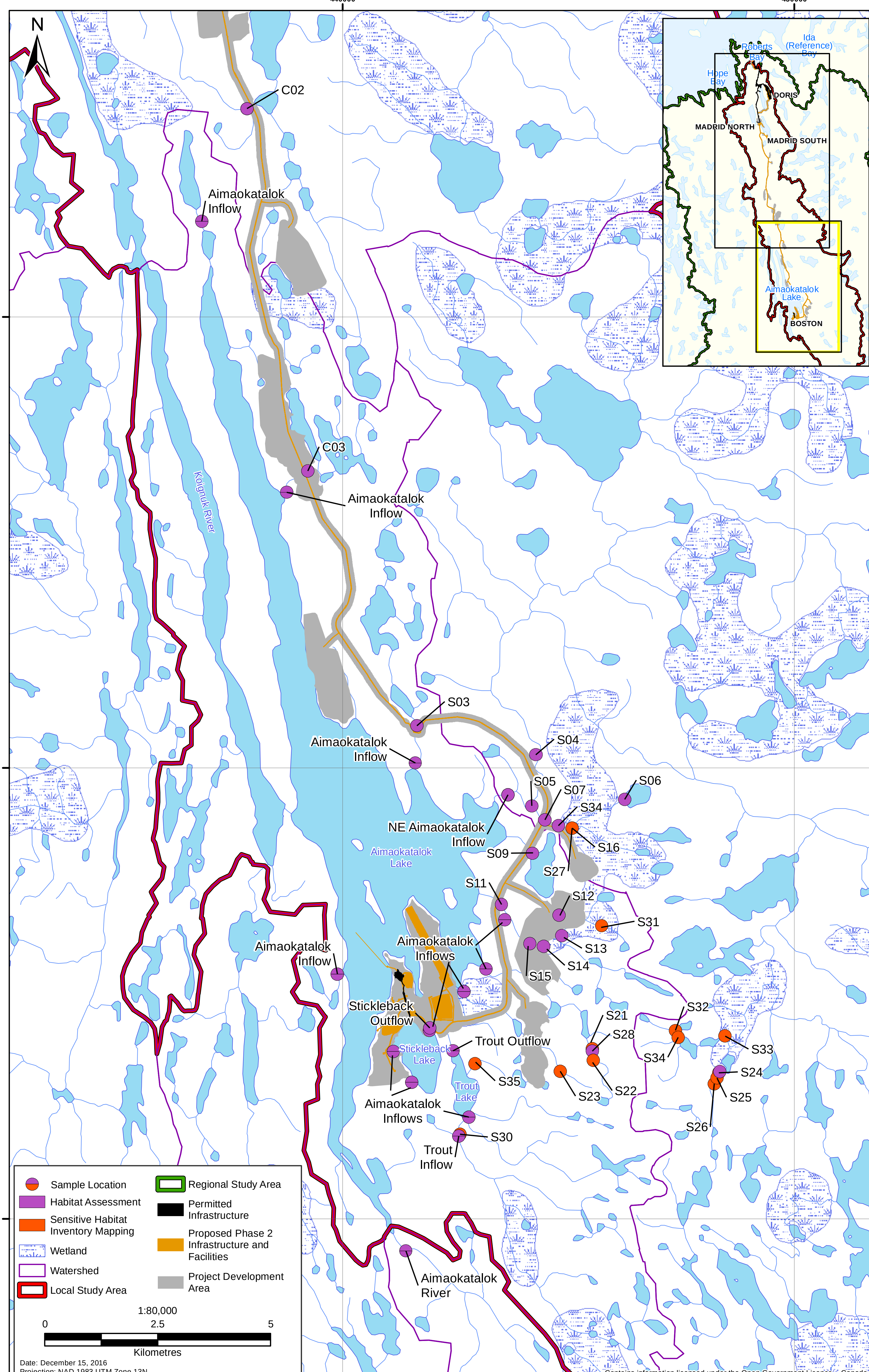
Figure 6.2-11
Freshwater Fish Habitat Surveys in Streams, South Belt, 1993-2015



An early example of reconnaissance surveys is the descriptions of habitat of lakes and streams of the Doris Watershed and of the Koignuk River in 1996 by Klohn-Crippen Consultants Ltd. (1995). Later examples include the survey of 14 headwater lakes of the Roberts Watershed in 2006 (Golder 2007a) and a survey of habitat at six sites along the length of the lower Koignuk River in 2007 (Golder 2008; Golder Associates Ltd. 2008b). Reconnaissance surveys were conducted on a total of 24 lakes and eight streams (Table 6.2-4), with the majority of the surveyed lakes located in the RSA (20) compared to the LSA North (five) and the LSA South (zero).

Bathymetric Mapping

Bathymetric surveys were conducted in a total of 15 lakes (Table 6.2-4). Eleven lakes were surveyed in the LSA: eight in the North Belt (Doris, Ogama, Patch, Wolverine, P.O., P.O. Connector, Imniagut, and Windy), three in the South Belt (Aimaokatalok, Trout, and Stickleback). Four lakes were surveyed in the RSA: Roberts, Little Roberts, Reference B, and Reference D. In some cases, surveys were completed a second time to increase accuracy or resolution of the survey using improved technology and techniques. Only results from the most recent surveys of each lake are presented in this EIS.

Volume 5, Section 3 (Limnology and Bathymetry) summarizes the methods and results of bathymetric mapping. Figures 3.2-3 and 3.2-4 show the locations of the surveyed lakes in the North LSA and RSA and the South LSA and RSA, respectively Appendix V5-3C shows bathymetric maps for 14 of the surveyed lakes (does not include P.O. Connector Lake).

Estimation of Lake Surface Area and Maximum Depth

In 2006, surface areas were estimated from maps for 20 small headwater lakes of the Roberts Watershed (Golder 2007a; Table 6.2-4). Bathymetry was not directly measured; however, maximum depths of 18 of those lakes were estimated from spot depth measurements using hand-held lines.

Habitat Assessment of Streams and Shorelines of Lakes and Ponds

Habitat assessments were conducted by slowly boating along the shoreline of lakes and ponds or by walking along the length of a stream. Habitat units were delineated and their characteristics were described. Habitat unit characteristics were used to define habitat quality for fish as good, fair, poor, or none.

Habitat units of the littoral zones of lakes and ponds were delineated from the type of substrate. Substrates of both streams and lakes were classified as bedrock, boulder, cobble, gravel, sand, silt, and organic material. Substrate size classes followed the modified Wentworth scale for particle size (<2 mm = fines, 2 to 64 mm = gravel, 64 to 256 mm = cobble, >256 mm = boulder). Substrate composition was recorded as a percent coverage (e.g., 70% cobble and 30% boulder) within delineated units. Patches of emergent and submergent vegetation were noted and recorded on a field map. Photographs were taken to illustrate various habitat types.

Habitat units of streams were identified based on habitat type (i.e., run, pool, riffle and flat), gradient, width, water depth, substrate composition, and availability of cover. From 1995 to 2008, a classification and rating system was sometimes used to assign habitat quality to each unit (O'Neil and Hildebrand 1986; Golder 2008). Photographs were taken to illustrate various habitat types. From 2009 to 2015, the Fish Habitat Assessment Procedure (FHAP) was used to survey instream habitat (Johnston and Slaney 1996). FHAP is the approved method for assessing stream fish habitat in British Columbia and is described in the following sub-section.

A total of 45 streams, 20 lakes, and 26 ponds were assessed for habitat quality from 1995 to 2015 (Table 6.2-4). Many waterbodies, particularly streams, were assessed multiple times because surveys were conducted at different sites within the waterbody.

Fish Habitat Assessment Procedure (FHAP)

FHAP was only applied to streams that have clearly defined channels. Survey lengths were divided into habitat units (pool, glide, riffle, and cascade) and assessed according to methods described by Johnston and Slaney (1996). FHAP was modified for use in Nunavut by excluding data specific to forested and montane areas. Pools are defined as areas of low turbulence, low velocity, low gradient, and relatively deep water. Glides are moderately shallow reaches of low turbulence, moderate velocity, and low gradient. Riffles are shallower areas of higher velocity and turbulence with gradients less than 4%. Cascades are reaches in which water flows down steep gradients (from 4% to vertical) with high velocity and high turbulence. Within each habitat unit, the physical features (e.g., gradient, mean depth, mean width, substrate composition, water velocity, availability of cover for fish, potential barriers, bank stability, and bank height) were measured. Data were collected with a measuring tape, meter stick, clinometer (for gradient), and by visual inspection.

These data were used to evaluate the overall quality of fish habitat at sites within a stream. Fish habitat quality was evaluated for all fish life-stages (e.g., spawning, rearing, adult feeding, and overwintering) and categorized as none, poor, fair or good. These evaluations plus fish catch data were used to determine if a stream site is fish-bearing.

Some streams have no clearly defined channel, with water flowing among boulder gardens and terrestrial vegetation. In these circumstances, FHAP was not used, but a description of the flow characteristics and potential fish habitat was provided. A detailed breakdown into different habitat types was not conducted. FHAP was used on a total of 56 streams: 20 in the LSA North, 21 in the LSA South and 15 in the RSA (Table 6.2-4).

Snorkel Surveys of Windy Lake Littoral Zone

Snorkel surveys were conducted at 18 sites along the littoral zone of Windy Lake in 2010, 2012, 2013 and 2014 (Rescan 2011b, 2012e; ERM 2014; ERM Rescan 2014c; Table 6.2-4). The purpose of the 2010 survey was a reconnaissance survey of substrate types. Six rock shoals were installed in April 2011 as compensation for the loss of fish habitat associated with the Doris Project in Tail Lake and Tail Lake Outflow, the site of the TIA. The shoals were intended to increase the quantity and quality of juvenile Lake Trout rearing habitat. The purpose of surveys in 2011, 2012, and 2013 was to assess the use of compensatory shoal habitat by Lake Trout and compare it to Lake Trout use of reference sites.

Snorkel surveys were initiated by defining the two end points of a survey reach using a handheld GPS unit. A snorkel survey was only conducted when the horizontal visibility was greater than 3 m. Two snorkelers slowly swam in a zigzag pattern, adjacent to each other for 15 minutes. Snorkeler observations of habitat and fish were recorded on an underwater slate board and subsequently transcribed to a field notebook.

Hydroacoustic Assessment of Lake Littoral and Pelagic Substrate

Mobile hydroacoustic and underwater video equipment were used to identify and map the type of substrate in deep-water and littoral zones of Doris (2009), Patch (2009), and Aimaokatalok (2010) lakes (Table 6.2-4). This allowed a more accurate assessment of habitat quality and lake productive capacity than could be achieved by visual surveys of the littoral zone. Hydroacoustic methods were the only way to assess substrate type in Doris Lake because it is a highly turbid lake compared to other lakes of the LSA North. Due to the large size of Aimaokatalok Lake, only two areas were surveyed using hydroacoustic methods: the Ore Deposit area, which is adjacent to the Boston deposit at the south end of the lake, and the Reference area, which is 2 km north of the Ore Deposit area. The Reference area was selected because it has a similar depth profile as the Ore Deposit area.

Sensitive Habitat Inventory Mapping (SHIM)

In 2010, all streams and wetlands located within proposed tailings, waste rock and infrastructure footprints were ground-truthed and mapped and habitat was assessed using the Sensitive Habitat Inventory Mapping (SHIM) protocol described by (Mason and Knight 2001; Rescan 2011d). SHIM is used as a standard for watercourse and fish habitat mapping in British Columbia. These methods were adapted for streams found in Nunavut. SHIM is designed to ensure the collection and mapping of reliable, high quality, current, and spatially accurate information about fish habitats and watercourses.

The geographic coordinates of stream and wetland sampling sites were located with a DGPS unit. Moving in an upstream direction, streams were mapped, barriers were identified, and habitat assessments were conducted. The presence of falls greater than 2 m high, steep cascades, channel gradients greater than 30%, and locations where habitat becomes discontinuous or insufficient to support fish were identified as the “end of fish use” point. The “end of fish use” for each stream was further confirmed with fish sampling.

Detailed fish habitat data was collected in the field at the same time as streams and wetlands were mapped. Spatial data was tied to fish habitat data collected in the field. Collection of habitat data followed a combination of the Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures (RIC 2001) and the FHAP (Johnston and Slaney 1996). A total of 23 streams were surveyed using SHIM: 10 in the LSA North and 13 in the LSA South (Table 6.2-4).

6.2.5.3 Freshwater Fish Community

A total of 14 species of fish were captured in lakes and streams of the LSA and RSA from 1993 to 2015 (Table 6.2-5). Ten of the species captured reside in freshwater for all or part of their life history. Four additional species – Greenland Cod, Arctic Flounder, Starry Flounder, and Fourhorn Sculpin – live predominantly in marine or brackish waters and occasionally move up large rivers for short distances.

Fish communities of lakes and streams of the LSA and RSA were sampled using eight methods, as follows:

- Backpack electrofishing in streams and along the shorelines of lakes;
- Minnow traps in streams and ponds and along the shorelines of lakes;
- Gillnets in lakes, ponds, and large streams;
- Angling in lakes and large streams;
- Beach seining on lake shorelines and large streams;
- Fyke nets in lakes and large streams;
- Fish fence on Roberts Outflow or Little Roberts Outflow; and
- Hydroacoustic techniques to estimate number and density of fish in lakes.

Table 6.2-5. Common and Scientific Names of Fish Species Captured in Freshwaters of the LSA and RSA, 1993-2015

Family	Common Name	Scientific Name	Code
Salmonidae	Arctic Char	*Salvelinus alpinus*	ARCH
	Lake Trout	*Salvelinus namaycush*	LKTR
	Lake Whitefish	*Coregonus clupeaformis*	LKWH
	Broad Whitefish	*Coregonus nasus*	BRWH
	Arctic Cisco	*Coregonus autumnalis*	ARCS
	Cisco[1]	*Coregonus artedi*	CISC
	Least Cicso	*Coregonus sardinella*	LSCS
	Arctic Grayling	*Thymallus arcticus*	ARGR
Gadidae	Greenland Cod	*Gadus ogas*	-
Gasterosteidae	Ninespine Stickleback	*Pungitius pungitius*	NNST
Lotidae	Burbot	*Lota lota*	BURB
Pleuronectidae	Arctic Flounder	*Liopsetta glacialis*	ARFL
	Starry Flounder	*Platichthys stellatus*	STFL
Cottidae	Slimy Sculpin	*Cottus cognatus*	SLCS
	Fourhorn Sculpin	*Triglopsis quadricornis*	FRSC

Sources: Species codes were taken from Sawatzky et al. (2007) and Tyson et al. (2011).
Dashes = no species code
LSA = Local Study Area and RSA = Regional Study Area.
1: Formerly known as Lake Cisco (Nelson et al. 2004; Sawatzky et al. 2007).

Table 6.2-6 shows a list of surveyed waterbodies by study area, watershed, types of waterbody, and fish community survey method, and Table 6.2-7 shows the numbers of surveyed waterbodies by method, study area, and watershed. Figures 6.2-12 to 6.2-15 show the locations of fish community surveys conducted from 1993 to 2015. The following sections describe each of the eight fish community survey methods employed.

Backpack Electrofishing

Backpack electrofishing was the most widely used fish sampling method and was used to collect small-bodied fish in streams and lakes from 1993 to 2015. Stream electrofishing surveys employed reconnaissance and removal methods. For reconnaissance surveys, the objective was to identify the fish species present and their relative abundance. (e.g., Rescan 1993, 1994; Rescan 1995). Hence, stop nets were not used to block off the sampling area. The operator waded upstream and sampled in the vicinity of suspected fish holding areas (e.g., around boulders). The accompanying netter collected stunned fish with a dip net and placed them in a water-filled holding bucket. Recorded information at each site included UTM coordinates, date and time of sampling, distance sampled, sampling effort (seconds of electrofishing), and electrofisher settings. After processing for species, number, and biological information, fish were released live back into the area of capture.

Table 6.2-6. Waterbodies Surveyed for Fish Communities in the LSA and RSA, 1993-2015

Area	Waterbody	Watershed	Waterbody Type	Backpack Electrofisher	Minnow Trap	Gillnet	Angling	Beach Seine	Fyke Net	Fish Fence	Hydroacoustics
LSA - North	Doris Lake	Doris	Lake	X	X	X	X	X	X	-	X
LSA - North	Imniagut Lake	Doris	Lake	X	X	X	-	-	-	-	-
LSA - North	Ogama Lake	Doris	Lake	X	X	X	X	X	-	-	-
LSA - North	P.O. Connector Lake	Doris	Lake	-	X	X	-	X	X	-	-
LSA - North	P.O. Inflow Lake	Doris	Lake	X	X	X	-	X	-	-	-
LSA - North	P.O. Lake	Doris	Lake	-	X	X	X	X	X	-	-
LSA - North	Patch Lake	Doris	Lake	X	X	X	X	X	X	-	X
LSA - North	Tail Lake	Doris	Lake	-	X	X	X	X	X	-	-
LSA - North	Wolverine Lake	Doris	Lake	X	X	X	X	X	-	-	-
LSA - North	Glenn Lake	Windy	Lake	X	X	X	-	-	-	-	-
LSA - North	Nakhaktok Lake	Windy	Lake	X	X	-	-	-	-	-	-
LSA - North	Windy Lake	Windy	Lake	X	X	X	X	X	-	-	-
LSA - North	Doris area streams N18 to N21 (N20)	Doris	Stream	X	-	-	-	-	-	-	-
LSA - North	Doris Inflow	Doris	Stream	X	-	-	-	-	-	-	-
LSA - North	Doris Outflow	Doris	Stream	X	X	-	X	-	-	-	-
LSA - North	Ogama Inflow	Doris	Stream	X	X	-	X	-	X	-	-
LSA - North	Ogama Outflow	Doris	Stream	X	X	-	-	-	X	-	-
LSA - North Belt	P.O. Inflow	Doris	Stream	X	-	-	-	-	-	-	-
LSA - North Belt	P.O. Outflow	Doris	Stream	X	X	-	-	X	-	-	-
LSA - North Belt	Patch Outflow	Doris	Stream	-	-	-	-	X	-	-	-
LSA - North Belt	Tail Outflow	Doris	Stream	X	X	-	-	-	-	-	-
LSA - North Belt	Pond 2	Doris	Pond	X	X	-	-	-	-	-	-
LSA - North Belt	Pond Q20 to Q22	Doris	Pond	X	-	-	-	-	-	-	-
LSA - North Belt	Quarry 2 to 4 (site Q02 to Q04)	Doris	Pond	X	-	-	-	-	-	-	-
LSA - North Belt	Quarry 9 to 11 (site Q09 to Q11)	Aimaokatalok	Pond	-	X	-	-	-	-	-	-

Area	Waterbody	Watershed	Waterbody Type	Backpack Electrofisher	Minnow Trap	Gillnet	Angling	Beach Seine	Fyke Net	Fish Fence	Hydroacoustics
LSA - North Belt	Quarry 5, 6,8 (Q05, Q06, Q08)	Koignuk	Pond	X	X	-	-	-	-	-	-
LSA - North Belt	Glenn Inflow	Windy	Stream	X	-	-	-	-	-	-	-
LSA - North Belt	Glenn Outflow	Windy	Stream	X	X	-	-	-	-	-	-
LSA - North Belt	Windy Inflow	Windy	Stream	X	-	-	-	-	-	-	-
LSA - North Belt	Windy Outflow	Windy	Stream	X	X	-	-	-	-	-	-
LSA - North Belt	Koignuk River	Koignuk	Stream	X	X	X	X	-	-	-	-
LSA - North Belt	Pond Q13 to Q16	Koignuk	Pond	X	X	-	-	-	-	-	-
LSA - North Belt	East of Roberts Bay (site N02)	Roberts	Stream	X	-	-	-	-	-	-	-
LSA - North Belt	Roberts Bay Inflow (site N01)	Roberts	Stream	-	-	-	-	-	-	-	-
LSA - North Belt	Unnamed stream (Roberts Bay Discharge Access Road)	Roberts	Stream	X	-	-	-	-	-	-	-
LSA - South Belt	Aimaokatalok Lake	Aimaokatalok	Lake	X	X	X	X	X	X	-	X
LSA - South Belt	Stickleback Lake	Aimaokatalok	Lake	-	X	X	-	-	-	-	-
LSA - South Belt	Trout Lake	Aimaokatalok	Lake	-	X	X	-	X	-	-	-
LSA - South Belt	Aimaokatalok Inflows	Aimaokatalok	Stream	X	X	-	-	-	-	-	-
LSA - South Belt	Aimaokatalok River	Aimaokatalok	Stream	X	-	-	-	-	-	-	-
LSA - South Belt	Boston area sites C01 to C03)	Aimaokatalok	Stream	X	-	-	-	-	-	-	-
LSA - South Belt	Boston Area sites S03 to S35	Aimaokatalok	Stream	X	-	-	-	-	-	-	-
LSA - South Belt	Boulder Creek	Koignuk	Stream	X	-	-	-	-	-	-	-
LSA - South Belt	Stickleback Outflow	Aimaokatalok	Stream	X	X	-	-	-	-	-	-
LSA - South Belt	Stream S33	Aimaokatalok	Stream	X	X	-	-	-	-	-	-
LSA - South Belt	Stream S34	Aimaokatalok	Stream	X	-	-	-	-	-	-	-
LSA - South Belt	Trout Inflow	Aimaokatalok	Stream	X	-	-	-	-	-	-	-

Area	Waterbody	Watershed	Waterbody Type	Backpack Electrofisher	Minnow Trap	Gillnet	Angling	Beach Seine	Fyke Net	Fish Fence	Hydroacoustics
LSA - South Belt	Trout Outflow	Aimaokatalok	Stream	X	X	-	-	-	-	-	-
LSA - South Belt	Ponds Q23 to Q25	Aimaokatalok	Pond	X	X	-	-	-	-	-	-
LSA - South Belt	Koignuk River	Koignuk	River	X	X	X	X	X	-	-	-
RSA	Lake 04	Roberts	Lake	-	-	X	-	-	-	-	-
RSA	Lake 05	Roberts	Lake	X	-	X	-	X	-	-	-
RSA	Lake 06a	Roberts	Lake	-	-	X	-	-	-	-	-
RSA	Lake 06b	Roberts	Lake	X	-	X	-	-	-	-	-
RSA	Lake 06c	Roberts	Lake	X	-	X	-	X	-	-	-
RSA	Lake 06d	Roberts	Lake	X	-	X	X	X	-	-	-
RSA	Lake 07	Roberts	Lake	X	X	X	-	-	-	-	-
RSA	Lake 09	Roberts	Lake	-	-	X	-	-	-	-	-
RSA	Lake 10	Roberts	Lake	X	X	X	X	-	-	-	-
RSA	Lake 12	Roberts	Lake	X	X	X	X	-	-	-	-
RSA	Lake 13	Roberts	Lake	X	-	X	X	-	X	-	-
RSA	Lake 14	Roberts	Lake	-	X	X	-	-	-	-	-
RSA	Lake 31a	Roberts	Lake	X	-	-	X	-	-	-	-
RSA	Lake 31b	Roberts	Lake	-	-	X	-	X	-	-	-
RSA	Lake 32	Roberts	Lake	X	X	X	X	-	-	-	-
RSA	Lake 32a	Roberts	Lake	X	X	X	X		-	-	-
RSA	Lake 33	Roberts	Lake	-	X	X	X	-	-	-	-
RSA	Lake 35	Roberts	Lake	X	-	-	-	-	-	-	-
RSA	Roberts Lake	Roberts	Lake	X	X	X	X	X	X	-	-
RSA	Little Roberts Lake	Roberts	Lake	X	X	X	X	-	X	-	-
RSA	Pelvic Lake	Roberts	Lake	-	-	X	-	-	-	-	-
RSA	Reference Lake A	Reference A	Lake	X	X	X	-	-	-	-	-
RSA	Reference Lake B	Reference B	Lake	-	X	X	-	-	-	-	-
RSA	Reference Lake D	Reference D	Lake	-	X	X	-	-	-	-	-
RSA	Boston Reference Lake	Aimaokatalok	Lake	X	X	X	-	-	-	-	-

Area	Waterbody	Watershed	Waterbody Type	Backpack Electrofisher	Minnow Trap	Gillnet	Angling	Beach Seine	Fyke Net	Fish Fence	Hydroacoustics
RSA	Roberts Inflow E03	Roberts	Stream	X	-	-	-	-	-	-	-
RSA	Roberts Inflow E06	Roberts	Stream	X	X	-	-	-	-	-	-
RSA	Roberts Inflow E07	Roberts	Stream	X	X	-	-	-	-	-	-
RSA	Roberts Inflow E09	Roberts	Stream	X	X	-	-	-	-	-	-
RSA	Roberts Inflow E10	Roberts	Stream	X	X	-	-	-	-	-	-
RSA	Roberts Inflow E11	Roberts	Stream	X	X	-	-	-	-	-	-
RSA	Roberts Inflow E12	Roberts	Stream	X	X	-	-	-	-	-	-
RSA	Roberts Inflow E13	Roberts	Stream	X	X	-	-	-	-	-	-
RSA	Roberts Inflow E14	Roberts	Stream	X	X	-	-	-	-	-	-
RSA	Roberts Inflow E15	Roberts	Stream	X	-	-	-	-	-	-	-
RSA	Roberts Inflow E31	Roberts	Stream	X	-	-	-	-	-	-	-
RSA	Roberts Inflow E32	Roberts	Stream	X	-	-	-	-	-	-	-
RSA	Roberts Inflow E33	Roberts	Stream	X	-	-	-	-	-	-	-
RSA	Roberts Inflow E34	Roberts	Stream	X	-	-	-	-	-	-	-
RSA	Roberts Inflow E36	Roberts	Stream	X	-	-	-	-	-	-	-
RSA	Roberts Outflow	Roberts	Stream	X	X	X	X	X	X	X	-
RSA	Little Roberts Outflow	Roberts	Stream	X	-	-	-	-	-	X	-
RSA	Pelvic Outflow	Pelvic	Stream	X	-	-	-	-	X	-	-
RSA	Pelvic Inflow	Pelvic	Stream	X	-	-	-	-	-	-	-
RSA	Reference A Outflow	Reference A	Stream	X	X	-	-	-	-	-	-
RSA	Reference B Outflow	Reference B	Stream	X	X	-	-	-	-	-	-
RSA	Reference D Outflow	Reference D	Stream	X	-	-	-	-	-	-	-

X = survey conducted. Dashes indicate no surveys were conducted.
LSA = Local Study Area and RSA = Regional Study Area.

