15. Assessment of Potential Fish and Fish Habitat Effects

15.1 INTRODUCTION

This chapter is an assessment of potential fish and fish habitat effects, in relation to the Brucejack Gold Mine Project (the Project). Fish and fish habitat is a critical component of the aquatic environment and is protected under the *Fisheries Act* (1985). Fish and fish habitat is thus linked to important identified valued components (or sub-components) including surface water quality, surface water quantity, primary and secondary producers, as well as human health. Fish are also important to Canadians from an economic, recreational, and cultural perspective. The proposed Project could affect fish and fish habitat through the life of the Project via:

- expansion of access roads;
- transmission line installation;
- aerodrome installation; and
- mine site water discharge.

Such effects may occur during the Construction, Operation, Closure, and Post-closure phases. A pre-development fish and fish habitat baseline was thus established to allow for the prediction and assessment, as well as mitigation and management, of potential Project-related effects and will be incorporated into mine development and management planning. Project-specific cumulative baseline study reports and associated data from 2010, 2011, and 2012 are located in Appendix 15-A.

15.2 REGULATORY AND POLICY FRAMEWORK

Several federal and provincial regulations guide development where it pertains to fish and fish habitat protection. These include the:

- Canada *Fisheries Act* (1985);
- Metal Mining Effluent Regulations (SOR/2002-222);
- Canada *Species at Risk Act* (2002a);
- Canadian Biodiversity Strategy (Environment Canada 1995);
- British Columbia (BC) *Water Act* (1996);
- BC *Fish Protection Act* (1997); and
- BC *Environmental Management Act* (2003).

The following sections describe these acts, regulations, and guidelines and how they apply to the protection of fish and fish habitat.

15.2.1 Canada *Fisheries Act*

The *Fisheries Protection Policy Statement* (DFO 2013) supports changes made to the *Fisheries Act* (1985) in 2012. The *Fisheries Protection Policy Statement* replaces Fisheries and Oceans Canada's (DFO) *No Net Loss Guiding Principle* for fish habitat within the *Policy for the Management of Fish Habitat* (DFO 1991).

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 of the *Fisheries Act*); provisions for flow and passage (sections 20 and 21 of the *Fisheries Act*); and a framework for regulatory decision-making (sections 6 and 6.1 of the *Fisheries Act*). These provisions guide the Minister's decision-making process in order to provide for sustainable and productive fisheries.

The amendments centre on the prohibition against *serious harm to fish* and apply to fish and fish habitat that are part of or support commercial, recreational, or Aboriginal fisheries. Proponents are responsible for avoiding and mitigating *serious harm to fish* that are part of or support commercial, recreational, or Aboriginal fisheries. When proponents are unable to completely avoid or mitigate *serious harm to fish*, their projects will normally require authorization under subsection 35(2) of the *Fisheries Act* (1985) in order for the project to proceed without contravening the Act.

DFO interprets *serious harm to fish* as:

- the death of fish;
- a permanent alteration to fish habitat of a spatial scale, duration, or intensity that limits or diminishes the ability of fish to use such habitats as spawning grounds, nursery, rearing, food supply areas, migration corridors, or any other area in order to carry out one or more of their life processes; and
- the destruction of fish habitat of a spatial scale, duration, or intensity that results in fish no longer being able to rely on such habitats for use as spawning grounds, nursery, rearing, food supply areas, migration corridor, or any other area in order to carry out one or more of their life processes.

After efforts have been made to avoid and mitigate impacts, any residual *serious harm to fish* should be addressed by offsetting. An offset measure is one that counterbalances unavoidable *serious harm to fish* resulting from a project with the goal of maintaining or improving the productivity of the commercial, recreational, or Aboriginal fishery. Offset measures should support available fisheries' management objectives and local restoration priorities.

Baseline fish and fish habitat studies were designed to address the previous federal policy as well as the existing federal policy.

15.2.2 Metal Mining Effluent Regulations

Using a natural waterbody frequented by fish for mine waste disposal requires an amendment to the Metal Mining Effluent Regulations (MMER; SOR/2002-222), which is a federal legislative action. The MMER, enacted in 2002, were developed under subsections 34(2), 36(5), and 38(9) of the *Fisheries Act* to regulate the deposit of mine effluent, waste rock, tailings, low-grade ore, and overburden into natural waters frequented by fish. These regulations, administered by Environment Canada, apply to both new and existing metal mines. Schedule 2 of the MMER lists waterbodies designated as tailings impoundment areas. A waterbody is added to that Schedule through a regulatory amendment.

The MMER (SOR/2002-222) regulations stipulate environmental effects testing and monitoring activities that must be undertaken by metal mines as a condition of depositing effluent. The stipulated activities examine aspects of aquatic ecosystems in receiving waterbodies that may indicate individual, ecosystem, and population-level health. The monitoring of these characteristics must be summarized in interpretive reports provided to the Ministry of Environment.

Permission to deposit mine effluent is contingent on the completion of appropriate monitoring activities allowing the assessment of effects on aquatic ecosystems. Baseline studies were designed to meet the requirements of the MMER (SOR/2002-222) by following guidelines recommended by Environment Canada (2012).

15.2.3 Canada *Species at Risk Act*

The federal *Species at Risk Act* (SARA; 2002a) is designed to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses and identifies species at risk. No fish species at risk were found in the baseline fish and fish habitat study area.

15.2.4 Canadian Biodiversity Strategy

The Canadian Biodiversity Strategy (Environment Canada 1995) seeks to conserve and use biological resources in a sustainable manner, as well as increase the understanding of ecosystems and the need to conserve biodiversity. Fish and fish habitat are specifically addressed in the strategy and provide strategic direction to alleviate anthropogenic stresses on aquatic environments. The fisheries baseline assessment identifies species and habitats throughout the baseline fish and fish habitat study area, including species of concern and critical habitats, so that they may be adequately managed to prevent a loss of biodiversity.

15.2.5 British Columbia *Water Act*

The provincial *Water Act* (1996) regulates changes in or about a stream and ensures that water quality, fish and wildlife habitat, and the rights of licence users are not compromised. The baseline study was designed to identify fish habitat as well as streams and rivers that may not be defined as fish habitat but that may be affected by development.

15.2.6 British Columbia *Fish Protection Act*

The provincial *Fish Protection Act* (1997) focuses on ensuring sufficient water for fish, protecting and restoring fish habitat, improving riparian protection and enhancement, and providing local government with more power with regard to environmental planning. In practice, this means that any fish and fish habitat will be considered in the assessment of water withdrawals. The baseline study identified the locations of critical fish habitat allowing for the impacts of water withdrawals on these habitats to be properly assessed.

15.2.7 British Columbia *Environmental Management Act*

The provincial *Environmental Management Act* (2003) regulates waste discharge to protect water, air, and land quality. All discharges of waste related to the Project will be assessed to determine their potential impact on water quality and fish and fish habitat.

15.2.8 Management Plans and Agreements

Fisheries objectives and management direction are outlined in one strategic-level Land Resource Management Plan (LRMP; i.e., the Cassiar Iskut-Stikine LRMP [BC ILMB 2000]), one Sustainable Resource Management Plan (SRMP; i.e., the Nass South SRMP [BC MFLNRO 2012]), a Nisga'a strategic-level plan (the Nisga'a Land Use Plan [NLG 2002]), and certain agreements (e.g., Nisga'a Final Agreement [NLG, Government of Canada, Province of BC 1999]). The Project lies within the boundaries of these plans and agreements. The assessment of fish and fish habitat was informed by the information presented in these plans and agreements.

15.3 BASELINE CHARACTERIZATION

Many fish species serve an important role in the ecological, economic, and cultural health of BC and Canada. Salmonid species in particular are captured for food and sport, supporting local economies and cultures, while other species may serve as indicators of environmental health and water quality. The Project encompasses several fish-bearing streams, rivers, and lakes that could potentially be affected by development. The following sections review the existing fish and fish habitat information for the Project and assess the potential effects of the Project on the local and regional resource.

15.3.1 Regional Overview

The Project lies in the Coast Mountains of northwest BC, approximately 65 kilometres (km) northwest of Stewart and 21 km south-southeast of the closed Eskay Creek Mine. The proposed Brucejack Mine Site is located in the headwaters of the Sulphurets Creek watershed, which is a tributary of the Unuk River. The current exploration access road travels through the upper Bowser River and Wildfire Creek watersheds, both tributaries of the Bell-Irving River, which flows into the Nass River. The proposed transmission line follows the upper Bowser River south, crossing over into the Salmon River watershed, which flows into the Pacific Ocean at Hyder, Alaska.

Fish distribution in the fish and fish habitat study area is typical of the mountainous northwest region of the province with salmonid species generally limited to large rivers and their tributaries. Headwater areas, such as the Brucejack Mine Site, are predominantly fishless due to gradient barriers and the absence of overwintering fish habitat. Many rivers in the fish and fish habitat study area are glacial and feature high turbidity, low temperatures, and low productivity, all of which yield low fish density and species richness.

Several fish species are known to occur in the fish and fish habitat study area. These include Bull Trout (*Salvelinus confluentus*), Dolly Varden (*S. malma*), Rainbow Trout (*O. mykiss*), Coastal Cutthroat Trout (*O. clarkii*), Mountain Whitefish (*Prosopium williamsoni*), and the Pacific Salmon species: Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*O. kisutch*), and Sockeye Salmon (*O. nerka*). Of these, Coastal Cutthroat Trout and Bull Trout are blue-listed (provincially rare species) in BC (BC MOE 2009a). Some populations of Bull Trout are also listed under SARA (2002a) as being of special concern; however, these do not include Pacific populations outside of the south coast of BC (Government of Canada 2012). All of these species fall within the family Salmonidae. Most salmonid species spawn in the late summer or fall, with migrations generally taking place in the weeks or months immediately preceding spawning (Table 15.3-1). In contrast, Rainbow Trout/Steelhead and Coastal Cutthroat Trout spawn in the spring and steelhead (the anadromous form of Rainbow Trout) may migrate throughout the year prior to overwintering in freshwater before spawning.

15.3.2 Historical Activities

Several historical and current human activities are within close proximity to the proposed Project. These include mining exploration and production, hydroelectric power generation, forestry, and road construction and use.

The Granduc Mine was a copper mine, located approximately 25 km south of the Project, which operated from 1970 to 1978 and 1980 to 1984. The mine included underground workings, a mill site near Summit Lake, and an 18.4-km tunnel connecting them. In addition, a 35-km all-weather access road was built from the communities of Stewart, BC and Hyder, Alaska to the former mill site near Summit Lake. The area of the former mill site near Summit Lake is currently used as staging for several mineral exploration projects in the region. Its terminus of the Granduc Access Road is 25 km south of the proposed Brucejack Mine Site and is currently used by mineral exploration traffic and tourists accessing the Salmon Glacier viewpoint.

Table 15.3-1. Fish Life History Periodicity for Species Identified within the Baseline Fish and Fish Habitat Study Area

		Month											
Species	**Life Stage**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Bull Trout	Spawning												
	Fry Rearing												
	Parr Overwintering												
	Adult Migration												
Chinook Salmon	Spawning												
	Fry Rearing												
	Parr Overwintering												
	Adult Migration												
Coho Salmon	Spawning												
	Fry Rearing												
	Parr Overwintering												
	Adult Migration												
Dolly Varden	Spawning												
	Fry Rearing												
	Parr Overwintering												
	Adult Migration												
Mountain Whitefish	Spawning												
	Fry Rearing												
	Parr Overwintering												
	Adult Migration												
Coastal Cuthroat Trout	Spawning												
	Fry Rearing												
	Parr Overwintering												
	Adult Migration												
Rainbow Trout/Steelhead	Spawning												
	Fry Rearing												
	Parr Overwintering												
	Adult Migration												
Sockeye Salmon/Kokanee	Spawning												
	Fry Rearing												
	Parr Overwintering												
	Adult Migration												

Note: periodicity based on observations and data from the study area, historical information from other watersheds in the region, and other literature (McPhail 2007).

The Sulphurets Project was an advanced underground exploration project of Newhawk Gold Mines located at the currently proposed Brucejack Mine Site. Underground workings were excavated between 1986 and 1990 as part of an advanced exploration and bulk sampling program. Reclamation efforts following the Newhawk advanced exploration work included deposition of waste rock and ore within Brucejack Lake.

The exploration phase of the proposed Brucejack Gold Mine Project commenced in 2011 and has included a drilling program, bulk sample program, construction of an exploration access road from Highway 37 to the west end of Bowser Lake, and rehabilitation of an existing access road from the west end of Bowser Lake to the Brucejack Mine Site.

In 2010, construction began on the Long Lake Hydroelectric Project, which is located approximately 42 km south of the Project. It includes re-development of a 20-metre (m)-high rock-fill dam located at the head of Long Lake, and a new 10-km-long 138-kV transmission line.

Historical forestry activities occurred within the immediate Project Area between Highway 37 and Bowser Lake, south of the Wildfire Creek and Bell-Irving River confluence. Additional details regarding historical and current human activities nearby the Project are described in Section 15.9.

Most historical and current activities near the Project area have limited interactions with fish and fish habitat in the Project area. The Sulphurets and Brucejack Gold Mine projects' activities at Brucejack Lake included the deposition of materials into Brucejack Lake. Brucejack Lake is not fish-bearing and is several kilometres upstream from potential fish habitat (Newhawk 1989; Price 2005).

Access roads constructed for the Sulphurets and Brucejack Gold Mine projects' exploration activities interact with fish and fish habitat only at stream crossings in the Bell-Irving River, Wildfire Creek, Todedada Creek, Scott Creek, and Bowser River watersheds.

Forestry activity in the Project area has occurred near Wildfire Creek, the Bell-Irving River, and tributaries and lakes in the Wildfire Creek and Bell-Irving River watersheds. The associated clearcuts have affected the vegetation community in the watershed, and thus have the potential to influence sediment runoff into fish habitat located in the Project area.

Current and historical Granduc Mine activity may impact the Salmon River and Bowser River watersheds. The Granduc development is located near the headwaters of both rivers. The associated activities and development may affect the hydrology, water quality, and characteristics of fish habitat in both watersheds. The tailings produced by the historical mine were released into the Bowser River and deposited in the mainstem, potentially affecting water and sediment quality and potentially damaging fish habitat. The effects of these activities on fish habitat and communities have not been studied.

15.3.3 Baseline Studies

Baseline fish and fish habitat studies were conducted in 2010, 2011, and 2012 within a fish and fish habitat study area (Rescan 2013a). The objectives of the studies varied slightly from year to year based on alterations to the proposed project design; however, the overarching objectives were to:

- assess the quality of fish habitat in streams, rivers, and lakes;
- locate and document barriers to fish movement within the study area;
- identify critical habitat, particularly for spawning salmon, in the baseline fish and fish habitat study area;

- determine fish presence, community composition, and distribution in streams, rivers, lakes, and wetlands within the baseline fish and fish habitat study area; and
- characterize aspects of the physiology and biology of sentinel fish species in the baseline study area, including tissue metal content and indicators of survival, energy use, and energy storage in accordance with guidelines contained in the MMER (SOR/2002-222) of the *Fisheries Act* (1985).

15.3.3.1 Data Sources

A number of historical studies provide information on the major waterbodies in the baseline study area, although most are limited in scope or geographic range. Data relevant to this baseline study area were gathered through online tools and catalogues such as Habitat Wizard (BC MOE 2009b) and Mapster (DFO 2009), federal and provincial reports, and reports prepared for use by industry or other organizations.

One pertinent report to the baseline study area was prepared for the British Columbia Ministry of Environment (BC MOE) by Saimoto and Saimoto (1998). It describes a reconnaissance level fisheries inventory of the Bell-Irving and Bowser River watersheds. Specifically, it contains fish community data for major waterbodies in the Bowser River watershed, one of the two main watersheds where Project development is expected; however, it does not provide descriptions of fish habitat. Additional information was accessed from baseline reports prepared for Seabridge Gold Inc.'s KSM Project, including fish habitat descriptions, and fish community and biological data for select streams in the baseline study area (Rescan 2009, 2010, 2012b). Other pertinent reports related to the exploration access road within the baseline study area were Cambria Gordon (2012), FINS Consulting (2011), and Pretium Resources Inc. (Pretivm 2012). There were a total of 14 fish-bearing stream crossings during the construction of the exploration access road for the Brucejack Exploration Project. Documents prepared for the Newhawk Gold Mines Ltd. Sulphurets Project provided data relevant to the proposed Project development, particularly in the Unuk River watershed (Tripp 1987, 1988; Newhawk 1989).

Several lakes in the baseline study area have been surveyed for their recreational fisheries potential, as well as to determine fish habitat and community composition as part of the Reconnaissance 1:20,000 Inventory program, and for past proposed developments in the area (Withler 1956; Hancock and Marshall 1984; Tripp 1987, 1988; Coombes 1988; Rescan 2010). These surveys focused primarily on Bowser Lake, although a few included other waterbodies in the Bowser River watershed, including Brucejack Lake (Newhawk 1989). While some historical information is available for streams and rivers in the baseline study area, most is limited to escapement numbers (Alexander and Koski 1995; Pahlke, McPherson, and Marshall 1996; Weller, Jones, and Holm 2005). Nearly all of the historical data available pertain entirely to fish presence and distribution, with very little information regarding fish habitat or community structure.

15.3.3.2 Methods

Baseline Study Area

Fish habitat and community were studied in the Project baseline study area between 2010 and 2012 (Appendix15-A).

The baseline fish and fish habitat study area was defined to allow characterization of fish and fish habitat in all areas that could potentially be affected by any future Project activities. The study area includes major watersheds and waterbodies both within and adjacent to the Project property, potential infrastructure, as well as sites downstream of or adjacent to development associated with the Project (Figure 15.3-1).

Watershed characterization sites were studied with the objective of identifying general fish habitat and fish community characteristics of major watersheds (Figure 15.3-2; Table 15.3-2). Key watersheds were identified through examination of historical information, aerial surveys, and general watershed characteristics. The Bell-Irving River, Bowser River, Wildfire Creek, Todedada Creek, Scott Creek, Todd Creek, and Unuk River watersheds were selected for study as they represent the range of stream types and characteristics present in the baseline study area, with additional observations from the Salmon River watershed.

In addition to the watershed characterization survey, a linear survey was conducted along the east bank of the upper Bowser River to identify and quantify potential fish habitat along a transect associated with the proposed transmission line route (Figure 15.3-1). The transect stretches from the proposed Brucejack Mine Site, southeast along the Knipple Glacier, south from Knipple Lake to the headwaters of the Bowser River and along Summit Lake and parts of the Salmon River watershed.

Fish Habitat

All major watercourses in the baseline fish and fish habitat study area were divided into reaches based on Resource Inventory Standards Committee guidelines (RISC 2001). Reaches contain relatively homogenous habitat and reach breaks are located where there are large changes in habitat characteristics such as stream width, gradient, or morphology. Habitat characteristics were summarized by stream reach. Streams were assessed using methods based on the *Reconnaissance 1:20,000 Fish and Fish Habitat Inventory Protocol* (RISC 2001) and the *Reconnaissance 1:20,000 Fish and Fish Habitat Inventory: Site Card Field Guide* (RISC 1999). This protocol involved characterizing fish habitat over a 100-m-long section of stream by measuring physical attributes. Physical attributes measured or estimated included width, depth, availability of instream cover, canopy closure, substrate size, and gradient. Temperature, pH, and conductivity of the stream water were measured. Stream turbidity was estimated visually. Visual observations were made of the riparian vegetation, bank characteristics, stream morphology, and hillslope coupling. Stream features such as islands, bars, fish barriers, beaver dams, and debris jams were noted. The overall quality of the sites for fish spawning, rearing, overwintering, and migrating was described based on professional judgement. Barriers to fish movement were noted and photographs, measurements, and descriptions of each barrier were taken. All photographs can be found in the appendices of the baseline reports (Appendix15-A).

A subset of sites on major streams was selected for more detailed fish habitat surveys due to their location within the potential mine receiving environment. In addition to the reconnaissance level inventory following the RISC protocols (RISC 2001), the sites were surveyed based on the methodology outlined in the *Fish Habitat Assessment Procedures* (Johnston and Slaney 1996), a system developed for the BC Watershed Restoration Program. Representative sections of each reach were chosen for assessment and individual habitat units were measured with respect to length, bankfull and wetted width and depth, substrate composition, residual pool depth, bank stability, bank height, and instream cover. These measurements allow for a greater ability to characterize changes in habitat resulting from potential mine impacts.

Lake sampling was based on the *Reconnaissance (1:20,000) Fish and Fish Habitat Inventory Protocol* for lakes (RISC 2001). Information regarding the lakes' shape, size, depth, vegetation, shoreline, cover, fish access, and surrounding terrain were measured or visually estimated. Inlets and outlets were located for mapping via geographic information system (GIS). Lakes were surveyed from an inflatable boat.

Figure 15.3-1
Baseline Fish and Fish Habitat Study Area

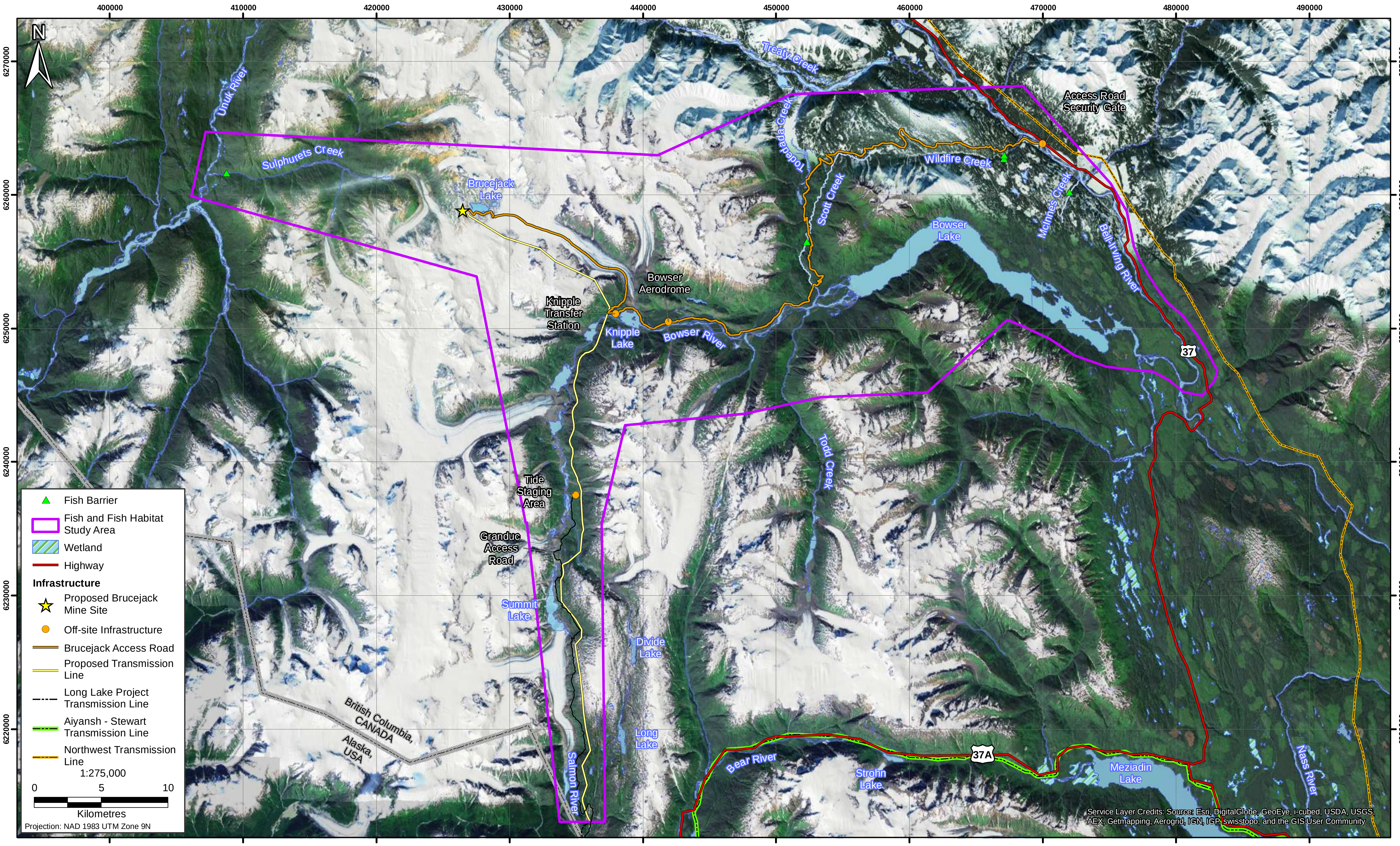


Figure 15.3-2
Baseline Fish and Fish Habitat Sampling Sites, 2010 to 2012

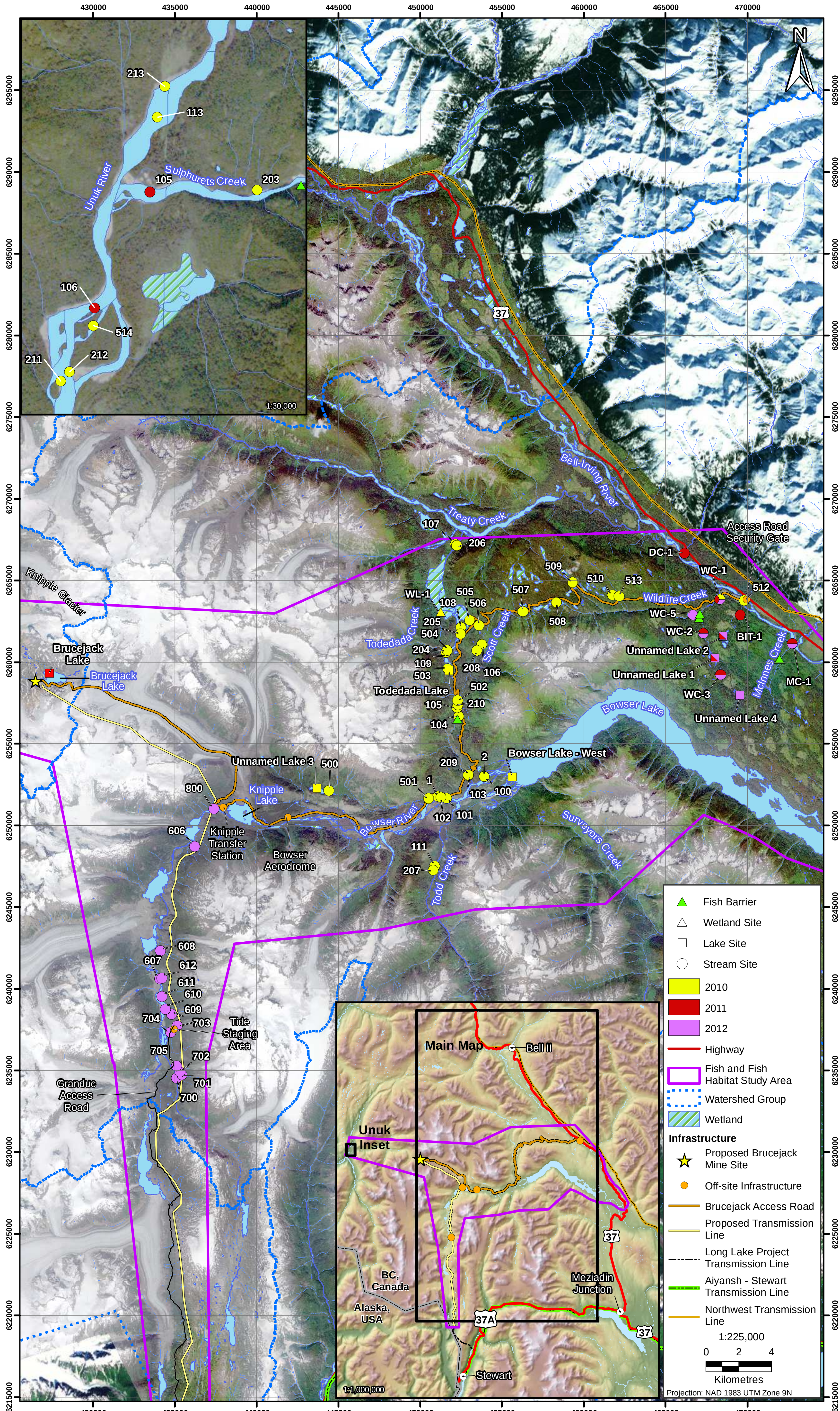


Table 15.3-2. Baseline Fish and Fish Habitat Sampling Site Rationale

Watershed	Site Name	Location		Site Description	Site Type	Receiving Environment Site Class (Near/ Mid/ Far-Field)	Rationale
		Easting	Northing				
Bell-Irving	512	469811	6263784	Bell-Irving, upstream of Wildfire Creek	Watershed Characterization	-	Major waterbody
	MC1	472737	6261147	McInnes Creek, at stream mouth	Reference Environment	-	Habitat representative of many streams in study area
	BIT1	469564	6262888	Tributary to Bell-Irving	Watershed Characterization	-	Habitat representative of many streams in the watershed
	DC1	466159	6266674	Deltaic Creek, near stream mouth	Reference Environment	-	Habitat representative of many streams in the watershed
Bowser	1	451088	6251772	Between Scott Creek and Bowser Lake	Watershed Characterization	-	Major waterbody
	2	453896	6252998	Bowser River, upstream of Scott Creek	Watershed Characterization	-	Major waterbody
	100	453917	6252990	Bowser River side channel	Watershed Characterization	-	Major waterbody
	101	451616	6251657	Bowser River, upstream of Scott Creek	Watershed Characterization	-	Major waterbody
	102	451275	6251714	Bowser River, upstream of Scott Creek	Watershed Characterization	-	Major waterbody
	500	444405	6252126	Outlet of Unnamed Lake 3	Watershed Characterization	-	Habitat representative of many streams in the watershed
	501	450512	6251650	Bowser River tributary	Watershed Characterization	-	Habitat representative of many streams in the watershed
	606	436210	6248729	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	607	434073	6240630	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	608	434113	6242357	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	609	434803	6238469	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	610	434418	6238763	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	611	434221	6239553	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	612	434214	6240676	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	700	435113	6234566	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	701	435425	6234765	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	702	435317	6234935	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	703	435142	6237759	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	704	434738	6237370	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	705	435118	6235309	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	800	437339	6250967	Upper Bowser tributary	Linear Survey	-	Located along linear survey transect
	Unnamed Lake 3	443743	6252143	Lake in headwaters of Bowser River tributary	Watershed Characterization	-	Major waterbody
	Bowser Lake	455662	6253745	Large lake between upper and lower Bowser River	Watershed Characterization	-	Major waterbody
Scott	103	452949	6253051	Scott Creek, downstream of fish barrier	Watershed Characterization	-	Major waterbody
	104	452364	6256689	Scott Creek, upstream of fish barrier	Watershed Characterization	-	Habitat representative of many streams in the watershed
	105	452252	6257225	Scott Creek tributary	Watershed Characterization	-	Habitat representative of many streams in the watershed
	208	453468	6260718	Scott Creek tributary	Watershed Characterization	-	Major waterbody
	209	452937	6253083	Scott Creek, downstream of fish barrier	Watershed Characterization	-	Determining end of fish use
	210	452306	6257398	Scott Creek, upstream of fish barrier	Watershed Characterization	-	Habitat representative of many streams in the watershed
	502	452291	6257669	Scott Creek tributary	Watershed Characterization	-	Determining end of fish use
	507	456275	6263109	Scott Creek tributary, headwaters	Watershed Characterization	-	Major waterbody
Todd Creek	111	450882	6247507	Todd Creek mainstem	Watershed Characterization	-	Major waterbody
	207	450797	6247264	Todd Creek mainstem	Watershed Characterization	-	Habitat representative of many streams in the watershed
Todedada Creek	106	453763	6261089	Todedada tributary, headwaters	Watershed Characterization	-	Major waterbody
	107	452159	6267218	Todedada mainstem in wetland area	Watershed Characterization	-	Major waterbody
	108	452498	6262132	Todedada mainstem, upstream of wetland	Watershed Characterization	-	Major waterbody
	109	451577	6260592	Todedada mainstem, headwaters	Watershed Characterization	-	Major waterbody
	204	451575	6260610	Todedada mainstem, headwaters	Watershed Characterization	-	Major waterbody
	205	452477	6261738	Todedada mainstem, headwaters	Watershed Characterization	-	Major waterbody
	206	452234	6267150	Todedada mainstem in wetland area	Watershed Characterization	-	Habitat representative of many streams in the watershed
	503	451695	6259604	Inlet to Todedada Lake	Watershed Characterization	-	Habitat representative of many streams in the watershed
	504	451657	6260735	Todeadada tributary	Watershed Characterization	-	Habitat representative of many streams in the watershed
	505	453024	6262582	Todedada wetland tributary	Watershed Characterization	-	Habitat representative of many streams in the watershed
	506	453594	6262260	Todedada wetland tributary	Watershed Characterization	-	Habitat representative of many streams in the watershed
	Todedada Lake	451734	6259451	Lake in headwaters of Todedada Creek	Watershed Characterization	-	Major waterbody
	WL-1	453594	6262260	Large wetland on Todedada Creek	Watershed Characterization	-	Major waterbody
Unuk River	112	408363	6261530	Sulphurets Creek, upstream of barrier	Receiving Environment	Far-field	Downstream of mine site and infrastructure
	113	407571	6262191	Unuk River side channel	Watershed Characterization	-	Major waterbody
	203	408387	6261597	Sulphurets Creek, downstream of barrier	Receiving Environment	Far-field	Downstream of mine site and infrastructure
	211	406786	6260036	Unuk River, downstream of Sulphurets Creek	Receiving Environment	Far-field	Downstream of mine site and infrastructure
	212	406857	6260112	Unuk River side channel	Receiving Environment	Far-field	Downstream of mine site and infrastructure
	213	407633	6262443	Unuk River, upstream of Sulphurets Creek	Watershed Characterization	-	Major waterbody
	514	407051	6260489	Unuk River, downstream of Sulphurets Creek	Receiving Environment	Far-field	Downstream of mine site and infrastructure
	UR1	407511	6261580	Unuk River side channel	Receiving Environment	Far-field	Downstream of mine site and infrastructure
	SC1	407061	6260634	Sulphurets Creek, downstream of barrier	Receiving Environment	Far-field	Downstream of mine site and infrastructure
Wildfire Creek	508	458326	6263660	Wildfire Creek tributary, upstream of fish barrier	Watershed Characterization	-	Determining end of fish use
	509	459307	6264890	Wildfire Creek tributary, upstream of fish barrier	Watershed Characterization	-	Determining end of fish use
	510	461746	6264122	Wildfire Creek tributary, upstream of fish barrier	Watershed Characterization	-	Determining end of fish use
	511	468322	6263846	Wildfire Creek mainstem, below barrier	Watershed Characterization	-	Determining end of fish use
	513	462158	6264044	Wildfire Creek tributary, upstream of fish barrier	Watershed Characterization	-	Determining end of fish use
	WC1	468336	6264206	Wildfire Creek mainstem, below barrier	Reference Environment	-	Habitat representative of many streams in the watershed
	WC2	467306	6261771	Wildfire Creek mainstem, upstream of fish barrier	Watershed Characterization	-	Determining end of fish use
	WC3	468036	6259424	Wildfire Creek mainstem, upstream of fish barrier	Watershed Characterization	-	Determining end of fish use
	WC5	466688	6262896	Wildfire Creek mainstem, upstream of fish barrier	Watershed Characterization	-	Determining end of fish use
	Unnamed Lake 1	467825	6260560	Headwaters of Wildfire Creek tributary	Watershed Characterization	-	Major habitat type
	Unnamed Lake 2	468726	6261285	Headwaters of Wildfire Creek tributary	Watershed Characterization	-	Major habitat type
	Unnamed Lake 4	469533	6257982	Headwaters of Wildfire Creek tributary	Watershed Characterization	-	Major habitat type

Dashes indicate site is not expected to be within Receiving Environment

One wetland in the headwaters of Todedada Creek was included in the baseline surveys. WL1 was surveyed in June and August of 2010. The survey included transects of large wetland sections and point observations in smaller ponds. Open water width and depth were measured to estimate the amount of useable fish habitat. The dominant and subdominant substrate types were reported. Type and amount of riparian vegetation and instream cover were estimated. Overall habitat quality for spawning, rearing, overwintering, and migration was noted.

