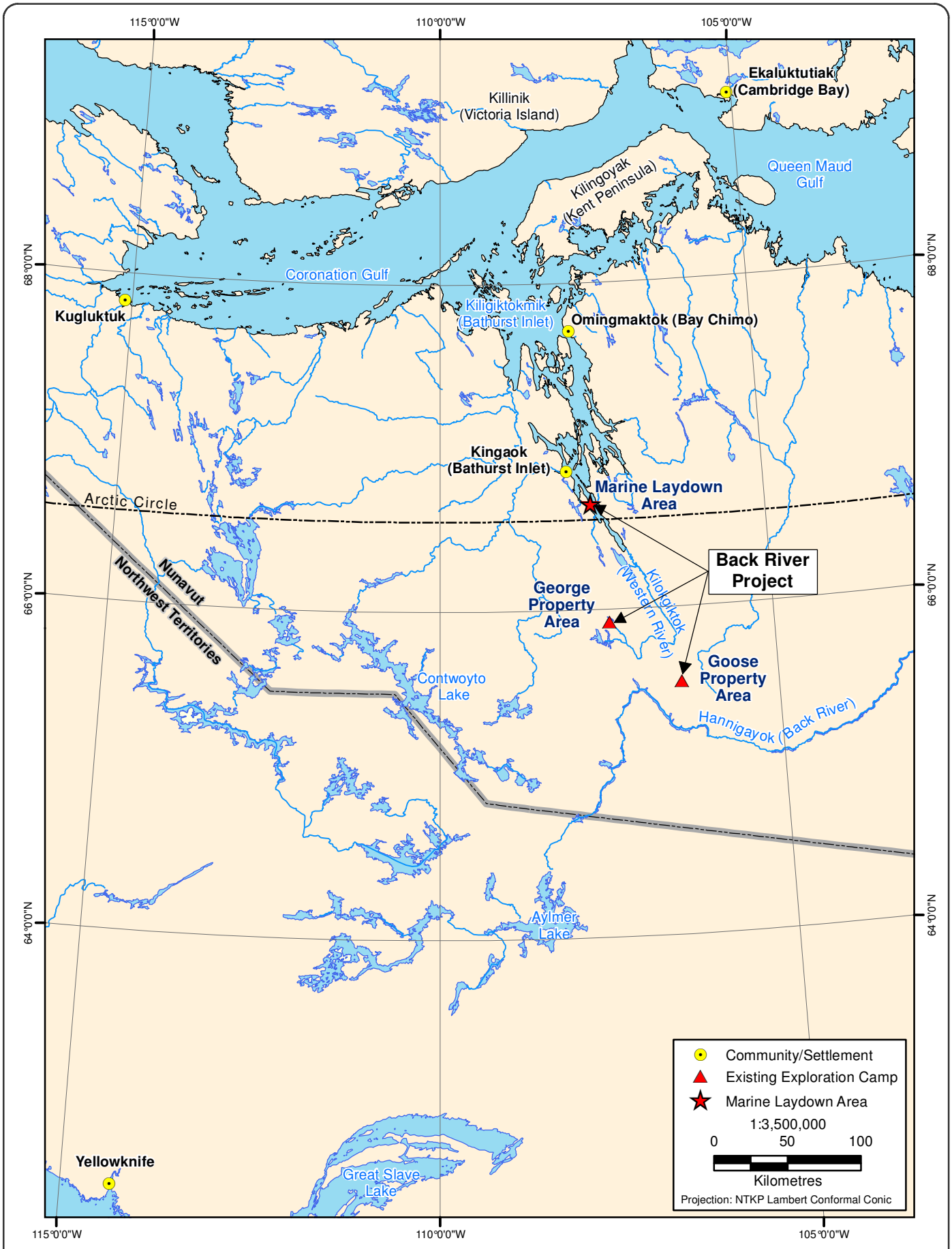


Figure 3.1-1

Project Location

Sabina GOLD & SILVER CORP.

Rescan an ERM company

PROJECT # 0194096-0040 GIS # BAC-01-057b December 17 2013

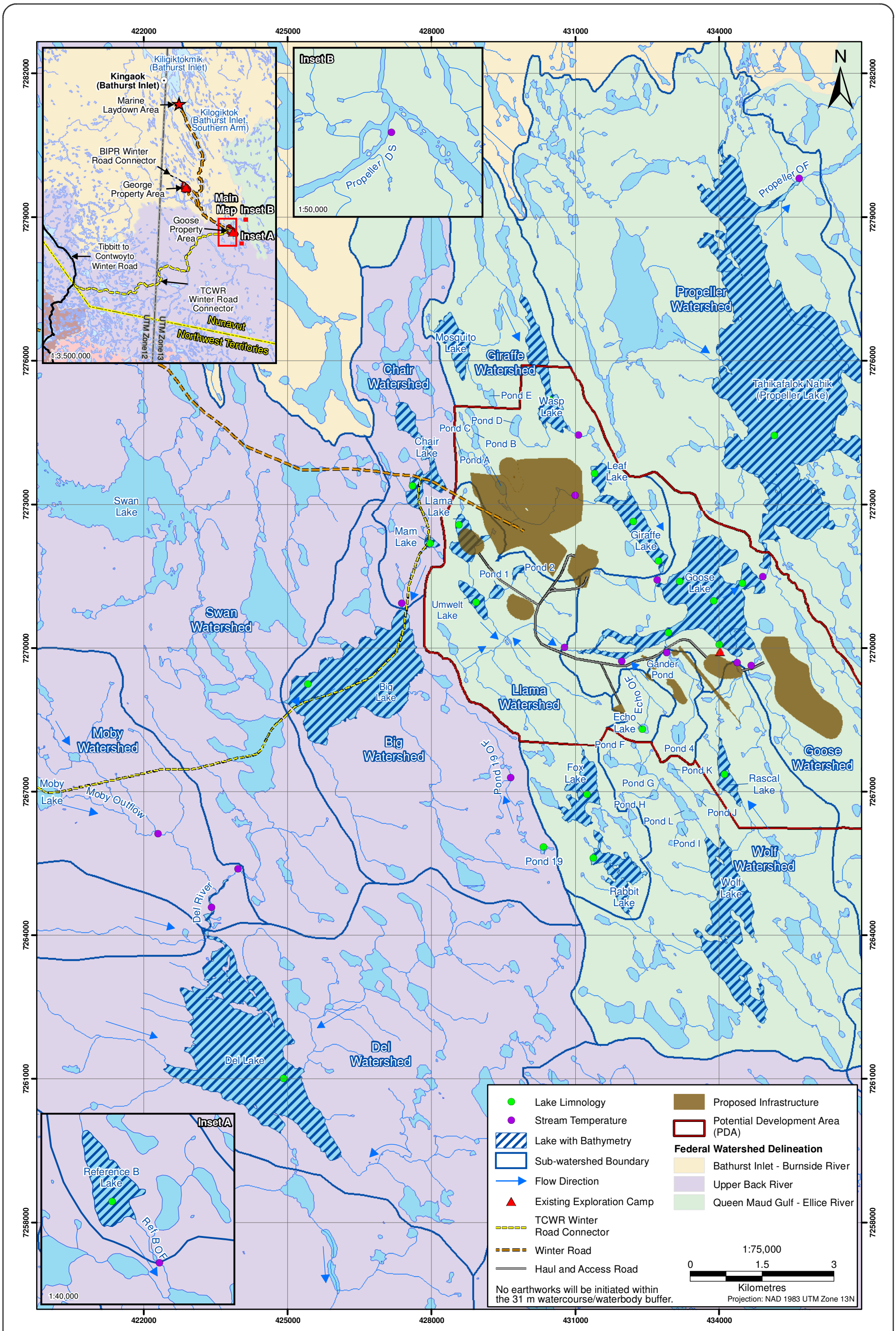


Figure 3.1-2

Sabina GOLD & SILVER CORP.

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

Figure 3.1-2

Rescan an ERM company

PROJECT # 0194096-0040 GIS # BAC-01-057a December 17 2013

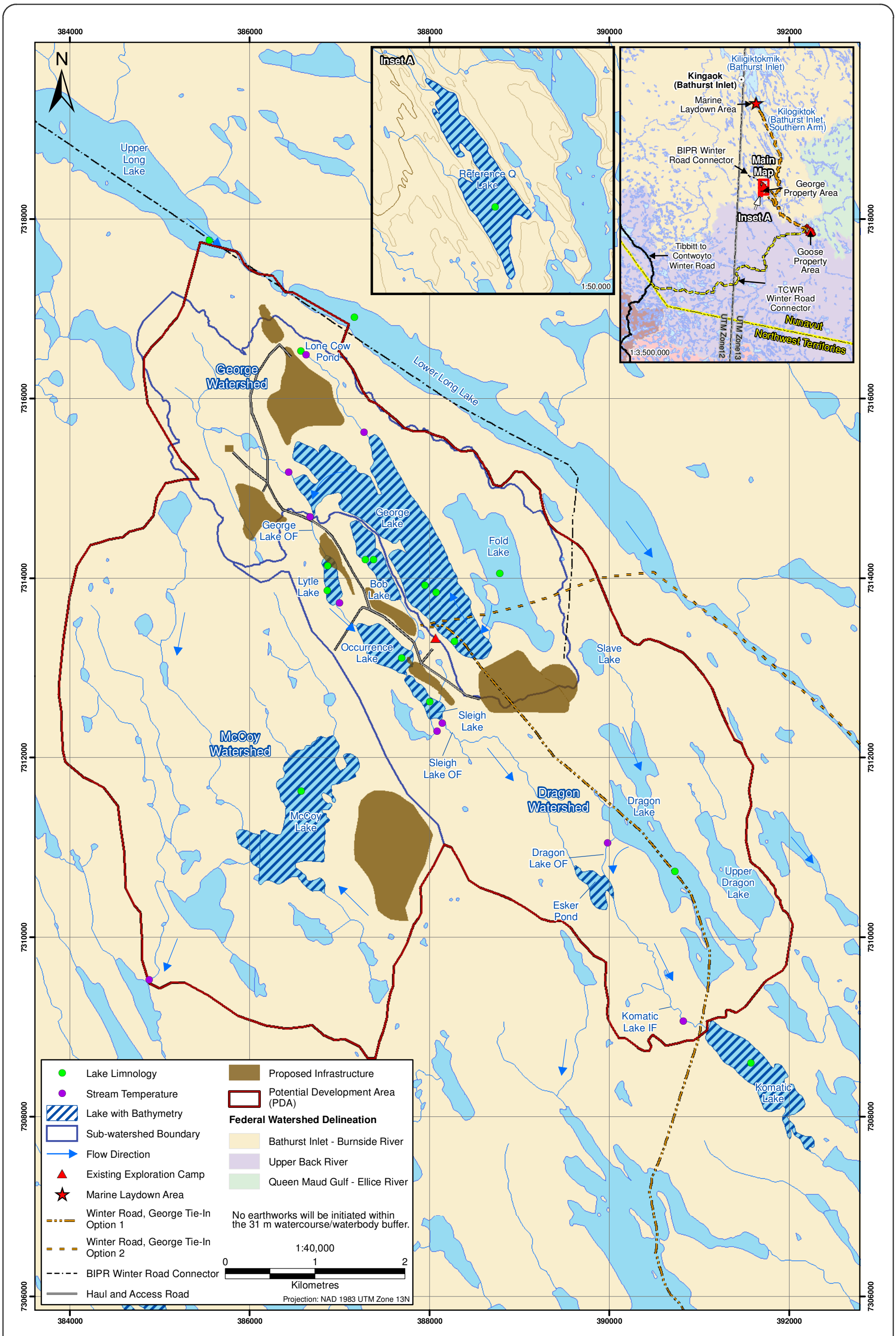


Figure 3.1-3

Sabina GOLD & SILVER CORP.

Limnology and Bathymetry Sampling Conducted in the George Property Area for the Back River Project, 2006 to 2013

Figure 3.1-3

Rescan an ERM company

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 DEIS 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 2010-2013 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.

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 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 or an RBR-420 conductivity, temperature, and depth probe (five streams in August 2012; Table 3.1-2; Figures 3.1-2 and 3.1-3).

3.1.5 Lake Limnology and Bathymetry

Data is available for 24 lakes from the Goose Property Area and 16 lakes from the George Property Area. A list of the data available for each lake is shown in Table 3.1-1, and lakes are shown on Figures 3.1-2 and 3.1-3.

3.1.5.1 Lake Limnology

Baseline limnology data has been collected from the Goose and George Property areas from 2010 to 2013 (Rescan 2011, 2012, 2013a, 2013b). Additional information was collected in the Goose Property Area in 1994, 2006, and 2007, and in the George Property Area in 2006 and 2007 (Table 3.1-1). Physical limnology data was collected as temperature during the baseline program.

Waterbodies in the two property areas 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 3-4°C near the sediment-water interface (Figure 3.1-4). 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 in the George and Goose Property areas were almost always vertically mixed (e.g., Goose and George lakes; Figure 3.1-4). Only Llama Lake in 2011 and Reference C Lake 2012 had appreciable depth-related changes in water temperature; Llama Lake (depth: 13.6 m) had a weak thermocline between 3 and 7 m depth (Figure 3.1-4), and the deeper Reference C Lake (depth: 34.6 m) had a strong thermocline between 18 and 22 m depth. 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.

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 m 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 3.1-1. 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 Property Area*** Goose Lake	***Goose Property Area*** Goose Lake ***George Property Area*** Fold Lake George Lake Bob Lake Lytle Lake Occurrence Lake	***Goose Property Area*** Goose Lake ***George Property Area*** Fold Lake Lone Cow Pond George Lake Bob Lake Lytle Lake Occurrence Lake	***Goose Property Area*** Llama Lake* Umwelt Lake* Chair Lake* Mam Lake* Reference B Lake*	***Goose Property Area*** Giraffe Lake Llama Lake Pond 1* Pond 2* Umwelt Lake Goose Lake Propeller Lake Reference B Lake	***Goose Property Area*** Giraffe Lake* Rabbit Lake* Fox Lake* Echo Lake Rascal Lake Goose Lake* Propeller Lake Pond 19 Big Lake* Moby Lake Del Lake* ***George Property Area*** Fold Lake George Lake* Lytle Lake Occurrence Lake* Sleigh Lake* Dragon Lake Komatic Lake Lower Long Lake Reference C Lake*	***Goose Property Area*** 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 ***George Property Area*** Fold Lake George Lake Bob Lake* Occurrence Lake Slave Lake Dragon Lake Esker Lake* Komatic Lake* McCoy Lake* Upper Long Lake Lower Long Lake Reference Q 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 and George (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, George, Fold and Bob Lakes; 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

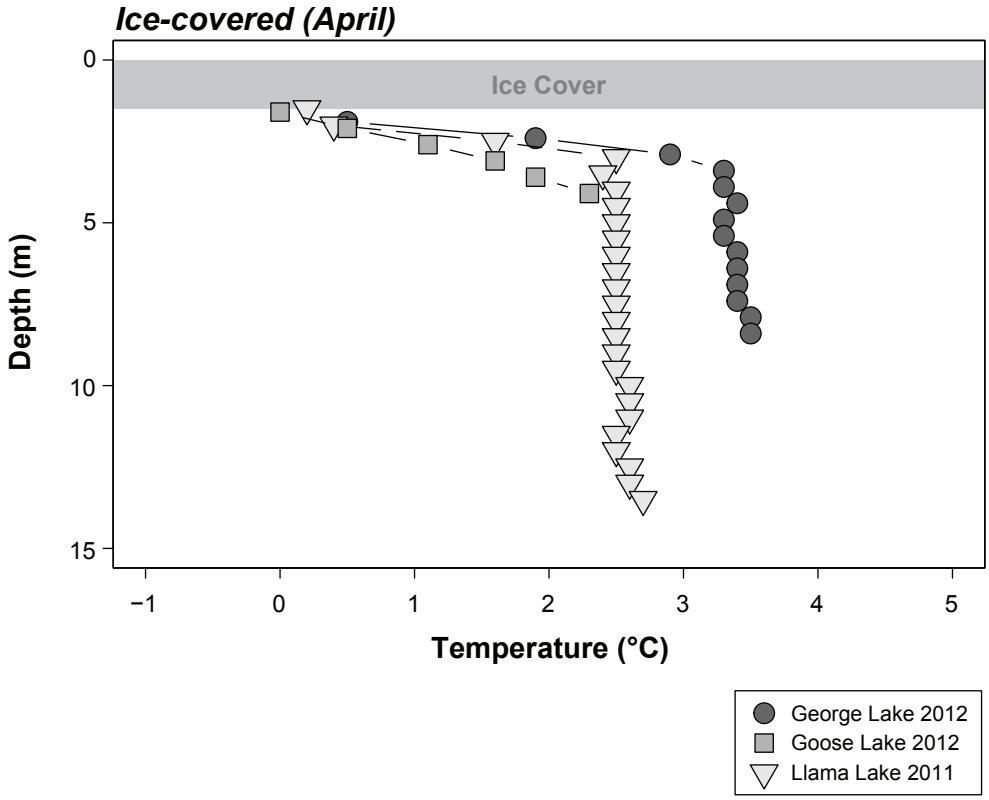
Notes:

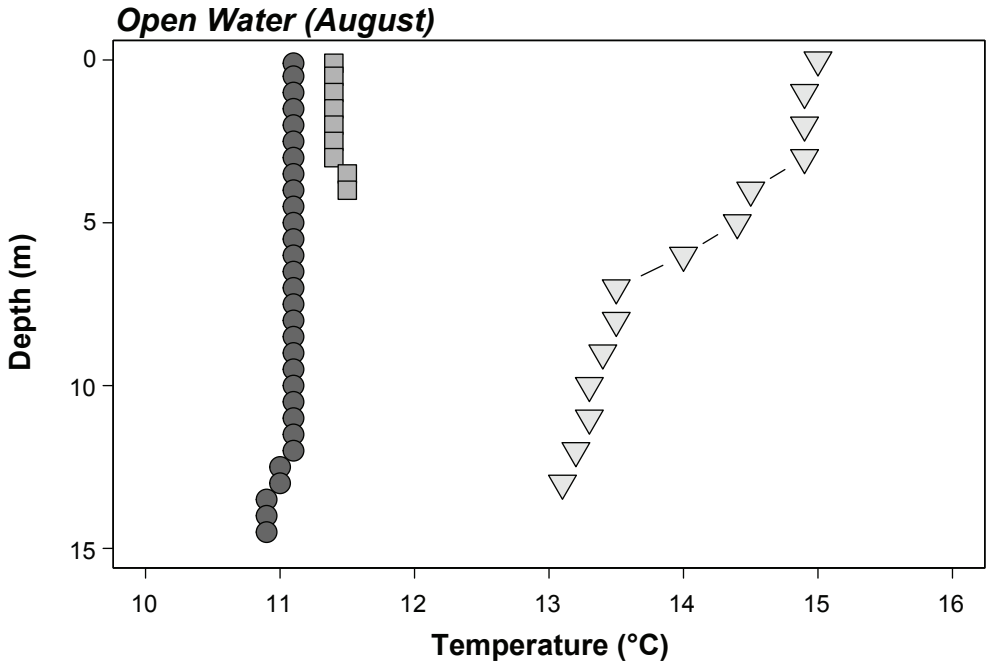
* *Indicates bathymetry was conducted.*

† *Proposed winter 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.*

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, RBR-420 CTD (George Property Area in August)	YSI Sonde
Data collected	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature
Stream(s) sampled	***Goose Property Area*** Wolf OF Goose IF RM Goose OF	***Goose Property Area*** Goose IF RM Echo OF Goose OF ***George Property Area*** George IF 1 George IF 2 George OF	***Goose Property Area*** Echo OF Wolf OF Goose IF SE Goose OF Propeller OF ***George Property Area*** Lone Cow OF George IF 1 George OF Moon ST Sleigh OF	***Goose Property Area*** Giraffe OF Llama OF Echo OF Wolf OF Goose OF Propeller OF Propeller D/S Chair OF Reference B OF	***Goose Property Area*** 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 ***George Property Area*** George OF Sleigh OF Dragon OF Dragon Watershed OF Reference C OF	***Goose Property Area*** Wasp OF TIA OF Giraffe OF Umwelt OF Llama OF Goose Neck IF Goose OF Propeller OF Reference B OF ***George Property Area*** George OF Lytle OF Sleigh OF Dragon Watershed OF McCoy US McCoy Watershed OF Reference Q OF
Number of replicates per site	1	1	1	1	1	1





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

Figure 3.1-4

Sabina GOLD & SILVER CORP.

Rescan Engineers & Scientists

Table 3.1-3. Summary of Secchi Depths in George and 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
George Property Area	0.4	4.0	35	7.8	36

**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 the complete bathymetric baseline program is presented in Appendix V6-3D. Overall, lakes in the George and Goose Property areas 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 to 4.5 m. 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). George Lake, in contrast, in generally between 3 and 10 m deep (Figure 3.1-6). Only the larger Goose (34.6 m), George (14.2 m), Llama (13.6 m), and Chair lakes (10.3 m) had maximum depths greater than 10 m.

Table 3.1-4. Summary of Lake Morphologies in George and Goose Property Areas, 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)

(continued)

Table 3.1-4. Summary of Lake Morphologies in George and Goose Property Areas, Back River Project (completed)

Waterbody	Max Depth (m)	Volume (m^3)	Surface Area (m^2)	Shoreline Length (m)	Source
George Property					
Reference B Lake	5.1	862,150	322,400	2,980	Rescan (2011)
George Lake	14.2	5,143,120	1,665,300	10,980	Rescan (2013a)
Bob Lake	6.2	325,280	165,290	2,390	Rescan (2013b)
Lytle Lake	1.8	78,380	77,020	1,520	Rescan (2013a)
Occurrence Lake	2.1	257,990	200,050	2,160	Rescan (2013a)
Sleigh Lake	1.5	73,160	86,430	1,830	Rescan (2013a)
Esker Lake	0.5	27,700	94,760	1,970	Rescan (2013b)
Komatic Lake	9.1	951,040	433,080	3,770	Rescan (2013b)
McCoy Lake	9.0	1,907,430	1,004,780	8,580	Rescan (2013b)
Reference C Lake	34.6	11,670,330	1,313,070	8,100	Rescan (2013a)
Reference Q Lake	19.4	3,438,280	1,072,540	8,380	Rescan (2013b)

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

3.1.6 Stream Temperatures

Data are available for 20 streams from the Goose Property Area and 15 streams from the George Property Area. A list of the sampled streams is presented in Table 3.1-2 and displayed in Figures 3.1-2 and 3.1-3.

Stream water temperatures during the freshet in June ranged from 3 to 14°C, and increased to between 7 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 in 2012 were ~7°C cooler than in June 2007 and June 2013. The variation in August lake water temperatures between 2011 and 2012 (Section 3.1.5.1) was not observed in stream water temperatures, which was perhaps due to the different processes of heat exchange between water, the underlying substrate, and the atmosphere.

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

	Stream Temperature (°C)			
	Min	Mean	Max	n
George Property Area				
June	3.3	7.7	13.5	15
July	10.2	12.8	19.4	6
August	6.8	13.8	18.4	9
September	1.1	4.6	7.3	11
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

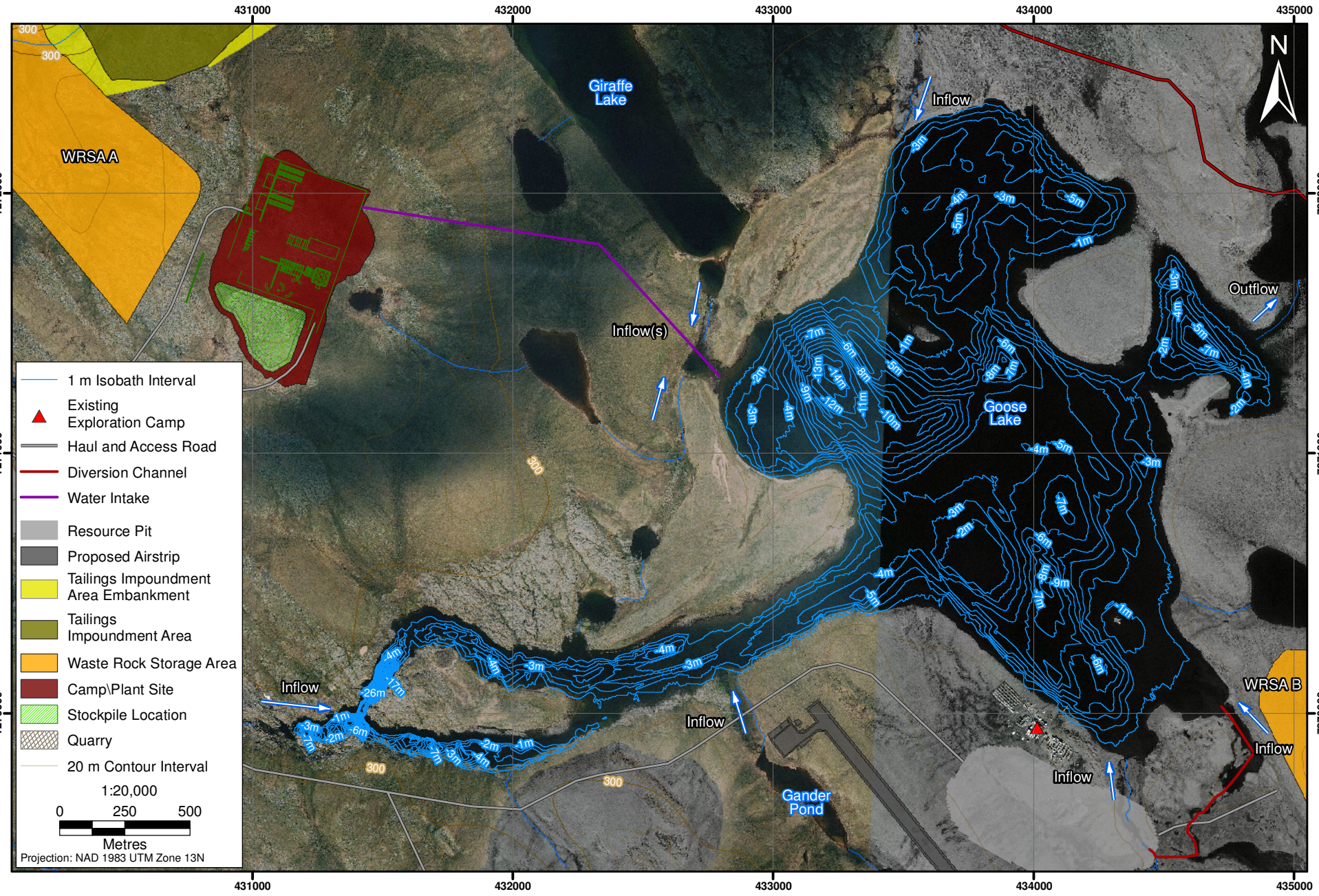


Figure 3.1-5

Sabina GOLD & SILVER CORP.

Bathymetry of Goose Lake, Goose Property Area

Figure 3.1-5

Rescan an ERM company

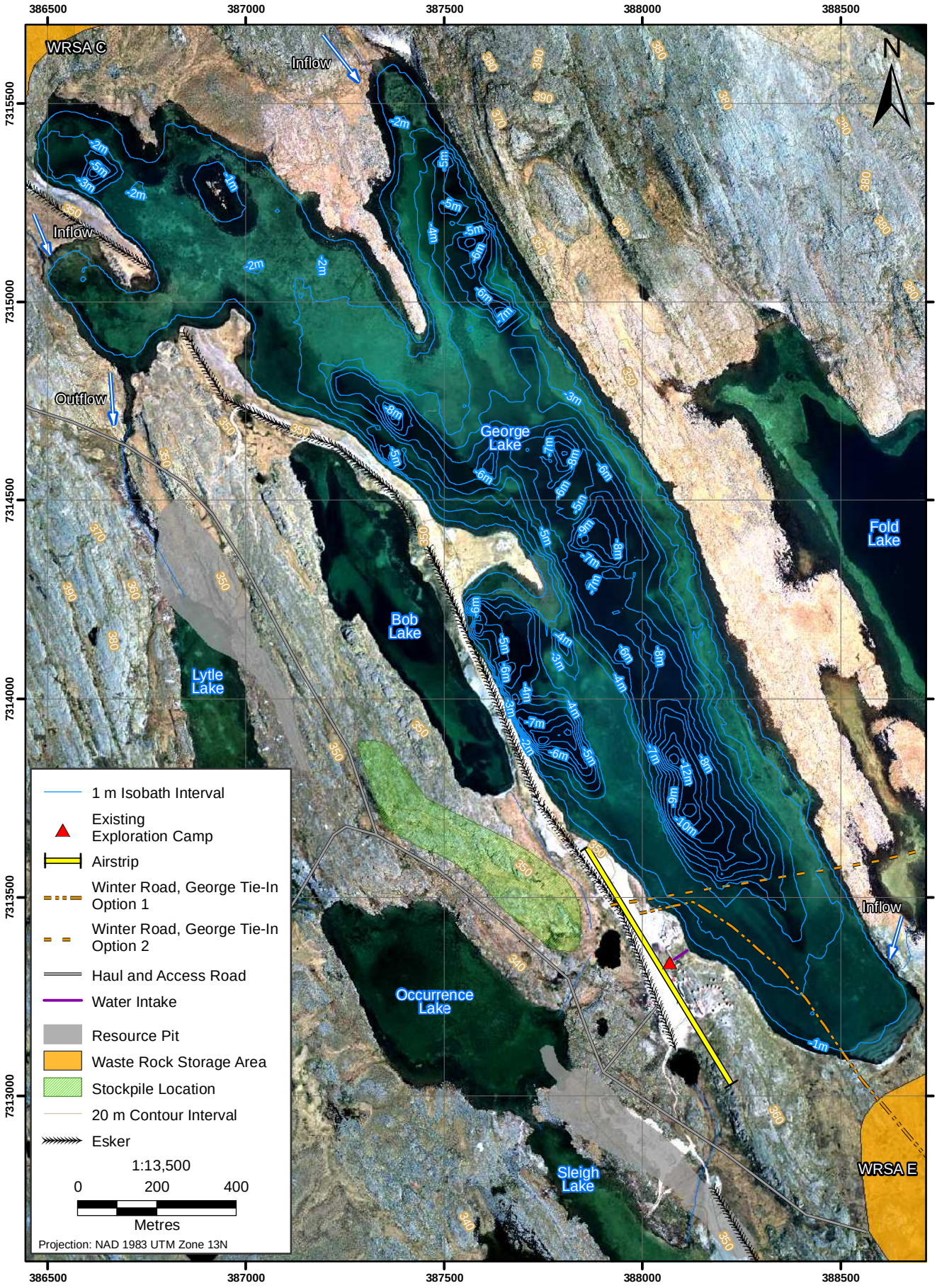


Figure 3.1-6

Sabina GOLD & SILVER CORP.

Bathymetry of George Lake, George Property Area

Rescan an ERM company

3.2 INCORPORATION OF TRADITIONAL KNOWLEDGE (TK)

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)
>
> *"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)

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 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 DEIS. However, information on water quality, including potable water, was present in the TK reports and water quality and quantity are VECs in this DEIS (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 DEIS. All information requested in the EIS Guidelines (NIRB 2013) relating to physical limnology and bathymetry is included in this DEIS.

4. Freshwater Water Quality

Rescan™
an ERM company

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 the west Kitmeot region of Nunavut in the continuous permafrost zone of the continental Canadian Arctic. It is composed of three main areas: the Goose Property Area, the George Property, and the Marine Laydown Area (MLA; Figure 4.1-1). All areas would be connected by winter roads. All proposed infrastructure at the Goose Property lies within the Ellis River Watershed. The Ellis River Watershed flows to the northwest, and enters the ocean on the west side of Bathurst Inlet (see Federal Watershed map in Chapter 1 of this Volume). The Back River Watershed lies south of the proposed infrastructure in the Goose Property Area and flows to the east eventually entering the Arctic Ocean south of Gjoa Haven. Lakes and streams in the George Property Area drain into the Western River Watershed that flows north and enters Bathurst Inlet at its southernmost point.

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, 2013c).

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 because of negligible groundwater reserves outside of the permafrost and a lack of unfrozen surface water. 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.

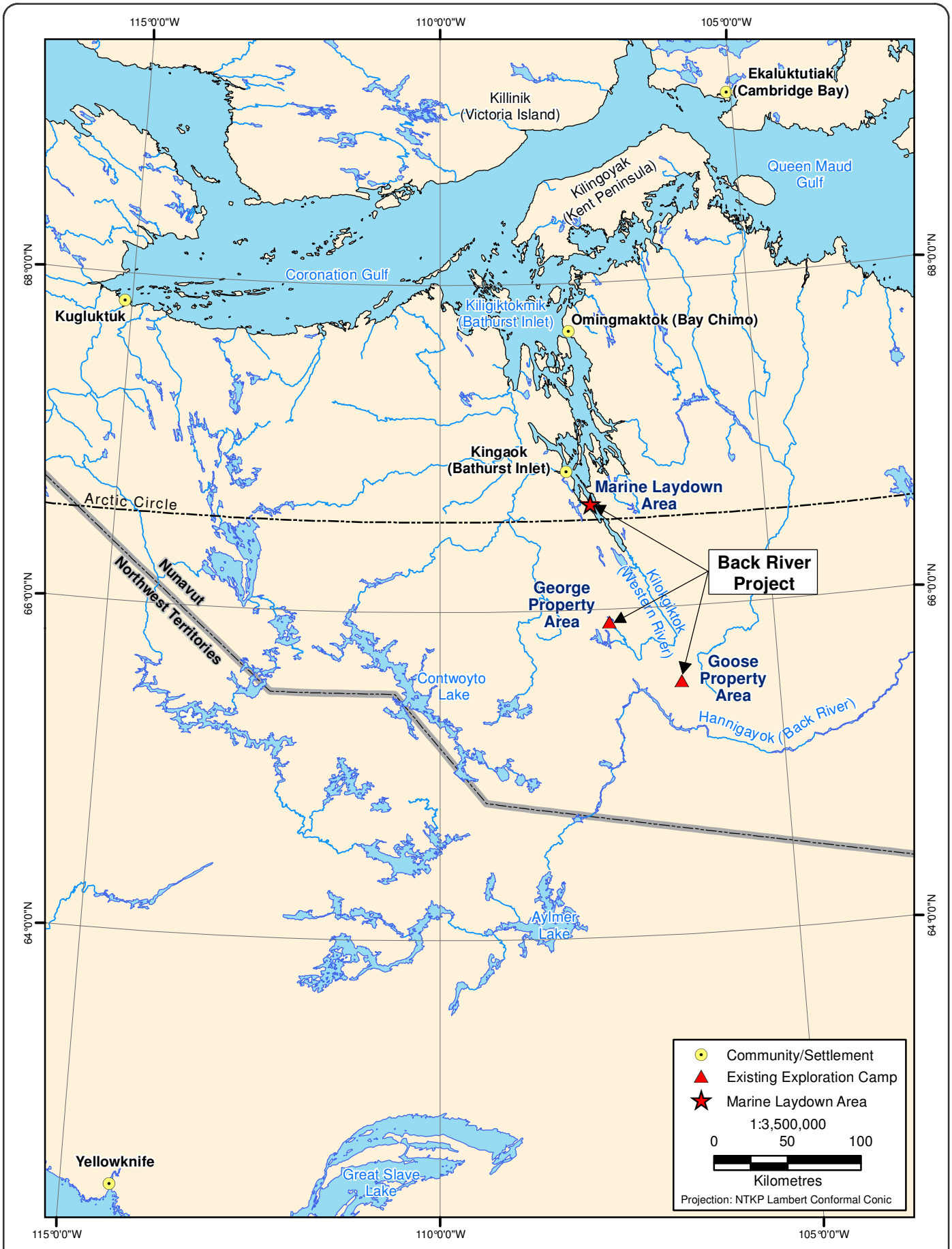


Figure 4.1-1

Project Location

Sabina GOLD & SILVER CORP.

Rescan an ERM company

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 special designation for the region surrounding the George and Goose Property areas, but the caribou calving grounds in the region have been designated PSE-R2 (Nunavut Planning Commission 2012). The proposed Hiukitak River Cultural Area is on the eastern shore of Bathurst Inlet, and is 40 km east of Kingaok, 60 km north-east of the proposed MLA, and 140 km north of the George Property Area.

4.1.3 Baseline Study Area

Freshwater baseline studies have been carried out in the Project area since 1993, with the most continuous sampling conducted by Rescan Environmental Services Ltd. (Rescan) from 2010 to 2013. Baseline studies conducted in 2010 and 2011 focused on the Goose Property Local Study Area (LSA), while studies in 2012 and 2013 focused on both the George and Goose Property LSA. Sampling conducted near the MLA is covered in the Marine Environment volume (Volume 7). Figures 4.1-2 and 4.1-3 show the Goose and George Property areas, the Goose and George LSA, and their associated waterbodies.

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 DEIS 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 2013c).

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: Environmental Database Evaluation* (Canamera Geological Ltd. 1996);
- *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

The baseline lake water quality data has been collected in the Project region in 1993, 1994, 1997, 2006, 2007, 2010, 2011, 2012, and 2013. A list of the data available for each lake is shown in Table 4.1-1 and the sampled lakes are shown on Figures 4.1-4 and 4.1-5.

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 2013 (Table 4.1-1). In the comprehensive baseline surveys from 2010 to 2013, 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 2013, 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 profiles in lakes in the 2010-2013 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.

Streams

Stream water quality data has been collected in the Project region during 1993, 1994, 1997, 2006, 2007, 2010, 2011, 2012, and 2013. A list of the data available for each stream is shown in Table 4.1-2 and the sampled streams are shown on Figures 4.1-4 and 4.1-5.

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.

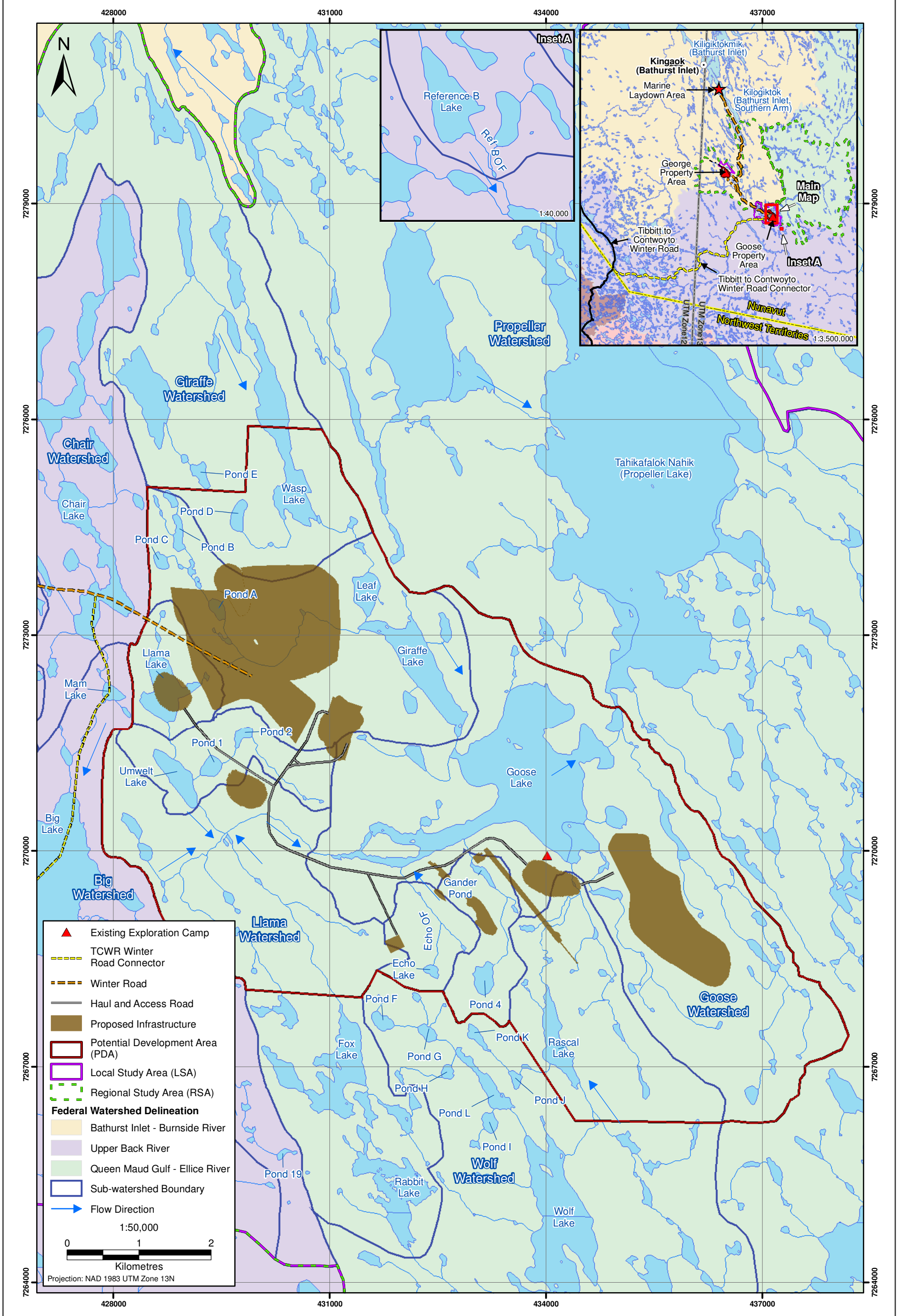


Figure 4.1-2

Sabina GOLD & SILVER CORP.

Waterbodies in the Goose Property Area

Figure 4.1-2

Rescan an ERM company

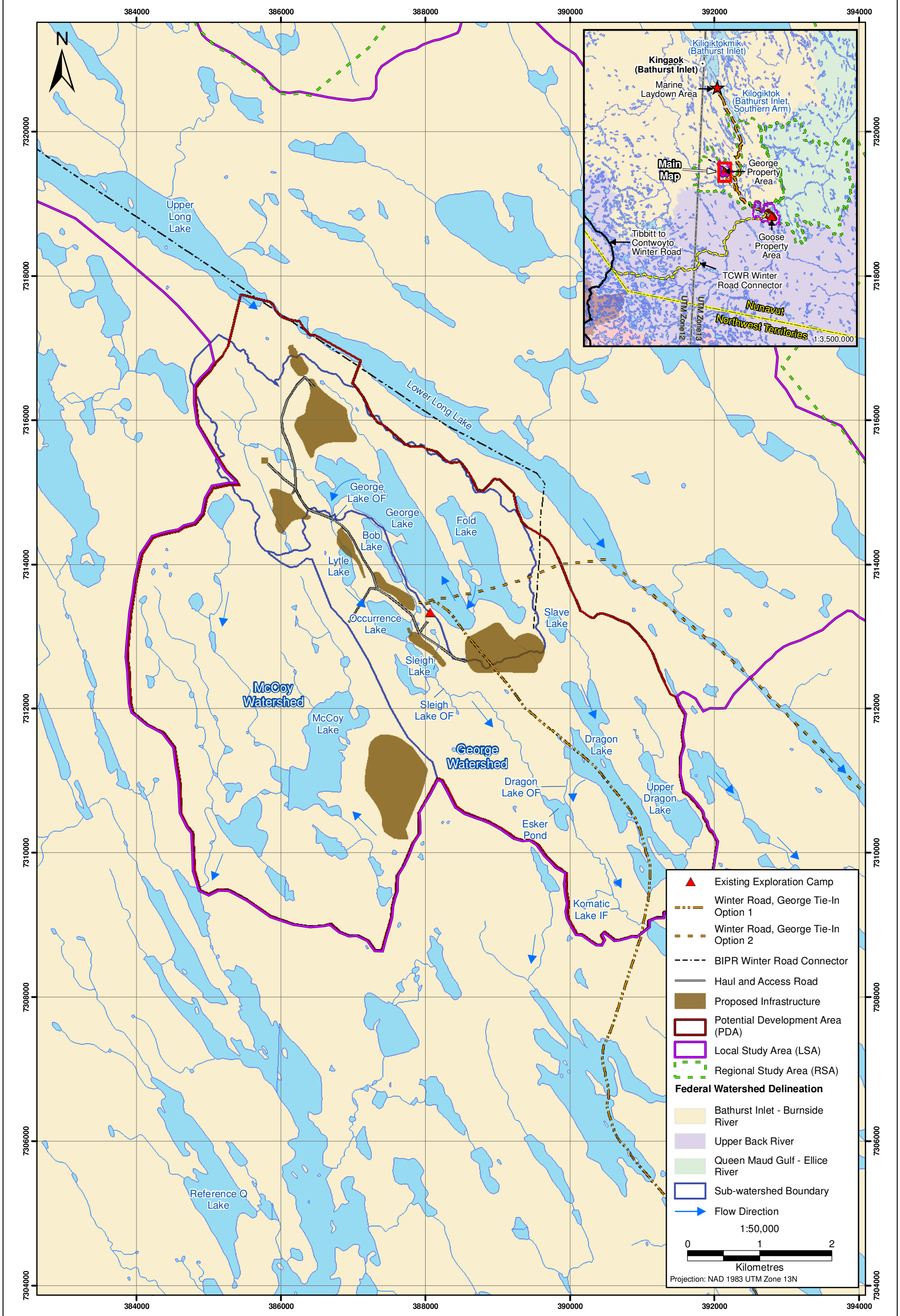


Figure 4.1-3

Sabina GOLD & SILVER CORP.

Waterbodies in the George Property Area

Figure 4.1-3

Rescan an ERM company

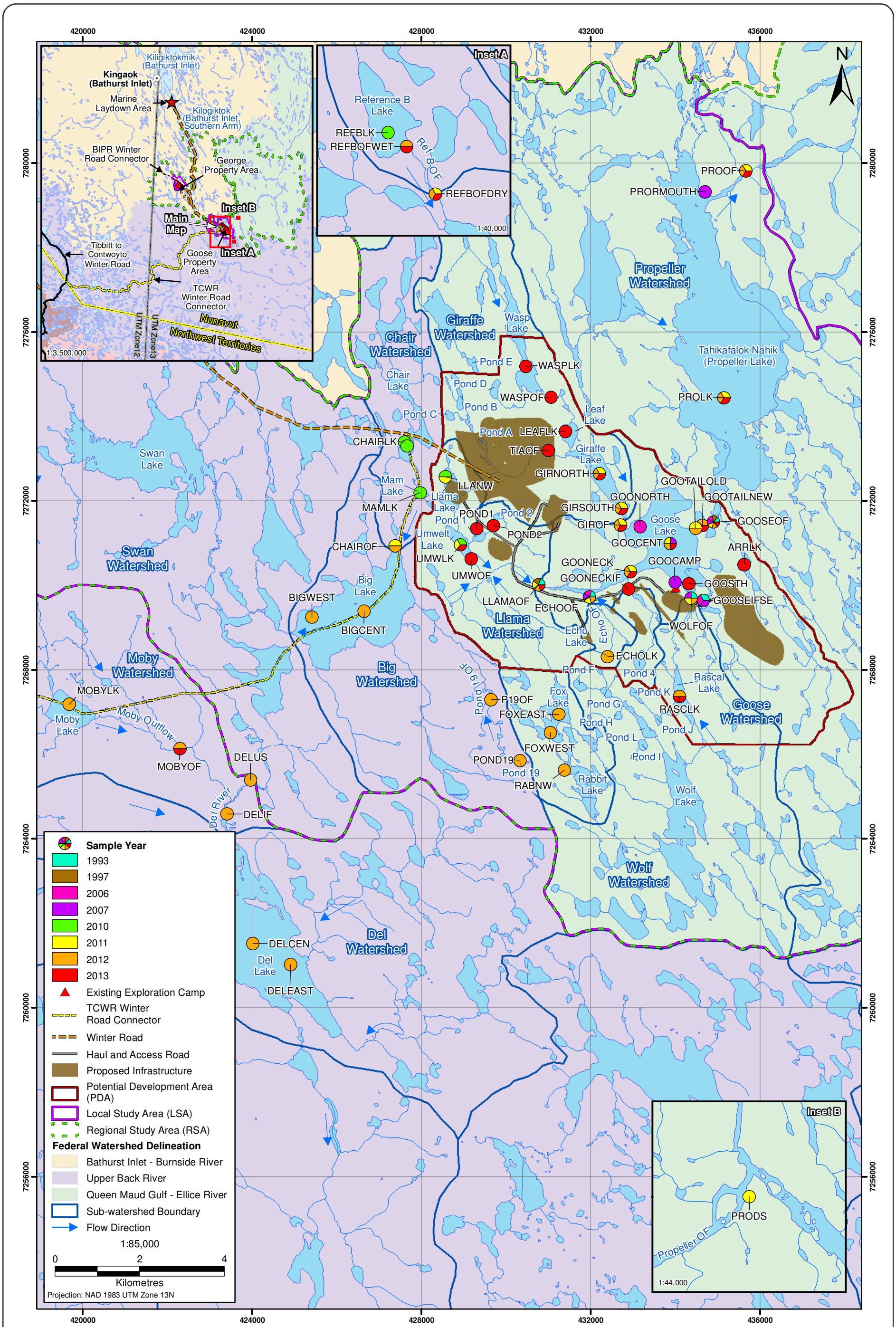


Figure 4.1-4

Sabina GOLD & SILVER CORP.