Table 6.2-7. Number of Waterbodies Surveyed for Fish Communities in the LSA and RSA, 1993-2015

	LSA - North Belt			LSA - South Belt			RSA			Total			
Method	**Lake**	**Pond**	**Stream**	**Lake**	**Pond**	**Stream**	**Lake**	**Pond**	**Stream**	**Lake**	**Pond**	**Stream**	**Years**
Electrofisher	9	12	28	1	5	53	17	1	25	26	18	106	1993-2015
Minnow trap	12	15	8	3	8	5	13	0	11	28	23	24	1994-2014
Gillnet	11	0	1	3	0	1	26	0	1	40	0	3	1993-2015
Angling	7	0	3	1	0	1	10	0	1	18	0	5	1995-2015
Beach seine	9	0	2	2	0	1	5	0	1	16	0	4	1996-2008
Fyke net	5	0	2	1	0	0	3	0	2	9	0	4	2002-2012
Fence	0	0	0	0	0	0	0	0	2	0	0	2	2002-2015
Hydroacoustic	2	0	0	1	0	0	0	0	0	3	0	0	2009-2015

FHAP = Fish Habitat Assessment Procedure and SHIM = Sensitive Habitat Inventory Mapping.
LSA = Local Study Area and RSA = Regional Study Area.

For the removal method, the objective was to identify the members of the fish community and to estimate their number and density (number/m2; e.g., Golder 2007a; Rescan 2011d). Small-mesh stop nets were placed at both ends of a stream survey length, and the electrofisher team waded from one end to the other collecting fish and recording fishing effort (i.e., number of electrofishing second). Then, the fish were processed for species, number, and biological information, but were not released. Instead, they were held live in water-filled buckets. A second and third pass were conducted with fish processing between passes, and then stop nets were removed and all fish were released live to the stream. The consecutive decline in electrofishing CPUE over the three passes was used to estimate the total number of fish in the survey area. Dividing that number by the area of the survey (i.e., stream length times mean width) provided fish density.

Electrofishing surveys of lakes were conducted in shallow water (<1 m depth) along the shoreline where habitat allowed. Electrofishing was not possible in boulder habitat for safety reasons. A total of 150 sites were surveyed with backpack electrofishers: 106 stream sites, 26 lake sites, and 18 pond sites (Table 6.2-7). The number of sampling events was greater than the total number of waterbodies because many streams and lakes were surveyed multiple times at different sites.

<u>Minnow Traps</u>

Minnow traps were used to collect small-bodied fish in lakes and streams from 1994 to 2014. Each trap consisted of two wire mesh cylinders that were locked together using a clip attached to a rope and marker buoy. Mesh size was 3.2 mm. Each end had a small opening for fish to enter. Each minnow trap was baited with a small amount of dry crab bait or another type of commercial bait. Minnow traps were placed on the streambed or along the shore of lakes or ponds in shallow water, usually less than 2 m deep, and allowed to fish for up to 24 hours. Recorded information at each site included UTM coordinates, the number of traps, and the date and time of installation and retrieval.

Minnow traps were installed in a total of 74 waterbodies: 24 streams, 28 lakes, and 23 ponds (Table 6.2-7). The number of installed traps was greater than the total number of sampled waterbodies because clusters of traps were installed in streams and lakes at multiple times at different sites.

<u>Gillnets</u>

Gillnets were used for sampling large-bodied fish in lakes and large streams. For all gillnetting efforts from 1993 to 2015, information recorded for each gillnet set included UTM coordinates, date and time of set and lift, and water depth.A variety of gillnet sizes and meshes were used from 1993 to 2015. A brief review illustrates the diversity of gillnets used through the 25 year long sampling period.

Gillnets were used in 1993 and 1994, but the sizes and meshes were not reported (Rescan 1993, 1994). In 1995, three-panel gillnets were used with each panel being 15.3 m long and 2.4 m deep with mesh sizes of 3.8 cm, 6.4 cm, and 8.9 cm stretched mesh (Rescan 1995). Gillnets were set at the surface or they were weighted so they sat at the lake bottom.

In 2003, set gangs were comprised of either single panels of 1.9 cm or 8.9 cm stretched mesh, and/or variable mesh size experimental gill nets (RL&L/Golder 2003). Each panel was 1.5 m deep by 15.2 m long. The nets were of the sinking type with mesh sizes ranging from 1.9 to 10.2 cm. The 1.9 cm mesh nets were used most frequently in Roberts, Little Roberts, and Doris lakes to target small fish.

Figure 6.2-12
Freshwater Fish Community Surveys in Lakes and Ponds, North Belt, 1993-2015

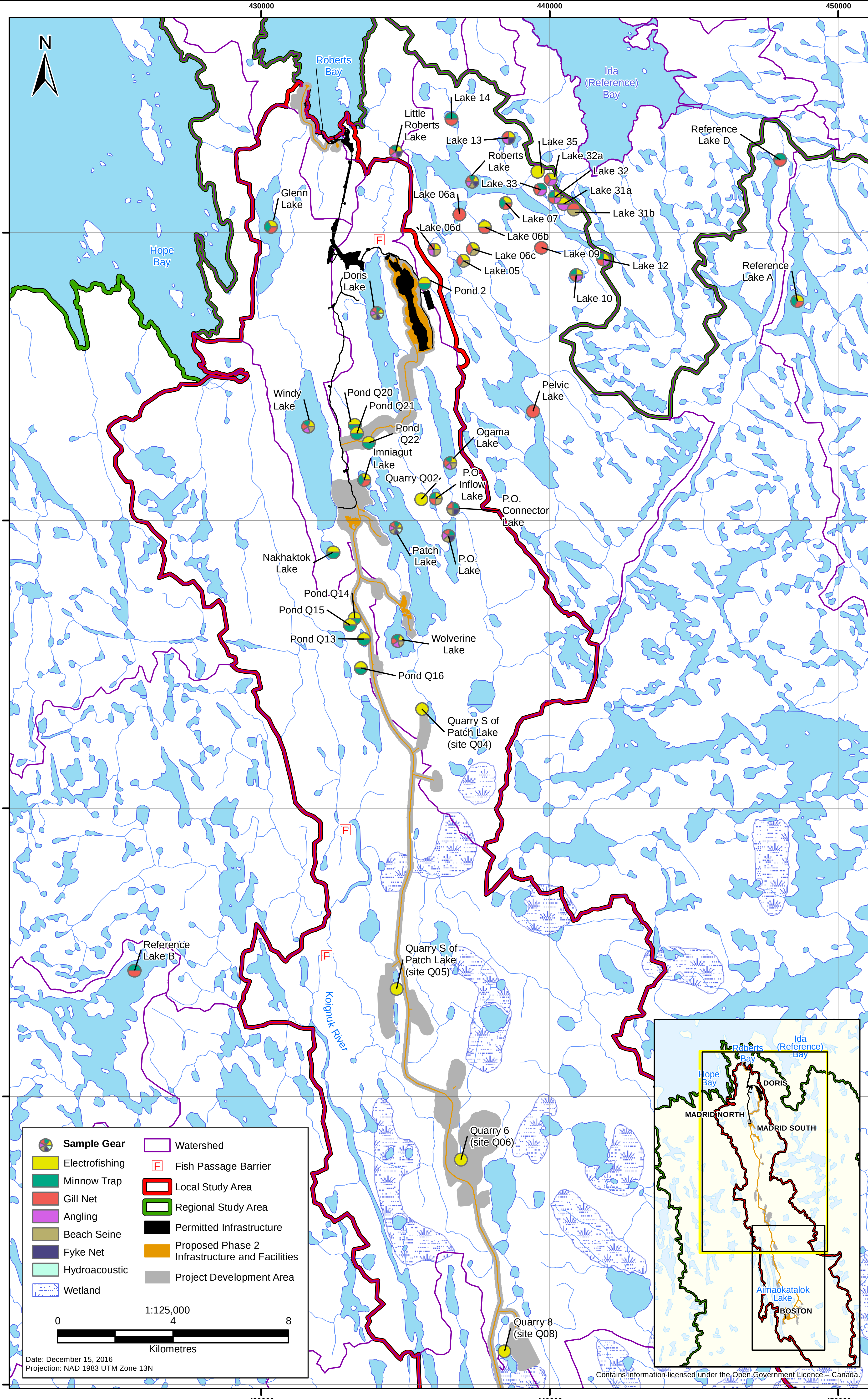


Figure 6.2-13
Freshwater Fish Community Surveys in Lakes and Ponds, South Belt, 1993-2015

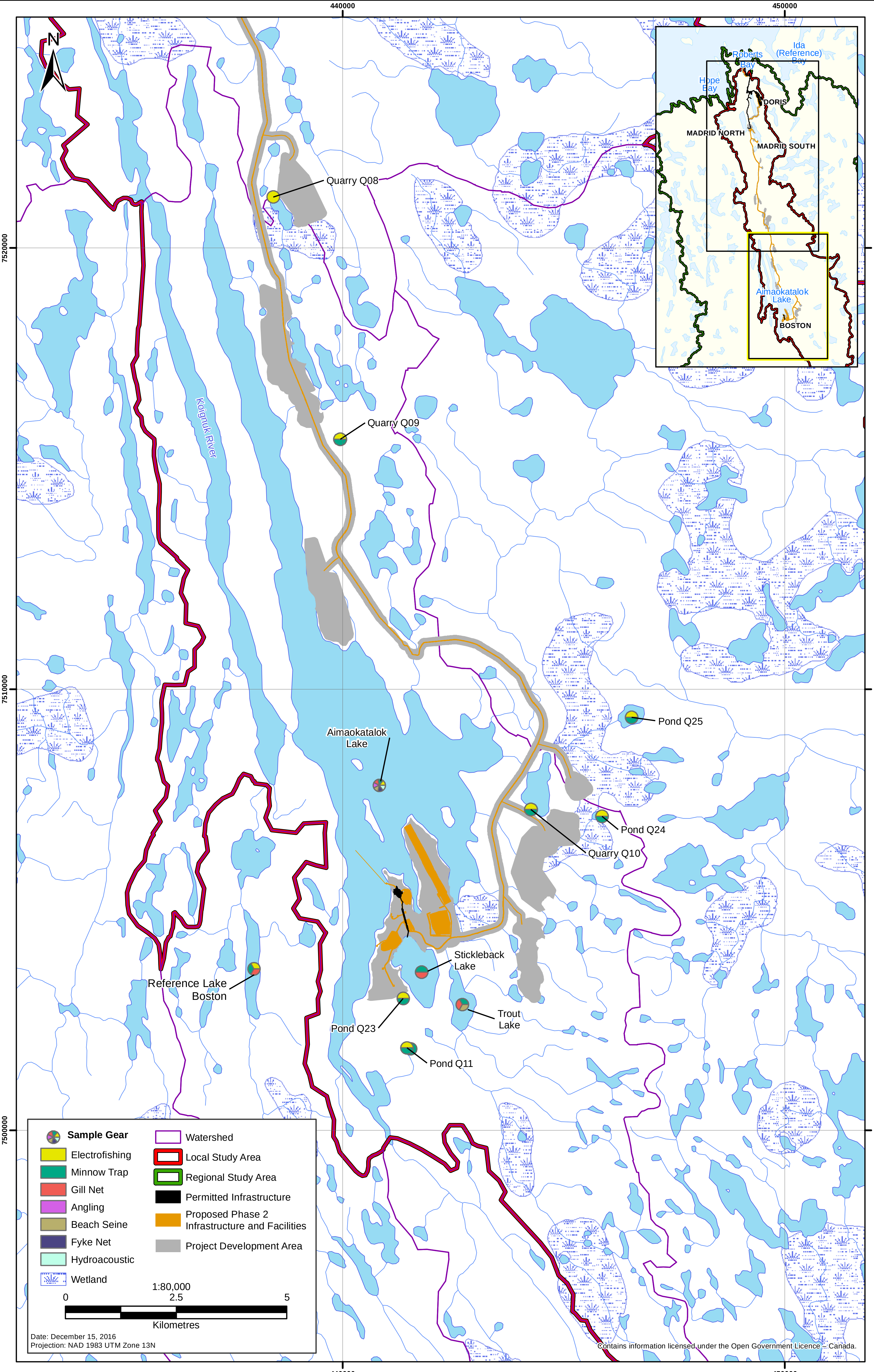


Figure 6.2-14
Freshwater Fish Community Surveys in Streams, North Belt, 1993-2015

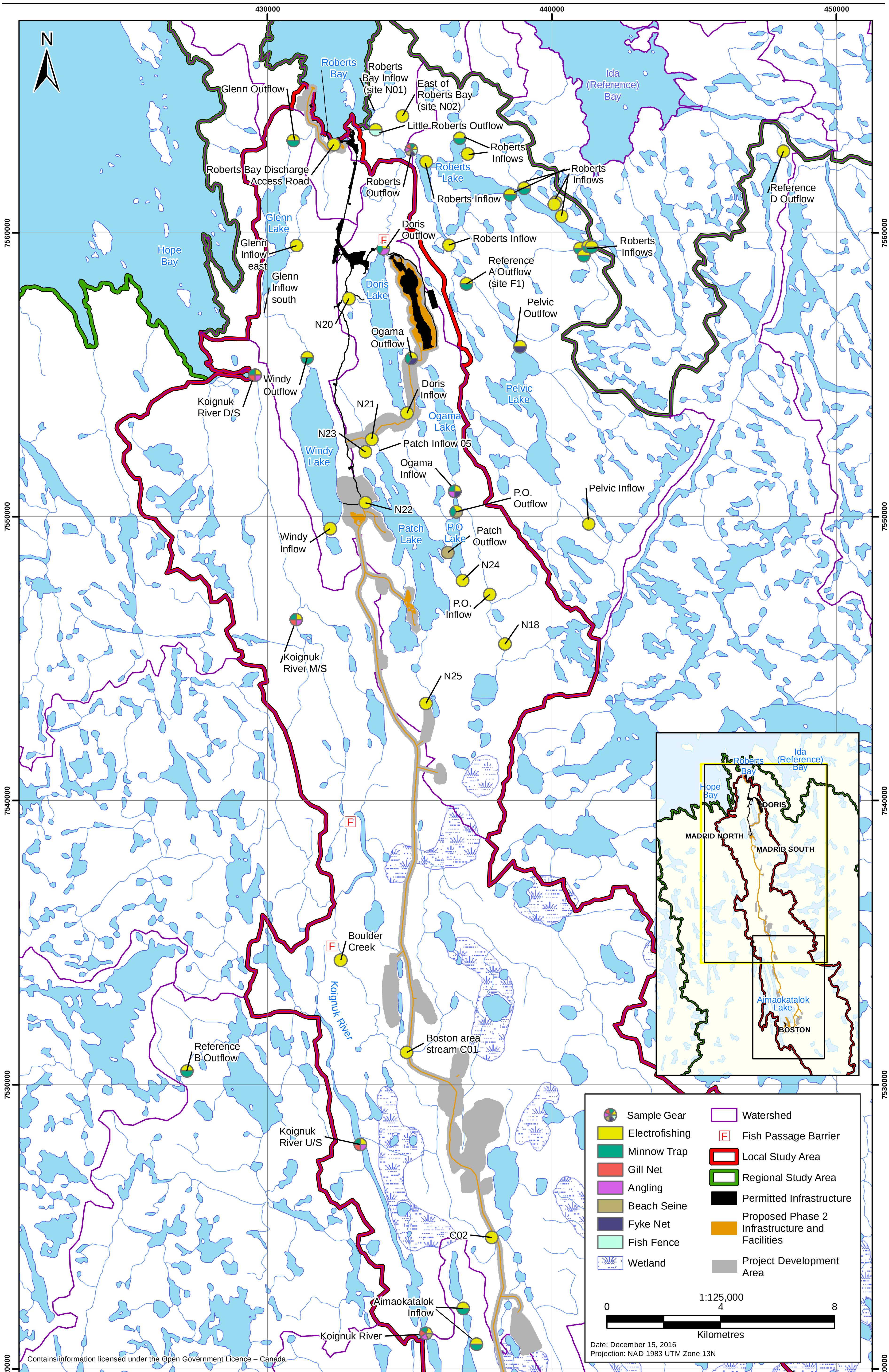
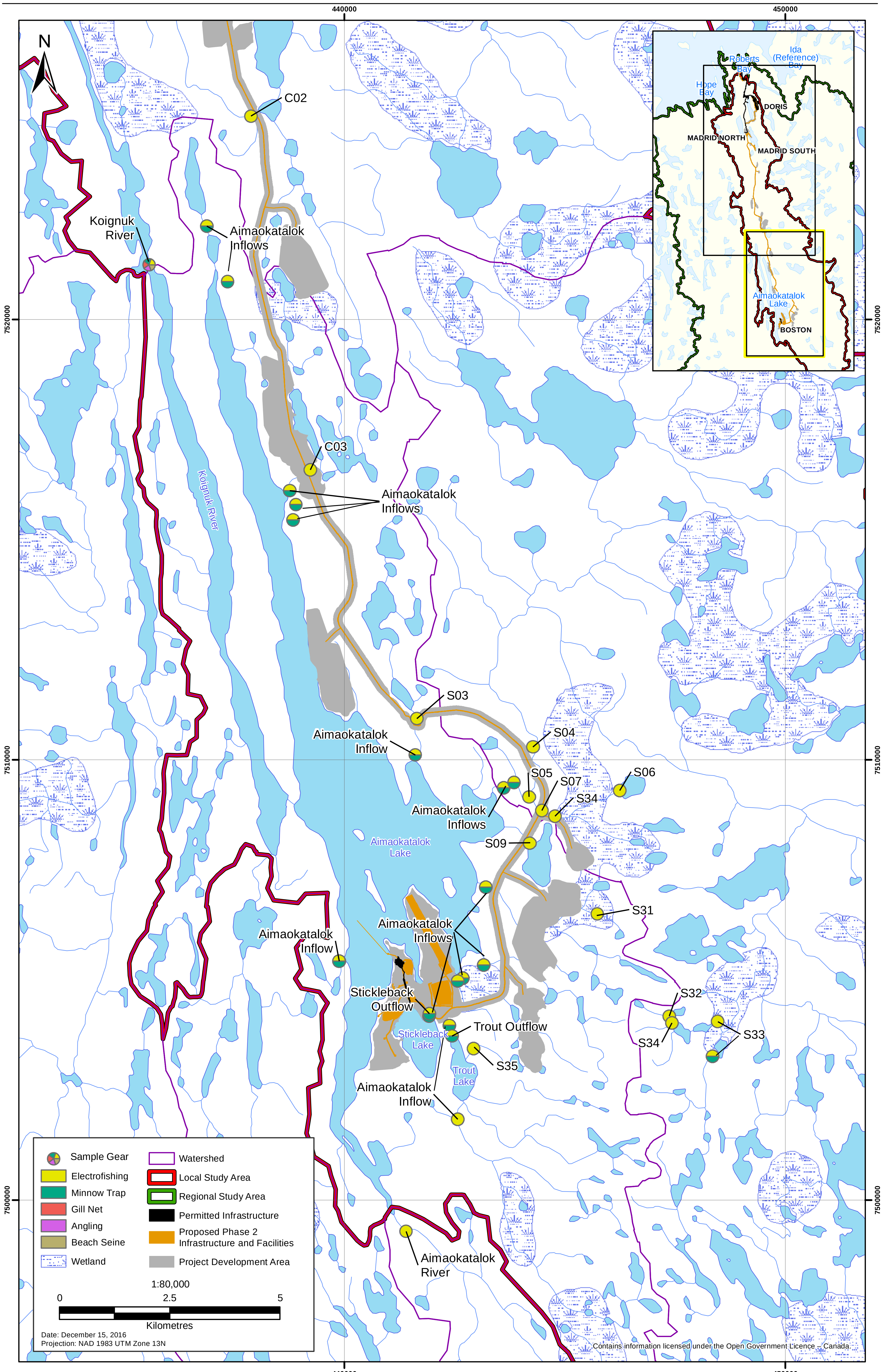


Figure 6.2-15
Freshwater Fish Community Surveys in Streams, South Belt, 1993-2015



In 2008, variable mesh experimental gill nets were employed to sample large-bodied fish (Golder Associates Ltd. 2009). Each experimental gill net was composed of three panels measuring 15.2 by 1.8 m each. Mesh sizes were 3.81, 5.08, and 6.35 cm. Set times were limited to one to three hours to minimize capture related mortalities. In 2010 and 2011, lakes were sampled using monofilament index gillnet gangs consisting of six panels, ranging from 25 to 89 mm stretched mesh (Rescan 2011d). Each gillnet gang was tied in the following order: Panel 1 – 25 mm; Panel 2 – 76 mm; Panel 3 – 51 mm; Panel 4 – 89 mm; Panel 5 – 38 mm; and Panel 6 – 64 mm. Each panel measured 15.2 m long by 2.4 m deep for an area of 36.48 m2 and a total area of 218.88 m2 per gang. All gillnets had a lead line at the bottom and a floating line at the top of the net. Both floating and sinking nets were used.

Gillnets were set in a total of 40 waterbodies: 40 lakes and three large streams (Table 6.2-7). The three sampled streams were the Koignuk River, Roberts Outlet, and Little Roberts Outlet.

Angling

Angling was used to capture large-bodied fish in lakes and streams from 1995 to 2015. It was conducted by casting from shore, and barbless lures were used to reduce mortality. Recorded data included UTM coordinates, date and time of capture, hours fished, and the number of rods that were used. A total of 23 waterbodies were angled: 18 lakes and five large streams (Table 6.2-7).

Beach Seining

Beach seining was used to capture small-bodied fish in shallow areas of lakes and streams from 1996 to 2008. Sandy beaches were the most suitable habitat for beach seining. The net was 9 m long, with a mesh size of 6 mm, and was equipped with a central collection bag (i.e., the bunt) with a mesh size of 3 mm. One end of the net was fixed to the shoreline and then the other end was quickly swung around with a small boat to enclose a volume of nearshore habitat. The whole net was then pulled ashore and the catch was removed from the bunt. Information collected included UTM co-ordinates, date, time, water temperature, substrate type, and the length and effective width of each haul (to determine CPUE). Beach seines were used in a total of 20 waterbodies: 16 lakes and four large streams (Table 6.2-7).

Fyke Nets

Fyke nets are used to capture fish moving along lake shores and migrating up or down streams. They were used in the LSA and RSA from 2002 to 2012. In lakes, fyke net sets were placed approximately 30 m off shore. Each fyke net consisted of a single trap net with two 7.6 m wings and a 7.6 m lead to shore. The trap was 0.9 m long and 0.9 m wide, contained two throats (7.5 × 7.5 cm each), and was constructed of 1.0 cm dark grey knotless nylon mesh. Wings and lead were also constructed of 1.0 cm dark grey knotless nylon and were 0.9 m deep. The lead panel was set perpendicular from shore and bisected the trap entrance. Wing net panels were attached to either side of the trap entrance and were stretched out parallel to shore. The combination of the lead panel and wings acted to confine and guide fish into the trap. Fyke nets were held in place by metal stakes driven into the lake bottom. In streams, the fyke net was set up with two wings that stretched from the trap to shore. No centre lead was used. This arrangement blocked off the entire stream channel and funneled all migrants into the trap.

Information collected from fyke net sampling included UTM co-ordinates, water temperatures, and the dates and times at which the trap was opened and fish were retrieved for collection of biological information. After processing, fish were released back to their lake or stream in the direction of travel.

Fyke nets were installed in a total of 13 waterbodies: 9 lakes and 4 streams (Table 6.2-7). They were used in five lakes in the LSA North (Doris, Tail, Patch, P.O. Connector, and P.O.), three lakes in the

RSA (Roberts, Little Roberts, and 15), and Aimaokatalok Lake in the LSA South. The four streams were Roberts Outflow and Pelvic Outflow in the RSA and Ogama Inflow and Ogama Outflow of the LSA North.

Fish Fence

Two fish fences were installed annually in Roberts Outflow during the ice-free season from 2002 to 2015 (and for two years in Little Roberts Outflow) as part of the Doris fish habitat compensation program. Objectives and methods of the fence changed over those 13 years, as summarized by ERM (2016c).

From 2002 to 2005, the two objectives of the fences were, first, to monitor the August-September migration of adult Arctic Char returning from the ocean to spawn and overwinter in Roberts Lake, and, second, to measure the mortality of char as they migrated through a boulder garden between the two fences. In 2006 and 2007, the location of the fence study was moved to Little Roberts Outflow and the objective changed to monitor the June-July migration of Arctic char smolts from Roberts Lake to the sea using only one fence.

The two fences were re-installed in Roberts Outflow in 2010. From 2010 to 2015, the objective of the fence study was to monitor both the upstream migration of adults and the downstream migration of smolts. In 2013, the traps, which were previously manually operated, were replaced by an automated counting system – the Vaki Riverwatcher system. This avoided encounters between fish biologists and Grizzly Bears that fed on the Arctic Char migration. From 2002 to 2012, the traps of the fish fence were checked daily to monitor movement patterns of fish. During each daily check of the fence, the date, time of day and water temperature were recorded and fish were removed from the traps, processed for biological information, and released in their direction of movement. From 2013 to 2015, much of that information was collected remotely.

Hydroacoustics

Mobile hydroacoustics were used to measure fish number (with 95% confidence intervals), fish density (fish/m^3), and spatial distribution of fish species in Doris (2009 and 2015), Patch (2009), and Aimaokatalok (2010) lakes (Rescan 2010a, 2011d; ERM 2016a). Survey methods generally followed protocols for the sampling of fish populations with hydroacoustics described in Thorne (1983), Brandt (1996), and MacLennan and Simmonds (1992). Hydroacoustic estimates of fish number were assigned to species using relative proportions of species captured in gillnet sampling performed before or after the hydroacoustic survey.

Fish Processing

All captured fish were identified to species, and most were measured for fork length to the nearest 1 mm and for weight to the nearest 0.1 g. When catch was high and survey time was short a representative sample of the catch was measured for length and weight. The incidence of parasites or deformities, erosion, lesions, or tumors (DELTs) was recorded. Fish, except incidental mortalities and those sacrificed for biological or tissue sampling, were released live back to the waterbody from which they were caught.

Many fish were sampled for ageing structures such as scales, fin rays, and otoliths. Scales were collected with a knife below the posterior margin of the dorsal fin on the left side of the fish. Two to three rays of the left pelvic fin were collected with scissors or pliers. Otoliths (i.e., ear bones) were only collected from incidental mortalities or from fish lethally sampled for tissues.