Fish Community

Each stream site where potential fish habitat was identified, was evaluated for fish community composition and sampled using backpack electrofishers following the methods detailed in Johnston et al. (2007). Lake fish communities were sampled using minnow traps in shallow littoral areas and gillnets in deeper areas of the lakes. The wetland was sampled following the methods used at stream sites. As there was no single defined channel, deep wetted areas throughout the wetland were sampled with the electrofisher, rather than a single continuous section.

Each captured fish was identified by species, counted, and measured for fork length and total weight. If external parasites were observed, then their presence was recorded. Incidental mortalities were dissected to determine sex and sexual maturation. Representative photographs of each species of fish were taken. Scales and/or pelvic fin rays were collected from a subset of fish for aging purposes. Genetic analysis of fish tissue samples taken during 2010 sampling was used to confirm the identification of some Dolly Varden and Bull Trout, which are very similar in appearance and may hybridize in the baseline study area (Saimoto and Saimoto 1998).

Additional Dolly Varden/Bull Trout were captured in Sulphurets Creek, Unuk River, McInnes Creek (reference), and Wildfire Creek (reference), to permit a more detailed examination of physiological parameters, including those recommended in the *Metal Mining Environmental Effects Monitoring (EEM) Technical Guidance Document* (Environment Canada 2011). These parameters included indicators of energy use and storage, external and internal health indicators (such as visible tumours and parasites), and tissue metal concentrations. Sulphurets Creek and the Unuk River are receiving environments downstream of proposed project infrastructure, and McInnes Creek and Wildfire Creek provided additional information based on proximity to previously-proposed infrastructure. Dolly Varden/Bull Trout were chosen as the sentinel species due to their presence throughout the baseline fish and fish habitat study area.

15.3.4 Characterization of Fish and Fish Habitat Baseline Condition

15.3.4.1 Overview

The baseline fish and fish habitat study area falls largely within the Unuk and Bowser River watersheds, two large-river systems with diverse fish communities (Figure 15.3-3). Dolly Varden, Bull Trout, Rainbow Trout, Mountain Whitefish, Chinook Salmon, Coho Salmon, Sockeye Salmon, Coastal Cutthroat Trout, and Longnose Sucker (*Catostomus catostomus*) were captured in the study area between 2010 and 2013. Chum Salmon and Pink Salmon are historically reported in the Unuk River, but were not captured during baseline studies. Genetic analysis confirmed that Dolly Varden and Bull Trout exist sympatrically throughout most of the study area. No Bull Trout were found in the Unuk River watershed during these baseline studies or in previous studies in the area (McPhail 2007; Rescan 2009, 2010, 2012c; unpublished data collected by Rescan in 2013). As both species are demonstratively present in the Bell-Irving River watershed, individuals that were not identifiable to the species level will be considered unknown. Dolly Varden/Bull Trout were the only species captured in all watersheds, and species richness was higher in watersheds with larger streams and lakes than in watersheds with smaller streams. Table 15.3-3 shows a summary of species present in each watershed grouping. Figure 15.3-4 shows the species captured during baseline studies at each sampling location in the fish and fish habitat study area.

Table 15.3-3. Fish Species Present in the Fish and Fish Habitat Study Area Watersheds

Species	Scientific Names	Bell-Irving River	Bowser River	Scott Creek	Todd Creek	Todedada Creek	Unuk River	Wildfire Creek	Sulphurets Creek
Dolly Varden/ Bull Trout	*Salvelinus malma/ S. confluentus*	X	X	X	X	X	X	X	X[3]
Rainbow Trout/Steelhead*	*Oncorhynchus mykiss*	X	X	-	-	X	-[2]	X	-
Coho Salmon	*Oncorhynchus kisutch*	X	X[1]	-	-	X[1]	X	-	-
Chinook Salmon	*Oncorhynchus tshawytscha*	X	-[2]	-	-	-	X	X	-
Sockeye Salmon	*Oncorhynchus nerka*	-[2]	X	-	-	X[1]	-[2]	-	-
Mountain Whitefish	*Prosopium williamsoni*	-[2]	X	-[2]	-	X	-	-[2]	-
Longnose Sucker	*Catostomus catostomus*	-	X	-	-	-	-	-	-
Chum Salmon	*Oncorhynchus keta*	-	-	-	-	-	-[2]	-	-
Pink Salmon	*Oncorhynchus gorbuscha*	-	-	-	-	-	-[2]	-	-
Coastal Cutthroat Trout	*Oncorhynchus clarkii*	-	-	-	-	-	X	-	-

[1] = species presence confirmed during spawning surveys only
[2] = not captured, presence indicated by historical data
[3] = species captured downstream of cascade
- = not captured
** Steelhead have been documented historically in the region. As juvenile Steelhead are indistinguishable from juvenile Rainbow Trout morphologically and genetically, identification is not possible.*

15.3.4.2 Unuk River Watershed

<u>Unuk River</u>

The Unuk River watershed is a large, glaciated, productive system originating in BC (Figure 15.3-3). It eventually flows through the state of Alaska into the Pacific Ocean at Burrows Bay. The drainage encompasses an area of approximately 3,885 km^2, with the lower 39 km located in Alaska. The Unuk River watershed features a variety of types of tributary streams including high-gradient, glacier-fed streams such as Sulphurets Creek and low-gradient, groundwater-fed streams such as Coulter Creek. Brucejack Lake is located within the Sulphurets Creek watershed, which is a tributary to the Unuk River. Brucejack Lake and its outflow, Brucejack Creek, are separated from Sulphurets Lake by the Sulphurets Glacier.

Within the baseline study area, the Unuk River has a maximum channel width of 176 m and a maximum wetted width of 107 m. While the Unuk River itself is large, it is braided in several areas and contains small, shallow side channels and tributaries. Water in the Unuk River watershed is turbid and cold due to glacial influences. Cover is infrequent and the majority of instream cover is created by overhanging vegetation at the river edge and instream boulders. Rearing habitat for salmonids is of fair quality and is primarily limited to river edges and secondary channels associated with gravel bars, while spawning and overwintering habitat is of good quality (Rescan 2013a, 2013b).

Figure 15.3-3

Watershed Boundaries and Fish Passage Barriers in the Baseline Fish and Fish Habitat Study Area

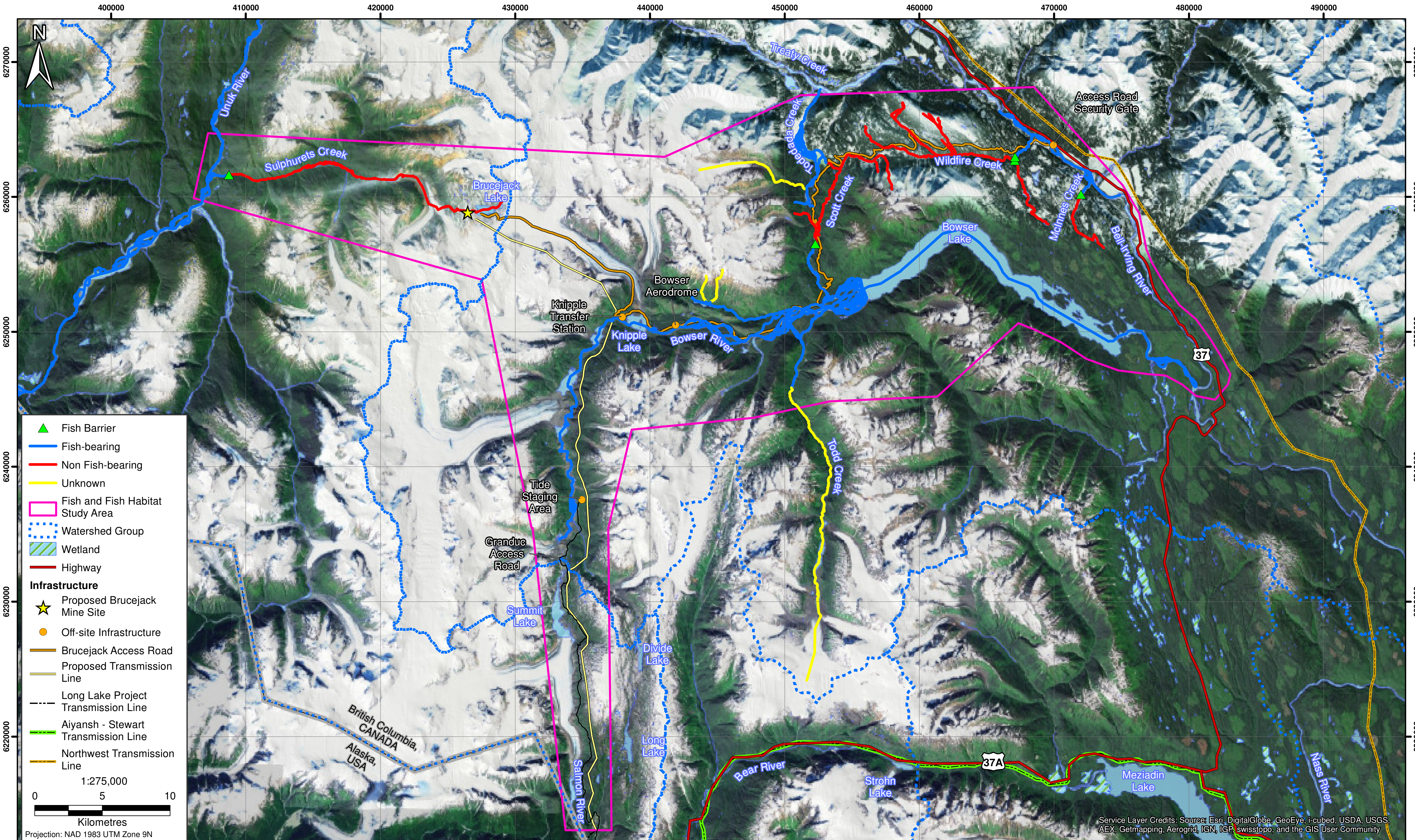
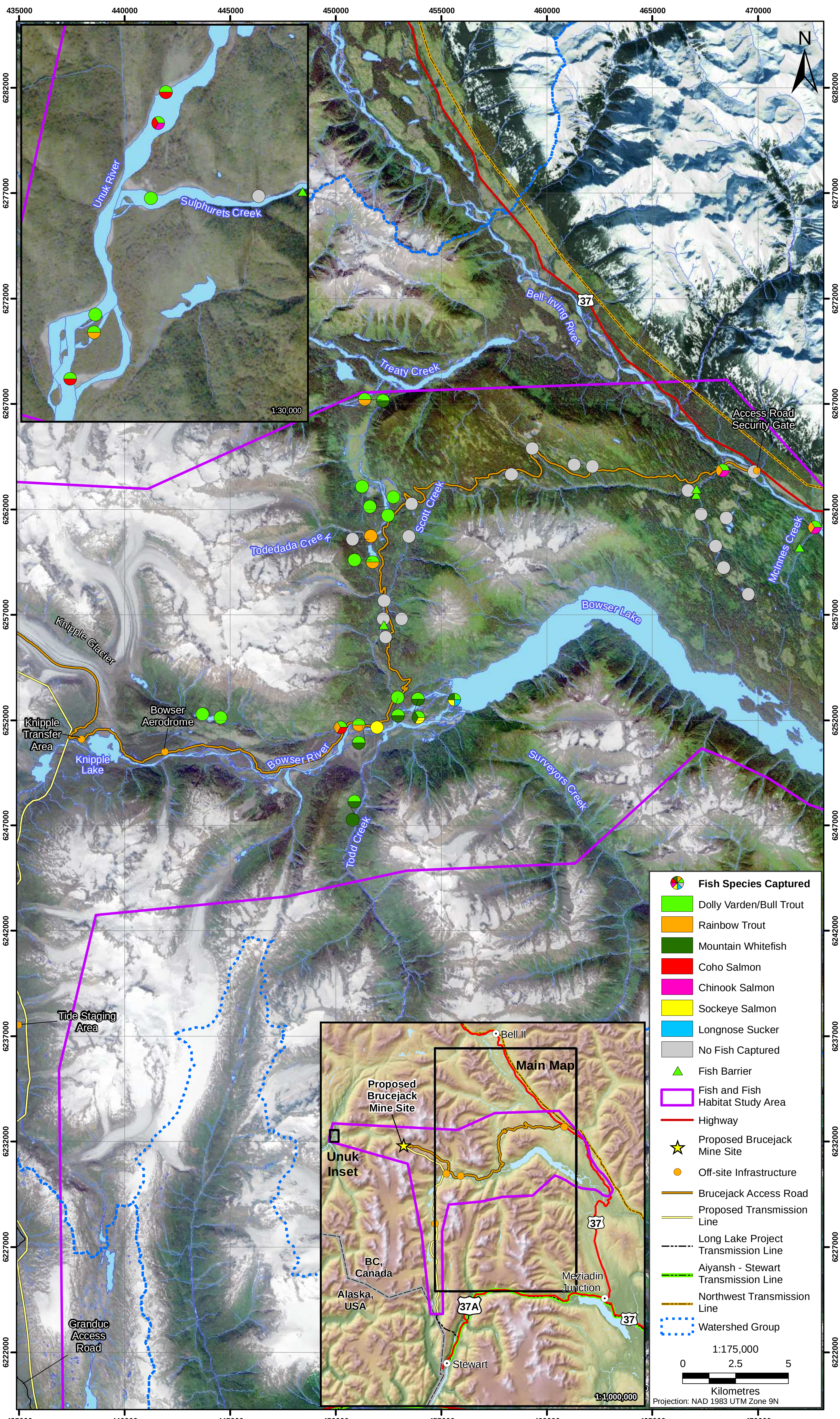


Figure 15.3-4
Fish Species Captured in the Baseline Fish and Fish Habitat Study Area



Although the Unuk River watershed within the United States has been well studied, there are limited fisheries data available for the Canadian reaches, apart from studies conducted for the Newhawk Gold Mines Sulphurets Project (Tripp 1987, 1988; Newhawk 1989) and the Seabridge Gold KSM Project (Rescan 2013b). The Unuk River system supports populations of Chinook Salmon, Sockeye Salmon, Cutthroat Trout, and Coho Salmon, a proportion of which have been traced to the upper reaches of the Unuk River watershed (Newhawk 1989; Pahlke, McPherson, and Marshall 1996; Weller, Jones, and Holm 2005). Surveys suggest that the majority of salmon spawning takes place in the lower reaches of the river in Alaska (Mecum and Kissner 1989) and in Border Lake, located off the mainstem approximately 2 km upstream of the BC-Alaska border (Anthony, Finger, and Armstrong 1965; Pahlke, McPherson, and Marshall 1996). Border Lake discharges into the Unuk River and is known to possess recruitment of Chinook, Sockeye, Pink, Coho, and Chum Salmon (Tripp 1987; DFO 1987). The canyons located upstream of Border Lake restrict the upstream migration of Pink and Chum Salmon. However, spawning and rearing of Sockeye, Chinook, and Coho Salmon are known to extend as far upstream as Storie Creek, which is approximately 15 km upstream of the confluence of Sulphurets Creek and the Unuk River (Knight Piesold Ltd. and Homestake Canada Inc. 1993; Rescan 2013b). Only Dolly Varden were captured in the Unuk River upstream of Storie Creek (Knight Piesold Ltd. and Homestake Canada Inc. 1993; Rescan 2013b). Chinook, Coho, and Sockeye Salmon, as well as Dolly Varden, have been captured in the reaches of the Unuk River included in the fish and fish habitat study area (Tripp 1987; Newhawk 1989; Rescan 2009, 2010). Coastal Cutthroat Trout were captured within the fish and fish habitat study area during baseline studies, although limited in abundance compared to the other stream-rearing species present.

Results of genetic studies conducted on char from the Unuk River indicate that all of the char in the river are likely Dolly Varden (Rescan 2013a). Dolly Varden were the most abundant species captured during baseline studies, and rear throughout the mainstem of the Unuk River (Rescan 2013a, 2013b). Resident and anadromous Dolly Varden are present within the Unuk River watershed. It is known that Dolly Varden display both anadromous and resident forms within a single watershed (Palmer and King 2005) and have shown varied use of saltwater from year to year (Dunham et al. 2008). Often, within a watershed, anadromous and resident populations exhibit differences in maximum size, with distinct trophic niches, movement patterns (Denton et al. 2009), and regimes of selection.

Dolly Varden taken from the Unuk River as part of the Metal Mining Effluent Regulations (SOR/2002-222) fell into the zero to two-year age classes, with a mean age of one year. The mean fork length ranged from 80 millimetres (mm) in 2010 to 84 mm in 2011. The mean condition (K) of these fish ranged from 1.1 in 2011 to 1.4 in 2010, suggesting high energy storage.

Tissue metals concentrations among Dolly Varden from Sulphurets Creek and Unuk River indicate that fish downstream of the Brucejack Mine Site exhibit naturally high tissue metal residues for certain metals. Concentrations of mercury in some of the analyzed fish from the Unuk River were greater than tissue residue guidelines. Concentrations of selenium in Dolly Varden tissue collected during baseline studies were above the BC MOE tissue residue guideline of 1 micrograms/gram (µg/g) wet weight (ww; equivalent to approximately 4 µg/g dry weight [dw] using a 75% moisture content; Nagpal 2001; BC MOE 2006b) in fish sampled from Sulphurets Creek (Appendix 15-B).

The diet of Dolly Varden from the Unuk River was dominated by benthic and epibenthic organisms. These included Ephemeroptera (mayflies), Trichoptera (caddisflies), and Plecoptera (stoneflies). The diet was similar to that of Dolly Varden captured in other watersheds and typical of stream salmonids.

Sulphurets Creek

Sulphurets Creek is a large creek that runs west from Sulphurets Glacier to the Unuk River, and receives water from Brucejack Lake, Brucejack Creek, and several other large tributaries of glacial origin. The first 1,300 m of Sulphurets Creek upstream from the confluence with the Unuk River is primarily a long, low-gradient riffle with trace amounts of instream cover and marginal fish habitat. Upstream of this reach, a 200-m-long series of cascades creates a barrier to fish migration. Upstream of the barrier, the cold water temperatures, high turbidity, and lack of instream cover reduce the potential for fish spawning and rearing. Over 9,700 electrofishing seconds of sampling, 45 hours of gillnetting, and 1,445 hours of minnow trapping effort have been undertaken upstream of the cascades, and no fish have been captured (Rescan 2013b). As a result, Sulphurets Creek and its tributaries are confirmed non-fish-bearing above this point.

Brucejack Lake

Brucejack Lake is located at high elevation (1,370 metres above sea level [masl]) in the headwaters of Sulphurets Creek and is non-fish-bearing. The single outlet for the lake discharges west into Brucejack Creek and passes beneath Sulphurets Glacier before entering Sulphurets Creek upstream of the fish barrier. The lake is fed entirely by runoff from the surrounding glaciers and hillslopes, which enters the lake via four permanent inlets and many small ephemeral inlets. As a result of its glacial and snow-melt origins, the lake water is cold. Brucejack Lake is deep with a maximum depth greater than 80 m. The lake is surrounded by an alpine landscape, with no large vegetation to provide woody debris and no aquatic or overhanging vegetation to provide fish cover. The shoreline is comprised of steep bedrock and boulder slopes with avalanche slope beaches that are primarily gravel and sand. Gillnetting and minnow trapping efforts in Brucejack Lake have not resulted in the capture of any fish, and the lake is confirmed as non-fish-bearing (Newhawk 1989; Price 2005).

15.3.4.3 Bowser River Watershed

Bowser River and Tributaries

The areas of the Bowser River that fall within the fish and fish habitat study area include the reaches from the headwaters of the Bowser River to Bowser Lake (Figure 15.3-3). Within the fish and fish habitat study area, the Bowser River is divided by Knipple Lake, a cold, turbid, glacial lake with low fisheries value. The reaches of the Bowser River mainstem between Bowser Lake and Knipple Lake are characterized by wide floodplains with wide, braided channels, and swift and turbulent flow (Saimoto and Saimoto 1998; Cambria Gordon 2012; FINS Consulting 2011). However, the floodplain has abundant, clear-water side channels that provide rearing habitat for juvenile salmonids (Coombes 1988). The substrate is primarily composed of fines and gravels, and shows evidence of high bedload movement. The headwater reaches of the Bowser River above Knipple Lake are more confined than the downstream reaches, follow a single channel, and have generally low fish habitat value.

Many streams in the Bowser River watershed are of glacial origin, resulting in turbid water in tributaries and the mainstem. Some of the smaller tributaries of the Bowser River are groundwater fed, and where they flow across the floodplain they contain abundant instream cover, low gradients, and abundant spawning and rearing habitat for fish. Upstream of the floodplain, fish habitat in tributaries is limited by high stream gradients in excess of 10%.

A linear survey was conducted parallel to the headwater reaches of the Bowser River, which assessed stream crossings along the proposed Brucejack Transmission Line route. Only one crossing was found to be fish-bearing: the crossing of the Bowser River. The route north of the Bowser River crossing runs over or directly adjacent to the Knipple Glacier and does not cross any streams with potential for fish habitat. The linear survey identified only small, high-gradient streams (greater than 20%) south of the Bowser River crossing. Most of the surveyed streams originate as runoff from glaciers and snowpack in the surrounding mountains, and as a result are cold and turbid. With the exception of the Bowser River crossing, all assessed crossings are high-gradient streams with measured gradients in excess of 20%.

None of the sites with gradients in the 20 to 30% range exhibit channel morphology suitable for Dolly Varden or other fish. Steep gradients, waterfalls, or cascades near the mouth of many streams prevent fish access to any upstream reaches. Most streams contain little cover and are cold and turbid due to their glacial origins. Bedrock substrate is common along the survey transect, and where gravel or cobble substrates were observed, the stream channel had carved away substrate creating deep banks.

Adult Dolly Varden have historically been caught immediately upstream of Bowser Lake (Saimoto and Saimoto 1998), and were reported by Tripp (1987) to be found throughout the Bowser River. Mountain Whitefish and Bull Trout have been found in Bowser River near the outlet of Knipple Lake (Tripp 1987; Saimoto and Saimoto 1998). Triple-pass electrofishing by Saimoto and Saimoto (1998) in the Bowser River upstream of Bowser Lake found fish densities to be low, which may indicate poor-quality fish habitat. However, groups of spawning Sockeye Salmon were observed in the delta area, approximately 1 km upstream of Bowser Lake and a single adult female salmon (species unspecified) was caught 3.2 km upstream of the lake in 1979 (Hancock and Marshall 1984; Tripp 1988). Dolly Varden have been captured in the Bowser River upstream of Knipple Lake but are expected to be present at very low densities relative to other reaches in the region (Rescan 2010). Chinook Salmon, Coho Salmon, Rainbow Trout/Steelhead, and Longnose Suckers have been observed near or below Bowser Lake in historical studies (Alexander and Koski 1995; Saimoto and Saimoto 1998).

Bowser Lake

Bowser Lake is the second largest lake in the Nass River watershed, with a length of 23 km and a surface area of 3,610 hectares (ha; Coombes 1988). The maximum depth reported in Bowser Lake is 152 m (BC MOE 2009b). It is the receiving waterbody for most of the Bowser River and for Scott Creek. The upper reaches of the Bowser River discharge into the western end of Bowser Lake at a heavily braided inlet with numerous inflows and side channels. Habitat assessments at Bowser Lake were restricted to the west end of the lake, which receives water from upstream tributaries and is closest to potential project infrastructure. While the majority of the lake is bounded by steep bedrock shorelines and occasional small gravel beaches, the western end is characterized by a large alluvial fan created by the Bowser River. The shoreline in this section consists of gradually sloping sandbars and mud flats vegetated with sparse grass and shrubs. The alluvial fan, which forms a delta, provides the only substantial littoral zone in the western half of Bowser Lake. Alluvial deposits have created a shallow (less than 2 m deep) shelf that stretches approximately 30 m out from the shoreline. Beyond this shelf, the lake depth rapidly increases. When surveyed, the water within the lake was highly turbid due to glacial silt, restricting visibility to approximately 5 cm. This observation was also common in earlier surveys of the lake (Coombes 1988; Tripp 1988).

Bowser Lake has been identified as having high fisheries value for the Gitanyow First Nation and Nisg̲a'a Nation. Dolly Varden have historically been fished among the islands in Bowser Lake and may also spawn and rear in the western end of the lake (Withler 1956; Coombes 1988). Dolly Varden and Bull Trout were also captured in the western end of the lake and in its tributaries during baseline studies.

Bowser River inlet and portions of the lake are believed to provide spawning habitat for a substantial Sockeye Salmon population (Coombes 1988; Tripp 1988). The last three years of available Sockeye Salmon escapement data for this area (1997 to 1999) indicate returns of 3,000 to 66,625 Sockeye Salmon, making it one of the four main stocks in the Nass system (BC MOE 2008). The Bowser Lake population makes up approximately 8% of the Nass River stock (English, Mochizuki, and Robichaud 2012). The 1.3 marine age class is the dominant age at return for Bowser Lake (Rutherford et al 1994). Bowser Lake Sockeye Salmon have the earliest run timing and the smallest fork length compared to other Sockeye Salmon lakes within the Nass Watershed (Rutherford et al 1994).

Bowser River juvenile Sockeye are highly surface oriented compared to other Sockeye population within the Nass Watershed due to the glacial turbidity (MacLellan and Hume 2011). In 2009, fisheries assessment surface trawls indicated higher densities of Sockeye near shore, usually where water depth was less than 20 m, with the majority of the population in the top 4 m of the water column. Juvenile Sockeye densities (near-shore and off-shore) were extrapolated for the whole lake to produce an abundance estimate of 131,000 (MacLellan and Hume 2011).

Age 2 juvenile Sockeye are most abundant in Bowser Lake (McCreight et al. 1993; Rutherford et al 1994). However, freshwater age composition in Bowser Lake varies significantly from year to year (Rutherford et al 1994). Bowser Lake juvenile Sockeye have the lowest circulus counts and growth zone widths compared to other Sockeye Salmon lakes within the Nass Watershed, due to the glacially turbidity of the lake (Rutherford et al 1994). In 2009, cladocerans were absent in Bowser Lake and the plankton community was dominated by the copepod Diacyclops (MacLellan and Hume 2011). As expected, there were no cladocerans in the diet of Bowser Lake juvenile Sockeye and copepods were the most abundant prey item (MacLellan and Hume 2011). However, terrestrial insects were also relatively abundant in the diet and provided the most biomass to juvenile Sockeye diet.

The lake inlet may be used as rearing and spawning habitat for Coho Salmon (Coombes 1988; Tripp 1988). Coho Salmon have been observed in Bowser Lake and its outlet (BC MOE 2009b). One adult Coho Salmon was observed in a groundwater tributary to Bowser Lake during spawning surveys in October 2010.

Mountain Whitefish and Longnose Sucker have also been observed in the lake (Withler 1956; Coombes 1988). Adult whitefish and suckers were captured in the western end of Bowser Lake during baseline studies, while young-of-the-year whitefish and suckers were captured in abundance in groundwater-fed channels feeding into the western end of the lake. Longnose Sucker were also captured in wetland habitats upstream of Bowser Lake during baseline studies for the KSM Project (Rescan 2013b).

Mountain Whitefish and Dolly Varden in Bowser Lake are found in lower densities and show a reduced growth rate when compared to other lakes in the Nass River watershed (Withler 1956). In general, the lake is thought to have relatively low fishing potential (Coombes 1988), although it is still important for the Nisga'a Nation. Withler (1956) speculated that the low fish density and growth rates are due to the highly turbid water of Bowser Lake and the lack of good salmonid spawning habitat in much of the lake.

Unnamed Lake 3

Unnamed Lake 3 is a small headwater lake on a tributary of the Bowser River with 20.1 ha of surface area (Figure 15.3-2). The maximum depth recorded in this lake was 16.5 m. Unnamed Lake 3 has three permanent inlets and a single outlet. Steep, rocky walls characterize the north and south shorelines, and in these sections there is no littoral zone. The shoreline at the east and west ends of the lake, near the primary inlets and outlet, is shallow and sloping and may provide good habitat for spawning and rearing fish. Shoreline vegetation is a mixture of young deciduous forest and mature coniferous forest. There is evidence of a past forest fire along the south side of the lake.

Unnamed Lake 3 is strongly coupled to the surrounding hillside. There are several active avalanche chutes on the north side of the lake and abundant large woody debris that has been swept into the lake from the surrounding forest. Beavers were active in the area during the habitat survey, as shown by several large lodges on the east end of the lake.

Dolly Varden/Bull Trout are present in Unnamed Lake 3 and were captured in abundance during baseline studies in 2010. Gillnet and minnow trap catch-per-unit-effort (CPUE) were higher in Unnamed Lake 3 than in any other lakes sampled in the fish and fish habitat study area. The mean size of Dolly

Varden/Bull Trout captured was smaller than other lakes in the baseline study area, with a mean length of 192 mm. No other fish sampling has historically been done in this lake (BC MOE 2008).

15.3.4.4 Scott Creek Watershed

Scott Creek

Scott Creek is a large creek that discharges into the Bowser River upstream of Bowser Lake (Figure 15.3-2). The headwaters of Scott Creek drain water from the mountains east and west of the main valley. Two main tributaries converge to flow south towards Bowser River. After the confluence of these branches, approximately 5 km upstream of the stream mouth, Scott Creek passes through an entrenched area that is inaccessible by helicopter or on foot. Fish are prevented from reaching the upper portion of the creek by impassable falls, cascades, and rapids located 5.2 km upstream from the stream mouth (Cambria Gordon 2012; Coombes 1988; FINS Consulting 2011; Saimoto and Saimoto 1998). However, excellent potential spawning and rearing habitat was noted upstream of this point by Saimoto and Saimoto (1998), as well as during baseline studies. A total of 2,326 seconds of electrofishing effort were expended sampling the mainstem and tributaries upstream of the barrier over two seasons, during which no fish were captured, confirming the status as non-fish-bearing.