Locations of Baseline Lake and Stream Water Quality, Goose Property Area, 1993 to 2013

Figure 4.1-4

Rescan an ERM company

PROJECT # 0194096-0040 GIS # BAC-01-059b October 23 2013

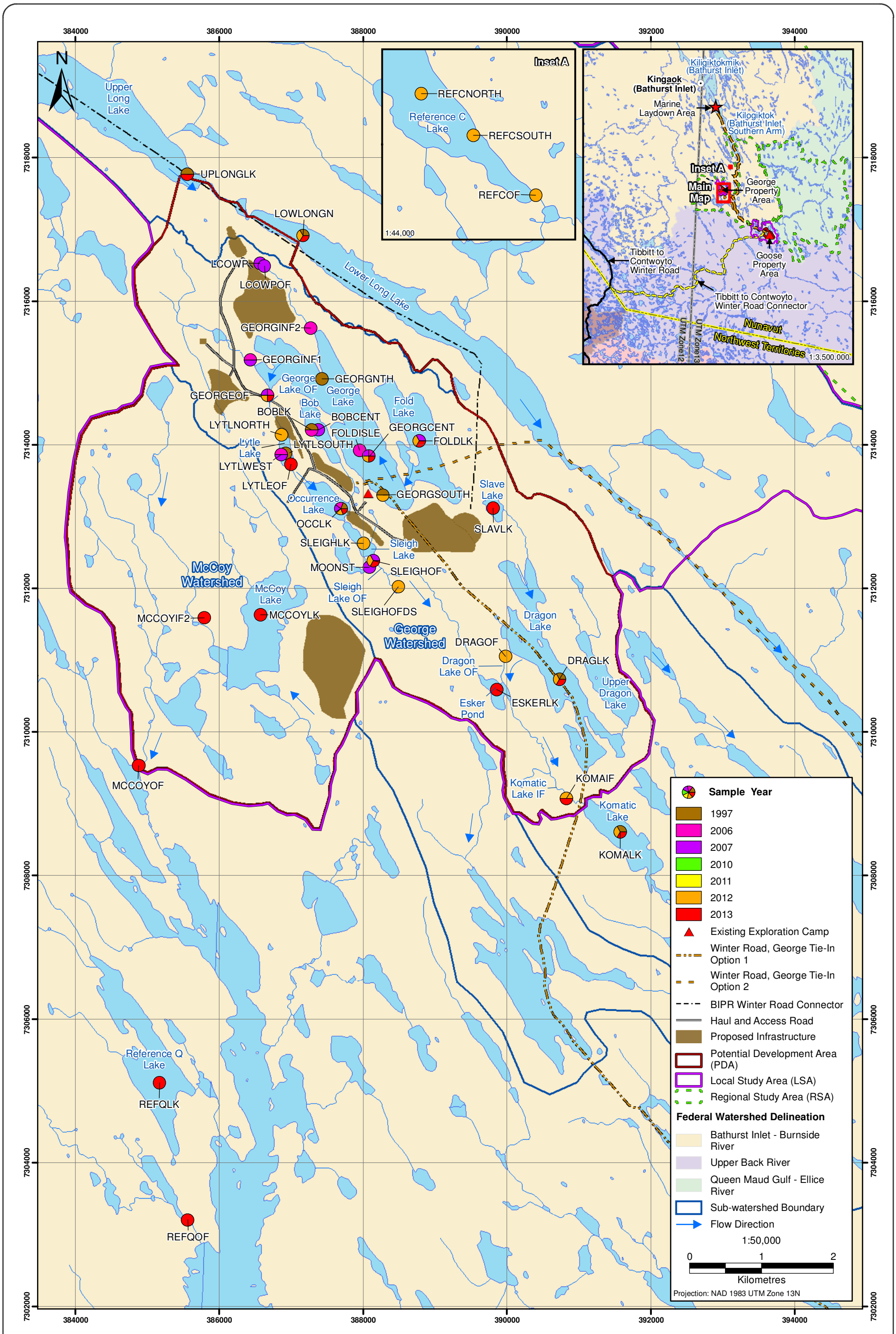


Figure 4.1-4

Sabina GOLD & SILVER CORP.

Locations of Baseline Lake and Stream Water Quality, George Property Area, 1997 to 2013

Figure 4.1-4

Rescan an ERM company

Table 4.1-1. Baseline Lake Water Quality Sampling Conducted for the Back River Project, 1993 to 2013

Year	1993	1994	1997	2006	2007	2010	2011	2012	2013
Sampling Month(s)	Jun, Aug	Jun, Aug	May, Jul, Aug	Sept	Jun/Jul, Aug, Sept	August	April, August	April, August	April, July
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.	Rescan Environmental Services Ltd.
Sampling Method	Shoreline grab sample	Van Dorn bottle	Methods unavailable	Surface grab for shallow samples; Van Dorn sampler for deep samples	Kemmerer vertical sampler	Niskin (Apr), GO-FLO (August)	Niskin (Apr), GO-FLO (August)	Niskin (Apr), GO-FLO (August)	Niskin (Apr), GO-FLO (August)
Analytical Lab	ALS Environmental	ALS Environmental	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	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	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 Property Area* Goose Lake	*Goose Property Area* Goose Lake	*Goose Property Area* Goose Lake *George Property Area* George Lake Bob Lake Lytle Lake Occurrence Lake Dragon Lake Komatic Lake Upper Long Lake Lower Long Lake	*George Property Area* Fold Lake George Lake Bob Lake Lytle Lake Occurrence Lake	*Goose Property Area* Goose Lake *George Property Area* Fold Lake Lone Cow Pond George Lake Bob Lake Lytle Lake Occurrence Lake	*Goose Property Area* Llama Lake Umwelt Lake Chair Lake Mam Lake Reference B Lake	*Goose Property Area* Giraffe Lake Llama Lake Umwelt Lake Goose Lake Propeller Lake Reference B Lake	*Goose Property Area* 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 *George Property Area* Fold Lake George Lake Lytle Lake Occurrence Lake Sleigh Lake Dragon Lake Komatic Lake Lower Long Lake Reference C Lake	*Goose Property Area* Wasp Lake Leaf Lake Giraffe Lake Umwelt Lake Rascal Lake Goose Lake Arrow Lake Propeller Lake Reference B Lake *George Property Area* Fold Lake George Lake Bob Lake Lytle Lake Occurrence Lake Slave Lake Dragon Lake Esker Lake Komatic Lake McCoy Lake Upper Long Lake Lower Long Lake Reference Q Lake
Number of Replicates per Site	n = 1	n = 1	n = 2	n = 1 at shallow lakes and n = 2 at deep lakes	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
Depths of Replicates (m)	Unknown	Unknown	Unknown	0.5 m below the surface and in deep lakes (Goose and George) 1 m above sediment	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)

Table 4.1-2. Baseline Stream Water Quality Sampling Conducted for the Back River Project, 1993 to 2013

Year	1993	1994	1997	2006	2007	2011	2012	2013
Sampling Month(s)	June, August	June, August	May, July, August	September	June/July, August, September	June, August, September	June, August, September	June, July
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.
Sampling Method	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
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
Stream(s) Sampled	*Goose Property Area* Llama OF Echo OF Goose Neck IF Wolf OF Goose Southeast IF	*Goose Property Area* Llama OF Echo OF Goose Neck IF Wolf OF Goose Southeast IF Goose OF	*Goose Property Area* Llama OF Goose OF	*Goose Property Area* Echo OF Goose Southeast IF Goose OF	*Goose Property Area* Echo OF Wolf OF Goose Southeast IF Goose OF Propeller OF Downstream *George Property Area* Lone Cow Pond OF George Inflow 1 (NW) George OF Moon Stream Sleigh OF	*Goose Property Area* Giraffe OF Llama OF Wolf OF Goose OF Propeller D/S Chair OF Reference B OF	*Goose Property Area* 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 *George Property Area* George OF Sleigh OF Dragon OF Dragon Watershed OF Reference C OF	*Goose Property Area* Wasp OF Giraffe IF Giraffe OF Umwelt OF Llama OF Goose Neck IF Goose OF Propeller OF Reference B OF *George Property Area* George OF Lytle OF Sleigh OF Dragon Watershed OF McCoy US McCoy Watershed OF Reference Q OF
Number of Replicates per Site	n = 1	n = 1	n = 1	n = 1	n = 1	n = 2	n = 2	n = 2

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 comprising 13% of the Goose Property LSA and 20% of the George Property 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). Goose LSA lakes were slightly more acidic than George LSA lakes, which was likely due to differences in the composition of the geology of the landscape. 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, 2013c). 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), Bob Lake (May 1997), Occurrence Lake (July 1997), Lone Cow Pond (July, August, September 2007), Chair, Mam and Reference B lakes (August 2010), Goose Lake (August 2011) and Rabbit and Rascal lakes (August 2012). The low pH of 2007 Low Cow Pond samples was associated with high metal concentrations and may have been due to proximity to metal deposits.

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

Parameter	Property	n	Min	Mean	Max	% Samples Outside of CCME Guidelines
pH	Goose	98	4.8	6.9	8.1	10
	George	93	6.3	7.2	8.3	2
Total Alkalinity (mg $CaCO_3$/L)	Goose	95	2.3	6.4	32.5	-
	George	68	2.5*	12.3	78.0	-
Hardness (mg $CaCO_3$/L)	Goose	98	3.6	15.3	81.5	-
	George	93	6.0	25.5	78.8	-
Conductivity (µS/cm)	Goose	98	11	39.5	174	-
	George	93	16	61.8	166	-
Total Dissolved Solids (mg/L)	Goose	98	4	30.0	128	-
	George	93	8	37.6	111	-

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

Lakes in both 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 concentrations of total dissolved solids and conductivity (Table 4.1-3). Mean levels of hardness, conductivity, and alkalinity were slightly greater in the George Property lakes, likely due to differences in the surrounding geology.

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 reflect 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 and George Property Areas, 1993 to 2013

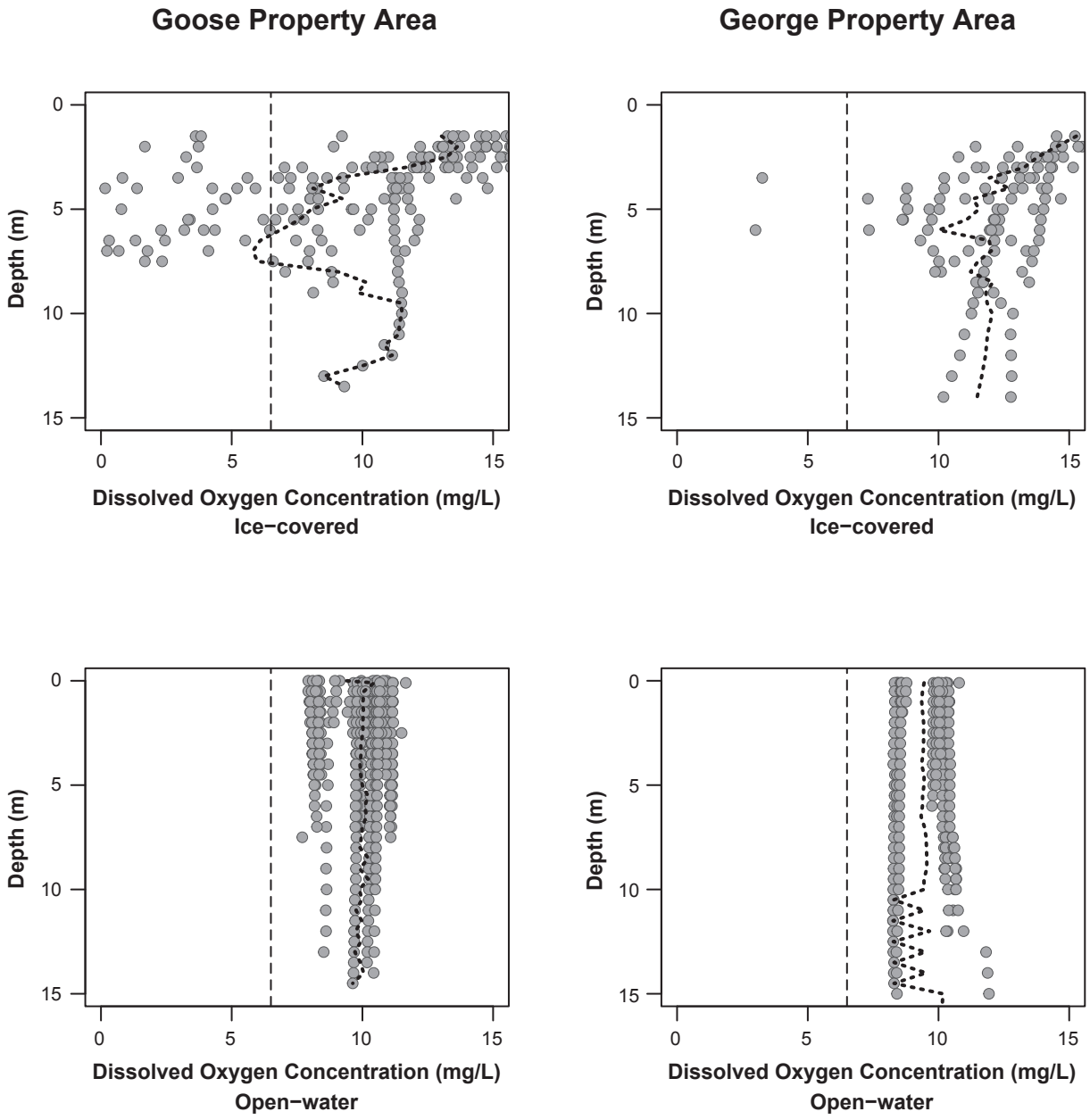
Parameter	Property	n	Min	Mean	Max
TSS (mg/L)	Goose	98	0.5*	1.63	7.0
	George	93	0.5*	1.83	6.0
Turbidity (NTU)	Goose	93	0.13	0.35	1.1
	George	62	0.13	0.34	1.1

**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 4.1-6). 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. Lakes in the Goose LSA were more likely to have lower dissolved oxygen concentrations near the sediment surface in the ice-covered season than George LSA lakes (Figure 4.1-6). Near-sediment oxygen concentrations less than 1 mg/L were observed under the ice in Propeller, Big, and Giraffe lakes, whereas the lowest dissolved oxygen concentration in the George LSA lakes was 3 mg/L in Komatic Lake (April 2012; Rescan 2013a). Many lakes in the Goose 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). This contrasted with the relatively greater under-ice concentrations in the George LSA where there were only two observations near 3 mg/L (Dragon and Komatic lakes; April 2012).



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).

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

Figure 4.1-6

Sabina GOLD & SILVER CORP.

Rescan Engineers & Scientists

During the open-water season, dissolved oxygen concentrations and saturation levels were greater in Goose Property lakes than in George LSA lakes. Dissolved oxygen concentrations averaged 10.0 mg/L (ranged between 7 mg/L and 12 mg/L) in Goose LSA lakes and 9.2 mg/L (ranged between 8 mg/L and 12 mg/L) in George LSA lakes, with the greatest concentrations found below the thermocline in Reference Lake C in 2012 (Rescan 2013a). Dissolved oxygen saturation levels followed a similar trend, ranging from 85 to 100% in Goose LSA lakes compared with 75% to 80% in George Property lakes.

Dissolved oxygen concentrations were greater than the CCME guideline for early life stages (9.5 mg/L) at all Goose LSA lake sites at all depths in the open-water season. For lakes within the George LSA, dissolved oxygen concentrations tended to be less than the CCME dissolved oxygen guideline, except some deep waters (~20 m) in Reference Lake C. Dissolved oxygen concentrations were greater than the CCME guidelines for other life stages (6.5 mg/L; CCME 2012) in all lakes 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 Goose and George LSA lakes can be 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, and greater in the Goose LSA lakes than in George LSA lakes (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 2013). 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 2013).

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

Nutrient	Property	n	Min	Mean	Max	% of Samples with Concentrations above CCME Guidelines[‡]
Nitrate-N (mg/L)[†]	George	87	0.0025*	0.014	0.07	0
	Goose	96	0.0025*	0.014	0.31	0
Ammonia-N (mg/L)	Goose	98	0.0025*	0.013	0.081	0
	George	93	0.0025*	0.007	0.070	0
Total Phosphorus (mg/L)	Goose	95	0.002	0.005	0.040	0
	George	78	0.001*	0.008	0.067	0
Orthophosphate (mg/L)	Goose	96	0.0005*	0.0006	0.004	0
	George	87	0.0005*	0.0010	0.005[+]	0

[‡] *CCME water quality guidelines for the protection of aquatic life (CCME 2013).*
** The minimum value shown is calculated as ½ of the lowest detection limit.*
[+] *The maximum value shown is calculated as ½ of the highest detection limit.*
[†] *All nitrate concentrations were significantly less than the conservative long-term CCME guideline for nitrate of 13 mg/L.*

Ortho-phosphate 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 2013). However, variation was observed within lakes and between seasons and years that could result in substantial 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	Goose LSA	George LSA
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	Bob Lake, Dragon Lake, Fold Lake, George Lake, Komatic Lake, Lower Long Lake, Lytle Lake, McCoy Lake, Occurrence Lake, Reference Lake C, Reference Lake Q, Sleigh Lake, Upper Long 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	Bob Lake, Dragon Lake, Esker Lake, Fold Lake, George Lake, Komatic Lake, Lower Long Lake, Lytle Lake, Occurrence Lake, Reference Lake C, Slave Lake, Upper Long Lake
Mesotrophic	0.010 – 0.020 mg/L	Arrow Lake, Del Lake, Umwelt Lake	Bob Lake, George Lake, Komatic Lake, Lytle Lake
Meso-eutrophic	0.020 – 0.035 mg/L	Echo Lake, Goose Lake	Bob Lake, Fold Lake, George Lake, Occurrence Lake
Eutrophic	0.035 – 0.1 mg/L	Goose Lake	George Lake, Lower Long 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 total phosphorus concentrations in some lakes like George 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, with lakes in the George LSA having greater metal concentrations than those in the Goose LSA (Tables 4.1-7 and 4.1-8). 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, 2013c). 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 2013).*
† 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.

Table 4.1-8. Summary of Lake Water Metal Concentrations in the George Property Area, 1994 to 2013

Metal	n	Total Metal Concentration (mg/L)			% of Samples with Concentrations above CCME Guidelines*
		Min	Mean	Max	
Aluminum	72	0.0015†	0.026	0.405	7
Arsenic	72	0.000025†	0.0005	0.0016	0
Boron	72	0.0025†	0.0085	0.0440	0
Cadmium‡	72	0.000004	0.000011	0.00006	19[a]
Copper	72	0.0009	0.0019	0.0048	42
Iron	72	0.005†	0.063	0.680	3
Lead	72	0.000025†	0.00026	0.0022	6
Mercury[b]	72	0.000005†	0.000015	0.000059	4
Molybdenum	72	0.000025†	0.000094	0.0004	0
Nickel	72	0.00013	0.0044	0.018	0
Uranium	47	0.000005†	0.000038	0.00041	0
Zinc	72	0.0005†	0.0052	0.027	0

Notes: Samples collected in the 2006 and 2007 programs were excluded because of elevated analytical detection limits. Samples from Low Cow Pond were also excluded because of the high concentrations of metals that unnecessarily skew the summary statistics.
** CCME water quality guidelines for the protection of aquatic life (CCME 2013).*
† The minimum value shown is calculated as ½ the lowest detection limit.
‡ 58% 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] 94% 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 (Tables 4.1-7 and 4.1-8). These naturally-elevated metal concentrations were greater than their CCME guideline levels in a number of lake samples in the Project area (Tables 4.1-9 and 4.1-10). Copper concentrations were greater than their CCME guideline in 42% of George LSA lake samples and 35% of Goose LSA lake samples. Many lakes proximate to proposed Project activities had naturally elevated copper concentrations (e.g., Occurrence, Bob, George, Long, Komatic, and Goose lakes). Aluminum, iron, nickel, and lead concentrations were rarely greater than CCME guidelines in a subset of Project lakes proximate to deposits and proposed activities (e.g., Occurrence, George, Long, Goose, and Wasp lakes).

Table 4.1-9. 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.*

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.

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 4.1-11).

Table 4.1-10. Water Quality Parameters with Sample Concentrations Greater than CCME Guideline Values in George Property Lakes, 1997 to 2013

Lake	Parameters with Values Greater than CCME Guidelines
Occurrence Lake	pH*, Al, Cu, Hg
Bob Lake	pH*, Al, Cu
Lone Cow Pond	pH*
George Lake	pH*, Al, Cd, Cu, Fe, Pb
Fold Lake	Pb
Lytle Lake	Cu
Sleigh Lake	Cu
Esker Lake	Cu
Slave Lake	Cu
Upper Long Lake	Al, Cu, Fe, Hg
Lower Long Lake	Cu, Pb
McCoy Lake	Cu
Dragon Lake	Cu
Komatic Lake	Cd, Cu, Pb, Hg
Reference Q Lake	Cu

Note: Exceedances are listed if sample concentration was greater than the CCME guidelines (CCME 2013).
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 George Property Area lakes were less than 6.5.*

Table 4.1-11. Summary of Lake Water Free Cyanide Concentrations (mg/L) in the Goose and George Property Areas, 1997 to 2013

Property	n	Min	Mean	Max
Goose	69	0.0005*	0.0008†	0.0029‡
George	47	0.0005*	0.0005*	0.0005*

** 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 2013).

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 Goose and George LSA were largely circum-neutral, with pH levels ranging from 5.6 to 8.2 (Table 4.1-12; Rescan 2011, 2012, 2013a, 2013c). 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). Streams in the Goose LSA tended to be more acidic than those in the George LSA, which was consistent with trends in lake pH. The highest pH levels in each season were observed in Reference C OF, which ranged from 7.7 to 8.1 (Rescan 2012, 2013a). 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).

Table 4.1-12. Summary of Stream Water Chemistry in the Goose and George Property Areas, 1993 to 2013

Parameter	Property	n	Min	Mean	Max	% Samples Outside of CCME Guidelines
pH	Goose	109	5.6	6.7	7.5	20
	George	42	5.7	7.0	8.2	2
Total Alkalinity (mg/L $CaCO_3$)	Goose	104	1.8	5.0	17	-
	George	42	2.5*	9.2	68	-
Hardness (mg $CaCO_3$/L)	Goose	109	0.5*	16	133	-
	George	42	2	24	63	-
Conductivity (µS/cm)	Goose	109	10.5	40	334	-
	George	42	15.6	60	122	-
Total Dissolved Solids (mg/L)	Goose	109	1*	36	403	-
	George	42	4	37	87	-

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

Streams in the Goose and George LSA also had low buffering capacity and soft water (hardness < 60 mg CaCO3/L; Table 4.1-12; Rescan 2011, 2012, 2013a, 2013c). Like the Project lakes, alkalinity and hardness were slightly greater in streams in the George LSA than in the Goose LSA.

4.1.6.2 Stream TSS and Turbidity

In general, Project area streams had clear water, with no apparent differences between the Goose and George LSA. Most streams had TSS concentrations less than the detection limit (3 mg/L; Table 4.1-13) and detectable TSS concentrations were only observed in samples from Dragon Watershed OF, George OF, Lytle OF, Chair OF, Echo OF, Reference B OF, and Del IF (Rescan 2011, 2012, 2013a, 2013c). The greatest TSS concentration (10.3 mg/L) was measured in Dragon Watershed OF, which had a unique sandy substrate rather than the common cobble and boulder substrates in most Project area streams. Turbidity levels were also low at most streams, ranging from 0.14 to 2.6 NTU (Table 4.1-13). The exceptions were Del IF in June 2011 (1.8 NTU), Reference B OF in September 2012 (2.1 NTU), and Dragon Watershed OF in August 2012 (2.6 NTU; Rescan 2012, 2013a).

Table 4.1-13. Summary of Stream Water TSS and Turbidity in the Goose and George Property Areas, 1993 to 2013

Parameter	Property	n	Min	Mean	Max
TSS (mg/L)	Goose	109	0.5*	1.8	11
	George	42	0.5*	1.7	8
Turbidity (NTU)	Goose	101	0.14	0.63	2.4
	George	40	0.2	0.5	2.6

**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.

Open-water dissolved oxygen concentrations were greater in Goose Property streams than in George Property streams. Dissolved oxygen concentrations ranged between 3.7 mg/L and 13.1 mg/L in Goose Property streams and between 8.3 mg/L and 12.8 mg/L in the George 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 five George LSA streams and nine Goose LSA streams (Table 4.1-14). 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 4.1-14. Stream Sites with Water Dissolved Oxygen Concentrations Less than the CCME Guideline for Early Life Stages in the Goose and George Property Areas, 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
George	Dragon OF, George IF 1, George OF, Dragon Watershed OF, Sleigh OF

4.1.6.4 Stream Nutrients

Streams surveyed had low nutrient concentrations, with no clear differences between Goose and George LSA streams. Like the surveyed lakes, streams in the Project area generally had low concentrations of inorganic nitrogen (ammonia, nitrate, and nitrite; Table 4.1-15). Most stream sites had ammonia concentrations near the analytical detection limit (0.005 mg/L) 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) and McCoy Watershed OF (0.33 mg/L NO_3-N in July 2013). All streams had ammonia, nitrate and nitrite concentrations much less than their respective CCME guideline concentrations (CCME 2012).

Table 4.1-15. Summary of Stream Water Nutrient Concentrations in the Goose and George Property Areas, 1994 to 2013

Nutrient	Property	n	Min	Mean	Max	% Samples Outside of CCME Guidelines
Nitrate-N (mg/L)	Goose	106	0.0025*	0.039	0.61	0
	George	40	0.0025*	0.024	0.33	0
Ammonia-N (mg/L)	Goose	109	0.0025*	0.0076	0.049	0
	George	42	0.0025*	0.0074	0.026	0
Total Phosphorus (mg/L)	Goose	97	0.0010*	0.0059	0.028	0
	George	29	0.0023	0.0060	0.029	0
Orthophosphate (mg/L)	Goose	106	0.0005*	0.0010	0.005	0
	George	40	0.0005*	0.0011	0.005+	0

Note: Total phosphorus samples from 2006 and 2007 were excluded due to elevated background values.
** The minimum value shown is calculated as ½ of the lowest detection limit.*
+The maximum value shown is calculated as ½ of the highest detection limit.

All streams sampled had total phosphorus concentrations less than 0.03 mg/L (Table 4.1-15) 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 4.1-16; CCME 2013). A subset of lakes had samples that were within mesotrophic and meso-eutrophic trigger ranges: the Dragon Watershed and McCoy Watershed outflows in the George LSA, and Chair OF, Goose Neck IF, and Reference B OF in the Goose LSA.

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

Trophic Status	Total Phosphorus Concentration	George Property	Goose Property
Ultra-oligotrophic	< 0.004 mg/L	Dragon OF, George OF, McCoy Watershed OF, Reference C OF, Reference Q OF, Sleigh OF, Sleigh DS	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	Dragon OF, George OF, Dragon OF, Dragon Watershed OF, Lytle OF, McCoy IF, Reference C OF, Reference Q OF, Sleigh OF, Sleigh DS	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	Dragon Watershed OF, McCoy Watershed OF	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.

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 (Tables 4.1-17 and 4.1-18). Aluminum, boron, chromium and iron tended to be greater in several Goose LSA streams, while arsenic concentrations tended to be greater in the George LSA streams. There was no clear spatial trend in metal concentrations, with no streams having 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 (Tables 4.1-17 and 4.1-18; Rescan 2011, 2012, 2013a, 2013c).

Naturally elevated copper concentrations were observed in several Project streams (e.g., Sleigh OF, 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 the McCoy Watershed OF and the Dragon Watershed OF in the George LSA and Goose OF and Propeller OF in the Goose LSA. These concentrations were often greater than CCME guideline levels (Tables 4.1-19 and 4.1-20; CCME 2013).

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.

Table 4.1-18. Summary of Stream Water Metal Concentrations in the George Property Area, 1997 to 2013

Metal	n	Metal Concentration (mg/L)			% of Samples in Concentrations Greater than CCME Guidelines*
		Min	Mean	Max	
Aluminum	27	0.0015†	0.023	0.087	0
Arsenic	27	0.000105	0.00061	0.0015	0
Boron	27	0.0025†	0.0047	0.0076	0
Cadmium‡	27	0.000005†	0.000010	0.000023	22[a]
Copper	27	0.00061	0.0021	0.0032	56
Iron	27	0.000025	0.000029	0.000079	0
Lead	27	0.005†	0.075	0.27	0
Mercury[b]	27	0.000005†	0.000005	0.000005	0
Molybdenum[c]	27	0.000025†	0.000027	0.000071	0
Nickel	27	0.00005†	0.0059	0.016	0

(continued)

Table 4.1-18. Summary of Stream Water Metal Concentrations in the George Property Area, 1997 to 2013 (completed)

Metal	n	Metal Concentration (mg/L)			% of Samples in Concentrations Greater than CCME Guidelines*
		Min	Mean	Max	
Uranium[d]	27	0.000005[†]	0.000034	0.00033	0
Zinc	27	0.0015[†]	0.0037	0.014	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 2013).*
[†] The minimum value shown is calculated as ½ the lowest detection limit.
[‡] 56% 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] 100% of mercury concentrations were less than analytical detection limits.
[c] 93% of molybdenum concentrations were less than analytical detection limits.
[d] 52% of uranium concentrations were less than analytical detection limits.

Table 4.1-19. 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*, Cu, Hg
Echo OF	pH*, Cu
Wolf OF	pH*
Goose IF Southeast	pH*
Goose IF Neck	pH*, Cd, Fe
Goose OF	pH*, Cd, Cu, Hg
Giraffe OF	pH*, Cu
Giraffe IF	Cu
Umwelt OF	pH*
Pond 19 OF	Cu
Moby OF	Cu, Fe, Ni
Chair OF	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; all observations of pH outside of this range in George Property Area lakes were less than 6.5.*

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 4.1-21).

Table 4.1-20. Water Quality Parameters with Sample Concentrations Greater than CCME Guideline Values in George Property Area Streams, 1997 to 2013

Lake	Parameters with Values Greater than CCME Guidelines
George OF	pH*
Sleigh OF	Cd, Cu
Sleigh OF Downstream	Cu
Lytle OF	Cd, Cu
Dragon Watershed OF	Cd, Cu
McCoy IF	Cu
McCoy OF	Cd, Cu
Reference Q OF	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 George Property Area lakes were less than 6.5.*

Table 4.1-21. Summary of Stream Water Free Cyanide Concentrations (mg/L) in the Goose and George Property Areas, 1997 to 2013

Property	n	Min	Mean	Max
Goose	78	0.0005*	0.0008†	0.0025‡
George	27	0.0005*	0.0005*	0.0005*

** 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)

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) was reviewed for information on freshwater water quality (see Volume 3, Chapter 3 of the DEIS). TK information documented in the NKTP report (KIA 2012) included observations of many changes in water quality over the past few decades. These included "shallower lakes and rivers that drained to the ocean, reductions in river flow, smaller fish spawning runs, and the Arctic Ocean [taking] longer to freeze" (KIA 2012). In general, these changes were associated with decreased water quality and were attributed to less rain and snowfall, changes in weather, increased human effects such as dust, mineral exploration and mine development, melting of permafrost because of global warming, airborne pollutants, too many tourists, garbage on the land, and an overpopulation of geese (KIA 2012).

All Inuit traveled extensive distances throughout the year for hunting, trapping, fishing, and trading. The travel routes were not only for efficient travel, but were places to harvest caribou, fish, trap, and live. The Inuit use of the land is termed "lifeways" and freshwater quality is an important component of the value of the land. Potable water was not always readily available on the land, and often required substantial effort to obtain. Inuit generally preferred large lakes over shallow, small lakes for drinking water, and high water clarity is an important characteristic of water quality. Camps were

often established near reliable sources of drinking water and travelling Inuit would obtain water wherever available. Potable water sources include lakes, flowing rivers, pools under cliffs, underground streams and springs, and pools from rain or melting snow in rock crevasses and wetlands (Rescan 2007; KIA 2012). Specific waterbodies in the study area used by Inuit for collecting drinking water were not identified historically (KIA 2012) or recently (Rescan 2013b).

The following text on water quality is from the TK report:

> *The climate is changing and the weather is different now. Even the lakes have changed. Long ago when you made tea using water from the river or lakes it used to be good. Now the water doesn't make very good tea anymore. The Coppermine River is starting to change too. Inuit have begun to talk about the changes now. Even to drink out of the river is not very good because the water is changing…* C44, KIA (2012).

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.

4.2.4 Incorporation of TK for Effects Assessment

Inuit have observed changes in water quality over the past few decades, and these changes are incorporated into the existing environment and baseline information. TK was therefore incorporated into 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 was 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 2013) 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 DEIS.

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 2013), and outlined in the General Methodology for Project Effects Assessment (Volume 9, Chapter 1).

4.4.1 Spatial Boundaries

The spatial boundaries used for the assessment of the freshwater water quality VEC included a LSA for each of the Goose and George Properties and a larger RSA for both properties.

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 2013). The LSA for the VEC freshwater water quality was divided into two areas:

1. The Goose Property LSA. The LSA boundary (365 km^2) includes the Goose Property PDA and matches the boundaries of the Propeller and Big watersheds (Figure 4.4-1); and
2. The George Property LSA. The LSA boundary (105 km^2) includes the George Property PDA, and matches the boundaries of the Dragon, George, McCoy, and Lower Long watersheds (Figure 4.4-1).

For each LSA, the potential direct Project effects were predicted to occur within the immediate sub-watersheds where Project infrastructure and activities were proposed. Within each Property Area, the outer boundaries of these sub-watersheds then formed the continuous outer boundary for that LSA. This conservative delineation of the LSA was designed to capture all freshwater ecosystems where direct effects on the freshwater water quality VEC that could be reasonably expected to occur due to Project activities.

The potential changes to the Goose Property Area and George Property Area have been addressed in the freshwater water quality assessment. Potential effects related to the MLA are addressed in the Marine Environment Volume (Volume 7).

4.4.1.2 Regional Study Area

The RSA includes the PDA, the LSA plus additional areas within which there is the potential for indirect or cumulative effects. The RSA used for the VEC freshwater water quality effects assessment is divided into two areas:

1. The Goose Property RSA. The RSA boundary (6,815 km^2) includes part of the Ellice River Watershed and encompasses the PDA and the LSA. All Project infrastructure resides within the Ellice Watershed. The upper ~80 km of the watershed was included rather than the entire watershed (Figure 4.4-1); and
2. The George Property RSA. The RSA boundary (4,034 km^2) includes part of the Western River Watershed and encompasses the PDA and LSA. All Project infrastructure resides within the Western River Watershed. The upper portion of the watershed that drains in to the Western River at the southern tip of Bathurst Inlet is included in the RSA (Figure 4.4-1).

PROJECT # 0194096-0040 GIS # BAC-01-064 October 10 2013

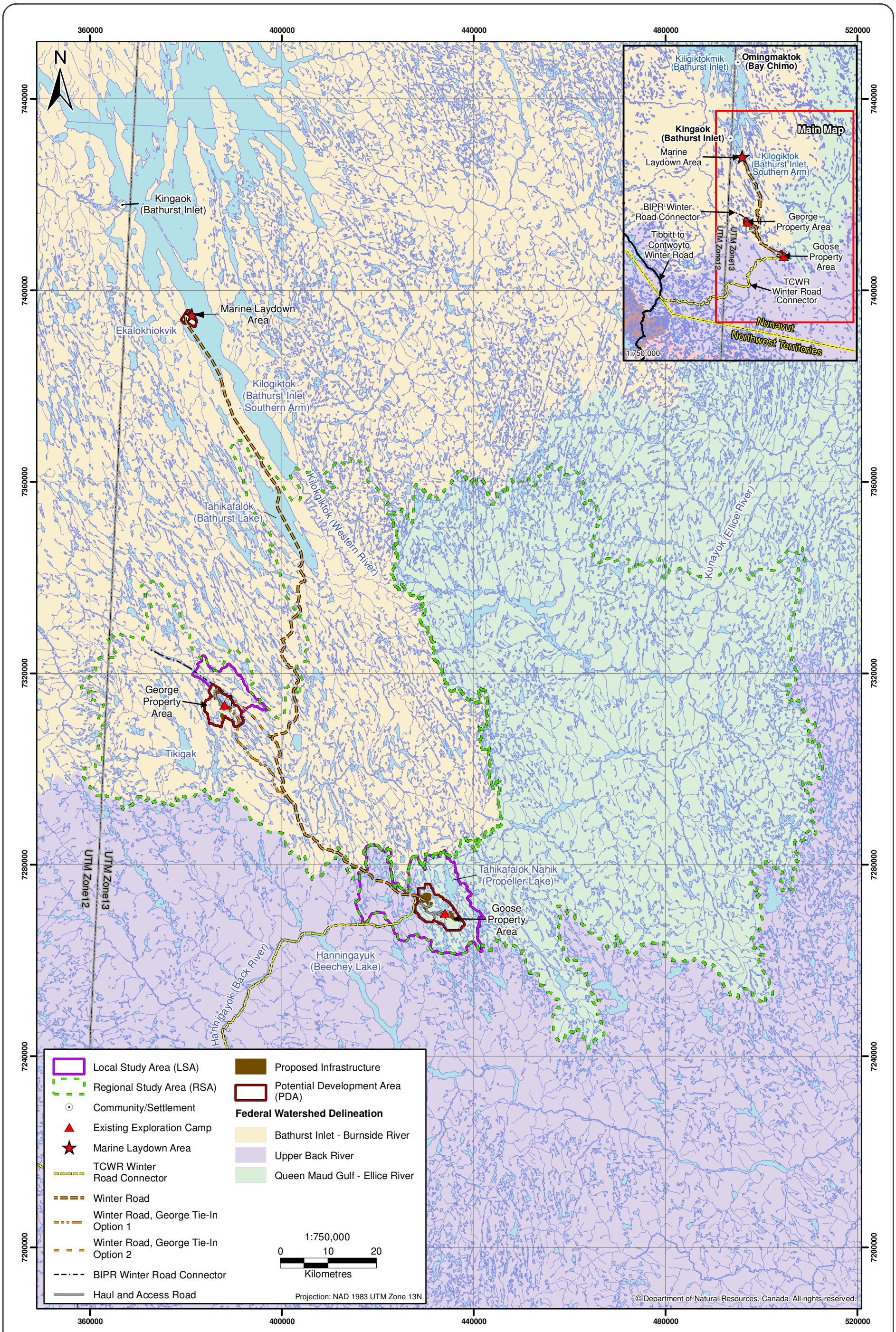


Figure 4.4-1

Sabina GOLD & SILVER CORP.

Local Study Area and Regional Study Area for Freshwater Water Quality

Figure 4.4-1

Rescan an ERM company

It was assumed that effects on freshwater water quality can be disseminated through the surface water environment and affect other connected waterbodies. It was also assumed that potential water quality effects were not spread over land between unconnected waterbodies.

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:

- Site Preparation: 2 years;
- Construction Phase: 2 years;
- Operations Phase: 10 years;
- Reclamation and Closure Phase: 10 years;
- Post-closure Phase: 3 years minimum;
- 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, 2013). 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 (NIRB 2013). If particular metals were naturally above CCME guidelines (e.g., copper), 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).

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*

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 may 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 thresholds and guidelines have been established to protect aquatic life (CCME 2013). 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 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, 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, 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, deposition
Metals	Metals suspended or dissolved in water	Project activities may contribute metals to waterbodies in runoff, discharge or deposition	Runoff, deposition, discharge
Hydrocarbons	Petroleum hydrocarbon compounds	Project activities may contribute hydrocarbon compounds in runoff, discharge, or deposition	Runoff, 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	550 mg/L (short term) 13 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 2013)*
	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 George Property Area (25 mg/L $CaCO_3$) was 0.000015 mg/L and 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 (25 mg/L $CaCO_3$ for the George Property Area and 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 2013) 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.

The majority of 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 *Site Preparation, 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:

- *Site Preparation, Construction, and Decommissioning Activities* - Project activities that include the clearing of overburden, dewatering, earthworks, and construction activities for pads and infrastructure.
- *Winter Roads* - Project activities related to the construction and operation of winter 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, 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 would 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**	**Site Preparation, Construction, Decommissioning Activities**	**Winter Roads**	**Site Contact Water**	**Mine Contact Water**	**Water Use**	**Quarries and Borrow Pits**	**Explosives**	**Fuels, Oils, and PAH**	**Treated Sewage Discharge**	**Dust Deposition**
Site Preparation 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 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			
	Marine Laydown Area: on-land laydown areas and fuel storage			X					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
	Tailings storage				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**	**Site Preparation, Construction, Decommissioning Activities**	**Winter 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 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			
	Marine Laydown Area: Fuel storage and handling			X					X		
Reclamation and Closure	Open pits				X						
	Underground mines				X						
	Tailings storage				X						
	Water use for tailings management					X					
	Waste rock storage areas				X						
	Winter 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				
	Marine Laydown Area reclamation	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 volume and flow may have on freshwater waterbodies.
- *discharge*, which is the direct input of Project water into freshwater waterbodies.
- *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
Site preparation, construction, and decommissioning activities	Runoff, discharge	pH, TSS, nutrients, metals, hydrocarbons	Site preparation, Construction, Operations, Reclamation and Closure
Winter roads	Runoff, water withdrawal	TSS, metals, hydrocarbons	Site preparation, Construction, Operations, Reclamation and Closure
Site contact water	Runoff	pH, TSS, nutrients, metals, hydrocarbons	Site preparation, 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	Site preparation, Construction, Operations, Reclamation and Closure
Quarries and borrow pits	Runoff	pH, TSS, metals, hydrocarbons	Site preparation, Construction, Operations
Explosives	Runoff, aerial deposition	Nutrients, hydrocarbons	Site preparation, Construction, Operations
Fuels, Oils, and PAH	Runoff, Aerial deposition	Hydrocarbons	Site preparation, Construction, Operations, Reclamation and Closure
Treated Sewage Discharge	Discharge	TSS, nutrients, hydrocarbons, BOD	Site Preparation, Construction, Operations, Reclamation and Closure
Dust deposition	Aerial deposition	TSS and metals	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 Site Preparation, Construction, and Decommissioning Activities

Ground preparation will be required in the Site Preparation and Construction phases throughout the PDA to construct necessary Project infrastructure, including buildings, roads, and mine works. Site preparation 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 site preparation activities would also include the construction of water management structures, such as ditches, diversion structures, and berms to mitigate runoff, and earthworks for the TIA, the WMFs, and the collection pond at the MLA. 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 site preparation and 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 Site Preparation 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 Lake (Goose Property Area) and portions of Lytle and Occurrence lakes (George Property Area) 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. In addition, construction of the retention dykes for the dewatering activities at the George Property Area may increase the concentration of sediments through runoff and re-suspension.

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 Roads

Winter roads will be used to connect the three main areas of the Project. Winter roads will be used in the Site Preparation, Construction, and Operations phases, and possibly in the Reclamation and Closure phase, and the pathways of interaction are through runoff and water withdrawals. The construction of winter roads may affect vegetation cover along the shores of waterbodies, which could increase runoff and erosion. Winter 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 re-suspend 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, WRSA, and ore stockpiles, drilling fluids from ongoing exploration activities, mill process water, and water in the TIA. 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 be in permafrost throughout their depth and no groundwater inflow will occur. The underground works at the Umwelt deposit will reach a maximum depth of 680 m, with a predicted maximum inflow of 10 L/s (see Appendix V6-2A, this volume). 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 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 Propeller lakes in the Goose Property Area and from George Lake in the George Property Area 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 re-suspend 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 Site Preparation, 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), 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, 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 Site Preparation, 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 Site Preparation, 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 the tundra. The pathway of interaction between treated sewage and the freshwater environment is, therefore, 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 Site Preparation, 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:

- Fuel Management Plan (Volume 10, Chapter 4);
- Spill Contingency Plan (Volume 10, Chapter 5);
- Ore Storage Plan (Volume 10, Chapter 8);
- Mine Waste Rock and Tailings Management Plan (Volume 10, Chapter 9);
- Landfill and 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);
- Metal Leaching and Acid Rock Drainage Management Plan (Volume 10, Chapter 22); and
- Mine Closure and Reclamation Plan (Volume 10, Chapter 29).

4.5.3.1 Site Preparation, Construction, and Decommissioning Activities

The primary pathway of interaction between the Project activities in the Site Preparation 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. Site road crossings will be constructed according to the DFO Nunavut Operational Statement for Clear Span Bridges (Fisheries and Oceans Canada 2009). Temporary stream crossings will be constructed according to the DFO Nunavut Operational Statement for Temporary Stream Crossings (Fisheries and Oceans Canada 2009). In-water work will be conducted during approved timing windows presented in the DFO Nunavut Operational Statement for Timing Windows (Fisheries and Oceans Canada 2009). Only geochemically suitable rock quarries and borrow sources (i.e., using non-potentially acid-generating rock) will be used to construct roads, pads, and structures (Metal Leaching and Acid Rock Drainage 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 will be located well away from watercourses; and
- Refuelling 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.

The potential effects from dewatering 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 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. 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 TIA.

Changes to water quality during site preparation, construction, and decommissioning activities will be monitored under the Site Water Monitoring and Management Plan (Volume 10, Chapter 7) the Aquatic Effects Monitoring Program (Volume 10, Chapter 19) and to ensure drainage and erosion controls are effective. Previously designed and executed AEMPs have been shown to be effective at monitoring site preparation and construction phases 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 2013). 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.

Potential residual effects from site preparation, construction, and decommissioning activities on freshwater water quality may occur.

4.5.3.2 Winter Roads

The two interaction pathways for potential effects from winter roads on the freshwater water quality VEC are water withdrawals and runoff (during ice off). Water withdrawals for winter 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 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 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 roads (Road Management Plan; Volume 10, Chapter 14).

The effects from winter roads on the VEC freshwater water quality through the water withdrawal and runoff pathways were predicted to be negligible because winter road operations will be in compliance with regulations and guidelines. Thus, no residual effects from winter 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; Metal Leaching and Acid Rock Drainage 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 the TIA (Goose Property Area), WMFs (George Property Area), or collection pond (MLA) 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). During construction, all contact water will be monitored and treated to meet CCME guidelines in fish-bearing receiving environment. 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 all mine contact away from the freshwater environment. All mine contact water from runoff and inflow sources will be collected and directed to the TIA (Goose Property Area) and the WMFs (George Property Area) 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, and tailings stored in the TIA. The TIA has been designed as a zero discharge facility, ensuring no potentially poor-quality water will be introduced to the freshwater environment while in operation. The WMFs will discharge water that will meet MMER discharge criteria to the terrestrial environment and any discharged water will meet CCME criteria at the nearest fish bearing receiving waterbody (Project Description, Volume 2; Site Water Monitoring and Management Plan, Volume 10, Chapter 7). If necessary during the Reclamation and Closure and Post-closure phases, water will be discharged from the TIA and WMFs but any discharge would be treated to meet CCME water quality guidelines thus ensuring no negative effects to aquatic life (Project Description, Volume 2, Chapter 8; Mine Closure and Reclamation Plan; Volume 10, Chapter 29). 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 the source waterbody, with AEMP monitoring (Volume 10, Chapter 19) tracking potential changes to freshwater water quality. During summer, the limit to water drawdown will prevent water level in Goose Lake from decreasing more than 6 cm/day. During late winter, the limit to water drawdown will prevent water level from decreasing below 10 cm under ice (Volume 6, Chapter 1). Water withdrawal from Propeller Lake has been designed to avoid effects on critical fish habitat. Maximum withdrawal for Propeller Lake was set at 10% of the outflow volume, below the maximum permissible withdrawal volume to protect fish habitat (Fisheries and Oceans Canada 2009, 2010). Withdrawals from Propeller Lake are anticipated to occur during the Operations and the Reclamation and Closure phases. A maximum of 1,510 m^3/day of water will be withdrawn during most of the year with an increase to 2,510 m^3/day during freshet in June. Maximum withdrawal for George Lake was set at 10% of the outflow volume, below the maximum permissible withdrawal volume for the protection of critical fish habitat (Fisheries and Oceans Canada 2009, 2010). During the Site Preparation, Construction, Operations, and Closure and Reclamation phases, the maximum water withdrawals from George Lake were limited to 45 m^3/day for domestic use, and 70 m^3/day for industrial use. This anticipated reductions in water level in Goose, George, and Propeller lakes in both summer and winter are considered negligible and 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 to be less than the 10% of the outflow volumes of the source waterbodies. At this maximum limit, the water level of Goose Lake is expected to decrease, but remain within the range of natural variation. During summer, the limit to water drawdown will prevent water level from decreasing more than 6 cm/day and no effects on the VEC freshwater water quality would be predicted at those withdrawal levels.