Aging analysis of scales, fin rays and otoliths was performed by various individuals and companies. From 2009 onwards, John Tost of North Shore Environmental Services, Thunder Bay, Ontario, was the principal ageing consultant. Age was estimated by counting the number of annuli (or yearly rings) in each structure. Scales were attached to plastic fiches and annuli were counted with a microfiche reader. Fin rays were air-dried and then mounted in a 50:50 epoxy medium. Microsections were cut using a Beuler Isomet diamond saw and mounted on slides and annuli were counted with a compound microscope. Otoliths were air-dried, cracked and passed over a flame to increase the visibility of annuli. Otoliths were then mounted in Plasticine and immersed in oil for better inspection using a compound microscope. When more than one structure was used for aging, the one with the highest confidence in the annuli count was used.

Fish that died during to capture or handling were autopsied and sex and sexual maturity were identified. Otoliths were usually taken for ageing. In some years, and for some waterbodies, tissue samples (e.g., muscle and liver) were taken from Lake Trout, Lake Whitefish, Lake Char, Cisco, or Ninespine Stickleback for metals analysis. Gonads and livers were also weighed to calculate gonadosomatic index (gonad weight/body weight) and hepatosomatic index (liver weight/body weight).

Biological Information

Fish population sampling in lakes, ponds, and streams of the RSA between 1993 and 2015 has resulted in a large database of waterbody-specific information including fish-bearing status of waterbodies, species richness (number of species in a waterbody), species incidence (number of waterbodies with specific species), and population number and density (i.e., fish/ha). This information is presented and discussed in Section 6.2.6.3.

The fish community sampling database also contains population-level information on fish length, weight, the incidence of DELTs, age, sex ratio, sexual maturation, gonadosomatic index, and hepatosomatic index in sampled waterbodies. Due to the extensive nature of the database, this information is not summarized here but it is available in baseline reports (see Section 6.2.4) for use as historical data to be compared with similar data collected during construction, operations, and closure of Phase 2.

Fish Tagging

In selected lakes and streams, fish longer than 300 to 500 mm were tagged with uniquely numbered Hallprint or Floy T-bar anchor tags. Tags were inserted below the dorsal fin. In more recent years, tagged fish were also injected with Passive Integrated Transponder (PIT) tags (e.g., Golder 2008). PIT tags and injectors were sterilized with diluted isopropyl alcohol prior to each use.

The purpose of tagging fish was two-fold: to track fish as they moved through rivers and lakes and to enable mark-recapture estimates of Lake Trout population number in Tail and Patch lakes. Tag recovery information was mainly used to track Arctic Char and Lake Trout as they moved into and out of the Roberts Lake drainage through Little Roberts Outflow, Little Roberts Lake, Roberts Outflow, Roberts Lake, and headwater lakes of Roberts Lake. This information is presented and discussed in Section 6.2.5.3 (Life Histories and Habitat Preferences of Fish Species). Results of the mark-recapture population studies are presented and discussed in Section 6.2.6.3 (Estimates of Lake Fish Population Number and Density).

Lake Trout were tagged in 11 lakes: 7 lakes of the LSA North (Doris, Tail, Ogama, Patch, P.O., P.O. Connector, and Windy), Aimaokatalok Lake in the LSA South, and 3 lakes in the RSA (Roberts, Little Roberts, and Pelvic) (Table 6.2-8). They were also tagged in Doris Outflow, Glenn Outflow, Roberts Outflow, Little Roberts Outflow, Pelvic Outflow, and tributaries to Roberts Lake. Arctic Char were tagged in lakes and streams of the Roberts Watershed and in Pelvic Outflow. Lake Whitefish were tagged in five lakes: Doris, Patch, Pelvic, Windy, and Aimaokatalok. Broad Whitefish were tagged in Little Roberts Lake.

Table 6.2-8. Fish Species Tagged in the LSA and RSA, 1993-2015

Area	Water Body	Watershed	Waterbody Type	Lake Trout	Arctic Char	Lake Whitefish	Broad Whitefish	Tagging Years
LSA - North Belt	Doris Lake	Doris	Lake	X	-	X	-	1997, 2002, 2009
LSA - North Belt	Tail Lake	Doris	Lake	X	-	-	-	2000, 2002
LSA - North Belt	P.O. Connector Lake	Doris	Lake	X	-	-	-	2003
LSA - North Belt	P.O. Lake	Doris	Lake	X	-	-	-	2003, 2008
LSA - North Belt	Ogama Lake	Doris	Lake	X	-	-	-	2008
LSA - North Belt	Patch Lake	Doris	Lake	X	-	X	-	1997, 2003, 2005, 2008, 2009
LSA - North Belt	Windy Lake	Windy	Lake	X	-	X	-	1997
LSA - North Belt	Doris Outflow	Doris	Stream	X	-	-	-	2003
LSA - North Belt	Pelvic Outflow	Doris	Stream	X	X	-	-	2003
LSA - North Belt	Glenn Outflow	Windy	Stream	X	-	-	-	2003
LSA - South Belt	Aimaokatalok Lake	Aimaokatalok	Lake	X	-	X	-	1997
RSA	Roberts Lake	Roberts	Lake	X	X	-	-	2005-2007, 2010-2012
RSA	Little Roberts Lake	Roberts	Lake	X	X	-	X	2000, 2002, 2006
RSA	Pelvic Lake	Roberts	Lake	X	-	X	-	1998
RSA	Roberts Inflows E04-E36	Roberts	Stream	X	X	-	-	2007, 2010-2011, 2013
RSA	Roberts Outflow	Roberts	Stream	X	X	-	-	2004-2006, 2010-2013
RSA	Little Roberts Outflow	Roberts	Stream	X	X	-	-	2006-2007

X = survey conducted. Dashes indicate no surveys were conducted.
LSA = Local Study Area and RSA = Regional Study Area.

Tagging of Lake Trout and Arctic Char was conducted on Roberts Outflow or Little Roberts Outflow every year that the fish fences were operational from 2000 to 2013. Tagging on other lakes and streams was done intermittently from 1997 to 2009. All Lake Trout and Arctic Char that were subsequently caught in “tagging lakes” were examined for the presence of a tag. Once PIT tags were introduced, captured lake trout were scanned with a PIT tag reader to determine if they had been previously tagged. For tagged fish, the tag number and type of tag was recorded and that fish was labelled as a ‘recapture’ for data entry.

<u>Stomach Contents</u>

Stomach contents were collected from fish that died from capture or handling, as well as fish that were sacrificed for tissue metals analysis. For many stomachs, the contents were examined on the spot and notes were made of dominant prey items. For selected fish, stomachs were removed and preserved in formalin. These samples were sent to taxonomists for detailed analysis. In 2010 and 2011, preserved stomach contents were sent to Applied Technical Services in Victoria, British Columbia.

Stomach contents were collected to determine the diet of different species and life stages of fish and infer their trophic position. Results of analyses of stomach contents are briefly presented in the relevant parts of Section 6.2.5.3 (Life Histories and Habitat Preferences of Fish Species).

Stomach contents were examined from five species: Lake Trout, Lake Whitefish, Arctic Char, Least Cisco, and Cisco (Table 6.2-9). Lake Trout stomach contents were examined from ten lakes and three streams. Lake Whitefish stomach contents were examined from seven lakes. Arctic Char stomachs were examined from Little Roberts Lake and Roberts Outflow. Least Cisco stomach contents were examined from Roberts Lake and Little Roberts Lake. Cisco stomach contents were examined from Roberts Lake.

<u>Tissue Metals Concentrations</u>

Tissue samples were collected from 1993 to 2010 and analyzed for metal concentrations as a baseline for monitoring the uptake of metals by fish that reside in waterbodies that may potentially be affected by Hope Bay Project activities.

Samples of muscle and/or liver were taken from selected large-bodied fish species. For each fish, after collection of biological data, a 1 to 5 g piece of muscle tissue was taken, stripped of bones and skin, rinsed in clean lake water, and placed in an individually labelled Whirl-Pak bag. Whole livers from each fish were stored in the same manner. Due to their small body size, Ninespine Stickleback had to be prepared as composite, whole-body samples to meet the minimum tissue weights required for analysis. Tissue samples were frozen immediately and were kept frozen until they were delivered to an analytical laboratory.

Fish tissue samples were collected from five species of large-bodied fish: Lake Trout, Lake Whitefish, Cisco, Arctic Grayling, and Arctic Char (Table 6.2-10). Beginning in 2010, Ninespine Stickleback samples were collected as part of the Doris AEMP. Lake Trout tissue samples were collected from 14 lakes: seven in the LSA North, two in the LSA South, and five in the RSA. Lake Whitefish tissue samples were collected from six lakes: four in the LSA North, one in the LSA South, and one in the RSA. Ninespine Stickleback tissue samples were collected from four lakes (Doris, Little Roberts, Reference B, and Reference D) and five streams in the LSA South located downstream of potential tailings impoundment areas. Tissue samples for Cisco, Arctic Grayling, and Arctic Char were collected from Doris Lake, Trout Lake, and Roberts Outflow, respectively.

Table 6.2-9. Fish Stomach Content Sampling in the LSA and RSA, 1993-2015

Area	Water Body	Watershed	Waterbody Type	Lake Trout	Lake Whitefish	Arctic Char	Least Cisco	Cisco	Sampling Year
LSA - North Belt	Doris Lake	Doris	Lake	X	X	-	-	-	1997, 2002
LSA - North Belt	P.O. Lake	Doris	Lake	X	-	-	-	-	2009
LSA - North Belt	Patch Lake	Doris	Lake	X	X	-	-	-	1997
LSA - North Belt	Tail Lake	Doris	Lake	X	-	-	-	-	2000, 2002, 2011
LSA - North Belt	Windy Lake	Windy	Lake	X	X	-	-	-	1997, 2009
LSA - South Belt	Aimaokatalok Lake	Aimaokatalok	Lake	X	X	-	-	-	1993, 1997, 2010
RSA	Roberts Lake	Roberts	Lake	X	X	-	X	X	2005
RSA	Little Roberts Lake	Roberts	Lake	X	-	X	X	-	2000, 2002, 2009
RSA	Reference Lake D	Reference D	Lake	X	X	-	-	-	2010
RSA	Pelvic Lake	Roberts	Lake	X	X	-	-	-	1998
RSA	Roberts Outflow	Roberts	Stream	-	-	X	-	-	2005, 2006
RSA	Reference A Outflow	Reference	Stream	X	-	-	-	-	2009
RSA	Reference B Outflow	Reference B	Stream	X	-	-	-	-	2009

X = survey conducted. Dashes indicate no surveys were conducted.
LSA = Local Study Area and RSA = Regional Study Area.

Table 6.2-10. Fish Tissue Sampling in the LSA and RSA, 1993-2015

Area	Water Body	Watershed	Waterbody Type	Lake Trout	Ninespine Stickleback	Lake Whitefish	Cisco	Arctic Grayling	Arctic Char	Sampling Years
LSA - North Belt	Doris Lake	Doris	Lake	X	X	X	X	-	-	1995-1997, 2010
LSA - North Belt	Tail Lake	Doris	Lake	X	-	-	-	-	-	1995, 2011
LSA - North Belt	Ogama Lake	Doris	Lake	X	-	-	-	-	-	1996
LSA - North Belt	Patch Lake	Doris	Lake	X	-	X	-	-	-	1995-1997
LSA - North Belt	P.O. Lake	Doris	Lake	X	-	X	-	-	-	2009
LSA - North Belt	Windy Lake	Windy	Lake	X	-	-	-	-	-	1996, 1997, 2009
LSA - South Belt	Aimaokatalok Lake	Aimaokatalok	Lake	X	-	X	-	-	-	1993, 1995-1997, 2010
LSA - South Belt	Trout Lake	Aimaokatalok	Lake	X	-	-	-	X	-	1995-1996
LSA - South Belt	Boston tailings #1 (site S21)	Aimaokatalok	Stream	-	X	-	-	-	-	2010
LSA - South Belt	Boston tailings stream 2 (site S22)	Aimaokatalok	Stream	-	X	-	-	-	-	2010
LSA - South Belt	Boston tailings stream 1 (site S23)	Aimaokatalok	Stream	-	X	-	-	-	-	2010
LSA - South Belt	Boston tailings stream 3 (site S25)	Aimaokatalok	Stream	-	X	-	-	-	-	2010
LSA - South Belt	Boston tailings #1 (site S28)	Aimaokatalok	Stream	-	X	-	-	-	-	2010
RSA	Roberts Lake	Roberts	Lake	X	-	-	-	-	-	2005
RSA	Little Roberts Lake	Roberts	Lake	X	X	-	-	-	-	2009, 2010
RSA	Reference Lake A	Reference A	Lake	X	-	-	-	-	-	2009
RSA	Reference Lake B	Reference B	Lake	X	X	-	-	-	-	2009-2010
RSA	Reference Lake D	Reference D	Lake	X	X	X	-	-	-	2010
RSA	Pelvic Lake	Roberts	Lake	X	-	X	-	-	-	1998
RSA	Roberts Outflow	Roberts	Stream	-	-	-	-	-	X	2006

X = survey conducted. Dashes indicate no surveys were conducted.
LSA = Local Study Area and RSA = Regional Study Area.

ALS Environmental analyzed the tissue samples for metals concentrations according to procedures adapted from the United States Environmental Protection Agency (EPA; US EPA 1995). Samples were divided into two parts: one part for measurement of metal concentrations (on a wet weight basis) and a second part for measurement of percent moisture so that the results could be converted to mg/kg dry weight. Each sample was homogenized either mechanically or manually prior to digestion. The hotplate digestion method involved the use of nitric acid followed by repeated additions of hydrogen peroxide. Total concentrations of 25 metals were measured by Inductively Coupled Plasma – Mass Spectroscopy or ICPMS.

Results of the analysis of fish tissue metals concentrations are not presented in the Freshwater Fish chapter of the EIS and instead are presented in Volume 6, Section 5 (Human Health and Environmental Risk Assessment)

Quality Assurance and Quality Control

The Vaki Riverwatch video monitoring system was used from 2013 to 2015 on fish counting fences installed on Roberts Outflow. The QA/QC for this system was to double-check a subset of video images. After the initial assessment of underwater videos, a second fish biologist randomly selected and reviewed 10% of the videos to check the accuracy of species identification.

All age structures were read a minimum of two times. If consistency was not met between the first two reads, a third was undertaken. If consistency was not accomplished within three reads, the structure was deemed un-ageable and no age was assigned. Age readers were given no information on weight, length or sex, so that age estimates were based solely on the annular structure of the fin ray. All readings were conducted as “blind” (independent from each other). Quality assurance and quality control (QA/QC) was then conducted by an alternate ageing technician on 10% of randomly selected structures. The QA/QC readings were also conducted “blind” to determine consistency and accuracy.

To assess the accuracy of the metal analyses, ALS conducted two measures of quality control: method blanks and comparison with reference material. A method blank is a test in which no tissue was added. A reference material such as lobster hepatopancreas, certified by the National Research Council of Canada, was subjected to the same analytical procedures as the fish tissue samples. The measured concentrations of each metal were then compared to the known metal concentrations in the certified material to determine if they fell within the 95% confidence limits expected for each metal.

To assess the variability of fish tissue metal analysis, and hence the homogeneity of the samples, a small number of samples were each split into two replicates and the relative percent difference (RPD) between replicate metal concentrations (and percent moisture) was calculated as:

$$RPD = 100((sample - duplicate)/((sample + duplicate)/2))).$$

RPD were not calculated if one or both of the values were less than the Method Detection Limit (MDL). In general, analytical variability is much higher near the MDL than is considered acceptable. Therefore, those RPD were classified as “RPD-not available” or RPD-NA.

Other potential RPD were not calculated because both values were between one and five times higher than the MDL. The *British Columbia Field Sampling Manual* (BCMWLAP 2003) recommends that only RPD calculated from concentrations each of which is greater than five times the MDL should be used for assessing data quality. Instead of an RPD, the absolute difference between the values was calculated.

All remaining RPD were assumed to be valid. RPD were considered acceptable if they met the RPD limits established by ALS (30% for percent moisture and 45% for metals). ALS interpreted these results as showing low variability of analyses.

6.2.6 Characterization of Baseline Conditions

The key findings of surveys of freshwater fish habitat, inclusive of biological resources (i.e., phytoplankton, periphyton, zooplankton, and benthic invertebrates), and physical characteristics, and fish communities in the LSA and RSA are summarized below.

6.2.6.1 Freshwater Fish Habitat – Biological Resources

Lake Phytoplankton

Phytoplankton biomass and phytoplankton abundance were highly variable among lakes in the LSA and RSA. In general, lakes in the North Belt LSA and the RSA fell into one of two broad categories: 1) lakes with low phosphorus concentrations, low phytoplankton biomass and abundance levels, and communities dominated by diatoms, cryptophytes, chrysophytes, or chlorophytes, and 2) lakes with high phosphorus concentrations, high phytoplankton biomass and abundance levels, with communities dominated by cyanobacteria.

LSA – North Belt

In the North Belt LSA, most lakes had relatively low mean chlorophyll *a* concentrations (<2 µg/L) and low mean phytoplankton abundance levels (<700 cells/mL; Table 6.2-11). These low biomass and abundance lakes included: Glenn, Imniagut, P.O., Patch, Windy, and Wolverine lakes. Diatoms tended to be the most abundant phytoplankton group within these lakes, followed by cryptophytes (Table 6.2-11). The most common phytoplankton species in these lakes included the centric diatom *Cyclotella ocellata* and the small cryptomonad *Rhodomonas minuta* (Table 6.2-11).

In contrast, Doris, Ogama, and Nakhaktok lakes all had higher phytoplankton biomass with mean biomass levels ranging from 5.1 to 18.0 µg chl *a*/L, and maximum levels ranging from 10.2 to 56.4 µg chl *a*/L. These lakes also had high phytoplankton abundance, with means ranging from 6,310 to 18,669 cells/mL and maxima ranging from 16,641 to 62,303 cells/mL (Table 6.2-11); these abundances were roughly one to two orders of magnitude greater than those observed in the low abundance lakes. The highest biomass and abundance levels were recorded in Doris Lake. Cyanobacteria (also known as blue-green algae) were the predominant phytoplankton group in the high biomass and abundance lakes, and the most abundant species of cyanobacteria were *Aphanizomenon flos-aquae* and *Oscillatoria tenuis* (Table 6.2-11).

The phytoplankton communities were likely influenced by nutrient concentrations in the lakes as the high biomass, cyanobacteria-dominated lakes generally had higher phosphorus concentrations and were categorized as mesotrophic to eutrophic lakes (based on total phosphorus concentrations while the low biomass, diatom-dominated lakes generally contained lower concentrations of phosphorus and were categorized as ultra-oligotrophic to meso-eutrophic. However, total phosphorus concentrations in lakes were variable, and there were instances that typically high phosphorus lakes had sporadically low phosphorus concentrations (e.g., Doris Lake dropped to oligotrophic status in 2014), or that typically low phosphorus lakes had sporadically high phosphorus concentrations (e.g., P.O. Lake reached hyper-eutrophic status in 2007; Volume 5, Section 4).

Table 6.2-11. Summary of Lake Phytoplankton Biomass, Abundance, and Taxonomy in the LSA and RSA

Lake	Chlorophyll Biomass (µg chl *a*/L)			Phytoplankton Abundance (cells/mL)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	Mean	Max	Min	Mean	Max		
LSA - North Belt								
Doris Lake	0.56	8.50	56.4	2,971	18,669	62,303	Cyanobacteria	*Aphanizomenon flos-aquae* (cyanobacteria) & *Oscillatoria tenuis* (cyanobacteria)
Glenn Lake	0.80	1.35	2.41	546	-	546	Diatoms	*Cyclotella ocellata* (diatom)
Imniagut Lake	0.63	-	0.63	414	-	414	Cryptophytes	*Rhodomonas minuta* (cryptophyte)
Nakhaktok Lake	18.0	-	18.0	16,937	-	16,937	Cyanobacteria	*Aphanizomenon flos-aquae* (cyanobacteria)
Ogama Lake	1.18	5.06	10.2	1,338	6,310	16,641	Cyanobacteria	*Aphanizomenon flos-aquae* (cyanobacteria) & *Oscillatoria tenuis* (cyanobacteria)
P.O. Lake	0.34	1.34	2.50	69	-	69	Diatoms, Cryptophytes	*Cryptomonas erosa* (cryptophyte)
Patch Lake	0.11	0.80	2.02	168	253	364	Diatoms, Cryptophytes	*Cyclotella ocellata* (diatom) & *Rhodomonas minuta* (cryptophyte)
Windy Lake	0.06	1.30	8.19	21	164	259	Diatoms, Cyanobacteria	*Oscillatoria tenuis* (cyanobacteria) & *Cyclotella ocellata* (diatom)
Wolverine Lake	0.57	1.77	4.50	439	640	840	Diatoms, Chlorophytes	*Diatoma tenue* (diatom) & *Chlamydomonas sp.* (chlorophyte)
LSA - South Belt								
Aimaokatalok Lake	0.21	1.64	8.80	125	1,171	3,471	Cyanobacteria, Chlorophytes	*Gomphosphaeria* sp. (cyanobacteria), *Oscillatoria tenuis* (cyanobacteria) & *Crucigenia tetrapedia* (chlorophyte)
Stickleback Lake	0.76	1.68	4.20	527	2,355	7,962	Cyanobacteria	*Anacystis elachista* (cyanobacteria)
Trout Lake	0.65	4.51	24.9	53	1,277	3,900	Cyanobacteria	*Anabaena affinis* (cyanobacteria)

Lake	Chlorophyll Biomass (µg chl *a*/L)			Phytoplankton Abundance (cells/mL)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	Mean	Max	Min	Mean	Max		
RSA								
Boston Reference Lake	1.24	3.87	10.2	172	8,237	15,883	Cyanobacteria	*Anabaena affinis* (cyanobacteria)
Little Roberts Lake	0.95	4.98	26.9	1,858	13,638	39,509	Cyanobacteria	*Oscillatoria* spp. (cyanobacteria)
Naiqunnguut Lake	0.62	-	0.62	260	-	260	Chlorophytes, Cryptophytes	*Rhodomonas minuta* (cryptophyte)
Pelvic Lake	3.12	11.5	19.5	24,698	44,336	63,973	Cyanobacteria	*Oscillatoria* spp. (cyanobacteria)
Reference A Lake (2003)	3.17	8.9	16.3	-	-	-	-	-
Reference Lake A	0.86	-	0.86	478	-	478	Diatoms	*Cyclotella ocellata* (diatom)
Reference Lake B	0.21	0.60	2.06	181	198	215	Chrysophytes, Diatoms	*Rhodomonas minuta* (cryptophyte) & *Cyclotella ocellata* (diatom)
Reference Lake D	0.34	1.69	11.9	253	-	253	Diatoms	*Cyclotella stelligera* (diatom)
Roberts Lake	0.52	3.31	9.80	-	-	-	-	-

Notes:
[a] *Lowest available taxonomic level (usually genus or species).*

The mean Simpson's Diversity Indices ranged from 0.22 to 0.87 in the North Belt LSA, and mean genus richness ranged from 8 to 16. The North Belt lakes that had the lowest Simpson's Diversity Index and richness levels were cyanobacteria-dominated lakes (Doris and Nakhaktok lakes).

LSA – South Belt

In the South Belt LSA, Aimaokatalok and Stickleback lakes had relatively low mean biomass levels of 1.64 and 1.68 µg chl *a*/L, respectively, while Trout Lake had a higher mean biomass of 4.51 µg chl *a*/L (Table 6.2-11). Trout Lake also had the highest concentrations of total phosphorus and was categorized as a mesotrophic to eutrophic lake, while Aimaokatalok and Stickleback lakes were oligotrophic to meso-eutrophic (see Volume 5, Section 4). Mean phytoplankton abundances ranged from 1,171 to 2,355 cells/mL in the South Belt lakes and were intermediate to abundances in the North Belt lakes. Cyanobacteria were the most abundant phytoplankton group in all three lakes, though chlorophytes (also known as green algae) were also abundant in Aimaokatalok Lake. The most common phytoplankton species in Aimaokatalok Lake were the cyanobacteria *Gomphosphaeria* sp. and *Oscillatoria tenuis* and the chlorophyte *Crucigenia tetrapedia*. The cyanobacteria *Anacystis elachista* and *Anabaena affinis* were the dominant species in Stickleback and Trout lakes, respectively (Table 6.2-11).

The South Belt LSA had the highest phytoplankton diversity among the study areas. The mean Simpson's Diversity Indices ranged from 0.79 to 0.81 and the mean genus richness ranged from 19 to 23.

RSA

In the RSA, there was a clear distinction between lakes that had high phytoplankton biomass and abundance and lakes with low biomass and abundance as was observed in the North Belt LSA lakes. Four lakes in the RSA, Naiquunguut Lake and Reference lakes A, B, and D, all had relatively low mean chlorophyll *a* concentrations (<2 µg chl *a*/L) and low mean phytoplankton abundance levels (<700 cells/mL; Table 6.2-11). The most abundant phytoplankton group in Reference lakes A and B was diatoms. In Reference Lake D, diatoms and chrysophytes made up the majority of the phytoplankton community, while chlorophytes and cryptophytes were most abundant in Naiqunnguut Lake. As was the case in the North Belt LSA low biomass and abundance lakes, the most common phytoplankton species in the four low biomass and abundance RSA lakes included the diatom *Cyclotella ocellata* and the cryptomonad *Rhodomonas minuta* (Table 6.2-11). With the exception of Reference Lake D, which covered a wide range of trophic categories from ultra-oligotrophic to eutrophic, the remaining three low biomass and abundance lakes had the lowest phosphorus concentrations among RSA lakes, and were categorized as either ultra-oligotrophic, oligotrophic, or mesotrophic (based on total phosphorus concentrations; Volume 5, Section 4).

In contrast, Boston Reference Lake, Little Roberts Lake, and Pelvic Lake all had relatively high biomass (mean chlorophyll concentrations ranging from 3.87 to 11.5 µg chl *a*/L) and abundance levels (mean abundance ranging from 8,237 to 44,336 cells/mL), and were dominated by cyanobacteria. The most prevalent cyanobacteria species in these lakes were *Anabaena affinis* and *Oscillatoria* spp. Boston Reference Lake, Little Roberts Lake, and Pelvic Lake also had relatively high phosphorus concentrations and were categorized as mesotrophic to hyper-eutrophic (see Volume 5, Section 4).