Below the cascades, Scott Creek is of low to moderate gradient. Fish habitat in the mainstem is of fair to poor quality due to high water velocity and extensive riffle habitat, but secondary channels and side channels provide pool and glide habitat with lower water velocity and abundant fish cover. Woody debris, undercut banks, and overhanging vegetation are the dominant cover types.

Surveyed tributaries to Scott Creek were generally small, high gradient, and of marginal habitat quality due to gradient, lack of cover and lack of overwintering habitat. Some high-quality potential habitat was identified in tributaries near the Scott Creek headwaters, but these tributaries are located in non-fish-bearing sections of the watershed and do not contain fish.

Dolly Varden juveniles and adults have been found at two locations in the lower reaches of Scott Creek (Tripp 1987, 1988; Saimoto and Saimoto 1998; Rescan 2010; Cambria Gordon 2012; FINS Consulting 2011), 2.8 km upstream of its confluence with Bowser River (Tripp 1988), and 4 km upstream of the confluence (Saimoto and Saimoto 1998). Genetic analysis of fish captured during baseline studies for this project indicated that all of the fish captured in Scott Creek in 2010 were Bull Trout; however, Dolly Varden were captured in the Bowser River, with evidence of hybridization occurring between Bull Trout and Dolly Varden within Scott Creek (Saimoto and Saimoto 1998; Rescan 2009). Mountain Whitefish use the creek for both spawning and rearing, but have only been recorded at low population densities (Tripp 1988).

Spawning Sockeye Salmon were observed in groundwater-fed channels close to Scott Creek in September and October 2010. No salmon were observed in the mainstem of Scott Creek itself.

15.3.4.5 Wildfire Creek Watershed

Wildfire Creek

Wildfire Creek is a tributary to the Bell-Irving River, entering upstream of the confluence of the Bell-Irving and the Bowser rivers. Near the mouth, Wildfire Creek is of moderate gradient. The downstream reach of the stream was assessed as having fair-quality fish habitat, as the dominance of riffle habitat limited available overwintering areas and the low amount of instream cover reduced the quality for rearing. Approximately 1 km upstream, the gradient increases and the channel consists of riffle and cascade morphology. Wildfire Creek contains a number of 1-m high waterfalls in the lower 2.5 km of the creek (Cambria Gordon 2012; FINS Consulting 2011; Saimoto and Saimoto 1998). A 2-m-high waterfall and series of cascades located 2.5 km upstream of the confluence with the Bell-Irving River blocks fish passage to the upper reaches of the stream (Saimoto and Saimoto 1998). No fish have been captured above this reach, despite 3,707 electrofishing seconds and 1,154 hours of minnow trapping effort and 123 hours of gillnetting effort over the course of three years from 2010 to 2012 (Appendix 15-A).

Above the barrier, the mainstem of Wildfire Creek is of moderate gradient (maximum gradient = 8%), high velocity, and is dominated by cascade and riffle habitat. This stream reach flows through a canyon, which limits access to the channel and confines lateral movement of the channel.

The headwater reaches of Wildfire Creek are narrow (mean wetted width = 2.4 m) and of low gradient. The habitat is heterogeneous, with riffle and pool habitats observed. Moderate amounts of cover were observed, including overhanging and instream vegetation, boulders, pools, undercut banks, and small woody debris.

Tripp (1987) and Saimoto and Saimoto (1998) reported Rainbow Trout, Dolly Varden, and Mountain Whitefish in the lower reaches of Wildfire Creek. Baseline studies for this project also resulted in the capture of Chinook Salmon. Rainbow Trout and Dolly Varden were the most abundant species captured (Rescan 2013a). Two char from Wildfire Creek were genetically analyzed and determined to be Dolly Varden; however, Bull Trout may also be present based on their presence in other streams in this area (Rescan 2013a). Whereas Rainbow Trout juveniles and adults have been found throughout the lower 2.5 km of the creek, Mountain Whitefish, Chinook salmon, and Dolly Varden have only been observed in the 100 m directly upstream of the creek mouth (Cambria Gordon 2012; FINS Consulting 2011; Saimoto and Saimoto 1998).

Dolly Varden captured in Wildfire Creek for MMER (SOR/2002-222) sampling ranged in age from 0 to 3 years. The mean size of Dolly Varden captured ranged from 92 mm in 2011 to 124 mm in 2012. Mean condition ranged from 0.98 in 2012 to 1.1 in 2010, indicating that fish were generally healthy. The hepatosomatic index (HSI), an indicator of energy storage and fish health, was higher in 2012 (0.23) than 2011 (0.10). The mean age of fish captured was one year in all of the years sampled.

Tissue metal concentrations among Dolly Varden from Wildfire Creek were similar to those observed in other streams in the fish and fish habitat study area. Concentrations of mercury did not exceed the Canadian Council of Ministers of the Environment (CCME) and BC tissue residue guideline of 0.132 µg/g dw, assuming 75% tissue moisture content (Health Canada 2011).

<u>Wildfire Tributary</u>

The southern tributary of Wildfire Creek is located on a plateau. Directly upstream of the confluence with the mainstem of Wildfire Creek, the tributary resembles the mainstem with a moderate gradient and abundant cascade and riffle habitat. Cascade barriers are present in the lowest reach near Wildfire Creek, preventing fish passage into the upper reaches. The upstream reach of the stream is a deep, slow channel flowing through grass dominated riparian areas. The creek flows through or near several small ponds and wetlands. The substrate in this stream reach is entirely fine organic sediment and sand. Instream vegetation, overhanging vegetation, and woody debris are the dominant habitat types, and abundant instream cover is available. While this tributary of Wildfire Creek contains potential high-quality fish habitat, it is above the fish barrier and is non-fish-bearing.

Other tributaries in the Wildfire Creek watershed grouping are often associated with small wetlands and ponds. While instream cover is abundant, many of the tributaries are high gradient, small, and shallow, which may impact the ability of fish to migrate into the streams and to find appropriate overwintering habitat. As a result the potential fish habitat is of fair to marginal value in Wildfire Creek watershed grouping tributaries.

No fish have been captured or observed in Wildfire Tributary, despite over 2,000 seconds of electrofishing over two sampling years.

Unnamed Lake 1

Three lakes were sampled in the Wildfire Creek watershed. All three are associated with the headwaters of the southern tributary of Wildfire Creek and are located on a large plateau. All three lakes are determined to be non-fish-bearing based on their location above the Wildfire Creek fish barrier and the lack of fish captured after substantial sampling effort.

Unnamed Lake 1 is a small lake (16.6 ha) discharging north into the southern tributary of Wildfire Creek. It is located on a plateau to the west of the Bell-Irving River, on relatively flat terrain at an elevation of 675 masl. It is approximately 5 m deep, with a narrow littoral zone composed of fines and organic substrate. A small gravel and sand bar at the northwest inlet is the only area where non-organic substrates comprise a noticeable portion of the substrate. The location of the bar—directly in front of a small inlet that was stagnant even during a flood event—suggests that at one time higher flows at the inlet may have created an alluvial fan in the lake. Salmonid spawning habitat requires gravel substrate, and no habitat appropriate for spawning was observed in the lake, its inlets, or its outlets. Cover is abundant in Unnamed Lake 1 in the form of aquatic vegetation and large woody debris (LWD) along the lake edges. Large aquatic invertebrates are numerous and can be seen throughout the lake.

No fish have been captured in Unnamed Lake 1, despite two seasons of sampling with gillnets and minnow traps. Over 300 minnow trap hours and 82 gillnet hours were expended in this lake to confirm its non-fish-bearing status.

Unnamed Lake 2

Unnamed Lake 2 has a surface area of 20.8 ha and is located on the same plateau as Unnamed Lake 1 near the watershed divide between the Wildfire Creek watershed and the Bell-Irving River watershed. As with Unnamed Lake 1, the substrate of Unnamed Lake 2 is primarily organic fines. There is a shallow bar mid-lake in which the fines are mixed with small boulders. This bar marks the transition between the shallow northeast arm of the lake from the deeper south and west portions. The northeast arm of the lake is extensively populated by aquatic vegetation. The remainder of the littoral zone contains abundant LWD and aquatic vegetation. The area surrounding Unnamed Lake 2 has been extensively logged, although the logging has not extended to the water’s edge.

No fish have been captured in Unnamed Lake 2, despite two seasons of sampling with gillnets and minnow traps. Over 230 minnow trap hours and 40 gillnet hours have been expended in this lake to confirm its non-fish-bearing status over two years.

Unnamed Lake 4

Unnamed Lake 4 is located upstream of Unnamed Lake 1. It is small (less than 10 ha), shallow (approximately 4 m maximum depth), and covered with emergent vegetation. LWD is abundant through much of the lake. The substrate is dominated by fine sediments with small amounts of boulder and cobble substrate. Three small inlets are located to the south and west of the lake. The lake drains to the northwest through two outflows. The gradient of both inflows and outflows is low (less than 1%) and the fine organic substrate provides no spawning habitat for salmonids.

No fish have been captured in Unnamed Lake 4, despite two seasons of sampling with gillnets and minnow traps. Over 270 minnow trap hours and 7 gillnet hours were expended to confirm the non-fish-bearing status of this lake.

15.3.4.6 Bell-Irving Watershed

Bell-Irving River

The Bell-Irving River runs alongside the eastern extent of the baseline study area. Several watersheds within the baseline study area, including the Bowser River and Wildfire Creek watersheds, discharge into the Bell-Irving River. The Bell-Irving River is approximately 165 km in length, and is a tributary of the Nass River. Many tributaries of the Bell-Irving River are glacial or mountainous in origin. During periods of high glacial runoff, including spring and summer, the water in the Bell-Irving River may be highly turbid.

Within the baseline study area, the Bell-Irving River is large and highly active, with regularly shifting sandbars and water clarity ranging from lightly turbid to highly turbid. Numerous tributaries discharge into the Bell-Irving River. Tributaries entering from the east are relatively low gradient and support fish populations. Tributaries entering the Bell-Irving River from the west are higher gradient and may contain barriers preventing fish migration. Tributaries assessed as part of the baseline program include the Bowser River, McInnes Creek, and Wildfire Creek.

The sampled reaches of the Bell-Irving River are moderate in size and braided, exhibiting large-channel morphology. There are trace amounts of cover present, with the majority provided by the boulder-dominated substrate. The Bell-Irving River was the only reach surveyed in the study area where bedrock was a dominant or subdominant substrate type. The deep channel has the potential to provide overwintering, rearing, and spawning habitat, while low-velocity water at the edges of the channel supports rearing juvenile fish.

The Bell-Irving River and its tributaries support Chinook salmon, Coho Salmon, Sockeye Salmon, Rainbow Trout/Steelhead, Dolly Varden, Bull Trout, and Mountain Whitefish (BC MOE 2008). Dolly Varden, Bull Trout, Rainbow Trout, Coho Salmon, and Chinook Salmon were captured during baseline studies. The mainstem of the Bell-Irving River provides spawning habitat for large populations of Chinook and Coho Salmon, but the high flows and turbid water can cause poor rearing conditions, so juvenile fish may move into the lower portions of Bell-Irving tributaries (Cambria Gordon 2012; FINS Consulting 2011; Saimoto and Saimoto 1998). CPUE was generally high in the Bell-Irving River during baseline studies, and Rainbow Trout was the dominant species captured.

The Bell-Irving River is a traditional fishing site for the Skii km Lax Ha and Gitanyow First Nation. The Skii km Lax Ha have traditional Steelhead and salmon fishing sites along the west side of the Bell-Irving River between Treaty and Wildfire creeks. The Gitanyow First Nation has also fished the Bell-Irving River, particularly south of the Bowser River.

McInnes Creek

McInnes Creek is small and high gradient, but numerous small and medium-sized pools throughout the stream present good rearing and overwintering habitat for salmonids, and gravel-dominated glides provide good spawning habitat. A large beaver pond adjacent to the stream may provide additional habitat. Unlike many streams in the baseline study area, the water in McInnes Creek is clear, which is beneficial for fish species that locate prey visually. A waterfall approximately 1 km upstream from the stream mouth prevents fish passage to the headwaters of the stream, although no sampling has been conducted above the barrier to determine its fish-bearing status.

Dolly Varden/Bull Trout and Rainbow Trout were captured in the lowest reach of McInnes Creek. All of the Dolly Varden/Bull Trout captured in 2011 were young-of-the-year, with fork lengths ranging from 40 to 96 mm.

Most of the Dolly Varden captured from McInnes Creek for MMER (SOR/2002-222) purposes were young-of-the-year or age one, with mean fork lengths ranging from 40 mm in 2011 to 87 mm in 2012 (Rescan 2013a). The mean condition of fish captured ranged from 0.97 in 2012 to 1.09 in 2011. Liver weight and HSI were lower among fish from McInnes Creek than in fish from other streams, possibly indicating lower energy storage. No mature fish were captured to develop estimates of fecundity or gonad size.

Tissue metal concentrations among Dolly Varden from McInnes Creek were similar to those observed in other streams in the fish and fish habitat study area. Concentrations of mercury did not exceed the Health Canada (2011) guideline.

15.3.4.7 Todd Creek Watershed

<u>Todd Creek</u>

Todd Creek is a moderately large, deep stream that flows north from its headwaters in the mountains to the Bowser River directly upstream of Bowser Lake. Todd Creek and its tributaries are primarily steep and glacial in origin. As a result, water clarity in the watershed is generally low. Cover is infrequent in the mainstem, and the majority of habitat units identified are riffles with little potential for overwintering fish habitat. There are no significant lakes or wetlands in the watershed.

Bull Trout were the only species captured in Todd Creek during baseline studies, and CPUE was low in comparison to other watersheds in the fish and fish habitat study area; however, fish size was generally higher than other watersheds. This may indicate that Todd Creek provides rearing habitat for sub-adult to adult Bull Trout.

No historical sampling of Todd Creek was conducted prior to baseline studies.

15.3.4.8 Todedada Creek Watershed

<u>Todedada Creek</u>

Todedada Creek is a tributary to Treaty Creek and is outside the Bowser River system. Todedada Creek has its headwaters close to Scott Creek, separated by a narrow watershed divide. Near the mouth of Todedada Creek, the mainstem flows through a large wetland. The creek mainstem forms a distinct, flowing channel through the wetland with a mean wetted width of 12.1 m. The surrounding area is flooded, filled with small permanent and temporary wetted channels, and influenced by substantial overland water flow. Additional water is contributed by groundwater seepage and a tributary that discharges into the wetland from the east. The wetland consists of multiple channels and deep pools of open water. The substrate in the mainstem of this reach is primarily fines and gravel with trace amounts of larger substrates. Deep pools, overhead vegetation, instream vegetation, and LWD all provide abundant cover and habitat for fish. Good quality fish habitat is available for rearing, spawning, and overwintering purposes and riffle, glide, and pool habitat types were identified.

Upstream of the wetland, the mainstem of Todedada Creek has a mean wetted width of 20.5 m, and the banks show evidence of erosion. Most surveyed habitat units were riffles, although pool and cascade habitats were also observed near the outflow of Todedada Lake.

Tributaries to Todedada Creek vary in the quality of fish habitat provided. Where streams run through the wetland or other low-elevation areas, fish habitat is of good quality, with abundant rearing habitat and areas of spawning and overwintering habitats. The headwaters of tributaries and those near Todedada Lake provide lower-quality habitat, usually due to high-gradient stream channels.

Todedada Creek provides important spawning habitat for Coho Salmon and Sockeye Salmon, with the confluence of the two main branches being used extensively during the spawning periods in September and October (Cambria Gordon 2012; FINS Consulting 2011; Tripp 1988; Rescan 2011b). Adult salmon have been observed in a number of other areas of the creek, and much of the system appears suitable for spawning. Rainbow Trout, Dolly Varden, Bull Trout, and Mountain Whitefish have also been found in Todedada Creek and may use it for spawning (Tripp 1987; Saimoto and Saimoto 1998).

Todedada Lake

Todedada Lake is a headwater lake located in the Todedada Creek watershed at an elevation of 681 masl. It is a small (23.5 ha surface area), clear lake with a maximum depth of approximately 17 m. Most of the inlets are steep and therefore unlikely to provide habitat for fish. The primary inlet, located on an avalanche chute on the west side of the lake, is an exception and may be used by fish as spawning habitat. Most spawning activity likely takes place in the lake outlet.

The littoral zone in Todedada Lake is narrow, in many places extending less than 5 m from the shore. LWD and submerged vegetation are abundant in the littoral zone, providing extensive cover for fish.

Dolly Varden and Rainbow Trout were captured in Todedada Lake in 2010, with Dolly Varden being the dominant species. Most of the Dolly Varden and Rainbow Trout captured were adults of between 300 and 420 mm in length, and several of the Dolly Varden were approaching spawning condition.

15.3.4.9 Salmon River Watershed

The Salmon River watershed was not included in the baseline fish and fish habitat study area; however, the fish and fish habitat study area for the Application for an Environmental Assessment Certificate/ Environmental Impact Study (Application/EIS) was expanded to include this area due to the proposed routing of the transmission line. Given no fish and fish habitat baseline studies were conducted in this watershed, information was gathered from Canadian and American government reports and journal articles.

Summit Lake

Summit Lake is an ice-dammed lake on the southern end by the Salmon Glacier. Prior to 1961, the lake drained northward over a bedrock sill into the Bowser River (Jones et al. 1985). In December 1961, probably after a long period of thinning and retreat of Salmon Glacier, a subglacial tunnel developed in the ice dam and the lake drained into the Salmon River quickly (Mathews and Clague 1993). The sudden drainage of the ice-dammed lake, referred to as *jokulhlaup*, occurred frequently after this event. In the early years (1960s), the lake emptied roughly every other year during the fall or early winter (October through December). But recently, the releases have been occurring almost annually and considerably earlier in the year (late July through August). The water draining from Summit Lake during a jokulhlaup flows 3 km from the terminus of Salmon Glacier in a confined valley and 5 km in a canyon before emerging into the lower Salmon River. Here it flows over a braided stream that passes through Hyder, Alaska, and drains into Portland Canal. It has been noticed that the flood magnitude and damages have generally decreased since the 1960s (Devaris 2013). The annual jokulhlaup cycle is likely to continue until the glacier retreats to the point that it no longer forms an effective seal (Mathews and Clague 1993).

Salmon River

No comprehensive species lists are available for the Salmon River, but Coho Salmon and Chum Salmon are reported in the mainstem and tributaries (Novak 1983). In particular, a tributary known as Fish Creek, located 17 km downstream of the Salmon Glacier, has been identified as important spawning and rearing habitat for Chum Salmon, and is reputed to produce some of the largest Chum Salmon in North America. The fish-bearing status of the reaches of the Salmon River upstream of the Canada-US border is not known at this time.

15.4 ESTABLISHING THE SCOPE OF THE ASSESSMENT FOR FISH AND FISH HABITAT

This section of the assessment of fish and fish habitat includes a description of the scoping process used to identify potentially affected valued components (VCs), select assessment boundaries, and identify the potential effects of the Project that are likely to arise from the Project's interaction with an intermediate component or receptor VC. Scoping is fundamental to focusing the Application/EIS on those issues where there is the greatest potential to cause significant adverse effects. The scoping process for the assessment of fish and fish habitat consisted of the following four steps:

- *Step 1:* undertaking an issues scoping process to select components, sub-components, and indicators based on a consideration of the Project's potential to interact with fish and fish habitat;
- *Step 2:* consideration of feedback on the results of the scoping process from technical experts and the EA Working Group[1];
- *Step 3:* definition of assessment boundaries for fish and fish habitat and/or sub-components; and
- *Step 4:* identification of key potential effects on fish and fish habitat and/or sub-components.

These steps are described in detail below.

15.4.1 Selecting Receptor Valued Components

Receptor VCs are used to focus the Application/EIS on the issues of highest concern. Receptor VCs are specific attributes of the biophysical and socio-economic environments that have environmental, social, economic, heritage, or health significance. Receptor VCs also have the potential to be indirectly affected by changes in the baseline condition of other environmental components thereby acting as receptors of that change. Indirect effects may, in turn, also affect the baseline condition of the receptor VC. To be considered for assessment, a component must be of recognized importance to society, the local community, or the environmental system, and there must be a perceived likelihood that the receptor VC will be affected by the proposed Project. Receptor VCs are scoped during consultation with key stakeholders, including Aboriginal communities and the EA Working Group. Consideration of certain receptor VCs may also be a legislated requirement, or known to be a concern because of previous project experience.

As described in Section 6.4.1.1, a scoping exercise was conducted during the development of a draft Application Information Requirements (AIR) to explore potential Project interactions with candidate receptor VCs, and to identify the key potential adverse effects associated with that interaction.

[1] The EA Working Group is a forum for discussion and resolution of technical issues associated with the proposed Project, as well as providing technical advice to the British Columbia Environmental Assessment Office (BC EAO) and Canadian Environmental Assessment Agency (CEA Agency), which remain ultimately responsible for determining significance. It comprises representatives of provincial, federal, and local government, and Aboriginal groups.

The results of the scoping exercise were circulated for review and approval by the EA Working Group, and feedback from that process was integrated into the Application/EIS.

Subject areas are classified as either an intermediate component or receptor VC and are further refined into sub-components and indicators as described in Section 6.4.1.3. Before selecting the VC sub-components, two procedures were performed. First, baseline information was acquired by sampling fish and fish habitat from waterbodies within the baseline study area, including a background literature review. Then, issue scoping was undertaken through consultation. This process considered input from the Aboriginal groups, local interest groups, regional and local government agencies, technical expertise, and/or the general public. For the sake of simplicity, fish and fish habitat receptor VC subcomponents will be hereafter referred to as fish and fish habitat VCs.

Together, this approach reflects a balanced and informative synthesis of a wide range of information. Conservation status was determined by consulting the following sources to identify species at risk and those of conservation concern:

- Canada's *Species at Risk Act* (2002a);
- COSEWIC;
- DFO;
- BC MOE;
- BC Conservation Data Centre; and
- BC Blue List and Red List.

Fish and fish habitat was identified as a VC as a result of the scoping process, and refined as follows:

- fish habitat - habitat loss and alteration; and
- fish (Dolly Varden, Bull Trout, Coho Salmon, Sockeye Salmon, Chinook Salmon) - direct mortality, sensory disturbance, water quality degradation (metals, contaminants, total suspended solids [TSS]).

In addition to predictive study results from the surface water quantity intermediate component, water quality and aquatic resources data will be used to support the effects assessment for fish and fish habitat.

15.4.1.1 Potential Interactions between the Project and Fish and Fish Habitat

Table 15.4-1 provides an impact scoping matrix of fish and fish habitat VCs that have a possible or likely interaction with Project components and activities. A full impact scoping matrix for all intermediate and receptor VCs is provided in Chapter 6 (Table 6.4-1).

Interactions between the Project and fish and fish habitat were assigned a colour code as follows:

- not expected (white);
- possible (grey); and
- likely (black).

Interactions coded as not expected (white) are considered to have no potential for adverse effects on a receptor VC and are not considered further.

Table 15.4-1. Interaction of Project Components and Physical Activities with Fish and Fish Habitat

Project Components and Physical Activities by Phase	Fish	Fish Habitat
Construction Phase		
Activities at existing adit		
Air transport of personnel and goods		
Avalanche control		
Chemical and hazardous material storage, management, and handling		
Construction of back-up diesel power plant		
Construction of Bowser Aerodrome		
Construction of detonator storage area		
Construction of electrical tie-in to BC Hydro grid		
Construction of electrical substation at Brucejack Mine Site		
Construction of equipment laydown areas		
Construction of helicopter pad		
Construction of incinerators		
Construction of Knipple Transfer Area		
Construction of local site roads		
Construction of mill building (electrical induction furnace, backfill paste plant, warehouse, mill/ concentrator)		
Construction of mine portal and ventilation shafts		
Construction of Brucejack Operations Camp		
Construction of ore conveyer		
Construction of tailings pipeline		
Construction and decommissioning of Tide Staging Area construction camp		
Construction of truck shop		
Construction and use of sewage treatment plant and discharge		
Construction and use of surface water diversions		
Construction of water treatment plant		
Development of underground portal and facilities		
Employment and labour		
Equipment maintenance/machinery and vehicle refuelling/fuel storage and handling		
Explosives storage and handling		
Grading of the mine site area		
Helicopter use		
Installation and use of Project lighting		
Installation of surface and underground crushers		
Installation of transmission line and associated towers		
Machinery and vehicle emissions		
Potable water treatment and use		
Pre-production ore stockpile construction		

(continued)

Table 15.4-1. Interaction of Project Components and Physical Activities with Fish and Fish Habitat (continued)

Project Components and Physical Activities by Phase	Fish	Fish Habitat
Construction Phase *(cont'd)*		
Procurement of goods and services		
Quarry construction		
Solid waste management		
Transportation of workers and materials		
Underground water management		
Upgrade and use of exploration access road		
Use of Granduc Access Road		
Operation Phase		
Air transport of personnel and goods and use of aerodrome		
Avalanche control		
Backfill paste plant		
Back-up diesel power plant		
Bowser Aerodrome		
Brucejack Access Road use and maintenance		
Brucejack Operations Camp		
Chemical and hazardous material storage, management, and handling		
Concentrate storage and handling		
Contact water management		
Detonator storage		
Discharge from Brucejack Lake		
Electrical induction furnace		
Electrical substation		
Employment and labour		
Equipment laydown areas		
Equipment maintenance/machine and vehicle refuelling/fuel storage and handling		
Explosives storage and handling		
Helicopter pad(s)		
Helicopter use		
Knipple Transfer Area		
Machine and vehicle emissions		
Mill building/concentrations		
Non-contact water management		
Ore conveyer		
Potable water treatment and use		
Pre-production ore storage		
Procurement of goods and services		
Project lighting		

(continued)

Table 15.4-1. Interaction of Project Components and Physical Activities with Fish and Fish Habitat (continued)

Project Components and Physical Activities by Phase	Fish	Fish Habitat
Operation Phase *(cont'd)*		
Quarry operation		
Sewage treatment and discharge		
Solid waste management/incinerators		
Subaqueous tailings disposal		
Subaqueous waste rock disposal		
Surface crushers		
Tailings pipeline		
Truck shop		
Transmission line operation and maintenance		
Underground backfill tailing storage		
Underground backfill waste rock storage		
Underground crushers		
Underground: drilling, blasting, excavation		
Underground explosives storage		
Underground mine ventilation		
Underground water management		
Use of mine site haul roads		
Use of portals		
Ventilation shafts		
Warehouse		
Waste rock transfer pad		
Water treatment plant		
Closure Phase		
Air transport of personnel and goods		
Avalanche control		
Chemical and hazardous material storage, management, and handling		
Closure of mine portals		
Closure of quarry		
Closure of subaqueous tailing and waste rock storage (Brucejack Lake)		
Decommissioning of Bowser Aerodrome		
Decommissioning of back-up diesel power plant		
Decommissioning of Brucejack Access Road		
Decommissioning of camps		
Decommissioning of diversion channels		
Decommissioning of equipment laydown		
Decommissioning of fuel storage tanks		
Decommissioning of helicopter pad(s)		

(continued)

Table 15.4-1. Interaction of Project Components and Physical Activities with Fish and Fish Habitat (completed)

Project Components and Physical Activities by Phase	Fish	Fish Habitat
Closure Phase *(cont'd)*		
Decommissioning of incinerators		
Decommissioning of local site roads		
Decommissioning of Mill Building		
Decommissioning of ore conveyer		
Decommissioning of Project lighting		
Decommissioning of sewage treatment plant and discharge		
Decommissioning of surface crushers		
Decommissioning of surface explosives storage		
Decommissioning of tailings pipeline		
Decommissioning of transmission line and ancillary structures		
Decommissioning of underground crushers		
Decommissioning of waste rock transfer pad		
Decommissioning of water treatment plant		
Employment and labour		
Helicopter use		
Machine and vehicle emissions		
Procurement of goods and services		
Removal or treatment of contaminated soils		
Solid waste management		
Transportation of workers and materials (mine site and access roads)		
Post-closure Phase		
Discharge from Brucejack Lake		
Employment and Labour		
Environmental monitoring		
Procurement of goods and services		
Subaqueous tailing and waste rock storage		
Underground mine		

Notes:
Black = likely interaction between project components/physical activities and a valued environmental or socio-economic component
Grey = possible interaction between project components/physical activities and a valued environmental or socio-economic component
White = interaction not expected between project components/physical activities and a valued environmental or socio-economic component

15.4.1.2 Consultation Feedback on Receptor Valued Components

VC scoping feedback was received for the selected VCs from Aboriginal groups, EA Working Group comments during the AIR and EIS guidelines review phase, and comments received during public comment periods. The comments received supported the selected sub-components. No other VCs were suggested by Aboriginal Groups, public agencies, or the public.

15.4.1.3 Summary of Receptor Valued Components Included/Excluded in the Application for an Environmental Assessment Certificate/ Environmental Impact Statement

The federal *Fisheries Act* (1985a) protects fish of commercial, recreational, and Aboriginal importance. In addition, several species of fish in the baseline fish and fish habitat study area are migratory and pass through Canadian and Alaskan waters as they travel between freshwater and marine environments. The identified fish and fish habitat VCs included in the Application/EIS process are:

- Fish, which includes:
  - Dolly Varden (*Salvelinus malma*);
  - Bull Trout (*S. confluentus*); and
  - Pacific salmon, including Coho Salmon (*Oncorhynchus kisutch*), Chinook Salmon (*O. tshawytscha*), and Sockeye Salmon (*O. nerka*).
- Fish habitat.

The identified fish species were grouped together because of similar species habitat requirements and distribution within the baseline fish and fish habitat study area. All proposed fish and fish habitat VCs identified in the AIR were included in the Application/EIS process and the rationale for their inclusion in the Application/EIS process is identified in Table 15.4-2 and described further as follows:

- Dolly Varden: Dolly Varden is a yellow-listed species (species of concern) in BC. Dolly Varden has the widest distribution and abundance compared to all other species within the baseline fish and fish habitat study area, based on baseline and historical data, but are not present at the Brucejack Mine Site. Stream-resident, migratory (sea-run), and lake-resident life history forms are present within the baseline fish and fish habitat study area. Resident and anadromous Dolly Varden are present within the Unuk River watershed. It is known that Dolly Varden display both anadromous and resident forms within a single watershed (Palmer and King 2005), and have shown varied use of saltwater from year to year (Dunham et al. 2008). Often, within a watershed, anadromous and resident populations exhibit differences in maximum size, with distinct trophic niches, movement patterns (Denton et al. 2009), and regimes of selection. This fish species has been selected as a VC, because they are an important part of stream ecosystems, particularly higher-gradient streams. This species responds to changes in the aquatic environment with respect to their ecological and physiological requirements for long-term sustainability. Dolly Varden was selected as the keystone species for monitoring fish and aquatic environment health for numerous ecological reasons. Resident Dolly Varden is a fish species with limited movement and dispersal (Bryant and Lukey 2004; Ihlenfeldt 2005). The species possesses short- to medium-term longevity (8 to 9 years), prey preference is benthic invertebrates, age and length to maturation is short (3 to 5 years; 130 to 162 mm), and spawning is site-specific (Environment Canada 2012; Ihlenfeldt 2005; McPhail 2007).
- Bull Trout: Bull Trout is a blue-listed species (species of concern) in BC. Bull Trout distribution is less widespread within the baseline study area than is Dolly Varden distribution, based on baseline and historical data. Stream-resident, fluvial, and adfluvial life history forms are present within the baseline fish and fish habitat study area, but are not present at the Brucejack Mine Site. Bull Trout are known to hybridize with Dolly Varden where these species occur in sympatry, as in the Bell-Irving and Bowser watersheds within the baseline fish and fish habitat study area. Ecological and niche selection are important to maintain Bull Trout populations that coexist with Dolly Varden. These fish are sought and consumed by sport anglers. They have been identified as culturally significant for the Nisg̱a'a Nation. The Tahltan Nation has also identified Bull Trout and their habitat as culturally significant (THREAT 2009).

- Anadromous (Migratory) Pacific Salmon, including Coho, Chinook, and Sockeye: These species use certain watersheds within the baseline fish and fish habitat study area as spawning, rearing, and overwintering habitat. Coho Salmon spawn in the Todedada Creek mainstem and tributaries (Rescan 2013a) and Bowser River tributaries. Sockeye Salmon spawn in the Bowser River mainstem upstream of Bowser Lake and Todedada Creek tributaries (Hancock and Marshall 1984; Tripp 1988; Rescan 2013a). Pacific salmon are culturally and economically important to the Nisga'a Nation. Through the Nisga'a Final Agreement (NLG, Government of Canada, Province of BC 1999), Nisga'a Nation has the right to harvest an allocation of salmon. Pacific salmon are also central to the culture and economies of the Skii km Lax Ha and the Tahltan Nation. These species are also valuable for both commercial and recreational fisheries.
- Fish Habitat: Fish habitat is defined as those parts of the environment on which fish depend, directly or indirectly, to carry out their life processes (DFO 1986). Thus, fish habitat is also important to the future economic, social, and cultural wellbeing of Nisga'a Nation and Nisga'a citizens. Nisga'a Lisims Government has indicated that salmon returning to the Bell-Irving River tributaries are important to Nisga'a Nation. Salmon habitat in Bowser River and Todedada Creek is also important to Nisga'a Nation, since Nisga'a harvest salmon in the lower reaches of the Nass River, and some of these salmon spawn or rear in these watercourses. Due to the cultural and economic importance of fish, fish habitat is also important to the Tahltan Nation and the Skii km Lax Ha. As identified by the Skii km Lax Ha, the Bowser River watersheds are culturally and ecologically important for subsistence fishing. Fish habitat includes riparian habitat and physical instream features (e.g., LWD, boulders, and pools) that support spawning, rearing, overwintering, and migration life history stages. Potential effects to instream habitat and riparian habitat are addressed through this assessment.