Proposed water withdrawals during the Operations Phase from Goose Lake may reduce the volume in the Goose Outflow Stream by up to 21% (Volume 6, Chapter 1). Stream flows can vary more than 10-fold over a season (Volume 6, Chapter 1), and can vary substantially in response to precipitation events in summer. Therefore, the peak reduction in flow in Goose Outflow was predicted to be within the natural variation of the hydrograph. 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 (Metal Leaching and Acid Rock Drainage 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 will be diverted 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 (Site Preparation and Construction phases) or diverted to the TIA/WMFs (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).

No effects were predicted from the storage, manufacture, and transport of explosives during all phases of the Project because of the mitigation and management measures. 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. However, 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.

Due to the mitigation and management measures, including the monitoring and management plans, no residual effects from explosives in runoff were predicted 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. Hence, there are no anticipated residual effects from the use, storage, and transportation of explosives on the VEC freshwater water quality.

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 (TIA, WMFs, or MLA collection pond) and will not be discharged into the freshwater environment. Prior to the completion of the water management infrastructure during the Site Preparation and Construction phases, 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. No sewage effluent will be discharged to the freshwater environment during any phase of the Project (Landfill and Waste Management Plan; Volume 10, Chapter 10 of the DEIS). Instead, treated sewage effluent will be discharged on-land at approved sites at Goose and George Properties and the MLA. 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. Three of these potential effects were identified as residual effects: 1) *Site preparation, construction, and decommissioning activities*; 2) *site contact water*; and 3) *mine contact water*. 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 Site Preparation, Construction, and Decommissioning Activities

The mitigation and management measures were predicted to be effective and minimize potential effects from runoff associated with site preparation, 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 (Metal Leaching and Acid Rock Drainage Management Plan; Volume 10, Chapter 22). The proposed mitigation and management measures will minimize the quantity of material transported in runoff (e.g., TSS, metals) and the likelihood of runoff reaching the freshwater environment. Some runoff into nearby waterbodies could be possible during the early stages of site preparation and construction (Site Preparation and Construction phases) before water management structures are fully operational (e.g., TIA, WMFs, 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.

Residual effects from site preparation, construction, and decommissioning activities are predicted on the VEC freshwater water quality during the Site Preparation and Construction phases 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 site preparation, 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 site preparation, 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. Therefore, the effects on the VEC freshwater water quality from site preparation, 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 site preparation, 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. However, Project activities will occur when the site water management infrastructure is not functional (e.g., before commissioning during the Site Preparation and Construction phases). 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 Site Preparation and Construction phases 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 Site Preparation and Construction 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 Site Preparation and Construction phases, 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. The effects on mine contact water on freshwater water quality were predicted to be negligible because of the diversion of all mine contact water, including runoff from WRSAs, to the water management structures. Therefore, no residual effects from mine contact water are predicted on the VEC freshwater water quality during the Operation Phase.

However, Project activities will occur when the site water management infrastructure is not functional (e.g., before commissioning during the Site Preparation and Construction phases and after decommissioning in the Reclamation and Closure and Post-closure phases). Some interaction with 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 Site Preparation and Construction phases when the water management features are in the process of being constructed and commissioned, and possibly during the Reclamation and Closure phase. The current site water management and closure plans are conceptual and will be further developed with the Feasibility Study. Assessments supporting FEIS may necessitate both quantitative (such as modelling) and qualitative predictions.

Mine contact water may interact with the freshwater environment during the Site Preparation, Construction, and Reclamation and Closure phases. Mine contact water will be monitored and managed, and treated if necessary, to ensure it will meet MMER discharge limits if applicable and CCME guidelines once water enters fish-bearing receiving environments (Project Description, Volume 2, Chapter 8; Mine Closure and Reclamation Plan; Volume 10, Chapter 29). Water quality indicators will therefore be 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), *medium-term* in duration, and *sporadic* as runoff or discharge 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 *medium* because of the quantitative input from the baseline environmental data and the confidence in the mitigation and management strategies.

The residual effect of mine contact water on the VEC freshwater water quality is predicted to be **Not Significant**.

4.5.5 Significance of Residual Effects

Three residual effects for the VEC freshwater water quality were assessed and resulted in the following significance ratings:

- site preparation, construction, and decommissioning activities – rated Not Significant;
- site contact water – rated Not Significant; and
- mine contact water – 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 4.5-7.

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 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.

Table 4.5-7. 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
Site Preparation, Construction, and Decommissioning Activities	Site Preparation, Construction	Negative	Low	Short-term	Sporadic	Local	Reversible	Moderate	Medium	Not Significant
Site Contact Water	Site Preparation, Construction	Negative	Low	Short-term	Sporadic	Local	Reversible	Moderate	Medium	Not Significant
Mine Contact Water	Site Preparation, Construction, Reclamation and Closure, and Post-closure	Negative	Low	Medium-term	Sporadic	Local	Reversible	Moderate	Medium	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 2013), a longer timeline than the development and operations phases of the Project were considered.

The following periods were identified and evaluated as the temporal boundary for the CEA for freshwater water quality:

- Past — The year 2001 was selected as the historical temporal boundary, representing a time when rigorous baseline studies and activities first occurred in the CEA study areas. Effects of past activities were captured in baseline studies.
- Existing — Projects and activities undergoing construction or operating concurrently with the Back River Project.
- Foreseeable Future — The future temporal boundary for cumulative effects on freshwater water quality was determined to be a function of the expected resiliency of the freshwater environment with respect to residual Project effects. All residual effects were predicted to be short-term (< 5 years) in duration except the residual effect of dust deposition that were predicted to be medium-term (< 20 years). Therefore, the future temporal boundary for the cumulative effects assessment was set at 20 years.

4.6.2 Potential Interactions of Residual Effects with Other Projects

The following residual Projects effects on freshwater water quality were identified:

- Site preparation, construction, and decommissioning activities;
- Site contact water; and
- Mine contact water.

The spatial boundary of the CEA is the freshwater water quality RSA (see Section 4.4.1). The temporal boundary for the CEA is any past, present, or reasonably foreseeable future projects (see list of projects in Volume 9, Chapter 1). The only project that could interact with the Back River Project freshwater water quality residual effects is the proposed Bathurst Inlet Port and Road project. There is no predicted spatial overlap between the Project residual effects that were confined to the freshwater water quality LSA and any potential effects from the Bathurst Inlet Port and Road Project, which would be confined to the proposed road corridor in the far northwestern portion of the George Property RSA (Figure 4.4-1). Therefore, no potential cumulative effects on the VEC freshwater water quality were predicted.

4.7 TRANSBOUNDARY EFFECTS

All residual Project effects to freshwater quality were confined to the LSA, which lies entirely within Nunavut; therefore, no transboundary residual effects from Project activities on the VEC freshwater water quality were predicted.

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 DEIS, and detailed in the following plans:

- Site Water Monitoring and Management Plan (Volume 10, Chapter 7);
- Fuel Management Plan (Volume 10, Chapter 4);
- Spill Contingency Plan (Volume 10, Chapter 5);
- Ore Storage Plan (Volume 10, Chapter 8);
- Mine Waste Rock and Tailings Management Plan (Volume 10, Chapter 9);
- Landfill and 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);
- Metal Leaching and Acid Rock Drainage 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 TIA (Goose Property Area), Water Management Facility (George Property Area), or collection pond (MLA).
	Infrastructure and waste rock storage areas at the George Property have been confined to the local watersheds where the deposits are located, thereby confining potential influences 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 TIA has been designed as a zero discharge facility, ensuring no potentially poor quality water is introduced 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 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 license.
	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 4.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Water 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. Modern incineration equipment will be installed to minimize airborne contaminant loading of polycyclic aromatic hydrocarbons.
	Culvert maintenance will be conducted following the DFO Nunavut Operational Statement for Culvert Maintenance (DFO Nunavut Operational Statement: Culvert Maintenance, version 3.0 (2007)).
	Instream work will be conducted during approved timing windows presented in the DFO Nunavut Operational Statement for Timing Windows. (DFO Nunavut Operational Statement: Timing Windows, version 3.0 (2007)).
	Site road crossings will be constructed according to the DFO Nunavut Operational Statement for Clear Span Bridges (DFO Nunavut Operational Statement: Clear Span Bridges, version 3.0 (2007)).
	Temporary stream crossings will be constructed according to the DFO Nunavut Operational Statement for Temporary Stream Crossings (DFO Nunavut Operational Statement: Temporary Stream Crossing, version 1.0 (2007)).
	Winter road construction will follow the DFO Nunavut Operational Statement for Ice Bridges and Snow Fills (DFO Nunavut Operational Statement: Ice Bridges and Snow Fills, version 3.0 (2007)).
	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 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 TIA (Goose Property Area), Water Management Facilities (George Property Area), or collection pond (MLA).
	Sewage will be treated, and treated sewage effluent will be discharged to the tundra.
	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.

(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 *(cont'd)*	
	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 TIA 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 well away 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. Vehicular access across a watercourse or waterbody will be by road or bridge, or other acceptable method according to DFO Operational Statements and Standards and Best Practices for Instream Works. 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 License) 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.

(continued)

Table 4.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Water Quality (completed)

Mitigation Category	Mitigation Measures
5. Monitoring	
	An Aquatic Effects Monitoring 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 and George Properties 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 License. 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 Conceptual 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;
- the Aquatic Effects Monitoring Program (AEMP; Volume 10, Chapter 19); 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: site preparation, construction, and decommissioning activities; winter 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. Three residual effects were identified after mitigation and management:

- site preparation;
- site contact water; and
- mine contact water.

Using the thresholds identified for the key indicators, each of these residual effects were rated with *low* magnitude and ultimately were rated as Not Significant because of 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 many other management plans in Volume 10. All residual effects to freshwater water quality were predicted to be restricted to the LSA. Residual effects are expected to be reversible with water quality returning to baseline conditions because of the resiliency of the freshwater environment to the predicted residual Project effects.

No interactions between other projects and the Back River Project freshwater water quality residual effects were expected and no cumulative effects were predicted to occur.

4.11 SUPPORTING AND SUPPLEMENTAL INFORMATION

This section provides information requested in the EIS guidelines (NIRB 2013) 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 2013).

4.11.1 Drinking Water Baseline

The current Project Description includes the drinking water sources for the Project (Table 4.11-1; Volume 2). The existing exploration camps are currently using Goose and George lakes as potable water sources, and have not experienced any drinking water quality issues with these sources. Current water quality data are available for Goose and George 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 would come from a desalination unit using Bathurst Inlet water. The desalinization plant will be operated according 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
George Property Area	George Lake
Marine Laydown Area	Bathurst Inlet (desalinated water)

All available water quality baseline data for George (n = 113) and Goose (n = 126) lakes 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, 2013c).

The mean baseline concentrations of all guideline metals were below the Canadian drinking water quality guidelines (Table 4.11-2). Only the 95th percentile of baseline concentrations of aluminum and iron at George Lake were greater than Health Canada's drinking water quality guidelines. All other metal concentrations were below the guidelines. High concentrations of aluminum and iron in George Lake are natural occurrences. The guideline for aluminum is an operational guideline for the use of aluminum salts as a coagulation agent for drinking water treatment and not a health-based concentration. Health Canada comments that the current weight of evidence does not indicate negative health effects at aluminum levels found in drinking water. The guideline for iron is an aesthetic objective based on taste and staining, but no evidence exists of dietary iron toxicity in the general population. Therefore, the drinking water sources that are currently being used for exploration activities 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

Metals	Drinking Water Guidelines[1] (mg/L)	Detection Limits (mg/L)	George Lake[2]		Goose 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)
Aluminum	0.1	0.003-0.02	0.0445	0.207	0.0236	0.0694
Antimony	0.006	0.00005-0.002	<0.002	<0.002	<0.002	<0.002
Arsenic	0.010	0.00005-0.0004	<0.0004	0.000603	<0.0004	<0.0004
Barium	1	0.00005	0.00332	0.00563	0.00808	0.0137
Beryllium	-	0.00001-0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Bismuth	-	0.0005-0.002	<0.002	0.00230	<0.002	<0.002
Boron	5	0.005	0.0121	0.0328	0.00606	0.0151
Cadmium	0.005	0.00001	0.0000106	0.0000300	<0.00001	0.0000273
Calcium	-	0.02	6.34	11.6	3.89	6.50
Chromium	0.05	0.0001-0.0005	<0.0005	0.00163	<0.0005	0.000730
Cobalt	-	0.0001-0.0004	0.000637	0.00136	<0.0004	<0.0004
Copper	1	0.0001-0.0005	0.00190	0.00275	0.00203	0.00375
Iron	0.3	0.01	0.0683	0.337	0.0340	0.0703
Lead	0.010	0.00005-0.0003	0.000425	0.00129	<0.0003	0.000421
Lithium	-	0.005	<0.005	<0.005	<0.005	<0.005
Magnesium	-	0.005	2.36	3.84	1.81	2.91
Manganese	0.05	0.00005	0.0122	0.0314	0.00394	0.00876
Mercury	0.001	0.00001-0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum	-	0.00005-0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Nickel	-	0.001	0.00475	0.00811	0.00494	0.00792
Phosphorus	-	0.3	0.00624	<0.3	0.00485	0.150
Potassium	-	0.05	0.472	0.760	0.452	0.685
Selenium	0.01	0.00005-0.0002	<0.0002	0.000310	<0.0002	0.000213
Silver	-	0.00001	<0.00001	0.0000125	<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)	George Lake[2]		Goose 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	0.997	1.67	0.855	1.28
Strontium	-	0.0001-0.0002	0.0232	0.0420	0.0210	0.0363
Thallium	-	0.00005-0.003	<0.003	<0.003	<0.003	<0.003
Tin	-	0.0001-0.002	<0.002	0.00241	<0.002	<0.002
Titanium	-	0.0003-0.01	<0.01	<0.01	<0.01	<0.01
TSS	-	3-4	<4	<4	<4	<4
Uranium	0.02	0.00001	<0.00001	<0.00001	<0.00001	0.0000110
Vanadium	-	0.00005	0.000243	0.000538	0.000190	0.000500
Zinc	5	0.001-0.003	0.00698	0.0224	<0.003	0.00485

Notes:
[1] Health Canada (2012). Guidelines for Canadian Drinking Water Quality Summary Table. Maximum acceptable concentrations and other values.
[2] George Lake sites (n = 15): Centre, North and South.
[3] Goose Lake sites (n = 26): Camp, Centre, Neck, South, Tail New, Tail Old.
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

Rescan™
an ERM company

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 in the west Kitmeot region of Nunavut in the continuous permafrost zone of the continental Canadian Arctic. It is composed of three main areas, the Goose Property Area, the George Property Area, and the Marine Laydown Area (MLA; Figure 5.1-1). All areas would be connected by winter roads. All proposed infrastructure at the Goose Property lies within the Ellis River Watershed. The Ellis River Watershed flows to the northwest and enters the ocean on the west side of Bathurst Inlet (see Federal Watershed map in Chapter 1 of this Volume). The Back River Watershed lies south of the proposed infrastructure, in the Goose Property Area, and flows to the east, eventually entering the Arctic Ocean south of Gjoa Haven. Lakes and streams in the George Property Area drain into the Western River Watershed that flows north and enters Bathurst Inlet at its southernmost point.

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 because of negligible groundwater reserves outside of the permafrost and a lack of unfrozen surface water. 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 temperature 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).

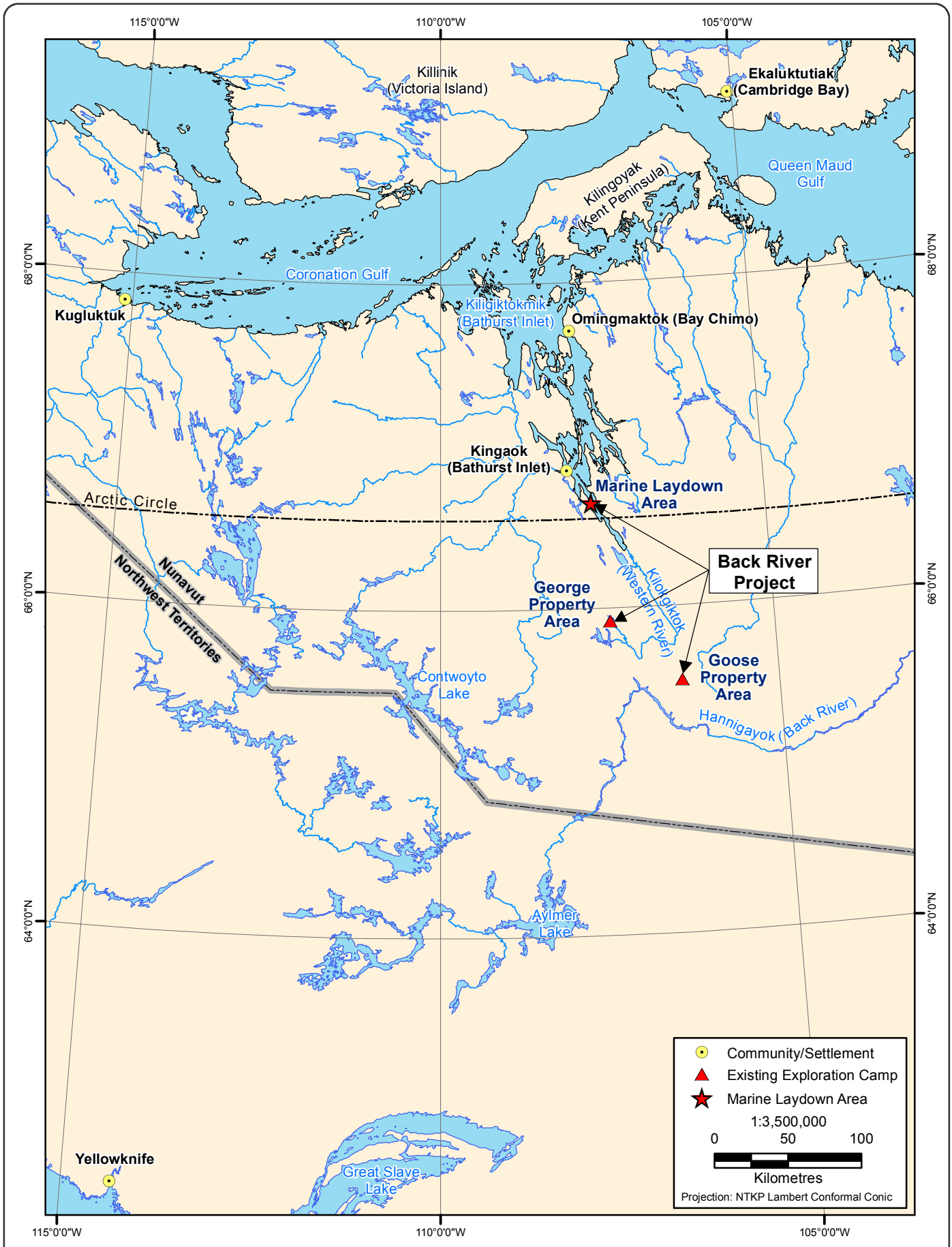


Figure 5.1-1

Project Location

Sabina GOLD & SILVER CORP.

Rescan an ERM company

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 special designation for the region surrounding the George and Goose Property areas, but the caribou calving grounds in the region have been designated PSE-R2 (Nunavut Planning Commission 2012). The proposed Hiukitak River Cultural Area is on the eastern shore of Bathurst Inlet, 40 km east of Kingaok, 60 km northeast of the proposed MLA, and 140 km north of the George Property Area.

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 2013, with the most continuous sampling conducted by Rescan from 2010 to 2013. Baseline studies in 2007, 2012, and 2013 gathered data from both the George and Goose Local Study Areas (LSA), whereas the 2010 and 2011 programs focused on the Goose LSA. Sampling conducted near the MLA is covered in the Marine Environment volume (Volume 7). Figures 5.1-2 and 5.1-3 show the Goose Property and George Property LSAs 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 DEIS 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).

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 30 lakes at 39 lake stations between 2007 and 2013 (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 Figures 5.1-2 (Goose LSA) and 5.1-3 (George LSA).

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

Year	2007	2010	2011	2012	2013
Sampling month	August	August	August	August	July
Sampling agency	Gartner Lee Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.
Sampling method	Ekman grab	Ekman grab	Ekman grab	Ekman grab	Ekman grab
Analytical lab	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
Lakes sampled	*Goose Property Area* Goose Lake *George Property Area* Fold Lake Bob Lake Lytle Lake Occurrence Lake*	*Goose Property Area* Llama Lake Umwelt Lake Chair Lake Mam Lake Reference B Lake	*Goose Property Area* Llama Lake Umwelt Lake Giraffe Lake Goose Lake Propeller Lake Reference B Lake	*Goose Property Area* Giraffe Lake Rabbit Lake Fox Lake Echo Lake Rascal Lake Goose Lake Propeller Lake Pond 19 Big Lake Del Lake *George Property Area* Fold Lake George Lake Lytle Lake Occurrence Lake Sleigh Lake Dragon Lake Komatic Lake Lower Long Lake Reference C Lake	*Goose Property Area* Wasp Lake Leaf Lake Giraffe Lake Umwelt Lake Rascal Lake Goose Lake Propeller Lake Reference B Lake *George Property Area* George Lake Bob Lake Occurrence Lake Esker Pond Dragon Lake Komatic Lake McCoy Lake Reference Q Lake
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
Composition of a single replicate	composite of three pooled grabs	single grab	composite of two pooled grabs	single grab	single grab

* *Sample collected from shore*

PROJECT #0194096-0040 GIS # BAC-01-067a October 28 2013

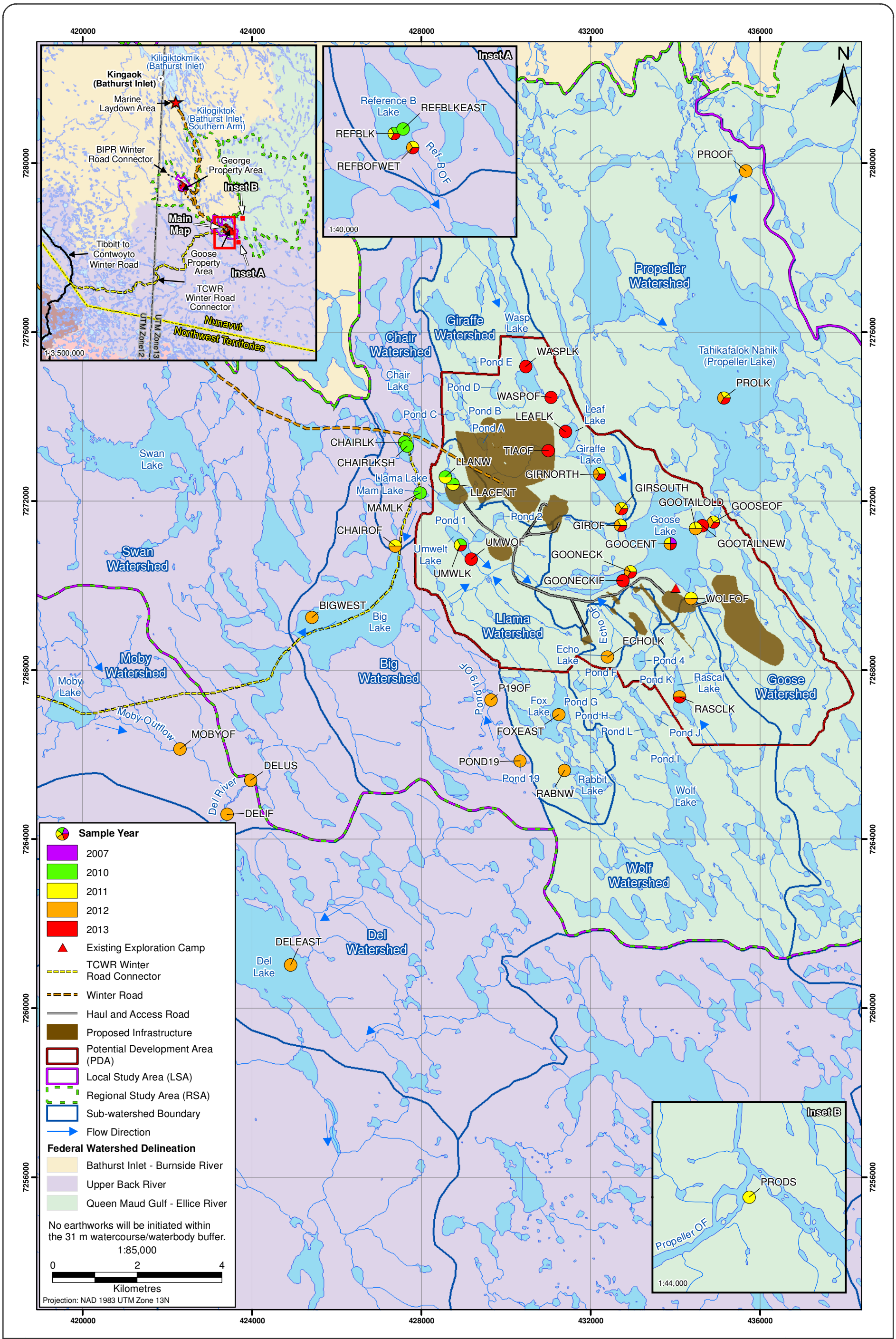


Figure 5.1-2

Sabina GOLD & SILVER CORP.

Locations of Baseline Lake and Stream Sediment Quality, Goose Property Area, 2007 to 2013

Figure 5.1-2

Rescan an ERM company

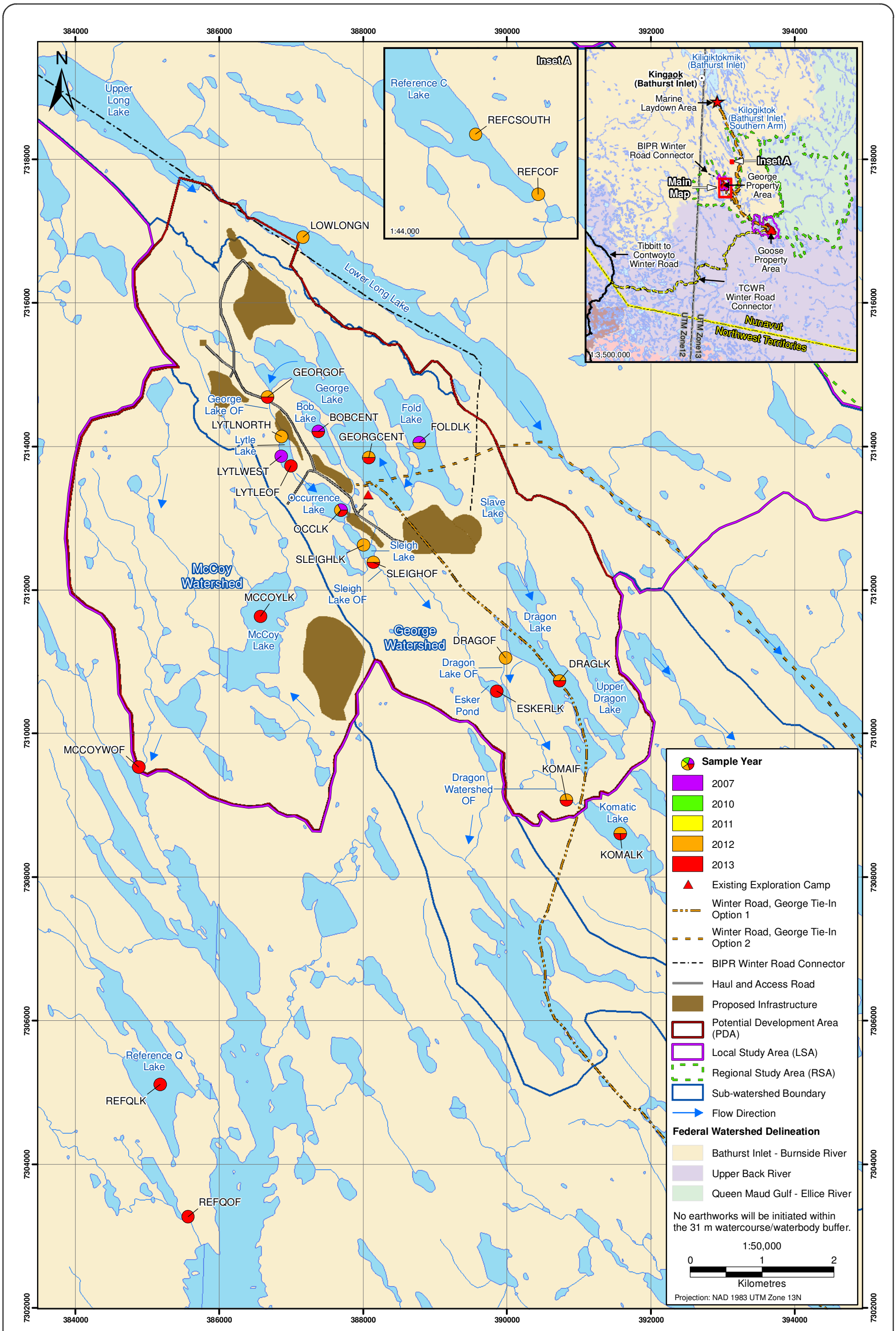


Figure 5.1-3

Sabina GOLD & SILVER CORP.

Locations of Baseline Lake and Stream Sediment Quality, George Property Area, 2007 to 2013

Figure 5.1-3

Rescan an ERM company

Streams

Baseline sediment quality data were collected from 23 streams between 2011 and 2013 (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 Figures 5.1-2 (Goose LSA) and 5.1-3 (George LSA).

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

Year	2011	2012	2013
Sampling month	August	August	July
Sampling agency	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.	Rescan Environmental Services Ltd.
Sampling method	Bowl and spoon	Bowl and spoon	Bowl and spoon
Analytical lab	ALS Environmental	ALS Environmental	ALS Environmental
Data collected	Chemistry and particle size	Chemistry and particle size	Chemistry and particle size
Streams sampled	*Goose Property Area* Giraffe OF Wolf OF Goose OF Propeller D/S Chair OF Reference B OF	*Goose Property Area* Giraffe OF Wolf OF Goose OF Propeller OF Chair OF Pond 19 OF Del US Moby OF Del IF Reference B OF *George Property Area* George OF Sleigh OF Dragon OF Dragon Watershed OF Reference C OF	*Goose Property Area* Wasp OF Giraffe IF Giraffe OF Umwelt OF Goose Neck IF Goose OF Reference B OF *George Property Area* George OF Lytle OF Sleigh OF Dragon Watershed OF McCoy Watershed OF Reference Q OF
Number of replicates per site	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

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: 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 2013). 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 small, due to the relatively low flux of material from the landscape into the freshwater environment. Estimates for sedimentation rates range 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 24 sites in the Goose LSA and nine lake sites in the George LSA between 2007 to 2013 (Table 5.1-1). Lake sediments collected from the Goose LSA were mainly comprised of silt or sand, with a combined mean of 90% silt and sand. Pond 19 sediments in the Goose LSA had the greatest levels of coarser material, with a mean gravel content of 18% (Rescan 2013a). Similarly, the lake sediments collected from the George LSA were mainly comprised of silt or sand, with a combined mean of 89% silt and sand (Table 5.1-3).

Table 5.1-3. Summary of Lake Sediment Particle Size Composition in the Goose and George LSA, 2007 to 2013

	Min	Mean	Max
Goose (n = 130)			
% Gravel	0.05	1.4	23
% Sand	0.64	27	95
% Silt	2.3	62	92
% Clay	0.11	9.0	75
George (n = 58)			
% Gravel	0.05	1.5	26
% Sand	0.17	33	97
% Silt	0.64	68	91
% Clay	0.24	9.4	21

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.

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. Total organic carbon (TOC) tended to be greater in sediments in the Goose LSA lakes than the George LSA lakes (Table 5.1-4). Mean TOC in baseline lake sediment samples from the Goose LSA ranged from 0.27% to 15.2%, 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). Mean total organic carbon (TOC) in baseline lake sediment samples from the George LSA ranged from 0.2% to 8.2%, with the three lowest mean values occurring at Bob, Komatic and McCoy lakes, which had the lowest proportion of silt in their sediments (Rescan 2013a, 2013b).

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

	Min	Mean	Max
Goose (n = 156)			
TOC (%)	0.27	6.2	15.2
George (n = 54)			
TOC (%)	0.18	3.7	8.2

Note: This table used all available sediment quality data. Where data was < DL, 0.5×DL was used to calculate metrics.

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, 2013). 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.

Goose LSA

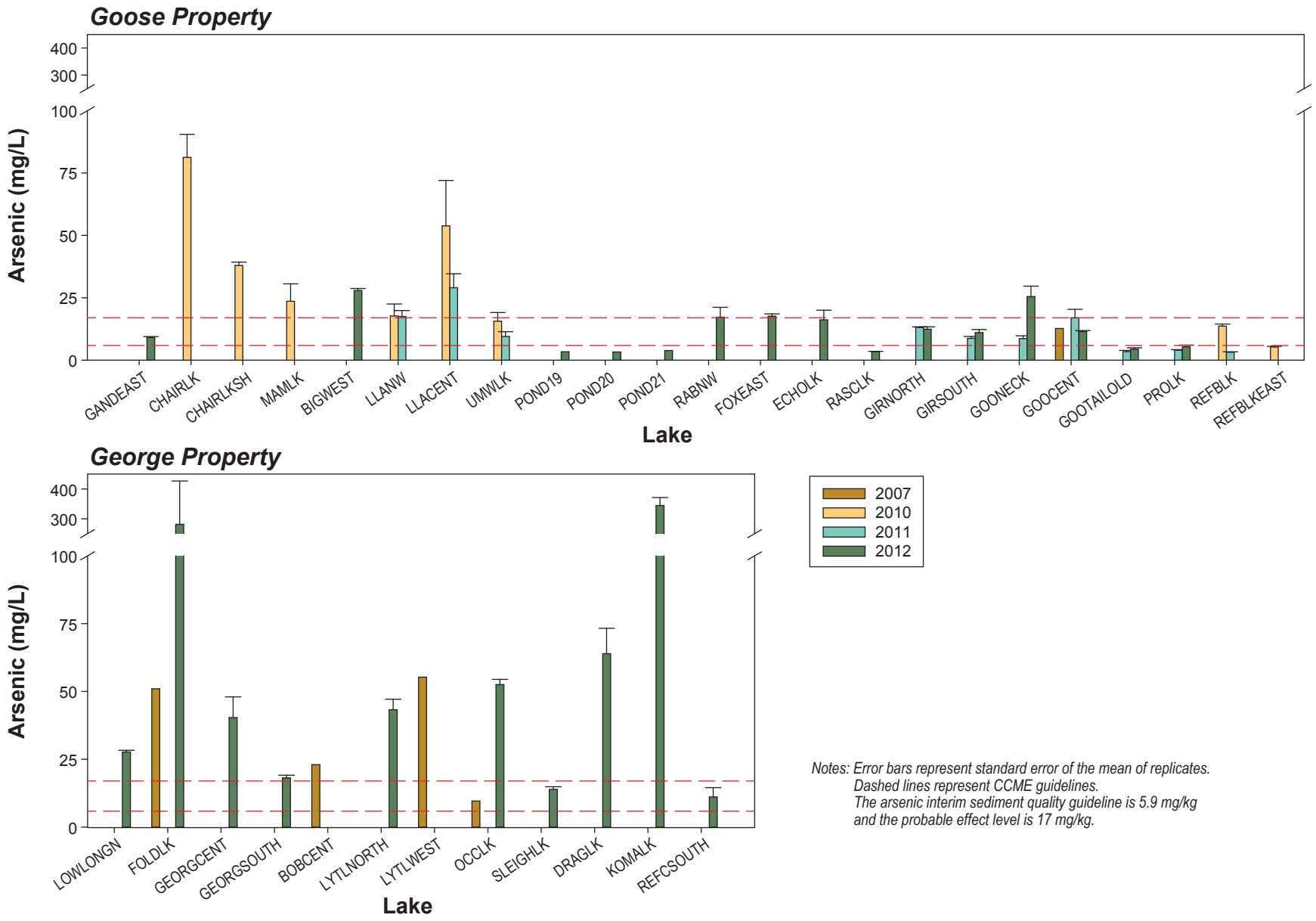
Table 5.1-5 presents a summary of the total metal concentrations with CCME guidelines in the sediments of the Goose LSA lakes surveyed between 2010 and 2013. Metals data from 2007 were not used due to high analytical detection limits.

Table 5.1-5. Summary of Lake Sediment Metal Concentrations in the Goose 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 < 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 2013).*

Goose LSA lake sediment samples had naturally elevated baseline metal concentrations, and concentrations were frequently greater than CCME guidelines for arsenic and copper and occasionally for cadmium, chromium, and zinc (Tables 5.1-5 and 5.1-6). Generally, mean metal concentrations were greater and were more frequently greater than guideline levels in the Goose LSA lake sediments than in George LSA lake sediments. Of the 129 historical and baseline samples collected from the Goose SLA area, 46% had arsenic concentrations greater than the CCME ISQG and 31% had concentrations greater than the CCME PEL (Figure 5.1-4). 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 Goose LSA lakes 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.



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 5.1-4

Sabina GOLD & SILVER CORP.

Sediment Arsenic Concentrations in Goose and George Property Area Lakes, Back River Project, 2007 to 2012

Figure 5.1-4

Rescan™ Engineers & Scientists

Table 5.1-6. Goose 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 2013).*

George LSA

Table 5.1-7 presents a summary of the total metal concentrations in the sediments of the George LSA lakes surveyed between 2010 and 2013. Metals data from 2007 were not used due to high analytical detection limits.

Table 5.1-7. Summary of Lake Sediment Metal Concentrations in the George LSA, 2010 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	4.4	17	1,050	87	11
Cadmium	0.025	0.39	1.3	20	0
Chromium	26	53	130	65	11
Copper	7.0	86	190	83	0
Lead	1.7	7.2	12	0	0
Mercury	0.0025	0.036	0.10	0	0
Zinc	31	140	470	54	6

Note: This table excluded the 2007 metals data, which had higher detection limits than the 2010 to 2013 data. Where data was < DL, 0.5 DL was used to calculate metrics. 54 samples were included in the analysis.
** CCME Sediment Quality Guidelines for the Protection of Aquatic Life (CCME 2013).*

Like lakes in the Goose LSA, George LSA lake sediments had naturally elevated metal concentrations that were often greater than the CCME ISQG for arsenic, cadmium, chromium, copper and zinc (Tables 5.1-7 and 5.1-8). Of the 54 historical and baseline samples collected from the George LSA, only one replicate at Reference C Lake was less than the arsenic ISQG (Table 5.1-8). Arsenic concentrations in 87% of samples were greater than the CCME PEL, with the mean at Komatic Lake (497 mg/kg) more than 29 times the CCME PEL (Figure 5.1-4; Rescan 2013a, 2013b). Chromium was the only other metal where observed mean sediment concentrations were greater than the PEL (2012 – Occurrence Lake; Rescan 2013a). Most George LSA lakes had mean sediment copper concentrations that were greater than CCME ISQG, and some lakes had sediments with mean metal concentrations that were greater than the cadmium, chromium and zinc CCME ISQG (Table 5.1-8). Seven lakes in the George LSA had sediments with metal concentrations greater than the CCME guidelines for at least four different metals and Komatic and McCoy lakes had concentrations greater than guidelines for five metals (As, Cd, Cr, Cu, and Zn; Rescan 2013a, 2013b).

Table 5.1-8. George 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*
Fold Lake	silt	As, Cr, Cu	As
George Lake	sand; silt	As, Cr, Cu	As
Bob Lake	silt	As, Cd, Cu, Zn	As
Lytle Lake	silt	As, Cr, Cu, Zn	As
Occurrence Lake	sand (2007); silt (2012, 2013)	As, Cr, Cu, Zn	As
Sleigh Lake	sand	As	Cr
Dragon Lake	silt	As, Cr, Cu, Zn	As
Esker Pond	silt	As, Cr, Cu, Zn	As
Komatic Lake	silt	As, Cd, Cr, Cu, Zn	As
McCoy Lake	silt	As, Cd, Cr, Cu, Zn	As
Long Lake	silt	As, Cr, Cu	As
Reference Q Lake	silt	As, Cu	As, Zn
Reference C Lake	silt	As, Cu	-

Note: This table excluded the 2007 metals data, which had higher detection limits than the 2010 to 2013 data. Where data was < DL, 0.5 DL was used to calculate metrics. 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.
** CCME Sediment Quality Guidelines for the Protection of Aquatic Life (CCME 2013).*

5.1.6 Stream Physical and Chemical Sediment Quality Characteristics

5.1.6.1 Stream Sediment Composition

Baseline sediment quality samples were collected from 16 stream sites in the Goose LSA and eight stream sites in the George LSA in 2011, 2012, and 2013 (Table 5.1-2). Stream sediments at both Properties were mainly comprised of sand (43-53%), with small proportions of gravel- and silt-sized particles (22-29%), and smaller proportions of clay (<5%; Table 5.1-9). Slightly greater proportions of sand were found in the Goose LSA streams (53%) than in George LSA streams (43%), while greater levels of silt (29%) were observed at the George LSA streams than the Goose LSA streams (22%).

Table 5.1-9. Summary of Stream Sediment Particle Size Compositions in the Goose and George LSA, 2011 to 2013

	Min	Mean	Max
Goose (n = 65)			
% Gravel	0.05	23	77
% Sand	1.4	53	93
% Silt	0.05	22	91
% Clay	0.05	2.6	19
George (n = 31)			
% Gravel	0.05	24	97
% Sand	1.4	43	98
% Silt	0.05	29	88
% Clay	0.05	4.1	15

Note: This table used all available sediment quality data. Where data was < DL, 0.5 DL was used to calculate metrics.

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 Goose LSA stream sediments ranged from 0.05 to 29%, with the greatest percentage occurring in Reference B Outflow sampling site (Table 5.1-10; Rescan 2012a, 2013a). Mean TOC in George LSA stream sediments ranged from 0.11% to 19%. George Outflow, Lytle Outflow, Reference Lake Q Outflow and McCoy Watershed OF all had elevated TOC concentrations (>12%; Rescan 2013a, 2013b).

Table 5.1-10. Summary of Stream Sediment Total Organic Carbon Concentrations in the Goose and George LSA, 2011 to 2013

	Min	Mean	Max
Goose (n = 65)			
TOC (%)	0.05	6.1	29
George (n = 31)			
TOC (%)	0.11	5.0	19

Note: This table used all available sediment quality data. Where data was < DL, 0.5 DL was used to calculate metrics.

Substantial annual variation in sediment organic carbon concentration was 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

Goose LSA

Goose 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 Goose LSA were occasionally greater than CCME

guidelines for arsenic, copper, and zinc, and infrequently for chromium and cadmium (Table 5.1-11 and Table 5.1-12). Mean arsenic concentrations in sediments were greater than the CCME ISQG at eight of the 16 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 Reference B Outflow sediment (Table 5.1-12; Rescan 2012a, 2013a).

Table 5.1-11. Summary of Stream Sediment Metals Concentrations in the Goose 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 2013).*

Table 5.1-12. Goose 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 2013).*

George LSA

George LSA stream sediments had naturally elevated metal concentrations that were often greater than the CCME sediment quality guidelines for arsenic, chromium and copper, and occasionally for zinc (Table 5.1-13). Arsenic concentrations at all streams sampled in the George LSA were greater than the CCME ISQG, and were greater than the CCME PEL at George, McCoy Watershed, and Dragon outflows by a factor of 3.4, 2.0, and 2.1, respectively (Rescan 2013a, 2013b). No other metal had mean concentrations greater than the CCME PEL in any stream. Elevated sediment chromium concentrations were more prevalent in the George LSA than in the Goose LSA. Mean chromium concentrations were greater than the CCME ISQG at the Sleigh Outflow, Dragon Outflow and Komatic Inflow sites, whereas

copper concentrations at the George Outflow site were greater than the CCME ISQG (Table 5.1-14). The Lytle OF site had the greatest number of metals with sediment concentrations greater than CCME sediment quality guidelines (Rescan 2013a, 2013b).

Table 5.1-13. Summary of Stream Sediment Metal Concentrations in the George 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	1.4	26	97	91	55
Cadmium	0.025	0.16	0.74	3	0
Chromium	14	47	68	68	0
Copper	4.3	45	130	36	0
Lead	1.6	4.5	11	0	0
Mercury	0.0025	0.024	0.085	0	0
Zinc	14	73	170	19	0

Note: This table used all available sediment quality data. Where data was < DL, 0.5 DL was used to calculate metrics. 31 samples were included in the analysis.
** CCME sediment quality guidelines for the protection of aquatic life (CCME 2013).*

Table 5.1-14. George LSA Streams with Sediment Metal Concentrations Greater than CCME Sediment Quality Guidelines, 2010 to 2013

Stream	Dominant Particle Type	Metals Greater than ISQG*	Metals Greater than PEL*
George OF	silt	As, Cu	As
Lytle OF	silt	As, Cr, Cu, Zn	As
Sleigh OF	sand	As, Cr	-
Dragon OF	gravel and sand	As, Cr	As
Komatic IF	sand	As, Cr	-
McCoy OF	gravel	As, Cr, Cu	As
Reference Q OF	gravel	As, Cr, 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 2013).*

5.2 INCORPORATION OF TRADITIONAL KNOWLEDGE (TK)

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 DEIS). 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 2013) 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 DEIS.

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 in 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).

5.4.1 Spatial Boundaries

The spatial boundaries used for the assessment of the VEC freshwater sediment quality included a LSA for each of the Goose and George Properties and a larger RSA for both properties.

5.4.1.1 Local Study Area

The LSA included the Potential Development Area (PDA) for each property and delineates the area where there is the reasonable potential for direct effects due to Project activities on the VEC freshwater sediment quality. The LSA for the VEC freshwater sediment quality was divided into two areas:

1. The Goose Property LSA. The LSA boundary (365 km^2) includes the Goose Property PDA and matches the boundaries of the Propeller and Big watersheds (Figure 5.4-1); and
2. The George Property LSA. The LSA boundary (105 km^2) includes the George Property PDA, and matches the boundaries of the Dragon, George, McCoy, and Lower Long watersheds (Figure 5.4-1).

For each LSA, potential direct Project effects were predicted to occur within the immediate sub-watersheds where Project infrastructure and activities were proposed. Within each Property Area, the outer boundaries of these sub-watersheds then formed the continuous outer boundary for that LSA. This conservative delineation of the LSA was designed to capture all freshwater ecosystems where direct effects on the VEC freshwater sediment quality could be reasonably expected to occur due to Project activities.

The potential changes to the freshwater environment in the Goose Property Area and George Property Area were addressed in the freshwater sediment quality assessment. Potential effects related to the MLA are addressed in the Marine Environment Volume (Volume 7).