The mean Simpson's Diversity Indices for phytoplankton in the RSA ranged from 0.26 to 0.86, and the mean genus richness ranged from 8 to 21.

<u>Stream and River Periphyton</u>

LSA – North Belt

In the North Belt LSA, mean periphyton biomass ranged from 0.025 µg chl *a*/cm^2 in Patch Outflow to 0.28 µg chl *a*/cm^2 in AWRb stream (Table 6.2-12). Periphyton abundance was highly variable across sites, ranging from 37,113 cells/cm^2 in AWRa stream to 1,521,312 cells/cm^2 in Ogama Outflow (Table 6.2-12). The periphyton abundance in Ogama Outflow was markedly higher than any other monitored stream in the study areas, and was nearly an order of magnitude higher than the North Belt site with the next highest mean abundance (Koignuk River (upstream, midstream, and downstream): 185,396 cells/cm^2). Diatoms were the dominant periphyton group in all North Belt streams and rivers, and *Diatoma tenue* was generally the most abundant species. In Doris Outflow, downstream of the productive Doris Lake, both diatoms and cyanobacteria were abundant, and the cyanobacterium *Oscillatoria tenuis* was the most common species (Table 6.2-12). The mean Simpson's Diversity Indices ranged from 0.31 to 0.86 and genus richness ranged from 9 to 18 in North Belt streams and rivers. Windy Outflow had particularly low mean Simpson's Diversity Index diversity (0.31) and richness (9) for periphyton.

LSA – South Belt

In the South Belt LSA, periphyton biomass ranged from 0.041 µg chl *a*/cm^2 in AWRd stream to 0.44 µg chl *a*/cm^2 at Aimaokatalok Outflow (Table 6.2-12). Mean periphyton abundance was highly variable, ranging from 11,773 cells/cm^2 in AWRc stream to 407,347 cells/cm^2 in Aimaokatalok NE Inflow (Table 6.2-12). Aimaokatalok NE Inflow also had the highest total phosphorus concentrations among South Belt LSA streams, and was categorized as either meso-eutrophic or eutrophic (see Volume 5, Section 4). Diatoms were the dominant group in most streams and rivers, and the most common diatom species were *Synedra radians* and *Achnanthes minutissima*. The cyanobacterium *Gomphosphaeria naegelianum* was the most common species in Aimaokatalok NE Inflow, and an unidentified cyanobacterium was the dominant taxon in Trout Outflow (Table 6.2-12). Simpson's Diversity Indices ranged from 0.56 to 0.88 in South Belt streams and rivers, and genus richness ranged from 11 to 23.

RSA

In the RSA, mean biomass ranged from 0.059 µg chl *a*/cm^2 in Reference A Outflow to 0.60 µg chl *a*/cm^2 in Pelvic Outflow (Table 6.2-12). Mean periphyton abundance ranged from 77,966 cells/cm^2 in Reference B Outflow to 378,000 cells/cm^2 in both Angimajuq River Reference and Pelvic Outflow (Table 6.2-12). Diatoms were generally the most abundant group, though cyanobacteria also made up a major fraction of the periphyton assemblage in some streams and rivers. The most common periphyton species in the RSA were similar to those observed in the LSA streams and rivers (Table 6.2-18). In the RSA, mean Simpson's Diversity Indices ranged from 0.57 to 0.87 and genus richness ranged from 8 to 23.

<u>Lake Zooplankton</u>

LSA – North Belt

Mean zooplankton abundance in the North Belt LSA lakes ranged from 2,939 organisms/m^3 in Glenn Lake to 282,282 organisms/m^3 in Nakhaktok Lake (Table 6.2-13). The lakes with relatively high mean and maximum zooplankton abundances (Nakhaktok, Doris, and Ogama lakes) were the same lakes that had the highest phytoplankton biomass and abundance, suggesting that zooplankton abundance was related to the abundance of their prey. Imniagut Lake was the exception, as this lake had relatively high zooplankton abundance (Table 6.2-13), but relatively low phytoplankton biomass and abundance (Table 6.2-13). The most common zooplankton taxa in the North Belt lakes were cyclopoid copepods and rotifers. Most of the copepods observed in the North Belt lakes were in their early life stages (nauplii or copepodites), and were not identified to the level of genus or species. The most abundant rotifer species were *Keratella quadrata* and *Kellicottia longispina*. The calanoid copepod species

Limnocalanus macrurus was the most abundant zooplankton taxon in Glenn Lake (Table 6.2-13). The mean Simpson's Diversity Indices in North Belt LSA lakes ranged from 0.14 in Glenn Lake to 0.71 in Imniagut and Patch lakes. Mean genus richness ranged from 3 in Glenn Lake to 12 in Wolverine Lake. Glenn and Windy lakes had the least abundant zooplankton communities (Table 6.2-13), as well as the least diverse (mean Simpson's Diversity Index and genus richness were 0.25 and 4, respectively, in Windy Lake).

LSA – South Belt

In the South Belt LSA, mean zooplankton abundance ranged from 28,977 organisms/m^3 in Aimaokatalok Lake to 129,355 organisms/m^3 in Stickleback Lake (Table 6.2-13). Zooplankton abundance in South Belt lakes was intermediate to the range of abundances recorded in North Belt Lakes. Similar to the North Belt LSA, the most common zooplankton groups in the South Belt LSA were cyclopoid copepods and rotifers. The most abundant species were *Cyclops* spp. (cyclopoid copepod) and *Kellicottia longispina* (rotifer, Table 6.2-13). The mean Simpson's Diversity Indices ranged from 0.34 in Stickleback Lake to 0.58 in Aimaokatalok Lake, and mean genus richness ranged from 8 in Stickleback Lake to 11 in Trout Lake.

RSA

In the RSA, mean zooplankton abundance ranged from 4,345 organisms/m^3 in Reference Lake A to 50,308 organisms/m^3 in Naiqunnguut Lake (Table 6.2-13). Rotifers were the most common group in the RSA lakes. *Kellicottia longispina* was the most abundant zooplankton species in three of the surveyed lakes (Boston Reference Lake, Little Roberts Lake, and Reference Lake A) and *Keratella quadrata* was the most abundant species in Pelvic Lake. Cladocerans were the most abundant group in Naiqunnguut Lake and Reference Lake D, and *Daphnia longiremis* and *Bosmina longirostris* were the most common cladoceran species in these lakes. Calanoid copepods were also abundant in Reference lakes A and B (Table 6.2-13). Reference Lake D had the least diverse zooplankton community (Simpson's Diversity Index of 0.3 and genus richness of 7). Naiqunnguut Lake had the highest mean diversity (0.78), and Little Roberts Lake had the highest mean genus richness (13).

<u>Lake Benthic Invertebrates</u>

LSA – North Belt

Benthic invertebrate abundance was highly variable among lakes in the study areas. Mean benthic invertebrate abundance in the North Belt LSA lakes ranged from 119 organisms/m^2 in Windy Lake (mid-depth) to 42,118 organisms/m^2 in P.O. Lake (shallow depth; Table 6.2-14). In general, benthic invertebrate abundance decreased with increasing sampling depth (i.e., shallow sites had the highest abundances), but there were exceptions to this trend (Table 6.2-14). In most lakes within the North Belt LSA, dipterans were the most common benthic taxon. Chironomids (a family within the order Diptera) were particularly abundant, especially the genus *Chironomus*. However, ostracods (small crustaceans also known as seed shrimp) were the most common benthic group at the sites with the highest mean benthic abundances (Imniagut Lake: 23,597 organisms/m^2, P.O. Lake: 42,118 organisms/m^2, and Wolverine Lake: 19,929 organisms/m^2; Table 6.2-14).

In the North Belt, mean Simpson's Diversity Indices ranged from 0.15 (Glenn Lake, deep depth) to 0.75 (Imniagut Lake, shallow depth) and genus richness ranged from 1 (Glenn Lake, deep depth) to 11 (Nakhaktok Lake, shallow depth). In general, sites with relatively low benthic invertebrate abundance (e.g., deep site in Glenn Lake, mid-depth site in Patch Lake) also tended to have low levels of genus diversity and richness.

Table 6.2-12. Summary of Stream and River Periphyton Biomass, Abundance, and Taxonomy in the LSA and RSA

Stream	Chlorophyll Biomass (µg chl *a*/cm^2)			Periphyton Abundance (cells/cm^2)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	Mean	Max	Min	Mean	Max		
LSA - North Belt								
AWRa	0.197	-	0.197	37,113	-	37,113	Diatoms	*Diatoma tenue* (diatom)
AWRb	0.283	-	0.283	53,218	-	53,218	Diatoms	*Achnanthes linearis* (diatom)
Doris Outflow	0.038	0.218	0.530	72,392	183,487	278,725	Diatoms, Cyanobacteria	*Oscillatoria tenuis* (cyanobacteria)
Glenn Outflow Downstream	0.034	-	0.034	115,204	-	115,204	Diatoms	*Diatoma tenue* (diatom)
Koignuk River (Upstream, Midstream, Downstream)	0.010	0.106	0.216	6,220	185,395	382,983	Diatoms	*Diatoma tenue* (diatom) & *Achnanthes minutissima* (diatom)
Ogama Outflow	0.250	-	0.250	427,234	1,521,312	3,187,329	Diatoms	*Diatoma* spp. (diatom)
P.O. Outflow	0.053	-	0.053	70,236	-	70,236	Diatoms	*Diatoma tenue* (diatom)
Patch Outflow	0.025	-	0.025	102,400	119,095	135,789	Diatoms	*Diatoma tenue* (diatom)
Windy Outflow	0.030	-	0.030	63,053	88,551	128,547	Diatoms	*Diatoma tenue* (diatom)
LSA - South Belt								
Aimaokatalok NE Inflow	0.196	-	0.196	113,868	407,347	987,472	Cyanobacteria	*Gomphosphaeria naegelianum* (cyanobacteria)
Aimaokatalok Outflow	0.440	-	0.440	158,614	-	158,614	Diatoms	*Tabellaria flocculosa* (diatom)
AWRc	0.084	-	0.084	11,773	-	11,773	Diatoms	*Synedra radians* (diatom)
AWRd	0.041	-	0.041	13,903	-	13,903	Diatoms	*Synedra radians* (diatom)
Koignuk River	0.285	-	0.285	142,222	-	142,222	Diatoms	*Achnanthes minutissima* (diatom)
Stickleback Outflow	0.161	-	0.161	29,465	259,030	563,973	Diatoms	*Achnanthes minutissima* (diatom)
Trout Outflow	0.132	-	0.132	84,165	352,393	601,529	Cyanobacteria, Chlorophytes	unidentified cyanobacterium
RSA								

Stream	Chlorophyll Biomass (µg chl *a*/cm^2)			Periphyton Abundance (cells/cm^2)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	**Mean**	**Max**	**Min**	**Mean**	**Max**		
Aimaokatalok River	0.111	-	0.111	26,158	213,854	582,187	Cyanobacteria, Diatoms	*Gomphosphaeria naegelianum* (cyanobacteria)
Angimajuq River Reference	0.185	-	0.185	378,164	-	378,164	Diatoms	*Tabellaria flocculosa* (diatom)
Boston Reference Outflow	-	-	-	174,996	210,974	246,952	Cyanobacteria	*Diatoma tenue* (diatom)
Little Roberts Outflow	0.007	0.191	1.30	58,352	276,636	484,340	Diatoms	*Diatoma tenue* (diatom)
Pelvic Outflow	0.600	-	0.600	252,467	377,993	453,109	Diatoms, Cyanobacteria	*Oscillatoria tenuis* (cyanobacteria) & *Diatoma tenue* (diatom)
Reference A Outflow	0.059	-	0.059	149,118	-	149,118	Diatoms	*Diatoma tenue* (diatom)
Reference B Outflow	0.006	0.067	0.372	15,841	77,966	140,090	Diatoms	*Achnanthes minutissima* (diatom)
Reference D Outflow	0.027	0.119	0.410	188,720	-	188,720	Diatoms	*Achnanthes minutissima* (diatom)
Roberts Outflow	0.018	0.153	0.292	-	-	-	-	-

Notes: Chlorophyll biomass data from 1997 and 1998 were not included as they were roughly 2 to 3 orders of magnitude higher than the rest of the values in the dataset.
a Lowest available taxonomic level (usually genus or species).

Table 6.2-13. Summary of Lake Zooplankton Abundance and Taxonomy in the LSA and RSA

Lake	Zooplankton Abundance (organisms/m^3)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	Mean	Max		
LSA - North Belt					
Doris Lake	8,861	36,931	85,496	Rotifers	*Kellicottia longispina* (rotifer)
Glenn Lake	2,939	-	2,939	Copepods (Calanoid)	*Limnocalanus macrurus* (calanoid copepod)
Imniagut Lake	255,194	-	255,194	Copepods	copepod nauplii
Nakhaktok Lake	282,282	-	282,282	Rotifers	*Keratella quadrata* (rotifer)
Ogama Lake	13,456	60,736	95,399	Copepods (Cyclopoid)	cyclopoid copepodites
P.O. Lake	23,845	-	23,845	Copepods (Cyclopoid)	cyclopoid copepodites
Patch Lake	13,127	15,309	18,799	Copepods (Cyclopoid)	cyclopoid copepodites
Windy Lake	835	4,628	8,333	Rotifers	*Conochilus sp.* (rotifer)
Wolverine Lake	5,221	8,926	12,630	Rotifers	*Kellicottia longispina* (rotifer) & *Conochilus unicornis* (rotifer)
LSA - South Belt					
Aimaokatalok Lake	1,816	28,977	78,652	Copepods (Cyclopoid) & Rotifers	*Kellicottia longispina* (rotifer) & *Cyclops spp.* (cyclopoid copepod)
Stickleback Lake	684	129,355	911,697	Copepods (Cyclopoid) & Rotifers	*Kellicottia longispina* (rotifer) & *Cyclops spp.* (cyclopoid copepod)
Trout Lake	3,750	79,787	269,733	Rotifers	*Kellicottia longispina* (rotifer)
RSA					
Boston Reference Lake	2,001	7,442	16,589	Rotifers	*Kellicottia longispina* (rotifer)
Little Roberts Lake	4,206	5,432	7,187	Rotifers	*Kellicottia longispina* (rotifer)
Naiqunnguut Lake	50,308	-	50,308	Cladocerans	*Daphnia longiremis* (cladoceran)
Pelvic Lake	13,303	44,797	76,290	Rotifers	*Keratella quadrata* (rotifer)
Reference Lake A	4,345	-	4,345	Rotifers & Copepods (Calanoid)	*Kellicottia longispina* (rotifer)
Reference Lake B	39,050	40,153	41,256	Copepods (Calanoid) & Rotifers	diaptomid copepodites
Reference Lake D	6,931	-	6,931	Cladocerans	*Bosmina longirostris* (cladoceran)

Notes: a Lowest available taxonomic level (usually genus or species).

LSA – South Belt

In the South Belt LSA, mean benthic invertebrate abundance ranged from 1,257 organisms/m^2 in Aimaokatalok Lake (deep depth) to 23,551 organisms/m^2 in Stickleback Lake (shallow depth, Table 6.2-14). In Aimaokatalok Lake, the only lake in the South Belt LSA that was sampled at multiple depths, mean benthic abundance was highest in the shallow sites. The benthic communities in each of the three South Belt LSA lakes were dominated by different benthic groups, with Trout Lake being dominated by dipterans, whereas the benthic assemblages in Aimaokatalok and Stickleback lakes consisted of more even mix of taxonomic groups. Bivalve molluscs belonging to the family Sphaeriidae (pea clams) were the most common benthic invertebrates in Aimaokatalok Lake, ostracods were the most abundant group in Stickleback Lake (though dipterans were also very abundant), and the dipteran genus *Zalutschia* (in the chironomid family) was the most common taxon in Trout Lake (Table 6.2-14).

In the South Belt, mean Simpson's Diversity Indices ranged from 0.36 (Trout Lake, shallow depth) to 0.85 (Stickleback Lake, shallow depth). Genus richness in the South Belt lakes ranged from 7 (Aimaokatalok Lake, deep depth) to 17 (Stickleback Lake, shallow depth).

RSA

In the RSA, mean benthic invertebrate abundance ranged from 147 organisms/m^2 in Reference Lake A (deep depth) to 16,746 organisms/m^2 in Reference Lake D (shallow depth; Table 6.2-14). Dipterans were the most abundant benthic group in all but two lakes in the RSA. The most common dipteran genera in the RSA lakes were *Paratanytarsus*, *Stictochironomus*, *Tanytarsus*, and *Chironomus* (all within the chironomid family; Table 6.2-14). Mean values for Simpson's Diversity Indices for benthic organisms in the RSA ranged from 0.38 (Reference Lake A, deep depth) to 0.74 (Naiqunnguut Lake, shallow depth) and richness ranged from 2 (Reference Lake A, deep depth) to 11 (Little Roberts Lake, shallow depth).

<u>Stream and River Benthic Invertebrates</u>

LSA – North Belt

Mean benthic invertebrate abundance in streams and rivers of the North Belt LSA ranged from 1,695 organisms/m^2 in Patch Outflow to 26,674 organisms/m^2 in Doris Outflow (Table 6.2-15). There was not only high variability in benthic abundance between streams, but also within streams. In Doris Outflow, for example, benthic abundance ranged from 761 (in 1997) to 207,867 organisms/m^2 (in 2000). Dipterans were the predominant benthic group in all streams. A diverse variety of dipteran genera were recorded in North Belt LSA streams, including the black fly *Simulium* and the chironomids *Hydrobaenus*, and *Rheotanytarsus* (Table 6.2-15). Mean values for Simpson's Diversity Indices ranged from 0.65 (Glenn Outflow Downstream) to 0.85 (AWRb), and genus richness ranged from 9 (AWRa) to 19 (Doris Outflow) for the benthic community.

LSA – South Belt

In the South Belt LSA, mean benthic invertebrate abundance ranged from 726 organisms/m^2 in the Koignuk River to 24,482 organisms/m^2 in Aimaokatalok Outflow (Table 6.2-15). The relatively large population of benthic invertebrates in Aimaokatalok Outflow consisted almost entirely of *Hydra* (small animals belonging to the phylum Cnidaria). In the remaining streams and rivers of the South Belt LSA, ostracods and dipterans (mostly chironomids) were abundant (Table 6.2-15). Benthic diversity was particularly low in Aimaokatalok Outflow (0.12), which can be explained by the nearly homogenous benthic assemblage consisting of 94% *Hydra*. In the remaining streams and rivers in the South Belt, mean Simpson's Diversity Indices ranged from 0.66 (Trout Outflow) to 0.84 (Koignuk River). Mean benthic genus richness ranged from 10 (Aimaokatalok Outflow) to 19 (Koignuk River).

Table 6.2-14. Summary of Lake Benthic Invertebrate Abundance and Taxonomy in the LSA and RSA

Lake	Depth Interval[a]	Benthic Invertebrate Abundance (organisms/m²)			Predominant Group (numerically)	Predominant Genera (numerically)[b]
		Min	Mean	Max		
LSA - North Belt						
Doris Lake	Shallow	1,366	2,078	3,496	Dipterans	various chironomids
	Mid	2,059	2,148	2,237	Dipterans	*Chironomus* & *Phaenopsectra* (dipterans)
	Deep	601	1,942	4,519	Dipterans	*Chironomus* & *Stictochironomus*(dipterans)
Glenn Lake	Shallow	700	1,484	2,267	Ostracods & Dipterans	Ostracods & *Procladius* (dipteran)
	Deep	179	419	658	Ostracods & Dipterans	Ostracods & *Heterotrissocladius* (dipteran)
Imniagut Lake	Shallow	23,597	-	23,597	Dipterans	Ostracods
Nakhaktok Lake	Shallow	7,743	-	7,743	Dipterans	*Chironomus* (dipterans)
	Mid	7,602	-	7,602	Dipterans	*Chironomus* (dipterans)
Ogama Lake	Shallow	1,007	2,521	4,800	Dipterans	*Tanytarsus* & *Procladius* (dipterans)
	Mid	1,867	-	1,867	Dipterans	Chironomini (diptera)
P.O. Lake	Shallow	583	42,118	83,653	Ostracods	Ostracods
Patch Lake	Shallow	829	9,510	41,261	Ostracods & Dipterans	Ostracods
	Mid	342	-	342	Dipterans	*Procladius* (dipteran)
	Deep	800	1,056	1,542	Ostracods & Dipterans	Ostracods & *Stictochironomus* (dipteran)
Windy Lake	Shallow	89	764	2,444	Ostracods & Dipterans	Ostracods
	Mid	119	-	119	Dipterans	*Cricotopus* (dipteran)
	Deep	77	2,160	7,733	Ostracods	Ostracods
Wolverine Lake	Shallow	1,713	19,929	61,267	Ostracods & Molluscs	Ostracods
LSA - South Belt						
Aimaokatalok Lake	Shallow	193	5,755	21,988	Dipterans & Molluscs	Sphaeriidae (mollusc)
	Mid	1,677	-	1,677	Molluscs	*Sphaerium* (mollusc)
	Deep	18	1,257	4,652	Dipterans & Molluscs	Sphaeriidae (mollusc)
Stickleback Lake	Shallow	479	23,551	41,339	Ostracods & Dipterans	Ostracods

Lake	Depth Interval[a]	Benthic Invertebrate Abundance (organisms/m^2)			Predominant Group (numerically)	Predominant Genera (numerically)[b]
		Min	Mean	Max		
Trout Lake	Shallow	136	14,919	43,258	Dipterans	*Zalutschia* (dipteran)
RSA						
Boston Reference Lake	Shallow	4,237	11,650	30,969	Ostracods, Dipterans, & Molluscs	Ostracods & Sphaeriidae (mollusc)
Little Roberts Lake	Shallow	859	13,342	28,545	Dipterans	*Paratanytarsus* (dipteran)
Naiqunnguut Lake	Shallow	1,019	-	1,019	Dipterans	*Stictochironomus* (dipteran)
Pelvic Lake	Shallow	1,378	6,081	12,627	Ostracods & Dipterans	Ostracods & *Tanytarsus* (dipteran)
	Mid	3,659	-	3,659	Dipterans	*Phaenopsectra* (dipteran)
	Deep	133	339	604	Dipterans	*Chironomus* (dipteran)
Reference Lake A	Shallow	1,235	-	1,235	Dipterans	*Stictochironomus* (dipteran)
	Deep	147	-	147	Dipterans	*Chironomus* (dipteran)
Reference Lake B	Shallow	1,034	-	1,034	Dipterans	*Micropsectra* (dipteran)
	Mid	2,662	4,420	6,178	Dipterans	*Tanytarsus* (dipteran)
	Deep	1,656	2,386	3,677	Molluscs & Dipterans	Tubificinae (oligochaete) & Sphaeriidae (mollusc)
Reference Lake D	Shallow	8,800	16,746	26,812	Dipterans	*Paratanytarsus* (dipteran)
Roberts Lake	Shallow	8,720	-	8,720	Dipterans	*Paratanytarsus* (dipteran)

Notes:
a Shallow = 0-5 m, Mid = 5-10 m, Deep = 10+ m
b Lowest available taxonomic level (usually genus).

Table 6.2-15. Summary of Stream and River Benthic Invertebrate Abundance and Taxonomy in the LSA and RSA

Stream	Benthic Invertebrate Abundance (organisms/m^2)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	Mean	Max		
LSA - North Belt					
AWRa	2,051	-	2,051	Dipterans	*Sergenta* (dipteran)
AWRb	9,256	-	9,256	Dipterans	Osctracods
Doris Outflow	761	26,674	207,867	Dipterans	Chironomidae larvae (dipteran)
Glenn Outflow Downstream	7,021	-	7,021	Dipterans	*Hydrobaenus* (dipteran)
Koignuk River (Upstream, Midstream, Downstream)	599	3,126	10,951	Dipterans	various chironomids (dipterans)
Ogama Outflow	7,178	13,443	23,194	Dipterans	*Rheotanytarsus*& *Simulium* (dipterans)
P.O. Outflow	5,028	-	5,028	Dipterans	Nematodes
Patch Outflow	146	1,695	3,156	Dipterans	*Orthocladius* (dipteran)
Windy Outflow	358	2,075	4,097	Dipterans	*Simulium* (dipteran)
LSA - South Belt					
Aimaokatalok NE Inflow	267	2,403	4,407	Dipterans & Ostracods	Ostracods & *Valvata sincera sincera* (mollusc)
Aimaokatalok Outflow	24,482	-	24,482	Cnidarians	*Hydra* (cnidarian)
AWRc	1,203	-	1,203	Dipterans	*Psectrocladius* (dipteran)
Koignuk River	726	-	726	Dipterans	*Paratanytarsus* (dipteran)
Stickleback Outflow	251	3,110	10,043	Ostracods & Dipterans	Ostracods
Trout Outflow	1,451	5,325	13,896	Dipterans	Chironomidae larvae (dipteran)
RSA					
Aimaokatalok River	286	664	1,067	Dipterans	various chironomids
Angimajuq River Reference	774	-	774	Dipterans	*Paratanytarsus* (dipteran)
Boston Reference Outflow	462	19,704	38,946	Dipterans	*Rheotanytarsus* (diptera)
Little Roberts Outflow	85	6,206	25,042	Dipterans	various chironomids
Pelvic Outflow	3,068	21,777	51,757	Dipterans	Simuliidae (dipteran)

Stream	Benthic Invertebrate Abundance (organisms/m^2)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	Mean	Max		
Reference A Outflow	2,462	-	2,462	Dipterans	*Hydrobaenus* (dipteran)
Reference B Outflow	1,151	1,958	3,157	Dipterans	*Paratanytarsus* (dipteran)
Reference D Outflow	2,064	8,426	24,015	Dipterans	Naidinae (oligochaete) & *Hydra* (cnidarian)
Roberts Outflow	3,740	6,943	15,801	Dipterans	various chironomids (dipterans)

Notes:

[a] *Lowest available taxonomic level (usually genus or species).*

RSA

In the RSA, mean abundance ranged from 664 organisms/m^2 in Aimaokatalok River to 21,777 organisms/m^2 in Pelvic Outflow (Table 6.2-11). Ditperans were the dominant benthic group in all RSA streams and rivers. The chironomid genera *Paratanytarsus* and *Rheotanytarsus* and the black fly family Simuliidae were among the most abundant dipteran taxa. Mean Simpson's Diversity Indices and richness were lowest in Reference A Outflow (0.45 and 9, respectively) and highest in Aimaokatalok River (0.87 and 20) and Little Roberts Outflow (0.85 and 21).