Table 15.4-2. Fish and Fish Habitat Receptor Valued Components Included in the Application for an Environmental Assessment Certificate/ Environmental Impact Statement

	Identified by*				
Sub-components	**AG**	**G**	**P/S**	**IM**	**Rationale for Inclusion**
Fish – Dolly Varden	x	x	-	x	Yellow-listed fish species. Indicator stream ecosystem species.
Fish – Bull Trout	x	x	-	x	Blue-listed fish species. Indicator stream ecosystem species.
Fish – Pacific Salmon	x	x	-	x	Culturally/commercially valuable species. Indicator species, important for sport fishing.
Fish Habitat	x	x	-	x	Potential degradation or loss of habitat.

**AG = Aboriginal Group; G = Government; P/S = Public/Stakeholder; IM = Impact Matrix*

No additional receptor VCs were proposed by Aboriginal groups, government, and public/stakeholders. Therefore, no receptor VCs were excluded from the effects assessment.

15.4.2 Assessment Boundaries for Fish and Fish Habitat

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 receptor VCs, as well as the constraints that may be placed on the assessment of those interactions due to political, social, and economic realities (administrative boundaries), and limitations in predicting or measuring changes (technical boundaries). The definition of these assessment boundaries is an integral part of the assessment process of fish and fish habitat, and encompasses possible direct, indirect, and induced effects of the Project on fish and fish habitat, inclusive of Project effects on relevant intermediate components, as well as the trends in processes that may be relevant.

15.4.2.1 Spatial Boundaries

Local Study Area

A Local Study Area (LSA) typically encompasses watersheds in the immediate area of the Project with a potential for direct effects. For the Project, a LSA effects assessment boundary was defined according to watershed boundaries within the Project as shown in Figure 15.4-1. The LSA is not the same as the baseline study area; however the LSA is within the baseline study area boundaries. The LSA includes streams, wetlands, and lakes that are located within and downstream of the proposed ancillary components such as access roads, aerodrome, transmission line, construction camps, and transfer station. There are no fish or fish habitat present near the Brucejack Mine Site based upon baseline and historical data (Rescan 2013a).

Regional Study Area

The Regional Study Area (RSA) includes the portion of the watersheds downstream of the Project with a potential for direct effects, as well as watersheds upstream of those with a potential for direct effects. The RSA is not the same as the baseline study area; however the RSA is within the baseline study area boundaries. The RSA includes watersheds along the Brucejack Access Road and Brucejack Transmission Line. Bowser Lake was included within the RSA because Bowser River discharges into the lake, Bowser Lake was assessed in the baseline study area, Aboriginal Groups harvest fish from the lake, and the lake provides rearing habitat for Sockeye Salmon. However, there are no predicted direct effects within Bowser Lake due to the Project. Fish and fish habitat are present in the RSA, as shown in Figure 15.4-1. One factor that determined the placement of the RSA boundary was the water quality effects potential extent of change due to Project discharge. Along the Unuk River, the RSA for the Project extends downstream to the BC-Alaska Border.

Potential effects and habitat losses are considered with respect to fish and fish habitat existing in the RSA. Potential effects are assessed at the scale of the entire length of a stream, or an entire lake, as appropriate for that local biological community, and to the extent that these potential effects could affect an entire community rather than individuals. Applicable potential effects on a sub-local scale are noted and considered in this assessment and in the cumulative environmental effects assessment.

15.4.2.2 Temporal Boundaries

For the purposes of the effects assessment, the temporal boundaries include the following four phases:

- Construction: 2 years;
- Operation: 22 years;
- Closure: 2 years (includes project decommissioning, abandonment and reclamation activities); and
- Post-closure: minimum of 3 years (includes ongoing reclamation activities and post-closure monitoring).

15.4.3 Identifying Potential Effects on Fish and Fish Habitat

15.4.3.1 Overview

The effects assessment explicitly addresses potential fish and fish habitat issues and concerns associated with Construction, Operation, Closure, and Post-closure of the Project. The assessment takes a VC approach, focusing on selected fish species, groups of fish species, and fish habitat. VCs include species that have conservation status; biological importance; or are regional species that have particular cultural, social, or economic significance to Aboriginal groups, the province of BC, or other Canadians.

Project fish and fish habitat issues identified in the AIR include:

- direct habitat effects due to construction of the mine and associated infrastructure;
- direct and indirect effects on fish health due to changes in water quality, noise and vibration, and loss of productive capacity;
- changes in water quantity and quality in habitats downstream of potential discharges; and
- changes in fish harvesting patterns due to changes in access and human presence.

The Application/EIS describes the methods and standards used to determine the effects of the Project on fish and fish habitat and will consider:

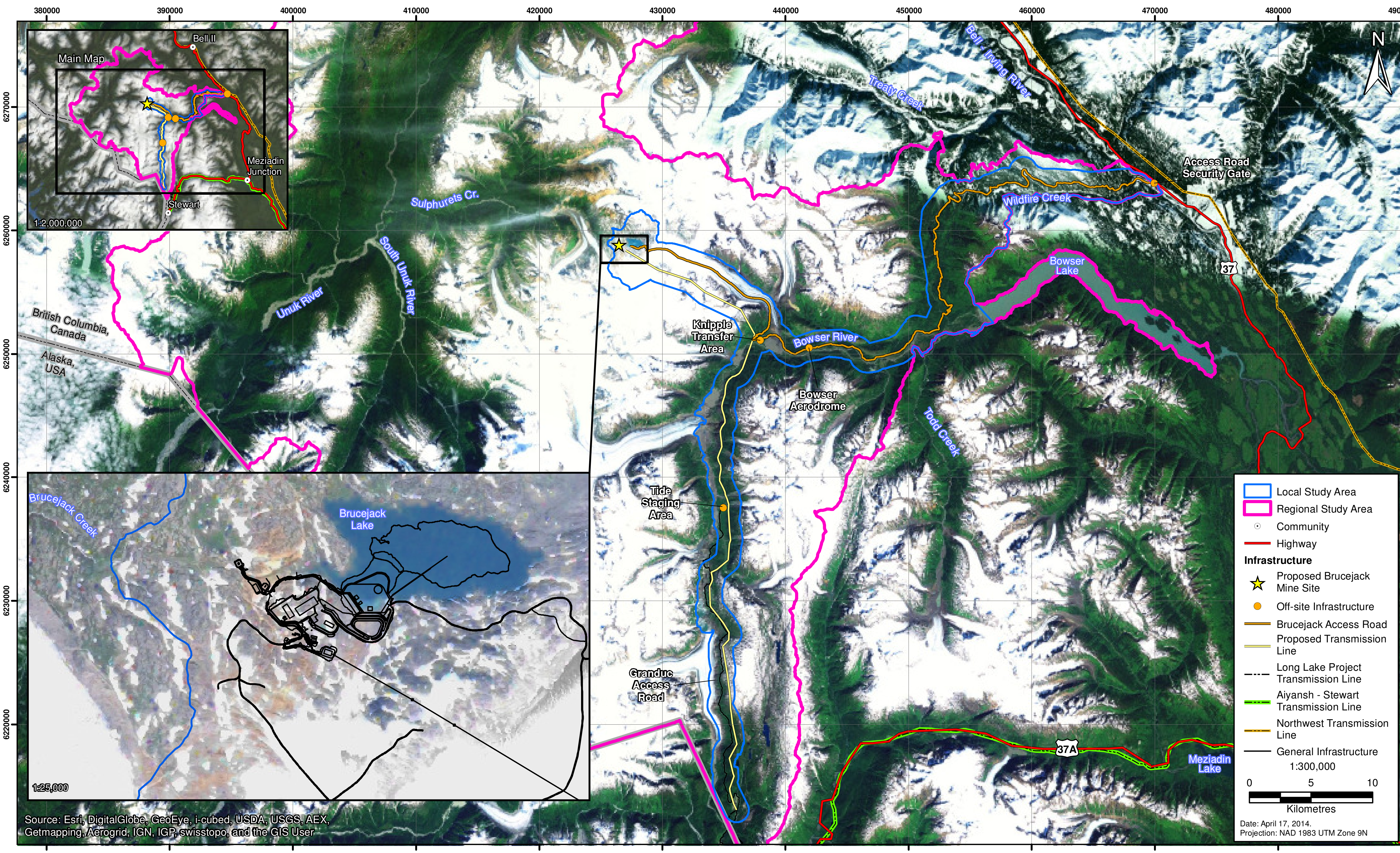
- productive capacity of fish habitat (i.e., link to aquatic resources);
- seasonality of fish utilization and fish-bearing status of potentially affected waterbodies;
- habitat loss or alteration (project footprint, water quantity), including aquatic vegetation; riparian vegetation; and sensitive areas such as spawning grounds, nursery areas, overwintering habitat, and migration corridors;
- natural barriers to fish migration;
- changes in quantity and quality of groundwater entering surface waterbodies;
- rare and/or sensitive species and habitat (as listed by COSEWIC or SARA [2002a]);
- species of cultural, spiritual, or traditional use important to Aboriginal groups;
- traditional ecological knowledge, when and where available;
- changes to fish harvesting; and
- direct (chronic and acute toxicity) and indirect (change in fish growth, fecundity, and bioenergetics from alterations in primary and secondary productivity) effects to fish due to changes in water chemistry (e.g., suspended solids, nutrients, major ions, and metals) from Project-related discharges that may affect surface water quality.

Many of the issues listed above overlap in terms of definition and scope. For the purposes of the fish and fish habitat section, they are grouped into four categories for scoping of effects:

- direct mortality;
- erosion and sedimentation;
- change in water quality (e.g., petroleum product spills, sewage effluent, metals, and other chemical toxicity); and
- habitat loss (i.e., removal or physical alteration).

Figure 15.4-1
Fish and Fish Habitat Local and Regional Study Areas

ERM



Habitat loss refers to the removal or physical alteration of the environment that is used either directly or indirectly by fish. Riparian vegetation is included as fish habitat because it provides numerous functions including shading, stabilizing stream banks and controlling erosion, and contributing LWD and organic litter. Physical changes to fish habitat are addressed in this chapter. Habitat loss or alteration due to water quantity changes was not considered a potential effect for the Project because there will be no interaction between water quantity changes and fish. Water quantity changes are associated with mine site water management within immediately downstream of Brucejack Lake and Creek. No fish are present within Brucejack Lake and Creek and water quantity changes in Sulphurets Creek are not predicted (Chapter 10, Surface Water Hydrology Predictive Study). Fish are present in lower Sulphurets Creek approximately 20 km downstream of the Brucejack mine site.

Adverse effects to water quality can reduce the health of fish populations. Water quality changes can result in direct and indirect sublethal effects. Sublethal effects are those that may affect the relative health or behaviour of individual fish within the LSA and RSA. Examples include increased stress, decreased health or condition, habitat avoidance, and loss of primary and secondary producers causing decreased fish growth. Sub-lethal effects do not result in direct or immediate mortality, but may ultimately decrease the fitness and fecundity of individual fish, and possibly translate to population level effects in the long term. Adverse effects of water quality on aquatic habitat (i.e., primary and secondary producers) are addressed in Chapter 14, Assessment of Potential Aquatic Resources Effects.

Direct mortality of fish can occur because of fishing (increased access will increase fishing pressure), impact from construction machinery, dewatering during construction, in addition to salvage and relocation of fish to other waterbodies during road maintenance activities. Sedimentation can result in the immediate or near-immediate death of fish, such as smothering embryos by an erosion event.

Noise and vibration, as identified in the AIR, were not considered a potential effect for the Project because there will be no interaction between noise and fish. Noise is associated with blasting activities and fish are not present within or near the Brucejack Mine Site or west of the Bowser Aerodrome (Section 15.3.3.2) where blasting activities will or may occur.

All of the potential effects overlap in terms of their definition and scope. Each pathway describes one primary effect, but multiple effects may occur. Potential effects of the Project on fish and fish habitat were identified by reviewing the Project components and baseline data (Appendix 15-A). If a Project component was considered not to have any potential for interaction (and thus no potential effect), no further consideration was given to that Project component in the assessment (Table 15.4-1).

15.4.3.2 Construction

The scoping exercise identified potential effects caused by Project construction associated with direct mortality, erosion and sedimentation (including road runoff and dust), and change in water quality (nutrients, process chemicals, and petroleum products).

There is one fish bearing stream crossing along the proposed Transmission Line route, the Bowser River, which will be easily spanned with towers positioned well outside of the riparian zone. There are no current plans to upgrade the exploration access road stream crossing structures. However, if stream crossing structure upgrades are required then the use of heavy equipment in and around water has the potential to result in direct mortality of fish during upgrades of the exploration access road. Erosion and sedimentation into streams and waterbodies potentially could be caused by the exploration access road upgrade activities and installation of the proposed transmission line and associated towers. The use of heavy equipment in and around water has the potential to result in petroleum product spills.

During Construction, the use of construction camp sewage treatment plants and their discharge may affect fish directly or indirectly through alteration of primary and secondary producers causing changes in fish growth. The transportation of chemicals and petroleum products could result in a spill into streams and waterbodies along the access roads.

15.4.3.3 Operation

The scoping exercise identified potential effects caused by Project operation associated with direct mortality, erosion and sedimentation, and change in water quality (metals, nutrients, process chemicals, and petroleum products).

Potential effects identified for the Operation phase are similar to those anticipated to occur during Construction. Potential effects associated with erosion and sedimentation, as well as petroleum product spills, may result predominantly from maintenance activities such as road grading. The transportation of chemicals and petroleum products could result in a spill into streams and waterbodies along the Brucejack Access Road. Direct mortality may occur during maintenance of access road stream crossings.

Potential effects associated with sewage effluent may result from the operation of camps. Fish in the Unuk River and lower Sulphurets Creek may experience direct (increased metals uptake) and indirect (altered primary and secondary producers causing changes in fish growth) effects associated with Brucejack Mine Site ore processing and resulting water quality from Brucejack Lake during Operation.

15.4.3.4 Closure

The scoping exercise identified potential effects caused by the Project Closure phase and associated with direct mortality, erosion and sedimentation, and change in water quality (metals, process chemicals, and petroleum products).

Most activities during this phase involve decommissioning Project infrastructure and returning the site to baseline condition. These activities will involve the use of heavy equipment in or around water for the decommissioning of Project infrastructure (e.g., road and bridges). As a result of working in and around water, erosion and sedimentation of waterbodies (e.g., sedimentation to streams from road decommissioning) and water quality degradation (e.g., petroleum product spills) could occur when conducting Closure activities.

Metals and process chemicals causing fish toxicity and indirect effects (altered primary and secondary producers causing changes in fish growth) could also occur through the continual operation and maintenance of the water treatment plant.

15.4.3.5 Post-closure

The scoping exercise identified potential effects caused by the Project's Operation and Closure phase associated with change in water quality (metals and process chemicals). Metals and process chemicals causing fish toxicity and indirect effects (altered primary and secondary producers causing changes in fish growth) could occur after the water treatment plant is phased out during closure).

15.5 EFFECTS ASSESSMENT AND MITIGATION FOR FISH AND FISH HABITAT

15.5.1 Key Effects on Fish and Fish Habitat

15.5.1.1 Identifying Key Effects

Activities during the Construction, Operation, Closure, and Post-closure phases vary depending upon the infrastructure. Some of these activities could potentially affect fish and fish habitat.

Potential effects of the Project on fish and fish habitat were identified in the scoping assessment (Table 15.4-1). To ensure all potential effects were identified, a matrix table was used to identify interactions between the identified effects and all aspects of the Project, as they pertain to the

Project's Construction, Operation, Closure, and Post-closure phases. A summary of the results is provided in Tables 15.5-1 and 15.5-2, which provide scoping conclusions for all Project phases for the fish and fish habitat sub-components, respectively.

Table 15.5-1. Ranking Potential Effects on Fish

Project Components/ Projects and Activities	Potential Effects on Fish		
	Direct Mortality	Erosion and Sedimentation	Change in Water Quality
Construction Phase			
Chemical and hazardous material storage, management and handling	○	○	● (yellow)
Construction and use of sewage treatment plant and discharge	○	○	● (yellow)
Construction of Bowser Aerodrome	○	● (yellow)	● (yellow)
Construction of Knipple Transfer Area	○	● (yellow)	● (yellow)
Installation of the transmission line and associated towers	○	● (yellow)	● (yellow)
Use of Granduc Access Road	○	○	● (yellow)
Operation Phase			
Air transport of personnel and goods and use of aerodrome	○	○	● (yellow)
Brucejack Access Road use and maintenance	● (yellow)	● (yellow)	● (yellow)
Chemical and hazardous material storage, management, and handling	○	○	● (yellow)
Discharge from Brucejack Lake	○	○	● (yellow)
Transmission line operation and maintenance	○	● (yellow)	● (yellow)
Closure Phase			
Decommissioning of Brucejack Access Road	● (yellow)	● (yellow)	● (yellow)
Chemical and hazardous material storage, management, and handling	○	○	● (yellow)
Post-closure Phase			
Discharge from Brucejack Lake	○	○	● (yellow)

Notes:
○ = No interaction anticipated.
● (green) = Negligible to minor adverse effect expected; implementation of best practices, standard mitigation, and management measures; no monitoring required, no further consideration warranted.
● (yellow) = Potential moderate adverse effect requiring unique active management/monitoring/mitigation; warrants further consideration.
● (red) = Key interaction resulting in potential significant major adverse effect or significant concern; warrants further consideration.

Table 15.5-2. Ranking Potential Effects on Fish Habitat

Project Components/ Projects and Activities	Potential Effects on Fish Habitat	
	Erosion and Sedimentation	Habitat Loss
Construction Phase		
Construction of Bowser Aerodrome	● (yellow)	● (yellow)
Construction of Knipple Transfer Area	● (yellow)	● (yellow)
Installation of transmission line and associated towers	● (yellow)	● (yellow)
Upgrade and use of Brucejack Access Road	● (yellow)	● (yellow)

(continued)

Table 15.5-2. Ranking Potential Effects on Fish Habitat (completed)

Project Components/ Projects and Activities	Potential Effects on Fish Habitat	
	Erosion and Sedimentation	Habitat Loss
Operation Phase		
Brucejack Access Road use and maintenance	● (yellow)	● (yellow)
Transmission line operation and maintenance	● (yellow)	● (yellow)
Closure Phase		
Decommissioning of Brucejack Access Road	● (yellow)	● (yellow)

Notes:
○ = *No interaction anticipated.*
● (green) = *Negligible to minor adverse effect expected; implementation of best practices, standard mitigation, and management measures; no monitoring required, no further consideration warranted.*
● (yellow) = *Potential moderate adverse effect requiring unique active management/monitoring/mitigation; warrants further consideration.*
● (red) = *Key interaction resulting in potential significant major adverse effect or significant concern; warrants further consideration.*

From the scoping assessment, four potential effects were identified. These included direct mortality, habitat loss and alteration, erosion and sedimentation (including dust), and change in water quality (including petroleum product spills, sewage effluent, metals, and other chemical toxicity). Physical changes to fish habitat are addressed in this chapter. Adverse effects of water quality on primary and secondary producers (i.e., related to fish habitat) are addressed in Chapter 14, Assessment of Potential Aquatic Resources Effects. However, direct adverse effects on primary and secondary producers and their indirect effects on fish (e.g., growth and fecundity) are addressed in this chapter. Each of these potential effects, including mitigation and residual effects, will be discussed in detail in the following sections.

The fish and fish habitat effects assessment was prepared according to applicable scientifically defensible management guidelines. The assessment was based on currently available knowledge of species behaviour, presence, distribution, population biology, and ecology. Consideration was also given to linkages between predicted physical and biological changes resulting from the proposed development on both the individual and local population levels.

Given the hierarchical nature of biological systems, potential effects on fish are discussed with regard to changes at both the individual level (i.e., behaviour, physiological condition, and survival) and the population level (i.e., population size, distribution, mortality rate, and reproductive fitness). Effects at the population level are of greater concern than those at the individual level; thus, the assessment primarily focuses on the effects to local populations. However, population boundaries are not always distinct. A population is a group of organisms coexisting at the same time and place and capable of interbreeding, or is a group of non-specific organisms that occupy a loosely defined geographic region and exhibit reproductive continuity from generation to generation. Because the exact geographic boundaries for the local populations considered in this assessment are dynamic, the assessment is primarily qualitative.

<u>Effect of Direct Mortality</u>

For the purposes of the effects assessment, the Brucejack Access Road has been built, such that the effects assessment only considers the use, maintenance and potential upgrades to the road.

Project-specific modes of potential direct mortality to fish in the RSA include the Brucejack Access Road. For the Project, direct mortality could take place during all Project phases because the access road will require periodic maintenance and decommissioning.

The geographic scope of direct mortality will be localized, but localized effects can result in far-reaching effects depending on the fish species affected, their life history characteristics, and abundance. Impact with construction machinery and increased fishing access can affect fish species by causing mortality to all fish life history stages.

Potential causes of direct mortality to fish in the LSA and RSA include: construction equipment working in water for access road maintenance, dewatering activities for construction during bridge and culvert maintenance, salvage and relocation of fish downstream during maintenance activities, and fish stranding during maintenance. Effects from direct mortality are expected to be low as these activities are unlikely to occur.

Another form of direct mortality is increased angler pressure and harvesting of fish species from increased road access. Although all of the Project workers will not be anglers, some proportion of the workforce will be, and this influx of anglers has the potential to increase the fishing pressure on sport and traditional fish populations in lakes and rivers within the LSA and RSA.

<u>Effect of Erosion and Sedimentation</u>

Potential Project-specific sources of erosion and sedimentation include Brucejack Access Road, Brucejack Transmission Line, Bowser Aerodrome, and the Knipple Transfer Area. Sedimentation and erosion could take place during the Construction, Operation, and Closure phases of a number of Project activities. These activities have the potential to cause temporary increases in turbidity. The geographic scope of erosion and sedimentation can range from localized to far-reaching events, depending on the amount and type (e.g., particle size) of sediment that is introduced into the aquatic environment

Sedimentation could occur from erosion events during maintenance activities and construction (e.g., materials accidently pushed into streams, loosening materials along stream banks) and runoff during spring freshet and summer rains. Other sources of TSS include particulates from construction equipment activity, road runoff, and dust. Erosion and sedimentation can affect fish habitat in many ways, including the physical alterations to habitat in the form of increased turbidity. In turn, sedimentation can affect aquatic organisms by smothering primary and secondary producers at various life stages, reducing visibility, diminishing feeding efficiency, increasing exposure to elevated metal concentrations, and leading to habitat avoidance by aquatic organisms.

Erosion events can be lethal to incubating fish eggs in streambeds and larvae present in the substrate because of fine sediment being deposited within the interstitial spaces of gravel (Platts and Megahan 1975; Lisle 1989). Sediment can block oxygen transport across the membrane to the growing embryo, creating hypoxic (low oxygen) or even anoxic (no oxygen) conditions (Turnpenny and Williams 1980; Ingendahl 2001). Also, larvae that have hatched can become buried under the sediment, which creates a physical barrier that prevents them from emerging (Chapman 1988; Crisp 1996). High TSS levels can lead to behavioural changes in fish such as alterations in migration routes and spawning behaviour (Cordone and Kelley 1961).

TSS produced by erosion and the particulates within can cause minor physical damages, such as gill damage, leading to decreased fitness because of reduced ability to feed, spawn, and avoid predators. Increased respiratory and osmoregulatory stress can occur as a result of abrasion to the gill filaments and matting action reducing the surface area (Cordone and Kelley 1961; Newcombe and MacDonald 1991;

Sutherland and Meyer 2007). Moderate gill damage to small riverine fish has been shown to occur at suspended sediment levels greater than 100 mg/L, with severe damage at 500 mg/L (Sutherland and Meyer 2007). Eye damage also is possible, but sediment loads would have to be very high in fast-moving water because the continuous secretion of mucus washes away most sediment particles and protects the eyes.

The resulting decrease in water clarity, due to increased TSS, and enhanced particle loads could reduce primary production by decreasing photosynthesis and through scouring of the substrates they adhere to. Sediments may accumulate in some streams that are shallow with low discharge rates. Silt deposited from erosion and erosion events can affect invertebrate production as gravel interstices are filled by silt, and algae are buried or abraded (Beschta et al. 1995). In these instances, invertebrate assemblages are typically made up of a few tolerant, colonizing species (Newbold, Erman, and Roby 1980; Murphy, Hawkins, and Anderson 1981; Hawkins, Murphy, and Anderson 1982; Laniberti et al. 1991). This loss of substrate complexity, including LWD, tends to decrease the diversity of aquatic invertebrates.

Fish habitat may also be affected by catastrophic slope failures, debris torrents, and avalanches associated with access roads and their stream crossings. Road building has been associated with increased rates of slope failure and large-scale erosion, particularly in steep, coastal watersheds (Furniss, Roelofs, and Yee 1991). Debris torrents in streams can affect fish and productivity in streams for hundreds of years by scouring channels to bedrock, depositing fine sediment over downstream habitat, and blocking access to upstream habitat.

Recovery from sedimentation will be more rapid in high-velocity streams relative to wetlands or lakes. Many streams and rivers in the RSA have naturally high sediment loads due to glacial origins, and thus will not be affected to the same extent as clear, low-velocity streams.

Effects of Change in Water Quality

The health of fish, other aquatic life, and sediment quality are all intimately linked to the quality of the water in the aquatic environment. Chemical contaminants may enter the aquatic environment from a number of sources as a result of Project activities during all phases and may pose a risk to fish.

A number of different chemical classes may be used or naturally present within the LSA and RSA. Examples of types of chemicals that could be introduced into the aquatic environment as a result of Project activities include metals, process chemicals (e.g., chemicals used in water treatment or ore processing), petroleum products, and nitrogen and phosphorus associated with sewage disposal. Each of these classes of chemicals will be discussed, including potential sources and general potential impacts on fish and fish habitat.

The potential effects considered in this section relate only to the Project activities that may occur under normal operating conditions. Effects related to substantial spills or unusual events (e.g., accidents, infrastructure failure) are addressed in Chapter 31, Accidents and Malfunctions.

Identification of metals that may be of concern to fish and fish habitat associated with discharges from Brucejack Lake (at Brucejack Creek) were determined quantitatively in Chapter 13, Assessment of Potential Surface Water Quality Effects, based on water quality predictions during various phases of the Project. The potential impacts of Project activities on fish, from the introduction of nitrogen, phosphorus, and chemicals, were assessed quantitatively.

Metals

Metals occur naturally in the water and sediments of the LSA and RSA due to the presence of mineral-rich deposits, sometimes at concentrations above federal and/or provincial guideline limits.

The generation of metal leaching/acid rock drainage (ML/ARD) can affect the aquatic environment through the alteration of pH due to the introduction of acid. Acidification can also increase the proportion of metals present in the dissolved phase, which are more bioavailable, since metals are often more soluble at lower pH. This can lead to increased exposure to metals and risk of toxicity in fish. The potential for fish or fish habitat exposure to acidic water or metals could occur during all phases of the Project (Construction, Operation, Closure, and Post-closure). Sources of metals due to Project activities may include point sources (e.g., discharges from Brucejack Lake). Potential sources of ML/ARD include any locations where potentially acid generating (PAG) rock may be exposed.

Exposure of fish in the aquatic environment to extremes in pH or metals can lead to both lethal and sub-lethal effects. At high enough concentrations, metals can cause mortality in exposed organisms. At lower concentrations, sub-lethal effects may occur; although these effects do not cause immediate mortality, they can affect population dynamics or stability in the long term. The interaction of acidic water with metals can change metal speciation and increase the mobility and bioavailability of metals in the aquatic environment, thereby altering the toxicological implications of exposure. Low pH, such as what naturally occurs in the fish and fish habitat study area can mobilize surface-bound metals, leading to increased potential for toxic effects on fish. The toxicology of mixtures of metals and other chemicals in the aquatic environment is poorly understood, although it is known that antagonistic, additive, synergistic, or potentiating effects are possible outcomes.

ML/ARD has been shown to cause lethality at high concentrations and various other toxic effects at lower concentrations, which are largely attributed to the metal content. High, acutely lethal concentrations of metals or changes in pH are not expected to occur in the LSA and RSA, as addressed in Chapter 13, Assessment of Potential Surface Water Quality Effects, except in the event of a large chemical spill. Spills and other accidents are addressed elsewhere (Chapter 31, Accidents and Malfunctions); thus, acutely lethal effects are not considered likely to occur as a result of normal Project activities, and are not considered further.

Fish are sensitive to changes in environmental pH. Exposure to acidic aquatic environments can lead to sub-lethal effects such as alteration in blood acid-base regulation and disruption of ionoregulation (Wood 1992). In chronic exposures, contact with low pH can lead to decreased growth and development, impaired swimming ability, increased stress and impaired smoltification in fish (Wood 1989; Kennedy and Picard 2012).

Sub-lethal toxicity of metals in fish can manifest as effects on various physiological functions, and can be different for each metal. Toxicity occurs because of metal interaction with the external surfaces of the organism or metal uptake through water or diet and can result in osmoregulatory impairment, immunotoxicity, neurotoxicity, endocrine disruption, embryotoxicity, or behavioural changes (Evans 1987; Baatrup 1991; Kime 1998; Hansen et al. 1999; Sanchez-Dardon et al. 1999; Todd et al. 2006; Chapman et al. 2009). Exposure to metals can also cause a generalized stress response in fish that can lead to similar effects including immunosuppression, osmoregulatory imbalance, and decreased growth because of higher metabolic demands (Todd et al. 2006). The stress response is caused by metal accumulation or damage at the gill, or metal uptake and pH surges that in turn stimulate increased gas exchange (Wood 1992). Olfactory toxicity in fish has also been associated with exposure to low pH, metals, and various other contaminants (Tierney et al. 2010). Some metals, such as copper, can interact with sensory nerves located in the olfactory rosettes causing avoidance responses or impairment of the ability to “smell,” which can alter normal olfactory-mediated behaviours (Tierney et al. 2010).

Exposure of fish to metals in their aquatic habitat can lead to accumulation of those contaminants in fish tissue. As part of baseline studies, whole body tissue metal analysis was conducted for Dolly Varden collected at two sites downstream of the Project discharge location: Sulphurets Creek (SC3, 4 fish, 2008/09), and Unuk River (UR1, 8 fish, 2013; Appendix 15-B). Muscle tissue metal analysis was conducted for Dolly Varden collected at one site downstream of the Project discharge location: Unuk River (UR1, 5 fish, 2011). The location of the sample sites are shown in Figure 15.3-2, and results of these analyses are provided in Table 15.5-3. The results indicate that fish downstream of the Brucejack Mine Site, in lower Sulphurets Creek, had naturally high tissue metal residues for certain metals. Concentrations of selenium in Dolly Varden tissue collected during baseline studies (Sulphurets Creek – Site SC3 and Unuk River – Site UR1) were above the BC MOE tissue residue guideline of 1 µg/g ww (equivalent to approximately 4 µg/g dw using a 75% moisture content conversion; Nagpal 2001; BC MOE 2006b) (Table 15.5-3). Selenium has been associated with reproductive and developmental toxicity, particularly in egg-laying vertebrates (Chapman et al. 2009). It is currently unknown whether fish are experiencing sub-lethal toxic effects since the effects thresholds for fish vary between species; however, evidence suggests that Dolly Varden may be less sensitive to selenium toxicity than other fish species (McDonald et al. 2010).