PROJECT #0194096-0002 GIS # BAC-01-053 December 16 2013

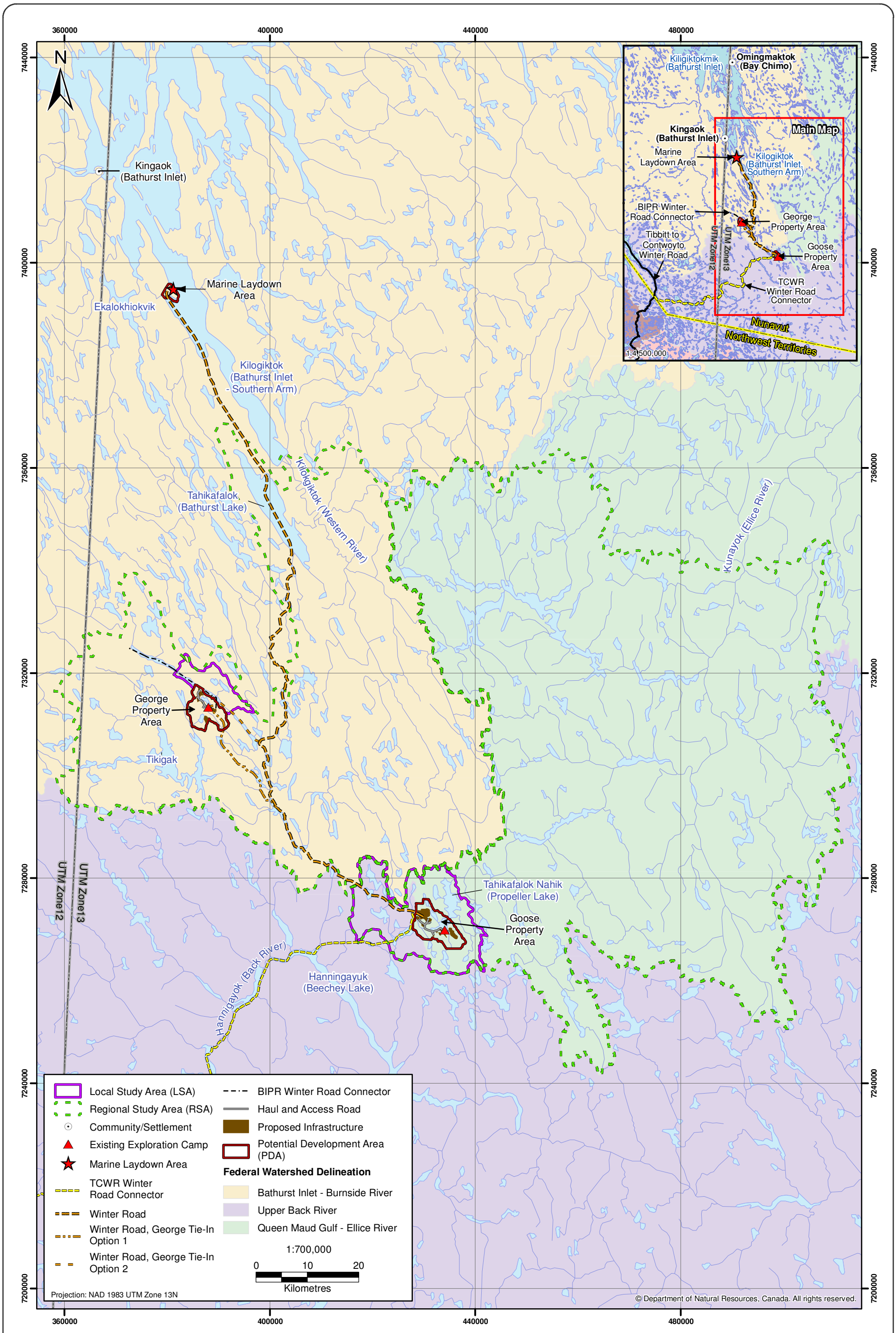


Figure 5.4-1

Sabina GOLD & SILVER CORP.

Local Study Area and Regional Study Area for Freshwater Sediment Quality

Figure 5.4-1

Rescan an ERM company

5.4.1.2 Regional Study Area

The RSA includes the PDA, the LSA, and additional areas within which there is the potential for indirect or cumulative effects from Project activities on the VEC freshwater sediment quality. Like the LSAs, there are two corresponding RSAs for each Property:

1. The Goose Property RSA. The RSA boundary (6,815 km^2) includes part of the Ellice River Watershed and encompasses the PDA and the LSA. All Project infrastructure resides within the Ellice Watershed. The upper ~80 km of the watershed was included rather than the entire watershed (Figure 5.4-1); and
2. The George Property RSA. The RSA boundary (4,034 km^2) includes part of the Western River Watershed and encompasses the PDA and LSA. All Project infrastructure resides within the Western River Watershed. The upper portion of the watershed that drains in to the Western River at the southern tip of Bathurst Inlet is included in the RSA (Figure 5.4-1).

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:

- Site Preparation: 2 years;
- Construction Phase: 2 years;
- Operations Phase: 10 years;
- Reclamation and Closure Phase: 10 years;
- Post-closure Phase: 3 years minimum;
- Other potential phases:
  - Temporary Closure: less than 2 years,
  - Care and Maintenance Phase: 2-10 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.

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, 2013). 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., copper), 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).

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*

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.

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 interact with the freshwater environment along a number of pathways and may change any of these indicators to outside of acceptable or 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 5.5-3. 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, 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 deposition	Runoff, deposition, discharge
Hydrocarbons	Petroleum hydrocarbon compounds	Contribute metals in runoff, discharge, and deposition	Runoff, 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 2013). 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
	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 2013)*	

[†] *CCME sediment quality guidelines for the protection of aquatic life (CCME 2013).*

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 2013) 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.

The majority of 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 *Site Preparation, 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:

- *Site Preparation, 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 Interaction Group							
Project Phase	**Project Activity**	**Site Preparation, Construction, Decommissioning Activities**	**Site Contact Water**	**Mine Contact Water**	**Quarries and Borrow Pits**	**Explosives**	**Fuels, Oils, and PAH**	**Treated Sewage Discharge**	**Dust Deposition**
Site Preparation 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						
	Chemical and hazardous material storage and management		X						
	Explosives storage and handling					X			
	Marine Laydown Area: on-land laydown areas and fuel storage						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
	TIA 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**	**Site Preparation, Construction, 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			
	Marine Laydown Area: Fuel storage and handling						X		
Reclamation and Closure	Open pits			X					
	Underground mines			X					
	TIA			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
Site preparation, construction, decommissioning activities	Runoff, discharge	particle size, nutrients, metals, hydrocarbons	Site Preparation, Construction, Operations, Reclamation and Closure
Site contact water	Runoff	particle size, nutrients, metals, hydrocarbons	Site Preparation, Construction, Operation, Temporary Closure, Care and Maintenance, Reclamation and Closure, Post-closure
Mine contact water	Runoff, discharge	particle size, nutrients, metals	Site Preparation, Construction, Operation, Temporary Closure, Care and Maintenance, Reclamation and Closure, Post-closure
Quarries and borrow pits	Runoff	particle size, nutrients, metals	Site Preparation and Construction
Explosives	Runoff, aerial deposition	nutrients, hydrocarbons	Site Preparation, Construction, Operations
Fuels, Oils, and PAH	Runoff, aerial deposition	particle size, hydrocarbons	Site Preparation, Construction, Operation, Reclamation and Closure
Treated Sewage Discharge	Discharge	nutrients, hydrocarbons	Site Preparation, Construction, Operations, Reclamation and Closure
Dust deposition	Aerial deposition	particle size and metals	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 Site Preparation, Construction, and Decommissioning Activities

Ground preparation for Project infrastructure, including buildings, roads, and mine works, would occur during the Site Preparation and Construction phases throughout the Potential Development Area (PDA) in the LSAs. Site preparation 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 site preparation activities would also include the construction of the water management infrastructure, such as ditches and berms, and earthworks for the Tailings Impoundment Area (TIA, Goose Property Area) and the Water Management Facilities (WMFs, George Property Area). 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 site preparation 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 Site Preparation 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 (Goose Property Area) and portions of Lytle and Occurrence lakes (George Property Area) 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. In addition, construction of the retention dykes for the dewatering activities at the George Property Area may increase the concentration of sediments through runoff and re-suspension.

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, and ore stockpiles, drilling fluids from ongoing exploration activities, mill process water, and water in the TIA. 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 will reach a maximum depth of 680 m, with a predicted maximum inflow of 10 L/s (Appendix V6-2A, this Volume). 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 Site Preparation, 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. 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, 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 Site Preparation, 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 PAH 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.

Combustible waste, including the solids from sewage treatment, will be combusted using an incinerator. Incomplete combustion can create hydrocarbons that can be deposited into freshwater environment via direct deposition or runoff from the landscape.

The potential effects from fuels and other hydrocarbons may occur during the Site Preparation, 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 the tundra. The pathway of interaction between treated sewage and the freshwater environment is, therefore, 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 the Site Preparation, Construction, Operations, and Reclamation and Closure 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:

- Fuel Management Plan (Volume 10, Chapter 4);
- Spill Contingency Plan (Volume 10, Chapter 5);
- Ore Storage Plan (Volume 10, Chapter 8);
- Mine Waste Rock and Tailings Management Plan (Volume 10, Chapter 9);
- Landfill and 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);
- Metal Leaching and Acid Rock Drainage Management Plan (Volume 10, Chapter 22); and
- Mine Closure and Reclamation Plan (Volume 10, Chapter 29).

5.5.3.1 Site Preparation, Construction, and Decommissioning Activities

The primary pathway of interaction between the Project activities in the Site Preparation 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. Site road crossings will be constructed according to the DFO Nunavut Operational Statement for Clear Span Bridges (Fisheries and Oceans Canada 2009). Temporary stream crossings will be constructed according to the DFO Nunavut Operational Statement for Temporary Stream Crossings (Fisheries and Oceans Canada 2009). In-water work will be conducted during approved timing windows presented in the DFO Nunavut Operational Statement for Timing Windows (Fisheries and Oceans Canada 2009). Only geochemically suitable rock quarries and borrow sources (i.e., using non-potentially acid-generating rock) will be used to construct roads, pads, and structures (Metal Leaching and Acid Rock Drainage 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 will be located well away from watercourses; and
- Refuelling and maintenance activities will not occur, 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. 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 TIA.

Changes to sediment and water quality during site preparation, 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 (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 site preparation and construction phases 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 2013). 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 site preparation, 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 the TIA (Goose Property Area) and WMFs (George Property Area) 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 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 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 the TIA (Goose Property Area) and the WMFs (George Property Area) 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, and tailings stored in the TIA and this will be managed under the Mine Waste Rock and Tailings Management Plan (Volume 10, Chapter 9). The TIA has been designed as a zero discharge facility, ensuring no potentially poor-quality water will be introduced to the freshwater environment while in operation. The WMFs will discharge water that will meet MMER discharge criteria to the terrestrial environment and any discharged water will meet CCME criteria at the nearest fish bearing receiving waterbody (Project Description, Volume 2; Site Water Monitoring and Management Plan, Volume 10, Chapter 7). If necessary during the Reclamation and Closure and Post-closure phases, water will be discharged from the TIA and WMFs but any discharge would be treated to meet CCME water quality guidelines thus ensuring no negative effects to aquatic life (Volume 2, Chapter 8; Mine Closure and Reclamation Plan; Volume 10, Chapter 29). 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 (Metal Leaching and Acid Rock Drainage Management Plan; Volume 10, Chapter 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 will be diverted 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 CCME water quality guidelines. 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:

- 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 (Site Preparation and Construction phases) or diverted to the TIA/WMFs (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 Aquatic Effects Management Plan (Volume 10, Chapter 19).

No effects were predicted from the storage, manufacture, and transport of explosives during all phases of the Project because of the mitigation and management measures. 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. However, 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. Therefore, no residual effects from the runoff of blasting residues were predicted.

Due to the mitigation and management measures, no residual effects from explosives in runoff were predicted on the VEC freshwater sediment quality.

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 (TIA and WMFs) and will not be discharged into the freshwater environment. Prior to the completion of the water management infrastructure during the Site Preparation and Construction phases, 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 (Landfill and Waste Management Plan; Volume 10, Chapter 10 of the DEIS). Instead, treated sewage effluent will be discharged to the tundra at Goose and George Properties and the MLA. 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. Three of these potential effects were identified as residual effects: 1) *site preparation, construction, and decommissioning activities*, 2) *site contact water*, and 3) *mine contact water*. 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 5.5-1. Table 5.5-2 provides a description of the significance ratings used for residual effects.

5.5.4.1 Site Preparation, Construction, and Decommissioning Activities

The mitigation and management measures were predicted to be effective at minimizing potential effects from runoff associated with site preparation, 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 (Metal Leaching and Acid Rock Drainage Management Plan; Volume 10, Chapter 22). The proposed mitigation and management measures will minimize the quantity of material transported in runoff (e.g., TSS, metals) and the likelihood of runoff reaching the freshwater environment. Some runoff into nearby waterbodies could be possible during the early stages of site preparation and construction (Site Preparation and Construction phases) before water management structures are fully operational (e.g., TIA, WMFs, 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 site preparation, 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. Therefore, the effects on the VEC freshwater sediment quality from site preparation, 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 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 preparation 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 functional (e.g., before commissioning during the Site Preparation and Construction phases). 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 Site Preparation, Construction, and Reclamation and Closure phases when the water management features are in active.

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 Site Preparation and Construction phases), 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. 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 WRSA and ore piles, will be diverted to the water management facilities and will not contact the freshwater environment. The effects on mine contact water on the VEC freshwater sediment quality were predicted to be negligible because of the diversion of all mine contact water, including runoff from WRSAs, to the water management structures. Therefore, no residual effects from mine contact water are predicted on the VEC freshwater sediment quality during the Operations Phase.

However, Project activities will occur when the site water management infrastructure is not functional (e.g., before commissioning during the Site Preparation and Construction phases and after decommissioning in the Reclamation and Closure Phase). Some interaction with nearby waterbodies could be possible during this period; therefore, residual effects from mine contact water are predicted on the VEC freshwater sediment quality during the Site Preparation and Construction phases when the water management features are in the process of being constructed and commissioned. Discharge of mine contact water may occur during the Reclamation and Closure and Post-closure phases. The current site water management and closure plans are conceptual and will be further developed with the Feasibility Study. Assessments supporting FEIS may necessitate both quantitative (such as modelling) and qualitative predictions.

Mine contact may interact with the freshwater environment during the Site Preparation, Construction, and Reclamation and Closure phases. Mine contact water will be monitored and managed, and treated if necessary, to ensure it will meet CCME guidelines once in contact with fish-bearing waterbodies (Project Description, Volume 2, Chapter 8; Mine Closure and Reclamation Plan; Volume 10, Chapter 29). Water quality indicators will therefore be within CCME water quality guidelines (as discussed in Section 4.5.5.1 of Chapter 4, this Volume), and therefore predicted to have no effects on freshwater sediment quality outside of CCME guidelines. Therefore, the predicted magnitude of the residual effect to the VEC freshwater sediment quality was *low*. The effects were predicted to be footprint (within the PDA) or *local* (restricted to the LSA), *medium-term* in duration, 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 fully *reversible*. The probability of occurrence was estimated to be *moderate* due to the uncertainties related to precipitation, and confidence was *medium* because of the quantitative input from the baseline environmental data and the confidence in the mitigation and management strategies.

The residual effect of mine contact water on the VEC freshwater sediment water is predicted to be **Not Significant**.

5.5.5 Significance of Residual Effects

Three residual effects for the VEC freshwater sediment quality were assessed and resulted in the following significance ratings:

- Site Preparation, Construction, and Decommissioning Activities – rated Not Significant;
- Site Contact Water – rated Not Significant; and
- Mine Contact Water – 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.

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. For wildlife, this boundary is typically defined by the home range of a wildlife VEC within the particular life cycle season which the Project may influence the VEC.
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 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 were considered.

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
Site Preparation	Site Preparation, Construction, Reclamation and Closure	Negative	Low	Short-term	Sporadic	Local	Reversible	Moderate	Medium	**Not Significant**
Site Contact Water	Site Preparation, Construction, Reclamation and Closure	Negative	Low	Short-term	Sporadic	Local	Reversible	Moderate	Medium	**Not Significant**
Mine Contact Water	Site Preparation, Construction, Reclamation and Closure	Negative	Low	Medium-term	Sporadic	Local	Reversible	Moderate	Medium	**Not Significant**

5.6.2 Potential Interactions of Residual Effects with Other Projects

The following residual Projects effects on freshwater sediment quality were identified:

- Site preparation, construction, and decommissioning activities;
- Site contact water; and
- Mine contact water.

The spatial boundary of the CEA is the freshwater sediment quality RSA (see Section 5.4.1). The temporal boundary for the CEA is any past, present, or reasonably foreseeable future projects (see list of projects in Volume 9, Chapter 1). The only project that could interact with the Back River Project freshwater sediment quality residual effects is the proposed Bathurst Inlet Port and Road project. There is no predicted spatial overlap between the Project residual effects that were confined to the freshwater sediment quality LSAs and any potential effects from the Bathurst Inlet Port and Road Project, which would be confined to the proposed road corridor in the far northwestern portion of the George Property RSA (Figure 5.4-1). Therefore, no potential cumulative effects on the VEC freshwater sediment quality were predicted.

5.7 TRANSBOUNDARY EFFECTS

Transboundary effects may be expected to occur if residual effects from the Project were identified and extend beyond the LSAs. However, all residual effects to the VEC freshwater sediment quality were confined to the LSAs, which lie entirely within Nunavut. Therefore, no transboundary residual effects from Project activities on the VEC freshwater sediment quality were predicted.

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.

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 DEIS, and detailed in the following plans:

- Site Water Monitoring and Management Plan (Volume 10, Chapter 7);
- Fuel Management Plan (Volume 10, Chapter 4);
- Spill Contingency Plan (Volume 10, Chapter 5);
- Ore Storage Plan (Volume 10, Chapter 8);
- Mine Waste Rock and Tailings Management Plan (Volume 10, Chapter 9);
- Landfill and 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);
- Metal Leaching and Acid Rock Drainage Management Plan (Volume 10, Chapter 22); and
- Mine Closure and Reclamation Plan (Volume 10, Chapter 29).

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 directed to the TIA (Goose Property Area), Water Management Facility (George Property Area), or collection pond (MLA).
	Infrastructure and waste rock storage areas at the George 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 TIA has been designed as a zero discharge facility, ensuring no potentially poor quality water is introduced 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 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 (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 Operational Statement for Culvert Maintenance (Fisheries and Oceans Canada 2009).
	Instream work will be conducted during approved timing windows presented in the DFO Nunavut Operational Statement for Timing Windows (Fisheries and Oceans Canada 2009).
	Site road crossings will be constructed according to the DFO Nunavut Operational Statement for Clear Span Bridges (Fisheries and Oceans Canada 2009).
	Temporary stream crossings will be constructed according to the DFO Nunavut Operational Statement for Temporary Stream Crossings (Fisheries and Oceans Canada 2009).

(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 *(cont'd)*	
	Winter road construction will follow the DFO Nunavut Operational Statement for Ice Bridges and Snow Fills (Fisheries and Oceans Canada 2009).
	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 TIA (Goose Property Area), Water Management Facility (George Property Area), or collection pond (MLA).
	Sewage will be treated, and treated sewage effluent will be discharged to the tundra.
	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 TIA 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 well away from watercourses.

(continued)

Table 5.8-1. Mitigation and Adaptive Management Measures for Potential Project Effects on Freshwater Sediment Quality (completed)

Mitigation Category	Mitigation Measures
3. Best Management Practices (*cont'd*)	
	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. Vehicular access across a watercourse or waterbody will be by road or bridge, or other acceptable method according to DFO Operational Statements and Standards and Best Practices for Instream Works (Fisheries and Oceans Canada 2009). 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 Monitoring 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 and George Properties 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) 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.

5.9 PROPOSED MONITORING PROGRAMS

5.9.1 Conceptual 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: site preparation, 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 of 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. Three residual effects were identified after mitigation and management:

- site preparation, construction, and decommissioning;
- site contact water; and
- mine contact water.

Using the thresholds identified for the key indicators, each of these residual effects were rated with *low* magnitude 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 LSAs. 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 interactions between other past, present, or future projects and the Back River Project freshwater sediment quality residual effects were expected and no cumulative effects were predicted to occur.

6. Freshwater Fish/Aquatic Habitat

Rescan™
an ERM company

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 western Nunavut in the continuous permafrost zone of the continental Canadian Arctic. It is composed of three main areas: the Goose Property Area, the George Property Area, and the Marine Laydown Area (MLA; Figure 6.1-1). All areas would be connected by winter roads. All proposed infrastructure at the Goose Property lies within the Ellis River Watershed. The Ellis River Watershed flows to the northwest, and enters the ocean on the west side of Bathurst Inlet (see Federal Watershed map in Chapter 1 of this Volume). The Back River Watershed lies south of the proposed infrastructure in the Goose Property Area and flows to the east eventually entering the Arctic Ocean south of Gjoa Haven. Lakes and streams in the George Property Area drain into the Western River Watershed that flows north and enters Bathurst Inlet at its southernmost point.

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 2012e). 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, 2012b, 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.

Both the Goose and George Properties are in the headwater regions of their respective watersheds and have 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 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; 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.

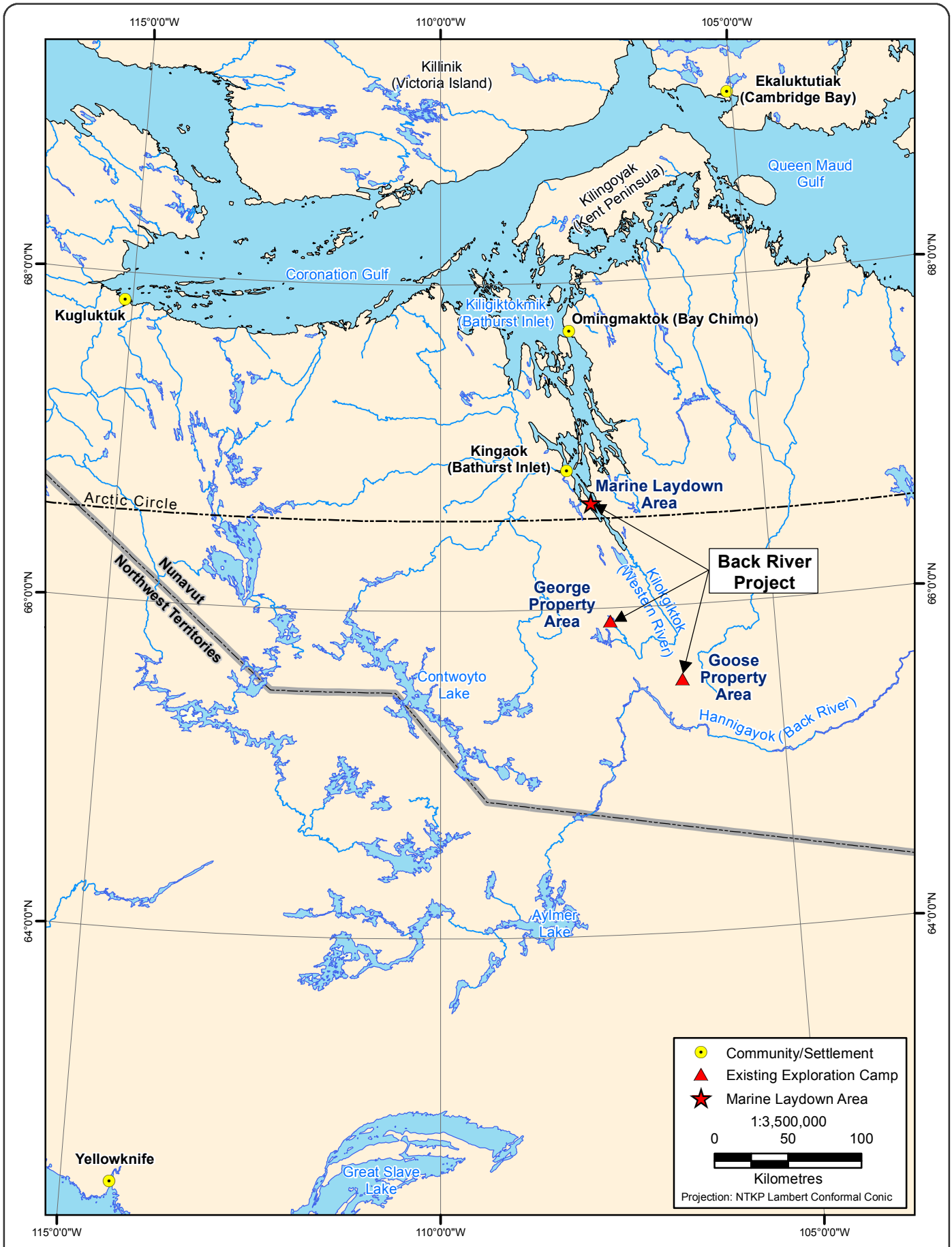


Figure 6.1-1

Project Location

Sabina GOLD & SILVER CORP.

Rescan an ERM company

The changes to the *Fisheries Act* include a prohibition against causing serious harm to fish that are part of or support a commercial, recreational, or Aboriginal 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 commercial, recreational, and Aboriginal 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 commercial, recreational, or Aboriginal fisheries;
- fisheries management objectives;
- whether there are measures and standards to avoid, mitigate, or offset serious harm to fish that are part of a commercial, recreational, or Aboriginal 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 commercial, recreational, or Aboriginal 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) has no special designation in the George and Goose RSAs, but the caribou calving grounds outside the RSA have been designated PSE-R2. The proposed Hiukitak River Cultural Area is on the eastern shore of Bathurst Inlet outside the RSA, and is located 40 km east of Kingaok, 60 km north-east of the proposed Marine Laydown Area (MLA), and 140 km north of the George Property.

6.1.4 Baseline Study Area

Freshwater fish/aquatic habitat baseline studies were undertaken from 2010 to 2013 in the Back River Project area. Baseline studies conducted in 2010 and 2011 focused on the Goose Property, while studies in 2012 and 2013 focused on both the George and Goose Properties. Figures 6.1-2 and 6.1-3 show the Goose and George Local Study Areas (LSAs), along with waterbodies where baseline fish habitat studies were conducted.

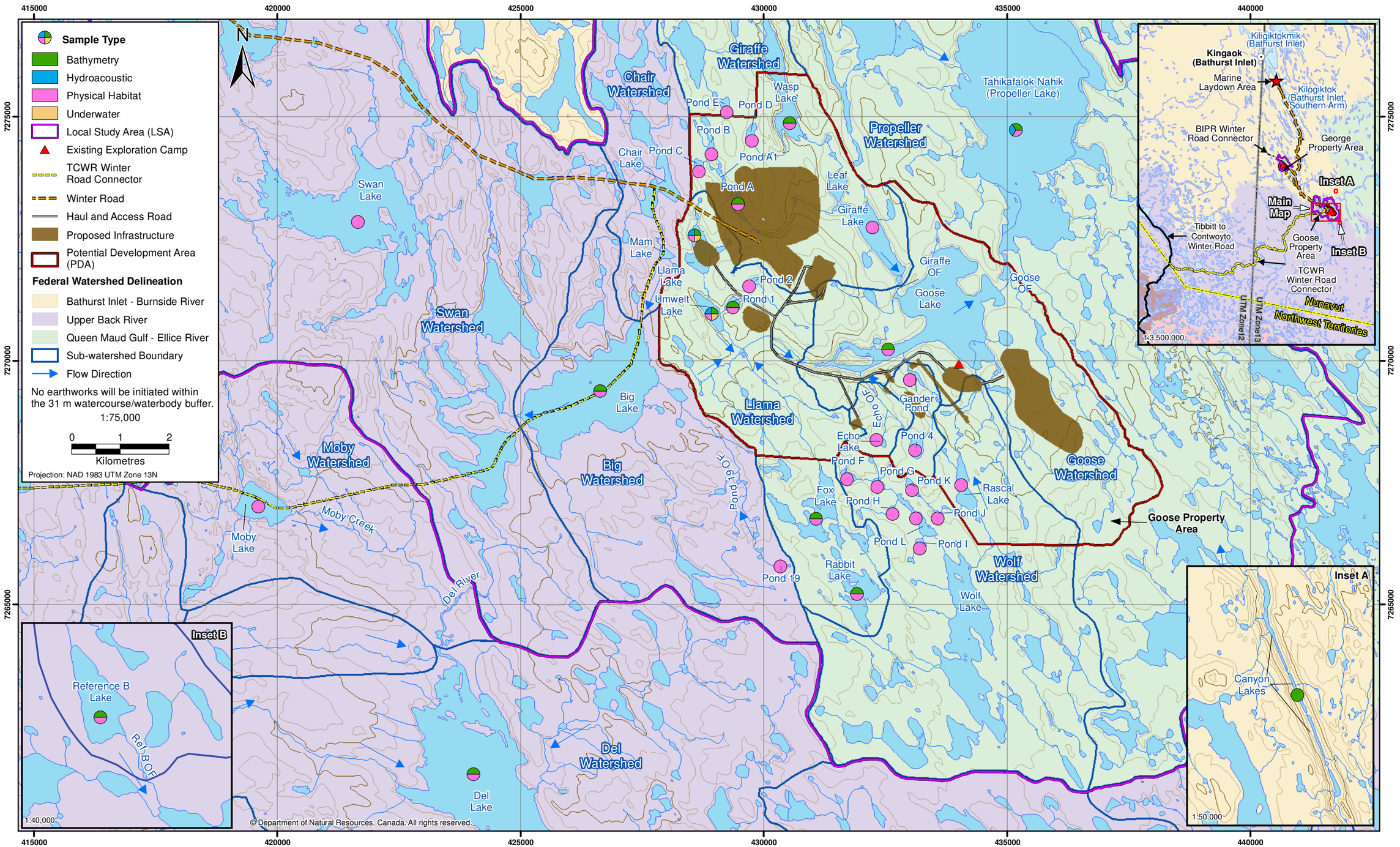
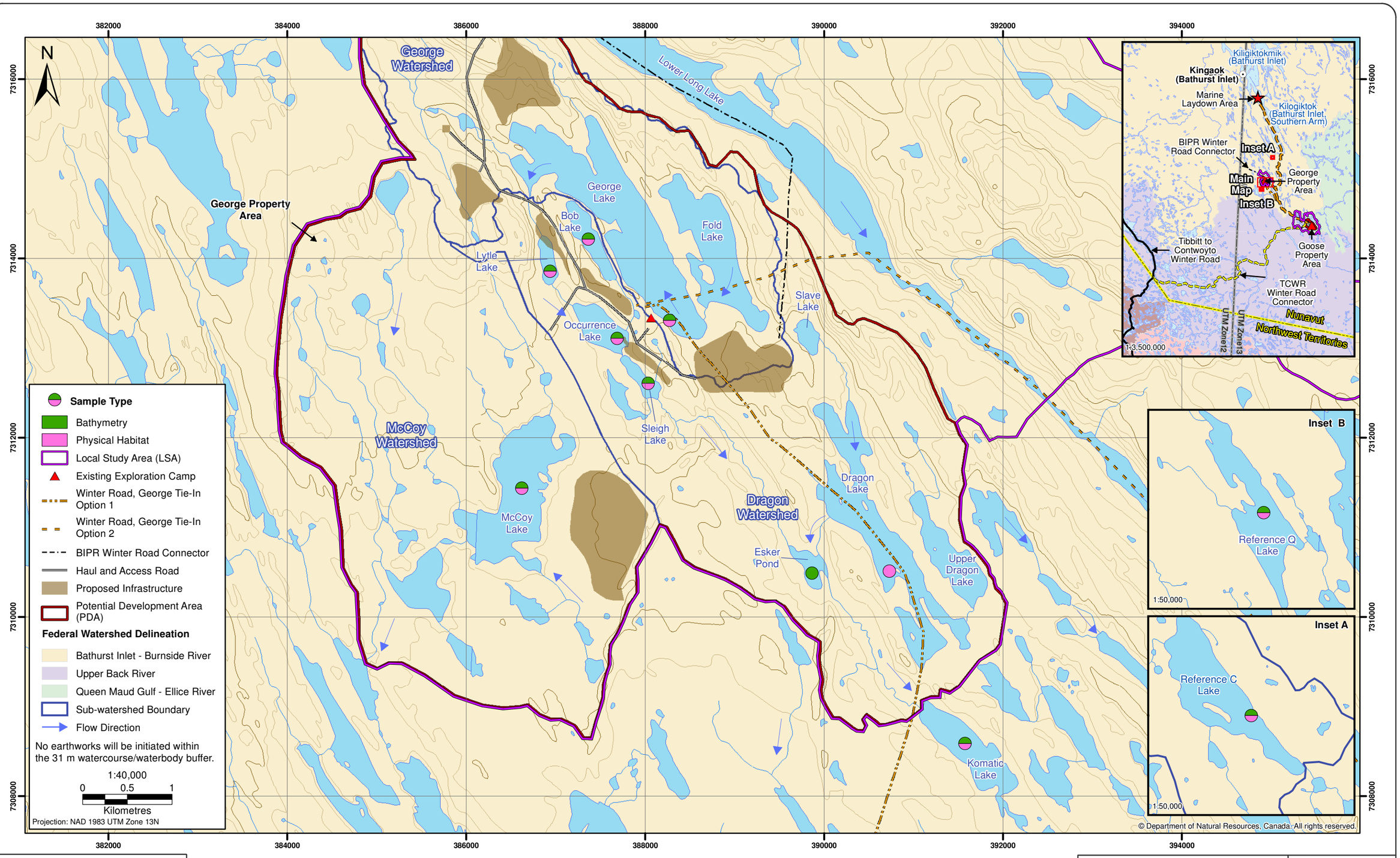


Figure 6.1-2

Lake/Pond Fish Habitat Baseline Data (2010 - 2013) for the Goose Property Area



© Department of Natural Resources, Canada. All rights reserved.

Sabina GOLD & SILVER CORP.

Rescan an ERM company

Figure 6.1-3

Lake/Pond Fish Habitat Baseline Data (2010 - 2013) for the George Property Area

6.1.5 Baseline Studies

6.1.5.1 *Information Sources*

Comprehensive baseline fish habitat and aquatic habitat data are available for the Goose and George Properties from 2010 to 2013 (Rescan 2010, 2012a, 2012b, 2012c, 2012d, 2013a, 2013b). Supplemental historical data are also available prior to 2010. The following provides a summary of the available baseline data from 2010 to 2013.

2010 Baseline Studies (Goose Property Area)

- 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 (Goose Property Area)

- 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 2012b, 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 (Goose and George Property Areas)

- Fish Habitat Baseline (Rescan 2012c, Appendix V6-6C):
  - Assess fish habitat at stream crossings near potential site roads;
  - Assess fish habitat that could be affected by potential mine development at the Goose and George Properties; and
  - Assess and map fish habitat within the footprint of a potential tailings storage area in the Moby Lake watershed.
- Freshwater Baseline (Rescan 2012d, Appendix V6-3C):
  - Lake Assessments:
    Collect baseline August phytoplankton, zooplankton and benthos density and community composition data in 24 lake sites in the Goose and George Properties.
  - Stream Assessments:
    Collect baseline August periphyton, and benthos density and community composition data in 17 stream sites in the Goose and George Properties.

2013 Baseline Studies (Goose and George Property Areas)

- Fish Habitat Baseline (Rescan 2013b); results will be available in early 2014:
  - Collect baseline fish habitat information in Giraffe, Propellor, 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); results will be available in early 2014.

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 and two lake sites in the George Property Area.
- *George Lake Project — 1997 Data* (Norecol Dames & Moore 1997): conducted fish habitat assessments on Goose Lake and Big Lake in 1996 near the current Goose Property Area. 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.
- *Preliminary Studies of Fish and Fish Habitat in the George Lake Area, N.W.T.* (Sekerak 1990): conducted preliminary assessments of fish habitat in the area surrounding George Lake. Lake habitat assessments included George Lake, Fold Lake, Bob Lake, Lytle Lake, Occurrence Lake, Esker Pond, Komatic Lake, Dragon Lake, Upper Dragon Lake, and Upper and Lower Long Lake. Stream assessments were conducted on Kanosak Creek, Dragon Creek and on the channels connecting Fold Lake to George Lake and Upper Long Lake to Lower Long Lake.

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 and George Property Areas between 2010 and 2013. 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 (Figures 6.1-2 and 6.1-3). In addition to bathymetry, bottom habitat typing was performed with a hydroacoustic echosounder at several lakes including: Umwelt, Llama, Reference B and Propeller. Figures 6.1-2 and 6.1-3 present the locations and types of physical habitat surveys conducted between 2010 and 2013 in the Goose and George Property Areas.

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 22 lakes collected from 2007, 2011, 2012, and 2013 (Rescan 2012b; 2012d [Appendix V6-3B, V6-3C]; 2013a; Figures 6.1-4 and 6.1-5; Table 6.1-1).

Table 6.1-1. Summary of Baseline Lake Phytoplankton Sampling Conducted at George and Goose Property Areas

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	Rescan
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 Property	Goose Property	Goose Property
	Goose Lake	Goose Lake	Goose Lake	Goose Lake
	Propeller Lake	Llama Lake	Propeller Lake	Propeller Lake
		Giraffe lake	Giraffe Lake	Giraffe Lake
		Umwelt Lake	Rabbit Lake	Umwelt Lake
		Reference B Lake	Fox Lake	Reference B Lake
			Rascal Lake	Rascal Lake
			Big Lake	Leaf Lake
			Moby Lake	Wasp Lake
			Del Lake	
	George Property		George Property	George Property
	Lytle Lake		George Lake	George Lake
	Bob Lake		Lytle Lake	Bob Lake
			Occurrence Lake	Occurrence Lake
			Dragon Lake	Dragon Lake
			Komatic Lake	Komatic Lake
			Fold Lake	Esker Lake
			Lower Long Lake	McCoy Lake
			Reference C Lake	Reference Q Lake
			Sleigh 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 18 lakes between 2011 and 2012 (Rescan 2012b; 2012d; Figures 6.1-4 and 6.1-5). 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.

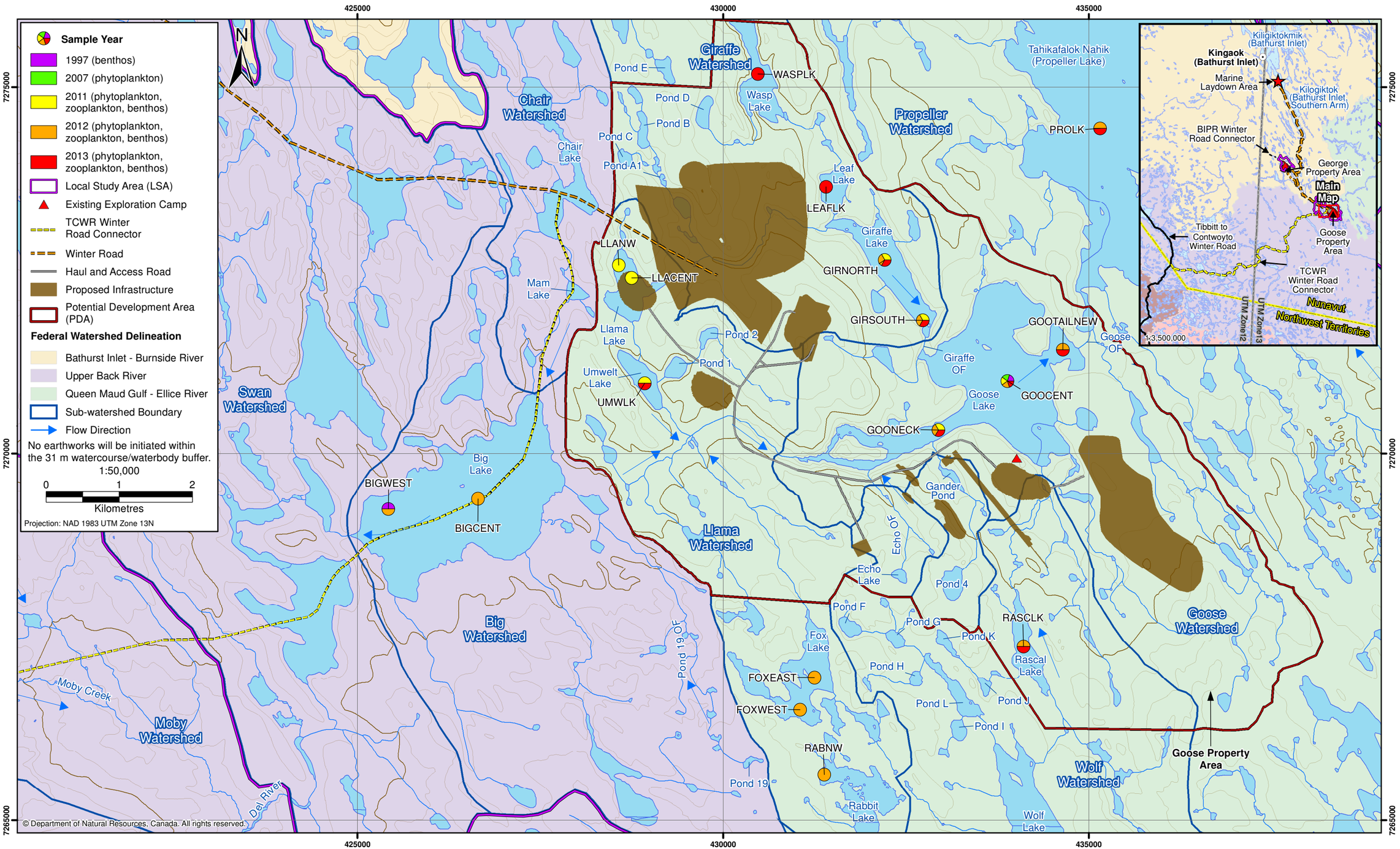
Zooplankton data were collected from both Giraffe and Goose lakes in 2011 and 2012. Zooplankton density and taxonomy samples were collected at each lake site, with three replicate vertical hauls conducted at each site using plankton net fitted with a 118 µm mesh. The net was lowered to 1 m above the 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, and 2013 (Rescan 2012b, 2012d; 2013a; Table 6.1-2; Figures 6.1-4 and 6.1-5).

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.

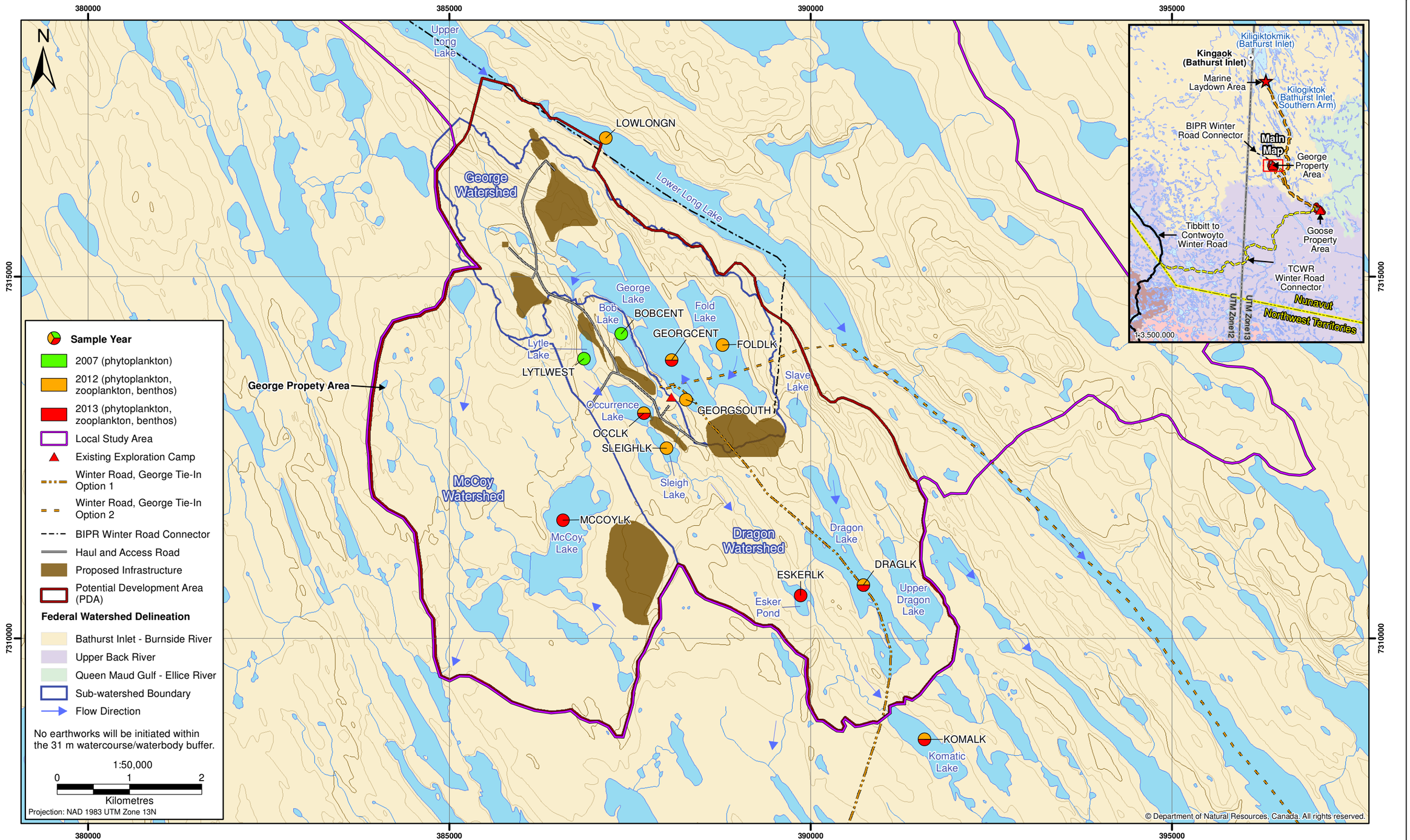


© Department of Natural Resources, Canada. All rights reserved.

Sabina GOLD & SILVER CORP. Rescan an ERM company

Figure 6.1-4

Lake/Pond Fish Habitat – Aquatic Resources Baseline Data (1997 - 2013) for the Goose Property Area



Sabina GOLD & SILVER CORP.

Rescan an ERM company

Figure 6.1-5

Lake/Pond Fish Habitat — Aquatic Resources Baseline Data (2007 - 2013) for the George Property Area

Table 6.1-2. Summary of Baseline Lake Zooplankton Sampling Conducted at the Goose and George Property Areas

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
		George Property
		Dragon Lake
		Fold Lake
		George Lake
		Komatic Lake
		Lower Long Lake
		Lytle Lake
		Occurrence Lake
		Reference C Lake
Number of Replicates per Site	n = 3	n = 3

Table 6.1-3. Summary of Baseline Lake Benthos Sampling Conducted at the Goose and George Property Areas

Year	1997	2011	2012	2013
Sampling Month(s)	August	August	August	July
Sampling Agency	Norecol Dames and Moore	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
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
Analytical Lab	ECCON Environmental, unknown location	Dr. Jack Zloty, Summerland, BC	EcoAnalysts, Moscow ID, USA	EcoAnalysts, Moscow ID, USA
Lake(s) Sampled	Goose Property	Goose Property	Goose Property	Goose Property
	Goose Lake	Goose Lake	Goose Lake	Goose Lake
	Big Lake	Giraffe Lake	Giraffe Lake	Giraffe Lake

(continued)

Table 6.1-3. Summary of Baseline Lake Benthos Sampling Conducted at the Goose and George Property Areas (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 <u>George Property</u> George Lake Occurrence Lake Dragon Lake Komatic Lake Fold Lake Lower Long Lake Lytle Lake Sleigh Lake Reference C Lake	Rascal Lake Umwelt Lake Reference B Lake Propeller Lake Leaf Lake Wasp Lake <u>George Property</u> George Lake Occurrence Lake Dragon Lake Komatic Lake Bob Lake Esker Lake McCoy Lake Reference Q 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
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
Area Sampled per Replicate (m^2)	0.0232	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*

<u>Freshwater Fish Habitat — Physical Characteristics</u>

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.

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.*

Figures 6.1-6 and 6.1-7 present the locations of stream fish habitat surveys conducted between 2010 and 2013 in the Goose and George Property Areas.