6.2.6.2 Freshwater Fish Habitat – Physical Characteristics

<u>LSA – North Belt</u>

Lakes are the predominant form of fish habitat in the North Belt LSA and supply most of the perennial fish habitat. Bathymetric surveys showed that lakes in the North Belt LSA are small to medium sized, with maximum depths ranging from 4.0 m (Wolverine) to 21.2 m (Windy) (Table 3.2-6 in Volume 5, Section 3). Several lakes in the area are shallower than 10 m. Surface areas of surveyed lakes range from 150,000 m^2 (Imniagut) to 5,674,000 m^2 (Patch) and volumes range from 367,500 m^3 (Imniagut) to 59,137,500 m^3 (Windy). There are un-surveyed lakes in this area with surface areas less than 150,000 m^2.

Fines (e.g., silt clay or mud) are the predominant substrate type in lakes of the North Belt LSA. Fine substrates are especially dominant in lakes in relatively close proximity to the ocean and for turbid lakes such as Glenn and Doris lakes. Gillnet and hydroacoustic assessments conducted at Doris and Patch lakes showed concentrations of fish associated with deep habitat over substrates of mud or fines.

The Koignuk River within the North Belt LSA is large enough that it may provide perennial habitat for fish in some deep pools in the lower reaches, although the river has not been sampled for fish or dissolved oxygen concentrations during winter. (For purposes of convenience, the Koignuk River is labelled as North Belt LSA even though it stretches from Aimaokatalok Lake to Hope Bay.) Two barriers, a 5 m high waterfall 18.5 km from the mouth of the river and a 10 m-high waterfall 23.8 km from the mouth, appear to be high enough to prevent upstream migration of anadromous fish during average flows, although downstream migration may be possible. Their status as barriers is supported by the presence of two separate fish communities in the river: 1) resident fish in the upper river above the barriers; and 2) resident, anadromous (e.g. Arctic Char), and brackish water (e.g., Arctic Flounder) fish species in the lower river below the barriers. "Resident" in this river may simply mean resident during the ice-free season. Absent deep pools in the river, resident freshwater fish are expected to migrate to lakes to overwinter. Substrate of the Koignuk River is predominantly fines, which limits habitat use for various fish species, particularly spawning.

Streams in the North Belt LSA are typical of slow-moving streams flowing through tundra wetlands. Most are ephemeral and provide temporary habitat for fish during periods of relatively high flow (i.e., spring and early summer months). Outflow streams from lakes are typically larger and flow throughout the open-water season, but freeze to the substrate in the winter (e.g., Glenn Outflow, Doris Outflow). Channel and instream habitat characteristics are generally similar among these streams with some exceptions: Glenn Outflow and Doris Outflow differ substantially in habitat type. Streams supply relatively high quality habitat, especially for small-bodied fish species such as Ninespine Stickleback. Juvenile Lake Trout and Arctic Char were also observed using these large streams for rearing habitat. All streams in the RSA (with the possible exception of deep pools in the lower reaches of the Koignuk River) freeze to the bottom in winter.

A waterfall on Doris Outflow is an impassable barrier to upstream fish migration hence there are two separate fish communities on that stream: one above the waterfall that migrate between that section of Doris Outflow and Doris Lake (e.g., Lake Trout and Cisco) and a second downstream of the waterfall that supports resident, anadromous, and marine fish species.

Most ponds in the North Belt LSA have poor habitat quality and many are non-fish-bearing because they contain little or no overwintering or spawning habitats and they have poor connectivity to larger waterbodies. Generally, ponds with greater maximum depths (>2 m) and/or connectivity to larger bodies of water were found to contain only small-bodied species such as Ninespine Stickleback. The generally poor habitat quality of ponds is due mainly to their small size – which is why they are named ponds rather than lakes. There is no scientific definition of a pond versus a lake, although ponds tend to have other characteristics associated with their small size such as an relative absence of surface waves (due to short fetch) and uniform temperatures.

LSA – South Belt

The South Belt LSA is dominated by one large lake (Aimaokatalok Lake; formerly named Spyder Lake) that has surface area of 22,969,460 m^2, a volume of 147,125,400 m^3, and a maximum depth of 30 m (Table 3.2-6 in Volume 5, Section 3). Stickleback and Trout lakes, two smaller lakes south of Aimaokatalok Lake, are both shallow (maximum depth = 4.9 m and 6.1 m, respectively) and have surface areas of 995,000 m^2 and 552,000 m^2, respectively.

Within the Ore Deposit area of Aimaokatalok Lake, relatively small and soft substrates made up 79% of the total substrate area: sand/gravel (40%) and mud (39%). The Reference area also had small, soft substrate but it made up only 57% of its area (37% sand/gravel and 20% mud), Cobble/large rock is the predominant substrate, covering 42% of the area. Visual observations of shoreline habitat at Stickleback and Trout lakes indicated that fines and cobble are the dominant and subdominant forms of substrate, respectively.

In 2009 and 2010, detailed fish habitat assessments were conducted at 59 sites in streams and ponds adjacent to potential infrastructure sites. A total of 15,199 linear metres of fish habitat was assessed, with 9,460 m assessed in high freshet flows and 5,739 m in low summer flows. These sites were broken down into a total of 352 habitat units. Pools were the most common habitat type (36%) followed by glides (31%) and riffles (25%), while other habitat types and cascades made up a small portion of the total (5% and 3%, respectively). Streams were generally ephemeral in the area and offered temporary habitat for fish during periods of relatively high flow (i.e., spring and early summer months).

Fine substrate was by far the most common substrate type (72%) in ponds, followed by boulder (9%), cobble (7%), bedrock (6%), and gravel (6%). Since the Hope Bay Project is located far beyond the tree line, no large woody debris was found at any site and small woody debris (primarily from native willows) was found at only one site where it provided 2.5% cover.

Average cover for fish at each site was 76%, with instream vegetation and pool making up 61% of the total (34% and 27%, respectively). Boulder cover was next most common (9%), followed by undercut bank (5%), overhanging vegetation (2%) and finally small woody debris, which made up less than 1% of the total.

RSA

Surveyed lakes in the RSA vary widely in size and depth. Little Roberts Lake has a surface area of only 102,000 m^2, but Reference Lake B has a surface area of 7,695,000 m^2 – a range of nearly two orders of magnitude (Table 3.2-6 in Volume 5, Section 3). Little Roberts Lake is also among the shallowest of surveyed lakes (maximum depth = 4.8 m); Roberts Lake is the deepest lake (maximum depth = 37.5 m).

Small headwater lakes in the Roberts Lake drainage range in surface area from 6,000 m^2 to 360,000 m^2 and in maximum depth from <2.0 m to 13.6 m (Table 6.2-16). Mean area of those headwater lakes is 99,000 m^2 (SE = 20,000, n = 20) and mean maximum depth is 4.7 m (SE = 0.8, n = 18).

Table 6.2-16. Surface Areas and Maximum Depths of Headwater Lakes of the Roberts Watershed

Lake	Area (m^2)	Max depth (m)
04	139,000	4.3
05	58,000	5.4
06a	360,000	3.0
06b	97,000	6.0
06c	55,000	4.0
06d	58,000	1.0[a]
07	51,000	3.0
07a	143,000	4.0
09	42,000	1.0[a]
10	198,000	13.6
12	45,000	5.7
13	259,000	4.5
14	185,000	4.2
31	6,000	1.0[a]
31a	17,000	-
31b	76,000	3.7
32	55,000	-
32a	28,000	8.0
33	69,000	11.0
35	31,000	1.2

Source: Golder (2007a).
a = half of maximum possible depth.
Dashes indicate no data available.

In the RSA, fish habitat was surveyed in 2009 and 2010 at Reference lakes A, B, and D, and Little Roberts Lake. (Habitat in other lakes of the RSA such as Pelvic and Roberts lakes was surveyed in previous years and was found to be generally similar to that of the reference lakes.) Shoreline substrates of the reference lakes were predominantly bedrock with minimal littoral zone due to the steep shorelines. Subdominant substrate types included boulder, fines, and cobble. Potential Lake Trout spawning shoals were characterized by clean, round cobble and boulder with large interstitial spaces within the substrate. In contrast, the littoral habitat of Little Roberts Lake was predominantly fines and organics, particularly at the inflows and at the outflow of the lake. Boulder and bedrock were also observed along the relatively steep western and northern shorelines.

Stream habitat was also surveyed in 2009 and 2010 in the outflows of three reference lakes, and one river. Streams were predominantly low gradient and consisted of riffle and glide habitat. Stream bed material was a mixture of gravel, cobble, boulder, and bedrock. Boulders were observed as the predominant substrate type and identified as the greatest source of cover for fish. Reference streams generally displayed a high amount of total cover.

A section of the Aimaokatalok River upstream of Aimaokatalok Lake was assessed as a reference site. During freshet, a 200 m section of the river was assessed. During low summer flows, 106 m of that section was assessed again. Two glides and one riffle were identified at the site, with glides making up over 90% of the total length of the site. The site was 83 m wide during freshet flows and shrunk to 9.5 m wide in the summer. Substrate was predominantly boulders with lesser amounts of cobble, gravel, and fine materials mixed in. Due to substrate composition, all cover at the site was cover from boulders.

6.2.6.3 Freshwater Fish Community

Fish Species Richness

Tables 6.2-17, 6.2-18, and 6.2-19 show the number of fish species (i.e., fish species richness) for lakes, ponds, and streams, respectively. A total of nine species were found in lakes, 2 species in ponds, and 14 species in streams. None of these species are currently considered threatened or endangered (COSEWIC 2010). Figures 6.2-16 and 6.2-17 show waterbodies in the LSA and RSA that have been sampled for fish. Waterbodies where fish were captured (any species) are identified as “fish presence confirmed”. Waterbodies that were sampled, but where no fish of any species were captured are identified as “no fish caught”.

Lakes

Four lakes in the North Belt LSA (Doris, Patch, P.O., and Windy) each have five species (Table 6.2-17). The other eight lakes sampled in the North Belt LSA have between one species (Nakhaktok and Imniagut lakes) and four species (Ogama and Glenn lakes).

In the South Belt LSA, Aimaokatalok Lake has a species richness of seven and the other two lakes that were sampled have between two species (Stickleback Lake) and three species (Trout lakes).

In the RSA, two lakes (Roberts and Little Roberts lakes) have a documented species richness of seven and the other 25 lakes have a species richness ranging from zero (Lakes 05, 06c, 07, 07a, 09, 14, 31, and 35) to four (Reference Lake B, Pelvic Lake, and Lake 04).

There are at least two factors influencing fish species richness in lakes (as well as in streams and ponds): size of waterbody and connection to the sea. Trophic status, as indexed by nutrient concentration, is known to influence fish production in lakes (Plante and Downing 1993), but not fish species richness.

Positive relationships between fish species richness and lake surface area have been reported for many regions of the world. Examples include Ontario (Eadie et al. 1986) and large lakes around the globe (Vadeboncoeur, McIntyre, and Vander Zanden 2011). The relationship is due to the increase in the diversity of habitat types with increasing lake size. The more habitat types there are, the more species can be supported. Similar relationships have been reported between fish species richness and stream area (e.g., Eadie et al. 1986).

A regression of log(fish species richness) on log(lake surface area) for 25 pooled lakes from the LSA and RSA was highly significant ($P<0.001$) and explained 50% of the variance in log(fish species richness) (Figure 6.2-18). (Logarithmic transformation was required because of the three orders of magnitude range in lake area. This regression included Tail Lake to maximize sample size. Before it was fished out and converted to the TIA, Tail Lake supported Ninespine Stickleback and Lake Trout.)

Figure 6.2-16
Fish Presence in Sampled Freshwater Habitats, North Belt, 1993 - 2015

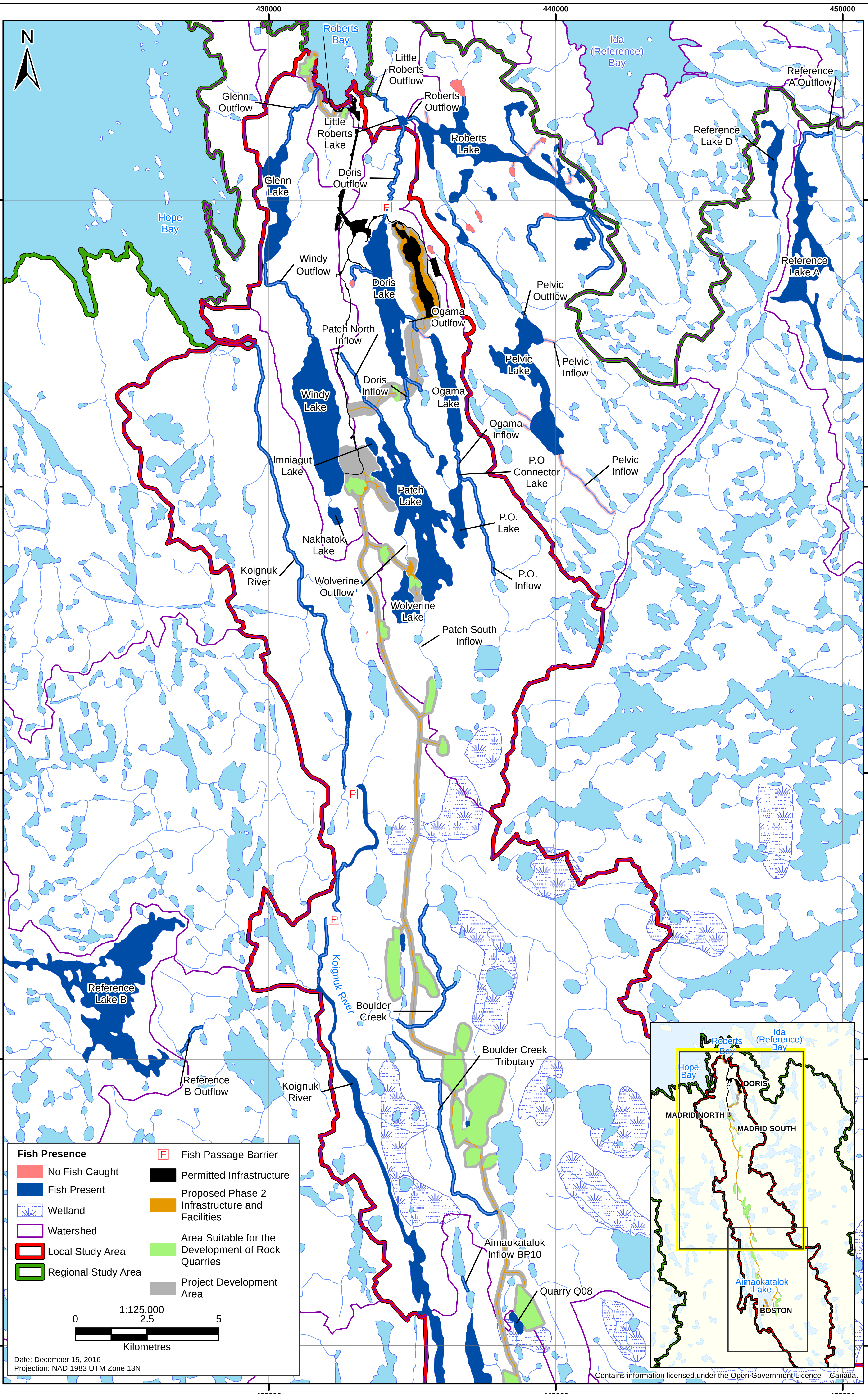


Figure 6.2-17
Fish Presence in Sampled Freshwater Habitats, South Belt, 1993 - 2015

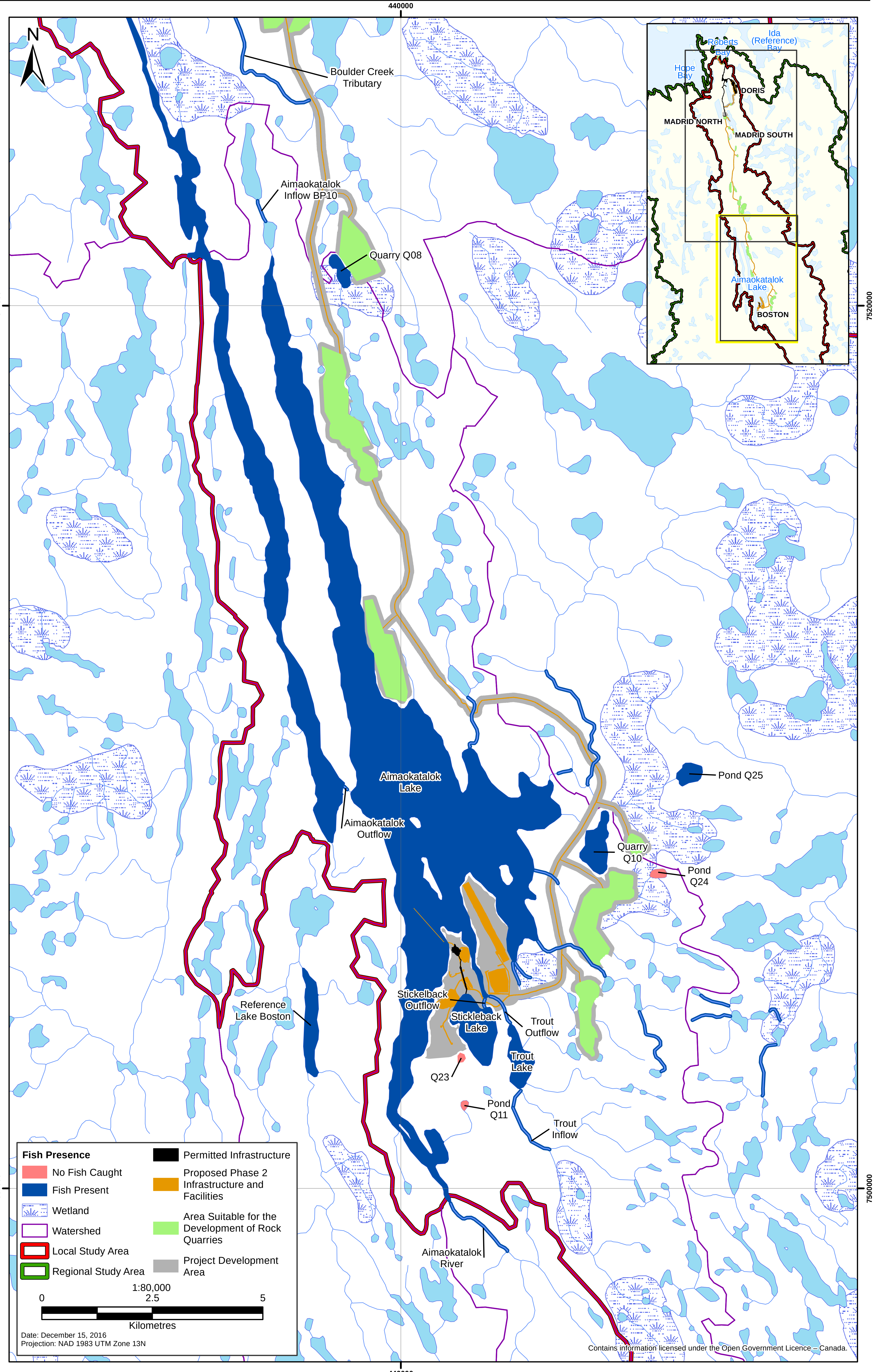


Figure 6.2-18

Regression of Fish Species Richness on Lake Surface Area of Lakes in the LSA and RSA

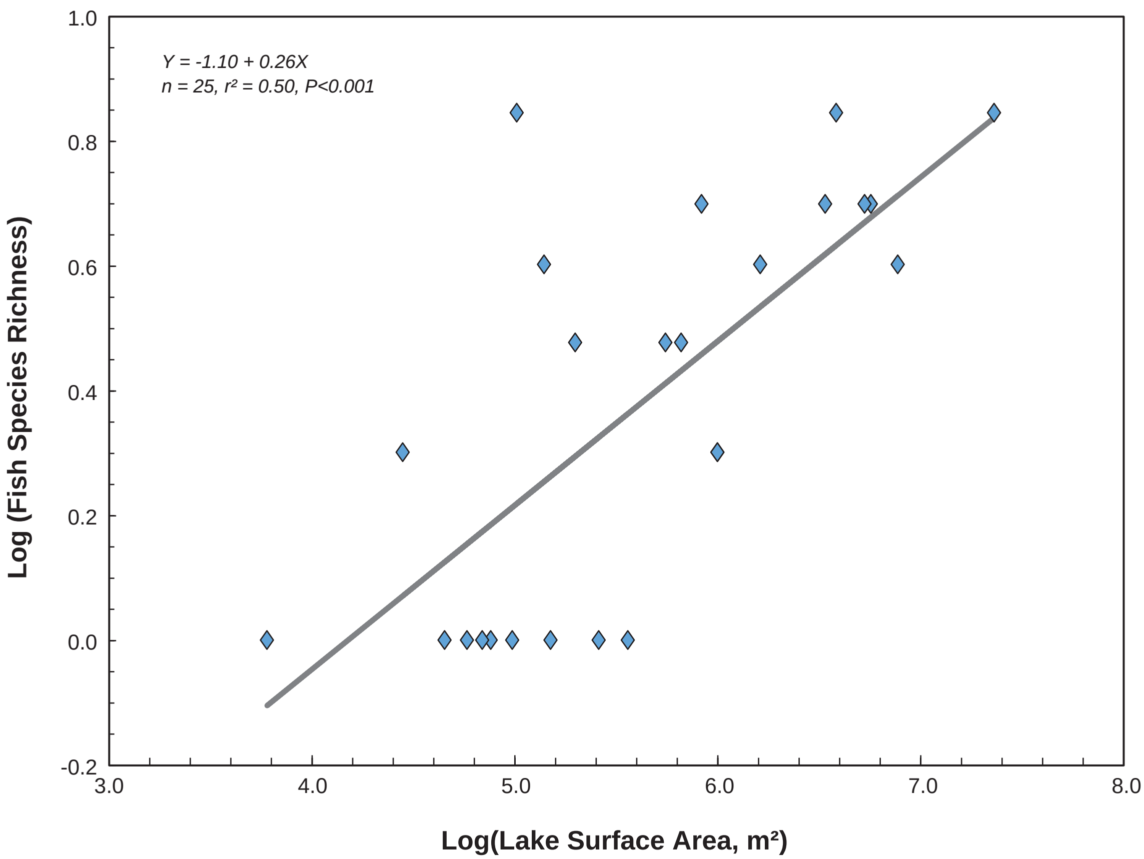


Table 6.2-17. Fish Communities of Lakes in the LSA and RSA, 1993-2015

Waterbody Name	Watershed	Ninespine Stickleback	Lake Trout	Lake Whitefish	Cisco	Arctic Char	Least Cisco	Arctic Grayling	Broad Whitefish	Slimy Sculpin	Number of Species	Sampling Years
LSA - North Belt												
Doris Lake	Doris	X	X	X	X	-	X	-	-	-	5	1995, 1996, 2003, 2005, 2007, 2009, 2015
Patch Lake	Doris	X	X	X	X	-	X	-	-	-	5	1995-1996, 2006, 2007, 2008, 2009
P.O. Lake	Doris	X	X	X	X	-	X	-	-	-	5	2006, 2009
Windy Lake	Windy	X	X	X	X	-	-	-	-	X	5	1995-1996, 2008-2009, 2012-2014
Ogama Lake	Doris	X	X	X	X	-	-	-	-	-	4	1995-1996, 2006, 2009
Glenn Lake	Windy	-	X	X	X	X	-	-	-	-	4	2007, 2009
P.O. Connector Lake	Doris	X	X	X	-	-	-	-	-	-	3	2006
P.O. Inflow Lake	Doris	X	-	-	X	-	-	-	-	-	2	2006
Wolverine Lake	Doris	X	-	-	-	-	X	-	-	-	2	2006, 2007, 2008
Imniagut Lake	Doris	X	-	-	-	-	-	-	-	-	1	2014
Nakhaktok Lake	Windy	X	-	-	-	-	-	-	-	-	1	2014
LSA - South Belt												
Aimokatalok Lake	Aimaokatalok	X	X	X	X	-	X	X	-	X	7	1993-1994, 1996, 2006, 2008, 2010
Trout Lake	Aimaokatalok	X	X	-	-	-	-	X	-	-	3	1995-1996, 2006, 2010
Stickleback Lake	Aimaokatalok	X	-	-	-	-	-	X	-	-	2	1995, 2006, 2010
RSA												
Roberts Lake	Roberts	X	X	X	X	X	X	-	X	-	7	2002-2007, 2010-2012
Little Roberts Lake	Roberts	X	X	X	X	X	X	-	X	-	7	2000, 2002-2003, 2009
Lake 04	Roberts	-	X	X	X	-	-	-	X	-	4	2006
Reference Lake B	Reference B	X	X	-	-	X	-	-	-	X	4	2009-2010
Pelvic Lake	Roberts	-	X	X	X	-	X	-	-	-	4	1998, 2002, 2005
Lake 10	Roberts	X	X	-	-	X	-	-	-	-	3	2006-2007

Waterbody Name	Watershed	Ninespine Stickleback	Lake Trout	Lake Whitefish	Cisco	Arctic Char	Least Cisco	Arctic Grayling	Broad Whitefish	Slimy Sculpin	Number of Species	Sampling Years
Lake 32	Roberts	X	X	-	-	X	-	-	-	-	3	2006-2007
Reference Lake A	Reference A	X	X	X	-	-	-	-	-	-	3	2009
Reference Lake D	Reference D	-	X	X	X	-	-	-	-	-	3	2010
Boston Reference Lake	Aimaokatalok	X	X	-	X	-	-	-	-	-	3	2006
Lake 32a	Roberts	X	-	-	-	X	-	-	-	-	2	2006
Lake 06a	Roberts	-	-	-	-	X	-	-	-	-	1	2006
Lake 06b	Roberts	X	-	-	-	-	-	-	-	-	1	2006
Lake 06d	Roberts	X	-	-	-	-	-	-	-	-	1	2006
Lake 12	Roberts	X	-	-	-	-	-	-	-	-	1	2006
Lake 13	Roberts	-	-	-	-	X	-	-	-	-	1	2006
Lake 31a	Roberts	X	-	-	-	-	-	-	-	-	1	2006
Lake 31b	Roberts	X	-	-	-	-	-	-	-	-	1	2006
Lake 33	Roberts	-	-	-	-	X	-	-	-	-	1	2006
Lake 05	Roberts	-	-	-	-	-	-	-	-	-	0	2006
Lake 06c	Roberts	-	-	-	-	-	-	-	-	-	0	2006
Lake 07	Roberts	-	-	-	-	-	-	-	-	-	0	2006
Lake 07a	Roberts	-	-	-	-	-	-	-	-	-	0	2006
Lake 09	Roberts	-	-	-	-	-	-	-	-	-	0	2006
Lake 14	Roberts	-	-	-	-	-	-	-	-	-	0	2006
Lake 31	Roberts	-	-	-	-	-	-	-	-	-	0	2006
Lake 35	Roberts	-	-	-	-	-	-	-	-	-	0	2006
Number of Lakes		**26**	**19**	**14**	**14**	**10**	**8**	**3**	**3**	**3**		

X = species reported. Dashes indicate no species reported.
LSA = Local Study Area and RSA = Regional Study Area.