Table 15.5-3. Tissue Metal Concentrations of Dolly Varden in the Baseline Fish and Fish Habitat Study Area, 2008 to 2013

	Sulphurets Creek (SC3) (n = 4)			Unuk River (UR1) (n = 5)			Unuk River (UR1) (n = 8)		
Tissue Type	**Whole Body**			**Muscle**			**Whole Body**		
Parameters	**Minimum**	**Maximum**	**Mean**	**Minimum**	**Maximum**	**Mean**	**Minimum**	**Maximum**	**Mean**
Physical Tests									
Moisture (%)	73.9	76.7	74.9	73.9	77.6	76.3	72.4	77.2	75.2
Total Metals									
Aluminum	53.2	204.0	132.8	79.1	379.3	195.7	<2.0	99.90	29.91
Antimony	<0.05	0.056	<0.05	<0.05	0.050	<0.05	<0.010	0.02	<0.010
Arsenic	0.38	0.66	0.51	0.32	1.10	0.66	0.14	0.42	0.22
Barium	5.52	6.33	6.04	1.73	8.66	4.13	0.86	6.60	3.15
Beryllium	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.010	<0.010	<0.010
Bismuth	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.010	<0.010	<0.010
Cadmium	0.548	0.806	0.700	0.025	0.065	0.040	0.11	0.89	0.37
Calcium	17,132	22,976	19,841	566	1,004	797	4,380	30,500	17,885
Chromium	0.620	3.710	1.462	0.205	<0.5	0.491	<0.050	11.20	2.28
Cobalt	0.480	0.736	0.625	0.206	0.425	0.305	0.19	1.74	0.47
Copper	10.0	24.3	16.5	1.9	8.9	3.8	3.58	26.70	9.61
Iron	142	324	232	na	na	na	44.20	268.00	103.76
Lead	0.083	0.180	0.144	<0.1	0.245	0.134	<0.020	0.22	0.04
Lithium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.10	<0.10	<0.10
Magnesium	1,195	1,300	1,245	1,285	1,478	1,347	921	1,450	1,161
Manganese	10.52	13.95	12.54	3.42	12.84	7.21	2.35	22.30	7.88
Mercury	0.056	0.094	0.070	0.057	0.147	0.102	0.051	0.122	0.084
Molybdenum	0.063	0.632	0.216	<0.05	0.069	<0.05	<0.020	0.07	0.03
Nickel	<0.50	1.69	0.57	<0.50	0.54	<0.50	<0.050	6.38	0.91
Phosphorus	16,667	20,600	18,634	na	na	na	11,600	26,100	17,900
Potassium	12,337	13,915	13,172	na	na	na	12,300	16,700	14,913
Selenium	4.29	4.60	4.47	2.94	3.90	3.34	2.59	5.25	3.93

(continued)

Table 15.5-3. Tissue Metal Concentrations of Dolly Varden in the Baseline Fish and Fish Habitat Study Area, 2008 to 2013 (completed)

	Sulphurets Creek (SC3) (n = 4)			Unuk River (UR1) (n = 5)			Unuk River (UR1) (n = 8)		
Tissue Type	**Whole Body**			**Muscle**			**Whole Body**		
Total Metals *(cont'd)*									
Sodium	2,837	3,270	3,061	na	na	na	3,200	4,800	3,600
Strontium	21.5	27.9	24.7	0.8	2.3	1.5	4.14	29.50	16.46
Thallium	0.052	0.077	0.068	0.022	0.065	0.048	0.02	0.07	0.04
Tin	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.10	0.13	<0.10
Titanium	4.29	7.98	6.55	na	na	na	Na	na	na
Uranium	<0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.0020	0.01	0.00
Vanadium	0.198	0.770	0.531	0.482	2.069	1.044	<0.10	0.43	0.16
Zinc	120	153	133	28	40	32	71.20	126.00	94.55

na = not analyzed.
Concentrations are expressed in µg/g dry weight, unless otherwise noted.
Shaded concentrations exceed tissue residue guidelines for methylmercury (0.132 µg/g dry weight, 0.033 µg/g wet weight; to protect consumers of aquatic life) or selenium (4 µg/g dry weight, 1 µg/g wet weight; to protect aquatic life). Note that guidelines are based on wet weight concentrations, which have been converted to dry weight assuming 75% moisture content in fish tissue.

Mercury can also bioaccumulate through the food chain and pose a greater risk to higher trophic level organisms. Elevated tissue mercury concentrations in fish have been associated with sublethal effects such as decreased growth, developmental and reproduction abnormalities, and neurological and behavioural effects (Kidd and Batchelar 2012). Concentrations of mercury in some of the analyzed fish from the Unuk River were greater than tissue residue guidelines (shown as maximum concentrations in Table 15.5-3), which are intended to be protective of consumers of fish such as wildlife and humans. The CCME and BC tissue residue guideline is 0.033 µg/g ww, which is approximately 0.132 µg/g dw, assuming 75% tissue moisture content. Most or all of the mercury present in fish tissue is likely in the form of methylmercury (CCME 2000), and for the purposes of comparison to guidelines, it has been assumed to be 100% methylmercury. It is unlikely that the current mercury residues in the fish are directly toxic to the fish. Beckvar, Dillon, and Read (2005) estimate that a mercury tissue residue threshold for fish of 0.2 µg/g ww (approximately 0.8 µg/g dw, assuming 75% tissue moisture) is protective against adverse sub-lethal effects in both juvenile and adult fish. This tissue residue threshold was not exceeded.

The productive capacity in aquatic habitat could also be potentially altered as a result of the Project activities (see Chapter 14, Assessment of Potential Aquatic Resources Effects). Acids and metals leaching into aquatic environments can lead to decreased biomass, densities, and diversities in primary and secondary producer communities (Kimmel 1983; McKnight and Feder 1984). Aquatic insects are also affected by low pH, with lethality occurring below a pH of 5.4, and emergence impairment beginning at a pH of 5.9 (Bell 1971; McKean and Nagpal 1991). Therefore, direct effects on aquatic resources can have an indirect effect on fish growth and fecundity. Sediment quality can be affected by the overlying water quality, and increases in metal concentrations in the water may lead to increased partitioning of those metals into sediments or aquatic biota. Acidic aquatic pH can also lead to the liberation of sediment-bound metals, which can then enter the dissolved phase and be more bioavailable to aquatic organisms resulting in toxicity.

Process Chemicals

Chemicals used in ore processing or for environmental protection (e.g., water treatment process chemicals) may be present at the Brucejack Mine Site during all Project phases and may pose a risk of toxicity to downstream fish and fish habitat in the LSA and RSA. Metal concentrates produced at the mill building will be present at the Brucejack Mine Site during the Operation phase. Since the main risk associated with metal concentrates is spills related to traffic accidents or other unusual incidents, this will be addressed in Chapter 31, Accidents and Malfunctions, and metal concentrates will not be considered further in this chapter. Process chemicals are introduced after the water treatment process, in the mill building, and may be released in discharge effluent during the normal course of Project activities, which will be considered as part of the effects assessment in this section.

Important or heavily used chemicals that will be used during Project activities include potassium amyl xanthate (PAX; ore processing), lime and/or NaOH (water treatment), hydrochloric acid (water treatment), and flocculants (water treatment). Sodium cyanide will not be used as a process chemical in the mill building, and thus will not be present in the discharge from Brucejack Lake.

PAX is used as a collector in the flotation step of ore processing. There is limited information available on the persistence or toxicity of this chemical in the environment. However, Vigneault, Desforges, and McGeer (2009) report that at concentrations of 0.5 mg/L, PAX can impair algal growth, although an aquatic invertebrate and a macrophyte were shown to be less sensitive.

At low concentrations, lime is used to raise the pH in acidified waterbodies (Hultbert and Andersson 1982). Lime is also proposed for use in the water treatment processes in the WTP during all phases of Project activity to increase the precipitation and removal of metals from water. At higher concentrations it can be hazardous to fish and fish habitat. The primary way lime affects fish habitat is by raising water pH, which can increase the toxicity of ammonia by converting ammonium ions (NH_4^+) to more toxic, uncharged ammonia molecules (NH_3). It can also increase the total dissolved solids in receiving waters, due to increased calcium concentrations. Calcium contributes to water hardness, and for many metals (e.g., cadmium, copper, lead, and nickel) increasing water hardness is associated with decreasing metal toxicity. However, increased total dissolved solids or calcium concentrations can also have adverse effects ranging from impairing growth and reproduction in some invertebrates or macrophytes to decreasing fertilization success in salmonids, as well as mortality at high concentrations (Stekoll et al. 2009; Vigneault, Desforges, and McGeer 2009). Therefore, direct effects on aquatic resources can have an indirect effect on fish growth and fecundity. In general, a pH of 9 or more will cause mortality in most fish species (Ye and Randall 1991). When exposed to lower levels of alkalinity, fish experience impaired ammonia excretion and sodium influx that may result in changes to blood ammonia levels (Ye and Randall 1991).

Following the use of lime and/or NaOH in the water treatment process, the pH will be decreased again to a neutral level using acid. Hydrochloric acid will be used in the pH adjustment to neutral levels.

Polyacrylamide flocculants will be used in the water treatment plant and tailings thickener. Approximately half of the flotation tailings will be paste backfilled to the underground workings, while the other half of the flotation tailings will be deposited in Brucejack Lake, which outlets into Brucejack Creek. For aquatic invertebrates, flocculants can also interact with sensory surfaces such as antennae, leading to immobilization and death. Therefore, direct effects on aquatic resources can have an indirect effect on fish growth and fecundity. Some flocculants have been shown to cause acute lethality to fish, and toxicity is dependent on the charge associated with the compound (anionic, cationic, non-ionic). Toxicity of these compounds is through their interaction with respiratory surfaces, leading to impaired oxygen exchange and ultimately suffocation. In fish, cationic flocculants are often associated with the highest toxicity since gills have a negative charge and the flocculant has a positive charge that increases the likelihood of interaction at the gill surface. Anionic or non-ionic flocculants have a much lower toxicity, with LC50 values typically greater than 100 mg/L, although some (e.g., MagnaFloc 10) are reported to impair Rainbow Trout survival at 18 µg/L (Vigneault, Desforges, and McGeer 2009).

Petroleum Products

Potential Project-specific activities where petroleum products may be present include all Project access roads, the Brucejack Transmission Line, Bowser Aerodrome, and the Knipple Transfer Area. Fish and fish habitat are present within or near the above listed Project infrastructure. Release of petroleum products could occur during the Construction, Operation, and Closure phases due to a number of Project activities. Routine Project-related traffic creates a risk of diesel fuel or lubricants entering fish habitat, either directly or due to runoff associated with precipitation. Activities involving mechanized equipment in or near waterways, such as road, bridge, dam, or other infrastructure construction and activities during closure and post-closure reclamation can lead to introduction of small amounts of fuel, oil, or petroleum-based lubricants into the aquatic environment.

The potential geographic scope of petroleum product introduction into waterways can range from localized to far-reaching events depending on the amount that is introduced into the aquatic environment and watercourse discharge. The potential for spills and accidents involving large quantities of petroleum products are not explicitly considered here since this will be addressed in Chapter 31, Accidents and Malfunctions. The potential for petroleum products to enter waterways during normal Project activities is likely small in geographic scope, since only small quantities in localized areas would be introduced to aquatic environments. Petroleum products can affect fish and fish habitat in many ways, including physiological toxicity (lethal or sub-lethal effects) or behavioural changes in fish and loss of productive habitat capacity.

Most petroleum products that may enter waterways during normal Project activities (e.g., gasoline, diesel, fuel oil, and lubricants) are toxic to fish and can cause mortality at high enough levels (Tagatz 1961; Hedtke and Puglisi 1982; Lockhart et al. 1996). Toxicity occurs through the water soluble constituents and emulsions causing damage to gill epithelia, nerve damage, liver damage, and general organ failure (Fryday et al. 1996; Omoregie and Ufodike 2000). Disturbances in blood chemistry, such as increased haematocrit (percent volume of red blood cells in blood), haemoglobin concentration, erythrocyte counts, plasma glucose, and cortisol, along with variable changes in plasma chloride and potassium levels, may occur (Zbanyszek and Smith 1984; Alkindi et al. 1996). Acute and chronic stress responses, as indicated by alteration in blood chemistry and cortisol production, can lead to behavioural changes such as decreased feeding activity, growth, and changes in swimming behaviour (Struhsaker 1977; Little and DeLonay 1996).

Contamination of aquatic resources leading to decreased productive capacity could potentially occur if petroleum products are released to the aquatic environment. Localized contamination of sediments may occur, since most petroleum products have constituents that are hydrophobic and will move from the water to the sediment. Accidental release of petroleum products (e.g., diesel fuel) have been shown to reduce primary and secondary producer densities and alter community structure (Lytle and Peckarsky 2001).

Nitrogen and Phosphorus

Introduction of nitrogenous compounds and phosphorus into the aquatic environment may occur as a result of Project activities involving nitrogen-based explosives and disposal of effluent from the Brucejack Mine Site sewage treatment plant. The primary nitrogenous compounds that may be a concern include ammonia, nitrate, and nitrite.

Blasting residues, composed of nitrogen species, will be generated during the Construction and Operation phases for the Project, but only within the Brucejack Mine Site. Fish are not located within the Brucejack Mine Site and are approximately 20 km downstream from Brucejack Lake; therefore, blast residues were not considered further in this effects assessment because potential effects would be negligible at that distance.

Potential sources of effluent containing both nitrogenous compounds and phosphorus include the Brucejack Mine Site sewage treatment plant during the Construction, Operation, and Closure phases. All other camps associated with the Project will include a septic field; therefore, there will be no discharge to surface waters and introduction of nitrogenous compounds and phosphorus into the aquatic environment will not occur. Effluent from the Brucejack Mine Site sewage treatment plant (discharge into Brucejack Lake) may have nitrogen (including both ammonia and nitrate) and phosphorus which, if not treated properly, can contribute to alterations in productive capacity and eutrophication, as well as the potential for toxicity to fish (CCME 2004) in downstream environments (lower Sulphurets Creek).

Nitrogen loading can increase the potential for eutrophication in aquatic systems if there are sufficient macronutrients (e.g., phosphorus), micronutrients (e.g., iron), light for primary production, and nitrogen is in limited supply. This could degrade water quality and alter primary producer growth and community composition away from baseline conditions if the system is nitrogen limited. Community shifts such as these may have a cascading effect, leading to changes in the structure of several successive trophic levels, including fish. On a population scale, continued exposure to elevated levels of nutrients could lead to changes in species diversity and abundance relative to control areas (Grigg 1994). In streams, how additional nutrients are manifested in primary productivity can also be affected by water temperature, availability of light, TSS content (which affects availability of light and contributes to scouring), and the flow or gradient of the stream.

Nitrogenous compounds, including ammonia, nitrate, or the oxidative intermediate nitrite, in high enough concentrations can be toxic (lethal) to all life history stages of fish due to gill and other tissue damage (Lewis and Morris 1986; Servizi and Gordon 1990; Camargo, Alonso, and Salamanca 2005). The toxicity of total ammonia is pH and temperature dependent, with higher pH and temperature contributing to higher ratios of the more toxic un-ionized ammonia (NH_3), which is reflected in the BC water quality guidelines for this compound.

At lower concentrations, exposure to nitrogenous wastes has been shown to cause sub-lethal effects, including a general stress response (Wendelaar Bonga 1997) in fish that can lead to sub-lethal changes in development (Weis and Weis 1989; Weis, Weis, and Greenberg 1989), decreased growth (Smith and Suthers 1999; Saborido-Rey et al. 2007), and decreased swimming performance (Shingles et al. 2001). As well, chronic exposure can alter immune system function resulting in an increase in the susceptibility of fish to infection (Carballo et al. 1995). Nitrate (10 mg NO_3-N/L) can lead to decreased growth in fish (Camargo, Alonso, and Salamanca 2005).

Other physiological changes in fish include nerve damage during development, along with damage to muscles and liver. Generally, invertebrates and algae are less sensitive to the toxic effects of nitrogenous compounds (Nordin and Pommen 1986). Early life stages of some invertebrates may experience increased mortality and decreased growth at very high nitrate concentrations (Camargo, Alonso, and Salamanca 2005). Therefore, direct effects on aquatic resources can have an indirect effect on fish growth and fecundity.

The constituents of effluent from sewage treatment plants have been shown to cause sub-lethal behavioural effects such as avoidance behaviour (Richardson, Williams, and Hickey 2001). As well, increases in parasite load can occur in areas of sewage effluent exposure (Siddall, Pike, and McVicar 1994), which can lead to physiological and behavioural changes (Poulin 1995). Effluent from sewage treatment plants has also been associated with endocrine disruption and reproductive alteration in fish (Jobling et al. 1998).

Effect of Habitat Loss

There is no fish or fish habitat within the Brucejack Mine Site. Potential Project-specific fish habitat loss includes access roads, the Brucejack Transmission Line, Bowser Aerodrome, and the Knipple Transfer Area. Habitat loss can take place during the Construction, Operation, and Closure phases of a number of Project activities. Fish habitat loss refers to removing or physically altering aspects of the environment that are directly or indirectly used by fish. More specifically, fish habitat loss can refer to the removal of riparian and instream habitat, and the restricting of fish passage. Habitat loss or alteration due to water quantity changes was not considered a potential effect for the Project because there will be no interaction between water quantity changes and fish. Water quantity changes are associated with Brucejack Mine Site water management within immediately downstream Brucejack Lake and Creek. Fish are not present within Brucejack Lake and Creek (20 km downstream in Lower Sulphurets Creek) and water quantity changes in Sulphurets Creek are not predicted (Chapter 10, Surface Water Hydrology Predictive Study).

Instream fish habitat consists of any part of a stream that is below the mean annual high-water mark. The high-water mark is typically a natural line or “mark” impressed on the bank or shore, indicated by erosion, shelving, changes in soil characteristics, destruction of terrestrial vegetation, or other distinctive physical characteristics. This definition generally corresponds to the 1:5 year flood interval or corresponding elevation (DFO 2007).

Riparian vegetation provides numerous functions including shading, stabilizing stream banks, controlling sediments, contributing LWD and organic litter, and regulating composition of nutrients. Losing riparian function can lead to fish habitat loss and alteration. Salmonid food webs receive important energy subsidies from terrestrial inputs of invertebrates and nutrients falling into streams from riparian vegetation (Wipfli and Gregovich 2002; Allan et al. 2003). Clearing riparian vegetation removes this resource over short distances and can affect the productive capacity of stream habitat over moderate distances.

Riparian vegetation contributes quantities of organic litter to low- and mid-order streams. This litter constitutes an important food resource for aquatic communities (Naiman et al. 1992). The quality, quantity, and timing of litter delivered to the stream channel depends on the vegetation type (i.e., coniferous versus deciduous), stream orientation, side slope angle, stream width, and the amount of stream meander (Cummins et al. 1994).

Riparian vegetation increases stream bank stability and resistance to erosion via two mechanisms. First, roots from woody and herbaceous vegetation bind soil particles together, helping to maintain bank integrity during erosive high stream flow events (Swanson et al. 1982). Roots promote the formation of undercut banks, an important habitat characteristic for many salmonids (Murphy and Meehan 1991). In wide valleys where stream channels are braided, meandering, or highly mobile, the zone of influence of root structure is greater.

LWD provide long-term nutrient storage and substrate for aquatic invertebrates; moderates flow disturbances; increases retention of allochthonous inputs, water, and nutrients; and provides refugia for aquatic organisms during high- and low-flow events (Bisson et al. 1987). The ability of LWD to perform these functions depends in part on the size and type of wood. In general, the larger the size of the debris, the greater its stability in the stream channel, because higher flows are needed to displace larger pieces (Bilby and Ward 1989). Woody debris within the channel increases velocity heterogeneity and habitat complexity by physically obstructing the stream flow and creating small pools and short riffles (Swanston 1991). Diverted currents create pools (plunge, lateral, and backwater) and riffles, flush sediments, and scour stream banks to create undercut banks (Cummins et al. 1994).

15.5.1.2 Mitigation Measures for Fish and Fish Habitat

Mitigation for Direct Mortality

Increased fishing access by the public within the LSA and RSA will be mitigated and controlled on the Brucejack Access Road during Construction and Operation. Limited sport fishing for trout, char (Bull Trout and Dolly Varden), and salmon already occurs within the LSA and RSA in the larger creeks, rivers, and lakes. The potential increase in fishing pressure and associated increase in fish harvesting due to the presence of the mine Construction and Operation workforces will be mitigated by the following features:

- gating of the Brucejack Access Road during Construction and Operation to prohibit the entry by non-authorized vehicles;
- design of gates and security measures to control access and mobility of snow machines and all-terrain vehicles;
- at Closure, all non-essential roads will be deactivated;
- implementing a company policy that prohibits employees and contractors from engaging in fishing while present at the Brucejack Mine Site or while travelling to and from the mine on company business; and
- transporting personnel to and from the Brucejack Mine Site so that employees have limited opportunity to engage in angling during mine Construction and Operation.

As a result of these administrative and mitigation measures, there will be no sanctioned opportunities for employees or contractors to engage in fishing while on site during mine Construction or Operation.

To mitigate direct mortality effects within fish-bearing streams, access road construction and maintenance activities will be done in accordance with best management practices (BMPs) such as the *Land Development Guidelines for the Protection of Aquatic Habitat* (DFO 1993), *Standards and Best Practices for Instream Works* (BC MWLAP 2004), and DFO's operational statements for bridge and culvert maintenance (DFO 2007). Appropriate fisheries operating windows for fish-bearing streams will be adhered to where possible. Mitigation strategies include isolating Project work sites to prevent fish movement into the work site, salvaging/removing fish from the enclosed work site, and environmental monitoring.

The Bowser River transmission line crossing will not involve instream structure or works; therefore direct mortality effects are not anticipated.

If BMPs and plans are implemented and followed, there is a low probability that a potential effect caused by direct mortality on fish species may not be fully mitigated. This low probability that a potential effect could occur is due to the efficiency and size selectivity of sampling gear to remove fish from a work area.

Mitigation for Erosion and Sedimentation

To minimize the effects on fish and their habitats, several mitigation measures relating to erosion and sedimentation will be required. Mitigation strategies will be tailored to address Project-specific issues associated with erosion and sedimentation. Mitigation objectives outlined in accordance with BMPs such as the DFO *Land Development Guidelines for the Protection of Aquatic Habitat* (DFO 1993), *Standards and Best Practices for Instream Works* (BC MWLAP 2004), *Fish-Stream Crossing Guidebook*

(BC MOF 2002), and Pacific Region Operational Statements (DFO 2007) all provide guidelines for the mitigation of erosion and sedimentation effects on fish and fish habitat.

Erosion and sedimentation will be mitigated in the LSA and RSA through the implementation of BMPs, particularly during construction and maintenance. BMPs relating to erosion and sedimentation are described under the Soils Management Plan for the Project (Section 29.13). The Soils Environmental Management Plan will provide performance-based environmental specifications for preventing and controlling the release of sediments during the Construction, Operation, and Closure phases to minimize adverse effects to downstream water quality.

These measures will be monitored and modified, as necessary, to ensure compliance with regulatory requirements and BMPs. When in-water work occurs, an environmental monitor will be on site monitoring water quality. Construction and maintenance activities near areas of fish-bearing waters will occur during appropriate fisheries operating windows for fish-bearing streams. In-water works outside of fisheries operating windows will only be conducted under a permit.

To minimize the effects of erosion and sedimentation (including dust) during access road maintenance, an access road maintenance plan will be developed and adhered to during the Project Construction, Operation, and Closure phases, which will be a component of the Transportation and Access Management Plan (Section 29.16) prepared for this Application/EIS.

Sedimentation to fish-bearing waters during transmission line construction and maintenance and not anticipated. The Bowser River transmission line crossing will be the only crossing of fish-bearing waters. At this location, the closest tower locations will be more than 560 m from the floodplain and the transmission line conductor will be located approximately 120 m above the high-water mark of the river. Thus no habitat loss will occur as existing tree and shrub riparian habitat will meet clearance standards for overhead transmission lines. Therefore, no trees will be removed within the riparian zone of the Bowser River crossing reducing the possibility of sedimentation to the Bowser River.

Along the full length of the transmission line, construction activities (i.e., equipment access, construction of transmission structures, and conductor stringing) will be conducted in a manner that minimizes riparian vegetation effects and maintains fish habitat and stream bank integrity. Therefore, the effects of sedimentation during transmission line construction and maintenance will be negligible.

Specific BMPs relating to the mitigation and/or minimizing of effects caused by erosion and sedimentation to the aquatic environment include:

- using water diversion structures to direct dirty water from the work zone to a sediment control area;
- installing silt fencing, geotextile cloth, straw bales, berms, or other sediment control structures;
- conducting instream work from the point farthest away from the construction access point and working backward;
- allowing constructed ponds to settle before connecting to the stream;
- storing soil, substrate, removed vegetation, and building materials in stable areas away from the channel;
- ensuring constructed banks are graded at a stable slope;
- stabilizing excavated materials and areas denuded of vegetation using temporary erosion control blankets, biodegradable mats, planted vegetation, or other erosion control techniques;

- environmental monitoring;
- repairing areas that are identified as potential sediment sources;
- using dust suppression on roads; and
- adhering to appropriate construction operating windows for instream work.

Mitigation for Change in Water Quality

In addition to the specific mitigation measures outlined for each class of chemical in the following sections, a comprehensive Aquatic Effects Monitoring Plan (Section 29.3) will be implemented. This monitoring plan will detect alterations to the receiving environment, including changes to fish health. Additional, monitoring to fish health will be triggered if alterations in water quality and aquatic resources are detected. This plan will include provisions for identification of causes of alteration and implementation of additional mitigation measures or adaptive management strategies, if effects are identified.

Mitigation for Metals

The ML/ARD Management Plan (Section 29.10) outlines measures that will be implemented to decrease the potential for impacts due to acid generation and subsequent mobilization of metals associated with PAG rock.

For the Brucejack Mine Site, a number of mitigation measures will be implemented under the ML/ARD Management Plan (Section 29.10). More than half of the waste rock will be re-deposited in the underground mine, and an estimated two million tonnes will be sub-aqueously stored in the southwest corner of Brucejack Lake. Freshwater diversion channels will be constructed to divert non-contact water away from Project infrastructure. Water that has been in contact with PAG or mine infrastructure will be directed to the water treatment plant. It is expected that this water may be acidic and contain higher concentrations of metals. In the mill building, a water treatment process will be applied to treat groundwater from the underground workings, runoff from the plant site excavation, and from the temporary waste rock stockpile. This process will decrease the concentrations of some metals and ions and adjust the pH from acidic to a more neutral pH (Chapter 13, Assessment of Potential Surface Water Quality Effects). Discharges from the water treatment plant will occur during the Operation phase of the Project year-round and will be closely managed to minimize potential for effects in the receiving environment (i.e., Brucejack Creek). The potential for water quality effects in Brucejack Creek (the receiving environment) will be monitored regularly through the implementation of an Aquatic Effects Monitoring Plan (Section 29.3).

TSS in the receiving environment will be mitigated by addition of flocculent to, tailings to limit suspension of solid, and use of a turbidity curtain.

Mitigation for Process Chemicals

The handling and storage of all process chemicals will follow BMPs, and general transportation, storage, and handling requirements that are outlined in the Hazardous Materials Management Plan (Section 29.7). While spills are not specifically considered in this chapter, the Spill Prevention and Response Plan (Section 29.14) will be implemented to quickly respond to and mitigate any unintended release or spill of chemicals that may affect the aquatic environment.

The concentration of flocculant is expected to be below levels that would cause adverse effects to aquatic life. Tailings will be flocculated in the tailings thickener; this water would then be discharged with the tailings to Brucejack Lake. Flocculant compounds with lower toxicity (non-ionic or anionic flocculants) will preferentially be used.

Mitigation for Petroleum Products

Petroleum products will be in use during the Construction, Operation, and Closure phases. To minimize the effects on fish and fish habitat, several mitigation measures relating to petroleum products will be required. Mitigation strategies will be tailored to address Project specific issues associated with petroleum product introduction into aquatic environments. Mitigation objectives outlined in accordance with DFO *Land Development Guidelines for the Protection of Aquatic Habitat* (DFO 1993), *BC MOE Standards and Best Practices for Instream Works* (BC MWLAP 2004), and Pacific Region Operational Statements (DFO 2007) all provide guidelines for the mitigation of petroleum product effects and spills on the aquatic environment.

Petroleum product introduction into the aquatic environment will be mitigated in the LSA and RSA through the implementation of BMPs, particularly in the Construction and Operation phases. BMPs relating to petroleum spills are described under the Spill Prevention and Response Plan (Section 29.14). This plan will provide performance-based environmental specifications for preventing and controlling the release of spills during the Construction, Operation, and Closure phases to minimize adverse effects to downstream water quality. These measures will be monitored and modified, as necessary, to ensure compliance with regulatory requirements and BMPs. When instream work occurs, an Environmental Monitor will be on site monitoring water quality, and for activities near areas of fish-bearing waters, appropriate fisheries operating window requirements for fish-bearing streams will be adhered to. In certain circumstances, instream work may need to occur outside of the least risk windows; however none is planned. Inin the unlikely event that instream work is required, necessary permits will be obtained from appropriate agencies and work will comply with permit conditions.

Specific BMPs relating to the mitigation and/or minimizing of effects caused by petroleum product introduction into the aquatic environment include:

- environmental monitoring;
- adhering to appropriate construction operating windows for instream work;
- fuel stored in bermed and lined containment facilities to prevent seepage into the soil;
- inspection of all equipment and machinery prior to and during instream/riparian work to ensure that it is clean and free of leaks;
- refuel mobile equipment outside riparian zones and ensure stationary machinery is not overfilled and refuel from containers by pump not by hand;
- provision of readily accessible spill kits in all areas where machinery or fuel tanks will be used, stored, or refuelled, and training of personnel in their use prior to beginning construction;
- spill prevention and control measures; and
- an emergency response plan.

Mitigation for Nitrogen and Phosphorus

Effluent from the sewage treatment plants at the Knipple Transfer Area and Bowser Aerodrome will include septic ground disposal systems that meet requirements for setback from waterbodies as required in the *Sewerage System Regulation* (BC Reg. 326/2004) to prevent any effects to surface waters. Secondary-treated effluent from the Brucejack Mine Site sewage treatment plant will be discharged to Brucejack Lake. This is not expected to have an effect outside of the initial dilution zone due to high dilution ratios, existing downstream sediment and water quality in Sulphurets Creek, limited aquatic life (periphyton and benthic invertebrates), and the absence of fish in these areas. Fish exposure to sewage effluent spills or leaks to streams is not expected to occur with proper design, engineering, and maintenance of the sewage disposal systems.

Mitigation for Habitat Loss

To mitigate fish habitat and passage effects related to the Brucejack Access Road maintenance of fish-bearing stream crossings, any work performed will follow DFO's operational statements for bridges and culverts (DFO 2007) and DFO's (1993) *Land Development Guidelines for the Protection of Aquatic Habitat*. Efforts will be undertaken to minimize potential effects from the Project on fish habitat and passage, and to avoid fish habitat loss. If any instream work within fish-bearing streams should occur, an environmental monitor will be on site to monitor work procedures. Appropriate fisheries operating windows for fish-bearing streams will be adhered to whenever feasible. Alternatively, appropriate permits will be acquired for out-of-window activities. Instream fish habitat loss related to the maintenance and use of the Brucejack Access Road is not anticipated through the Construction, Operation, Closure, and Post-closure phases of the Project.

There are no DFO operational statements that specifically deal with the removal of riparian vegetation for transmission line projects of this scope and magnitude. DFO's (2007) operational statement for overhead line construction applies specifically to transmission lines with voltage less than 60 kV. Only one fish-bearing stream crossing is anticipated along the proposed transmission line, which is the Bowser River. The placement of a transmission line over the Bowser River is not considered to result in habitat loss because existing tree and shrub riparian habitat already meet clearance standards for overhead transmission lines. Therefore, no additional trees will be removed within the riparian zone of the Bowser River crossing. Construction activities (i.e., equipment access, construction of transmission structures, and conductor stringing) will be conducted in a manner that minimizes riparian vegetation effects and maintains fish habitat and stream bank integrity.

To protect fish habitat near project infrastructure, such as the Bowser Aerodrome and Knipple Transfer Area, appropriate riparian zones will be applied as per the *Forest and Range Practices Act* (2002c).

In summary, Project-specific instream and riparian habitat loss in areas of fish habitat are not anticipated through the Construction, Operation, Closure, and Post-closure phases of the project.

15.6 RESIDUAL EFFECTS ON FISH AND FISH HABITAT

15.6.1 Direct Mortality

Residual effects on fish VCs (Bull Trout, Dolly Varden, and Pacific Salmon) may potentially occur because of direct mortality (Table 15.6-1).

Fish may be affected by Project components along the access road since they are present in the Bell-Irving River, Bowser Lake, Bowser River, and their tributaries. Fish do not inhabit streams in remaining areas of the Project, and thus will not be affected by direct mortality.

The primary goal of direct mortality mitigation strategies is to prevent machinery from impacting fish. A fishing policy that prohibits employees and contractors from fishing while present at the Brucejack Mine Site or while travelling to and from the mine on company business, will be implemented by the company. Although these mitigation and best management strategies are effective in minimizing direct mortality, these strategies may not fully prevent all mortality. Thus, some residual effects due to machinery contact potentially may occur due to the maintenance and decommissioning of the access road.

15.6.2 Erosion and Sedimentation

Residual effects on fish (Dolly Varden, Bull Trout, and Pacific Salmon) and fish habitat VCs may occur because of erosion and sedimentation (including dust and runoff) resulting from Project components in the Construction, Operation, and Closure phases (Tables 15.6-2 and 15.6-3).

Table 15.6-1. Potential Residual Effects on Fish Valued Component due to Direct Mortality

Sub-Component	Project Phase (timing of effect)	Project Component / Physical Activity	Description of Cause-Effect	Description of Mitigation Measure(s)	Description of Residual Effect
Bull Trout Dolly Varden Pacific Salmon	Construction Operation Closure	Upgrade and use of exploration access road; Brucejack Access Road use and maintenance; Decommissioning of Brucejack Access Road.	Impact with construction machinery causing fish mortality.	Use of best management practices to minimize fish mortality with construction machinery; Adhere to DFO's operational statements; Adhere to appropriate construction operating window for instream work; Site isolation.	Blunt tissue trauma causing mortality to early life history stages.
Bull Trout Dolly Varden Pacific Salmon	Construction Operation Closure	Upgrade and use of exploration access road; Brucejack Access Road use and maintenance; Decommissioning of Brucejack Access Road.	Increased fishing access causing increased harvest of game fish species.	Controlled access; Implement no fishing policy for employees.	Fishing harvest causing mortality to adult life stages.