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 2012b, 2012d; 2013a; Figures 6.1-8 and 6.1-9; Table 6.1-5). 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
Sampling Month(s)	August	August	August	July
Sampling Agency	Norecol Dames and Moore	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
Sampling Method	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

(continued)

Table 6.1-5. Summary of Baseline Stream Periphyton Sampling Conducted for the Back River Project (completed)

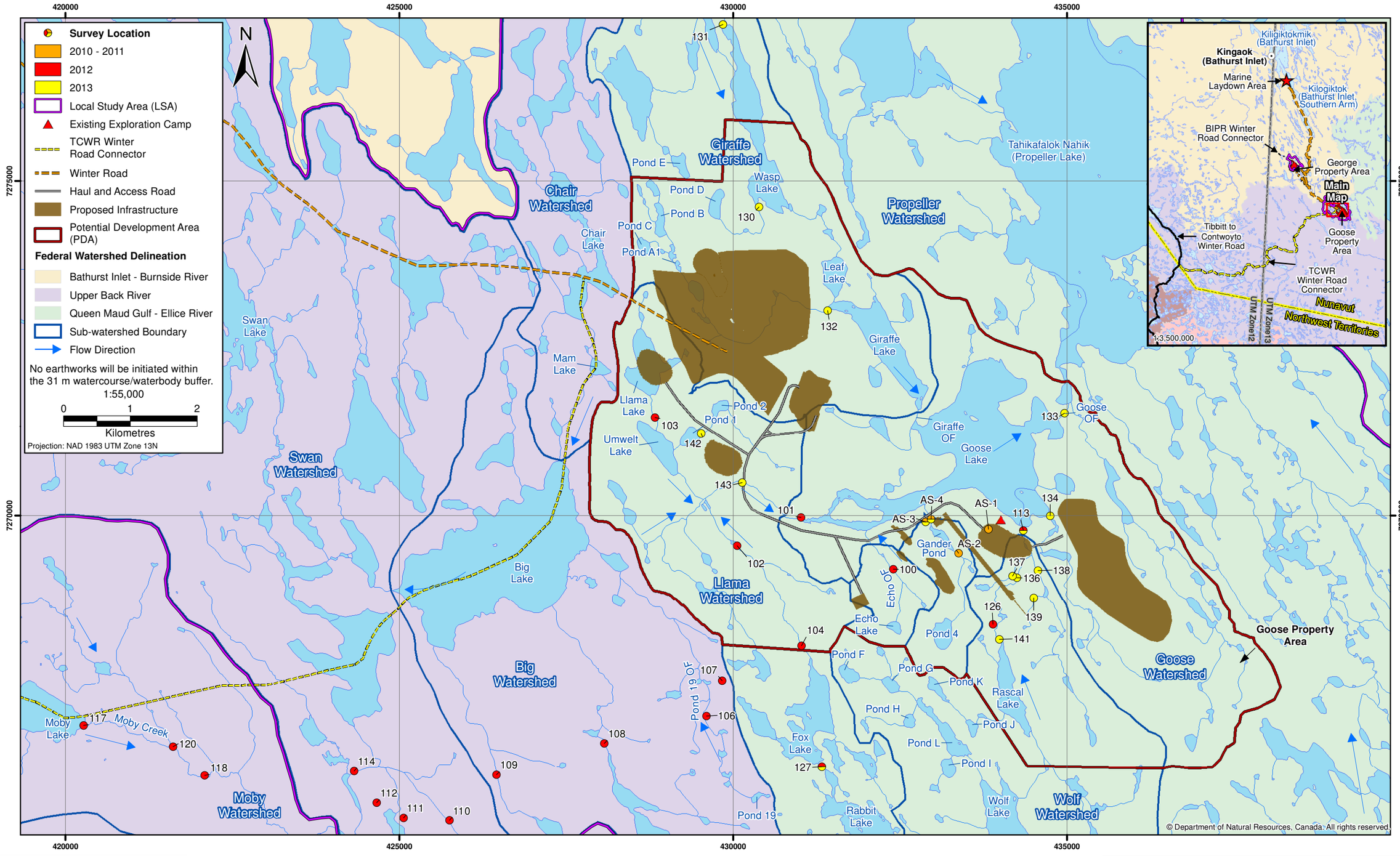
Analytical Lab (for chl *a*)	Unknown	ALS Environmental, Burnaby, BC	ALS Environmental, Burnaby, BC	ALS Environmental, Burnaby, BC
Stream(s) Sampled	Goose Property	Goose Property	Goose Property	Goose Property
	Goose OF	Goose OF	Goose OF	Goose OF
	Goose IF (SE)	Giraffe OF	Giraffe OF	Giraffe OF
	Wolf OF	Propeller D/S	Propeller OF	Propeller OF
		Reference B OF	Reference B OF	Reference B OF
		Chair OF	Chair OF	TIA OF
		Llama OF	Llama OF	Wasp OF
		Wolf OF	Wolf OF	Umwelt OF
			Del IF	
			Del US	
			Moby OF	
			Pond 19 OF	
			George Property	George Property
			George OF	George OF
			Sleigh OF	Sleigh OF
			Dragon OF	Lytle OF
			Komatic IF*	McCoy Watershed OF
			Reference C OF	Reference Q OF
Number of Replicates per Site	n = 1	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)
Area Sampled per Replicate (m^2)	0.0125	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 2012b, 2012d; 2013a; Figures 6.1-8 and 6.1-9; Table 6.1-6). 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.



Sabina GOLD & SILVER CORP.

Rescan an ERM company

Figure 6.1-6

Stream Fish Habitat Baseline Data (2010 - 2013) for the Goose Property Area

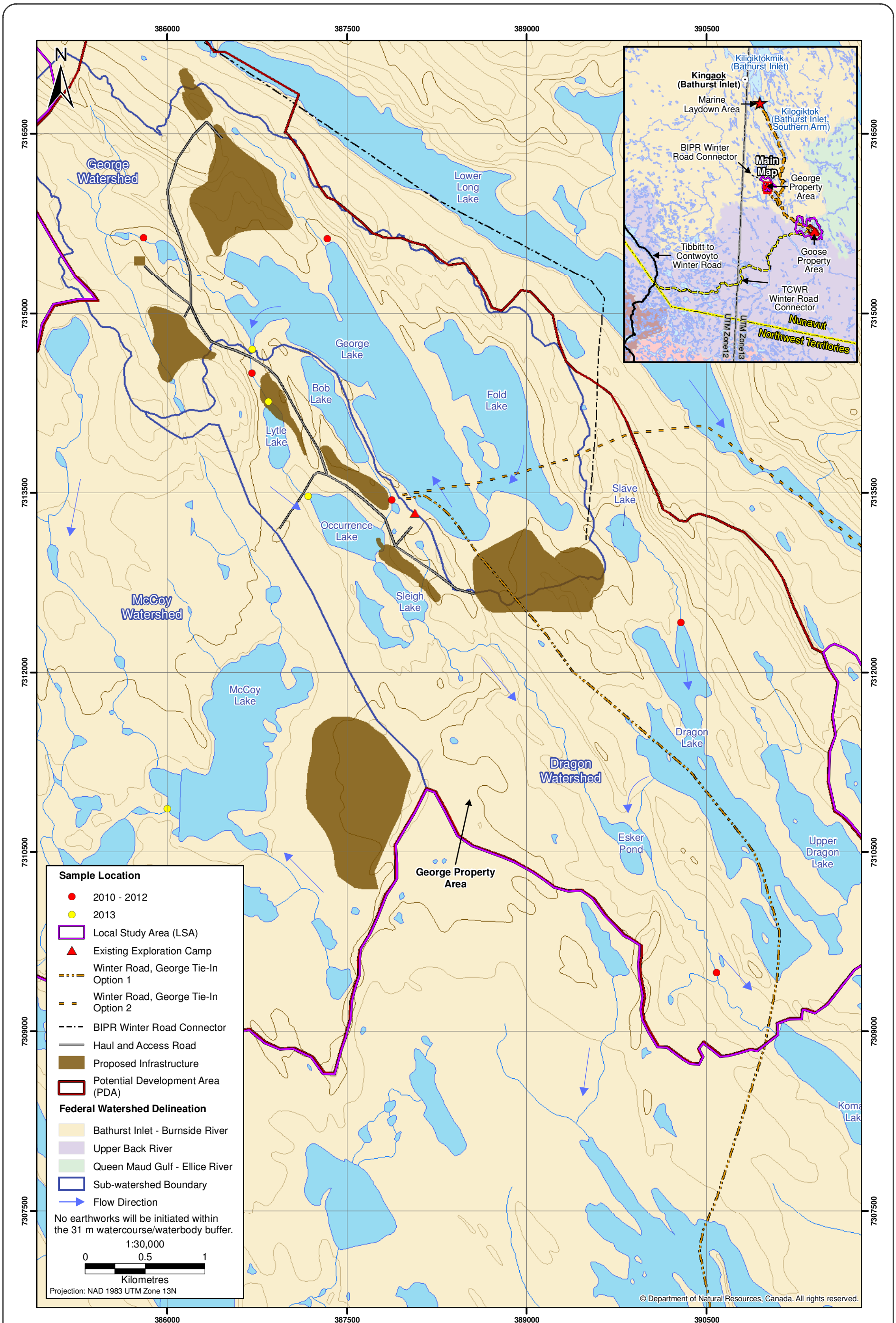


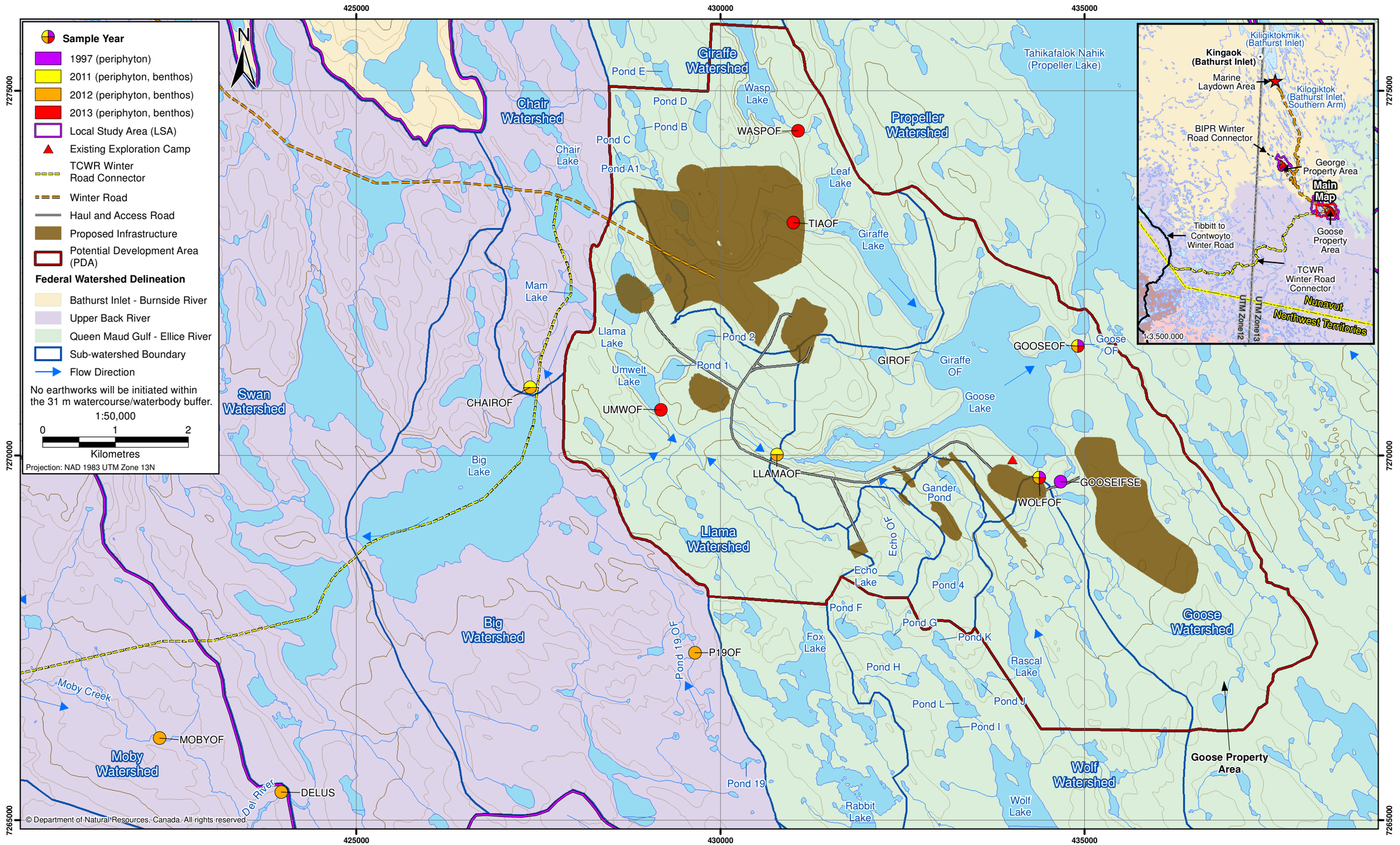
Figure 6.1-7

Sabina GOLD & SILVER CORP.

Stream Fish Habitat Baseline Data (2010 - 2013) for the George Property Area

Figure 6.1-7

Rescan an ERM company

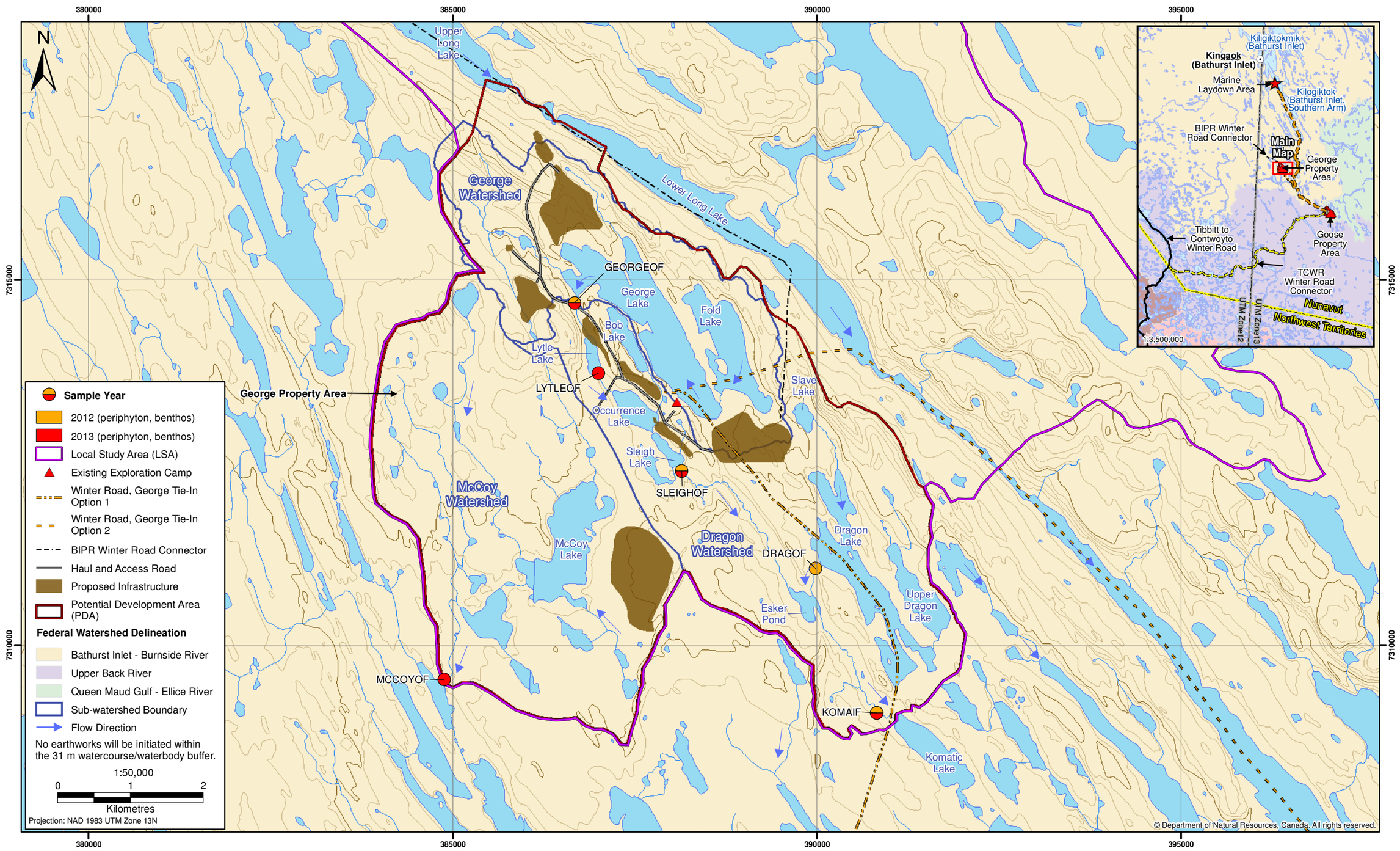


© Department of Natural Resources, Canada. All rights reserved.

Sabina GOLD & SILVER CORP. Rescan an ERM company

Figure 6.1-8

Stream Fish Habitat –
Aquatic Resources Baseline Data
(1997 - 2013) for the Goose Property Area



Sabina GOLD & SILVER CORP.

Rescan an ERM company

Figure 6.1-9

**Stream Fish Habitat –
Aquatic Resources Baseline Data
(2012 - 2013) for the George Property Area**

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
Sampling Month(s)	August	August	August	July
Sampling Agency	Norecol Dames and Moore	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
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
Analytical Lab	ECCON Environmental, unknown location	Dr. Jack Zloty, Summerland, BC	EcoAnalysts, Moscow, ID, USA	EcoAnalysts, Moscow, ID, USA
Stream(s) Sampled	Goose Property	Goose Property	Goose Property	Goose Property
	Wolf Outflow	Chair Outflow	Moby Outflow	WASP OF
	Goose SE IF	Llama Outflow	Del Inflow	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	
			George Property	George Property
			George Outflow	George OF
			Sleigh Outflow	Lytle OF
			Dragon Outflow	Sleigh OF
			Reference C Outflow	McCoy Watershed OF
			Komatic Inflow	Dragon OF (Kom. IF)
				Reference Q OF
Number of Replicates per Site	n = 5	n = 5	n = 5	n = 5
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
Area Sampled per Replicate (m^2)	0.0701 (based on above assumption)	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 Figures 6.1-8 and 6.1-9.

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 2012c). 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 2013

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	Medium	Good	Fair	Good	Good
Umwelt Lake	1,2,3,4	20.2	3.0	Low	Poor	Fair	Good	Poor
Big	3	403.8	5.6	Medium	Good	Poor	Good	Fair
Fox	3	72.0	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 19	3	1.8	< 2*	Low	Poor	Fair	Poor	None
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 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
Reference Sites								
Reference B Lake	1,2,3	36.0	5.1	Medium	Good	Fair	Good	Fair

** Maximum depth was estimated*
*** Forage fish include species such as Ninespine Stickleback and Slimy Sculpin.*
[1] Rescan (2010); [2] Rescan (2012a); [3] Rescan (2012c); [4] Rescan (2013a).

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.

Of the 17 ponds surveyed in 2011, 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 (*Pungitius pungitius*) 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).

George Property Area

The George Property contains a few deep lakes (e.g., George, Dragon, Fold) and several shallow lakes and ponds (e.g., Occurrence, Lytle, Sleigh), all connected by Kanosak Creek, and tributaries, flowing out of George Lake. The habitat provided in the George Property Area is typical of Arctic headwaters, with several small to medium-sized lakes connected by relatively small, shallow streams. The larger, deeper lakes like George and Dragon have suitable overwintering and spawning habitat for Lake Trout, while the smaller lakes may provide seasonal rearing and foraging habitat and serve as migration corridors for other fish species (Table 6.1-8). Spawning habitat for Lake Trout is also limited to the deeper lakes because deposited eggs must overwinter at depths that do not freeze to bottom.

Table 6.1-8. Summary of Fish Habitat Quality in George Property Area Lakes, 1990 and 2012

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*		
George Property								
George Lake	1,3	167	14.2	Medium	Good	Fair	Good	Good
Fold Lake	2	77	> 3	Medium	Good	Fair	Good	Fair
Lytle Lake	1,3	7.7	1.8	Low	Poor	Fair	Good	None
Occurrence Lake	1,3	20	2.1	Low	Poor	Good	Fair	None
Esker Pond	2	13	< 3	Low	Poor	Good	Poor	Poor
Sleigh Lake	3	8.6	1.5	Low	Poor	Good	Poor	None
Komatic Lake	1,4	45	9.1	Medium	Good	Fair	Good	Fair
Dragon Lake	1,2	125	> 3	Medium	Good	Fair	Good	Fair
Upper Dragon Lake	2	38	> 3	Medium	Good	Fair	Good	Fair
Bob Lake	4	16	6.2	Medium	Fair	Fair	Good	Fair
McCoy Lake	4	100	9.0	Medium	Good	Fair	Good	Good

Note: Table adapted from Sekerak (1990), and supplemented with data from 2012 baseline studies. No habitat surveys were conducted on lakes in the 2006 assessment (Golder Associates Ltd. 2007).
** Forage fish include species such as Ninespine Stickleback and Slimy Sculpin.*
[1] Rescan (2012c); [2] Sekerak (1990); [3] Rescan (2013a); [4] Rescan (2013b).



Plate 6.1-3. Typical shoreline of small ponds in the Goose Property, featuring organic substrate and aquatic vegetation. Pond A, July 2011.

The majority of good fish habitat in George Property lakes is provided by these relatively large, deep lakes. George Lake and Dragon Lake both feature boulder/cobble-dominated shorelines, large surface areas, and deeper depth (Plate 6.1-4; Table 6.1-8). The smaller lakes do not provide good fish habitat due to their shallow depths freezing to bottom in winter, lower winter oxygen concentration, mud substrate, and scarcity of cover (Plate 6.1-5).



Plate 6.1-4. Boulder-cobble shoreline habitat typical of lakes in the George Property. George Lake, August 2012.



Plate 6.1-5. Fine substrates, gravel, and aquatic vegetation along the shore of Occurrence Lake, George Property. August 2012.

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, and were lower than those observed in George Property lakes. 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).

George Property Area

In general, phytoplankton biomass was low at lakes in the George Property. Lakes were ultra-oligotrophic and taxonomic richness was variable and diversity was moderate.

George Property lake communities have low phytoplankton biomass and densities, a common feature of Arctic lakes in northern Canada (Moore 1978). All lakes surveyed had mean chl *a* concentrations and TP concentrations (Volume 6, Chapter 4) that would class them as ultra-oligotrophic (chl *a* < 2 µg/L, TP < 4 µg/L). The five lake sites with both under-ice and open-water samples had phytoplankton biomass levels that varied seasonally, tending to be higher in the low-light, under-ice samples. George Property lakes had a mean phytoplankton density of 1,530,000 cells/L, with lakes sampled in both seasons tending to have greater densities in the higher light open-water conditions.

George Property lake phytoplankton communities were mainly composed of cyanobacteria (Myxophyceae), cryptomonads (Cryptophyceae), green algae (Chlorophyceae), Chrysophytes (golden algae — Chrysophyceae), and diatoms (Bacillariophyceae). Abundant phytoplankton genera in the George Property samples included *Cyclotella* (centric diatom) *Kephyrion* (golden algae), *Chroococcus* and *Aphanocapsa* (both cyanobacteria). Diversity at the genus level was moderate, with a mean of 0.57 (Simpson's index), and richness varied from a mean of five genera/sample (George Lake Central, under ice) to 20 genera/sample (Komatic Lake, 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).

George Property Area

At the George Property, zooplankton density was low, but variable among years and lakes. Taxonomic richness and was variable among lakes. Zooplankton diversity was low in some lakes, but varied greatly.

Baseline zooplankton taxonomy samples were collected from nine lakes in the George Property Area during August 2012. Zooplankton densities in George Property lakes during August 2012 sampling ranged from a mean of 832 adults/m^3 in Lytle Lake (1.8 m deep) to 43,500 adults/m^3 in Fold Lake (> 3 m deep).

Zooplankton adult communities were mainly made up of crustaceans and rotifers, with different lakes having different compositions. Lower Long and Fold lakes had communities made up of over half rotifers, with most being the Brachionidae genera *Kellicottia* or *Keratella*. In other lakes, adult zooplankton communities were over half crustacean with dominant families varying between Diaptomidae (*Leptodiaptomus* spp.), Daphnidae (*Daphnia* spp.) and Cyclopidae (*Cyclops* sp.). Like the Goose Property lakes, these genera appeared to be typical of small Arctic to sub-arctic lakes (e.g., 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 between lakes, being highest in Lower Long, Fold, Dragon, Komatic, and Reference C lakes, and lowest in George Lake Central. Overall, mean richness ranged from 2.7 to 9.0 genera/sample, and mean diversity ranged from 0.05 to 0.80 (Simpson's index), with most lakes above 0.30 (analyzing adult zooplankton identified to the genus level). Note that sample volume was variable between lakes depending on site depth and random sampling effects (ranging from a mean of 0.54 m^3 to 1.57 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.

George Property Area

Benthos density was low, but highly variable among years and lakes at the George Property. Taxonomic richness and was low and variable among lakes. Benthos diversity was low to moderate, but varied considerably among lakes.

Benthos densities in the George Property lakes varied considerably among lakes, ranging from a mean of 600 individuals/m^2 (Reference C Lake) to 22,000 individuals/m^2 (Lytle Lake).

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 *Procladius, Paratanytarsus* and *Stictochironomus*.

Benthos richness and diversity varied among George Property Area lakes, with no consistent pattern. Richness ranged from a mean of 2.8 families/sample at Reference Lake C to a mean of 7 families/sample at George Lake. The benthos communities in the George Property Area lakes were moderately diverse, ranging from a mean of 0.09 at Lytle Lake to 0.63 (Simpson's index) at Occurrence Lake.

6.1.7 Setting — Stream Habitat

6.1.7.1 *Fish Habitat — Physical Characteristics*

Goose Property Area

A total of 21 stream sites were surveyed in the Goose Property Area in 2011 and 2012. Most of the surveyed sites were at potential mine site road crossings, although some 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 6.1-6). 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 6.1-7), and several cascades and boulder fields along the stream connecting Pond A to Giraffe Lake (Plate 6.1-8; Figure 6.1-2).



Plate 6.1-6. Typical stream in the Goose Property, with multiple, poorly defined channels and shallow flow. Wasp Inflow, June 2013.



Plate 6.1-7. Rock cascade feature on Umwelt Outflow, Goose Property, looking upstream. June 2012.



Plate 6.1-8. Boulder field feature on Giraffe inflow, Goose Property, looking upstream. June 2013.

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. Table 6.1-9 summarizes the habitat quality at each stream site surveyed in 2011 and 2012, as well as streams surveyed historically.

Table 6.1-9. Summary of Habitat Quality in Goose Property Area Streams, 1996 to 2012

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	3	126	Stream	None	Good	Poor	Good	High
Rabbit Outflow	3	127	Stream	None	Fair	Good	Fair	Medium
Data from 2013								
Unnamed		100-2013	NCD	None	None	None	None	None
Gander Outflow		101-2013	Stream	None	Fair	Fair	Good	Medium
Unnamed		102-2013	Stream	None	None	None	Fair	Low
Unnamed		103-2013	Stream	None	Fair	Fair	Good	Medium
Unnamed		105-2013	NCD	None	None	None	None	None
Giraffe Inflow		200-2013	Stream	None	None	None	None	None
Wasp Inflow		215-2013	Stream	None	Fair	Good	Good	Medium
Unnamed		500-2013	Stream	None	Fair	Good	Good	Medium
Unnamed		303-2013	Stream	None	Good	Good	Good	High
Gander Inflow		804-2013	Stream	None	Fair	Fair	Good	Medium
Propeller Inflow		814-2013	Stream	None	Good	Fair	Good	High

Notes: N/A = not applicable; NCD = non-classified drainage
[1] Norecol Dames & Moore (1997); [2] Rescan (2012a); [3] Rescan (2012b).

Rascal Outflow flows from Rascal to Goose lakes and was categorized as high quality habitat. 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 (Table 6.1-9).

George Property Area

Six stream sites were assessed in the George Property Area in 2012, including two sites on George Outflow and inflows to George and Dragon lakes. Of these, one site was classified as a non-classified drainage (NCD), with no defined channel and no fish habitat potential. Stream habitat was also assessed in George Outflow and Dragon Creek (between Dragon Lake and Komatic Lake) in 1990 (Sekerak 1990). In general streams at the George Property are shallow, often ephemeral and present little to no in-stream vegetation. Table 6.1-10 summarizes the habitat quality at each of the sites.

Table 6.1-10. Summary of Habitat Quality in George Property Area Streams, 1990 to 2013

Stream Name	Source	Site	Habitat Type	Overwintering Habitat Quality	Spawning Habitat Quality		Rearing Habitat Quality	Overall Habitat Quality
					Arctic Grayling	Forage Fish		
Unnamed	2	121	NCD	None	None	None	None	None
Esker Outflow (Kanosak Creek) - Reach 1	1	128	Stream	None	Fair	Poor	Good	Medium
George Outflow (Kanosak Creek) – Reach 2	1	N/A	Stream	None	Fair	Poor	Good	Medium
George Outflow (Kanosak Creek) – Reach 3	1	N/A	Stream	None	Good	Poor	Fair	Medium
George Outflow (Kanosak Creek) – Reach 4	1	N/A	Stream	None	Fair	Poor	Good	Medium
George Outflow (Kanosak Creek) – Reach 5	1	N/A	Stream	None	Fair	Poor	Good	Medium
George Outflow (Kanosak Creek) – Reach 6	1,3	404	Stream	None	Poor	Poor	Fair	Low
George Outflow (Kanosak Creek) – Reach 7	1,2,3	122/401	Stream	None	Poor	Poor	Fair	Low
Fold Outflow (Kanosak Creek) - Reach 8	1	N/A	Stream	None	Poor	Poor	Fair	Low
George Inflow	2,3	123/800	Stream	None	Fair	Fair	Good	Medium
George Inflow 2	2,3	124/400	Stream	None	Poor	Good	Poor	Low
Dragon Creek - Reach 1	1	N/A	Stream	None	Fair	Poor	Good	Medium
Dragon Creek - Reach 2	1	N/A	Stream	None	Poor	Poor	Poor	Low
Dragon Creek - Reach 3	1	N/A	Stream	None	Poor	Fair	Fair	Low
Dragon Creek - Reach 4	1	N/A	Stream	None	Poor	Fair	Fair	Low
Dragon Inflow	2	129	Stream	None	Fair	Poor	Good	Medium
McCoy Outflow	3	810	Stream	None	Poor	Good	Good	Medium

Notes: N/A = not applicable; NCD = non-classified drainage
[1] Sekerak (1990); [2] Rescan (2012c); [3] Rescan (2013a).

George Outflow can be broken down into seven reaches based on habitat type (Sekerak 1990). Most of the stream between Komatic Lake and George Lake is characterized by low gradient habitat featuring glides and occasional pools and riffles, typical of beaded tundra streams (Plate 6.1-9). In the upper reaches between George and Lytle lakes, the channel features boulder fields that may become

impassable at low water due to subsurface flow (Plate 6.1-10; Rescan 2012c). The bankfull depth of George Outflow does not exceed 1.5 m, making it unsuitable for fish overwintering. However, spawning and rearing habitat for Arctic Grayling was rated to be fair to good in reaches downstream of Sleigh Lake, and fair to poor in the reaches immediately downstream of George Lake (Sekerak 1990).



Plate 6.1-9. Shallow glide habitat on Sleigh Outflow, George Property. July 2012.



Plate 6.1-10. Boulder field on George Outflow near Lytle Lake at low water flow, George Property. July 2012.

Dragon Creek, which connects Dragon Lake to Komatic Lake, can be broken down into four reaches (Sekerak 1990). Similar to George Outflow, the lower reaches of Dragon Creek are typical of a beaded tundra stream, while the upper reaches are poorly defined and shallow. Overwintering habitat is not present due to the shallow depth, and habitat for spawning and rearing Arctic Grayling is best in the reach immediately upstream of Komatic Lake, and poor in the rest of the stream. Other streams sampled in the George Property Area featured smaller channels, with sections of poorly defined flow and seepages (Plate 6.1-11).



Plate 6.1-11. Typical small stream in the George Property Area, with poorly defined banks and frequent overland flow. Northeast inflow to George Lake. July 2012.

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.

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.

George Property Area

Baseline periphyton biomass and taxonomy samples were collected from five stream sites in the George Property Area during August 2012. In general, stream periphyton biomass was low to moderate, streams were oligotrophic and taxonomic richness and diversity was moderate to high.

Mean biomass levels were below 2 µg chl *a*/cm^2 in all sampled streams, which would have been classified as oligotrophic based on Dodds, Jones, and Welch (1998) scheme (TP < 2 µg). Periphyton densities were similar in streams near the proposed Project infrastructure (George Outflow, Sleigh Outflow, Dragon Outflow and Komatic Inflow), ranging from a mean of 56,000 cells/cm^2 (George Outlfow) to 77,000 cells/cm^2 (Dragon Outflow). Higher densities were observed further afield at the Reference C Outflow site at 419,000 cells/cm^2.

Stream periphyton communities tended to be dominated by cyanobacteria (Myxophyceae) and diatoms (Bacillariophyceae), with smaller proportions of green algae (Chlorophyceae) also present. Common genera observed in 2012 were the small pennate diatom *Achnanthidium* and the cyanobacteria *Leptolyngbya*.

Periphyton genera richness and diversity varied by stream. The mean number of genera observed at each stream ranged from 12.7 genera/sample (Sleigh Outflow) to 22.7 genera/sample (Dragon Outflow). Periphyton diversity at the genus level was high, with mean ranging from 0.80 (Reference C Outflow) to 0.85 (Sleigh Outflow) on the Simpson's diversity index.

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).

George Property Area

Baseline benthic taxonomy samples were collected from five stream sites in the George Property Area during August 2012. In general, stream benthos density was variable among years and locations, and taxonomic richness and diversity was moderate and variable.

Benthos samples showed considerable within stream and between stream variability, with mean densities ranging from 1,160 individuals/m^2 at Reference Lake C Outflow to 4,780 individuals/m^2 at Sleigh Outflow.

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, EPT: Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies), were found at all streams. EPT made up between 0.4% and 12% of the mean benthic community at George Property streams, with the lowest proportions being at Komatic Inflow and Reference C Outflow and the greatest proportions being at Sleigh Outflow.

Often a few genera were particularly abundant, suggesting benthos communities were dominated by a few groups and diversity was low. At all streams, the most abundant genus made up over 15% of the total benthic community, and the three most abundant genera made up over 30% of the total benthic community. These dominant genera varied among streams, although the dipterans *Thienemannimyia* and *Saetheria* and the Acari worm *Sperchon* were one of the three most abundant genera at more than one stream site.

Richness and diversity in George Property Area stream benthic communities were moderate and variable. Stream samples ranging from a mean of 9.0 families/sample at Sleigh Outflow to 17.6 families/sample at Dragon Outflow, while diversity ranged from 0.40 at Komatic Inflow to 0.78 at Dragon Outflow (Simpson's diversity 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)

6.2.1 Incorporation of TK for Existing Environment and Baseline Information

Available traditional knowledge (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 *NTKP* report (hereafter, 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*). The Western River lies within the Regional Study Area (RSA) of the George Property Area. In addition, the maps in the TK report indicate that, outside the Goose and George Property RSAs, other freshwater fishing sites of value to the Inuit occur in and around Beechey Lake, just south of the Goose and George Property RSAs.

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 in the George Property RSA, is fished, specifically for Lake Trout (*Salvelinus namaycush*). The participants also indicated that hunting and fishing take place along the length of this route. The people may stop at George Lake, located in the freshwater LSA of the George Property Area, 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 Goose Property LSA, was also identified as an area where fishing may occur while staying near Beechey Lake. While Goose Lake and George Lake may be fished by traditional land users, they are not known to be destinations or key locations for fishing (Volume 8, Chapter 4).

In the 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.

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 this report (Figures 31 and 32) and, 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 Report were reviewed for spatial and temporal boundaries (KIA 2012) . According to Figures 31 and 32 within Chapter 7 of the TK report, the Project's Potential Development Area (PDA) does not overlap with fishing locations identified in other parts of the RSA. Some important fishing areas are located within the northern reaches of the Western River which form the outer limits of the RSA for fish habitat.

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), the mitigation and management of fish habitat 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 Conceptual 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 Draft Conceptual Fish Offsetting Plan, including the development of additional or alternative options that could provide value to the local communities, is intended through 2014.

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 Aboriginal, recreational or commercial 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 (Volume 6, Chapter 6) 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). Moreover, Project design ensures that water and sediment quality in receiving environments will meet the conservative empirical thresholds of CCME guidelines, below which no adverse effects on aquatic life are predicted to occur.

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

6.4.1 Spatial Boundaries

The spatial boundaries used for the assessment of the VEC freshwater fish/aquatic habitat included a LSA and the RSA for each of the Goose and George Properties.

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 determined for the assessment of effects on VEC freshwater fish/aquatic habitat is divided into two areas (Figure 6.4-1):

1. The Goose Property LSA — The LSA boundary (365 km^2) includes the Goose Property Potential Development Area (PDA) and matches the boundaries of the Propeller and Big watersheds.
2. The George Property LSA — The LSA boundary (105 km^2) includes the George Property PDA, and matches the boundaries of the Dragon, George, McCoy, and Lower Long watersheds.

PROJECT #0194096-0015 GIS # BAC-06-098 October 25 2013

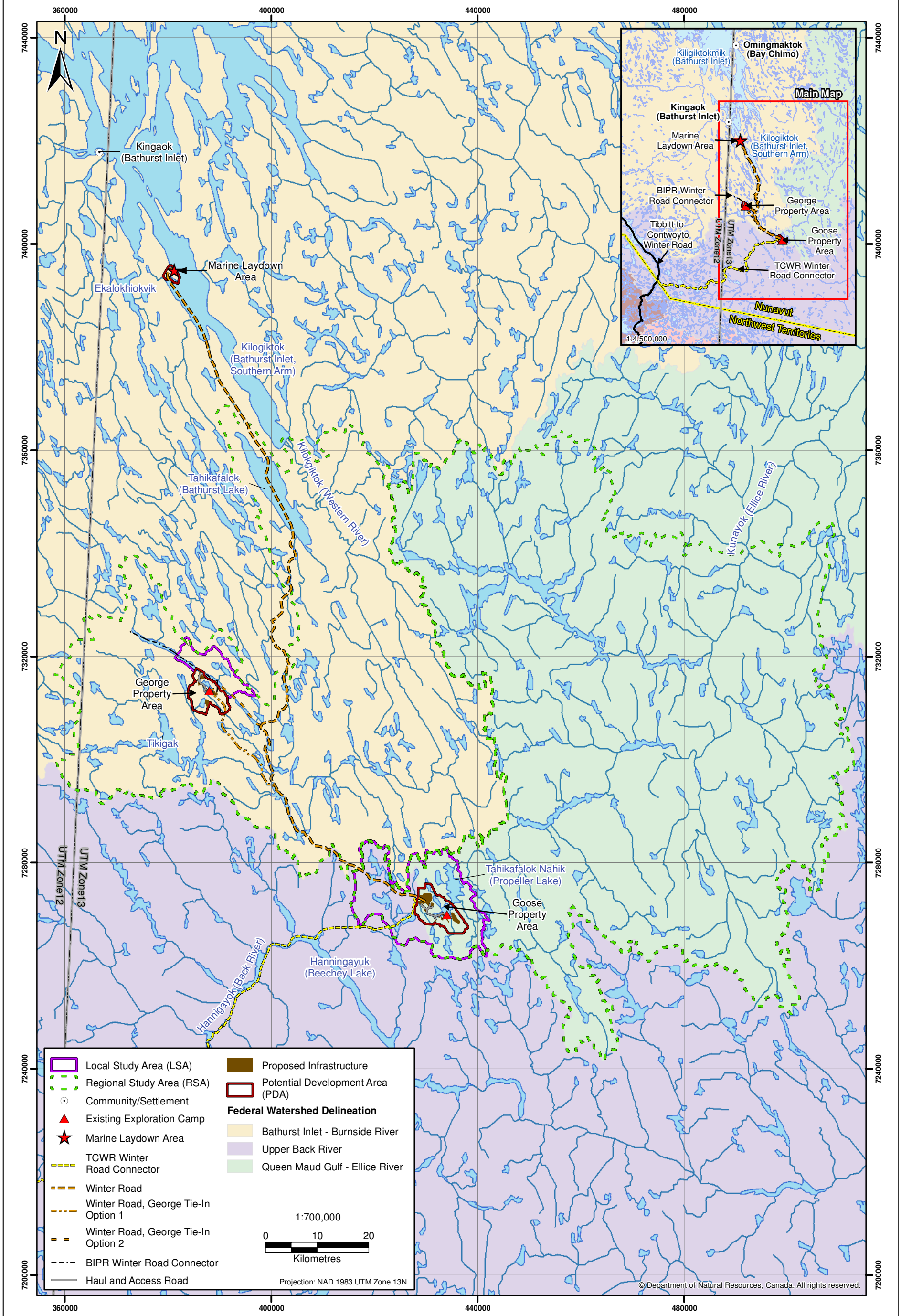


Figure 6.4-1

Sabina GOLD & SILVER CORP.

Local Study Area and Regional Study Area for Freshwater Fish/Aquatic Habitat

Figure 6.4-1

Rescan an ERM company

6.4.1.2 *Regional Study Area*

The RSA includes the PDAs, the LSAs, and additional areas within which there is the potential for indirect or cumulative effects. The RSA determined for the assessment of effects on the VEC freshwater fish/aquatic habitat assessment is divided into two areas (Figure 6.4-1):

1. The Goose Property RSA — The RSA boundary (6,815 km^2) includes part of the Ellice River Watershed and encompasses the PDA and the LSA. All Project infrastructure resides within the Ellice Watershed. The upper ~80 km of the watershed was included rather than the entire watershed.
2. The George Property RSA — The RSA boundary (4,034 km^2) includes part of the Western River Watershed and encompasses the PDA and LSA. All Project infrastructure resides within the Western River Watershed. The upper portion of the watershed that drains in to the Western River at the southern tip of Bathurst Inlet is included in the RSA.

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:

- Site Preparation – 2 years;
- Construction phase – 2 years;
- Operations phase – 10 years;
- Reclamation and Closure phase – 10 years;
- Post-closure phase 5 years minimum;
- 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 were 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.

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 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).

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.

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 in fish/aquatic habitat that is not mitigated through Project design and management, and is long-lasting or permanent within the zone of influence of the Project relative to reference condition.
Not Significant	Effect may result in a decrease in 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.

Freshwater fish/aquatic habitat may interact and be affected by Project activities in two ways: 1) 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 (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.

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 TIA, WRSAs, open pits, mill, camp, quarries and borrow pits, road and airstrip water crossings 2. Lake dewatering	1. All phases 2. Site Preparation and Construction
Water Use	1. Water withdrawal (camp, mill and winter roads)	1. Site Preparation, Construction, Operations, Reclamation, and Closure
Water, Effluent, and Dust Management	1. Contact water 2. Treated 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. Site Preparation, Construction, Operations 3. All phases 4. Site Preparation, Construction, Operations 5. All phases 6. Site Preparation, Construction, and Operations.

6.5.2.1 *Loss of Fish Habitat: Project Infrastructure Footprint*

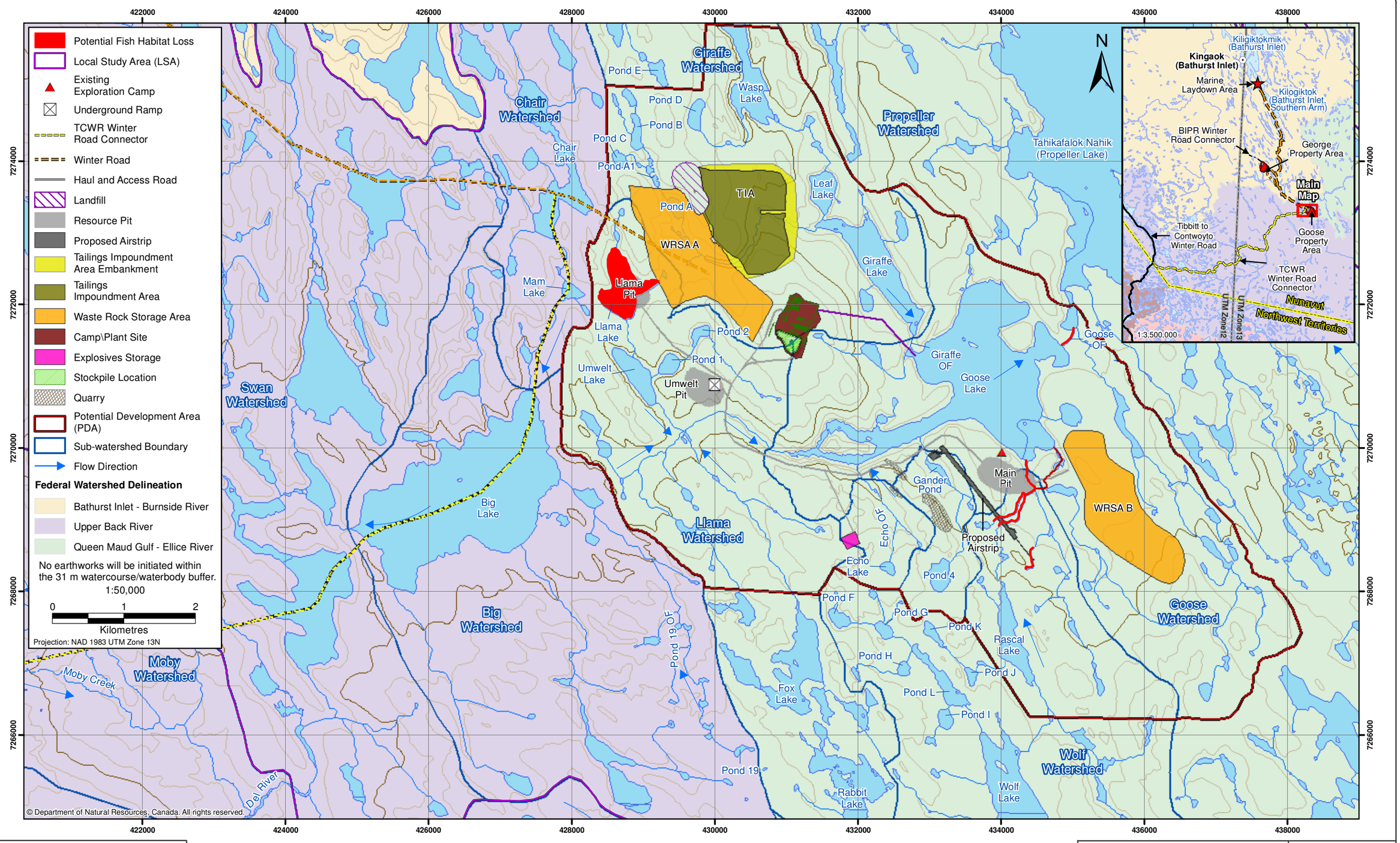
Locations of Project Infrastructure

Project infrastructure has the potential to interact with the VEC freshwater fish/aquatic habitat wherever the locations overlap with freshwater that is fish bearing (Figures 6.5-1 and 6.5-2). Potential effects on the VEC freshwater fish/aquatic habitat are anticipated during the Site Preparation and Construction phases in which the building of most infrastructure takes place, and during the Operations phase, when the expansion of open pits, waste rock storage areas, and TIA are likely to occur.

In lakes, the direct loss of habitat will occur in Llama Lake as the result of construction of the Llama Pit, at Lytle Lake as the result of construction of the Locale 1 Pit, and at Occurrence Lake due to construction of the Locale 2 Pit (Figures 6.5-1 and 6.5-2).

At Llama Lake (Goose Property), the entire lake will be drained in preparation for the construction of the Llama Pit, which represents a loss of 36.59 ha of lake habitat used by Lake Trout and Round Whitefish. The majority of the area of the lake is composed of shallow water (less than 4 m), with large, boulder-cobble substrate, followed by deepwater areas (greater than 4 m) with fine substrates, and nearshore areas (less than 2.5 m deep) with fine substrates. When considering the suitability of habitat for each species and each life stage, the weighted suitable areas for Lake Trout and Round Whitefish, respectively, are 50.9 ha and 47.6 ha, and the averaged suitable area is 48.9 ha. Llama Lake does not have a large amount of habitat that is classified as good or excellent for any fish life stage, but it was categorized as medium quality habitat overall as it provides the majority of deepwater overwintering habitat in the sub-watershed. Details and calculations regarding the habitat that will be lost at Llama Lake are provided in the Draft Conceptual Fish Offsetting Plan (Volume 10, Chapter 21).

At Lytle Lake (George Property), habitat loss will occur in a small section of lake due to construction of the Locale 1 Pit. The total area of habitat that will be lost is 1.53 ha, which includes 0.81 ha of nearshore habitat with large substrate and 0.72 ha of nearshore habitat with a fine sediment bottom. No fish have been captured in Lytle Lake; however, it is located between known fish-bearing waterbodies and is likely habitat only suitable for Arctic Grayling rearing and foraging during the open-water season. The lack of deepwater habitat makes Lytle Lake unsuitable for overwintering. The total weighted suitable area for Arctic Grayling that will be lost is 0.99 ha. Further details on the habitat loss in Lytle Lake are presented in the Draft Conceptual Fish Offsetting Plan (Volume 10, Chapter 21).