Table 6.2-18. Fish Communities of Ponds in the LSA, 1993-2015

Waterbody Name	Watershed	Ninespine Stickleback	Cisco	Number of Species	Sampling Years
LSA - North Belt					
Q13	Koignuk	X	X	2	2014
Tailings Alternate Site 2	Doris	X	-	1	2005
Q02	Aimaokatalok	X	-	1	2010
Q04	Aimaokatalok	X	-	1	2010
Q05	Aimaokatalok	X	-	1	2010
Q06	Aimaokatalok	X	-	1	2010
Q08	Aimaokatalok	X	-	1	2010
Q10-L1	Aimaokatalok	X	-	1	2010, 2014
Q10-L2	Aimaokatalok	X	-	1	2010, 2014
Q14	Koignuk	X	-	1	2014
Q15	Koignuk	X	-	1	2014
Q20	Doris	X	-	1	2014
Q21	Doris	X	-	1	2014
Pond1	Doris	-	-	0	2009
Pond 2	Doris	-	-	0	2009, 2014
Rock Quarry 2 Ponds	Doris	-	-	0	2005
Rock Quarry 3 Ponds	Doris	-	-	0	2005
Q16	Koignuk	-	-	0	2014
Q22	Doris	-	-	0	2014
LSA - South Belt					
Q10	Aimaokatalok	X	-	1	2014
Q25	Aimaokatalok	X	-	1	2014
Q11	Aimaokatalok	-	-	0	2014
Q23	Aimaokatalok	-	-	0	2014
Q24	Aimaokatalok	-	-	0	2014
Number of Ponds		15	1		

Area Codes: LSA = Local Study Area and RSA = Regional Study Area.
X = species reported. Dashes indicate no species reported.

Table 6.2-19. Fish Communities of Rivers and Streams in the LSA and RSA, 1993-2015

Watercourse	Watershed	Ninespine Stickleback	Lake Trout	Arctic Char	Arctic Grayling	Slimy Sculpin	Lake Whitefish	Cisco	Least Cisco	Burbot	Broad Whitefish	Arctic Flounder	Fourhorn Sculpin	Greenland Cod	Starry Flounder	Unidentified	Number of Species	Sampling Years
LSA - North Belt																		
Koignuk River	Koignuk	X	X	X[a]	X	X	X	-	-	X	-	X	X	X	-	-	10	1995, 1998, 2006-2010
Doris Outflow	Doris	X	X	X[a]	-	X	-	X	-	-	-	-	-	-	-	-	5	1995, 2003
Glenn Outflow	Windy	X	X	X	-	X	-	-	-	-	-	-	-	-	X	-	5	2000, 2003, 2009-2010
Ogama Inflow	Doris	X	X	-	-	-	X	X	-	-	-	-	-	-	-	-	4	1995, 2006
Ogama Outflow	Doris	X	X	-	-	-	X	X	-	-	-	-	-	-	-	-	4	2005-2006, 2009
Proposed road crossing 15	Doris	X	-	X	X	-	-	-	-	-	-	-	-	-	-	-	3	2000
Windy Outflow	Windy	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	3	2009-2010
Doris Inflow	Doris	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1995
Doris Outflow US	Doris	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1995, 2003, 2005, 2009
Doris Inflow	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2015
Doris Inflow	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2015
Patch Outflow	Doris	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2006
P.O. Inflow	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2006, 2010
P.O. Outflow	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2009
Proposed road crossing 13	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2000
Proposed road crossing 14	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2000
Stream N20	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010, 2014
Stream N21	Doris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	1	2010
Imniagut Outflow	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2014
Doris SE Inflow (site N09)	Doris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2010
Pond Q21 Outflow	Doris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2014
Pond Q22 Outflow	Doris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2014
LSA - South Belt																		
Trout Outflow	Aimaokatalok	X	X	-	X	X	-	-	-	X	-	-	-	-	-	-	5	1993, 1996, 2006, 2010
Aimaokatalok Inflows	Aimaokatalok	X	X	-	X	-	-	-	-	-	-	-	-	-	-	-	3	1996
Aimaokatalok River	Aimaokatalok	X	X	-	X	-	-	-	-	-	-	-	-	-	-	-	3	2006
Stickleback Outflow	Aimaokatalok	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-	3	1993, 1996, 2006, 2010
Boston Area (site S04)	Aimaokatalok	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	2	2010
Boston camp (site S16)	Aimaokatalok	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	2	2010
Aimaokatalok Outflow	Aimaokatalok	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1996
Trout Inflow	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2006
Boston PND road crossing (site S11)	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
Boston area (site C01)	Aimaokatalok	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	1	2010
Boston Area (site S03)	Aimaokatalok	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	1	2010
Boston tailings stream 2 (site S22)	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
Boston tailings stream 3 (site S25)	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
Boston area (site S31)	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
Boston camp (site S32)	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010

Watercourse	Watershed	Ninespine Stickleback	Lake Trout	Arctic Char	Arctic Grayling	Slimy Sculpin	Lake Whitefish	Cisco	Least Cisco	Burbot	Broad Whitefish	Arctic Flounder	Fourhorn Sculpin	Greenland Cod	Starry Flounder	Unidentified	Number of Species	Sampling Years
Boston camp (site S33)	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010, 2014
Boston camp (site S34)	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010, 2014
RSA																		
Little Roberts Outflow	Roberts	X	X	X	-	-	X	X	X	-	X	X	X	-	-	-	9	1995, 2003-2004, 2006-2007, 2011
Roberts Outflow	Roberts	X	X	X	-	-	X	X	X	-	X	-	-	-	-	-	7	2002-2005, 2010, 2012-2015
Pelvic Outflow	Roberts	X	X	X	-	-	X	X	X	-	-	-	-	-	-	-	6	2003, 2005
E04 Outflow	Roberts	X	X	X	-	-	-	-	X	-	-	-	-	-	-	-	4	2006-2007, 2010
Reference A Outflow	Reference A	-	X	-	-	X	-	X	X	-	-	-	-	-	-	-	4	2009
Roberts Inflow E09	Roberts	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	3	2003-2004, 2006, 2009-2013
Roberts Inflow E10	Roberts	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	3	2006-2007
Roberts Inflow E14	Roberts	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	3	2003-2004, 2006-2007, 2010-2012
Roberts Inflow E06	Roberts	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	2	2010
Roberts Inflow E13	Roberts	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	2	2003, 2006
Reference B Outflow	Reference B	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	2	2009
Roberts Inflow E03	Roberts	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2009
Roberts Inflow E11	Roberts	-	-	X	-	-	-	-	-	-	-	-	-	-	-		1	2003, 2007
Roberts Inflow E12	Roberts	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2003, 2006
Roberts Inflow E32	Roberts	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	1	2006
Roberts Inflow E07	Roberts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2003
Roberts Inflow E07a	Roberts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2006
Roberts Inflow E15	Roberts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2003
Roberts Inflow E31	Roberts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2006
Roberts Inflow E33	Roberts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2006
Roberts Inflow E35	Roberts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2006
Pelvic Inflows	Doris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2005
Number of Streams		**43**	**22**	**19**	**11**	**8**	**7**	**7**	**5**	**2**	**2**	**2**	**2**	**1**	**1**	**1**		

X = species reported. Dashes indicate no species reported.
LSA = Local Study Area and RSA = Regional Study Area.
a; Present downstream of barrier.

A second factor affecting fish species richness in lakes and streams is access to the sea for anadromous and brackish water species. For example, Little Roberts Lake has a surface area that is less than 3% that of Roberts Lake and less than 0.5% that of Aimaokatalok Lake but it has the same species richness (seven) as those two lakes. One reason is the presence in Little Roberts Lake of anadromous species such as Arctic Char that migrate through Little Roberts Lake and Roberts Outflow to Roberts Lake.

Trophic status of waterbodies may influence fish species richness as well as fish production. Table 5.2.6 in Volume 5, Section 5 shows the trophic status of lakes in the RSA and LSA as indexed by Total Phosphorus (TP) trigger ranges shown in *Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems* (CCME 2004). There are six classes: ultra-oligotrophic (TP<0.004 mg/L), oligotrophic (TP = 0.004-0.01 mg/L), mesotrophic (TP = 0.01-0.02 mg/L), meso-eutrophic (TP = 0.02-0.035 mg/L), eutrophic (TP = 0.035-0.1 mg/L), and hyper eutrophic (TP>0.1 mg/L). Section 6.2.5.1 discusses the use of those trophic statuses in explaining variation in phytoplankton densities and biomasses among lakes in the LSA and RSA.

Mean fish species richness was calculated for each of the six classes of trophic status using the richness values of lakes that were assigned to each class (Table 6.2-20). Mean richness ranged from 3.8 to 4.5 and there were no increasing or decreasing trends with trophic class. The standard errors (SE) of the means ranged from 0.4 to 0.6, which is similar in magnitude to the differences among means. This data does not support the hypothesis that fish species richness is influenced by trophic status.

Table 6.2-20. Fish Species Richness of Lakes for Six Trophic Classes

Trophic Status	Total Phosphorus Concentration (mg/L)	Lakes	Mean	SE	n
Ultra-Oligotrophic	<0.004	Windy, Reference A, Reference B, Reference D	3.8	0.5	4
Oligotrophic	0.004-0.01	Doris, Patch, P.O., Imniagut, Glenn, Windy, Aimaokatalok, Stickleback, Reference A, Reference B, Reference D, Roberts	4.3	0.5	12
Mesotrophic	0.01-0.02	Doris, Patch, P.O., Glenn, Windy, Ogama, Wolverine, Aimaokatalok, Stickleback, Trout, Boston Reference, Little Roberts, Reference B, Reference D, Roberts	4.4	0.4	15
Meso-eutrophic	0.02-0.035	Doris, P.O., Glenn, Ogama, Aimaokatalok, Stickleback, Trout, Boston Reference, Little Roberts, Pelvic, Reference D, Roberts	4.5	0.5	12
Eutrophic	0.035-0.1	Doris, Patch, Ogama, Wolverine, Nakhaktok, Trout, Little Roberts, Pelvic, Reference D	3.8	0.6	9
Hyper-eutrophic	>0.1	P.O., Boston Reference, Pelvic	4.0	0.6	3

Ponds

Ninespine Stickleback and Cisco are the only fish species found in ponds (Table 6.2-18), hence species richness ranged from zero to two. In the North Belt LSA, Q13 was the only pond with both species. Of the remaining 18 ponds, twelve had only Ninespine Stickleback and six had no fish. In the South Belt LSA, only ponds Q10 and Q25 contained Ninespine Stickleback. The remaining three ponds that were sampled had no fish. No ponds were surveyed in the RSA.

The low species richness for ponds compared to lakes is likely due to the much smaller size of ponds and the fact that many freeze to the bottom during winter, or nearly so, due to shallow depths.

However, since surface areas are not available for ponds it is not possible to test that hypothesis. Ponds may also have low species richness because they tend to be less connected to other waterbodies than lakes and to be more ephemeral on annual and decadal time scales than lakes.

Rivers and Streams

Fourteen species were found in streams and rivers (Table 6.2-19), which was five species more than were found in lakes. The five species found in streams and rivers, but not lakes, were Burbot, Arctic Flounder, Fourhorn Sculpin, Greenland Cod, and Starry Flounder. The latter four species reside in the sea, but are able to tolerate brackish water and move short distances up rivers and streams. Arctic Flounder, Fourhorn Sculpin, and Greenland Cod were found in the Koignuk River and Arctic Flounder and Fourhorn Sculpin were found in Little Roberts Outflow. Starry Flounder was found in Glenn Outflow; each of these waterbodies are connected directly to the ocean.

The Koignuk River has the highest species richness (ten) of any river or stream in the RSA and LSA, followed by Little Roberts Outflow (nine), Roberts Outflow (seven), and Pelvic Outflow (six). In the North Belt LSA, the remaining streams have observed species richness ranging from zero (e.g., Doris SE Inflow) to 5 (e.g., Doris Outflow and Ogama Outflow). In the South Belt LSA, the remaining streams have species richness ranging from one (e.g., Trout Inflow and Stickleback Inflow) to five (e.g., Trout Outflow). In the RSA, the remaining streams have fish species richness ranging from zero (e.g., Roberts Inflow 07) to 4 (e.g., Reference A Outflow).

The same two factors drive fish species richness in river and streams as in lakes: a positive correlation between species richness and stream area (e.g., Eadie et al. 1986) and access by anadromous and brackish water species. The high species richness of the Koignuk River is partly due to the presence of brackish water species such as Arctic Flounder, Fourhorn Sculpin, Greenland Cod, and Starry Flounder in the lower river below the first of two barriers to upstream migration.

<u>Fish Species Incidence</u>

Ninespine Stickleback is the most common of the nine fish species in lakes, being found in 26 of the 41 lakes surveyed or 63% of all lakes (Table 6.2-17). The other eight species in lakes are, in order of descending incidence, Lake Trout (19 lakes or 46%), Lake Whitefish (14 lakes or 33%), Cisco (14 lakes or 33%), Arctic Char (ten lakes or 24%), Least Cisco (eight lakes or 19%), Arctic Grayling (three lakes or 7%), Broad Whitefish (three lakes or 7%), and Slimy Sculpin (three lakes or 7%).

Ninespine Stickleback is also the most common species in ponds, being found in 15 of the 24 surveyed ponds or 63% (Table 6.2-18). The only other fish found in ponds, Cisco, was captured in two ponds or 8%.

Ninespine Stickleback is also the most common species in streams and rivers, being found in 43 of the 61 surveyed stream and river sites, or 70% (Table 6.2-19). The other 13 species found in streams and rivers are, in order of descending incidence, Lake Trout (22 streams or 36%), Arctic Char (19 streams or 31%), Arctic Grayling (eleven streams or 18%), Slimy Sculpin (eight streams or 13%), Lake Whitefish (seven streams or 11%), Cisco (seven streams or 11%), Least Cisco (five streams or 8%), Burbot (three streams or 5%), Broad Whitefish (two streams or 3%), Arctic Flounder (two streams or 3%), Fourhorn Sculpin (two streams or 3%), Greenland Cod (one stream or 2%), and Starry Flounder (one stream or 2%).

<u>Estimates of Lake Fish Population Number and Density</u>

Fish population estimates for lakes in the LSA were conducted with two methods: mark-recapture and hydroacoustics. Table 6.2-21 shows the estimates of fish population and density.

Table 6.2-21. Estimates of Lake Fish Population Number and Density

Lake	Species	Year	Method	Fish Number	Lower 95% CL	Upper 9% CL	Lake Area (ha)	Fish Density (no./ha)	Source
Tail	Lake Trout	2002	Peterson	2,630	1,313	4,275	76.6	34.3	RL&L/Golder (2003a)
Tail	Lake Trout	2002	Schnabel	2,632	1,725	5,511	76.6	34.4	RL&L/Golder (2003a)
Patch	Lake Trout	2007	MARK	1,159	825	1,680	567.4	2.0	Golder (2008a)
Doris	All fish	2009	Hydroacoustic	55,806	41,982	69,629	337.8	165.2	Rescan (2010)
Doris	Lake Trout	2009	Hydroacoustic	3,408	-	-	337.8	10.1	Rescan (2010)
Doris	Lake Whitefish	2009	Hydroacoustic	15,813	-	-	337.8	46.8	Rescan (2010)
Doris	Cisco	2009	Hydroacoustic	36,584	-	-	337.8	108.3	Rescan (2010)
Patch	All fish	2009	Hydroacoustic	33,619	17,499	49,740	567.4	59.3	Rescan (2010)
Patch	Lake Trout	2009	Hydroacoustic	18,259	-	-	567.4	32.2	Rescan (2010)
Patch	Lake Whitefish	2009	Hydroacoustic	14,142	-	-	567.4	24.9	Rescan (2010)
Patch	Cisco	2009	Hydroacoustic	1,218	-	-	567.4	2.1	Rescan (2010)
Aimokatalok (Ore Body - Day)	All fish	2010	Hydroacoustic	-	-	-	-	12.0	Rescan (2011a)
Aimokatalok (Ore Body - Dusk)	All fish	2010	Hydroacoustic	-	-	-	-	2.0	Rescan (2011a)
Aimokatalok (Reference - Day)	All fish	2010	Hydroacoustic	-	-	-	-	48.0	Rescan (2011a)

Dashes indicate no data available.

In 2002, a mark-recapture study of Lake Trout in Tail Lake of the North Belt LSA was conducted using the numbers of tagged trout and the numbers of recovered tagged and untagged trout, all caught by gillnets. A population of 2,360 trout (with 95% confidence limits (CL) of 1,313 to 4,275) was calculated with the Peterson method and a population of 2,362 (95% CL: 1,725 to 5,511) was calculated with the Schnabel method. Using the estimate of Tail Lake surface area of 76.6 ha measured in 2000 gave a Lake Trout density of 34 fish/ha.

In 2007, a mark-recapture study of Lake Trout in Patch Lake of the North Belt LSA was conducted using the MARK method to calculate a population of 1,159 trout (95% CL: 825 to 1,680). The surface area of Patch Lake is 567.4 ha so Lake Trout density was 2.0 fish/ha. A 2009 hydroacoustic survey of Patch Lake estimated a total of 33,619 fish in the lake (95% CL: 17,499 to 49,740), which gave a total fish density of 59.3 fish/ha. Gillnet sampling in that same year showed that the three major fish species made up the following percentages of the catch: Lake Trout (54.3%), Lake Whitefish (42.1%), and Cisco (3.6%). Therefore, numbers and densities in 2009 were as follows: Lake Trout (18,258 and 32.2 fish/ha), Lake Whitefish (14,142 and 24.9 fish/ha), and Cisco (1,218 and 2.1 fish/ha).

In 2009, hydroacoustic surveys were also conducted in Doris Lake for fish. The total number of fish in Doris Lake was estimated to be 55,806 (95% CL: 41,982 to 69,629). The surface area of Doris Lake is 337.8 ha so total fish density was 165.2 fish/ha. Gillnet sampling conducted before and after the hydroacoustic survey showed that the three major fish species made up the following percentages of the catch: Lake Trout (6.1%), Lake Whitefish (28.3%), and Cisco (65.5%). Therefore, numbers and densities were as follows: Lake Trout (3,408 and 10.1 fish/ha), Lake Whitefish (15,183 and 46.8 fish/ha), and Cisco (36,584 and 108.3 fish/ha).

Gillnet and hydroacoustic assessment data collected in 2009 in Doris Lake showed that Lake Trout and Cisco relative abundance and density increased with depth, while Lake Whitefish relative abundance was highest in shallow locations (0 to 5 m). Fish abundance increased with depth.

In 2010, hydroacoustic surveys were conducted at two areas of Aimaokatalok Lake: the Ore Body area and the Reference area. Fish density at the Ore Body area was 12.0 fish/ha during the day and 2.0 fish/ha at dusk. Fish Density at the Reference area was 48.0 fish/ha during the day. The mean density for both areas was 20.7 fish/ha.

In summary, there are two estimates of whole-lake fish density: 59.3 fish/ha for Patch Lake and 165.2 fish/ha for Doris Lake. A third estimate of whole-lake fish density of 20.7 fish/ha is available for Aimaokatalok Lake, if one makes a reasonable assumption that that surveys of the Ore Body and References areas are representative of the entire lake.

These three estimates of fish density agree with the ranking of trophic status of lakes as indexed by TP trigger ranges (CCME 2004). Aimaokatalok and Patch lakes, which have the lowest estimates of fish density, are both classified as oligotrophic-mesotrophic (Table 6.2-20). Doris Lake, which has the highest fish density, is classified as oligotrophic-eutrophic (Table 6.2-20).

<u>Life Histories, Habitat Preferences, and Distributions of Fish Species</u>

Tables 6.2-22 and 6.2-23 summarize the life histories and habitat preferences for fish species found in the LSA and RSA from 1993 to 2015. This information was summarized from Scott and Crossman (1973) and Richardson, Reist, and Minns (2001) plus other sources with information on fish distribution, migration, and diet that were derived from baseline surveys of the RSA and LSA.

Table 6.2-22. Life History Characteristics of Fish Species Captured during Freshwater Fish Community Surveys in the LSA and RSA

Species	Scientific Name	Primary Habitat-Depth Range	Spawning Timing	Spawning Habitat Preference	Fry Emergence Timing	Habitat Preference: Juvenile Rearing	Habitat Preference: Adult Rearing	Habitat Preference: Overwintering
Arctic Char (anadromous)	*Salvelinus alpinus*	Marine/ Freshwater - Benthopelagic	Sept - Oct	Freshwater lakes	Apr - Jul	Freshwater lakes and rivers	Marine, nearshore coastal areas, benthopelagic	Freshwater lakes
Arctic Grayling	*Thymallus arcticus*	Freshwater-Benthopelagic	May-Jun	Freshwater rivers and streams; gravel or rocky substrate	13-18 days after spawning	Freshwater lakes and rivers	Freshwater, benthopelagic	Freshwater lakes; deep pools in large rivers
Broad Whitefish	*Coregonus nasus*	Marine Estuaries / Freshwater - Benthopelagic	Aug - Oct	Freshwater rivers	Apr - May	Freshwater lakes and rivers	Freshwater, brackish, benthopelagic	Freshwater lakes
Burbot	*Lota lota*	Freshwater-Demersal	Jan - Mar	Freshwater lakes; bays and shoals with sand or gravel substrate	Feb - Jun	Freshwater lakes and rivers	Freshwater, benthopelagic	Freshwater lakes
Cisco	*Coregonus artedi*	Marine Estuaries / Freshwater - Benthopelagic	Sept - Oct	Freshwater lakes and rivers	Apr - May	Freshwater lakes and rivers	Freshwater, brackish, benthopelagic	Freshwater lakes
Least Cisco	*Coregonus sardinella*	Marine Estuaries / Freshwater - Benthopelagic	Sept - Nov	Freshwater, deep pools of rivers and lakes over sand and gravel substrates	Spring	Marine, nearshore, estuaries, move downstream to sea upon hatching	Freshwater (upriver migration in spring and summer), marine, nearshore, estuaries (downstream migration following spawning)	Estuaries, brackish water
Lake Trout	*Salvelinus namaycush*	Marine Estuaries / Freshwater - Benthopelagic	Sept - Nov	Freshwater lakes	Mar - Apr	Freshwater	Freshwater, brackish, benthopelagic	Freshwater lakes
Lake Whitefish	*Coregonus clupeaformis*	Marine Estuaries / Freshwater - Benthopelagic	Nov - Dec	Freshwater rivers and lakes	Apr - May	Freshwater or brackish	Freshwater, brackish, benthopelagic	Freshwater lakes

Species	Scientific Name	Primary Habitat-Depth Range	Spawning		Fry Emergence	Habitat Preference		
			Timing	Habitat Preference	Timing	Juvenile Rearing	Adult Rearing	Overwintering
Ninespine Stickleback	*Pungitius pungitius*	Marine Estuaries / Freshwater - Benthopelagic	Jun - Jul	Freshwater, nearshore areas in lakes, ponds, streams	15 days after spawning	Freshwater or brackish, shallow, sheltered	Brackish, shallow, sheltered	Freshwater, brackish
Slimy Sculpin	*Cottus cognatus*	Marine Estuaries / Freshwater-Demersal	Jun	Freshwater, nearshore areas with rocky substrate	30 days after spawning	Freshwater lakes and rivers	Freshwater, demersal	Freshwater lakes

Notes:
Dashes indicate information not available.
Demersal = bottom feeders; Benthopelagic = feed in open water and on bottom

Table 6.2-23. Spawning and Fry Emergence Timing for Freshwater Species in the LSA and RSA

Species	Life stage	Habitat	Substrate	Month Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Arctic Char (anadromous)	Spawning	Freshwater lakes	Gravel or rocky shoals									■	■		
	Fry emergence	Freshwater lakes	Gravel or rocky shoals					■	■						
Arctic Grayling	Spawning	Freshwater rivers and streams	Small gravel or rocky substrate					■	■						
	Fry emergence	Freshwater rivers and streams	Small gravel or rocky substrate						■	■					
Broad Whitefish	Spawning	Freshwater rivers	Gravel or rocky substrate								■	■	■		
	Fry emergence	Freshwater rivers	Gravel or rocky substrate				■	■							
Burbot	Spawning	Freshwater lakes; bays and shoals	Sand or gravel substrate	■	■	■									
	Fry emergence	Freshwater lakes; bays and shoals	Sand or gravel substrate		■	■	■	■	■						
Cisco	Spawning	Freshwater rivers and lakes	Any; Gravel or rocky substrate preferred									■	■		
	Fry emergence	Freshwater rivers and lakes	Any; Gravel or rocky substrate preferred				■	■							
Least Cisco	Spawning	Freshwater, deep pools of rivers and lakes	Sand or gravel substrate									■	■	■	
	Fry emergence	Freshwater, deep pools of rivers and lakes	Sand or gravel substrate					■	■						
Lake Trout (anadromous)	Spawning	Freshwater lakes; shorelines and shoals	Large cobble, boulder or rubble									■	■	■	
	Fry emergence	Freshwater lakes; shorelines and shoals	Large cobble, boulder or rubble			■	■								
Lake Whitefish	Spawning	Freshwater rivers and lakes	Sand, gravel or rock											■	■
	Fry emergence	Freshwater rivers and lakes	Sand, gravel or rock				■	■							

Species	Life stage	Habitat	Substrate	Month											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ninespine Stickleback	Spawning	Freshwater, nearshore areas in lakes, ponds, streams	Organics, aquatic vegetation												
	Fry emergence	Freshwater, nearshore areas in lakes, ponds, streams	Organics, aquatic vegetation												
Slimy Sculpin	Spawning	Freshwater, nearshore areas with rocky substrate	Gravel and rock												
	Fry emergence	Freshwater, nearshore areas with rocky substrate	Gravel and rock												

Notes:
Orange = spawning, green = fry emergence

Arctic Char

Arctic Char are present in northern coastal regions in rivers, lakes, estuaries, and marine environments. They exhibit both anadromous and lake resident (i.e., lacustrine) life histories. Arctic Char are the most economically important fish to the Inuit. In the Melville Sound area, commercial fisheries operate during upstream runs in Elu Inlet and the Kolgayok River (Fisheries and Oceans Canada 2004). TK shows that they are also a prized food fish (Section 6.1.1.1).