Table 15.6-2. Potential Residual Effects on Fish Valued Component due to Erosion and Sedimentation

Sub-Component	Project Phase (timing of effect)	Project Component / Physical Activity	Description of Cause-Effect	Description of Mitigation Measure(s)	Description of Residual Effect
Bull Trout Dolly Varden Pacific Salmon	Construction Operation Closure	Upgrade and use of exploration access road; Brucejack Access Road use and maintenance; Decommissioning of Brucejack Access Road.	Entry of sediment to waterbodies during instream construction and bridge/culvert removal; Entry of sediment to waterbodies from road runoff and dust during operation and maintenance.	Use of best management practices to minimize sediment entry to water bodies; Adhere to DFO's operational statements; Adhere to appropriate construction operating window for instream work and the Soil Environmental Management Plan; Riparian re-vegetation; Dust suppressionsuppression on roads; Site isolation; Water quality maintenance.	Smothering of eggs, decreased feeding efficiency, habitat avoidance.
Bull Trout Dolly Varden Pacific Salmon	Construction	Installation of transmission line and associated towers.	Entry of sediment to waterbodies during removal of riparian vegetation; Altered riparian vegetation.	Use of best management practices to minimize sediment entry to water bodies; Adhere to DFO's operational statements; Maintain riparian vegetation at Bowser River crossing.	None
Bull Trout Dolly Varden Pacific Salmon	Construction	Construction of Bowser Aerodrome; Construction of Knipple Transfer Area.	Entry of sediment to waterbodies from runoff.	Use of best management practices to minimize sediment entry to water bodies; Adhere to DFO's operational statements; Adhere to Soil Environmental Management Plan; Water quality maintenance; Apply appropriate riparian zones for fish bearing streams according to *Forest and Range Practices Act*.	None

Table 15.6-3. Potential Residual Effects on Fish Habitat Valued Component due to Erosion and Sedimentation

Sub-Component	Project Phase (timing of effect)	Project Component / Physical Activity	Description of Cause-Effect	Description of Mitigation Measure(s)	Description of Residual Effect
Fish Habitat	Construction Operation Closure	Upgrade and use of exploration access road; Brucejack Access Road use and maintenance; Decommissioning of Brucejack Access Road.	Entry of sediment to waterbodies during instream construction and bridge/culvert removal; Entry of sediment to waterbodies from road runoff and dust during operation and maintenance.	Use of best management practices to minimize sediment entry to waterbodies; Adhere to DFO's operational statements; Adhere to appropriate construction operating window for instream work and the Soil Environmental Management Plan; Riparian re-vegetation; Dust suppression on roads; Site isolation; Water quality maintenance.	Physical loss of fish habitat
Fish Habitat	Construction	Installation of transmission line and associated towers.	Entry of sediment to waterbodies during removal of riparian vegetation; Altered riparian vegetation.	Use of best management practices to minimize sediment entry to waterbodies; Adhere to DFO's operational statements; Maintain riparian vegetation at Bowser River crossing.	None
Fish Habitat	Construction	Construction of Bowser Aerodrome; Construction of Knipple Transfer Area.	Entry of sediment to waterbodies from runoff.	Use of best management practices to minimize sediment entry to waterbodies; Adhere to DFO's operational statements; Adhere to Soil Environmental Management Plan; Water quality maintenance; Apply appropriate riparian zones for fish bearing streams according to *Forest and Range Practices Act (2002)*.	None

Fish may be affected by the Brucejack Access Road, Brucejack Transmission Line, Bowser Aerodrome, and Knipple Transfer Area since they are present in streams within or near these Project activities. Fish do not inhabit streams in other Project areas and will thus not be affected by erosion and sedimentation.

Fish habitat is present along the access roads, Brucejack Transmission Line, near the Bowser Aerodrome and Knipple Transfer Area, and may be affected by these Project components.

The primary goal of sediment mitigation strategies is to prevent sediment from entering all waterbodies, especially those waterbodies where fish reside. Sediment mitigation strategies and BMPs will include the use of geotextile cloth surrounding sites susceptible to sediment entry near waterbodies, isolating Project work sites, and environmental monitoring. Additional sediment mitigation strategies and BMPs are also described in the Soil Environmental Management Plan (Section 29.13). They include, but are not limited to, using buffers or leave strips, using geotextile cloth surrounding sediment entry sites near waterbodies, isolating Project work sites, retaining vegetation and re-vegetating exposed riparian habitat, and environmental monitoring. Although these mitigation and best management strategies are effective in minimizing sediment entry to fish-bearing waterbodies, these strategies may not fully prevent all sediment entry. Thus, some residual effects due to erosion and sedimentation potentially may occur due to the Construction, Operation, and Decommissioning of these Project components in the LSA and RSA.

15.6.3 Change in Water Quality

15.6.3.1 Residual Effects for Metals

Residual effects on fish VCs may occur because of changes in water quality resulting from Project components in the Construction, Operation, and Closure phases for Dolly Varden and Pacific Salmon (Table 15.6-4).

Primary source of inflow to the water treatment plant will be seepage water from the underground workings. Other sources of inflow to the water treatment plant will be water associated with waste rock and tailings. This water will subsequently be passed through the water treatment plant, which discharges treated water to Brucejack Lake. Water flows from Brucejack Lake to Brucejack Creek into Sulphurets Creek, then into the Unuk River, and ultimately to the Pacific Ocean. Discharge from Brucejack Lake to Brucejack Creek will meet federal MMER and provincial guidelines during all Project phases.

Water quality modelling was conducted to predict the total concentrations of the various metals due to all mine effluent discharges to Brucejack Creek (Chapter 13, Assessment of Potential Surface Water Quality Effects). As hydrological regime is an important determinant of surface water quality in the Project area, water quality was assessed separately for both high flow (June to October) and low flow (November to May) periods. The scope of the water quality effects assessment only includes parameters with an approved BC water quality guideline for the protection of freshwater aquatic life (BC MOE 2006a, 2006b) and the following parameters with working BC water quality guidelines: cadmium, nickel, and chromium. Science-based environmental benchmarks (SBEB) were employed for nitrite, cadmium, copper, lead, silver and zinc; originally derived as part of the application for an *Environmental Management Act* permit for exploration phase discharges. SBEBs are based on BC water quality objectives and are further refined using specific methodologies to take local conditions into account. This ensures both the protection of the aquatic receiving environment but also informs impact and management decisions when use of BC Water qualities are not appropriate. Unless otherwise noted, any reference throughout this section to a predicted metal concentration in water refers to the total metal concentration, and reference to “the guidelines” means the BC Water Quality Guidelines for the Protection of Aquatic Life (BC MOE 2006a, 2006b) or SBEB. Details of the water quality model, analysis, and comparison to guidelines are provided in Chapter 13.

Table 15.6-4. Potential Residual Effects on Fish Valued Component due to Change in Water Quality

Sub-Component	Project Phase (timing of effect)	Project Component / Physical Activity	Description of Cause-Effect	Description of Mitigation Measure(s)	Description of Residual Effect
Bull Trout Dolly Varden Pacific Salmon	Construction Operation Closure	Chemical and hazardous material storage, management and handling	Toxicity of fish due to introduction of chemical products into aquatic environment during normal Project activities.	Use of best management practices to minimize chemical product entry to water bodies; Adhere to the Spill Prevention and Response Plan and Hazardous Materials Management Plan; Spill kits; Water Treatment Plant discharge treatment and water quality maintenance at Brucejack Lake outlet.	None
Bull Trout Dolly Varden Pacific Salmon	Construction	Construction and use of sewage treatment plant and discharge	Toxicity of fish due to introduction of nitrogenous compounds associated with sewage.	Industry Standards for Wastewater Treatment; Use of best management practices and industry wastewater treatment standards to treat effluent (secondary treatment) and minimize untreated effluent entry to water bodies from Brucejack Camp; Discharge effluent to septic field for all other camps.	None
Bull Trout Dolly Varden Pacific Salmon	Construction Operation Closure	Construction of Bowser Aerodrome; Installation of transmission line and associated towers; Upgrade and use of exploration access road; Bowser Aerodrome; Brucejack Access Road use and maintenance; Transmission line operation and maintenance; Decommissioning of Brucejack Access Road	Toxicity of fish due to introduction of petroleum products into aquatic environment during normal Project activities.	Use of best management practices to minimize petroleum product entry to water bodies; Adhere to DFO's operational statements; Adhere to appropriate construction operating window for instream work; Adhere to the Spill Prevention and Response Plan; Spill kits, Equipment maintenance, Stream setback distances; Water quality maintenance.	None
Bull Trout Dolly Varden Pacific Salmon	Operation Post-closure	Discharge from Brucejack Lake	Toxicity of fish due to metals or process chemical exposure downstream of WTP associated with scheduled discharge.	Collection of all contact water from within the Brucejack Mine Site catchment area and diversion of contact water to the Water Treatment Plant; Treat contaminated water prior to discharge into Brucejack Lake; Implement and adhere to applicable environmental management and monitoring plans.	None

In ecological risk assessment, the calculation of a hazard quotient (HQ) can be a useful screening tool for determining the potential for a chemical to cause toxicity in receptors, such as fish, in the receiving environment (US EPA 1998). HQ were calculated by dividing the predicted seasonal mean and maximum concentration of water quality parameters by the appropriate 30-day average or maximum guideline or SBEB. Water quality parameters with a HQ ≤ 1.0 were screened out of the assessment for residual effects, since the guidelines and applicable SBEBs are determined by BC Ministry of Environment to be protective of freshwater aquatic life receptors; therefore, there is no potential for adverse effects to water quality or fish. Water quality parameters with a HQ › 1.0 relative to the guideline limit were retained for a second screening step prior to significance determination. In the second screening step, predicted seasonal mean and maximum water quality parameters were compared to the seasonal mean and maximum baseline concentrations. This comparison of predicted concentrations to baseline concentrations provides a good indicator of the potential for incremental change due to Project-related activities. This step screens out those contaminants where concentrations are at or above guidelines under baseline conditions; naturally-occurring guideline exceedances are not a Project-related effect. If the HQ calculated during this screening step were greater than 1.0, the parameter was considered a possible Project-related chemical of particular concern (COPC) and retained for further assessment. If the final HQ is equal to or less than 1.0, the parameter was not considered a Project- related COPC and was not assessed further.

HQs are only useful as a screening tool to determine the potential for residual effects, but should not be used to assess the magnitude of potential effects (i.e., an HQ of 8 is not necessarily worse than an HQ of 2; US EPA 1998).

By following the COPC screening procedure as outlined above, the significance determination for fish toxicity effects included water quality parameters that are predicted to increase in concentration above water quality guidelines and above the range of natural variability. The screening procedure thus focuses the significance determination on those parameters with the potential for a Project-related effect. The significance determination considers, but is not limited to, factors such as uncertainty in guideline limits (e.g., due to safety factors or the underlying studies used to derive the guidelines), the sensitivity of potential receptors in the receiving environment, or other Project specific information (e.g., uncertainty in the predicted concentrations or other factors that may affect the metal concentration or toxicity).

For the purposes of residual effects assessment, the expected and upper case base case of the water quality model was considered. These predictions are based on mean and maximum water chemistry and hydrology and represent the water quality that is most likely to occur during the Operation, Closure, and Post-closure phases of the Project. Water quality was modelled at Site BJ 200 m downstream of Brucejack Lake (Chapter 13, Assessment of Potential Surface Water Quality Effects). At this site, a total of four COPC (arsenic, zinc, chromium, and total aluminum) had HQs greater than 1.0. These fours COPCs (or any other Project related metal) due to the Project are not expected to result in the potential for residual effects in the fish-bearing reach of Sulphurets Creek (Site SC3) or the Unuk River. This is because the stream discharge in the lower reach of Brucejack Creek and upper reach of Sulphurets Creek (glacial reach upstream of Sulphurets Lake) are orders of magnitude larger than Brucejack Creek (Chapter 10, Surface Water Hydrology Predictive Study), as a result the COPC concentrations would be greatly reduced to HQs less than 1.0 (Chapter 13). By the time a COPC reaches fish-bearing waters, 21 km downstream of Site BJ 200 m, the COPC concentration would be greatly reduced to HQs less than 1.0.

15.6.3.2 Residual Effects for Process Chemicals

Residual effects associated with flocculant use in the mill building and tailings thickener are not expected to occur, provided mitigation measures are implemented and BMPs are followed, since the concentrations of flocculant would not be high enough to cause toxic effects in the aquatic receiving environment. A similar conclusion can be made for PAX (used in ore processing), which would not be discharged at concentrations that are expected to cause an effect in fish. Therefore, the use of these chemicals would not be expected to result in potential residual effects on fish in the fish-bearing reach of Sulphurets Creek (Site SC3) and Unuk River (Site UR1).

Residual effects of other process chemicals can be determined based on the water quality model results (Chapter 13, Assessment of Potential Surface Water Quality Effects).

Lime and/or NaOH and hydrochloric acid will be used in the mill building to neutralize the pH before discharge. In the effluent discharged from the water treatment plant, the primary constituents discharged after water treatment will be calcium and chloride, respectively. While lime may also be used in other areas to address localized issues with the potential for ML/ARD, the water treatment plant will be the primary source for introduction of these chemicals to the receiving environment.

For the purposes of residual effects assessment, the expected and upper case base case of the water quality model was considered. These predictions are based on mean and maximum water chemistry and hydrology and represent the water quality that is most likely to occur during the Operation, Closure, and Post-closure phases of the Project. Water quality was modelled at Site BJ 200 m downstream of Brucejack Lake (Chapter 13, Assessment of Potential Surface Water Quality Effects). At this site, a total of four COPC (arsenic, zinc, chromium, and total aluminum) had HQs greater than 1.0. Chloride and calcium were included in the water quality model; however their HQs were less than 1.0 and not considered COPCs. Therefore, calcium and chloride are not expected to result in the potential for residual effects in the fish-bearing reach of Sulphurets Creek (Site SC3) or the Unuk River, which are approximately 21 km downstream.

15.6.3.3 Residual Effects for Petroleum Products

Mitigation measures for the introduction of petroleum products into aquatic environments are outlined in Section 15.5.1.2. Petroleum products spills will be mitigated through the implementation of the Spill Prevention and Response Plan (Section 29.14). Potential effects associated with petroleum spills are not expected to have a residual effect.

15.6.3.4 Residual Effects for Nitrogen and Phosphorus

The introduction of nitrogenous compounds and phosphorus into the aquatic environment is potentially toxic to fish. Two other potential effects on aquatic life from the introduction of nutrients are increasing primary productivity (eutrophication) and altering primary producer communities. These two effects are discussed in Chapter 14, Assessment of Potential Aquatic Resources Effects. However, direct effects on aquatic life can have an indirect effect on fish growth and fecundity. The potential for direct toxic effects associated with nitrogenous compounds and phosphorus on fish can be determined based on predictions made by the water quality model compared to BC water quality guidelines (Chapter 14).

The water quality model considered nutrient inputs to the Brucejack Lake from the Brucejack Camp sewage treatment plant and blasting residues from the water treatment effluent and waste rock placement in Brucejack Lake (Chapter 13, Assessment of Potential Surface Water Quality Effects). Therefore, the bulk of the input of nitrogen and phosphorus during Project Operation, Closure, and Post-closure is captured in the model predictions under the various chemicals associated with the nitrogen cycle (ammonia, nitrate, and nitrite) and total phosphorus. The water quality model makes predictions of water concentrations after all preventive mitigation measures have been applied; therefore, any compounds that are identified by the model as having concentrations greater than guideline limits downstream of Brucejack Lake in the fish bearing reach of Sulphurets Creek (Site SC3) and Unuk River (Site UR1) will be considered to have residual effects on fish.

The water quality model (base case) predicts that all forms of nitrogenous compounds (ammonia, nitrate, and nitrite) and phosphorus will be below water quality guidelines at the outlet of Brucejack Lake and all downstream sites during all the years modelled (up to 100 years). Thus, no direct toxicity and indirect growth effects (i.e., no predicted changes in primary and/or secondary productivity) are predicted for fish due to nitrogenous compounds from either blasting residues or sewage treatment plant effluent in the fish-bearing reach of Sulphurets Creek (Site SC3) or the Unuk River.

Effluent from all other Project-related camps will include septic ground disposal systems that meet requirements for setback from waterbodies to prevent any effects to surface waters. Fish exposure to sewage effluent spills or leaks to streams are not expected to occur with proper design and engineering of the ground sewage disposal systems. Thus, no toxicity is predicted for fish due to nitrogenous compounds from camp effluent.

15.6.3.5 Summary of Potential for Residual Effects due to Changes in Water Quality

Potential residual effects may occur due to changes in water quality resulting from Project components in various phases of the Project for Bull Trout, Dolly Varden, Rainbow Trout/Steelhead, and Pacific Salmon (Table 15.6-4).

The following direct potential effects and pathways were assessed:

- toxicity of fish due to metal or process chemical exposure associated with the Brucejack Lake discharge;
- toxicity of fish due to introduction of petroleum products into aquatic environments during normal Project activities; and
- toxicity of fish due to introduction of nitrogenous compounds associated with blasting residues or sewage.

The following indirect potential effects and pathways were assessed:

- change in fish growth, fecundity, and bioenergetics from alterations in primary and secondary productivity due to metal or process chemical exposure associated with the Brucejack Lake discharge;
- change in fish growth, fecundity, and bioenergetics from alterations in primary and secondary productivity due to introduction of petroleum products into aquatic environments during normal Project activities; and
- change in fish growth, fecundity, and bioenergetics from alterations in primary and secondary productivity due to introduction of nitrogenous compounds associated with blasting residues or sewage.

In the Brucejack mine site area, fish are not located in the waterbodies near where Project components are physically located (e.g., fish were not found above the cascades on Sulphurets Creek), although metals and chemicals introduced to the water in these areas could be carried downstream to areas where fish are found. However, the water quality modelling results indicate that after mitigation, the fish-bearing reach of Sulphurets Creek (Site SC3) and the Unuk River will not experience changes in water quality due to metals, process chemicals, nitrogen, or phosphorus. Potential residual effects on fish are not expected to occur with the mitigation measures outlined in Section 15.5.1.2, and therefore have not been carried forward in the effects assessment.

Potential residual effects of the release of petroleum products were not carried forward in the effects assessment because of the prevention and mitigation measures proposed. Potential residual effects for metals and process chemicals on fish toxicity were not carried forward in the effects assessments because the water quality model COPC concentrations will be greatly reduced to HQs less than 1.0 in fish-bearing waters of lower Sulphurets Creeks and the Unuk River, 21 km downstream. After all mitigation measures have been applied there are no potential for residual effects remaining.

15.6.4 Habitat Loss

No residual effects on fish habitat are expected regarding habitat loss (Table 15.6-5).

To mitigate fish habitat and passage effects related to maintenance of fish-bearing stream crossings along the Brucejack Access Road, any conducted work will follow DFO's operational statements for bridge and culvert (DFO 2007) and DFO's (1993) *Land Development Guidelines for the Protection of Aquatic Habitat*. Efforts will be undertaken to minimize potential effects from the Project on fish habitat and passage and to avoid fish habitat loss. Therefore, residual Project-specific instream and riparian habitat loss are not anticipated through the Construction, Operation, Closure, and Post-closure Project phases.

15.7 CHARACTERIZING RESIDUAL EFFECTS, SIGNIFICANCE, LIKELIHOOD, AND CONFIDENCE ON FISH AND FISH HABITAT

15.7.1 Residual Effects Characterization for Fish and Fish Habitat

15.7.1.1 Characterizing Residual Effects

Residual effects are characterized using standard criteria (i.e., the magnitude, geographic extent, duration, frequency, reversibility, resiliency, and ecological context). Standard ratings (e.g., major, moderate, minor/low, medium, and high) for these characterization criteria are provided in Section 6.6.2 of the methodology chapter; however, Table 15.7-1 provides a summary of definitions for each characterization criterion, specific to fish and fish habitat.

Characterization of residual effects, significance, confidence, and likelihood on fish and fish habitat are presented in Tables 15.7.2 and 15.7.3, respectively. The assessment considered results of fish and fish habitat baseline studies, feedback received during the pre-Application stage from review participants, regional planning documents, and scientific literature.

Several potential residual effects were identified that could affect fish and fish habitat in the LSA and RSA. These potential residual effects include direct mortality, erosion and sedimentation, and change in water quality due to petroleum products spills. Each of these potential residual effects is discussed below in relation to fish and fish habitat VCs and their geographic distribution in the LSA and RSA.

Population-level effects resulting from the combined direct and indirect effects could occur. Multiple effects may combine to produce a greater effect, as one effect may weaken the resilience of a VC to a subsequent or concurrent effect. The predicted "overall significance" of potential effects on each VC is assessed.

Table 15.6-5. Potential Residual Effects on Fish Habitat Valued Component due to Habitat Loss

Sub-Component	Project Phase (timing of effect)	Project Component / Physical Activity	Description of Cause-Effect	Description of Mitigation Measure(s)	Description of Residual Effect
Fish Habitat	Construction Operation Closure	Upgrade and use of exploration access road; Brucejack Access Road use and maintenance; Decommissioning of Brucejack Access Road.	Loss of instream and riparian habitat at stream crossings.	Adhere to DFO's operational statements.	None
Fish Habitat	Construction Operation	Construction of Bowser Aerodrome; Construction of Knipple Transfer Area; Installation of transmission line and associated towers; Transmission line operation and maintenance.	Loss of riparian habitat due to development.	Leave appropriate riparian zone widths for fish bearing streams.	None

Table 15.7-1. Definitions of Characterization Criteria for Residual Effects on Fish and Fish Habitat

Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Resiliency	Ecological Context	Likelihood	Confidence
How severe will the effect be?	*How long will the effect last?*	*How often will the effect occur?*	*How far will the effect reach?*	*To what degree is the effect reversible?*	*How resilient is the receiving environment or population? Will it be able to adapt to or absorb the change?*	*What is the current condition of the ecosystem and how commonly is it represented in the LSA?*	*How likely is the effect to occur?*	*How certain is this analysis? Consider potential for error, confidence intervals, unknown variables, etc.*
Low: The magnitude of effect differs from the average value for baseline conditions, but is within the range of natural variation of the local population and well below a guideline or threshold value (if it exists).	Short term: The effect lasts approximately 1 to 5 years.	Once: The effect occurs once during any phase of the Project.	Local: The effect is limited to the immediate Project footprint (e.g. within a 100 m buffer) and/or to individuals within the buffer.	Reversible short term: An effect that can be reversed relatively quickly (e.g., within a few days or less).	Low: The receiving environment or population has a low resilience to imposed stresses, and will not easily adapt to the effect.	Low: the receptor is considered to have little to no unique attributes or provision of functions is severely degraded.	Low: this effect is unlikely but could occur.	Low: < 50 % confidence. The cause-effect relationship(s) between the Project and its interaction with the environment is poorly understood and/or data for the Project area or scientific analyses are incomplete, leading to a high degree of uncertainty.
Moderate: the magnitude of effect differs from the average value for baseline conditions and approaches the limits of natural variation of the local population, but below or equal to a guideline or threshold value.	Medium term: The effect lasts from 6 to 25 years.	Sporadic: The effect occurs at sporadic or intermittent intervals during any phase of the Project.	Landscape: The effect extends beyond the project footprint to a broader watershed area, but remains tied to the footprint and/or to individuals within that watershed.	Reversible long term: An effect that can be reversed over many years.	Neutral: The receiving environment or population has a neutral resilience to imposed stresses and may be able to respond and adapt to the effect.	Neutral: The receiving environment considered to have some unique attributes and provides most functions that an undisturbed environment would provide.	Medium: this effect is likely, but may not occur.	Medium: 50 to 80 % confidence. The cause-effect relationship(s) between the Project and its interaction with the environment is not fully understood, and/or data for the Project area or scientific analyses are incomplete, leading to a moderate degree of uncertainty.
High: The magnitude of effect is predicted to differ from baseline conditions and exceed guideline or threshold values so that there will be a detectable change beyond the range of natural variation of the local population.	Long term: The effect lasts between 26 to 50 years.	Regular: The effect occurs on a regular basis during any phase of the Project.	Regional: The effect extends across the Regional Study Area and/or the population.	Irreversible: The effect cannot be reversed (i.e., is permanent).	High: The receiving environment or population has a high natural resilience to imposed stresses, and can respond and adapt to the effect.	High: The receiving environment or population is uncommon and occurs in a natural state and provides functions at a maximum capacity.	High: it is highly likely that this effect will occur.	High: > 80 % confidence. The cause-effect relationship(s) between the Project and its interaction with the environment is well understood, and/or data for the Project area or scientific analyses are complete, leading to a low degree of uncertainty.
	Far future: The effect lasts more than 50 years.	Continuous: An effect occurs constantly during any phase of the Project.	Beyond regional: The effect extends possibly across or beyond the province and/or the population.					

Table 15.7-2. Characterization of Residual Effects, Significance, Likelihood and Confidence on Fish

Description of Residual Effect	Evaluation Criteria: Magnitude *(low, moderate, high)*	Duration *(short, medium, long, far future)*	Frequency *(once, sporadic, regular, continuous)*	Geographic Extent *(local, landscape, regional, beyond regional)*	Reversibility *(reversible short term; reversible long term; irreversible)*	Resiliency *(low, neutral, high)*	Context *(low, neutral, high)*	Likelihood *(low, medium, high)*	Significance of Adverse Residual Effects *(not significant, significant)*	Confidence *(low, medium, high)*
Effect: Blunt tissue trauma causing mortality to all fish life stages. Project Component: Upgrade and use of exploration access road Timing: Construction	Low	Short	Sporadic	Local	Reversible short term	High	High	Low	Not significant	High
Effect: Blunt tissue trauma causing mortality to all fish life stages. Project Component: Brucejack Access Road use and maintenance Timing: Operation	Low	Short	Sporadic	Local	Reversible short term	High	High	Low	Not significant	High
Effect: Blunt tissue trauma causing mortality to all fish life stages. Project Component: Decommissioning of Brucejack Access Road Timing: Closure	Low	Short	Sporadic	Local	Reversible short term	High	High	Low	Not significant	High
Effect: Erosion and sedimentation causing smothering of eggs, decreased feeding efficiency, habitat avoidance Project Component: Upgrade and use of exploration access road Timing: Construction	Low	Medium	Sporadic	Local	Reversible medium term	Neutral	Neutral	Medium	Not significant	High
Effect: Erosion and sedimentation causing smothering of eggs, decreased feeding efficiency, habitat avoidance Project Component: Brucejack Access Road use and maintenance Timing: Operation	Low	Medium	Sporadic	Local	Reversible medium term	Neutral	Neutral	Medium	Not significant	High
Effect: Erosion and sedimentation causing smothering of eggs, decreased feeding efficiency, habitat avoidance Project Component: Decommissioning of Brucejack Access Road Timing: Closure	Low	Medium	Sporadic	Local	Reversible medium term	Neutral	Neutral	Medium	Not significant	High
Overall Effect	Low	Short	Sporadic	Landscape	Reversible medium term	Neutral	Neutral	Medium	Not significant	High

Table 15.7-3. Characterization of Residual Effects, Significance, Likelihood and Confidence on Fish Habitat

Description of Residual Effect	Evaluation Criteria							Likelihood (*low, medium, high*)	Significance of Adverse Residual Effects (*not significant, significant*)	Confidence (*low, medium, high*)
	Magnitude (*low, moderate, high*)	**Duration** (*short, medium, long, far future*)	**Frequency** (*once, sporadic, regular, continuous*)	**Geographic Extent** (*local, landscape, regional, beyond regional*)	**Reversibility** (*reversible short term; reversible long term; irreversible*)	**Resiliency** (*low, neutral, high*)	**Context** (*low, neutral, high*)			
Effect: Erosion and sedimentation causing loss of fish habitat Project Component: Upgrade and use of exploration access road Timing: Construction	Low	Medium	Sporadic	Local	Reversible medium term	Neutral	Neutral	Medium	Not significant	High
Effect: Erosion and sedimentation causing loss of fish habitat Project Component: Brucejack Access Road use and maintenance Timing: Operation	Low	Medium	Sporadic	Local	Reversible medium term	Neutral	Neutral	Medium	Not significant	High
Effect: Erosion and sedimentation causing loss of fish habitat Project Component: Decommissioning of Brucejack Access Road Timing: Closure	Low	Medium	Sporadic	Local	Reversible medium-term	Neutral	Neutral	Medium	Not significant	High
Overall Effect	Low	Medium	Sporadic	Local	Reversible medium term	Neutral	Neutral	Medium	Not significant	High

Direct Mortality

Direct mortality causing tissue damage and direct mortality for fish at all life stages may be associated with the construction, operation, and closure of access roads. This effect can be caused by direct contact with heavy equipment and dewatering activities during construction. For example, heavy equipment contacting instream substrate can cause direct mortality to incubating fish eggs. The magnitude of all effects associated with direct mortality will be minor because events will be localized and geographically isolated. In addition, direct mortality events will be of short duration and occur sporadically.

Since the timing and duration of events causing direct mortality is short, this effect can be reversed relatively quickly at the population level (not individual level; e.g., reversible short term) and the VC will be able to respond and adapt (e.g., resiliency is high). Mortality of fish was determined to be of high ecological context because salmon introduce marine derived nutrients into freshwater ecosystems and support aquatic productivity.

Erosion and Sedimentation

Sedimentation generated by the Project may cause several effects on fish and fish habitat. Potential effects include the smothering of eggs, decreased feeding efficiency due to reduced water quality, habitat avoidance, and loss of fish habitat. Sedimentation effects may occur during the Construction, Operation, and Closure phases of the Project related to maintenance and use of the Brucejack Access Road. The magnitude of all effects associated with erosion and sedimentation will be minor. The extent of the residual sediment effect will be at the landscape level as the sediments are flushed downstream. Erosion events, should they occur, will be of medium-term duration (effect lasts from one to five years) and would occur sporadically during all Project phases. The effects of erosion and sedimentation cannot be easily reversed, thus reversal will occur over many years (reversible medium term). Furthermore, fish may not be able to fully respond or adapt to the effects of erosion and sedimentation, thus resiliency was assessed as neutral. Sedimentation on fish was determined to be of neutral ecological context because fish in the receiving aquatic environment have attributes to deal with increased sediment loads (e.g., high flow).

15.7.1.2 Likelihood for Residual Effects on Fish and Fish Habitat

The likelihood of a residual effect occurring is expressed as a measure of probability to determine the potential for the Project to cause effects. The likelihood of a residual effect does not influence the determination of significance, rather it influences the risk of an effect occurring. Likelihood has been considered here in keeping with the most recent guidance issued in September 2013 by the BC EAO (2013): *Guidelines for the Selection of Valued Components and Assessment of Potential Effects*. The probability (likelihood) of the residual effect occurring was rated as low for all residual effects, except erosion and sedimentation was rated as medium.

15.7.1.3 Significance of Residual Effects on Fish and Fish Habitat

The potential residual effects on fish and fish habitat were associated with direct mortality, and erosion and sedimentation. These effects can possibly interact, creating additive or synergistic effects that have a different extent for the local fish population as a whole. Considering these potential effects on fish and fish habitat in combination with Project infrastructure in the LSA and RSA, and mitigation to minimize effects, the overall potential Project-related residual effect on local fish populations and habitat is not likely to affect the viability of fish and fish habitat VCs and is assessed as **not significant** for all residual effects and no additional follow-up monitoring is required.

15.7.1.4 Characterization of Confidence for Residual Effects on Fish and Fish Habitat

Confidence, which can also be thought of as scientific uncertainty, is a measure of how well residual effects are understood. The predicted residual effects were assessed for their reliability to portray the certainty in the predicted outcome, based on the acceptability of the data inputs and analytical methods used in the characterization.

The confidence in the significance predictions and mitigation measures being followed were rated as high for all potential residual effects. While uncertainty exists in every prediction of future change, the approach used to assess the effects on fish and fish habitat was developed to incorporate quantitative data from baseline reports and literature reviews. The goals were to remove as much subjectivity from the assessment as possible and to increase certainty in the predictions of alteration of fish and fish habitat, residual effects, and the determination of significance to ensure a robust, transparent, and defensible approach to the effects assessment of fish and fish habitat. Based upon the certainty associated with the significance conclusions, a more detailed risk assessment (e.g., additional sensitivity analyses) is not necessary.

15.8 SUMMARY OF RESIDUAL EFFECTS AND SIGNIFICANCE FOR FISH AND FISH HABITAT

Table 15.8-1 presents a summary of residual effects, mitigation, and significance on fish and fish habitat receptor VCs. All identified residual effects in Table 15.8-1 will be carried forward to the Cumulative Effects Assessment.