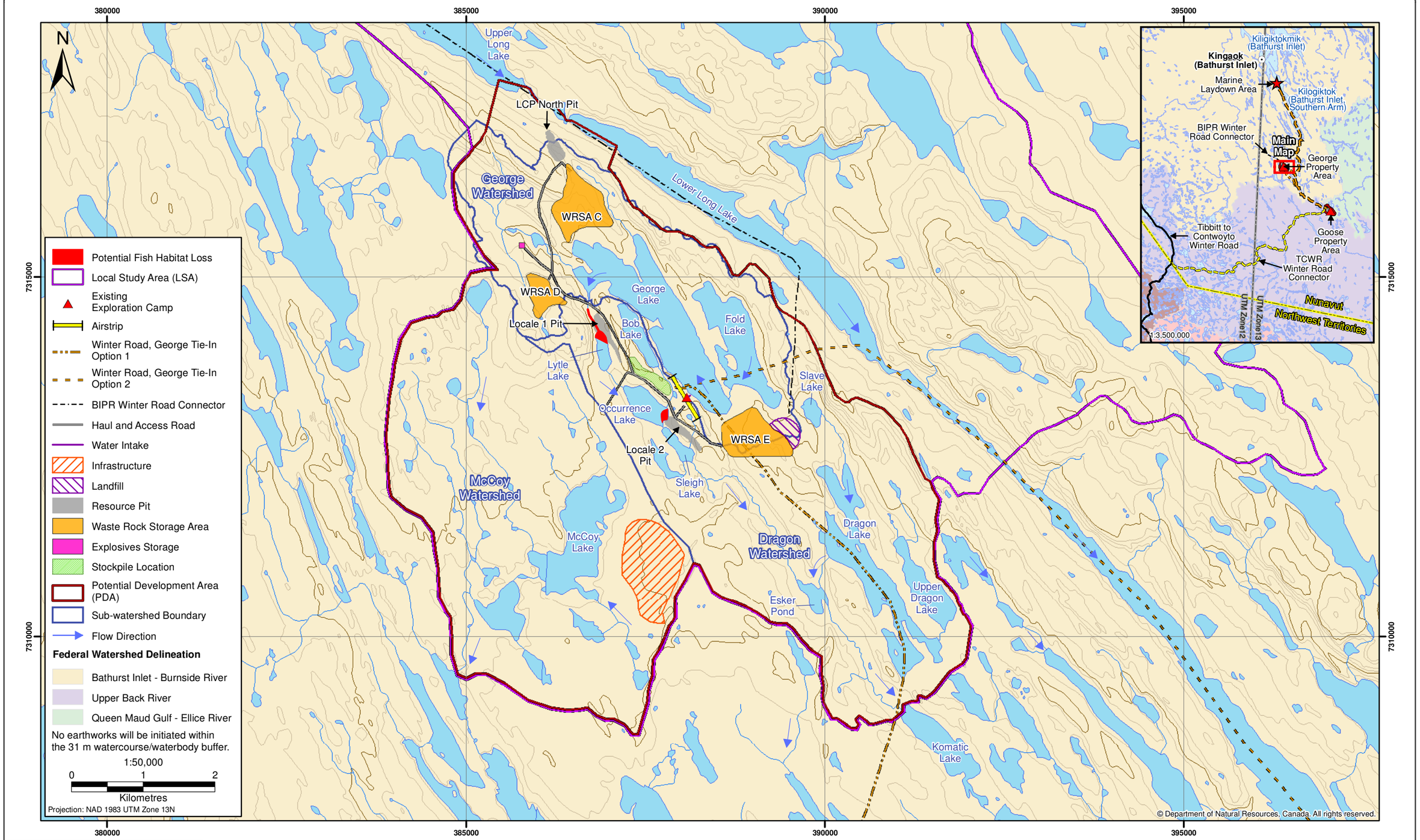
Sabina GOLD & SILVER CORP.

Rescan an ERM company

Figure 6.5-1

Infrastructure Layout and Locations of Potential Habitat Loss, Goose Property Area

PROJECT # 0194096-0028 GIS # BAC-06-158 October 23, 2013



Sabina GOLD & SILVER CORP.

Rescan an ERM company

Figure 6.5-2

Infrastructure Layout and Locations of Potential Fish Habitat Loss, George Property Area

A portion of Occurrence Lake in the George Property Area will be lost due to construction of the Locale 2 Pit. The total area of habitat that will be lost is 0.74 ha, of which the majority is nearshore habitat with a fine sediment bottom. Sampling has yielded only a single Arctic Grayling (in 2013). In winter the lake freezes to the bottom, making overwintering impossible, and lake is only suitable for Arctic Grayling rearing and foraging. The weighted suitable area that will be lost is 0.32 ha. Further details on the habitat loss in Occurrence Lake are presented in the Conceptual Fish Offsetting Plan (Volume 10, Chapter 21).

In streams, the majority of the direct loss of habitat will occur on the Rascal-Goose Stream (Goose Property) as the result of construction of the Main pit, airstrip, and service road to the WRSA, and at George Outflow (George Property) due to construction of the Locale 1 Pit (Figures 6.5-1 and 6.5-2).

At the Rascal-Goose Stream, direct habitat loss will occur in order to divert water around the airstrip and other mine infrastructure toward Gander Pond, south and west of the proposed airstrip. This will result in a loss of approximately 0.18 ha of in-stream habitat. This stream was surveyed in 2012 and 2013 (Rescan 2012d), 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 2012d), and contains fair to good quality nursery, rearing, and foraging habitat. The weighted suitable area for Arctic Grayling that will be lost is approximately 0.42 ha. Additional details on the habitat that will be lost within the Rascal-Goose Stream are presented in the Draft Conceptual Fish Offsetting Plan (Volume 10, Chapter 21).

Construction of the Locale 1 Pit will result in the loss of a portion of the stream between Lytle Lake and George Lake (George Outflow). The total area of habitat that will be lost is 0.42 ha, of which the majority is dominated by exposed boulders. Habitat in this section of stream is characterized by a wide boulder garden, which floods during high water but contains only isolated pools during low flow periods. The habitat is best suited for Arctic Grayling rearing and foraging, making the weighted suitable area that will be lost 0.714 ha. Further details on the habitat loss in George Outflow are presented in the Draft Conceptual Fish Offsetting Plan (Volume 10, Chapter 21).

Potential effects related to Project infrastructure may also be incurred on streams during site road construction. Site roads at the Goose and George properties will cross several fish-bearing streams. 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 final details of infrastructure design may require minor works that have the potential to affect fish habitat. Road crossings, water intake structures, boat launches, and other small site features that require work in or near fish-bearing water may mobilize sediment, destabilize stream banks or lake shores, damage riparian zones and alter flow patterns. There may also be a small direct footprint associated with such works, as in the case of a water intake system. The Project is being designed to avoid adversely affecting fish-bearing waters where possible by using appropriate road crossing methods and by designing water intake structures to be functional fish habitat if possible. As the potential footprint of these works is small and engineering details will continue to progress during feasibility studies, these smaller aspects of the Project footprint are not addressed further.

Lake Dewatering

Dewatering of lakes (Llama Lake) or portions of lakes (i.e., Lytle Lake and Occurrence Lake) will be required in order to construct open pits at each of these locations. 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 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.

6.5.2.2 *Loss of Fish Habitat: Water Use*

Water Withdrawal

Water for domestic and process use will be drawn from Goose and Propeller Lakes in the Goose Property, and from George Lake in the George Property 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 withdrawal from lakes has the potential to affect fish/aquatic habitat through multiple pathways, including a reduction in available fish habitat and changes to primary and secondary producers. 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). In addition, water withdrawal has the potential to modify water and sediment quality such that shifts in lower trophic level prey communities (invertebrate) are altered. Smaller, shallow lakes and ponds are more susceptible to habitat changes due to water withdrawals than large lakes.

Water withdrawal for winter road construction may also occur at select lakes and ponds along the proposed winter road corridors when required. Connection between the three main Project areas will be established via winter roads constructed during the winter months as needed during the life of the Project. In addition, a winter road connecting to the TCWR may be used as an alternative for resupply during some years.

In addition to the potential effects of water withdrawal on the VEC freshwater fish/aquatic habitat listed above, water draw for winter roads has the potential to restrict the temporal availability of fish habitat in streams. For example, improper decommissioning of winter road crossings may result in temporary barriers to fish passage by increasing erosion and bank instability during spring flooding (DFO 2007b).

The construction and presence of winter 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 roads also have the potential to affect lake shores. If improperly constructed, winter 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.

6.5.2.3 *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.

6.5.3 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 TIA and WRSAs have all been sited to avoid fish-bearing water and have been confined to local watersheds close to the main mine infrastructure.

Where fish habitat loss is expected (e.g., Llama, Lytle, and Occurrence lakes, and Rascal-Goose Stream), mitigation for lost habitat has been incorporated into the Draft Conceptual Fish Offsetting Plan (Volume 10, Chapter 21). The objective of the Conceptual 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.

The majority of effects related to road and airstrip use arise from the construction and maintenance of stream crossings. Several DFO operational statements have been developed to guide these processes and to ensure that fish and aquatic habitat is not adversely affected by development. Site road crossings will be constructed according to the DFO Nunavut Operations Statement for Clear Span Bridges (DFO 2007c). Temporary stream crossings will be constructed according to the DFO Nunavut Operations Statement for Temporary Stream Crossings (DFO 2007e). Culvert maintenance will be conducted following the DFO Nunavut Operations Statement for Culvert Maintenance (DFO 2007a). In-water work will be conducted during approved timing windows presented in the DFO Nunavut Operations Statement for Timing Windows (DFO 2007d). Any loss of habitat related to the construction of watercourse crossings will be included in the Draft Conceptual Fish Offsetting Plan (Volume 10, Chapter 21).

As a result of mitigation, 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 bounds the Project LSAs, specifically at Llama Lake and the Rascal-Goose Stream (Goose Property) and at Lytle Lake, Occurrence Lake and George Outflow (George Property). All habitat losses related to Project infrastructure and lake dewatering will be mitigated by establishing new, or

enhancing current Lake Trout and Arctic Grayling productivity near the Project area. Potential fish offsetting projects for the mitigation of lost fish habitat can be found in the Draft Conceptual Fish Offsetting Plan (Volume 10, Chapter 21).

Additional small infrastructure components that may arise with final site designs will adhere to available DFO standard operating procedures (SOPs) for road crossings, culverts, and water intake structures (e.g., screening any water intake hoses). Water intake structures will be designed to provide useable fish habitat if possible. Given the avoidance of fish-bearing waters altogether (e.g., road crossings) or the small size of the potential footprint of other small works (e.g., water intake structures or boat launches) it is assumed that mitigation measures including SOPs and other best management practices will be effective in avoiding adverse effects to fish habitat and these smaller aspects of the Project footprint are not addressed further.

Lake Dewatering

Any dewatering of lakes will be in accordance with a Lake Dewatering Plan, which is found in the Site Water Monitoring and Management Plan (Volume 10, Chapter 7). Where lake dewatering is expected to result in the loss of fish habitat (e.g., Llama, Lytle, and Occurrence lakes), mitigation by creating new habitat is planned (Draft Conceptual Fish Offsetting Plan: Volume 10, Chapter 21) 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 6.5-5). In addition, water will be recycled or re-used 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 6.5-5. Volume Limits to Water Use

Property	Phase	Maximum Water Use (m^3/day)	Lake Specific Maximum Water Use (m^3/day)
Goose Property Area	Site Preparation and Construction	Domestic Use: up to 210 Industrial Use: up to 70	Goose Lake: 280 year round Propeller Lake: None
	Operations	Domestic Use: up to 210 Industrial Use: up to 2,510; 4,510 in June	Goose Lake: 1,000; 2,000 in June Propeller Lake: 1,510, 2,510 in June
	Reclamation and Closure	Domestic Use: up to 210 Industrial Use: up to 70	Goose Lake: 1,000; 2,000 in June Propeller Lake: 1,510, 2,510 in June
George Property Area	Site Preparation and Construction	Domestic Use: up to 45 Industrial Use: up to 70	George Lake: 115 year round
	Operations	Domestic Use: up to 45 Industrial Use: up to 70	George Lake: 115 year round
	Reclamation and Closure	Domestic Use: up to 45 Industrial Use: up to 70	George Lake: 115 year round

To protect essential fish habitat in Goose Lake, the volume limit for water withdrawal was set at 210 m^3/day for domestic use, and 70 m^3/day for industrial use during the Site Preparation and Construction phases. During Operations and Reclamation and Closure phases, the maximum amount of water that will be withdrawn will be 1,000 m^3/day, with an increase up to 2,000 m^3/day during freshet.

At the maximum limit to withdrawal volumes (Table 6.5-5), 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). During summer, the limit to water drawdown will prevent water level from decreasing more than 0.06 m/day. During late winter, the limit to water drawdown will prevent water level from decreasing below 0.1 m under ice. This anticipated reduction in water level in Goose Lake in both summer and winter is considered negligible and 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). Additionally, drawdown levels of less than 0.15 m should not result in adverse effects to Lake Trout spawning since most trout spawn in waters greater than 0.15 m (Marcus, Hubert, and Anderson 1984).

Maximum limits to water withdrawal volume from Goose Lake would also affect discharge rate at the Goose Outflow stream — a wide, shallow connection between Goose and Propeller lakes — but 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 20.6% from the baseline outflow volume. 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 20.6% 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. 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).

Water withdrawal from Propeller Lake has been designed to avoid impacts to fish habitat. Maximum withdrawal for Propeller Lake was set at 10% of the outflow volume, below the maximum permissible withdrawal volume to protect fish habitat (DFO 2009, 2010). Withdrawals from Propeller Lake are anticipated to occur during the Operations and the Reclamation and Closure phases. A maximum of 1,510 m^3/day of water will be withdrawn during most of the year with an increase to 2,510 m^3/day during freshet in June.

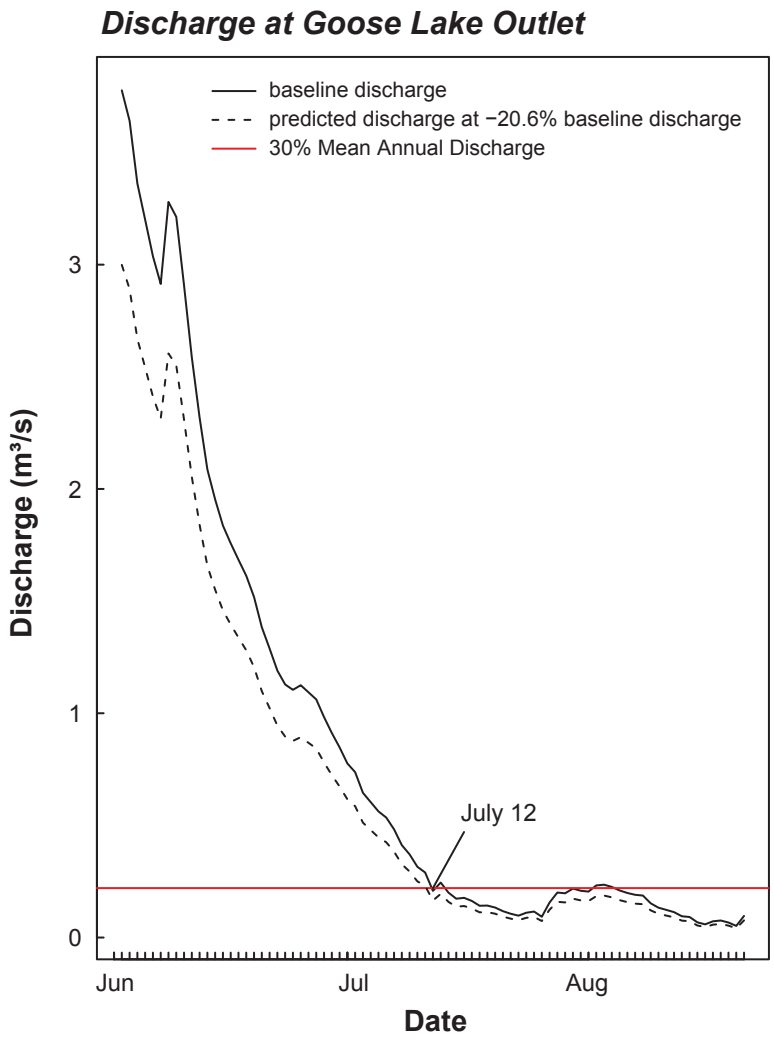
Maximum withdrawal for George Lake was set at 10% of the outflow volume, below the maximum permissible withdrawal volume for the protection of sensitive fish habitat (DFO 2009, 2010). During the Site Preparation, Construction, Operations, and Closure and Reclamation phases, the maximum water withdrawals from George Lake were limited to 45 m^3/day for domestic use, and 70 m^3/day for industrial use.

Water withdrawal from any lakes or rivers required for winter road construction will avoid impacts to the VEC freshwater fish/aquatic habitat by following DFO's Protocol for Winter Water Withdrawal from Ice-Covered Waterbodies in the Northwest Territories and Nunavut (DFO 2010) and DFO's Operations Statement on Mineral Exploration Activities (DFO 2009).

Where pumps are used for withdrawing water in fish-bearing waters or where fish salvage has not occurred, the intakes will be screened in accordance with the DFO Fresh Water Intake End of Pipe Screening Guideline (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.

6.5.3.3 *Deposition of Deleterious Substances*

The mitigation and management measures to avoid Project impacts on the VEC freshwater fish/aquatic habitat can be found in 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.



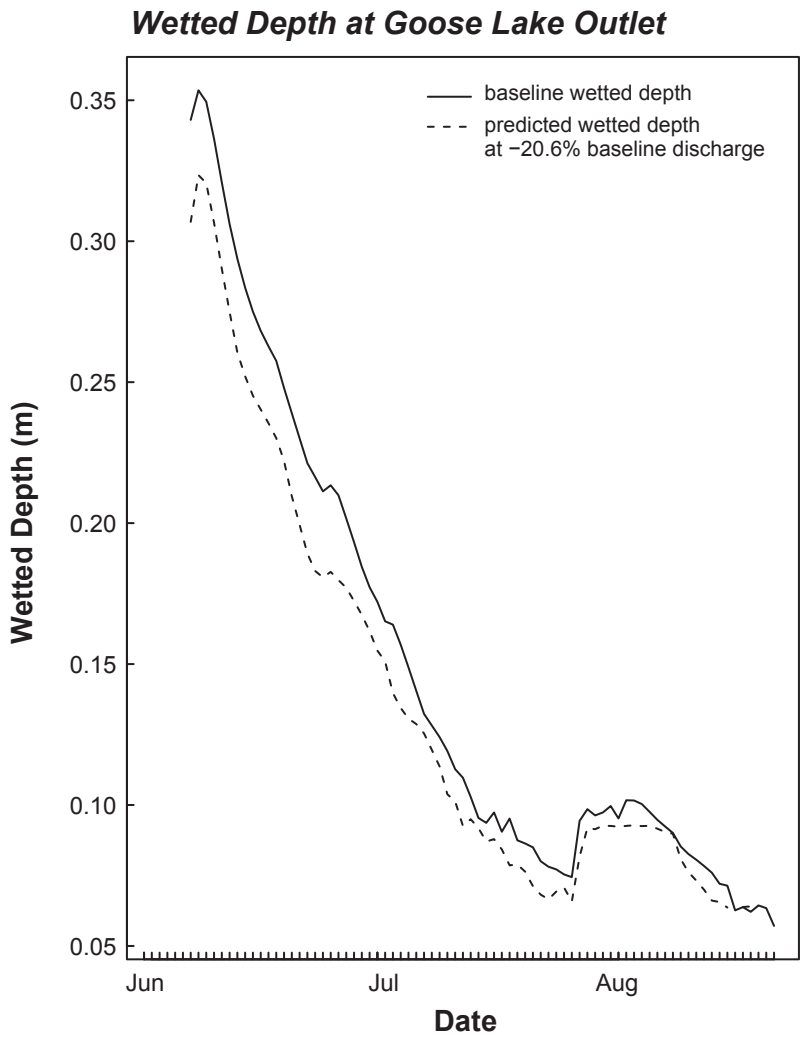


Figure 6.5-3

Sabina GOLD & SILVER CORP.

Daily Discharge and Wetted Depth at Goose Lake Outflow

Figure 6.5-3

Rescan Engineers & Scientists

The assessment of residual effects on the VEC Water Quality and Sediment Quality can be found in Volume 6, Chapters 4 and 5.

6.5.4 Characterization of Residual Effects

After the consideration of mitigation measures there are no anticipated residual effects on the VEC freshwater fish/aquatic habitat from the Project.

6.5.5 Significance of Residual Effects

With mitigation measures in place, including the Conceptual Fish Offsetting Plan and water use limits, 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 mitigation and management, the residual effects of Project activities on the VEC freshwater fish/aquatic habitat were predicted to be *negligible*, confined within the LSA, and **Not Significant**. 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

After mitigation and management, there are no anticipated residual effects on the VEC freshwater fish/aquatic habitat. 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:

- Draft Conceptual Fish Offsetting Plan (No Net Loss Plan) (Chapter 21);
- Aquatic Effects Management Plan;
- Overall Environmental Management Plan;
- Environmental Protection Plan;
- Fuel Management Plan;

- Spill Contingency Plans;
- Oil Pollution Emergency Plan;
- Site Water Monitoring and Management Plan;
- Mine Waste Rock and Tailings Management Plan;
- Landfill and Waste Management Plan;
- Incineration Management Plan;
- Explosives Management Plan;
- Road Management Plan ;
- Borrow Pits and Quarry Management Plan;
- Air Quality Monitoring and Management Plan;
- Metal Leaching and Acid Rock Drainage Management Plan; and
- Mine Closure and Reclamation Plan.

Mitigation by Project Design

The Project has been designed to avoid impacts on fish/aquatic habitat where possible. The major aspects of mitigation by project design include:

- locating the TIA and WRSA to avoid fish bearing water;
- locating infrastructure a minimum of 31 m away from fish-bearing waterbodies; and
- designing water use limits to avoid effects on high value fish habitat.

A full list of mitigation by project design can be found in Table 6.8-1.

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 operational statements and protocols, 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.

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 and George Properties 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 monitoring program will be developed to monitor the effectiveness of the Draft Conceptual Fish Offsetting Plan (Volume 10, Chapter 21). The monitoring program will be developed in conjunction 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.

Offsetting

A Draft Conceptual Fish Offsetting Plan is presented in Volume 10. This plan will be adapted to offset any and all PADs of fish habitat, and will be reviewed and approved by DFO, the KIA, and other interested parties.

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.

Table 6.8-1. Mitigation and Management Measures Summary

Mitigation Category	Mitigation Measures
1. Mitigation by Project Design	
	Infrastructure, waste rock storage areas, and the TIA at the Goose Property have been located within the same subwatersheds as the mine workings outside of the regional Upper Back River Watershed
	The TIA has been designed as a zero discharge facility, ensuring no potentially poor quality water is introduced to the freshwater environment, and avoids all fish-bearing waterbodies.
	A Conceptual Fish Offsetting Plan will be in place that has been approved by DFO, the KIA, and other interested parties, to offset or enhance for the permanent alteration or destruction of fish habitat. Freshwater offsetting will possibly include the following methods: • increased access to overwintering habitat for Lake Trout and Arctic Grayling by increasing lake depth; • increased access to rearing and spawning habitat for Lake Trout by installing artificial rock shoals in lakes; and/or • increased access to rearing and spawning habitat for Arctic Grayling by enhancing stream access and stream channels.

(continued)

Table 6.8-1. Mitigation and Management Measures Summary (continued)

Mitigation Category	Mitigation Measures
1. Mitigation by Project Design (*cont'd*)	
	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 Fresh Water Intake End of Pipe Screening Guideline (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.
2. Regulatory Requirements	
	Culvert maintenance will be conducted following the the DFO Nunavut Operational Statement for Culvert Maintenance (DFO Nunavut Operational Statement: Culvert Maintenance, version 3.0 (2007)).
	Instream work will be conducted during approved timing windows presented in the DFO Nunavut Operational Statement for Timing Windows. (DFO Nunavut Operational Statement: Timing Windows, version 3.0 (2007)).
	Site road crossings will be constructed according to the DFO Nunavut Operational Statement for Clear Span Bridges (DFO Nunavut Operational Statement: Clear Span Bridges, version 3.0 ([2007]).
	Temporary stream crossings will be constructed according to the DFO Nunavut Operational Statement for Temporary Stream Crossings (DFO Nunavut Operational Statement: Temporary Stream Crossing, version 1.0 [2007]).
	Winter road construction will follow the DFO Nunavut Operational Statement for Ice Bridges and Snow Fills (DFO Nunavut Operational Statement: Ice Bridges and Snow Fills, version 3.0 [2007]).
	Water withdrawal will follow DFO's Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut and DFO's Operational Statement on Mineral Exploration Activities (DFO Nunavut Operational Statement: Mineral Exploration Activities, version 1.0 [2009]).
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 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 TIA or other appropriate holding facility.
	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 Operational Statements and Standards and Best Practices for Instream Works.
	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).

(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 will 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.

6.9 PROPOSED MONITORING PROGRAMS

6.9.1 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 and George Properties 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 Conceptual Fish Offsetting Plan

A Draft Conceptual Fish Offsetting Plan can be found in Volume 10, Chapter 21. This Conceptual Fish Offsetting Plan will address all potential PADs of fish habitat by creating compensatory fish habitat elsewhere in the Project area. Freshwater fish/aquatic habitat offsetting may include the following methods:

- increasing access to overwintering habitat for Lake Trout and Arctic Grayling by increasing lake depth;
- increasing access to rearing and spawning habitat for Lake Trout by installing artificial rock shoals in lakes; and

- increasing access to rearing and spawning habitat for Arctic Grayling by enhancing stream access and stream channels.

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 (Volume 6, Chapter 6) 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) 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. In lakes, the direct loss of habitat will occur in Llama Lake as the result of construction of the Llama Pit, at Lytle Lake as the result of construction of the Locale 1 Pit, and at Occurrence Lake due to construction of the Locale 2 Pit. In streams, the direct loss of habitat will occur on the Rascal-Goose Stream as the result of construction of the Main Pit, airstrip, and service road to the WRSA; and at George Outflow due to construction of the Locale 1 Pit. Water withdrawal from Goose, Propeller, and George lakes 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, there are no residual effects anticipated on the VEC freshwater fish/aquatic habitat due to Project infrastructure. The primary mitigation measures include fish compensation through the Conceptual Fish Offsetting Plan, setting maximum limits to water withdrawal to protect sensitive fish habitat, and siting Project infrastructure to avoid fish-bearing water.

The lack of residual effects on fish habitat predicted from the Back River Project results in no opportunity for effects to act additively or synergistically with other projects, and no cumulative or transboundary effects on the VEC freshwater fish/aquatic habitat are expected to occur.

7. Freshwater Fish Community

Rescan™
an ERM company

7. Freshwater Fish Community

7.1 EXISTING ENVIRONMENT AND BASELINE INFORMATION

7.1.1 Overview and Regional Setting

Fish distribution in the Goose and George Property Areas is typical of inland, headwater regions of the Canadian Arctic. Lake Trout (*Salvelinus namaycush*) is the dominant freshwater fish species in the Project area, followed by Round Whitefish (*Prosopium cylindraceum*), Arctic Grayling (*Thymallus arcticus*), Slimy Sculpin (*Cottus cognatus*), and Ninespine Stickleback (*Pungitius pungitius*). 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 either the Goose or George Properties; however, they have been captured nearer Bathurst Inlet approximately 76 and 25 km north of the Goose and George Properties, respectively. 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).

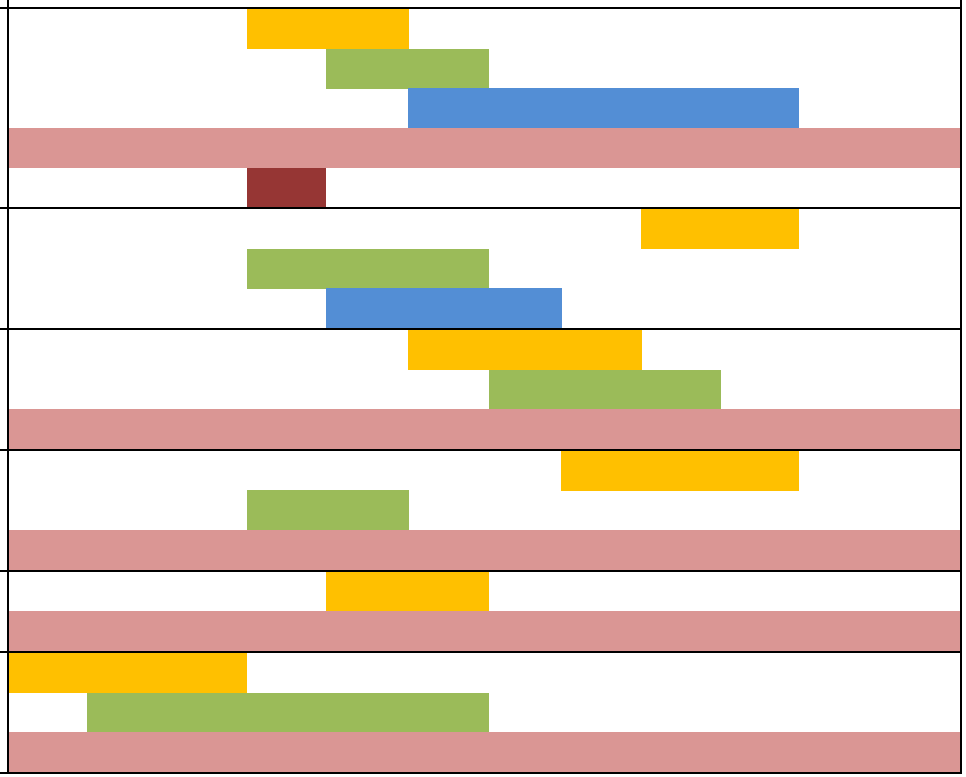
Round Whitefish are also lake spawners and lay their eggs in the fall over gravel substrates, often near river mouths (Scott and Crossman 1973). Some populations may undergo a spawning migration to reach preferred spawning grounds. Hatching occurs in the spring and juvenile and adults generally live 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. Adult 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).

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	
	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).

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; 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 commercial, recreational, or Aboriginal 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 commercial, recreational, and Aboriginal 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 commercial, recreational, or Aboriginal fisheries;
- fisheries management objectives;
- whether there are measures and standards to avoid, mitigate, or offset serious harm to fish that are part of a commercial, recreational, or Aboriginal 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 commercial, recreational, or Aboriginal 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 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) has no special designation in the George and Goose RSAs, but the caribou calving grounds outside the RSA have been designated PSE-R2. The proposed Hiukitak River Cultural Area is on the eastern shore of Bathurst Inlet outside the RSA, and is located 40 km east of Kingaok, 60 km north-east of the proposed Marine Laydown Area (MLA), and 140 km north of the George Property.

7.1.4 Baseline Study Area

Freshwater fish community baseline studies were undertaken from 2010 to 2012 in the Back River Project area. Baseline studies conducted in 2010 and 2011 focused on the Goose Property, while studies in 2012 focused on waterbodies in the both the Goose and George Properties. Figures 7.1-1 through 7.1-4 show the Goose Property and George Property Local Study Areas (LSAs), 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 2012 in the Goose and George Properties (Appendices V6-6A to V6-6C; Rescan 2010, 2012a, 2012c). Fish community studies were also undertaken in 2013, and results from these studies will be available in early 2014. The following provides a summary of the 2010 to 2013 available baseline data:

2010 Baseline Studies (Goose Property)

- 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.

2011 Baseline Studies (Goose Property)

- 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 (Goose and George Properties)

- 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 in lakes and streams that could be affected by mine development at the Goose and George Properties;
  - Collect baseline tissue metal samples and stomach content samples from potential receiving environment lakes in the Goose and George Properties; and
  - Assess fish presence and distribution within the footprint of a potential tailings storage area in the Moby Lake Watershed.

2013 Baseline Studies (Goose and George Properties)

- Fish and Fish Habitat Baseline (Rescan 2013):
  - Collect baseline fish community information in near-field and far-field lakes downstream of the proposed Tailings Impoundment Area (TIA);
  - Collect tissue metal data from fish in Giraffe, Goose, George, Reference B, Propeller, Komatic, and Reference Q Lakes using Lake Trout tissue plug and Slimy Sculpin whole body analyses;
  - Confirm fish-bearing status in ponds and streams associated with the proposed TIA;
  - 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 within the Goose and George Properties.

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, Fold Lake, Lytle Lake, Occurrence Lake, Bob Lake, Slave Lake, and Moon Lake in the George Property. Goose Lake was also sampled. Lake sampling was conducted by gillnetting and minnow trapping. Stream sampling via electrofishing was conducted on Kanosak Creek in the George LSA, and on the Goose Lake outflow stream in the Goose LSA.
- *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.
- *Preliminary Studies of Fish and Fish Habitat in the George Lake Area, N.W.T.* (Sekerak 1990):
  - Conducted preliminary assessments of fish habitat in the area surrounding George Lake. Lake habitat assessments included George Lake, Fold Lake, Bob Lake, Lytle Lake, Occurrence Lake, Esker Pond, Komatic Lake, Dragon Lake, Upper Dragon Lake, and Upper and Lower Long Lake. Stream assessments were conducted on Kanosak Creek, Dragon Creek and on the channels connecting Fold Lake to George Lake and Upper Long Lake to Lower Long Lake.

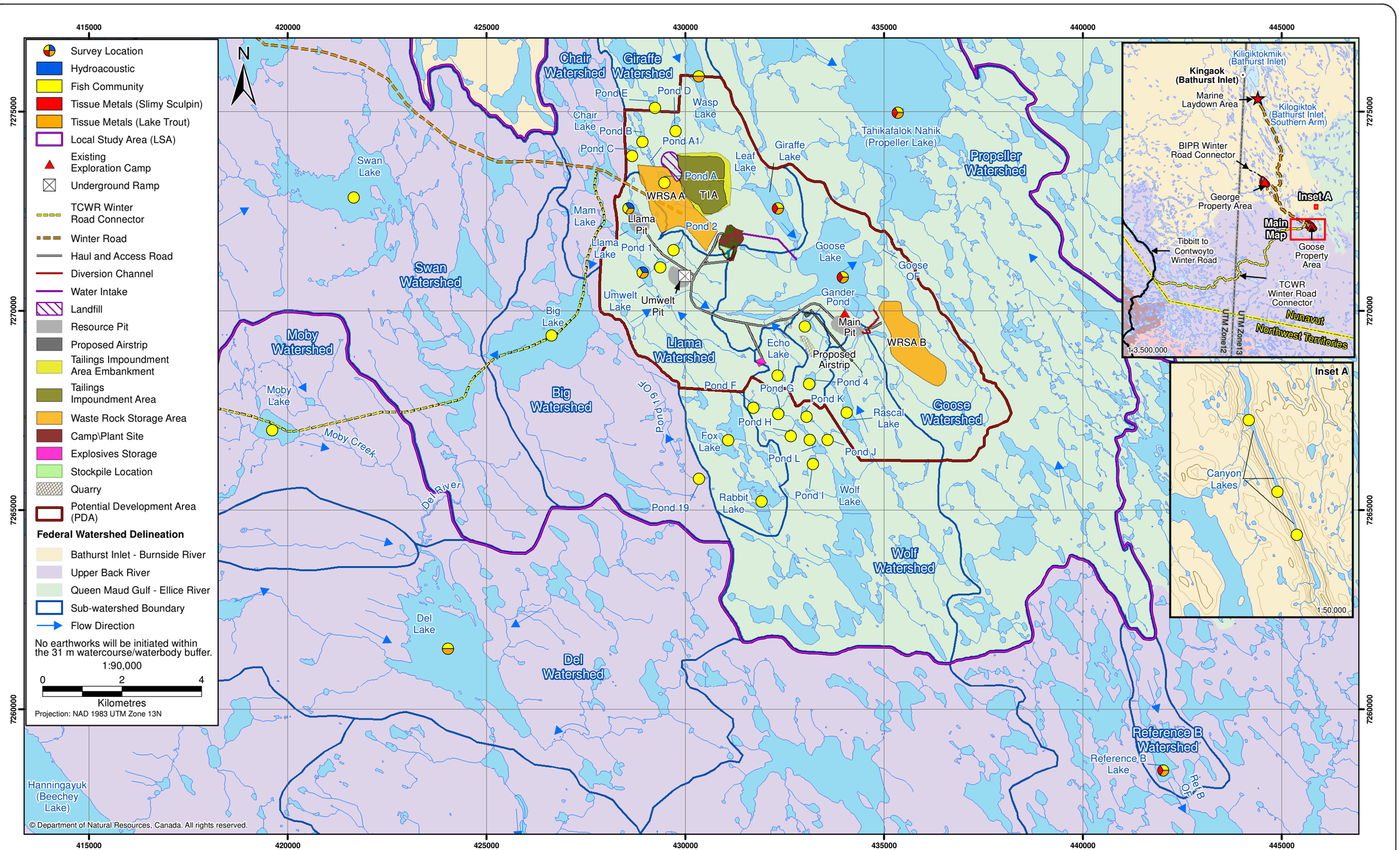
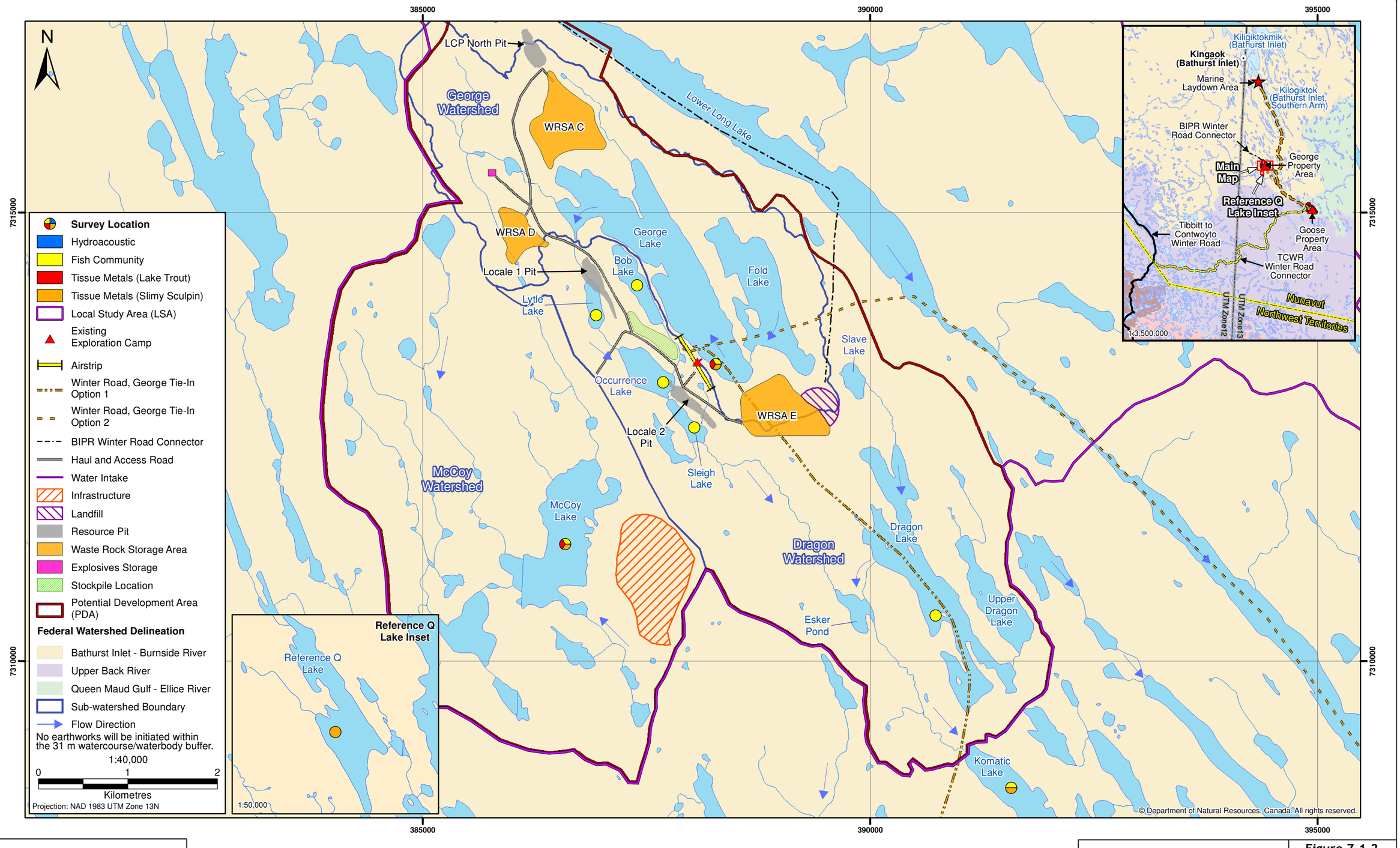


Figure 7.1-1

Lake/Pond Fish Community Baseline Data (2010 to 2013), Goose Property Area

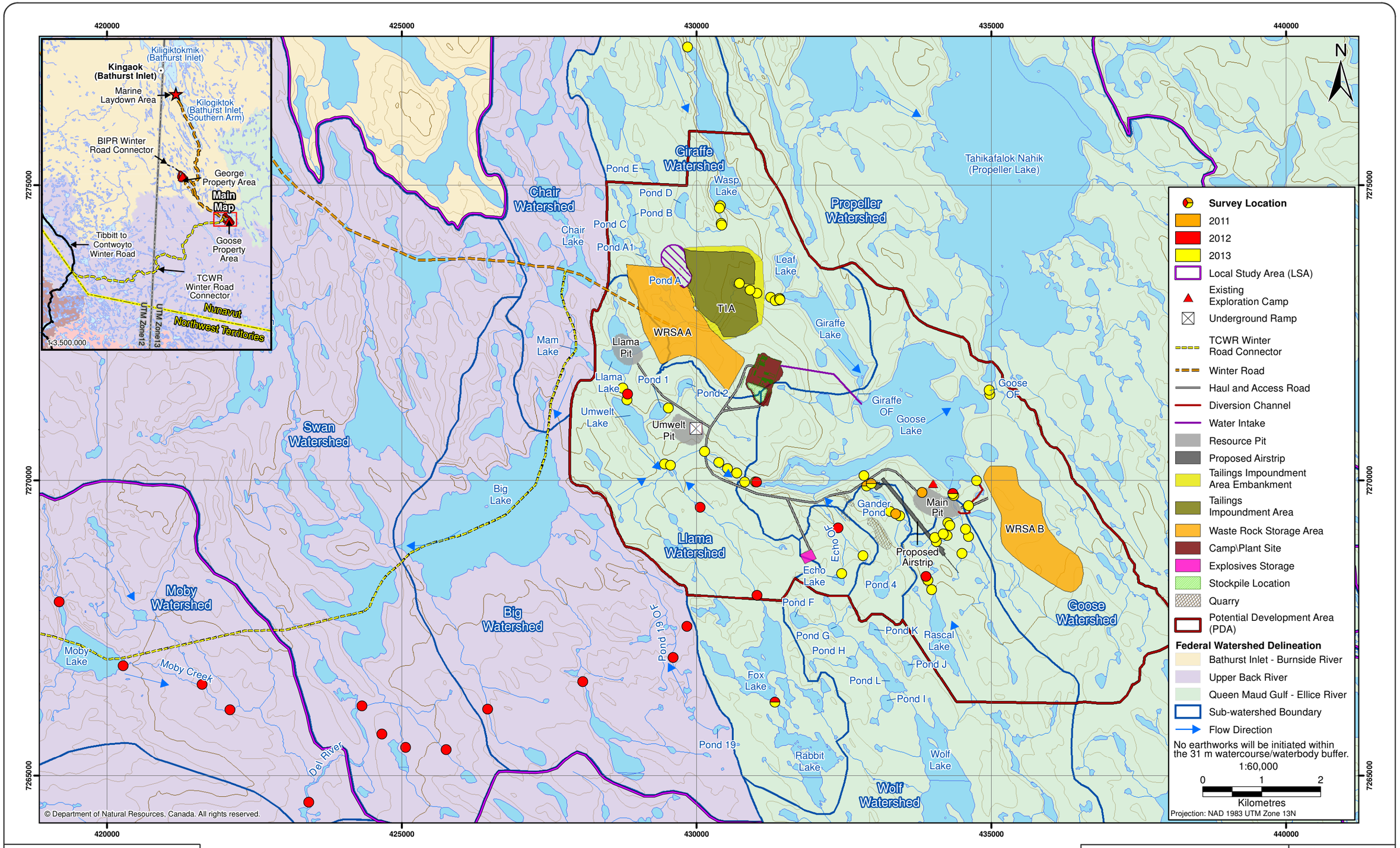


Sabina GOLD & SILVER CORP.

Rescan an ERM company

Figure 7.1-2

Lake/Pond Fish Community Baseline Data (2011 to 2013), George Property Area



© Department of Natural Resources, Canada. All rights reserved.

Sabina GOLD & SILVER CORP.

Rescan an ERM company

Figure 7.1-3

Stream Fish Community Baseline Data (2011 to 2013), Goose Property Area

PROJECT # 0194096-0040 GIS # BAC-06-073 October 28 2013

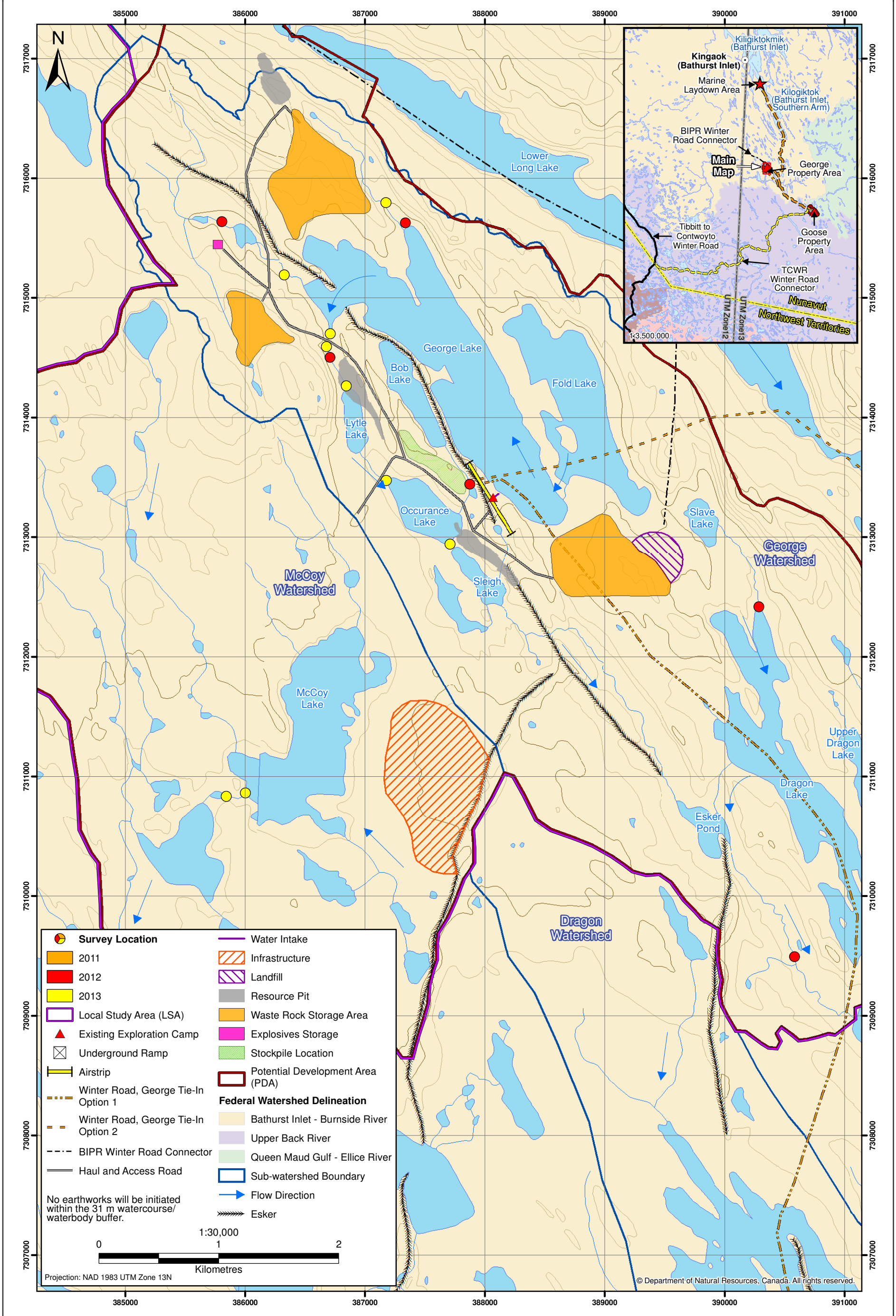


Figure 7.1-4

Sabina GOLD & SILVER CORP.

Stream Fish Community Baseline Data (2012 to 2013), George Property Area

Figure 7.1-4

Rescan an ERM company

In addition to these reports, traditional knowledge on fish species, fish distributions, and Inuit fishing areas was incorporated in the following assessment (KIA 2012).

Table 7.1-2 summarizes the lakes where fish sampling occurred in each year of historical studies.

Table 7.1-2. Summary of Lakes Where Fish Sampling Occurred, 1990 to 2013

Waterbody	Sekerak (1990)	Norecol (1997)	Golder (2007)	Rescan (2010)	Rescan (2012a)	Rescan (2012b)	Rescan (2013)
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
Pond 2					X		
Pond 3					X		
Pond 4					X		
Pond A					X		X
Pond A1					X		X
Pond A2							X
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		

(continued)

Table 7.1-2. Summary of Lakes Where Fish Sampling Occurred, 1990 to 2013 (completed)

Waterbody	Sekerak (1990)	Norecol (1997)	Golder (2007)	Rescan (2010)	Rescan (2012a)	Rescan (2012b)	Rescan (2013)
George Property							
George Lake	X		X			X	X
Occurrence Lake	X		X			X	X
Lytle Lake	X		X			X	X
Sleigh Lake						X	
Esker Pond	X						
Fold Lake	X		X				
Bob Lake	X		X				X
Moon Lake			X				
Dragon Lake	X					X	
Upper Long Lake	X						
Lower Long Lake	X						
Komatic Lake	X					X	X
Slave Lake			X				
McCoy Lake							X
Reference Q Lake							X
Reference C Lake						X	

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 and George Properties, as well as from reference waterbodies, in 2011, 2012 and 2013. Figures 7.1-1 and 7.1-2 show the locations where fish sampling was done during baseline studies between 2010 and 2013 within the Goose and George Properties, respectively.