In the central Canadian Arctic, spawning of Arctic Char takes place in lakes, because most rivers freeze completely in winter (Johnson 1980; Tables 6.2-22 and 6.2-23). Spawning occurs in the fall, usually September or October, over gravel or cobble shoals and shorelines of lakes. Males arrive first on the spawning grounds and establish and defend territories. Females arrive later and are courted by males. Depending on substrate size, a female may either dig a nest or redd, in which the eggs are deposited, or broadcast eggs in water 3 to 6 m deep. Eggs incubate under ice for about six months.

In most systems, char are ready to take their first migration to sea at age four to five years and at a length of 150 to 250 mm (Johnson 1980). Smolts out-migrate to the sea in spring and early summer and feed throughout summer. Young Arctic Char do not venture much past the brackish water of river estuaries, but as they grow, they develop a tolerance to higher salinity sea water. They feed in nearshore areas along the coast for the duration of the summer. More abundant food resources in marine waters allow anadromous Arctic Char to grow faster and larger than the freshwater form. In the autumn, all char return to freshwater to overwinter to escape freezing in the sea (Johnson 1980). Arctic Char overwinter in lakes. Freshwater populations of Arctic Char feed on planktonic crustaceans, amphipods, molluscs, insects, and fishes, while marine populations are primarily piscivorous.

Arctic Char of the LSA and RSA are only found in lakes and streams with access to the sea either current or historical. In the North Belt LSA, Arctic Char have been found in Glenn Lake and in Glenn Outflow, in Doris Outflow below the barrier, and in the lower Koignuk River below the first barrier located 18.5 km from the mouth of the river (Tables 6.2-17 and 6.2-19). (There is a second, higher barrier at kilometre 23.8.) Arctic Char are not present in lakes and streams of South Belt LSA nor are they present in any of the ponds surveyed in the LSA.

In the RSA, Arctic Char are present in the Roberts Watershed, including Little Roberts Outflow, Little Roberts Lake, Roberts Outflow, Roberts Lake, and the headwaters of Roberts Watershed including lakes 06a, 10, 13, 31b, 32, 32a, and streams E04 Outlet, Roberts Inflows E06, E09, E10, E11, E13, E14, E32, and Pelvic Outflow. Their presence in Pelvic Outflow suggests they may also be present in Pelvic Lake, although they have not been captured there.

Arctic Char are present in Reference Lake B and in Reference B Outflow, both of which are connected to the Koignuk River. The population in Reference Lake B is most likely a resident population because of the barrier to upstream migration at kilometre 18.5 on the Koignuk River. Also, spawning of Arctic Char in the Koignuk River is unlikely because most rivers in the central Arctic freeze to the bottom during winter. Those few Arctic Char that have been found in the Koignuk River may be strays from other river-lake systems such as the Roberts system or they may have out-migrated as juveniles from Reference Lake B through Reference B Outflow and then fallen over the 5 m high barrier waterfall. After feeding and growing in the sea, some of those fish would have returned to the Koignuk River in the autumn, failed to swim up the waterfall, and then left the river in search of overwintering possibilities in other nearby systems such as the Roberts system.

Arctic Char have never been captured in Aimaokatalok Lake, the headwater lake of the Koignuk River, most likely because of the two waterfalls at 18.5 km and 23.8 km from the mouth of the river.

The Arctic Char population of Glenn Lake may also follow a mixture of resident and anadromous life histories. The lack of Arctic Char catches in Glenn Outflow suggests a predominantly resident life history. However, Glenn Outflow was rated as good for migration and rearing (Rescan 2001) in one year, so some Arctic Char may migrate from the lake to the sea and back again through Glenn Outflow. Surveys in other years have shown that upstream migration through the riffles of Glenn Outflow would be difficult at low flows.

Arctic Char found in Doris Outflow downstream of the impassable waterfalls are juveniles and appear to use that stream only for rearing. Those juveniles have to overwinter in lakes and so they most likely use lakes in the Roberts system.

The Arctic Char populations of the Roberts Watershed may follow both resident and anadromous life histories (Swanson et al. 2010b). Multiple years of sampling with fish fences at Roberts Outflow and Little Roberts Outflow and with fyke nets in Roberts Lake and gillnets in headwater lakes has provided a large database on Arctic Char migration timing and biological characteristics such as body size and age.

Lake Trout

Lake Trout are found throughout Nunavut, mostly in deep lakes, but they may also be found in large, clear rivers. Lake Trout typically exhibit both lacustrine and adfluvial life history forms and some populations contain anadromous individuals. TK shows that they are an important food fish (Section 6.1.1.1).

In the central Canadian Arctic, spawning of Lake Trout takes place in lakes, because most rivers freeze completely in winter (Tables 6.2-22 and 6.2-23). Lake Trout typically spawn from late September through to November. Spawning grounds are almost always associated with cobble, boulder and gravel substrates, where there is no vegetative cover, in depths less than 1 m to greater than 10 m. Eggs settle into interstitial spaces amongst the rocks, where they incubate for four to five months, with eggs usually hatching in March or April. To avoid mortality, Lake Trout lay eggs at a depth deep enough to avoid freezing in winter (ice can reach depths of up to 2 m).

After spawning, Lake Trout disperse into deeper water habitats, greater than 10 m in depth, and are often found in the pelagic zone. All Lake Trout overwinter in lakes.

Eggs incubate over the winter in interstices of the substrate and fry emerge in March to April. Young-of-the-year remain in spawning areas from several weeks to several months, moving into deeper areas as water temperatures rise to greater than 15°C. Young-of-the-year may briefly venture into streams. Juveniles both prefer areas of cobble and boulder substrate for cover, and inhabit waters with a depth range of 2 m to greater than 10 m. Juveniles are often associated with large boulders, which they use for cover.

Adult Lake Trout generally remain in lakes, utilizing deep water habitat. Exceptions occur in larger rivers, where Lake Trout may be found in large, deep pools that do not freeze in winter, and at deep river mouths. Juvenile and adult Lake Trout are known for long migrations within lake-stream chains, presumably in search of habitat and prey.

Anadromous populations of Lake Trout have been reported from four Arctic lakes in the West Kitikmeot region of Nunavut (Swanson et al. 2010b). Two of these lakes (Glenn Lake and Roberts Lake) are within the North Belt LSA and RSA, respectively (Tables 6.2-17 and 6.2-19). Swanson et al. (2010a) reported that 37 of 135 (or 27%) Lake Trout from Roberts Lake that were examined for otolith microchemistry made annual marine migrations. Anadromous Lake Trout were in significantly better condition than resident Lake Trout. Mean age of first migration for Lake Trout was 13 years, which was significantly older than that for Arctic Char (five years).

Lake Trout are apex predators and feed on a wide variety of prey including fish, molluscs, crustaceans, freshwater sponges, small mammals, and birds. Analyses of stomach contents from fish caught in the RSA and LSA found prey items derived from both marine and freshwater sources. For example, the diet of Lake Trout in Aimaokatalok Lake by weight was approximately 55% salmonids and 41% aquatic invertebrates (mainly the isopod *Saduria entomon*). Lake Trout from Reference Lake B fed primarily on Ninespine Stickleback (66% by weight), with the remainder of the diet comprised of aquatic invertebrates. Marine and freshwater isopods and amphipods were also found in relatively high abundance. Some species of isopods and amphipods found in freshwater were originally of marine ancestry but were trapped in some lakes of the RSA as the land rose after the most recent de-glaciation.

Lake Trout are widely distributed throughout the LSA and RSA because of their lake-resident and anadromous life histories. In the North Belt LSA, Lake Trout have been found in the Koignuk River and in seven lakes (Doris, Ogama, P.O., Patch, P.O. Connector, Windy, and Glenn (Table 6.2-17). They were also present in Tail Lake before it was converted to the TIA. Lake Trout have also been found in the streams connecting those lakes (Doris Inflow, Doris Outflow, Ogama Inflow, Ogama Outflow, Patch Outflow, Windy Outflow, and Glenn Outflow) (Table 6.2-19). Lake Trout are not present in four small lakes (P.O. Inflow, Wolverine, Imniagut, and Nakhaktok) or in the streams connecting those lakes (P.O. Inflow, P.O. Outflow, and Imniagut Outflow) or in smaller inflows to Doris Lake. Lake Trout are not present in any of the ponds surveyed in the North or South Belt LSA (Table 6.2-18).

In the South Belt LSA, Lake Trout have been found in two lakes (Aimaokatalok and Trout) and in the streams connecting those lakes (Aimaokatalok Inflows, Aimaokatalok River, Aimaokatalok Outflow, and Trout Outflow) (Table 6.2-17 and 6.2-19). Lake Trout have not been found in Stickleback Lake, Stickleback Outflow, Trout Inflow, and many small streams in the Boston area.

In the RSA, Lake Trout have been found in the larger lakes of the Roberts system (Little Roberts, Roberts, 04, 10, 32, and Pelvic) and their connecting streams (Little Roberts Outflow, Roberts Outflow, E04 Outflow, Roberts Inflows E06, E09, E10, E13, and E14, and Pelvic Outflow) (Table 6.2-17 and 6.2-19). Multiple years of sampling with fish fences at Roberts Outflow and Little Roberts Outflow and with fyke nets in Roberts Lake and gillnets in headwater lakes has provided a large database on Lake Trout migration timing and biological characteristics such as body size and age.

Lake Trout are also present in Reference Lake A, Reference A Outflow, Reference Lake B, Reference Lake D, and Boston Reference Lake. The presence of Lake Trout in the lower Koignuk River and Reference Lake B suggests that they may also be present in Reference B Outflow during the ice-free period.

In summary, the widespread distribution of Lake Trout in the LSA and RSA indicates the presence of multiple spawning populations – at least one for each medium and large lake. There are probably two separate populations in the Koignuk River: one in the upper river that overwinters in Aimaokatalok Lake, and another group of trout that rear in the lower river and overwinters in headwater lakes of other river systems.

Lake trout are not found in small lakes and ponds because those waterbodies most likely lack overwintering or spawning habitat. The presence of Lake Trout in so many streams indicates extensive migrations, a well-known aspect of Lake Trout behaviour, and consequent mixing of populations.

Arctic Grayling

Arctic Grayling are commonly found in clear water of large cold rivers, streams, and lakes throughout Nunavut. They exhibit lacustrine, adfluvial (i.e., lake-river), and fluvial (i.e., river resident) life histories. They are not anadromous and are never found in marine or brackish water. TK shows that they are a food fish (Section 6.1.1.1).

Arctic Grayling spawn from late-May through June, primarily in streams although they have been observed spawning in shallow water in Alaskan lakes, in association with inlet and outlet streams (Tables 6.2-22 and 6.2-23). Grayling generally prefer to spawn over gravel or coarse sand substrates; however, they have been observed to spawn over substrates ranging from mud to boulder (Bishop 1971; Hubert et al. 1985). Spawning generally occurs at warmer water temperatures near mid-day, and no nest or redd is prepared. The female may spawn only once, or several times in different areas. Eggs incubate for 13 to 18 days before hatching, with young grayling remaining in the gravel for three to four days before emerging.

Juveniles are found in lotic and littoral areas at shallow depths (<0.5 m). Adults are found associated with sand, silt and gravel substrates in lakes, as well as rocky shorelines, and are typically a shallow water species, inhabiting depths <3.0 m deep. Although no specific information on overwintering habitat was found, grayling are assumed to overwinter in deep pools in rivers and in deep portions of lakes (Richardson, Reist, and Minns 2001).

Adult grayling feed on a variety of aquatic and terrestrial insects including mayflies, caddisflies, midges, bees, wasps, grasshoppers, ants, and a variety of beetles. Items occasionally found in the diet include fish, fish eggs, lemmings, and planktonic crustaceans.

Arctic Grayling have a more restricted distribution in the LSA and RSA than Lake Trout. In the LSA North, Arctic Grayling have been found only in the Koignuk River (Table 6.2-19). In the South Belt LSA, they have been found in three lakes (Aimaokatalok, Trout, and Stickleback; Table 6.2-17), in the streams that connect those lakes (Aimaokatalok River, Aimaokatalok Inflows, Trout Outflow, Stickleback Outflow; Table 6.2-19), and in several small streams of the Boston area that are tributaries to Aimaokatalok Lake (at sites C01, S04, and S16). They have not been found in Trout Inflow or Aimaokatalok Outflow. Arctic Grayling have not been found in any ponds in the LSA. In the RSA, Arctic Grayling have only been found in Reference B Outflow.

In summary, there are at least three populations of Arctic Grayling in the LSA and RSA: 1) one above the waterfalls of the Koignuk River that uses habitat in Aimaokatalok, Trout and Stickleback lakes and their connecting streams; 2) a second in Reference Lake B that uses spawning habitat in Reference B Outflow; and 3) a third population that uses spawning and rearing habitat in the lower Koignuk River and whose overwintering lakes are unknown.

Lake Whitefish

Lake Whitefish are found throughout Nunavut, predominantly in lakes, although they are also found in large rivers and brackish waters. Lake Whitefish may exhibit lacustrine, adfluvial, or anadromous life histories. TK does not indicate that they are a common food fish (Section 6.1.1.1).

Lake Whitefish spawn in both lakes and rivers over gravel, cobble, and boulders at depths less than 5 m (Tables 6.2-22 and 6.2-23). Eggs are released over the substrate and fall into interstices between rocks where they incubate for several months, hatching sometime from April to May. All Lake Whitefish overwinter in lakes.

Young-of-the-year are commonly found in the spawning area in shallow water (<1 m) near the surface, and prefer substrates of boulder, cobble, and sand with abundant emergent vegetation and woody debris. Adults are usually found in the open water at depths greater than 10 m and do not show a preference for substrate. Adults are predominantly benthic, although they may be found in the pelagic zone. Lake Whitefish have been reported to make onshore movements into shallow water at night, possibly to feed.

Lake Whitefish typically feed on a wide variety of benthic invertebrates, planktonic crustaceans, and small fish; however they have been known to also eat insects at the surface of the water. The diet of Lake Whitefish in Aimaokatalok Lake was primarily mysid shrimp.

Lake Whitefish are widely distributed in the LSA and RSA, largely overlapping the distribution of Lake Trout (Figures 6.2-21 and 6.2-22). In the North Belt LSA, Lake Whitefish have been found in seven lakes (Doris, Ogama, P.O., Patch, P.O. Connector, Windy, and Glenn (Table 6.2-17). They have also been found in Ogama Inflow and Ogama Outflow. This distribution suggests occasional use by Lake Whitefish of habitat in Patch Outflow, P.O. Outflow, and Windy Outflow.

Lake Whitefish are not present in any of the ponds surveyed in the North Belt LSA or South Belt LSA (Table 6.2-18).

In the RSA, Lake Whitefish have been found in lakes of the Roberts system (Little Roberts, Roberts, E04, and Pelvic) and in the outflow streams of those lakes (Little Roberts Outflow, Roberts Outflow, and Pelvic Outflow). They have also been found in Reference A Lake and Reference D Lake.

In the South Belt LSA, Lake Whitefish have been found in Aimaokatalok Lake, but not in Trout Lake or Stickleback Lake. They have not been found in any of the streams connecting those lakes or in small streams of the Boston area.

In summary, the lack of Lake Whitefish in small lakes and ponds indicates that they prefer deep lakes. This also follows from their focus on benthic prey. The relative absence of Lake Whitefish in streams indicates that they do not migrate among lakes to the same degree as Lake Trout.

Most of the Lake Whitefish found in lakes of the North Belt LSA and South Belt LSA are assumed to be lake-resident, i.e., not anadromous, because of the lack of direct access to the sea. The absence of Lake Whitefish in Glenn Outflow suggests that the population in Glenn Lake is also mainly resident. The absence of Lake Whitefish in Reference A Outflow and Reference D Outflow suggests that the populations in Reference Lake A and Reference Lake D are also resident. However, the presence of Lake Whitefish in Little Roberts Outflow, Roberts Outflow, and Pelvic Outflow suggests some degree of anadromy in Lake Whitefish of that drainage.

Cisco

The Cisco is one of three related species found in the central Arctic; the other two are Arctic Cisco and Least Cisco. Arctic Cisco has not been confirmed present in the freshwater fish LSA and RSA. Cisco used to be known as Lake Cisco. It primarily exhibits a lacustrine life history, although anadromous forms are known to occur.

Spawning takes place in the fall of the year in lakes and streams, usually from September to October (Scott and Crossman 1973; Tables 6.2-22 and 6.2-23). It typically takes place in shallow water 1 to 5 m deep, but deep-water spawning has been known to occur. Spawning most often takes place over sand and gravel substrates, but it has also been reported to occur over boulders, rubble, clay, mud and vegetation. Eggs incubate over the winter and hatch in the following spring just before ice breakup.

Juveniles rear in lakes and streams, initially close to shore and then further out in pelagic habitat over deeper water. In the LSA and RSA, all Cisco overwinter in lakes.

Being a pelagic species the lake cisco feeds primarily on plankton and to a lesser extent on large crustaceans, chironomid larvae, and young fish.

Ciscos are distributed in a similar manner as Lake Whitefish. In the North Belt LSA, Ciscos have been found in most of the larger lakes (Doris, Patch, Ogama, P.O., P.O. Inflow, Windy, and Glenn) (Table 6.2-17), as well as in Ogama Inflow and Ogama Outflow plus Doris Outflow below the barrier. Ciscos were found in only one pond – Q13 (Table 6.2-18).

In the RSA, they have been found in Little Roberts Outflow, Little Roberts Lake, Roberts Outflow, Roberts Lake, Lake 04, Pelvic Outflow, and Pelvic Lake (Table 6.2-19). They are also present in Reference A Outflow, Reference Lake D, and Boston Reference Lake. This distribution suggests that they are also present in Reference Lake A.

In the South Belt LSA, Ciscos have been found in Aimaokatalok Lake, but not in Trout Lake or Stickleback Lake or in any streams in South Belt LSA.

In summary, this distribution suggests that, like Lake Whitefish, Ciscos prefer to live in lakes and, unlike Lake Trout, only occasionally use stream habitat. Ciscos prefer deep lakes and rarely reside in small lakes and ponds.

It also suggests the presence of at least seven populations or population clusters of Cisco. The first resides in Doris, Patch, Ogama, P.O., and P.O. Inflow lakes. Migrants use Patch Outflow, P.O. Outflow, Ogama Inflow and Ogama Outflow to move among these lakes. The second population resides in Windy and Glenn lakes and uses Windy Outflow to move between lakes. The third population resides in Aimaokatalok Lake. The fourth population resides in lakes of the Roberts system and uses Little Roberts Outflow, Roberts Outflow, E04 Outflow, and Pelvic Outflow to move among lakes. The Ciscos that use habitat in Doris Outlet probably overwinter in lakes of the Roberts system. The remaining three populations reside in Reference Lake A, Reference Lake D, Boston Reference Lake, and their outflow streams.

Least Cisco

The Least Cisco has similar life histories and biology to Cisco (Tables 6.2-22 and 6.2-23). It has both lacustrine and semi-anadromous populations. Spawning occurs from September to November in lakes and deep pools in river over sandy substrate. Eggs hatch in spring and juveniles remain near the spawning site for the first year. They are largely pelagic and feed on zooplankton, crustaceans, and small fish.

Least Ciscos were found in a reduced sub-set of Cisco lakes and streams of the LSA and RSA. In the North Belt LSA, Least Ciscos were found in Doris, Patch, P.O., and Wolverine lakes (Table 6.2-17), but not in their connecting streams. This suggests that they rarely migrate among lakes and so they were rarely captured in streams.

Least Ciscos were not found in streams or ponds of the LSA (Table 6.2-18).

In the RSA, Least Ciscos were found in Little Roberts Outflow, Little Roberts Lake, Roberts Outflow, Roberts Lake, E04 Outflow, Pelvic Outflow, and Pelvic Lake. This suggests they must be present in Lake E04. They were also found in Reference A Outflow, which suggests they must also be present in Reference Lake A.

In the South Belt LSA, Least Ciscos were found only in Aimaokatalok Lake (Table 6.2-17). They were not found in any streams of the South Belt LSA.

This distribution is similar to that of Cisco, but with fewer lakes and streams. Like Ciscos, Least Ciscos prefer deep lakes and are found in Aimaokatalok Lake and throughout the Roberts system. They are even more reluctant than Ciscos to migrate through streams. There appear to be three populations or clusters of populations of Least Ciscos: one that lives in Doris, Patch, P.O., and Wolverine lakes, a second that lives in Aimaokatalok Lake, and a third that lives in the Roberts system.

Broad Whitefish

Broad Whitefish are harvested for food by Inuit (Section 6.1.1.1). They are most commonly found in streams, but can also be found in lakes as well as in brackish waters (Tables 6.2-22 and 6.2-23). They spawn in rivers from May to October on gravel bottoms, especially those with finer gravel. Fry emerge in March and April. Juveniles rear in lakes and rivers. Adults and juveniles overwinter in lakes. Adults are much larger than Lake Whitefish, and their maximum age is reported to be 15 years. Broad Whitefish are benthic feeders and mainly eat aquatic insect larvae, small molluscs, and crustaceans.

Broad Whitefish have a restricted distribution in the LSA and RSA. They were not found in lakes, streams, and ponds of the North Belt LSA and South Belt LSA. However, they were found in lakes and streams of the Roberts system in the RSA, including Little Roberts Lake, Roberts Lake, Lake 04, Little Roberts Outflow, and Roberts Outflow (Tables 6.2-17 and 6.2-19). It is reasonable to suggest that the tributary leading from Roberts Lake to Lake E04 has been used as a migration corridor. It is also reasonable to assume that some of the Broad Whitefish that reside in this system migrate to and from brackish water in Roberts Bay.

The Roberts system appears to facilitate anadromy in the fish species that reside in its lakes and streams, including Arctic Char, Lake Trout, Lake Whitefish, and Broad Whitefish.

Burbot

Burbot are the only freshwater member of the cod (Gadidae) family. They are widespread in northern Canadian lakes and streams. TK does not indicate that they are a common food fish (Section 6.1.1.1).

Burbot generally inhabit deep waters in lakes; however, they migrate into the shallow littoral zones to spawn in mid-winter (Scott and Crossman 1973; Tables 6.2-22 and 6.2-23). Juvenile Burbot often spend the early summer feeding in tributary streams to lakes. By July, most Burbot have returned to the deepest portions of the lakes.

Adult Burbot are apex predators, with a diet similar to Lake Trout (Scott and Crossman 1973; Cott, Johnston, and Gunn 2011). Juvenile Burbot feed on aquatic insects and crustaceans, while adults feed primarily on fish.

The distribution of Burbot in the LSA and RSA is less well known because they are more difficult to catch in lakes than other species due to their preference for deep, benthic habitat. Burbot were not found in any lakes in the LSA or RSA (Table 6.2-17). In the North Belt LSA, they were found only in the Koignuk River. It is not known where they overwinter. In the South Belt LSA, Burbot were only found in Trout Outflow (Table 6.2-19), which suggests they are present in Aimaokatalok Lake. They were not found in any streams in the RSA or in any ponds in the LSA.

Burbot in the LSA and RSA may have a population structure similar to that of Arctic Grayling: one population above the waterfalls of the Koignuk River that uses overwintering habitat in Aimaokatalok

Lake and juvenile rearing habitat in its tributaries, and a second group that rears in the lower Koignuk River, Reference B Outflow, and Reference Lake B.

Ninespine Stickleback

Ninespine Stickleback is widely distributed throughout Canada, occupying both freshwater and marine habitats. Stickleback may occupy a variety of habitats, including small streams and deep lakes (Tables 6.2-22 and 6.2-23). Ninespine Stickleback has the smallest body size of any of the 14 fish species captured in the RSA and can live in water too shallow for most other species. It has a wide tolerance ranges for temperature and dissolved oxygen. Ninespine Stickleback is not a food fish (Section 6.1.1.1). However, it is an important prey species for Lake Trout.

Ninespine Stickleback spawns in summer, usually in shallow water with organic, fines or mud substrates and aquatic vegetation (Scott and Crossman 1973; Arai and Goto 2005). Stickleback feed primarily on small aquatic insects and plankton (Scott and Crossman 1973).

Ninespine Stickleback is the most widely distributed fish species in the LSA and RSA as a result of its small size and wide tolerance for extremes of temperature and water quality (Tables 6.2-17, 6.2-18, and 6.2-19). It was found in every lake of the North Belt LSA with the apparent exception of Glenn Lake (Table 6.2-17). This exception may have been the result of low sampling effort or the use of a gear such as gillnets that do not easily catch such a small-bodied fish because there is no reason to suggest that Glenn Lake lacks their preferred habitat. Ninespine Stickleback has also been found in every surveyed stream of the North Belt LSA with the exception of Patch Outflow and three other smaller streams (Table 6.2-19). Their presence in Glenn Outflow and Windy Outflow strongly suggests they are also present in Glenn Lake.

Ninespine Stickleback is present in all three lakes of the South Belt LSA and in all streams of the South Belt LSA with the exception of Aimaokatalok Outlet and two small streams (sites C01 and S03) of the Boston area. They have been found in 13 of the 27 surveyed lakes and in eleven of the 22 surveyed streams. They were also found in 15 of the 24 ponds surveyed in South Belt LSA and the RSA (Table 6.2-18). Their absence in the other nine ponds was assumed to reflect real absence, considering the small, shallow nature of those ponds.

In summary, Ninespine Stickleback has been found in every waterbody of the LSA and RSA except for small lakes and ponds that are too shallow, ephemeral, and unconnected to support them.

Slimy Sculpin

Slimy Sculpin is a common species in cold, rocky streams and lakes of northern Canada. It is not a common food fish (Section 6.1.1.1)

Slimy Sculpin spawn in early summer in shallow habitat of lakes and streams (Scott and Crossman 1973; Tables 6.2-22 and 6.2-23). Fry emerge approximately 30 days later. Juveniles rear in lakes and streams. All Slimy Sculpin overwinter in lakes. Prey is mainly benthic invertebrates plus drifting insects captured while resident in streams.