Table 15.8-1. Summary of Residual Effects, Mitigation, and Significance on Fish and Fish Habitat

Residual Effects	Project Phase(s)	Mitigation Measures	Significance
Fish			
Blunt tissue trauma causing mortality to all fish life stages	Construction Operation Closure	Use of best management practices to minimize fish mortality with construction machinery; Adhere to DFO's operational statements; Adhere to appropriate construction operating window for instream work; Site isolation; Controlled access; Implement no fishing policy for employees/contractors	Not significant
Erosion and sedimentation causing smothering of eggs, decreased feeding efficiency, habitat avoidance	Construction Operation Closure	Use of best management practices to minimize sediment entry to waterbodies; Adhere to DFO's operational statements; Adhere to appropriate construction operating windows for instream work and the Soil Environmental Management Plan; Riparian re-vegetation; Dust suppressionsuppression on roads; Site isolation; Water quality maintenance	Not significant
Fish Habitat			
Erosion and sedimentation causing habitat loss	Construction Operation Closure	Use of best management practices to minimize sediment entry to waterbodies; Adhere to DFO's operational statements; Adhere to appropriate construction operating window for instream work and the Soil Environmental Management Plan; Riparian re-vegetation; Dust suppression on roads; Site isolation; Water quality maintenance	Not significant

15.9 CUMULATIVE EFFECTS ASSESSMENT FOR FISH AND FISH HABITAT

Cumulative effects are defined in this Application/EIS as "effects which are likely to result from the designated project in combination with other projects and activities that have been or will be carried out." This definition follows that in section 19(1) of the *Canadian Environmental Assessment Act, 2012* (2012) and is consistent with the International Finance Corporation Good Practice Note on Cumulative Impact Assessment (ESSA Technologies Ltd. and IFC 2012), which refers to consideration of other existing, planned and/or reasonably foreseeable future projects and developments. A cumulative effects assessment is a requirement of the AIR and the EIS Guidelines and is necessary for the proponent to comply with the *Canadian Environmental Assessment Act, 2012* (2012) and the BC *Environmental Assessment Act* (2002b).

The CEA Agency issued an Operational Policy Statement in May 2013 entitled *Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012* (CEA Agency 2013), which provides a method for undertaking a cumulative effects assessment. Recently, the BC EAO also released the updated *Guideline for the Selection of Valued Components and the Assessment of Potential Effects* (BC EAO 2013), which includes advice for determining the need for a cumulative effects assessment. The CEA assessment methodology adopted in this Application/EIS therefore follows the guidance of the CEA Agency as outlined above, as well as the selection criteria in BC EAO (2013).

The method involves the following key steps which are further discussed in the proceeding sub-sections:

- scoping;
- analysis;
- identification of mitigation measures;
- identification of residual cumulative effects; and
- determination of significance.

15.9.1 Establishing the Scope of the Cumulative Effects Assessment

The scoping process involves identifying the intermediate components and receptor VCs for which residual effects are predicted, defining the spatio-temporal boundaries of the assessment, and examining the relationship between the residual effects of the Project and those of other projects and activities.

15.9.1.1 Identifying Intermediate Components and Receptor Valued Components for the Cumulative Effects Assessment

Receptor VCs included in the fish and fish habitat cumulative effects assessment were selected using four criteria following BC EAO (2013).

1. There must be a residual environmental effect of the project being proposed.
2. Environmental effect must be demonstrated to interact cumulatively with the environmental effects from other projects or activities.
3. Other projects or activities must be known to have been or will be carried out and are not hypothetical.
4. The cumulative environmental effect must be likely to occur.

Project-related residual effects are anticipated for direct mortality, erosion and sedimentation for the fish and fish habitat VCs. Even if all activity-specific guidelines, mitigation and management plans, BMPs, DFO operational statements, operating windows, and laws are strictly adhered to, residual effects and cumulative effects may still occur. Section 15.7 provides a more detailed discussion of the residual effects on each sub-component.

15.9.1.2 Potential Interaction of Projects and Activities with the Brucejack Gold Mine Project for Fish and Fish Habitat

A review of the interaction between potential Project effects and effects of other projects and activities on fish and fish habitat was undertaken. The review assessed the projects and activities identified in Section 6.8.2 of the Assessment Methodology chapter, including:

- regional projects and activities that are likely to affect the receptor VC, even if they are located outside the direct zone of influence of the project;
- effects of past and present projects and activities that are expected to continue into the future (i.e., beyond the effects reflected in the existing conditions of the receptor VC); and
- activities not limited to other reviewable projects, if those activities are likely to affect the receptor VC cumulatively (e.g., forestry, mineral exploration, and commercial recreational activities).

Numerous other projects or activities may interact with the Brucejack Gold Mine Project, potentially affecting fish and fish habitat in a cumulative fashion (Table 15.9-1).

Table 15.9-1. Potential Cumulative Effect Interactions for Fish and Fish Habitat

	Valued Component	
Projects and Activities	**Fish**	**Fish Habitat**
Historical		
Eskay Creek Mine		
Galore Creek Project - Access Road Only		
Goldwedge Mine		
Granduc Mine (Past Producer)		
Johnny Mountain Mine		
Kitsault Mine (Past Producer)		
Silbak Premier Mine		
Snip Mine		
Snowfield Exploration Project		
Sulphurets Advanced Exploration Project		
Swamp Point Aggregate Mine		
Present		
Brucejack Exploration and Bulk Sample Program		
Forrest Kerr Hydroelectric Power		
Long Lake Hydroelectric		
McLymont Creek Hydroelectric Project		
Northwest Transmission Line		
Red Chris Mine		

(continued)

Table 15.9-1. Potential Cumulative Effect Interactions for Fish and Fish Habitat (completed)

Projects and Activities	Valued Component	
	Fish	**Fish Habitat**
Reasonably Foreseeable Future		
Arctos Anthracite Coal Mine		
Bear River Gravel		
Bronson Slope Mine		
Coastal GasLink Pipeline Project		
Galore Creek Mine		
Granduc Copper Mine		
Kerr-Sulphurets-Mitchell (KSM) Mine		
Kinskuch Hydroelectric Project		
Kitsault Mine		
Kutcho Mine		
LNG Canada Export Terminal Project		
Northern Gateway Pipeline Project		
Prince Rupert Gas Transmission Project		
Prince Rupert LNG Project		
Schaft Creek Mine		
Spectra Energy Transmission Line Project		
Storie Moly Mine		
Treaty Creek Hydroelectric Project		
Turnagain Mine		
Volcano Hydroelectric Project		
Land Use Activities - All Stages (past, present, future)		
Parks and Protected Areas		
Guide Outfitting		
Aboriginal Harvest (fishing, hunting/trapping, plant gathering)		
Hunting		
Trapping		
Commercial Recreation (including fishing)		
Forestry		

Black = likely interaction between Brucejack Gold Mine Project and other project or activity.
Grey = possible interaction between Brucejack Gold Mine Project and other project or activity.
White = unlikely interaction between Brucejack Gold Mine Project and other project or activity.

15.9.1.3 Spatio-temporal Boundaries of the Cumulative Effects Assessment

The cumulative effects 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 intermediate component and receptor VCs and with other projects and activities; the constraints that may be placed on the assessment of those interactions due to political, social, and economic realities (administrative boundaries); and limitations in predicting or measuring changes (technical boundaries). The definition of these assessment boundaries is an integral part of the fish and fish habitat cumulative effects assessment, and encompasses possible direct, indirect, and induced effects of the Project on fish and fish habitat.

Spatial Boundaries

Watersheds with the potential to be affected by the Project activities include the Unuk River, Sulphurets Creek, Bell-Irving River, and Bowser River watersheds. Past, present, and/or potential future activities may combine to affect fish and fish habitat in the LSA and RSA, in cumulative effects assessment boundaries, or in downstream watersheds. The fish and fish habitat cumulative effects assessment boundary is the same as the RSA. The RSA was selected based upon watersheds within, upstream, and downstream of the Project with a potential for direct effects. Since fish distribution and habitat utilization is related to watersheds, the same principles were applied to defining the cumulative effects assessment boundary. Projects that are located outside of the identified watershed boundaries were excluded from the cumulative effects assessment.

The past projects and human activities that may affect fish and fish habitat and spatially overlap potential effects from the Project are (Figure 15.9-1):

- the Eskay Creek Mine (effluent flows into the Unuk River);
- the Sulphurets Project (tailing drain into Sulphurets Creek);
- the Granduc Mine (concentrator effluent flowed into the Bowser River Valley to Bowser Lake; access corridor overlaps);
- fishing; and
- past forestry activities.

Present and future projects and human activities with potential effects to fish and fish habitat that overlap spatially with potential effects from the Project include:

- the Northwest Transmission Line (access corridor overlaps within Bell-Irving River watershed);
- the Granduc Copper Mine (access corridor overlaps);
- Brucejack Exploration (access road use);
- the KSM Project (discharge into Sulphurets Creek; development in Sulphurets Creek and Mitchell Creek; access corridor overlaps);
- fishing; and
- possible future forestry activities.

Temporal Boundaries

Effects to fish and fish habitat from past projects and human activities may temporally overlap with potential effects from the Project, if discharge from the activities persists in the aquatic environment or if habitat has not had sufficient time to recover from past effects.

Past projects and human activities that may overlap temporally with the Project are:

- the Eskay Creek Mine;
- the Sulphurets Project;
- the Granduc Mine;
- fishing; and
- past forestry activities.

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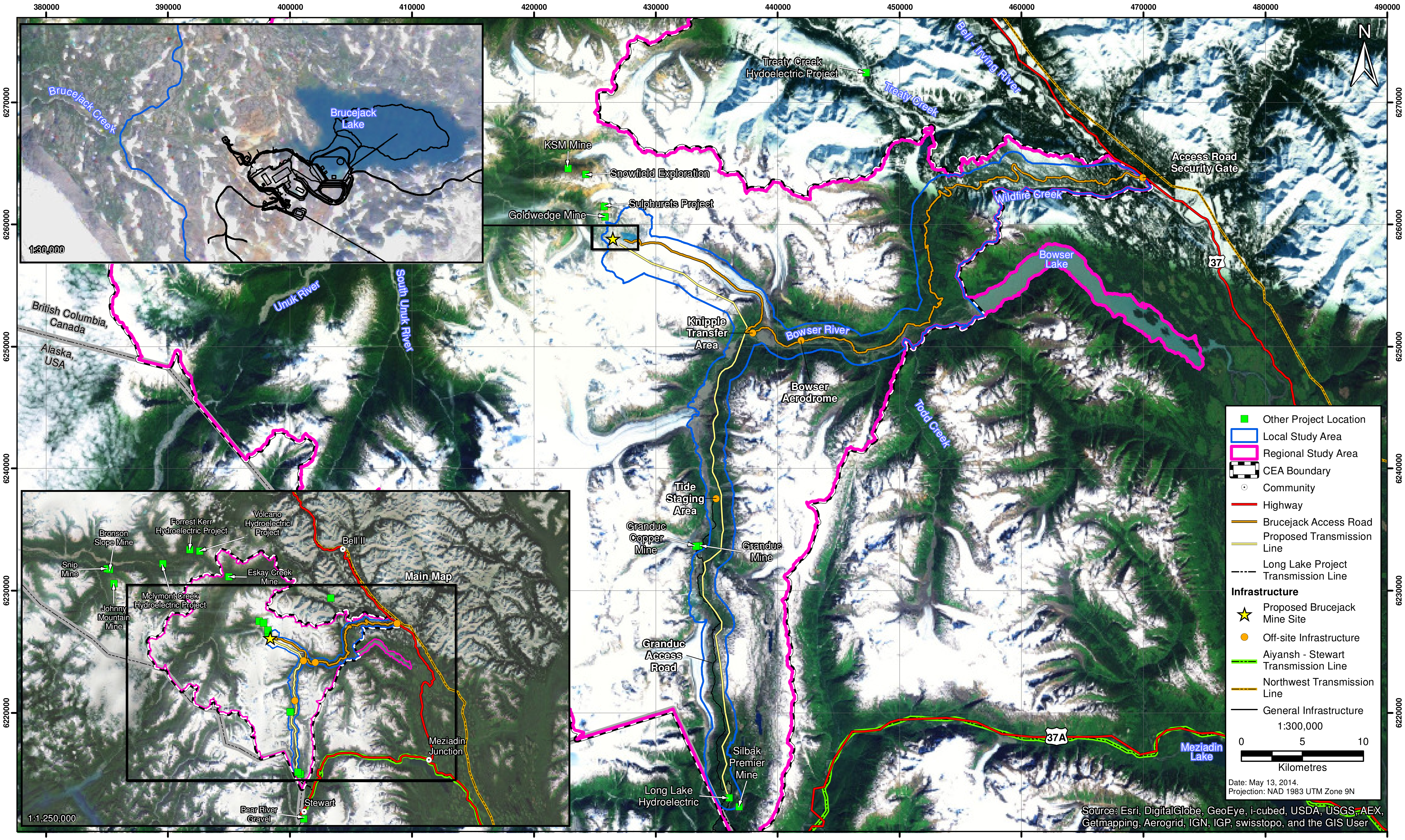
Figure 15.9-1
Cumulative Effects Assessment Boundary Showing all other Projects and Activities Relevant to Fish and Fish Habitat near the Project



Present and future projects and human activities with potential effects to fish and fish habitat that could overlap temporally with potential effects from the Project are:

- the Northwest Transmission Line;
- the Granduc Copper Mine;
- Brucejack Exploration;
- the KSM Project;
- fishing; and
- possible future forestry activities.

15.9.1.4 Potential for Cumulative Effects

Table 15.9-2 presents a summary of projects and activities with the potential to interact cumulatively with expected Project-specific residual effects for fish and fish habitat VCs.

Table 15.9-2. Potential Cumulative Effects between the Brucejack Gold Mine Project Fish and Fish Habitat and Other Projects and Activities

Residual Effect	Brucejack Gold Mine Project	Past Project or Activity	Existing Project or Activity	Reasonably Foreseeable Future Project or Activity	Type of Potential Cumulative Effect
Fish					
Blunt tissue trauma causing mortality to all fish life stages	X	Eskay Creek Mine Granduc Mine Fishing Forestry Activities	Northwest Transmission Line Brucejack Exploration Fishing	Granduc Copper Mine Kerr-Sulphurets-Mitchell (KSM) Mine Fishing Forestry Activities	Additive effect decreasing population size
Erosion and sedimentation causing smothering of eggs, decreased feeding efficiency, habitat avoidance	X	Eskay Creek Mine Granduc Mine Forestry Activities	Northwest Transmission Line Brucejack Exploration	Granduc Copper Mine Kerr-Sulphurets-Mitchell (KSM) Mine Forestry Activities	Additive effect decreasing population size and productive capacity
Fish Habitat					
Erosion and sedimentation causing loss of fish habitat	X	Eskay Creek Mine Granduc Mine Forestry Activities	Northwest Transmission Line Brucejack Exploration	Granduc Copper Mine Kerr-Sulphurets-Mitchell (KSM) Mine Forestry Activities	Additive effect decreasing available fish habitat

15.9.2 Analysis of Cumulative Effects

Cumulative effects on fish and fish habitat can occur when potential Project effects combine with effects caused by other projects. When effects from the Project and other activities combine, the effect of the initial effect can increase due to cumulative or synergistic/antagonistic responses. Cumulative effects from past, present, or potential future activities, along with the Project, were assessed to determine the overall effect to fish and fish habitat in the LSA and RSA and downstream watersheds.

No fish and fish habitat information was available for the Sulphurets Project. However, this project was located within the Sulphurets Creek watershed and close to the proposed Brucejack Gold Mine Project and KSM Project. Fish and fish habitat are not present in the Sulphurets Creek watershed (except the lower reach) based upon baseline studies (Rescan 2009, 2010, 2011a, 2012a, 2012b, 2012c), therefore potential impacts on downstream fish and fish habitat were likely similar to the impacts from the proposed Brucejack Gold Mine Project and are considered minor.

No fish and fish habitat information is available for past, present, or future forestry activities (e.g., access roads), fishing harvest, and mineral resource exploration. Therefore, potential effects were considered by their known cause and effect relationships (e.g., fishing increases direct mortality).

The Northwest Transmission Line occurs along Highway 37 and parallels the eastern fish and fish habitat cumulative effects boundary. For the clearing of the right-of-way (ROW) and construction of the transmission line, hundreds of fish bearing stream crossings were surveyed (Rescan 2008). Of these stream crossings, only two fish bearing stream crossings are located along the eastern cumulative effects boundary. These crossings occur outside the cumulative effects boundary; however, as the Northwest Transmission Line project occurs within 1 km of the boundary, all effects on fish and fish habitat were reviewed.

The fish and fish habitat cumulative effects boundaries are based upon the watersheds in which the proposed Brucejack Gold Mine Project is located. As such, the mine area of the KSM Project is located within the cumulative effects boundary (Sulphurets Creek and Unuk River watersheds), while the processing and tailings management area of the KSM Project is located outside of the cumulative effects boundary (Teigen Creek, Treaty Creek). Therefore, the mine area of the KSM Project was only included in the cumulative effects assessment, as identified potential effects within processing and tailings management area watersheds would not have an interaction with the proposed Brucejack Gold Mine Project. The KSM Project identified residual cumulative effect on fish and fish habitat due to changes in water quality (i.e., metals) downstream of the mine area, but it was not expected to be significant due to the mitigation plans. The KSM Project identified residual cumulative effect on fish and fish habitat due to habitat loss and alteration along the Coulter Creek Access Road, but it was not expected to be significant due to the fish habitat compensation and mitigation plans.

There was a total of 14 fish bearing stream crossings during the construction of the exploration access road for the Brucejack Exploration Project (Cambria Gordon 2012; FINS Consulting 2011; Pretivm 2012). There was no fish habitat loss associated with the construction of the stream crossings (Cambria Gordon 2012; Pretivm 2012). Fish species were not affected during the construction of the exploration access road. Ongoing effects of road maintenance are addressed in this assessment.

15.9.2.1 Cumulative Effects on Fish and Fish Habitat

<u>Project-specific Cumulative Effects of Direct Mortality</u>

Fishing and the use of heavy equipment in and around water may affect fish in a cumulative manner, if the activities were to drastically increase or spatially extend across a broad area. Increased fishing pressure on Bull Trout, Rainbow Trout/Steelhead, and Pacific Salmon may occur due to improved access to waterbodies near the LSA and RSA. Increased fishing pressure may occur because of all identified relevant projects and activities. The majority of past, present, and future projects may cumulatively increase fish mortality; however, the potential for increased mortality is low because there are no fish present within most project infrastructure. Fish are not present within the mine footprint areas of the Eskay Creek Mine, Granduc Mine (past project), Sulphurets Project, KSM Project, and Granduc Copper Mine (potential future project).

However, there are fish present within watercourses at past/present/future access roads. The use of heavy equipment caused by the construction and maintenance of access roads may contribute cumulatively to direct mortality effects; however, fish mortality did not occur as a result of exploration access road development.

Project-specific Cumulative Effects of Erosion and Sedimentation

The geographic scope of erosion and sedimentation can range from localized to far-reaching events depending on the amount and type (e.g., particle size) of sediment that is introduced into the aquatic environment. In addition, sedimentation effects can occur throughout the Project's Construction, Operation, and Closure phases. These spatial and temporal properties of erosion and sedimentation are likely similar for other projects and activities that may act cumulatively with potential Project-related erosion and sedimentation effects.

The majority of past, present, and future projects may cumulatively affect fish from increased sedimentation. The potential for increased sedimentation is low because there are no fish present within most project infrastructure, and fish are located a considerable distance (20 km) downstream from most project infrastructure. Fish are not present within the mine footprints of Eskay Creek Mine, Granduc Mine, Sulphurets Project, KSM Project, and Granduc Copper Mine. The nearest fish-bearing watercourse downstream of these projects are as follows: Eskay Creek Mine – Unuk River; Granduc Mine – Bowser River; Sulphurets Project – lower reach of Sulphurets Creek/Unuk River; KSM Project – lower reach of Sulphurets Creek/Unuk River; and Granduc Copper Mine – Bowser River.

However, there are fish present within watercourses at past, present, and future access roads, in which erosion events could occur. The use of heavy equipment caused by the construction and maintenance of access roads may contribute cumulatively to sedimentation effects on fish; however, sedimentation events did not occur as a result of exploration access road development.

Project-specific Cumulative Effects of Habitat Loss

Cumulative effects associated with fish habitat loss and alterations are expected to occur in the cumulative effects study area. There are no fish present within most areas with project infrastructure, such as the Eskay Creek, Granduc, Sulphurets, KSM Project, and Granduc Copper mines. The Northwest Transmission Line Project has caused the loss of fish habitat through the removal of riparian habitat due to the installation of the transmission line alignment. Construction of the exploration access road did not result in the loss of fish habitat within fish bearing stream crossings.

Lost and altered fish habitat will be compensated for as per federal project-specific Fish Habitat/Fisheries Offset Compensation plans. These compensation plans must be approved by DFO and must achieve no net loss of fish habitat/fisheries; therefore, cumulative effects associated with past, present, and future projects are minimal.

15.9.3 Mitigation Measures to Address Cumulative Effects

15.9.3.1 Mitigation Measures to Address Cumulative Effects on Fish and Fish Habitat

Project-specific Cumulative Effects Mitigations for Direct Mortality

The effects of direct mortality are generally spatially and temporally isolated. Thus, effects are unlikely to become cumulative if the mitigation and management plans pertaining to fishing and the use of equipment in and around water are applied. Project-specific cumulative effect mitigations are the same as previously mentioned in Section 15.5.1.2, Mitigation Measures for Fish and Fish Habitat.

It is anticipated that other projects will adopt the same mitigation strategies as the Project. Mitigation measures proposed for the Project are in accordance with standards stated in federal and provincial guidelines (e.g., DFO *Land Development Guidelines for the Protection of Aquatic Habitat* [DFO 1993], BC MWLAP *Standards and Best Practices for Instream Works* [BC MWLAP 2004], and Pacific Region Operational Statements [DFO 2007]), to which all projects are subject.

Project-specific Cumulative Effects Mitigations for Erosion and Sedimentation

Project-specific cumulative effect mitigations are the same as previously mentioned in Section 15.5.1.2, Mitigation Measures for Fish and Fish Habitat.

It is anticipated that other projects will adopt the same mitigation strategies as the Project. Mitigation measures proposed for the KSM Project are in accordance with standards stated in federal and provincial guidelines (e.g., DFO *Land Development Guidelines for the Protection of Aquatic Habitat* [DFO 1993], BC MOE *Standards and Best Practices for Instream Works* [BC MWLAP 2004], *Fish-Stream Crossing Guidebook* [BC MOF 2002], and Pacific Region Operational Statements [DFO 2007]), to which all projects are subject.

Project-specific Cumulative Effects Mitigations for Habitat Loss

Mitigation measures to prevent the loss and alteration of fish habitat will be implemented to minimize cumulative effects associated with habitat loss. Guidelines, BMPs, and DFO operational statements must be followed for each project and their activities to minimize the cumulative effect of habitat loss in the cumulative effects study area. Detailed and functional fish habitat compensation plans must also be developed and approved by DFO. Thus, additional mitigation to address potential habitat loss cumulative effects is not required.

15.9.4 Cumulative Residual Effects for Fish and Fish Habitat

Cumulative residual effects are those effects remaining after the implementation of all mitigation measures, as presented in Table 15.9-3. Cumulative residual effects are summarized as:

- direct mortality: blunt tissue trauma causing mortality to early life history stages, fishing harvest causing mortality to adult life stages;
- erosion and sedimentation: smothering of eggs, decreased feeding efficiency, habitat avoidance; and
- fish habitat: erosion and sedimentation causing physical loss of fish habitat.

Table 15.9-3. Summary of Cumulative Residual Effects on Fish and Fish Habitat

Fish and Fish Habitat	Timing of Cumulative Residual Effect	Description of Cause-Effect	Description of Additional Mitigation (if any)	Description of Cumulative Residual Effect
Fish				
Blunt tissue trauma	Construction Operation Closure	Impact with construction machinery causing fish mortality; Increased fishing access causing increased harvest of game fish species.	Use of best management practices to minimize fish mortality with construction machinery; Adhere to DFO's operational statements; Adhere to appropriate construction operating window for instream work; Site isolation; Controlled access; Implement no fishing policy for employees/contractors.	Blunt tissue trauma causing mortality to early life history stages; Fishing harvest causing mortality to adult life stages.

(continued)

Table 15.9-3. Summary of Cumulative Residual Effects on Fish and Fish Habitat (completed)

Fish and Fish Habitat	Timing of Cumulative Residual Effect	Description of Cause-Effect	Description of Additional Mitigation (if any)	Description of Cumulative Residual Effect
Fish *(cont'd)*				
Erosion and sedimentation	Construction Operation Closure	Entry of sediment to water bodies during instream construction and bridge/culvert removal; Entry of sediment to water bodies from road runoff and dust during operation and maintenance; Entry of sediment to water bodies during removal of riparian vegetation; and Altered riparian vegetation causing smothering of eggs, decreased feeding efficiency, habitat avoidance.	Use of best management practices to minimize sediment entry to water bodies; Adhere to DFO's operational statements; Adhere to appropriate construction operating window for instream work and the Soil Environmental Management Plan; Riparian re-vegetation; Dust suppression on roads; Site isolation; Water quality maintenance.	Smothering of eggs, decreased feeding efficiency, habitat avoidance.
Fish Habitat				
Erosion and sedimentation	Construction Operation Closure	Entry of sediment to water bodies during instream construction and bridge/culvert removal; Entry of sediment to water bodies from road runoff and dust during operation and maintenance; Entry of sediment to water bodies during removal of riparian vegetation; and Altered riparian vegetation causing habitat loss.	Use of best management practices to minimize sediment entry to water bodies; Adhere to DFO's operational statements; Adhere to appropriate construction operating window for instream work and the Soil Environmental Management Plan; Riparian re-vegetation; Dust suppressionsuppression on roads; Site isolation; Water quality maintenance.	Physical loss of fish habitat.

15.9.5 Characterizing Cumulative Residual Effects, Significance, Likelihood, and Confidence for Fish and Fish Habitat

The cumulative residual effects for each VC were characterized by considering the Project's incremental contribution to the cumulative residual effect under two scenarios:

- Future case without the Project: a consideration of residual effects from all other past, existing, and future projects and activities on a sub-component without the Brucejack Gold Mine Project.
- Future case with the Project: a consideration of all residual effects from past, existing, and future projects and activities on a sub-component with the Brucejack Gold Mine Project.

This approach helps predict the relative influence of the Brucejack Gold Mine Project on the residual cumulative effect for each VC, while also considering the role of other projects and activities in causing that effect.

15.9.5.1 Cumulative Residual Effects Characterization for Fish and Fish Habitat

In comparing these two scenarios, no changes in magnitude, duration, geographic extent, frequency, reversibility, resiliency, or ecological context are anticipated with the addition of the Project. Therefore, one scenario is presented below.

Tables 15.9-4 and 15.9-5 summarize the assessment of potential cumulative residual effects for fish and fish habitat. Several potential cumulative residual effects were identified that could affect fish and fish habitat in the RSA. These potential cumulative residual effects include direct mortality, erosion and sedimentation, and change in water quality due to petroleum products spills. Each of these potential residual effects is discussed below in relation to fish and fish habitat VCs and their geographic distribution in the RSA.

Direct Mortality

The magnitude of residual cumulative effects associated with direct mortality will be minor because events will be localized and geographically isolated. In addition, direct mortality events will be of short duration and will occur sporadically. Since the timing and duration of direct mortality is short, this effect can be reversed relatively quickly at the population level (not individual level), and the VC will be able to respond and adapt (i.e., resiliency is high).

Erosion and Sedimentation

The magnitude of residual cumulative effects associated with erosion and sedimentation will be minor because events will be localized and geographically isolated. Erosion events, should they occur, will be of medium-term duration (effect lasts from one to five years) and will occur sporadically during Project phases. The effects of erosion and sedimentation cannot be easily reversed, thus reversal will occur over several years (reversible medium term). Furthermore, fish and fish habitat may not be able to fully respond or adapt to the effects of erosion and sedimentation, thus resiliency was assessed as neutral.

15.9.5.2 Likelihood of Cumulative Residual Effects on Fish and Fish Habitat

In keeping with the BC EAO (2013), the likelihood of cumulative effects was considered prior to significance for fish and fish habitat. The probability (likelihood) of the residual cumulative effect occurring was rated as low for all residual effects, except erosion and sedimentation were rated as medium.

15.9.5.3 Significance of Cumulative Residual Effects on Fish and Fish Habitat

The potential cumulative residual effects on fish and fish habitat were associated with direct mortality, erosion and sedimentation, and change in water quality. These effects can possibly interact, creating additive or synergistic effects that have a different extent for the local fish population as a whole. Considering these potential effects on fish and fish habitat in combination with Project infrastructure in the LSA and RSA, and mitigation to minimize effects, the overall potential cumulative residual effect on local fish populations and habitat is not likely to affect the viability of fish and fish habitat VC sub-components and is assessed as **not significant** for all residual cumulative effects.

15.9.5.4 Confidence of Cumulative Residual Effects on Fish and Fish Habitat

Once a significance determination is made, the confidence in the significance prediction is evaluated to assess scientific certainty in the result. The confidence in the significance predictions and use of mitigation measures were rated as high for all potential residual effects. Based upon the certainty associated with the significance conclusions, a more detailed risk assessment (e.g., additional sensitivity analyses) is not believed to be necessary.

Table 15.9-4. Significance Determination of Cumulative Residual Effects for Fish – Future Case with the Project

	Cumulative Residual Effects Characterization Criteria									
Cumulative Residual Effects	**Magnitude** *(low, moderate, high)*	**Duration** *(short, medium, long, far future)*	**Frequency** *(once, sporadic, regular, continuous)*	**Geographic Extent** *(local, landscape, regional, beyond regional)*	**Reversibility** *(reversible short term; reversible long term; irreversible)*	**Resiliency** *(low, neutral, high)*	**Context** *(low, neutral, high)*	**Likelihood** *(low, medium, high)*	**Significance of Adverse Cumulative Residual Effects** *(not significant, significant)*	**Confidence** *(low, medium, high)*
Effect: Blunt tissue trauma causing mortality to all fish life stages. Project Component: Upgrade and use of exploration access road Timing: Construction	Low	Short	Sporadic	Local	Reversible short term	High	High	Low	Not significant	High
Effect: Blunt tissue trauma causing mortality to all fish life stages. Project Component: Brucejack Access Road use and maintenance Timing: Operation	Low	Short	Sporadic	Local	Reversible short term	High	High	Low	Not significant	High
Effect: Blunt tissue trauma causing mortality to all fish life stages. Project Component: Decommissioning of Brucejack Access Road Timing: Closure	Low	Short	Sporadic	Local	Reversible short term	High	High	Low	Not significant	High
Effect: Erosion and sedimentation causing smothering of eggs, decreased feeding efficiency, habitat avoidance Project Component: Upgrade and use of exploration access road Timing: Construction	Low	Medium	Sporadic	Local	Reversible medium term	Neutral	Neutral	Medium	Not significant	High
Effect: Erosion and sedimentation causing smothering of eggs, decreased feeding efficiency, habitat avoidance Project Component: Brucejack Access Road use and maintenance Timing: Operation	Low	Medium	Sporadic	Local	Reversible medium term	Neutral	Neutral	Medium	Not significant	High
Effect: Erosion and sedimentation causing smothering of eggs, decreased feeding efficiency, habitat avoidance Project Component: Decommissioning of Brucejack Access Road Timing: Closure	Low	Medium	Sporadic	Local	Reversible medium term	Neutral	Neutral	Medium	Not significant	High
Overall Effect	Low	Short	Sporadic	Landscape	Reversible medium term	Neutral	Neutral	Medium	Not significant	High

Table 15.9-5. Significance Determination of Cumulative Residual Effects for Fish Habitat - Future Case with the Project

Cumulative Residual Effects	Cumulative Residual Effects Characterization Criteria									
	Magnitude *(low, moderate, high)*	**Duration** *(short, medium, long, far future)*	**Frequency** *(once, sporadic, regular, continuous)*	**Geographic Extent** *(local, landscape, regional, beyond regional)*	**Reversibility** *(reversible short term; reversible long term; irreversible)*	**Resiliency** *(low, neutral, high)*	**Context** *(low, neutral, high)*	**Likelihood** *(low, medium, high)*	**Significance of Adverse Cumulative Residual Effects** *(not significant, significant)*	**Confidence** *(low, medium, high)*
Effect: Erosion and sedimentation causing loss of fish habitat Project Component: Upgrade and use of exploration access road Timing: Construction	Low	Medium	Sporadic	Local	Reversible medium term	Neutral	Neutral	Medium	Not significant	High
Effect: Erosion and sedimentation causing loss of fish habitat Project Component: Brucejack Access Road use and maintenance Timing: Operation	Low	Medium	Sporadic	Local	Reversible medium term	Neutral	Neutral	Medium	Not significant	High
Effect: Erosion and sedimentation causing loss of fish habitat Project Component: Decommissioning of Brucejack Access Road Timing: Closure	Low	Medium	Sporadic	Local	Reversible medium term	Neutral	Neutral	Medium	Not significant	High
Overall Effect	Low	Medium	Sporadic	Local	Reversible medium term	Neutral	Neutral	Medium	Not significant	High

15.10 CONCLUSIONS FOR FISH AND FISH HABITAT

The key assumptions of the fish and fish habitat effects assessment are:

- Assessment and determination of any potential residual and cumulative effects assumed that all guidelines, mitigation and management plans, BMPs, regulations, and operating standards designed to protect fish and aquatic resources are strictly adhered to.
- Assessment and determination of discharge-related potential effects on downstream fish and fish habitat relied upon the accuracy of water quality modelling data results.