Fish Sampling - Streams

Thirty-seven stream sites on the Goose Property and nine stream sites on the George Property were sampled between 2011 and 2013 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 and 7.1-4 show the locations where stream fish sampling was conducted during baseline studies between 2011 and 2013.

In addition, Sekerak (1990) sampled six stream sites by beach seine seining in 1990. This included four sites at George Outflow and two sites on Dragon Outflow. Golder Associates Ltd. (2007) also sampled three sites on this section of stream (known as Kanosak Creek) in 2006 by electrofishing.

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 and George Properties (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
			George LSA			George LSA
			George Lake			George Lake
			Reference C Lake			Komatic Lake
						McCoy Lake
						Reference Q Lake

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 Goose Property 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 and 2013 to determine fish distribution. Most of these did not contain any fish, which was attributed to their shallow depths (freezing to bottom) and ephemeral connections to large waterbodies. 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 2013.

Table 7.1-4. Fish Bearing Lakes and Ponds in the Goose Property LSA, 1997 to 2013

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 19	-	-	-	-	-	-	-
Pond "L"	-	-	-	X[3]	-	-	-
Pond "I"	-	-	-	X[3]	-	-	-
Pond "D"	-	-	-	-	-	X[3]	-
Pond 1	-	-	-	-	-	-	X[6]
15 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 (2013)*

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 CPUE of all species pooled) was recorded in Wasp Lake while the lowest was recorded in Propeller Lake (Figure 7.1-5). The mean total CPUE from 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 from 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 7.1-6). 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.

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.

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 in the Goose Property, 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.

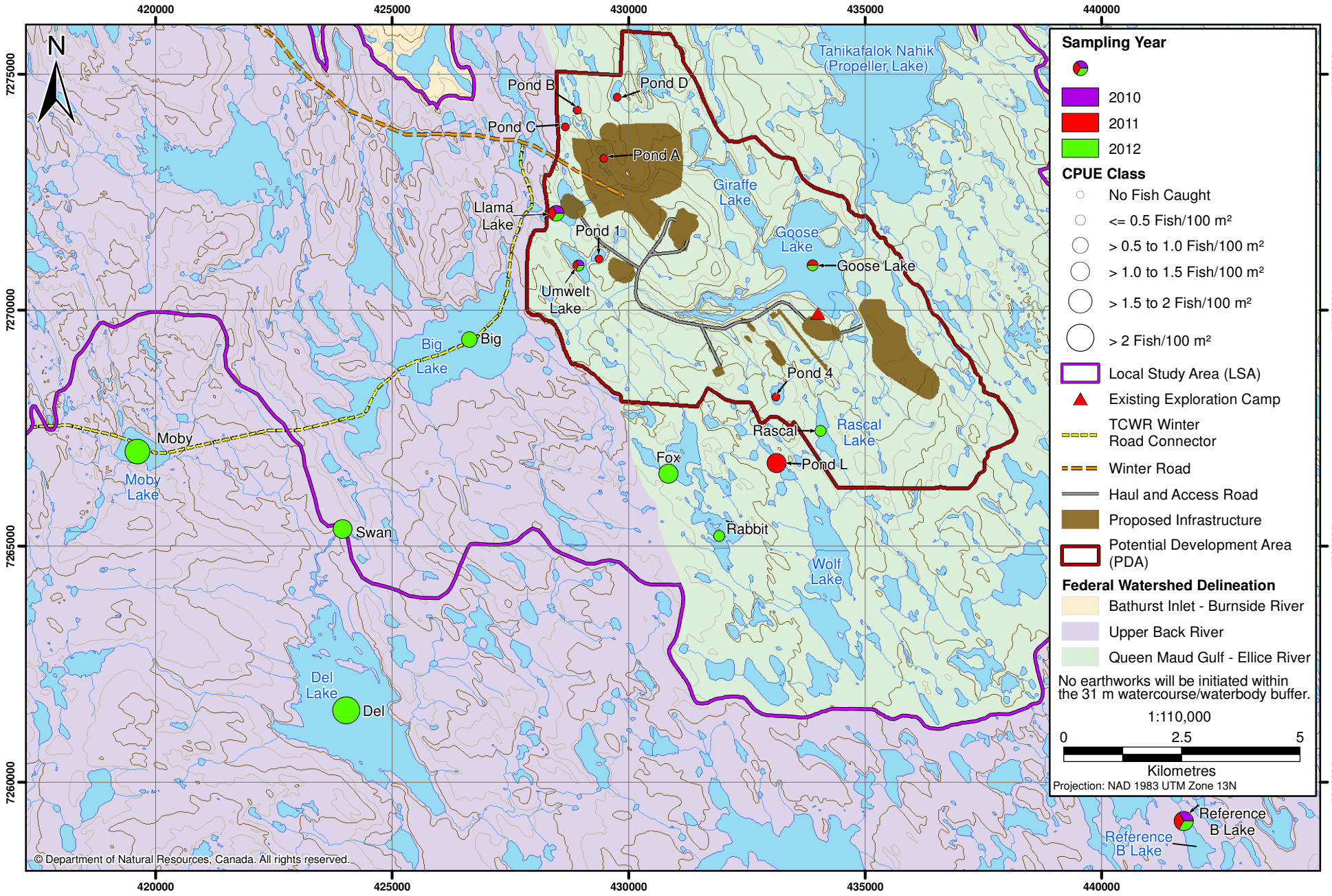


Figure 7.1-5

Sabina GOLD & SILVER CORP

Baseline Relative Abundance by Gillnet, Goose Property Area

Figure 7.1-5

Rescan an ERM company

PROJECT # 0194096-0040 GIS # BAC-06-060b October 28, 2013

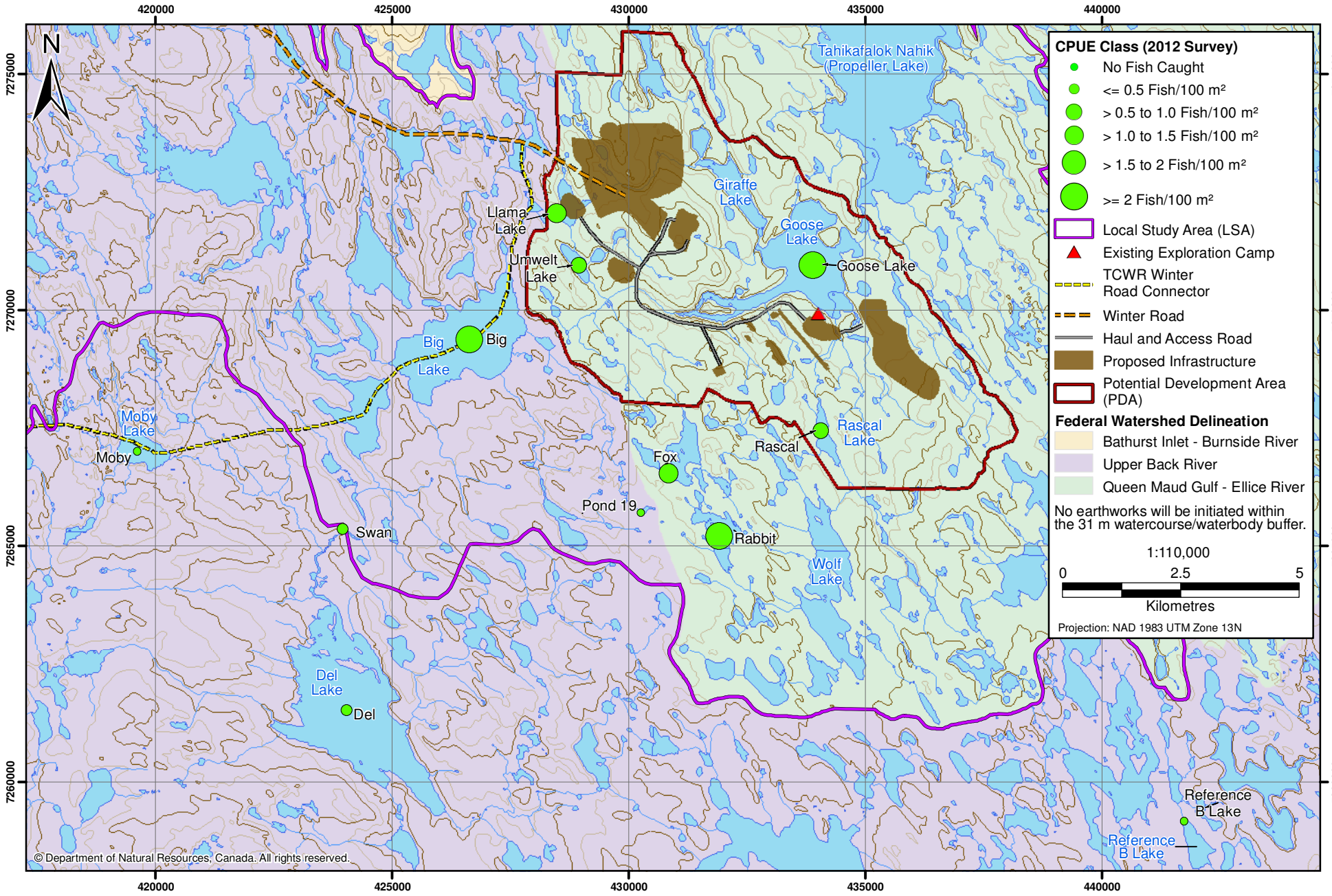


Figure 7.1-6

Sabina GOLD & SILVER CORP.

Baseline Relative Abundance by Beach Seine, Goose Property Area

Figure 7.1-6

Rescan an ERM company

George Property

Five fish species have been captured in lakes in the George Property LSA (Table 7.1-5). Lake Trout is the dominant species in lakes, followed by Round Whitefish, Arctic Grayling, Slimy Sculpin, and Burbot (Sekerak 1990; Golder Associates Ltd. 2007; Rescan 2012a, 2013). While no fish have been captured in Lytle Lake (downstream of George Lake), Arctic Grayling may use this lake seasonally as they migrate up and down the watershed (Golder Associates Ltd. 2007). No fish were captured in Occurrence Lake prior to 2013, when a single Arctic Grayling was captured, and two unidentified salmonids were observed (Rescan 2013).

Table 7.1-5. Fish Bearing Lakes in the in the George Property, 1990 to 2013

	Species				
Waterbodies Sampled	**Lake Trout** (*Salvelinus namaycush*)	**Round Whitefish** (*Prosopium cylindraceum*)	**Lake Whitefish** (*Coregonus clupeaformis*)	**Arctic Grayling** (*Thymallus arcticus*)	**Burbot** (*Lota lota*)
George Lake	X[1,2,3,4]	-	-	X[1,3,4]	X[3,4]
Sleigh Lake	-	-	-	X[3]	-
Fold Lake	X[1,2]	-	-	-	-
Bob Lake	X[2,4]	-	-	-	-
Upper Long Lake	X[1]	X[1]	-	-	-
Dragon Lake	X[3]	X[3]	-	X[3]	-
Occurrence Lake	X[4]	-	-	X[4]	-
Lytle Lake	-	-	-	-	-
Moon Lake	-	-	-	-	-
Slave Lake	-	-	-	-	-
Esker Pond	-	-	-	-	-
McCoy Lake	X[4]	X[4]	X[4]	-	X[4]
Komatic Lake	X[1,3,4]	X[1,3]	-	-	X[3,4]
Reference Q Lake	X[4]	X[4]	-	-	X[4]

Dashes indicate that no fish were captured
[1] *Sekerak (1990)*
[2] *Golder Associates Ltd. (2007)*
[3] *Rescan (2012c)*
[4] *Rescan (2013)*

In general, Lake Trout were the most common species caught in George Property LSA lakes, but the relative abundance varied among lakes sampled. The highest abundance (as CPUE) caught in gillnets was recorded in Dragon Lake, whereas the lowest was recorded in Occurrence Lake. Mean total CPUE in lakes sampled by gillnet ranged from 0.30 to 2.31 fish/100 m^2/h across all years of sampling (Figure 7.1-7). It is important to note that sampling in 1990 and 2006 was conducted with different-sized gillnets than those used in 2012 and 2013. This change in gear may have altered the likelihood of fish capture and may have caused the sizes of captured fish to differ between these sampling periods.

No fish were captured in lakes by beach seining in 1990 (Sekerak 1990); however, beach seining in 2012 and 2013 resulted in mean total CPUE ranging from 0.2 to 3.0 fish/100 m^2 (Rescan 2012c; 2013; Figure 7.1-8). The highest abundance of fish (as CPUE) for seining occurred in Dragon Lake. Arctic Grayling and Slimy Sculpin were the most commonly captured species in beach seine hauls, followed by Round Whitefish. Beach seine efficiency is compromised by habitat type and quality (e.g., rocky or steep shorelines); therefore, CPUE derived from beach seine should be considered less accurate than other methods of estimating the relative abundance of species in these lakes.

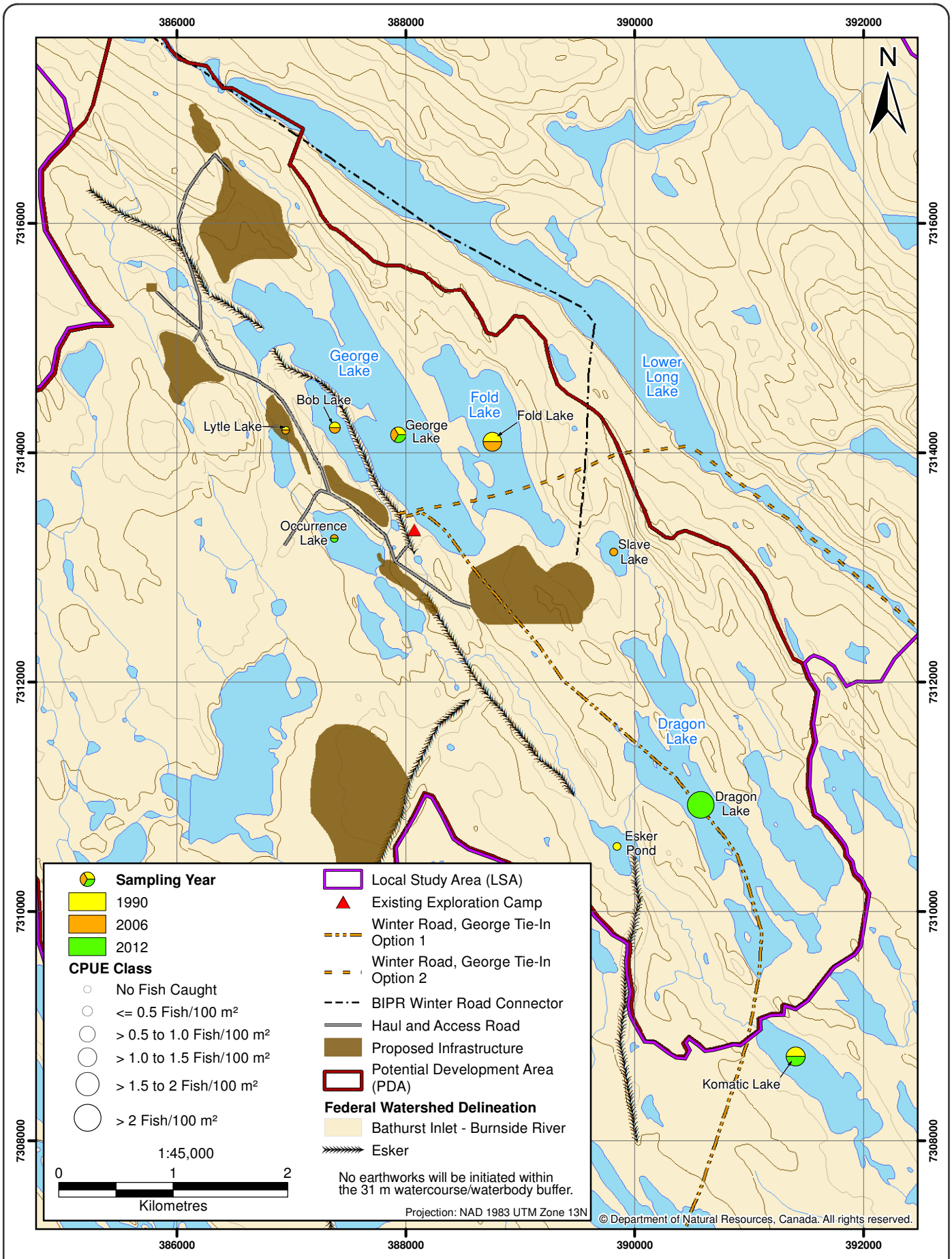
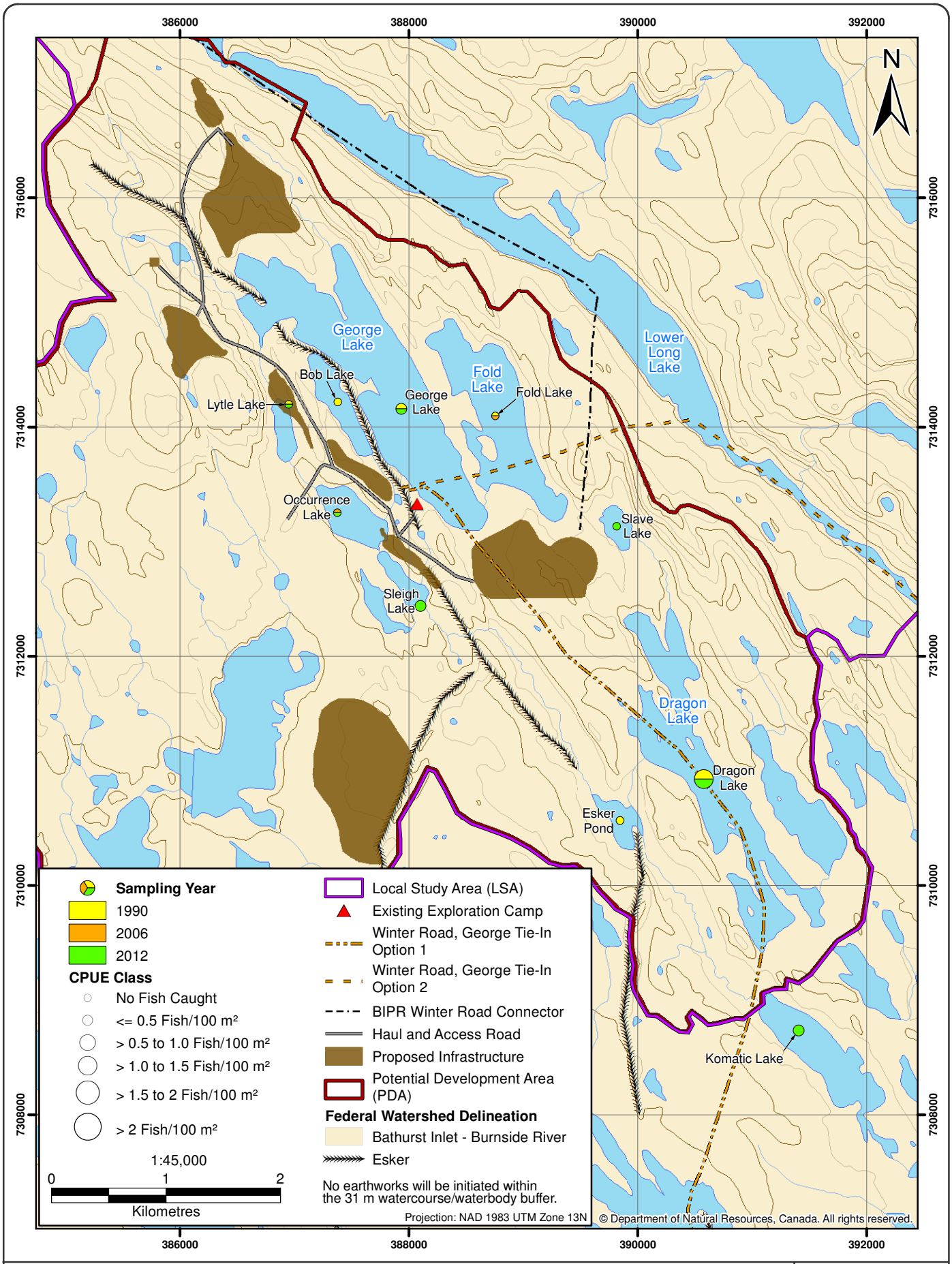


Figure 7.1-7

Baseline Relative Abundance by Gillnet, George Property Area

Sabina GOLD & SILVER CORP.

Rescan an ERM company



Sabina GOLD & SILVER CORP.

Baseline Relative Abundance by Beach Seine, George Property Area

Figure 7.1-8

Rescan an ERM company

Mean Lake Trout fork length ranged from 384 to 548 mm, and the largest Lake Trout were captured in George Lake (Rescan 2013). In all lakes, the majority of Lake Trout were between 400 and 500 mm, similar to the 1990 and 2006 despite the difference in gillnet mesh size among sampling years (Sekerak 1990; Golder Associates Ltd. 2007). Lake Trout were only captured by beach seine in George Lake in 2012 and the entire sample consisted of juveniles (mean fork length of 51.5 mm).

The mean condition factor of Lake Trout in the George LSA ranged from 0.84 to 1.06, within the range considered to be healthy for salmonids. The age of Lake Trout captured by gillnet ranged from 7 to 33 years, with the majority being between 10 and 11 years of age. Lake trout diet, sampled as stomach contents, was generally dominated by chironomids, cladocerans, and freshwater clams.

Round Whitefish in the George Property were captured in Komatic Lake by gillnet, and in Komatic and Dragon lakes by beach seine in 2012. In 2013, Round Whitefish were also captured in McCoy Lake and Reference Q Lake by gillnet. Komatic Lake had the largest Round Whitefish of those captured from all lakes in 2012, with an average fork length of 461 mm. Those captured by beach seine were primarily fry, which averaged 57 mm in fork length. All of the Round Whitefish captured by beach seine were yearlings, whereas the mean age of individuals captured by gillnet was 10 years.

Arctic Grayling were captured by beach seine in George Lake, Sleigh Lake, and Dragon Lake in 2012, and in George Lake and Occurrence Lake by gillnet in 2013. No Arctic Grayling were captured by gillnet in George Property lakes in 2012 despite. All of the grayling captured by seine were young-of-the-year, with mean fork lengths ranging from 46 mm in Dragon Lake to 65 mm in George Lake, and mean condition ranging from 0.90 in George Lake to 1.13 in Sleigh Lake. Grayling captured by gillnet in 2013 ranged in mean fork length from 110 mm in Occurrence Lake to 112 mm in George Lake.

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 Goose Inflow stream (connecting Rascal Lake to Goose Lake). Three stream sites in the Goose Property were sampled for fish in 2011 by electrofishing, and an additional 13 sites were sampled by electrofishing and visual observation in 2012. 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 Goose Inflow, 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. 2007).

Table 7.1-6 presents a summary of the species captured in streams in the Goose Project area between 2006 and 2013.

Table 7.1-6. Summary of Fish Species Captured in Goose Property Streams, 2006 to 2013

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]	-
Airstrip Stream	AS-1, AS-2	-	-	X[4]	X[4]	X[1,3,4]	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	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 (2013)*

George Property

Streams in the George Property contain Lake Trout, Arctic Grayling, Slimy Sculpin, Burbot, and Round Whitefish. Golder Associates Ltd. (2007) found that these stream communities were dominated by Burbot and Slimy Sculpin, whereas Sekerak (1990) found that Arctic Grayling were most abundant in this area. Baseline studies in 2012 found that Slimy Sculpin were generally abundant in most streams, while juvenile Lake Trout were found near lake inlets and outlets, and Arctic Grayling were only captured occasionally (Rescan 2012c). Table 7.1-7 presents a summary of the species captured in each of the waterbodies sampled between 1990 and 2012.

Table 7.1-7. Summary of Fish Species Captured in George LSA Streams, 1990 to 2013

Waterbodies Sampled	Species Captured				
	Lake Trout (*Salvelinus namaycush*)	**Round Whitefish** (*Prosopium cylindraceum*)	**Arctic Grayling** (*Thymallus arcticus*)	**Burbot** (*Lota lota*)	**Slimy Sculpin** (*Cottus cognatus*)
Kanosak Creek (George Outflow)	X[1,3,4]	-	X[1,2]	X[2]	X[2]
Kanosak Creek (Occurrence Outflow)	-	X[1]	X[1,2]	X[2]	X[2]
Kanosak Creek (Lytle Outflow)	-	-	-	-	-
Dragon Creek	-	-	-	-	-

(continued)

Table 7.1-7. Summary of Fish Species Captured in George LSA Streams, 1990 to 2013 (completed)

Waterbodies Sampled	Species Captured				
	Lake Trout (*Salvelinus namaycush*)	**Round Whitefish** (*Prosopium cylindraceum*)	**Arctic Grayling** (*Thymallus arcticus*)	**Burbot** (*Lota lota*)	**Slimy Sculpin** (*Cottus cognatus*)
George Inflow 1	X[3,4]	-	X[4]	-	X[4]
George Inflow 2	-	-	X[4]	-	-
Dragon Inflow	X[3]	-	X[3]	-	X[3]
Kanosak Creek (Esker Outflow)	-	-	X[3]	-	-

Dashes indicate that no fish were captured
[1] *Sekerak (1990)*
[2] *Golder Associates Ltd. (2007)*
[3] *Rescan (2012c)*
[4] *Rescan (2013)*

Abundance of stream fish was low and varied by time and location. In 2012, the abundance of fish (CPUE) captured in streams by electrofishing was highest downstream of Esker Pond and lowest downstream of George Lake. No fish were captured at George Inflow 2 (northeast inflow) and Dragon Inflow (from Slave Lake). In contrast, in 2006, the highest abundance (CPUE) was recorded downstream of Occurrence Lake, with Burbot making up the majority of the catch (Golder Associates Ltd. 2007). Abundance (CPUE) estimated by beach seine in streams in the George Property in 1990 was generally very low, with few fish being captured or observed (Sekerak 1990).

7.1.8 Metals in Fish Tissues

Baseline data on metal concentration in fish tissues is 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 (Sekerak 1990), in which the Lake Trout inhabiting this waterbody were also found to have tissue concentrations of mercury below 0.5 mg/kg wwt. Sekerak (1990) 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.

Sampling was conducted in 2013 with non-lethal tissue biopsies being analyzed in Lake Trout from Giraffe Lake and lethal tissue collection of Slimy Sculpin from Giraffe, Goose, Propeller and Reference Lake B lakes. Data for 2013 will be available in early 2014.

George Property

Eight Lake Trout from George Lake were analyzed for tissue metal concentrations in 2012. Mercury concentrations in the tissue of lake from George Lake ranged from 0.03 to 0.14 mg/kg wwt, which is lower that the Health Canada guideline of 0.5 mg/kg wwt. In addition, mercury concentration was lower in George Lake than that found in tissue sampled from fish at Goose Property lakes. Concentrations of most metals in Lake Trout tissues from George Lake were similar to those found in fish tissue from Goose and Llama lakes at the Goose Property. Exceptions to this pattern were observed in arsenic and selenium, which were higher in Lake Trout tissue from George Lake than those from Goose and Llama lakes.

Sampling was conducted at the George Property in 2013 with lethal tissue collection of Slimy Sculpin from George, McCoy, Komatic and Reference Q lakes. This data will be included when it becomes available by ALS.

7.2 INCORPORATION OF TRADITIONAL KNOWLEDGE (TK)

7.2.1 Incorporation of TK for Existing Environment and Baseline Information

Available traditional knowledge (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 NTKP Report(KIA 2012).*

Maps presented in Figures 30–32 in Chapter 7 of the *NTKP* report (hereafter, 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*). The Western River lies within the Regional Study Area (RSA) of the George Property Area. In addition, the maps in the TK report indicate that, outside the Goose and George Property RSAs, other freshwater fishing sites of value to the Inuit occur in and around Beechey Lake, just south of the Goose and George Property RSAs.

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 in the George Property RSA, is fished, specifically for Lake Trout (*Salvelinus namaycush*). The participants also indicated that hunting and fishing take place along the length of this route. The people may stop at George Lake, located in the freshwater LSA of the George Property, 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 Goose Property LSA, was also identified as an area where fishing may occur while staying near Beechey Lake. While Goose Lake and George Lake may be fished by traditional land users, they are not known to be destinations or key locations for fishing (Volume 8, Chapter 4).

In the 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.

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 TK Report (Figures 31 and 32) and, 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 Report were reviewed (KIA 2012). According to Figures 31 and 32 within Chapter 7 of the TK report, the Project's Potential Development Area (PDA) does not overlap with fishing locations identified in other parts of the RSA. Some important fishing areas are located within the northern reaches of the Western River which form the outer limits of the RSA for fish community.

7.2.4 Incorporation of TK for Mitigation and Adaptive Management

As a result of information obtained from the TK Report (KIA 2012), 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 Draft Conceptual 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 Conceptual Fish Offsetting Plan, including the development of additional or alternative options that could provide value to the local communities, is intended through 2014.

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 water and sediment is assessed in the VECs freshwater water and sediment quality (Volume 6, Chapters 4 and 5) using the following Canadian guidelines to protect aquatic life: Water Quality Guidelines for the Protection of Aquatic Life (Freshwater and Marine; CCME 2013); Interim Sediment Quality Guidelines (ISQGs) and Probable Effects Levels (PELs) for the Protection of Aquatic Life (Freshwater and Marine; CCME 2013).

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 local study areas (LSAs) and regional study areas (RSAs) for both the Goose and George Properties.

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 determined for the assessment of effects on the VECs Lake Trout and Arctic Grayling is divided in to two areas:

1. The Goose Property LSA. The LSA boundary (365 km^2) includes the Goose Property Potential Development Area (PDA) and matches the boundaries of the Propeller and Big watersheds (Figure 7.4-1).
2. The George Property LSA. The LSA boundary (105 km^2) includes the George Property PDA, and matches the boundaries of the Dragon, George, McCoy, and Lower Long watersheds (Figure 7.4-1).

7.4.1.2 *Regional Study Area*

The RSA includes the LSA plus additional areas within which there is the potential for indirect or cumulative effects. The RSA determined for the assessment of effects on the VECs Lake Trout and Arctic Grayling assessment is divided in to two areas:

1. The Goose Property RSA. The RSA boundary (6,815 km^2) includes part of the Ellice River Watershed and encompasses the PDA and the LSA. All Project infrastructure resides within the Ellice River Watershed. The upper ~80 km of the watershed was included rather than the entire watershed (Figure 7.4-1).
2. The George Property RSA. The RSA boundary (4,034 km^2) includes part of the Western River Watershed and encompasses the PDA and LSA. All Project infrastructure resides within the Western River Watershed. The upper portion of the watershed that drains in to the Western River at the southern tip of Bathurst Inlet is included in the RSA (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:

- Site Preparation – 2 years;
- Construction phase – 2 years;
- Operations phase – 10 years;
- Reclamation and Closure phase – 10 years;
- Post-closure phase 5 years minimum;
- 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.

PROJECT #0194096-0015 GIS # BAC-06-099 October 24 2013

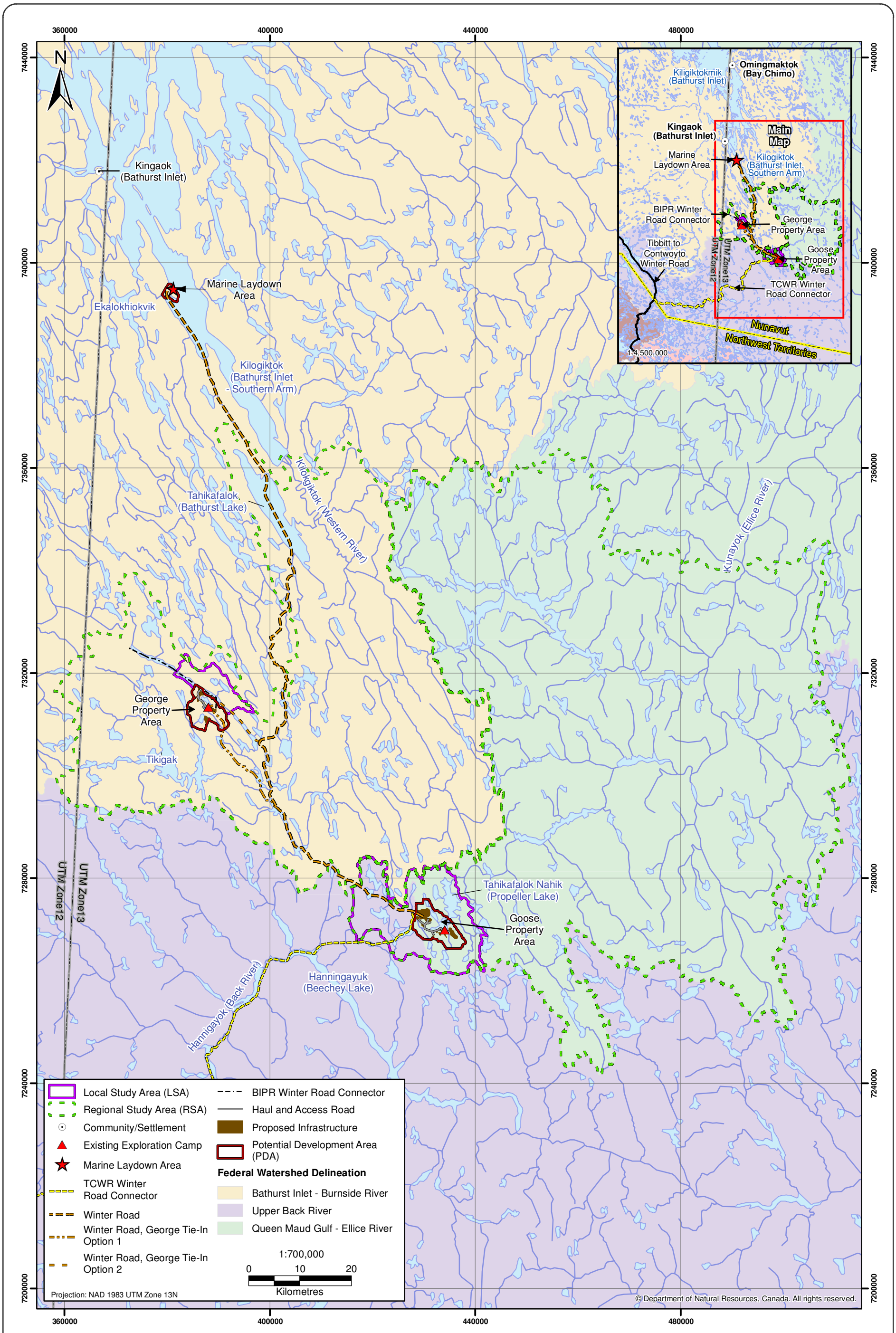


Figure 7.4-1

Sabina GOLD & SILVER CORP.

Local Study Area and Regional Study Area for Lake Trout and Arctic Grayling

Figure 7.4-1

Rescan an ERM company

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 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, Chapter 1).

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 zone of influence of the Project 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 in two ways: 1) Through direct mortality and changes to population abundance; or 2) Through decreased health and indirect mortality (Table 7.5-3). The characterization of potential effects related to decrease health and indirect mortality is not considered further as these pathways are addressed in other areas of the DEIS (as described in Section 7.3.2 above).

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).*

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 2. Winter road construction 3. Project Footprint	1. Site Preparation, Construction, Operations phases. 2. All Phases 3. All Phases
Water Use	1. Water withdrawal (camp, mill, winter roads)	2. All Phases
Blasting	1. Explosives Storage and Use	2. Site Preparation, Construction, Operations phases.

7.5.2.1 *Project Infrastructure Footprint*

Lake Dewatering

The current Project Description includes the dewatering of Llama Lake to access the Llama Deposit, and dewatering portions of Lytle and Occurrence lakes to access the Locale 1 and Locale 2 deposits.

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 and distribute frozen fish to local communities for food. 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 at 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. Migrating back to Llama Lake from Umwelt is unlikely in the late summer as the volume of flow between the lakes is low and likely prohibitive for migration in the late summer and fall. Once the connection between Umwelt and Llama lakes is severed to establish the Llama Pit, all Lake Trout remaining in Umwelt Lake will be unable to return to Llama Lake. These few individuals will likely suffer eventual mortality as three years of sampling has confirmed that Umwelt Lake does not sustain a Lake Trout population.

No Lake Trout have been captured in Lytle Lake or Occurrence Lake where the Locale 1 and Locale 2 pits will be located; therefore, no fish mortality is anticipated in those locations.

Arctic Grayling

Arctic Grayling resident in Umwelt Lake may potentially experience a reduction in population abundance as a consequence of the loss (dewatering) of Llama Lake. Umwelt Outflow serves as spawning and rearing habitat for Arctic Grayling and initial estimates suggest that the volume of water flowing out of Umwelt Lake will be reduced by 49% of baseline volume during the summer, whereas winter lake volume will remain within baseline (Appendix V6-1C). A reduction in outflow volume of this magnitude may potentially cause reduced spawning, diminished hatchling survival, shortened rearing time in the outflow, and a reduced ability of fish return to 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.

No Arctic Grayling have been captured in Lytle Lake, and only one has been captured in Occurrence Lake where the Locale 1 and Locale 2 pits will be located; therefore, fish mortality is unlikely in those locations.

Winter Roads

When required, winter road construction may occur over selected lakes, ponds, and streams along the proposed winter road corridors. Connection between the three main Project areas will be established via winter roads constructed during the winter months as needed during the life of the Project. In addition, a winter road connecting to the TCWR may be used as an alternative for resupply during some years.

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. Grayling spawn in small streams and rivers early in the spring when the ice melts. Spawning success appears to be strongly affected by stream blockages (Stewart et al. 2007). 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

Arctic Grayling

There is a potential for mortality and reduced population abundance of Arctic Grayling to occur in the Rascal-Goose stream during construction of the diversion of stream water to avoid the proposed airstrip extension and Main Pit. This stream is used heavily by Arctic Grayling for spawning and rearing. The alteration of this watercourse will result in the original highly productive stream being re-directed approximately 2 km to the west, from Rascal Lake Outflow through an existing smaller channel into Goose Lake (see Draft Conceptual Fish Offsetting Plan in Volume 10, Chapter 21). The loss of the habitat along the Rascal to Goose Stream could possibly strand Arctic Grayling within the stream during construction, or possibly alter migration patterns. Arctic Graying show some fidelity to both spawning and overwintering sites (Stewart et al. 2007) and may fail to use newly constructed spawning grounds, or select less optimal habitat for spawning, reducing their population abundance.

7.5.2.2 *Water Use*

Water for domestic and process use will be drawn from Goose and Propeller Lakes in the Goose Property and from George Lake in the George Property, 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 Withdrawal

Lake Trout

Lake Trout could be affected by water withdrawal from Goose Lake, George Lake, and Propeller Lake, as well as from lakes used to support the construction of winter roads. 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 at Goose Outflow, Propeller Outflow, and George Outflow.

Arctic Grayling spawn in streams in the early spring soon after ice-off (Stewart et al. 2007). Eggs incubate for two to three weeks, and alevins remain in 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. 2007). 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. DFO protocols will be followed to ensure that this does not happen.

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 the Goose Property (Llama Pit, Umwelt Pit, Main Pit) and the George Property (Locale 1 and 2).

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 mortalities, including Lake Trout and Arctic Grayling, associated with lake-dewatering of Llama, Lytle, and Occurrence lakes can be mitigated fully through the creation of new habitat as described in the Draft Conceptual Fish Offsetting Plan (Volume 10; Chapter 21). The plan can compensate for fish mortality by increasing fish production through habitat creation in other parts of the Project area. Potential reductions in the fish populations of Umwelt Lake due to the dewatering of Llama Lake have not been included in the Draft Conceptual Fish Offsetting Plan because there is uncertainty in some of the water quantity management measure that may occur, and uncertainty in the potential effects on the fish population.

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) outlined in the Draft Conceptual Fish Offsetting Plan (Volume 10, Chapter 21). Fish removal is not anticipated to be needed in Lytle and Occurrence Lake due to the absence of fish in those locations.

Fishing by mine staff will be banned within all Project areas and, thus, will not result in fish mortality.

Where pumps are used for withdrawing water in fish-bearing waters or where fish salvage has not occurred, the intakes will be screened in accordance with the DFO Freshwater Intake End of Pipe Screening Guideline (screens with openings no larger than 2.54 mm; DFO 1995). Outlets will have a diffuser or be located in an area not subject to erosion from outflows.

Fish mortalities predicted to result from water pumps used for withdrawing water will be mitigated through the use of screened intakes in accordance with the DFO Fresh Water Intake End of Pipe Screening Guideline (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.

As a result of mitigation, 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 LSAs and compensated fully through the Draft Conceptual Fish Offsetting Plan (Volume 10, Chapter 21).

Winter Roads

Water withdrawal from any lakes or rivers required for winter road construction will be designed to avoid mortality and reduction of population abundance for the VECs Lake Trout and Arctic Grayling by following DFO's Protocol for Winter Water Withdrawal from Ice-Covered Waterbodies in the Northwest Territories and Nunavut (DFO 2010) and DFO's Operations Statement on Mineral Exploration Activities (DFO 2009).

Winter road activities are predicted to be of *short duration*, and *highly localized* to individual waterbodies. 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. The TIA and Waste Rock Storage Areas (WRSA) have all been sited to avoid fish-bearing water and have been confined to local watersheds close to the main mine infrastructure.

Fish mortality and reductions in population abundance due to diversion of Rascal-Goose Stream will be mitigated through the creation of new habitat in the Conceptual Fish Offsetting Plan (Volume 10, Chapter 21). The diversion channel will be designed to provide productive fish habitat that will offset any losses of Arctic Grayling that are incurred.

As a result of mitigation, there are *no residual effects* anticipated on the VEC Lake Trout due to Project footprint. Any mortality of Lake Trout caused by disconnecting the stream between Umwelt and Llama lakes for the development of the Llama Pit is predicted to be *negligible* due to the very low number of Lake Trout that migrate between the two lakes. Only a single individual has been captured in Umwelt Lake in three sampling years and Llama Lake has the only possible population of Lake Trout to serve as a source of Lake Trout for Umwelt Lake. The loss (mortality) of the entire population of Lake Trout from Llama Lake will be fully mitigated by the creation or modification of new fish habitat as proposed in the Draft Conceptual Fish Offsetting Plan (Volume 10, Chapter 21).

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 7.5-5). In addition, water will be recycled or re-used where possible to reduce 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 7.5-5. Volume Limits for Water Use

Property	Phase	Maximum Water Use (m^3/day)	Lake Specific Maximum Water Use (m^3/day)
Goose Property Area	Site Preparation and Construction	Domestic Use: up to 210 Industrial Use: up to 70	Goose Lake: 280 year round Propeller Lake: None
	Operations	Domestic Use: up to 210 Industrial Use: up to 2,510; 4,510 in June	Goose Lake: 1,000; 2,000 in June Propeller Lake: 1,510, 2,510 in June
	Reclamation and Closure	Domestic Use: up to 210 Industrial Use: up to 70	Goose Lake: 1,000; 2,000 in June Propeller Lake: 1,510, 2,510 in June
George Property Area	Site Preparation and Construction	Domestic Use: up to 45 Industrial Use: up to 70	George Lake: 115 year round
	Operations	Domestic Use: up to 45 Industrial Use: up to 70	George Lake: 115 year round
	Reclamation and Closure	Domestic Use: up to 45 Industrial Use: up to 70	George Lake: 115 year round

To protect important habitat for Lake Trout and Arctic Grayling, the volume limit for water withdrawal from Goose Lake was set at 210 m^3/day for domestic use, and 70 m^3/day for industrial use during the Site Preparation and Construction phases. During Operations and Reclamation and Closure phases, the maximum amount of water that will be withdrawn will be 1,000 m^3/day, with an increase up to 2,000 m^3/day during freshet.

At the maximum limit to withdrawal volumes (Table 7.5-5), 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 2010). During summer, the limit to water drawdown will prevent water level from decreasing more than 0.06 m/day. During late winter, the limit to water drawdown will

prevent water level from decreasing below 0.1 m under ice. This anticipated reduction in water level in Goose Lake in both summer and winter is considered negligible and within DFO guidelines (DFO 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 the discharge rate at the Goose Outflow stream — a wide, shallow connection between Goose and Propeller lakes — but 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 20.6% from the baseline outflow volume. Baseline flow and water level in Goose Outflow are marginal to insufficient for fisheries production during critical periods (flow less than 30% Mean Annual Discharge; DFO 2013b; Figure 7.5-1) and the estimated 20.6% reduction in discharge due to maximum water withdrawal does not alter the date or duration of the period when Goose Outflow is marginal for fish use. 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).

Water withdrawal from Propeller Lake has been designed to avoid impacts to fish habitat. Maximum withdrawal for Propeller Lake was set at 10% of the outflow volume, below the maximum permissible withdrawal volume to protect fish habitat (DFO 2010). Withdrawals from Propeller Lake are anticipated to occur during the Operations and the Reclamation and Closure phases. A maximum of 1,510 m^3/day of water will be withdrawn during most of the year with an increase to 2,510 m^3/day during freshet in June.

Maximum withdrawal for George Lake was set at 10% of the outflow volume, below the maximum permissible withdrawal volume for the protection of sensitive fish habitat (DFO 2009, 2010). During the Site Preparation, Construction, Operations, and Closure and Reclamation phases, the maximum water withdrawals from George Lake were limited to 45 m^3/day for domestic use, and 70 m^3/day for industrial use.

Where pumps are used for withdrawing water in fish-bearing waters, the intakes will be screened in accordance with the DFO Freshwater Intake End of Pipe Screening Guideline (screens with openings no larger than 2.54 mm) (DFO 1995). Outlets will have a diffuser or be located in an area not subject to erosion from outflows.

Fish mortalities predicted to result from water pumps used for withdrawing water will be mitigated through the use of screened intakes in accordance with the DFO Fresh Water Intake End of Pipe Screening Guideline (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.

7.5.3.3 *Blasting*

Explosive use will follow the Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters (Wright and Hopky 1998). In addition, Sabina and the Explosives Operator will adopt Best Management Practices for blasting and the handling of explosives to avoid spillage and minimize ammonium residue remaining after blasting, thereby lowering the potential for contaminant loading in runoff.

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 George Property Area and 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 both Goose and George Property Areas, and will be stand-alone facilities with dedicated waste management systems and truck washing facilities.

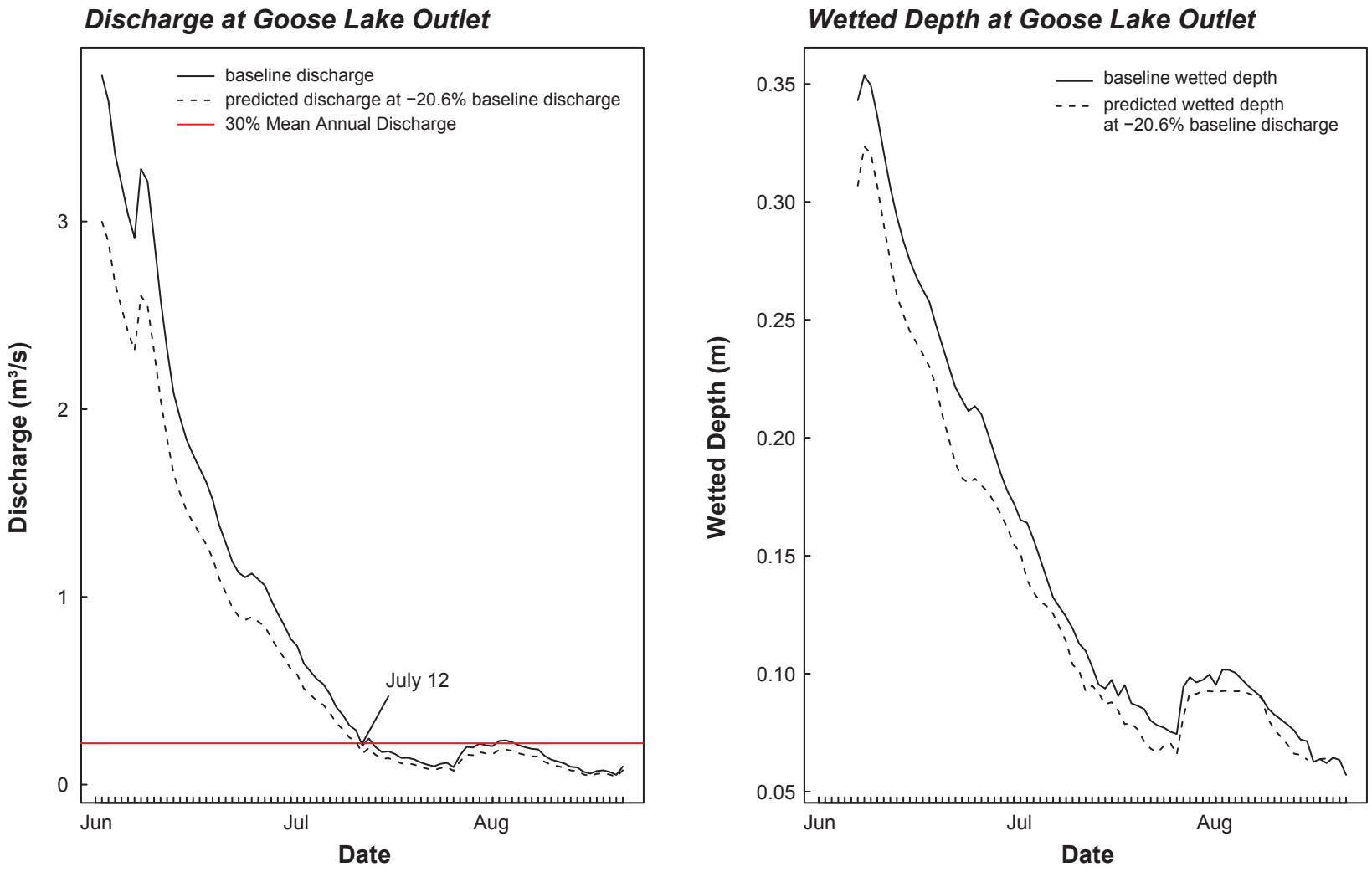


Figure 7.5-1

Sabina GOLD & SILVER CORP.

Daily Discharge and Wetted Depth at Goose Lake Outflow

Figure 7.5-1

Rescan Engineers & Scientists

7.5.4 Characterization of Residual Effects

Residual effects are those effects predicted to remain after the application of mitigation and management. No residual effects on the VEC Lake Trout are anticipated. A residual effect is predicted on the Arctic Grayling population in Umlwelt Lake due to upstream dewatering activities.

A residual effect arising from the Project on the freshwater fish community VEC Arctic Grayling is predicted. At Umwelt Lake, the magnitude of residual effects on Arctic Grayling spawning and hatchling survival due to the loss of Llama Lake and local drainages are anticipated to be *low* because spawning and hatching occur from April to June during freshet. Spawning and rearing will continue to take place when the outflow volume remains sufficiently high at freshet despite the estimated 49% reduction in outflow volume (Appendix V6-1C). The magnitude of residual effects on Arctic Grayling rearing and migration when flow is lowest (late summer and fall) is anticipated to be *moderate* because the highly adaptable life history of Arctic Grayling allows for flexibility in its rearing and foraging locations and can occur in lakes, streams and rivers (Evans, Reist, and Minns 2002). Therefore the overall magnitude criterion is assigned a rank of *moderate* in order to consider all life stages. Baseline data on habitat and fish presence suggests that Arctic Grayling in Umwelt Lake spawn in the lake (along the shoreline over gravel beds) and in the outflowing stream. The direction of the residual effect is *adverse*. The geographical extent of the residual effect is within the PDA (footprint) and confined to within the LSA; therefore it is considered to be *local*. The residual effect is anticipated to be of *moderate duration* and *immediately reversible* — spawning, rearing and migration should re-establish naturally with no intervention — if the water volume inputs from the Llama Lake portion of the subwatershed are reconnected to Umwelt Lake during closure. The effect will be *continuous* as long as Llama Lake remains dewatered and upstream drainages will report to the TIA during the life of the mine. The residual effect is *likely* to occur; however, it is predicted to be **Not Significant** due to the flexibility of Arctic Grayling life history. The significance rating is made with *low* confidence due to uncertainty in the management of water from the Llama Lake watershed.

7.5.5 Significance of Residual Effects

The following residual effect on the freshwater fish community is predicted (Table 7.5-6):

- Effect on Arctic Grayling mortality in Umwelt Lake due to the upstream dewatering of Llama Lake (**Not Significant**).

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

The potential cumulative effects resulting from interactions of the residual effects of the Project and other human activities are presented in Table 7.6-1. The table carries forward all of the potential residual effects identified in Section 7.5.5. Since the single residual effect of the Project is limited to the LSA and is considered to be Not Significant, and no other human impacts are predicted to affect fish communities within the LSA, no potentially interacting projects or activities were identified.

Table 7.5-6. Summary of Residual Effects and Significance Ratings for the VECs Lake Trout and Arctic Grayling

	Qualifier	Primary Criteria		Secondary Criteria			Qualifier	Significance Rating
Residual Effect	**Direction (positive, neutral, negative)**	**Magnitude (low, moderate, high)**	**Reversibility (reversible, reversible with effort, irreversible)**	**Duration (short, medium, long)**	**Frequency (once, sporadic, continuous)**	**Geographic Extent (footprint, local, regional, beyond regional)**	**Probability (unlikely, moderate, likely)**	**(Not Significant (N); Significant (S); Positive (P))**
Direct Mortality and Population Abundance: Umwelt Lake Arctic Grayling population downstream of Llama Lake	Negative	Moderate	Reversible	Medium	Continuous	Local	Likely	N

Table 7.6-1. Interaction of Freshwater Fish Community Residual Effects from the Back River Project

	Description of Residual Effect
Project Residual Effect	Residual effects on the population abundance of Arctic Grayling in Umwelt Lake due to loss of Llama Lake
Potentially-interacting Past Project(s) or Activity(ies)	none
Potentially-interacting Existing Project(s)	none
Potential-interacting Future Project(s)	none
Type of Potential Cumulative Effect	*No predicted cumulative effect*

7.7 TRANSBOUNDARY EFFECTS

The Project residual effect was restricted to the LSA; therefore, no transboundary effects are predicted.

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:

- Draft Conceptual Fish Offsetting Plan (No Net Loss Plan) (Chapter 21);
- Aquatic Effects Management Plan;
- Overall Environmental Management Plan;
- Environmental Protection Plan;
- Fuel Management Plan;
- Spill Contingency Plans;
- Oil Pollution Emergency Plan;
- Site Water Monitoring and Management Plan;
- Mine Waste Rock and Tailings Management Plan;
- Landfill and Waste Management Plan;
- Incineration Management Plan;
- Explosives Management Plan;
- Road Management Plan;
- Borrow Pits and Quarry Management Plan;
- Air Quality Monitoring and Management Plan;
- Metal Leaching and Acid Rock Drainage 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 TIA and WRSA 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.

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 operational statements and protocols, 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 and George Properties 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 Conceptual Fish Offsetting (No Net Loss) Plan (Volume 10, Chapter 21). The monitoring program will be developed in conjunction 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.

Offsetting

A Draft Conceptual Fish Offsetting Plan is presented in Volume 10, Chapter 21. The final Fish Offsetting Plan will be designed to meet the requirements of the *Fisheries Act* if the fish impacted are determined to be part of a Commercial, Recreational or Aboriginal fishery under the definitions contained in the *Fisheries Act*.

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.

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	
	Infrastructure, waste rock storage areas, and the TIA at the Goose Property have been located within the same subwatersheds as the mine workings outside of the regional Upper Back River Watershed
	The TIA has been designed as a zero discharge facility, ensuring no potentially poor quality water is introduced to the freshwater environment, and avoids all fish-bearing waterbodies.
	A Conceptual Fish Offsetting Plan will be in place that has been approved by DFO, the KIA, and other interested parties, to offset or enhance for the permanent alteration or destruction of fish habitat. Freshwater offsetting will possibly include the following methods: • increased access to overwintering habitat for Lake Trout and Arctic Grayling by increasing lake depth; • increased access to rearing and spawning habitat for Lake Trout by installing artificial rock shoals in lakes; and/or • increased access to rearing and spawning habitat for Arctic Grayling by enhancing stream access and stream channels.
	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 Fresh Water Intake End of Pipe Screening Guideline (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 6.8-1 in Volume 6, Chapter 6.
2. Regulatory Requirements	
	Culvert maintenance will be conducted following the the DFO Nunavut Operational Statement for Culvert Maintenance (DFO Nunavut Operational Statement: Culvert Maintenance, version 3.0 (2007)).
	Instream work will be conducted during approved timing windows presented in the DFO Nunavut Operational Statement for Timing Windows. (DFO Nunavut Operational Statement: Timing Windows, version 3.0 (2007)).
	Site road crossings will be constructed according to the DFO Nunavut Operational Statement for Clear Span Bridges (DFO Nunavut Operational Statement: Clear Span Bridges, version 3.0 ([2007]).
	Temporary stream crossings will be constructed according to the DFO Nunavut Operational Statement for Temporary Stream Crossings (DFO Nunavut Operational Statement: Temporary Stream Crossing, version 1.0 [2007]).
	Winter road construction will follow the DFO Nunavut Operational Statement for Ice Bridges and Snow Fills (DFO Nunavut Operational Statement: Ice Bridges and Snow Fills, version 3.0 [2007]).
	Water withdrawal will follow DFO's Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut and DFO's Operational Statement on Mineral Exploration Activities (DFO Nunavut Operational Statement: Mineral Exploration Activities, version 1.0 [2009]).

(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	
	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 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 TIA or other appropriate holding facility. 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 Operational Statements and Standards and Best Practices for Instream Works. 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 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 will 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.

7.9 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 and George Properties 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).

7.9.2 Conceptual Fish Offsetting Plan

The Draft Conceptual Fish Offsetting Plan can be found in Volume 10, Chapter 21. The Conceptual Fish Offsetting Plan will address all potential PADs of fish habitat by creating compensatory fish habitat elsewhere in the Project area. Freshwater fish/aquatic habitat offsetting may include the following methods:

- increasing access to overwintering habitat for Lake Trout and Arctic Grayling by increasing lake depth;
- increasing access to rearing and spawning habitat for Lake Trout by installing artificial rock shoals in lakes; and
- increasing access to rearing and spawning habitat for Arctic Grayling by enhancing stream access and stream channels.

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 (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). The potential for adverse *indirect* effects to fish health due to impacts on water quality, sediment quality, or food source items is assessed for the VECs freshwater water quality and freshwater sediment quality (Volume 6; Chapters 4 and 5) using the following Canadian guidelines to protect aquatic life: Water Quality Guidelines for the Protection of Aquatic Life (Freshwater and Marine; CCME 2013); Interim Sediment Quality Guidelines (ISQGs) and Probable Effects Levels (PELs) for the Protection of Aquatic Life (Freshwater and Marine; CCME 2013).

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.

As a result of proposed mitigation and management, only one non-significant residual effect was anticipated to arise from the Project footprint on the VEC Arctic Grayling. The primary mitigation measures include fisheries compensation through the Conceptual Fish Offsetting Plan, setting maximum limits to water withdrawal to protect sensitive fish habitat, and siting Project infrastructure to avoid fish-bearing water.

The residual effect on Arctic Grayling population abundance arises from the reduction of watershed inputs to Umwelt Lake caused by the loss of Llama Lake and local drainages. Umwelt Outflow serves as spawning and rearing habitat for Arctic Grayling, and the reduction in flow is anticipated have an

adverse effect with a *low to moderate* magnitude effect on spawning, rearing, and migration in the outflow stream. The geographical extent of the residual effect is within the PDA (footprint) and confined to within the LSA; therefore it is considered to be *local*. This effect is *moderate* in duration (for the life of the mine), *continuous* as long as Llama Lake remains dewatered, and *reversible* once watershed inputs are restored. The residual effect is *likely* to occur; however, it is predicted to be **Not Significant**. The significance rating is made with *low* confidence due to uncertainty in the management of water from the Llama Lake watershed.

The identified Project residual effect is confined to the LSA; therefore, it will not interact with other projects. As a result, no cumulative or transboundary effects are predicted.

References

Rescan™
an ERM company

References

Definitions of the acronyms and abbreviations used in this reference list can be found in the Acronyms and Abbreviations section.

1. SURFACE WATER HYDROLOGY

ACIA. 2005. *Arctic Climate Impact Assessment*. New York: Cambridge University Press.

Baffinland. 2012. *Mary River Project: Final Environmental Impact Statement*. Baffinland Iron Mines Corporation: Toronto, ON.

Brown, J., O. J. Ferrians Jr., J. A. Heginbottom, and E. S. Melnikov. 1998. *Circum-Arcitc map of permafrost and ground-ice conditions. revised February 2001. Scale 1:10 000 000*. National Snow and Ice Data Center/World Data Center for Glaciology. Digital Media: Boulder, CO.

Canadian Environmental Assessment Agency. 1992. *Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects*. http://www.CEAa-acee.gc.ca/default.asp?lang=En&n=D213D286-1&offset=&toc=hide (accessed March 2013).

Church, M. 1974. Hydrology and permafrost with reference to northern North America. *Proc. Workshop Seminar on Permafrost Hydrology,* Can. Nat. Comm., IHD, Ottawa, pp. 7 - 20.

DFO. 2007a. *DFO Nunavut Operational Statement: Ice Bridges and Snow Fills*. Version 3.0, DFO/2007-1329.

DFO. 2007b. *DFO Nunavut Operational Statement: Clear Span Bridges*. Version 3.0, DFO/2007-1329.

DFO. 2007c. *DFO Nunavut Operational Statement: Culvert Maintenance*. Version 3.0, DFO/2007-1329.

DFO. 2007d. *DFO Nunavut Operational Statement: Temporary Stream Crossing*. Version 1.0.

DFO. 2009. *DFO Nunavut Operational Statement on Mineral Exploration Activities*. Version 1.0.

DFO. 2010. *DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut*, Fisheries and Oceans Canada, 21 June 2010.

DFO. 2013. *Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada*, Science Advisory Report 2013/017, May 2013.

Dugan, H., Lamoureux, S. F., Lafrenière, M., and Lewis, T. 2009. Major hydrological and sediment yield response to summer rainfall in a small high arctic watershed. *Hydrological Processes*, doi: 10.1002/hyp.7285:

Hegmann, G., C. Cocklin, R. Creasey, S. Dupuis, A. Kennedy, L. Kingsley, W. Ross, H. Spaling and D. Stalker. 1999. *Cumulative Effects Assessment Practitioners' Guide*. http://www.CEAa-acee.gc.ca/default.asp?lang=En&n=43952694-1&offset=&toc=hide (accessed March 2013).

Herschy, R. W. 2009. *Streamflow measurement*. Third ed. New York, NY: Taylor & Francis.

Kane, D.L., Gieck, R.E., Hinzman, L.D. 1997. Snowmelt Modeling at Small Alaskan Arctic Watershed. *Journal of Hydrologic Engineering*. Vol. 2, No. 4, 204-210.

KIA. 2012. *Inuit Traditional Knowledge of Sabina Gold & Silver Corp. Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project* (NTKP). Prepared for Sabina Gold & Silver Corp. by Kitikmeot Inuit Association: Kugluktuk, NU.

Lewis, T. and S. F. Lamoureux. 2010. Twenty-first century discharge and sediment yield predictions in a small high arctic watershed. *Global and Planetary Change*, doi: 10.1016/j.gloplacha.2009.12.006.

MacLean, R., M. W. Oswood, J. G. I. Irons, and W. H. McDowell. 1999. The effect of permafrost on stream biogeochemistry: A case study of two streams in the Alaskan (USA) taiga. *Biogeochemistry*, 47: 239-67.

Nakicenovic, N., J. Alcamo, G. Davis, B. Vries, J. Fenhann, and S. Gaffin. 2000. *IPCC Special Report Emissions Scenarios, Summary for Policymakers. A Special Report of IPCC Working Group III*. Intergovernmental Panel on Climate Change.

NIRB. 2007. *Guide 2: Guide to Terminology and Definitions*. Nunavut Impact Review Board: Cambridge Bay, NU.

NIRB. 2013. *Guidelines for the Preparation of an Environmental Impact Statement for Sabina Gold & Silver Corp.'s Back River Project (NIRB File No. 12MN036)*. Issued April 2013 by the Nunavut Impact Review Board: Cambridge Bay, NU.

Pohl, S., P. Marsh, and B. R. Bonsal. 2007. Modeling the impact of climate change on runoff and annual water balance of an arctic headwater basin. *Arctic*, 60: 173-96.

Quinton, W. L. and P. Marsh. 1998. The influence of mineral earth hummocks on subsurface drainage in the continuous permafrost zone. *Permafrost and Periglacial Processes* 9.

Rescan. 2007. Appendix F-5 - Traditional Knowledge of Wildlife, Fish and Water Quality. In *The Bathurst Inlet Port and Road Project (BIPR) Draft Environmental Impact Statement*. Prepared for Bathurst Inlet Port and Road Joint Venture Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012a. *Back River Project 2011 Hydrology Baseline Report*. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd., Vancouver, BC.

Rescan. 2012b. *Back River Project 2012 Hydrology Baseline Report*. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd., Vancouver, BC.

Rescan. 2012c. *Memorandum: Thermistor data summary, Back River Project*. Submitted to Sabina Gold & Silver Corporation.

Rescan. 2012d. *Back River Project 2011 Freshwater Baseline Report*. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd., Vancouver, BC, January 2012.

Rescan. 2012e. *Back River Project 2012 Freshwater Baseline Report*. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd., Vancouver, BC, December 2012.

Rescan. 2013a. *Draft Environmental Impact Statement for Bathurst Inlet Port and Road Project*. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2013b. *Ekati Diamond Mine: 2012 Aquatic Effects Monitoring Program Part 2 – Data Report*, Prepared for BHP Billiton Canada Inc. by Rescan Environmental Services Ltd.: Yellowknife, NWT.

Rescan. n.d. *Back River Project 2013 Hydrology Baseline Report*. Prepared for Sabina Gold & Silver Corp. by ERM Rescan: Vancouver, BC (to be published).

Thorne, R. 2011. Uncertainty in the impacts of projected climate change on the hydrology of a subarctic environment: Liard River Basin. *Hydrology and Earth System Sciences*, doi: 10.5194/hess-15-1483-2011.

Woo, M-K. 1990. Permafrost Hydrology. In: *Northern Hydrology, Canadian Perspectives T. D. Prowse and C. S. L. Ommanney eds.* NHRI Science Report No. 1, 63-76.

Woo, M-K., M. Mollinga, and S. L. Smith. 2007. Climate warming and active layer thaw in the boreal and tundra environments of the Mackenzie Valley. *Canadian Journal of Earth Sciences*, 44: 733-43.

2. GROUNDWATER

Areva Resources Canada Inc. 2011. *Kiggivik Project Environmental Impact Statement Technical Appendix 5B: Geology and Hydrogeology Baseline*. Iqaluit, NU: Submitted by Areva Resources Canada Inc. to the Nunavut Impact Review Board.

Cater, D. 2011. *Technical Report: Back River Project, Nunavut Territory, Canada (NI 43-101)*. North Vancouver, B.C., Canada: Prepared for Sabina Gold & Silver Corporation.

CCME. 2013. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Summary Tables. In: Canadian Environmental Quality Guidelines. Winnipeg, Manitoba, Canada: Canadian Council of Ministers of the Environment.

Cumberland Resources Ltd. 2005. *Meadowbank Gold Project: Final Environmental Impact Statement*. Iqaluit, NU: Submitted by Cumberland Resources Ltd. to the Nunavut Impact Review Board.

Frape, S., and Fritz, P. 1987. Geochemical trends for groundwater from the Canadian Shield, in saline water and gases from crystalline rocks. *Geological Association of Canada Special Paper 33*, 19-38.

Frape, S., Fritz, P., and McNutt, R. 1984. Water-rock interaction and chemistry of groundwaters from the Canadian Shield. *Geochemica et Cosmochimica Acta 48*, 1617-1627.

Freeze, R., and Cherry, J. 1979. *Groundwater*. Upper Saddle River, N.J., U.S.A.: Prentice Hall, Inc.

Golder Associates Ltd. 2013. *Monitoring Well M11-1257 (Westbay Well) Groundwater Sampling Results: Meliadine Gold Project, Nunavut*. Kanata, ON: Prepared by Golder Associates Ltd. for Agnico-Eagle Mines Ltd.

KIA. 2012. *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)*. Kugluktuk, NU: Prepared for Sabina Gold & Silver Corp. by Kitikmeot Inuit Association.

Newmont. 2011. *Phase 2 Hope Bay Belt Project Proposal, Section 4.2.8: Groundwater*. North Vancouver, BC: Newmont Mining Corporation / Hope Bay Mining Ltd.

Rescan. 2013. *2013 Terrain and Soils Baseline Report*. Vancouver, B.C., Canada: Prepared for Sabina Gold and Silver Corporation by Rescan Environmental Services Ltd.

Rescan. 2014. Back River Project: 2013 Groundwater Quality Baseline Report. Vancouver, B.C., Canada: Prepared for Sabina Gold and Silver Corporation by Rescan Environmental Services Ltd., in preparation

Stotler, R., Frape, S., Ruskeeniemi, T., Ahonen, L., Onstott, T., & Hobbs, M. 2009. Hydrogeochemistry of groundwaters in and below the base of thick permfrost at Lupin, NU. *Journal of Hydrology, 373*, 80-95.

3. LIMNOLOGY AND BATHYMETRY

Bion Research Inc. and Hubert and Associates Ltd. 1994. *Environmental Pilot Survey - Goose Lake, NWT*. Prepared for Homestake Canada Inc.: Vancouver, B.C.

EBA. 2013. *Geophysical Survey — Sabina Back River Project*. Prepared for Sabina Gold & Silver Corp.: Edmonton, AB.

Gartner Lee Ltd. 2008. *Field Report - Back River Project Freshwater Aquatic Resources 2007*. Prepared for Dundee Precious Metals Inc.: Toronto, ON.

Golder Associates Ltd. 2007. *Back River Project: Environmental Baseline Studies, September 2006*. Prepared for Dundee Precious Metals Inc.: Edmonton, AB.

KIA. 2012. *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)*. Prepared for Sabina Gold & Silver Corp. by Kitikmeot Inuit Association: Kugluktuk, NU.

NIRB. 2013. *Guidelines for the Preparation of an Environmental Impact Statement for Sabina Gold & Silver Corp.'s Back River Project (NIRB File No. 12MN036)*. Nunavut Impact Review Board: Cambridge Bay, NU.

Nunavut Planning Commission. 2012. *Draft Nunavut Land Use Plan*. Cambridge Bay, NU.

Rescan. 2007. Appendix F-5 - Traditional Knowledge of Wildlife, Fish and Water Quality. In *The Bathurst Inlet Port and Road Project (BIPR) Draft Environmental Impact Statement*. Prepared for Bathurst Inlet Port and Road Joint Venture Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2011. *Back River Project: 2010 Lake Water and Sediment Quality Baseline Report*. Prepared for Sabina Gold & Silver Corp.: Vancouver, B.C.

Rescan. 2012. *Back River Project: 2011 Freshwater Baseline Report*. Prepared for Sabina Gold & Silver Corp.: Vancouver, B.C.

Rescan. 2013a. *Back River Project: 2012 Freshwater Baseline Report*. Prepared for Sabina Gold & Silver Corp.: Vancouver, B.C.

Rescan. 2013b. *Back River Project: 2013 Freshwater Baseline Report (in preparation)*. Prepared for Sabina Gold & Silver Corp.: Vancouver, B.C.

4. FRESHWATER WATER QUALITY

1990. Consolidation of Explosives Regulations, RRNWT. C. E-27.

Explosives Regulations, C.R.C., c. 599.

Metal Mining Effluent Regulations, SOR/2002-222.

Bion Research Inc. and Hubert and Associates Ltd. 1994. Environmental Pilot Survey - Goose Lake, NWT. Prepared for Homestake Canada Inc.: Vancouver, B.C.

Canamera Geological Ltd. 1996. George Lake Project: Environmental Database Evaluation. Prepared for Arauco Resources Ltd. : Vancouver, B.C.

CCME. 2000. Canada-Wide Standards for Mercury Emissions. Canadian Council of Ministers of the Environment: Quebec City.

CCME. 2001. Canada-Wide Standards for Dioxins and Furans. Canadian Council of Ministers of the Environment Quebec City.

CCME. 2007. A Protocol for the Derivation of Water Quality Guidelines for the Protection of Aquatic Life. Winnepeg, MB.

CCME. 2013. Canadian water quality guidelines for the protection of aquatic life: summary table. Updated 2013. In: Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment: Winnipeg, MB.

Fisheries and Oceans Canada. 2009. Nunavut Operation Statements. Yellowknife, NT.

Fisheries and Oceans Canada. 2010. DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut. Yellowknife, NT.

Gartner Lee Ltd. 2008. Field Report - Back River Project Freshwater Aquatic Resources 2007. Prepared for Dundee Precious Metals Inc.: Toronto, ON.

Golder Associates Ltd. 2007. Back River Project: Environmental Baseline Studies, September 2006. Prepared for Dundee Precious Metals Inc.: Edmonton, AB.

Government of Nunavut. 2012. Environmental Guideline for the Burning and Incineration of Solid Waste.

Health Canada. 2012. Guidelines for Canadian Drinking Water Quality – Summary Table. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Health Canada: Ottawa, ON.

Hubert and Associates Ltd. 2004. Summary of Environmental Baseline Data for the Area of George Lake and Goose Lake, Nunavut. Prepared for Miramar Hope Bay Ltd.: Vancouver, B.C.

KIA. 2012. Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP). Prepared for Sabina Gold & Silver Corp. by Kitikmeot Inuit Association: Kugluktuk, NU.

Lemmen, D. S., F. J. Warren, J. Lacroiz, and E. Bush. 2008. From Impacts to Adaptation: Canada in a Changing Climate 2007. Government of Canada: Ottawa, ON.

NIRB. 2013. Guidelines for the Preparation of an Environmental Impact Statement for Sabina Gold & Silver Corp.'s Back River Project (NIRB File No. 12MN036). Nunavut Impact Review Board: Cambridge Bay, NU.

Norecol Dames and Moore. 1993. Homestake Goose Lake Project: 1993 Water Quality Report, Goose Lake. Prepared for Homestake Canada Ltd.: Vancouver, BC.

Norecol Dames and Moore. 1997. George Lake Project 1997 Data. Kit Resources Ltd.: Vancouver, B.C.

Nunavut Planning Commission. 2012. Draft Nunavut Land Use Plan. Cambridge Bay, NU.

Prowse, T. D., F. J. Wrona, J. D. Reist, J. J. Gibson, J. E. Hobbie, L. M. J. Levesque, and W. F. Vincent. 2006. Climate change impacts on Arctic freshwater ecosystems and fisheries. Ambio, 35 (7): 347–58.

Rescan. 2007. Appendix F-5 - Traditional Knowledge of Wildlife, Fish and Water Quality. In The Bathurst Inlet Port and Road Project (BIPR) Draft Environmental Impact Statement. Prepared for Bathurst Inlet Port and Road Joint Venture Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2011. Back River Project: 2010 Lake Water and Sediment Quality Baseline Report. Sabina Gold & Silver Corp.: Vancouver, B.C.

Rescan. 2012. Back River Project: 2011 Freshwater Baseline Report. Sabina Gold & Silver Corp.: Vancouver, B.C.

Rescan. 2013a. Back River Project: 2012 Freshwater Baseline Report. Sabina Gold & Silver Corp.: Vancouver, B.C.

Rescan. 2013b. Back River Project: 2012 Socio-economic and Land Use Baseline Report. Prepared for Sabina Gold & Silver Corp.: Vancouver, BC.

Rescan. 2013c. Back River Project: 2013 Freshwater Baseline Report (in preparation). Sabina Gold & Silver Corp.: Vancouver, B.C.

5. FRESHWATER SEDIMENT QUALITY

1985. *Fisheries Act*, RSC. C. F-14.

1990. *Consolidation of Explosives Regulations*, RRNWT. C. E-27.

Explosives Regulations, C.R.C., c. 599.

CCME. 1999. *Protocol for the Derivation of Canadian Sediment Quality Guidelines for the Protection of Aquatic Life*. EPC-98E. Prepared by Environment Canada, Guidelines Division, Technical Secretariat of the CCME Task Group on Water Quality Guidelines, Ottawa: Winnepeg, MB.

CCME. 2000. *Canada-Wide Standards for Mercury Emissions*. Canadian Council of Ministers of the Environment: Quebec City.

CCME. 2001. *Canada-Wide Standards for Dioxins and Furans*. Canadian Council of Ministers of the Environment Quebec City.

CCME. 2013. *Canadian sediment quality guidelines for the protection of aquatic life: summary table. Updated 2013. In: Canadian environmental quality guidelines, 1999*. Canadian Council of Ministers of the Environment: Winnipeg, MB.

Fisheries and Oceans Canada. 2009. *Nunavut Operation Statements*.

Gartner Lee Ltd. 2008. *Field Report - Back River Project Freshwater Aquatic Resources 2007*. Prepared for Dundee Precious Metals Inc.: Toronto, ON.

Government of Nunavut. 2012. Environmental Guideline for the Burning and Incineration of Solid Waste.

Hermanson, M. H. 1990. ^{210}Pb and ^{137}Cs chronology of sediments from small, shallow Arctic lakes. *Geochim Cosmochim Ac*, 54 (5): 1443–51.

KIA. 2012. *Inuit Traditional Knowledge of Sabina Gold & Silver Corp., Back River (Hannigayok) Project, Naonaiyaotit Traditional Knowledge Project (NTKP)*. Prepared for Sabina Gold & Silver Corp. by Kitikmeot Inuit Association: Kugluktuk, NU.

Lemmen, D. S., F. J. Warren, J. Lacroiz, and E. Bush. 2008. *From Impacts to Adaptation: Canada in a Changing Climate 2007*. Government of Canada: Ottawa, ON.

Muir, D. C., G. A. Omelchenko, N. P. Grift, D. A. Savoie, W. L. Lockhart, P. Wilkinson, and G. J. Brunskill. 1996. Spatial trends and historical deposition of polychlorinated biphenyls in Canadian midlatitude and Arctic lake sediments. *Environ Sci Technol*, 30 (12): 3609–17.

NIRB. 2013. *Guidelines for the Preparation of an Environmental Impact Statement for Sabina Gold & Silver Corp.'s Back River Project (NIRB File No. 12MN036)*. Nunavut Impact Review Board: Cambridge Bay, NU.

Nunavut Planning Commission. 2012. *Draft Nunavut Land Use Plan*. Cambridge Bay, NU.

Prowse, T. D., F. J. Wrona, J. D. Reist, J. J. Gibson, J. E. Hobbie, L. M. J. Levesque, and W. F. Vincent. 2006. Climate change impacts on Arctic freshwater ecosystems and fisheries. *Ambio*, 35 (7): 347–58.

Rescan. 2011. *Back River Project: 2010 Lake Water and Sediment Quality Baseline Report*. Sabina Gold & Silver Corp.: Vancouver, B.C.

Rescan. 2012a. *Back River Project: 2011 Freshwater Baseline Report*. Sabina Gold & Silver Corp.: Vancouver, B.C.

Rescan. 2012b. *Doris North Gold Mine Project: 2011 Aquatic Effects Monitoring Program Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2013a. *Back River Project: 2012 Freshwater Baseline Report*. Sabina Gold & Silver Corp.: Vancouver, B.C.

Rescan. 2013b. *Back River Project: 2013 Freshwater Baseline Report (in preparation)*. Sabina Gold & Silver Corp.: Vancouver, B.C.

6. FRESHWATER FISH/AQUATIC HABITAT

1985. *Fisheries Act*, RSC 1985. C. F-14.

Metal Mining Effluent Regulations, SOR/2002-222.

Canada Gazette. 2006. *Regulations Amending the Metal Mining Effluent Regulations Amendments, P.C. 2006-1071*. Vol. 140, No. 21. Ottawa, ON.

Canada Gazette. 2012. *Regulations Amending the Metal Mining Effluent Regulations Amendments, P.C. 2012-215*. Vol. 146, No. 6. Ottawa, ON.

Cott, P. A. 2007. Fisheries Related Impacts of Water Withdrawal from Ice-Covered Lakes. M.Sc. diss., University of Guelph.

DFO. 1986. *The Department of Fisheries and Oceans: Policy for the Management of Fish Habitat*. Fisheries and Oceans Canada: Ottawa, ON.

DFO. 2007a. *Culvert Maintenance, version 3.0*. Fisheries and Oceans Canada Nunavut Operational Statement. http://www.dfo-mpo.gc.ca/regions/central/habitat/os-eo/provinces-territories-territoires/nu/os-eo07-eng.htm (accessed September 2013).

DFO. 2007b. *Ice Bridges and Snow Fills, version 3.0*. Nunavut Operational Statement. Iqaluit, NU: Fisheries and Oceans Canada - Eastern Arctic Area.

DFO. 2007c. *Ice Bridges and Snow Fills, version 3.0*. Fisheries and Oceans Canada - Eastern Arctic Area: Iqaluit, NU.

DFO. 2007d. *Nunavut In-Water Construction Timing Windows for the Protection of Fish and Fish Habitat: Fisheries and Oceans Canada Nunavut Operational Statement*. DFO 2007/1329. http://www.dfo-mpo.gc.ca/regions/central/habitat/os-eo/provinces-territories-territoires/nu/pdf/os-eo21_e.pdf (accessed September 2013).

DFO. 2007e. *Temporary Stream Crossing, version 1.0*. Nunavut Operational Statement. Iqaluit, NU: Fisheries and Oceans Canada - Eastern Arctic Area.

DFO. 2009. *Mineral Exploration Activities, version 1.0*. Fisheries and Oceans Canada Nunavut Operational Statement. http://www.dfo-mpo.gc.ca/regions/central/habitat/os-eo/provinces-territories-territoires/nu/pdf/os-eo24_e.pdf (accessed 15-Oct-2013).

DFO. 2010. *DFO Protocol for Winter Water Withdrawal from Ice-Covered Waterbodies in the Northwest Territories and Nunavut*. Fisheries and Oceans Canada: Iqaluit, NU.

DFO. 2013a. *Fisheries and Oceans Canada: Fisheries Protection Policy Statement*. Fisheries and Oceans Canada: Ottawa, ON.

DFO. 2013b. *Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada*. DFO. Can. Sci. Advis. Sec. Proceed. Ser. 2013/017. Fisheries and Oceans Canada: Ottawa, ON.

Dodds, W. K., J. R. Jones, and E. B. Welch. 1998. Suggested classification of stream trophic state: distributions of temperate stream trypes by chlorophyll, total nitrogen, and phosphorus. *Water Research*, 32: 1455-62.

Ellis, D. V. 1962. Observations on the Distribution and Ecology of Some Arctic Fish. *Arctic Institute of North America*, 15: 179-89.

Environment Canada. 2002. *Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring*. Environment Canada: Ottawa, ON.

Gartner Lee Ltd. 2008. *Field Report - Back River Project Freshwater Aquatic Resources 2007*. Dundee Precious Metals Inc.: Toronto, ON.

Golder Associates Ltd. 2007. *Back River Project: Environmental Baseline Studies, September 2006*. Dundee Precious Metals Inc. : Edmonton, AB.

Hobson, K. A. and H. E. Welch. 1995. Cannibalism and trophic structure in a high Arctic lake: insights from stable-isotope analysis. *Canadian Journal of Fisheries and Aquatic Sciences*, 52: 1195-201.

Johnston, N. T. and P. A. Slaney. 1996. *Fish Habitat Assessment Procedures*. Watershed Technical Circular 8.

KIA, ed. 2012. *Inuit Traditional Knowledge of Sabina Gold & Silver Corporation's Back River (Hannigayok) Project. Naonaiyaotit Traditional Knowledge Project (NTKP)*. Kugluktuk, NU: Prepared by the Kitikmeot Inuit Association for Sabina Gold & Silver Corp.

Koops, M. A., M. Koen-Alonso, K. E. Smokorowski, and J. C. Rice. 2013. *A Science-Based Interpretation and Framework for Considering the Contribution of the Relevant Fish to the Ongoing Productivity of Commercial, Recreational or Aboriginal Fisheries*. DFO. Can. Sci. Advis. Sec. Res. Doc. 2012/141. Fisheries and Oceans Canada: Ottawa, ON.

Marcus, M. D., W. A. Hubert, and S. H. Anderson. 1984. *Habitat Suitability Index Models: Lake Trout (Exclusive of the Great Lakes)*. Fish and Wildlife Service, U.S. Department of the Interior: Washington, DC.

Mason, B. and R. Knight. 2001. *Sensitive Habitat Inventory and Mapping*. Vancouver, BC: Community Mapping Network.

Moore, J. W. 1978. Distribution and abundance of phytoplankton in 153 lakes, rivers, and pools in the Northwest Territories. *Canadian Journal of Botany*, 56 (15): 1765-73.

NIRB. 2013. *Guidlines for Sabina Gold & Silver Corp.'s Preparation of an Environmental Impact Statement for the Back River Project (NIRB File No. 12MN036)*. Issued April 2013 by the Nunavut Impact Review Board: Cambridge Bay, NU.

Norecol Dames & Moore. 1997. *George Lake Project 1997 Data*. Prepared for Kit Resources Ltd. by Norecol Dames & Moore Ltd,: Vancouver, BC.

Nunavut Planning Commission. 2012. *Draft Nunavut Land Use Plan 2011/2012*. Nunavut Planning Commission: Iqaluit, NU.

O'Brien, W. J., M. Barfield, N. D. Bettez, G. M. Gettel, A. E. Hershey, M. E. McDonald, M. C. Miller, H. Mooers, J. Pastor, and C. Richards. 2004. Physical, chemical, and biotic effects on arctic zooplankton communities and diversity. *Limnology and Oceanography*, 49 (4): 1250-61.

O'Brien, W. J., C. Buchanan, and J. F. Haney. 1979. Arctic zooplankton community structure: exceptions to some general rules. *Arctic*, 32 (3): 237-47.

Power, M., J. D. Reist, and J. B. Dempson. 2008. Fish in high-latitude Arctic lakes. In *Polar Lakes and Rivers: Limnology of Arctic and Antarctic Aquatic Ecosystems*. Eds. W. F. Vincent and J. Laybourn-Parry. 249-67. Oxford: Oxford University Press.

Prowse, T. D., F. J. Wrona, J. D. Reist, J. E. Hobbie, L. M. J. Lévesque, and W. F. Vincent. 2006. General features of the Arctic relevant to climate change in freshwater ecosystems. *Ambio*, 35: 330-38.

Randall, R. G., M. J. Bradford, K. D. Clarke, and J. C. Rice. 2013. *A Science-Based Interpretation of Ongoing Productivity of Commercial, Recreational or Aboriginal Fisheries*. DFO. Can. Sci. Advis. Sec. Res. Doc. 2012/112. Fisheries and Oceans Canada: Ottawa, ON.

Rautio, M. and W. F. Vincent. 2006. Benthic and pelagic food resources for zooplankton in shallow high-latitude lakes and ponds. *Freshwater Biology*, 51 (6): 1038-52.

Rescan. 2010. *Back River Project: 2010 Fish and Fish Habitat Baseline Report*. Prepared for Sabina Gold & Silver Corporation by Rescan Environmental Services, Ltd.: Vancouver, BC.

Rescan. 2011. *Back River Project: 2010 Lake Water and Sediment Quality Baseline Report*. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012a. *Back River Project 2011 Fish and Fish Habitat Baseline Report*. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012b. *Back River Project: 2011 Freshwater Baseline Report*. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012c. *Back River Project: 2012 Fish and Fish Habitat Baseline Report*. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012d. *Back River Project: 2012 Freshwater Baseline Report*. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012e. *Bathurst Inlet Port and Road Project: Physical Oceanography Baseline Study, 2012*. Prepared for the Bathurst Inlet Port and Road Project by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2013a. *Back River Project: 2013 Fish and Fish Habitat Baseline Report*. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC. (in progress).

Rescan. 2013b. *Back River Project: 2013 Freshwater Baseline Report*. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC. (in progress).

Scott, W. B. and E. J. Crossman. 1973. *Freshwater Fishes of Canada*. Bulletin of the Fisheries Research Board of Canada 184. Ottawa, ON: Fisheries Research Board of Canada.

Sekerak, A. D. 1990. *Preliminary Studies of Fish and Fish Habitat in the George Lake Area, N.W.T.* Trigg, Woolett, Olson Consulting Ltd. : Yellowknife, NT.

Stewart, D. B., N. J. Mochnacz, J. D. Reist, T. J. Carmichael, and C. D. Sawatzky. 2007. *Fish life history and habitat use in the Northwest Territories: Arctic grayling (Thymallus arcticus)*. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2797.

Symons, C. C., S. E. Arnott, and J. N. Sweetman. 2012. Grazing rates of crustacean zooplankton communities on intact phytoplankton communities in Canadian Subarctic lakes and ponds. *Hydrobiologia*, 694 (1): 131-41.

Vincent, W. F. and J. E. Hobbie. 2000. Ecology of Arctic lakes and rivers. In *The Arctic: Environment, People, Policy*. Eds. M. Nuttall and T. V. Callaghan. 197-232. Amsterdam: The Gordon and Breach Publishing Group.

Vincent, W. F., J. E. Hobbie, and J. Laybourn-Parry. 2008. Introduction to the limnology of high-latitude lake and river ecosystems. In *Polar Lakes and Rivers: Limnology of Arctic and Antarctic Aquatic Ecosystems*. Eds. W. F. Vincent and J. Laybourn-Parry. 1-23. Oxford: Oxford University Press.

Vollenweider, R. A. and J. Kerekes. 1982. *Eutrophication of Waters. Monitoring, Assessment and Control*. Paris, France: OECD Cooperative Programme on Monitoring of Inland Water (Eutrophication Control), Environment Directorate, OECD.

Walters, V. 1955. Fishes of Western Arctic America and Eastern Arctic Siberia. *Bulletin of the American Museum of Natural History*, 106: 255-368.

7. FRESHWATER FISH COMMUNITY

1985. Fisheries Act, RSC 1985. C. F-14.

Metal Mining Effluent Regulations, SOR/2002-222.

Bishop, F. G. 1971. Observations on Spawning Habits and Fecundity of the Arctic Grayling. The Progressive Fish Culturist, 33 (1): 12-19.

Canada Gazette. 2006. Regulations Amending the Metal Mining Effluent Regulations Amendments, P.C. 2006-1071. Vol. 140, No. 21. Ottawa, ON.

Canada Gazette. 2012. Regulations Amending the Metal Mining Effluent Regulations Amendments, P.C. 2012-215. Vol. 146, No. 6. Ottawa, ON.

CCME. 2013. Sediment Quality Guidelines for the Protection of Aquatic Life: Summary

Table. http://st-ts.ccme.ca/ (accessed April 30, 2013).

Cott, P. A., T. A. Johnston, and J. M. Gunn. 2011. Food web position of burbot relative to lake trout, northern pike, and lake whitefish in four sub-Arctic boreal lakes. Journal of Applied Ichthyology, 27 (Suppl. 1): 49-56.

DFO. 1995. Freshwater Intake End-of-Pipe Fish Screen Guidelines. Ottawa, ON: Fisheries and Oceans Canada.

DFO. 2009. Mineral Exploration Activities, version 1.0. Fisheries and Oceans Canada Nunavut Operational Statement. http://www.dfo-mpo.gc.ca/regions/central/habitat/os-eo/provinces-territories-territoires/nu/pdf/os-eo24_e.pdf (accessed 15-Oct-2013).

DFO. 2010. DFO Protocol for Winter Water Withdrawal from Ice-Covered Waterbodies in the Northwest Territories and Nunavut. Fisheries and Oceans Canada: Iqaluit, NU.

DFO. 2013a. Fisheries and Oceans Canada: Fisheries Protection Policy Statement. Fisheries and Oceans Canada: Ottawa, ON.

DFO. 2013b. Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada. DFO. Can. Sci. Advis. Sec. Proceed. Ser. 2013/017. Fisheries and Oceans Canada: Ottawa, ON.

Evans, C. L., J. D. Reist, and C. K. Minns. 2002. Life History Characteristics Of Freshwater Fishes Occurring in the Northwest Territories and Nunavut, With Major Emphasis on Riverine Habitat Requirements. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2614.

Faulkner, S. G., W. M. Tonn, M. Welz, and D. R. Schmitt. 2006. Effects of explosives on incubating lake trout eggs in the Canadian Arctic. North American Journal of Fisheries Management, 26: 833-42.

Golder Associates Ltd. 2007. Back River Project: Environmental Baseline Studies, September 2006. Dundee Precious Metals Inc. : Edmonton, AB.

Hubert and Associates Ltd. 2004. Summary of Environmental Baseline Data for the Area of George Lake and Goose Lake, Nunavut. Miramar Hope Bay Ltd.: Vancouver, BC.

Hubert, W. A., R. S. Helzner, L. A. Lee, and P. C. Nelson. 1985. Habitat suitability index models and instream flow suitability curves: Arctic grayling riverine populations. U.S. Fish and Wildlife Service Biological Report 82(10.110).

KIA, ed. 2012. Inuit Traditional Knowledge of Sabina Gold & Silver Corporation's Back River (Hannigayok) Project. Kugluktuk, NU: Prepared for the Naonaiyaotit Traditional Knowledge Project (NTKP), Kitikmeot Inuit Association by Banci Consulting Ltd. and Spicker GIS Services.

Koops, M. A., M. Koen-Alonso, K. E. Smokorowski, and J. C. Rice. 2013. A Science-Based Interpretation and Framework for Considering the Contribution of the Relevant Fish to the Ongoing Productivity of Commercial, Recreational or Aboriginal Fisheries. DFO. Can. Sci. Advis. Sec. Res. Doc. 2012/141. Fisheries and Oceans Canada: Ottawa, ON.

Marcus, M. D., W. A. Hubert, and S. H. Anderson. 1984. Habitat Suitability Index Models: Lake Trout (Exclusive of the Great Lakes). Fish and Wildlife Service, U.S. Department of the Interior: Washington, DC.

NIRB. 2013. Guidlines for Sabina Gold & Silver Corp.’s Preparation of an Environmental Impact Statement for the Back River Project (NIRB File No. 12MN036). Issued April 2013 by the Nunavut Impact Review Board: Cambridge Bay, NU.

Norecol Dames & Moore. 1997. George Lake Project 1997 Data. Prepared for Kit Resources Ltd. by Norecol Dames & Moore Ltd,: Vancouver, BC.

Norecol Dames and Moore. 1997. George Lake Project 1997 Data. Kit Resources Ltd.: Vancouver, BC.

Nunavut Planning Commission. 2012. Draft Nunavut Land Use Plan 2011/2012. Nunavut Planning Commission: Iqaluit, NU.

Randall, R. G., M. J. Bradford, K. D. Clarke, and J. C. Rice. 2013. A Science-Based Interpretation of Ongoing Productivity of Commercial, Recreational or Aboriginal Fisheries. DFO. Can. Sci. Advis. Sec. Res. Doc. 2012/112. Fisheries and Oceans Canada: Ottawa, ON.

Rescan. 2010. Back River Project: 2010 Fish and Fish Habitat Baseline Report. Prepared for Sabina Gold & Silver Corporation by Rescan Environmental Services, Ltd.: Vancouver, BC.

Rescan. 2012a. Back River Project 2011 Fish and Fish Habitat Baseline Report. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012b. Back River Project: 2011 Freshwater Baseline Report. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012c. Back River Project: 2012 Fish and Fish Habitat Baseline Report. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012d. Back River Project: 2012 Freshwater Baseline Report. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2013. Back River Project: 2013 Fish and Fish Habitat Baseline Report. Prepared for Sabina Gold & Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC (in progress).

Scott, W. B. and E. J. Crossman. 1973. Freshwater Fishes of Canada. Bulletin of the Fisheries Research Board of Canada 184. Ottawa, ON: Fisheries Research Board of Canada.

Sekerak, A. D. 1990. Preliminary Studies of Fish and Fish Habitat in the George Lake Area, N.W.T. Trigg, Woolett, Olson Consulting Ltd. : Yellowknife, NT.

Stewart, D. B., N. J. Mochnacz, J. D. Reist, T. J. Carmichael, and C. D. Sawatzky. 2007. Fish life history and habitat use in the Northwest Territories: Arctic grayling (Thymallus arcticus). Canadian Manuscript Report of Fisheries and Aquatic Sciences 2797.

Tyson, J. D., W. M. Tonn, S. Boss, and B. W. Hanna. 2011. General Fish-out Protocol for Lakes and Impoundments in the Northwest Territories and Nunavut. Canadian Technical Report of Fisheries and Aquatic Sciences 2935.

Wright, D. G. and G. E. Hopky. 1998. Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters. Canadian Technical Report of Fisheries and Aquatic Sciences, 2107