The key limitation of the fish and fish habitat cumulative effects assessment is:

- Assessment and determination of any potential cumulative effects was based upon limited quantitative data available from interacting projects within the cumulative effects study area.

Table 15.10-1 presents a summary of the assessment of potential environmental effects for fish and fish habitat.

Table 15.10-1. Predicted Changes to Fish and Fish Habitat

Residual Effects	Project Phase(s)	Mitigation Measures	Significance of Residual Effects	
			Project	**Cumulative**
Fish				
Blunt tissue trauma	Construction Operation Closure	Use of best management practices to minimize fish mortality with construction machinery; Adhere to DFO's operational statements; Adhere to appropriate construction operating window for instream work; Site isolation; Controlled access; Implement no fishing policy for employees and contractors	Not significant	Not significant
Erosion and sedimentation	Construction Operation Closure	Use of best management practices to minimize sediment entry to waterbodies; Adhere to DFO's operational statements; Adhere to appropriate construction operating window for instream work and the Soils Environmental Management Plan; Riparian re-vegetation; Dust suppressionsuppression on roads; Site isolation; Water quality maintenance	Not significant	Not significant
Fish Habitat				
Erosion and sedimentation	Construction Operation Closure	Use of best management practices to minimize sediment entry to waterbodies; Adhere to DFO's operational statements; Adhere to appropriate construction operating window for instream work and the Soils Environmental Management Plan; Riparian re-vegetation; Dust suppressionsuppression on roads; Site isolation; Water quality maintenance	Not significant	Not significant

Residual non-significant effects for fish are direct mortality, erosion and sedimentation. There is negligible potential that Brucejack Lake discharge will lead to an increase in fish tissue metal concentrations downstream in Lower Sulphurets Creek (below the cascades) or in the Unuk River.

There is no anticipated Project-specific fish habitat loss caused through the construction, operation, and closure of Project infrastructure. Overall, potential Project-related residual effects on fish habitat were assessed as **not significant**.

REFERENCES

1985. *Fisheries Act*, RSC. C. F-14.

1996. *Water Act*, RSBC. C. 483.

1997. *Fish Protection Act*, SBC. C. 21.

2002a. *Canada Species at Risk Act*, SC. C. 29.

2002b. *Environmental Assessment Act*, SBC. C. 43.

2002c. *Forest and Range Practices Act*, SBC. C. 69. s. 149.1.

2003. *Environmental Management Act*, SBC. C. 53.

2012. *Canadian Environmental Assessment Act, 2012*, SC. C. 19. s. 52.

Metal Mining Effluent Regulations, SOR/2002-222.

Sewerage System Regulation, BC Reg. 326/2004.

Alexander, R. F. and W. R. Koski. 1995. *Distribution, timing and fate of steelhead returning to the Nass River watershed in 1993*. Nisga'a Fisheries Report No. NF93-10. Nisga'a Tribal Council: New Aiyansh, BC.

Alkindi, A. Y. A., J. A. Brown, C. P. Waring, and J. E. Collins. 1996. Endocrine, osmoregulatory, respiratory and haematological parameters in flounder exposed to the water soluble fraction of crude oil. *J Fish Biol,* 49:1291–305.

Allan, J. D., M. S. Wipfli, J. P. Caouette, A. Prussian, and J. Rodgers. 2003. Influence of streamside vegetation on inputs of terrestrial invertebrates to salmonid food webs. *Can J Fish Aquat Sci,* 60:309–20.

Anthony, V., G. Finger, and R. Armstrong. 1965. *King salmon (Oncorhynchus tshawytscha) spawning ground surveys in the Behm Canal Area of Southeastern Alaska*. Informational Leaflet 63. Alaska Department of Fish and Game: Juneau, AK.

Baatrup, E. 1991. Structural and functional effects of heavy metals on the nervous system, including sense organs, of fish. *Comp Biochem Physiol C,* 100:253-257.

BC EAO. 2013. *Guidelines for the selection of valued components and assessment of potential effects*. British Columbia Environmental Assessment Office: Victoria, BC.

BC ILMB. 2000. *Cassiar Iskut-Stikine Land and Resource Management Plan*. British Columbia Integrated Land Management Bureau. http://www.ilmb.gov.bc.ca/slrp/lrmp/smithers/cassiar/index.html (accessed September 2013).

BC MFLNRO. 2012. Nass South Sustainable Resource Management Plan. http://www.ilmb.gov.bc.ca/slrp/srmp/south/nass/index.html (accessed September 2013).

BC MOE. 2006a. A *compendium of working water quality guidelines for British Columbia*. http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html#table2. (accessed October 2013).

BC MOE. 2006b. *British Columbia approved water quality guidelines*. 2006 Edition. Prepared by the British Columbia Ministry of Environment, Environmental Protection Division: Victoria, BC.

BC MOE. 2008. *Fisheries Information Summary System (FISS)*. Ministry of Environment. http://a100.gov.bc.ca/pub/fidq/main.do (accessed June 2013).

BC MOE. 2009a. *BC Ministry of Environment*. BC Species and Ecosystems Explorer. http://a100.gov.bc.ca/pub/eswp/ (accessed January 2010).

BC MOE. 2009b. Habitat Wizard. BC Ministry of Environment, Ecosystems Branch. http://webmaps.gov.bc.ca/imfx/imf.jsp?session=954648956850 (accessed June 2013).

BC MOF. 2002. *Fish-stream crossing guidebook*. BC Forest Practices Code Guidebook. Victoria, BC: Forest Practices Branch, British Columbia Ministry of Forests.

BC MWLAP. 2004. *Standards and best practices for instream works*. British Columbia Ministry of Environment: n.p.

Beckvar, N., T. M. Dillon, and L. B. Read. 2005. Approaches for linking whole-body fish tissue residues of mercury of DDT to biological effects thresholds. *Environ. Toxicol. Chem,* 24:2094-2105.

Bell, H. L. 1971. Effect of low pH on the survival and emergence of aquatic insects. *Water Res.* 5:313-319.

Beschta, R. L., J. R. Boyle, C. C. Chambers, W. P. Gibson, S. V. Gregory, J. Grizzel, J. C. Hagar, J. L. Li, W. C. McComb, M. L. Reiter, G. H. Taylor, and J. E. Warila. 1995. *Cumulative effects of forest practices in Oregon*. Prepared for the Oregon Department of Forestry. Salem, OR; Oregon State University, Corvallis, OR.

Bilby, R. E. and J. W. Ward. 1989. Changes in characteristics and function of woody debris with increasing size of streams in western Washington. *Trans Am Fish Soc* 118:368–78.

Bisson, P. A., R. E. Bilby, M. D. Bryant, C. A. Dolloff, G. B. Grette, R. A. House, M. L. Murphy, K. V. Koski, and J. R. Sedell. 1987. Large woody debris in forested streams in the Pacific Northwest: past, present, and future. In *Streamside management: forestry and fishery interactions*. Ed. E. O. Salo and T. W. Cundy. 143–90. Contribution No. 57. Seattle, WA:. Institute of Forest Resources, University of Washington.

Bryant, M. D. and M. D. Lukey. 2004. Movement of Dolly Varden and cutthroat trout in high gradient headwater streams with implications for fish passage standards. USDA Forest Service: Juneau, AK.

Camargo, J. A., A. Alonso, and A. Salamanca. 2005. Nitrate toxicity to aquatic animal: a review with new data for freshwater invertebrates. *Chemosphere,* 58:1255–67.

Cambria Gordon. 2012. Brucejack Access Road: Review of stream crossings in support of DFO and Transport Canada review. Prepared for Pretium Resource Inc.: Terrace, BC.

Carballo, M., M. J. Muńoz, M. Cuellar, and J. V. Tarazona. 1995. Effects of waterborne copper, cyanide, ammonia, nitrite on stress parameters and changes in susceptibility to Saprolegniosis in rainbow trout (*Oncorhynchus mykiss*). *Appl Environ Microbiol,* 61: 2108-12.

CCME. 2000. Canadian environmental quality guidelines: tissue residue guidelines for the protection of wildlife consumers of aquatic biota, methylmercury. Canadian Council of Ministers of the Environment: Winnipeg, MB. http://st-ts.ccme.ca/ (accessed December 2012).

CCME. 2004. *Canadian environmental quality guidelines for the protection of aquatic life; phosphorus*: Canadian guidance for the management of freshwater systems. Winnipeg, MB: Canadian Council of Ministers of the Environment. http://st-ts.ccme.ca/ (accessed December 2012).

CEA Agency. 2013. *Operational policy statement: Assessing cumulative effects under the Canadian Environmental Assessment Act, 2012*. Canadian Environmental Assessment Agency: Ottawa, ON.

Chapman, D. W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. *Transactions of the American Fisheries Society* 117:1–21. Bethesda, MD.

Chapman, P. M., W. J. Adams, M. L. Brooks, C. G. Delos, S. N. Luoma, W. A. Maher, H. M. Ohlendorf , T. S. Presser, and D. P. Shaw. 2009. *Ecological assessment of selenium in the aquatic environment: Summary of a SETAC Pellston Workshop*. Society of Environmental Toxicology and Chemistry: Pensacola, FL.

Coombes, D. M. V. 1988. *A reconnaissance survey of Bowser Lake*. M.U. 6-16. Fisheries Branch, BC Environment: Victoria, B.C.

Cordone, A. J. and D. W. Kelley. 1961. *The influences of inorganic sediment on the aquatic life of streams*. California Fish and Game 47:188–227. Vol. 47, No. 2. California Department of Fish and Game, Inland Fisheries Branch: Sacramento, CA.

Crisp, D. T. 1996. Environmental requirements of common riverine European salmonid fish species in fresh water with particular reference to physical and chemical aspects. *Hydrobiologia,* 323: 201–21.

Cummins, K., D. Botkin, T. Dunne, H. Regier, M. Sobel, and L. Talbot. 1994. *Status and Future of Salmon of Western Oregon and Northern California: Management of the Riparian Zone for the Conservation and Production of Salmon*. Draft research report. Santa Barbara, CA: The Center for the Study of the Environment.

Denton, K.P., H. B. Rich Jr., and T. P. Quinn. 2009. Diet, Movement, and Growth of Dolly Varden in Response to Sockeye Salmon Subsidies. *Transactions of the American Fisheries Society* 138: 1207-1219.

Devaris, A. 2013. *Southeast Alaska Jokulhlaups, US National Weather Service, Juneau Alaska*. http://pajk.arh.noaa.gov/Articles/articles/jokulhlaups/Jokulhlaups.html (accessed March 2013).

DFO. 1987. *Unuk River reconnaissance, 1987*. Department of Fisheries and Oceans memorandum. Whitehorse, YK.

DFO. 1991. *The Department of Fisheries and Oceans: Policy for the management of fish habitat*. Department of Fisheries and Oceans: Ottawa, ON.

DFO. 1993. *Land development guidelines for the protection of aquatic habitat*. Department of Fisheries and Oceans, Ottawa, ON.

DFO. 2007. *Pacific Region Operational Statements*. http://www.pac.dfo-mpo.gc.ca/habitat/oseo/indexeng.htm (accessed October 2013).

DFO. 2009. *Mapster*. Fisheries and Oceans Canada. http://www.canbcdw.pac.dfo-mpo.gc.ca/ows/imf.jsp?site=mapster (accessed November 4, 2009).

DFO. 2013. *Fisheries Protection Policy Statement*. http://www.dfo-mpo.gc.ca/pnw-ppe/pol/index-eng.html (accessed January 2014).

Dunham, J., C. Baxter, K. Fausch, W. Fredenberg, S. Kitano, I. Koizumi, K. Morita, T. Nakamura, B. Rieman, K. Savvaitova, J. Stanford, E. Taylor, S. Yamamoto. 2008. Evolution, ecology, and conservation of Dolly Varden, white-spotted char, and bull trout. *Fisheries,* 33: 537-550.

English, K. K., T. Mochizuki, and D. Robichaud. 2012. *Review of north and central coast salmon indicator streams and estimating escapement, catch and run size for each salmon conservation unit*. Prepared for the Pacific Salmon Foundation and Fisheries and Oceans Canada by LGL Limited: Sidney, BC.

Environment Canada. 1995. *Canadian biodiversity strategy - Canada's response to the Convention on Biological Diversity*. Environment Canada: Ottawa, ON.

Environment Canada. 2011. 2011 *Metal Mining Environmental Effects Monitoring (EEM) Technical Guidance Document*. Environment Canada: Ottawa, ON.

Environment Canada. 2012. *2012 Metal Mining Environmental Effects Monitoring Technical Guidance*. Environment Canada: Ottawa, ON.

ESSA Technologies Ltd. and IFC. 2012. Good Practice Note – Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets. Jointly prepared by ESSA Technologies Ltd. and the International Finance Corporation – World Bank Group: Richmond Hill, ON and Washington, DC.

Evans, D. H. 1987. The fish gill: site of action and model for toxic effects of environmental pollutants. *Environ Health Perspect*, 71:41–58.

FINS Consulting. 2011. 2010 Stream assessment in the Bowser Lake area: Fish habitat assessments for select streams crossed by the proposed Silver Standard Mine Access Road. Prepared for Cypress Forest Consultants Ltd.: Terrace, BC.

Fryday, S. N. L., D. M. Andrew, A. D. M. Hart, and S. D. Langton. 1996. Effects of exposure to an organophosphate pesticide on the behavior and use of cover by captive starlings. *Environ Toxicol Chem,* 15:1590–96.

Furniss, M. J., T. D. Roelofs, and C. S. Yee. 1991. Road construction and maintenance. *American Fisheries Society Special Publication,* 19: 297-323.

Goodfellow, W. L., Ausley, L. W., Burton, D. T., Denton, D. L., Dorn, P. B., Grothe, D. R., Heber, M. A., Norberg-King, T. J., and Rodgers, J. H. 2000. Major ion toxicity in effluents: a review with permitting recommendations. *Environ Toxicol Chem*, 19:175-182.

Government of Canada. 2012. Species at Risk Public Registry. http://www.sararegistry.gc.ca (accessed May 2013).

Grigg, R. W. 1994. Effect of sewage discharge, fishing pressure and habitat complexity on coral ecosystems and reef fishes in Hawaii. *Marine Ecol Prog Ser,* 103: 25-34.

Hancock, M. J. and D. E. Marshall. 1984. Catalogue of salmon streams and spawning escapements of sub-districts 120 and 130 (Alsek-Stikine-Taku Watersheds). Canadian Data Report of Fisheries and Aquatic Sciences 456. Department of Fisheries and Oceans, Enhancement Services Branch: Vancouver, BC.

Hansen, J. A., D. F. Woodward, E. E. Little, A. J. DeLonay, and H. L. Bergman. 1999. Behavioral avoidance: possible mechanism for explaining abundance and distribution of trout species in a metal impacted river. *Environ Toxicol Chem,* 18:313–17.

Hawkins, C. P., M. L. Murphy, and N. H. Anderson. 1982. Effects of canopy, substrate composition, and gradient on the structure of macroinvertebrate communities in Cascade range streams of Oregon. *Ecology,* 63:1840–1856.

Health Canada. 2011. Canadian guidelines for chemical contaminants and toxins in fish and fish products. http://www.inspection.gc.ca/food/fish-and-seafood/manuals/standards-and-methods/eng/1348608971859/1348609209602 (acceseed October 2013).

Hedtke, S. F. and F. A. Puglisi. 1982. Short-term toxicity of five oils to four freshwater species. *Arch Environ Contamin Tox,* 11:425–30.

Hultbert, H. and I. B. Andersson. 1982. Liming of acidified lakes: induced long-term changes. *Water Air Soil Poll,* 18: 331-31.

Ihlenfeldt, N. 2005. An annotated bibliography: Above barrier resident Dolly Varden (*Salvelinus malma*) and related studies. Technical Report N. 05-05. Alaska Department of Natural Resources. Juneau, AK.

Ingendahl, D. 2001. Dissolved oxygen concentration and emergence of sea trout fry from natural redds in tributaries of the River Rhine. *J Fish Biol,* 58: 352–54.

Jobling, S., Nolan, M., Tyler, C.R., Brighty, G., and Sumpter, J.P. 1998. Widespread sexual disruption in wild fish. *Environ Sci Technol,* 32: 2498-2506.

Johnson, D. H., B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O'Neil, and T. N. Pearsons. 2007. Salmonid field protocols handbook: Techniques for assessing status and trends in salmon and trout populations. Maryland: American Fisheries Society.

Johnston, N. T. and P. A. Slaney. 1996. Fish habitat assessment procedures. Watershed Technical Circular 8.

Jones, D. P., K. E. Ricker, J. R. Desloges, and M. Maxwell. 1985. Glacier outburst flood on the Noeick River: the draining of Ape Lake, British Columbia. Geological Survey of Canada, Open File Report 1139.

Kennedy, C. J. and Picard, C. 2012. Chronic low pH exposure affects seawater readiness of juvenile Pacific sockeye salmon. *Fish Physiol. Biochem,* 38:1131-1143.

Kidd, K. and K. Batchelar. 2012. 5 – Mercury. Volume 31, Part B. In *Fish Physiology – Homeostasis and Toxicology of Non-Essential Metals*. Ed. C. M. Wood, A. P. Farrell, and C. J. Brauner. 237-295. San Diego, CA: Academic Press.

Kime, D. E. 1998. *Endocrine Disruption in Fish*. Boston, MA: Kluwer Academic Publishers.

Kimmel, W. G. 1983. The impact of acid mine drainage on the stream ecosystem. In *Pennsylvania Coal: Resources, Technology and Utilization*. Eds. S. K. Majumdar and W. W. Miller. Pittsburgh, PA: Pittsburgh Science and Technology Academy.

Knight Piesold Ltd. and Homestake Canada Inc. 1993. *Eskay Creek Project Application Report*. Prepared for Prime Resources Group Inc. and Stikine Resources Ltd.: Vancouver, BC.

Laniberti, G. A., S. V. Gregory, R. Ashkenas, R. C. Wildmaii, and K. M. S. Moore. 1991. Stream ecosystem recovery following a catastrophic debris flow. *Canadian Journal of Fisheries and Aquatic Sciences,* 48:196–208.

Lewis, W. M. and D. P. Morris. 1986. Toxicity of nitrite to fish: a review. *Trans Am Fish Soc,* 115:183–95.

Lisle, T. E. 1989. Sediment transport and resulting deposition in spawning gravels, North Coastal California. *Water Resour Res,* 25:1303–19.

Little, E. E. and A. J. DeLonay. 1996. Measures if fish behavior as indicators of sublethal toxicosis during standard toxicity tests. In *Environmental toxicology and risk assessment 4th Vol*. Ed. T. W. L. Point, F. T. Price, and E. E. Little. West Conshohocken, PA: American Society for Testing and Materials.

Lockhart, W. L., D. A. Duncan, B. N. Billeck, R. A. Danell, and M. J. Ryan. 1996. Chronic toxicity of the 'water-soluble fraction' of Norman Wells crude oil to juvenile fish. *Spill Sci Tech Bull,* 3:259–62.

Lytle, D. A. and B. L. Peckarsky. 2001. Spatial and temporal impacts of a diesel fuel spill on stream invertebrates. *Freshwater Biology,* 46:693–704.

MacLellan, S.G. and J.M.B. Hume. 2011. Pelagic fish surveys of 20 lakes in Northern British Columbia from: 2006 to 2009. Can. Dat. Rep. Fish. Aquat. Sci. 2950. Cultus Lake, BC.

Mathews, W. H. and J. J. Clague. 1993. The record of jokulhlaups from Summit Lake, northwestern British Columbia. *Canadian Journal of Earth Science,* 30: 499-508.

McDonald, B. G., deBruyn, A. M. H., Elphick, J. R. F., Davies, M., Bustard, D., and Chapman, P. 2010. Developmental toxicity of selenium to Dolly Varden char (*Salvelinus malma*). *Environ Toxicol Chem,* 29:2800-2805.

McKean, C. J. and N. K. Nagpal. 1991. Ambient water quality criteria for pH technical appendix. British Columbia Ministry of Environment, Water Quality Branch. Victoria, BC.

McKnight, D. M. and G. L. Feder. 1984. The ecological effect of acid conditions and precipitation of hydrous metal oxides in a Rocky Mountain stream. *Hydrobiologia,* 119:129–38.

McPhail, J. D. 2007. The freshwater fishes of British Columbia. University of Alberta Press. Edmonton, AB.

McCreight, D.K. M.R.S. Johanees, S.P. Murdoch, and K.D. Hyatt. 1993. Fish catch statistics in salmonid nursery lakes of the Nass River system under study by the Interim Measures Fisheries Program. Can. Dat. Rep. Fish. Aquat. Sci. 903. Nanaimo, BC.

Mecum, R. D. and P. D. Kissner. 1989. A study of chinook salmon in southeast Alaska. Fishery Data Series 117. Department of Fish and Game, Division of Sport Fish: Juneau, AK.

Murphy, M. L., C. P. Hawkins, and N. H. Anderson. 1981. Effects of canopy modification and accumulated sediment on stream communities. *Transactions of the American Fisheries Society,* 110:469–78.

Murphy, M. L. and W. Meehan. 1991. Stream ecosystems. *American Fish Society Special Publication* 19:17–46.

Nagpal, N. K. 2001. *Ambient water quality guidelines for selenium: overview*. Prepared for British Columbia Ministry of Environment: Water Protection Branch. Victoria, BC.

Naiman, R. J., T. J. Beechie, L. E. Benda, D. R. Berg, P. A. Bisson, L. H. MacDonald, M. D. O'Connor, P. L. Olson, and E. A. Steel. 1992. Fundamental elements of ecologically healthy watersheds in the Pacific Northwest coastal ecoregion. In *Watershed management: balancing sustainability and environmental change*. Ed. R. J. Nairnan. 127–88. New York, NY: Springer-Verlag.

Newbold, J. D., D. C. Erman, and K. B. Roby. 1980. Effects of logging on macroinvertebrates in stream with and without buffer strips. *Canadian Journal of Fisheries and Aquatic Sciences,* 37:1076–1085.

Newcombe, C. P. and D. D. MacDonald. 1991. Effects of suspended sediments on aquatic ecosystems. *North American Journal of Fisheries Management,* 11:72–82.

Newhawk. 1989. Stage I environmental and socioeconomic impact assessment for the Sulphurets Property. Newhawk Gold Mines Ltd.: Vancouver, BC.

NLG, Government of Canada, Province of BC. 1999. *Nisga'a Final Agreement*. Nisga'a Lisims Government, Province of British Columbia, and Government of Canada: New Aiyansh, BC.

NLG. 2002. *A land use plan for Nisga'a lands*. Lands Department: Directorate of Lands and Resources. New Aiyansh, BC.

Nordin R. N. and L. W. Pommen. 1986. Water quality criteria for nitrogen (nitrate, nitrite, and ammonia) technical appendix. British Columbia Ministry of Environment, Water Management Branch: Victoria, BC.

Novak, P. 1983. *Stream and fisheries rehabilitation activities in Fish Creek - Hyder*. Alaska Department of Fish and Game: Juneau, AK.

Omoregie, E. and B. C. Ufodike. 2000. Effects of water soluble fractions of crude oil on growth of the Nile tilapia, *Oreochromis niloticus* (L.). *Bull Environ Contam Toxicol,* 64:601–05.

Pahlke, K. A., S. A. McPherson, and R. P. Marshall. 1996. *Chinook salmon research on the Unuk River, 1994*. Alaska Department of Fish and Game Fishery Data Series No. 96-14.

Palmer, D. E. and B.E. King. 2005. *Migratory patterns of different spawning aggregates of Dolly Varden in the Kenai River watershed*. In Alaska Fisheries Technical Report Number 86. Edited by USFWS, Anchorage.

Platts, W. S. and W. Megahan. 1975. Time trends in channel sediment size composition in salmon and steelhead spawning areas: South Fork Salmon River, Idaho. USDA Forest Service General Technical Report. Ogden, UT: Intermountain Forest and Ranger Experimental Station.

Poulin, R. 1995. "Adaptive" changes in the behaviour of parasitized animals: A critical review. *Int Jr Parasitol,* 25: 1371-83.

Price, W. 2005. *Case studies of ML/ARD assessment and mitigation: Placement of the sulphurets waste rock in Brucejack Lake*. Prepared for Mine Environment Neutral Drainage (MEND) Program. MEND Report 9.1c

Pretivm. 2012. *Brucejack Project: Access road EIS*. Prepared for Pretium Resources Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2008. *Northwest Transmission Line Project: Fisheries and aquatic resources baseline report 2007*. Prepared for British Columbia Transmission Corporation by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2009. *KSM Project: 2008 fish and fish habitat baseline report*. Prepared for Seabridge Gold Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2010. *KSM Project: 2009 fish and fish habitat baseline report*. Prepared for Seabridge Gold Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2011b. *KSM Project: 2010 fish and fish habitat baseline report*. Prepared for Seabridge Gold Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012a. *KSM Project: 2012 fish and fish habitat baseline report*. Prepared for Seabridge Gold Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012b. *KSM Project: 2012 fish bearing status assessment*. Prepared for Seabridge Gold Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2013a. *Brucejack Project: 2012 fish and fish habitat baseline report*. Prepared for Pretium Resources Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2013b. *KSM Project: Application for an environmental assessment certificate/environmental impact statement*. Prepared for Seabridge Gold Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

RISC. 1999. *Reconnaissance (1:20,000) fish and fish habitat inventory: Site card field guide*. Resources Inventory Standards Committee: Victoria, BC.

RISC. 2001. *Reconnaissance (1:20,000) fish and fish habitat inventory: Standards and procedures*. Victoria, BC: Resources Inventory Standards Committee.

Richardson, J., E. K. Williams, and C. W. Hickey. 2001. Avoidance behaviour of freshwater fish and shrimp exposed to ammonia and low dissolved oxygen separately and in combination. *New Zealand J Marine Fresh Res,* 35: 625-33.

Rutherford, D.T., C.C. Wood, A.L. Jantz, and D.R. Southgate. 1994. Biological characteristics of Nass River sockeye salmon (*Oncorhynchus nerka*) and their utility for stock composition analysis of test fishery samples. Can. Tech. Rep. Fish. And Aquat. Sci. 1988. Nanaimo, BC.

Saborido-Rey, F., R. Domínguez-Petit, J. Tomás, B. Morales-Nin, and A. Alonso-Fernandez. 2007. Growth of juvenile turbot in response to food pellets contaminated by fuel oil from the tanker 'Prestige.' *Marine Ecol Prog Series,* 345: 271-79.

Saimoto, R. K. and R. S. Saimoto. 1998. *Reconnaissance level stream inventory of the Bell-Irving/Bowser watershed*. BC Ministry of Environment: Victoria, BC.

Sanchez-Dardon, J., I. Voccia, A. Hontella, S. Chilmonczyk, M. Dunier, H. Boermans, B. Blakley, and M. Fournier. 1999. Immunomodulation by heavy metals tested individually or in mixtures in rainbow trout (*Oncorhychus mykiss*) exposed in vivo. *Environ Toxicol Chem,* 18:1492-1497.

Servizi, J. A. and R. W. Gordon. 1990. Acute lethal toxicity of ammonia and suspended sediment mixtures to chinook salmon (*Oncorhynchus tshawytscha*). *Bull Environ Contam Toxicol,* 44:650–56.

Shingles, A., D. J. McKenzie, E. W. Taylor, A. Moretti, P. J. Butler, and S. Ceradini. 2001. Effects of sublethal ammonia exposure on swimming performance in rainbow trout (*Oncorhynchus mykiss*). *J Exper Biol,* 204: 2691-98.

Siddall, R., A. W. Pike, and A. H. McVicar. 1994. Parasites of flatfish in relation to sewage sludge dumping. *J Fish Biol* 45:193-209.

Smith, A. K. and I. M. Suthers. 1999. Effects of sewage effluent discharge on the abundance, condition and mortality of hulafish, *Trachinops taeniatus* (Plesiopidae). *Environ Poll,* 106: 97-106.

Stekoll, M. S., Smoker, W. W., Failor-Rounds, B. J., Wang, I. A., and Joyce, V. 2009. Response of the early developmental stages of hatchery reared salmonids to major ions in a simulated mine effluent. *Aquacult,* 298: 182-181.

Struhsaker, J. W. 1977. Effects of benzene (a toxic component of petroleum) on spawning Pacific herring, *Clupea harengus pallasi*. *FB,* 75:45–50.

Sutherland, A. B. and J. L. Meyer. 2007. Effects of increased suspended sediment on growth rate and gill condition of two southern Appalachian minnows. *Environmental Biology of Fishes,* 80:389–403.

Swanson, F. J., S. V. Gregory, J. R. Sedell, and A. G. Campbell. 1982. Land-water interactions: the riparian zone. In *Analysis of coniferous forest ecosystems in the Western United States Volume 14*. Ed. R. L. Edmonds. 267–91. Stroudsburg, PA: Hutchinson Ross Publishing Company.

Swanston, D. N. 1991. Natural processes. In *Influences of forest and rangeland management on salmonid fishes and their habitat*. Ed. W. R. Meelian. 139–79. Bethesda, Maryland: Special Publication 19. American Fisheries Society.

Tagatz, M. E. 1961. Reduced oxygen tolerance and toxicity of petroleum products to juvenile American shad. *Chesapeake Sci* 2:65–71.

THREAT. 2009. *Tahltan traditional use study of the proposed Northwest Transmission Line Project Interim report*. Tahltan Transmission Line Project Team. Tahltan Heritage Resources Environmental Assessment Team. n.p.

Tierney, K. B., D. H. Baldwin, T. J. Hara, P. S. Ross, N. L. Scholz, and C. J. Kennedy. 2010. Olfactory toxicity in fishes. *Aquat Toxicol,* 96: 2-26.

Todd, A. S., D. M. McKnight, C. L. Jaros, and T. M. Marchitto. 2006. Effects of acid rock drainage on stocked rainbow trout (*Oncorhynchus mykiss*): and in-situ, caged fish experiment. *Environ Monit Assess,* 130:111–27.

Tripp, D. 1987. *Fish and limnological surveys of Brucejack Lake and the Unuk, Bowser, and Bell-Irving river systems*. Prepared for Rescan Environmental Services Ltd. by D. Tripp: Vancouver, BC.

Tripp, D. 1988. *Report on fish surveys in the Bowser Lake and Todedada - Treaty Creek areas, October 7 - 10, 1988*. Prepared for Rescan Environmental Services Ltd. by D. Tripp Biological Consultants: Nanaimo, B.C.

Turnpenny, A. W. H. and R. Williams. 1980. Effects of sedimentation on the gravels of an industrial river system. *Journal of Fish Biology* 17:681–93.

US EPA. 1998. *Guidelines for ecological risk assessment*. United States Environmental Protection Agency: Washington, DC.

Vigneault, B., Desforges, M., and McGeer, J. 2009. *Mining reagents and by-products (e.g. thiosalts) as potential toxicants in mine effluents*. Environmental Effects Monitoring Workshop on Investigation of Cause for Metal Mining: Gatineau, QC.

Weis, J. S. and P. Weis. 1989. Effects of environmental pollutants on early fish development. *Rev Aquat Sci,* 1: 45-73.

Weis, J. S., P. Weis, and A. Greenberg. 1989. Treated municipal wastewaters: effects on development and growth of fishes. *Marine Environ Res,* 28: 527-32.

Weller, J. L., E. L. Jones, and A. B. Holm. 2005. *Production of coho salmon from the Unuk River, 2002-2003*. Fishery Data Series No. 05-21. Alaska Department of Fish and Game. n.p.

Wendelaar Bonga, S. E. 1997. The stress response of fish. *Physiol Rev,* 77:591–625.

Wipfli, M. S. and D. P. Gregovich. 2002. Export of invertebrates and detritus from fishless headwater streams in southeast Alaska: Implications for downstream salmonid production. *Freshwat Biol* 47:959–69.

Withler, I. L. 1956. *A survey of the sport-fish potential of the lakes of the Nass River system with particular reference to their use at water storage reservoirs*. British Columbia Fish and Wildlife Branch Fisheries Management Report No. 24.

Wood, C.M. 1989. The physiological problems of fish in acid waters. In *Acid toxicity and aquatic animals* ed. R. Morris, E.W. Taylor, D.J.A. Brown and J.A. Brown. 125-152. Cambridge, MA: Cambridge University Press.

Wood, C. M. 1992. Flux measurements as indices of H+ and metal effects on freshwater fish. *Aquat Toxicol,* 22:239–64.

Ye, X. and D. J. Randall. 1991. The effect of water pH on swimming performance in rainbow trout (*Salmo gairdneri*, Richardson). *Fish Physiol Biochem* ,9: 15-21.

Zbanyszek, R. and L. S. Smith. 1984. The effect of water-soluble aromatic hydrocarbons on some haematological parameters of rainbow trout, *Salmo gairdneri* Richardson, during acute exposure. *J Fish Biol*, 24:545–52.