In the North Belt LSA, they were found in the Koignuk River, Windy Lake, Glenn Outflow, and Doris Outflow below the barrier (Tables 6.2-17 and 6.2-19). Their presence in Windy Lake and Glenn Outflow suggests that they are also present in Windy Outflow and Glenn Lake.

In the South Belt LSA, Slimy Sculpin were found in Aimaokatalok Lake, Trout Outflow, Stickleback Outflow, and one small stream in the Boston area (site S05). In the RSA, they were found in Reference

Lake B and Reference A Outflow. This suggests that they are present in both Reference Lake A and Reference B Outflow.

In summary, there appear to be four populations of Slimy Sculpin in the LSA and RSA. The first overwinters in Windy Lake and Glenn Lake and uses rearing habitat in Windy Outflow and Glenn Outflow. The second population uses rearing habitat in Doris Outflow below the waterfall, but it has to overwinter in one or more lakes – most likely in Little Roberts Lake since Slimy Sculpin were not commonly caught in the fish fence on Roberts Outflow. The third population overwinters in Reference Lake B and rears in Reference B Outflow and the Koignuk River. The fourth population overwinters in Aimaokatalok Lake and uses rearing habitat in tributaries to that lake and in the upper Koignuk River above the two waterfalls.

6.3 VALUED COMPONENTS

6.3.1 Potential Valued Components and Scoping

Valued Ecological Components (VECs) are those components of the freshwater environment considered to be of scientific, ecological, economic, social, cultural, or heritage importance (Volume 2, Section 4). The selection and scoping of VECs considers biophysical conditions and trends that may interact with the proposed Phase 2 Project, variability in biophysical conditions over time, and data availability as well as the ability to measure biophysical conditions that may interact with Phase 2 and are important to the communities potentially impacted by Phase 2.

6.3.1.1 Scoping Process and Identification of VECs

The scoping of VECs follows the process outlined in the Effects Assessment Methodology (Volume 2, Section 4). VECs considered for inclusion in the freshwater fish effects assessment relate to the role of fish and fish habitat in the freshwater aquatic environment as well as the value placed on fish and fish habitat for commercial, recreational, traditional, and cultural use (NIRB 2012a).

The EIS guidelines (NIRB 2012a) propose a number of VECs that were considered for inclusion in the freshwater fish effects assessment. These are identified in the EIS guidelines as components of the freshwater aquatic environment, as follows:

- Aquatic ecology;
- Aquatic biota (including representative fish as defined in the *Fisheries Act*, benthic invertebrates, and other aquatic organisms);
- Habitat including fish habitat as defined in the *Fisheries Act*; and
- Commercial, recreational, and Aboriginal fisheries as defined in the *Fisheries Act*.

The VECs identified in the EIS guidelines represent an appropriate starting point to guide the identification and scoping of VECs (NIRB 2012a). The selection of VECs began with those proposed in the EIS guidelines and was further informed through consultation with communities, regulatory agencies, available TK, professional expertise, regulatory considerations, and the NIRB's final scoping report (Appendix B of the EIS Guidelines; NIRB 2012a). For an interaction to occur there must be spatial and temporal overlap between a VEC and Phase 2 components and/or activities. The determination of VECs and potential effects for inclusion in the freshwater fish effects assessment considered and was informed by:

- The Environmental Impact Statement (EIS) guidelines and appendices (NIRB 2012a);

- Available traditional knowledge information from the *Inuit Traditional Knowledge for TMAC Resources Inc., Hope Bay Project, Naonaiyaotit Traditional Knowledge Project* (NTKP) report (KIA 2016) which presents summary information and distribution maps of valued fish species, freshwater fish habitat, and traditional land use activities;
- Consultation and engagement with local and regional Inuit groups (for example, the KIA);
- The public, during public consultation and open house meetings held in the Kitikmeot communities (see Volume 2, Section 3; Public Consultation and Engagement);
- Consultation with regulatory agencies;
- Regulatory consideration of the legislation that exists to protect fish and fish habitat including the *Fisheries Act*, MMER Regulations, and SARA (no fish species listed under SARA identified in baseline studies); and
- Review of the freshwater fish and fish habitat sections of recently completed Nunavut EAs (e.g., Back River, Mary River).

The content and results of other EIS chapters were also reviewed to inform the selection of freshwater fish VECs and effects including Surface Hydrology (Volume 5, Section 1), Bathymetry and Limnology (Volume 5, Section 2), Freshwater Water and Sediment Quality (Volume 5, Section 3 and 4, respectively) and the Human Health and Environmental Risk Assessment (Volume 6, Section 5). These chapters are referenced in the assessment, where appropriate.

6.3.1.2 NIRB Scoping Sessions

Scoping sessions hosted by NIRB (NIRB 2012b) with key stakeholders and local community members (i.e., the public) focused on identifying the components that are important to local residents, as related to Phase 2. Comments made during these sessions were compiled and analysed as part of VEC scoping. Notably, the main remarks related to the freshwater environment and linked to freshwater fish were those concerned with water quality (fish habitat) and fishing as a traditional land use and harvesting activity. The comments received can be summarized as follows:

<u>Freshwater Quality</u>

- Dust during spring-run off could impact the environment.
- Water should be left as clean as when the mine first started.

<u>Land Use and Inuit Harvesting</u>

- Fish are eaten when Inuit go out on the land. The connection to the land is important and is a part of healing group.

6.3.1.3 TMAC Consultation and Engagement Informing VEC Selection

Community meetings for the Phase 2 Project were conducted in each of the five Kitikmeot communities as described in Section 3 of Volume 2. The meetings are a central component of engagement with the public and an opportunity to share information and seek public feedback. Overall, the community meetings were well attended and public feedback (questions, comments, and concerns) about proposed Phase 2 was obtained through open dialogue during Phase 2 presentations, through discussions that arose during the presentation of Phase 2 materials and comments provided in feedback forms. Questions, comments, and concerns related to freshwater fish included:

- Workers ability/permission to fish while at camp;

- Impacts to fish and fish health; and
- Plenty of whitefish and trout in Patch Lake.

6.3.2 Valued Components Included in the Assessment

The scoping analysis identified the following VECs for inclusion in the assessment:

1. Fish habitat
2. Fish community: Lake Trout
3. Fish community: Arctic Grayling
4. Fish community: Arctic Char (freshwater life history)
5. Fish community: Cisco/Whitefish (freshwater life histories)

The VECs selected to guide the assessment of the potential effects of Phase 2 on freshwater fish are those:

- that have potential to interact with the activities and components of Phase 2;
- identified as important by local communities, Inuit organizations, governments, regulators, and other stakeholders during consultation and engagement;
- protected under legislation including the *Fisheries Act,* and MMER Regulations; and
- informed by Inuit IQ (Volume 2, Section 2; Traditional Knowledge) and professional judgement.

Table 6.3-1 summarizes the VECs included in the freshwater fish assessment. The components of the freshwater aquatic environment proposed as VECs by the EIS guidelines (NIRB 2012a) were considered in the scoping process and recognized as being included in relevant freshwater environment assessment areas (e.g., surface hydrology, freshwater water quality, freshwater sediment quality) and/or as belonging to one of two broader categories of freshwater fish VECs: 1) fish habitat; and 2) fish community as represented by VEC fish species (See Table 4.3-1, Volume 2, Section 4).

Freshwater aquatic ecology (proposed as a VEC by the EIS guidelines) includes relationships between aquatic organisms and their environments and relationships among aquatic organisms. Potential Phase 2 effects on the freshwater aquatic environment are assessed in the preceding chapters of Volume 5 of this EIS including, Section 1 (Surface Hydrology), Section 4 (Freshwater Water Quality), and Section 5 (Freshwater Sediment Quality). In these chapters, effects on aquatic organisms through their interactions with the freshwater aquatic environment are also considered. For example, water quality and sediment quality indicators were used that have quantitative relationships or thresholds associated with supporting aquatic organisms and biogeochemical processes, including established guidelines for the protection of aquatic life. The assessment of effects on aquatic ecology is also incorporated into the assessment of the freshwater fish habitat VEC in this chapter through examination of potential effects on fish habitat, which includes physical characteristics (e.g., water quality, sediment quality, available area, flow) and biological resources (e.g., primary and secondary producers and forage fish). The freshwater fish habitat VEC assessment therefore considers aquatic ecology through potential project effects that may impact relationships between the aquatic environment (i.e., fish habitat) and aquatic organisms (i.e., components of fish habitat and fish.)

Freshwater aquatic biota including benthic invertebrates and other aquatic organisms (proposed as a VEC by the EIS guidelines), are incorporated into the freshwater fish effects assessment as part of the fish habitat VEC. Fish habitat was assessed as defined in the *Fisheries Act*, and therefore includes both the physical habitat and the forage fish and other biological resources (i.e., aquatic biota) that are essential to the productivity of fisheries.

Finally, fish habitat and commercial, recreational, and Aboriginal fisheries as defined in the *Fisheries Act* (proposed as VECs by the EIS guidelines) are incorporated as individual VECs in the freshwater fish effects assessment. Thus, all VECs proposed by the EIS guidelines have either been included in the freshwater fish effects assessment as indicated in Table 6.3-1 and/or are otherwise addressed elsewhere in the EIS.

Table 6.3-1. Valued Ecosystem Components Included in the Freshwater Fish Assessment

	Identified by			Rationale for Inclusion
VEC	**TK**	**NIRB Guidelines**	**Regulations and Regulators**	
Fish Habitat	X	X	X	TK and land users indicated freshwater fish habitats that are used as areas of general fishing effort in the Phase 2 area (KIA 2016). Habitat including fish habitat as defined in the *Fisheries Act* is identified as a candidate VEC in the EIS guidelines (NIRB 2012a). Fish habitat as defined in the *Fisheries Act* includes both biological resources and physical characteristics. Aquatic ecology, aquatic biota (including representative fish as defined in the *Fisheries Act*, benthic invertebrates, and other aquatic organisms) and habitat (including fish habitat as defined in the *Fisheries Act* which comprises both biological resources and physical characteristics) were identified as candidate VECs in the EIS guidelines (NIRB 2012a). Section 35 of the *Fisheries Act* prohibits “serious harm” to fish which includes any permanent alteration to, or destruction of fish habitat. Information from TK, land users, and baseline studies in the Phase 2 area indicate that multiple freshwater fish habitats overlap with Phase 2 activities.
Fish Community – Lake Trout	X	X	X	TK and land users identified Lake Trout as important food fish for Inuit (KIA 2016). Section 35 of the *Fisheries Act* prohibits “serious harm” to fish that are part of a CRA fishery. As a CRA fishery species, Lake Trout were identified as a candidate VEC and information on Lake Trout was specifically requested in the EIS guidelines with respect to the biophysical environment and impact assessment (NIRB 2012a). Information from TK, land users, and baseline studies in the Phase 2 area indicate that the distribution of Lake Trout overlaps with Phase 2 activities.

VEC	Identified by			Rationale for Inclusion
	TK	NIRB Guidelines	Regulations and Regulators	
Fish Community – Arctic Grayling	X	X	X	TK and land users identified Arctic Grayling as a species fished for by Inuit (KIA 2016). Section 35 of the *Fisheries Act* prohibits "serious harm" to fish that are part of a CRA fishery. As a CRA fishery species, Arctic Grayling were identified as a candidate VEC and information on Arctic Grayling was specifically requested in the EIS guidelines with respect to the biophysical environment and impact assessment (NIRB 2012a). Information from TK, land users, and baseline studies in the Phase 2 area indicate that the distribution of Arctic Grayling overlaps with Phase 2 activities.
Fish Community – Arctic Char (freshwater life history)	X	X	X	TK and land users identified Arctic Char as an important food fish for Inuit (KIA 2016). Section 35 of the *Fisheries Act* prohibits "serious harm" to fish that are part of a CRA fishery. As a CRA fishery species, Arctic Char were identified as a candidate VEC and information on Arctic Char was specifically requested in the EIS guidelines with respect to the biophysical environment and impact assessment (NIRB 2012a). Information from TK, land users, and baseline studies in the Phase 2 area indicate that the distribution of Arctic Char (freshwater life history) overlaps with Phase 2 activities.
Fish Community – Cisco/Whitefish (freshwater life history)	X	X	X	TK and land users identified cisco and whitefish as important food fish for Inuit (KIA 2016). Section 35 of the *Fisheries Act* prohibits "serious harm" to fish that are part of a CRA fishery. As CRA fishery species, cisco and whitefish were identified as candidate VECs in the EIS guidelines (NIRB 2012a). Information from TK, land users, and baseline studies in the Phase 2 area indicate that the distributions of Cisco, Least Cisco, Broad Whitefish, and/or Lake Whitefish overlap with the Phase 2 activities.

The **freshwater fish habitat** VEC comprises both the physical habitat and the forage fish and other biological resources that are essential to the productivity of fisheries. Forage fish species are those species that are dietary resources for other fish and are included in the fish habitat VEC based on their role as food supply or "fish that support" CRA fisheries as informed by the EIS guidelines (NIRB 2012a) and the *Fisheries Act*, respectively. Biological resources, as defined here and informed by the EIS guidelines (NIRB 2012a), include the primary producers (phytoplankton, diatoms, and periphyton) and secondary producers (zooplankton, benthic invertebrates,) that make up the lower trophic levels which form the base of fish dietary resources. Finally, freshwater water quality and/or freshwater sediment quality also form part of the freshwater aquatic environment that acts as habitat for fish and are considered under the fish habitat VEC.

This chapter assesses Phase 2 effects on the VEC of fish habitat. Direct effects may result from specific Project/environment interactions between Project activities and components, and the fish habitat VEC. Indirect effects may be the result of direct effects on the environment that lead to secondary or collateral effects on the fish habitat VEC. The assessment of Phase 2 effects on the fish habitat VEC includes only the *direct* effects of Phase 2 infrastructure and activities on the physical aspects of the aquatic environment that provide distinct habitat for CRA fisheries and fish that support CRA fisheries (i.e., forage fish). These activities include the loss or alteration of fish habitat due to encroachment of the Phase 2 infrastructure footprint, water withdrawal, and from accidental spills and releases of contaminants. *Indirect* effects of Phase 2 activities on the fish habitat VEC may result through effects on water quality, sediment quality, and biological resources. Freshwater Water Quality and Freshwater Sediment Quality are treated as stand-alone VECs in other chapters of this EIS (Volume 5, Sections 4 and 5) and are considered to adequately assess the potential indirect effects of Phase 2 activities on aspects of the fish habitat VEC, including water quality, sediment quality, and biological resource based on the following logic:

1. Potential Phase 2 project-related effects on fish habitat are mediated *indirectly* through trophic interactions between fish and their biological/dietary resources (primary and secondary producers).
2. Potential Phase 2 project-related effects on primary and secondary producers predominantly arise *indirectly* from changes to water quality and/or sediment quality.
3. Potential Phase 2 project-related effects on water quality and/or sediment quality arise *directly* from project activities and are assessed individually, as the VECs Freshwater Water Quality (Volume 5, Section 4) and Freshwater Sediment Quality (Volume 5, Section 5).
4. No significant residual effects are predicted for Freshwater Water Quality or Sediment Quality after mitigation, management, and monitoring measures are considered (Volume 5, Sections 4 and 5, respectively).

As a result of there being no predicted significant residual effects of the Phase 2 Project on freshwater water quality or sediment quality, indirect effects on fish habitat resulting from these VECs have not been further assessed in this chapter.

The freshwater **fish community** comprises the survival and abundance of individual fish VECs including **Lake Trout, Arctic Grayling,** and the freshwater life histories of **Arctic Char** and **Cisco/Whitefish.** Rationale for the selection of individual species VECs relied on guidance from the EIS guidelines, TK information, and the definition of commercial, recreational, and Aboriginal fisheries species under the *Fisheries Act* (Table 6.3-1). A single VEC was defined to represent the freshwater life histories of cisco and whitefish species (Cisco/Whitefish; including Cisco, Least Cisco, Broad Whitefish, and Lake Whitefish).

A combined Cisco/Whitefish VEC was selected for several reasons. First, strict and consistent differentiations between cisco, whitefish, and the different species of each were not consistently made in descriptions of fish distribution and use in available TK information. Second, it is difficult or impossible to differentiate among cisco species in the field, in some cases preventing confirmation of individual species distributions in baseline studies. Finally, the most common cisco and whitefish species present in the Phase 2 area (i.e., Cisco, Least Cisco, and Lake Whitefish) occupy similar habitats/ecological niches and thus effects on cisco and whitefish can be assessed based on habitat preferences, prey species, and life history timing considerations that are generally similar among species. Arctic Cisco are not included in the Cisco/Whitefish VEC. While available TK information specifically identified Arctic Cisco as a fish species used by Inuit in the TK study area (KIA 2016), baseline studies in the Hope Bay Project area since 1993 have not captured Arctic Cisco in the freshwater fish RSA (which encompasses a smaller area than the TK study area). Further, Arctic Cisco are anadromous and only enter freshwater river habitats to spawn in the fall, before returning to sea (Scott and Crossman 1973). Freshwater habitats appropriate for Arctic Cisco spawning (i.e., river habitats that do not freeze to the substrates in winter) are either not present, or limited to the Koignuk River, in the freshwater fish RSA.

This chapter assesses Phase 2 effects on fish community VECs. *Direct* effects may result from specific Project/environment interactions between Project activities and components, and the fish community VECs. *Indirect* effects may be the result of *direct* effects on the environment that lead to secondary or collateral effects on the fish community VECs. This chapter assesses the potential *direct* effects of Phase 2 on the survival and population abundance of individual fish species VECs. These *direct* effects may be caused by water use and/or by Phase 2 activities that physically harm fish (e.g., spills, blasting, interactions with industrial equipment, and water withdrawal). Individual fish health and survival could also potentially be *indirectly* affected by Phase 2 through the contamination of water or sediment as well as through the bioaccumulation of contaminants in fish through trophic interactions with primary and secondary producers. The *indirect* effects of Phase 2 activities on individual fish species VECs are not included in this chapter because they are assessed in other chapters within the EIS. The potential for adverse effects to fish health and survival due to changes in water quality and/or sediment quality has been scoped out of the assessment of fish community VECs because Freshwater Water Quality and Freshwater Sediment Quality are assessed in Volume 5, Sections 4 and 5, respectively. The assessments of water quality and sediment quality consider the potential for adverse effects on fish health and survival as they are based on indicators that have quantitative relationships or thresholds associated with supporting aquatic organisms, including established guidelines for the protection of aquatic life. The potential for bioaccumulation of contaminants in Lake Trout, Arctic Grayling, Arctic Char, and Cisco/Whitefish is quantitatively assessed in the Human Health and Environmental Risk Assessment (Volume 6, Section 5) using receptor fish species representative of different freshwater trophic levels and habitat preferences (i.e., Ninespine Stickleback, Lake Whitefish, and Lake Trout).

6.3.3 Valued Components Excluded from the Assessment

The freshwater aquatic environment VECs proposed in the EIS guidelines (NIRB 2012a) are included in the assessment as part of the selected freshwater fish habitat and fish community VECs or, have been adequately assessed by inclusion in one or more other relevant assessment areas such as Surface Hydrology (Volume 5, Section 1), Freshwater Water Quality (Volume 5, Section 4), and Freshwater Sediment Quality (Volume 5, Section 5). Thus, none of the proposed components of the freshwater aquatic environment VEC have been excluded from the assessment.

6.4 SPATIAL AND TEMPORAL BOUNDARIES

The spatial boundaries selected to shape this assessment are determined by Phase 2's potential impacts on freshwater fish. Temporal boundaries are selected that consider the different phases of the Phase 2 Project and their durations. Phase 2's temporal boundaries reflect those periods during which planned activities will occur and have potential to affect a VEC.

The determination of spatial and temporal boundaries also takes into account the development of the entire Hope Bay Project. The assessment considers both the incremental potential effects of Phase 2, which is the subject of this Application, as well as the total potential effects of the additional Project activities in combination with the existing and approved Projects including regional exploration and advanced exploration activities at Madrid and Boston.

The boundaries of watersheds containing and adjacent to the Phase 2 infrastructure footprint were used in consideration of the spatial extent of the Phase 2's potential impacts on freshwater fish VECs.

6.4.1 Project Overview

Through a staged approach, the Hope Bay Project is scheduled to achieve mine operations in the Hope Bay Greenstone Belt through mining at Doris, a bulk sample followed by commercial mining at Madrid North and South, and mining of the Boston deposit. To structure the assessment, the Hope Bay Project is broadly divided into: 1) the Approved Projects (Doris and exploration), and 2) the Phase 2 Project (this application).

6.4.1.1 The Approved Projects

The Approved Projects include:

1. the Doris Project (NIRB Project Certificate 003, NWB Type A Water Licence 2AM-DOH1323);
2. the Hope Bay Regional Exploration Project (NWB Type B Water Licence 2BE-HOP1222);
3. the Boston Advanced Exploration Project (NWB Type B Water Licence 2BB-BOS1217); and
4. the Madrid Advanced Exploration Project (NWB Type B Water Licence under Review).

<u>The Doris Project</u>

Following acquisition of the Hope Bay Project by TMAC in March of 2013, planning and permitting, advanced exploration and construction activities have focused on bringing Doris into gold production in early 2017. In 2016, the Nunavut Impact Review Board and Nunavut Water Board (NWB) granted an amendment to the Doris Project Certificate and Doris Type A Water Licence respectively, to expand mine operations to six years and mine the full Doris deposit. Mining and milling rates were increased to a nominal 1,000 tpd to 2,000 tpd.

The Doris Project includes the following:

- The Roberts Bay offloading facility: marine jetty, barge landing area, beach and pad laydown areas, fuel tank farm/transfer station, and quarries;
- The Doris Site: 280 person camp, laydown area, service complex (e.g., workshop, wash bay), quarries, fuel tank farm/transfer station, potable water treatment, waste water treatment, incinerators, explosives storage, and diesel power plant;
- Doris Mine works and processing: underground portal, temporary waste rock pile, ore stockpile, and processing plant;
- Water use for domestic, drilling and industrial uses, and groundwater inflows to underground development;
- Tailings Impoundment Area (TIA): Schedule 2 designation of Tail Lake with two dams (North and South dams), roads, pump house, and quarry;
- all-weather roads and airstrip, winter airstrip, and helicopter pads; and
- water discharge from the TIA will be directed to the outfall in Roberts Bay.

Hope Bay Regional Exploration Project

The Hope Bay Regional Exploration Project has been ongoing since the 1990s. Much of the previous work for the program was based out of the Windy Lake (closed in 2008) and Boston camps (put into care and maintenance in 2011). All exploration activities are currently based from the Doris Site with plans for some future exploration at the Boston Site. Components and activities for the Hope Bay Regional Exploration Project include:

- staging of drilling activities out or Doris or Boston sites;
- operation of exploration drills in the Hope Bay Belt area, which are supported by helicopter.

Boston Advanced Exploration

The Boston Advanced Exploration Project, which operates under a Type B Water Licence, includes:

- the Boston exploration camp, sewage and greywater treatment plant, fuel storage and transfer station, landfarm, and a heli-pad;
- mine works consisting of underground development for exploration drilling and bulk sampling, temporary waste rock pile, and ore stockpile;
- potable water and industrial water taken from Aimokatalok Lake; and
- treated sewage and greywater discharged to the tundra.

Since the construction of Boston will require the reconfiguration of the entire site, construction and operation of all aspects of the Boston Site will be considered as part of the Phase 2 Project for the purposes of the assessment.

Madrid Advanced Exploration

In 2014, TMAC applied for an advanced exploration permit to conduct a bulk sample at the Madrid North and Madrid South sites, which are approximately 4 km south of the Doris Site. The program includes extraction of a 50,000-tonne bulk sample, which will be trucked to the mill at the Doris Site for processing and placement of tailings in the TIA. All personnel will be housed at the Doris Site.

The Water Licence application is currently before the NWB. Madrid advanced exploration includes constructing and operating of the following at each of the sites:

- Madrid North and Madrid South: workshop and office, laydown area, diesel generator, emergency shelter, fuel storage facility/transfer station, contact water pond, and quarry;
- Madrid North and Madrid South mine works: underground portal and works, waste rock pad, ore stockpile, compressor building, brine mixing facility, saline storage tank, air heating facility, and vent raises; and
- a road from the Doris Site to Madrid with branches to Madrid North, Madrid North vent raise, and the Madrid South portal.

6.4.1.2 The Phase 2 Project

The Phase 2 Project includes the Construction and Operation of commercial mining at the Madrid (North and South) and Boston sites, the continued operation of Roberts Bay and the Doris sites to support mining at Madrid and Boston, and the Reclamation and Closure and Post-Closure phases of all sites. Excluded from the Phase 2 project, for the purposes of the assessment, are the Reclamation and

Closure and Post-closure of unaltered components the Doris Project as currently permitted and approved.

Construction

Phase 2 construction will utilize the infrastructure associated with Approved Projects.

Additional infrastructure to be constructed for the proposed Phase 2 Project includes:

- expansion of the Doris TIA (raising of the South Dam, construction of West Dam, and development of a west road to facilitate access);
- construction of an off-loading cargo dock at Roberts Bay (including a fuel pipeline, expansion of the fuel tank farm and laydown area);
- construction of infrastructure at Madrid North and Madrid South to accommodate mining;
- complete development of the Madrid North and Madrid South mine workings;
- construction of a process plant, fuel storage, power plant, and laydown at Madrid North;
- all weather access road (AWR) and tailings line from Madrid North to the south end of the TIA;
- AWR linking Madrid to Boston with associated quarries;
- all infrastructure necessary to support mining activities at Boston including construction of a new 200-person camp at Boston and associated support facilities, additional fuel storage, laydown area, ore pad, waste rock pad, process plant, airstrip, diesel power plant, and dry-stack tailings management area (TMA) at Boston; and
- infrastructure necessary to support ongoing exploration activities at both Madrid and Boston.

Operation

Phase 2 Project represents the staged development of the Hope Bay Belt beyond the Doris Project (Phase 1). Phase 2 operations includes:

- mining of the Madrid North, Madrid South, and Boston deposits;
- transportation of ore from Madrid North, Madrid South and Boston to Doris for processing, and transportation of concentrate from process plants at Madrid North and Boston to Doris for final gold refining once the process plants at Madrid North and Boston are constructed;
- use of Roberts Bay and Doris facilities, including processing at Doris and maintaining and operating the Roberts Bay outfall for discharge of water from the TIA;
- operation of a process plant at Madrid North to concentrate ore, and disposal of tailings at the Doris TIA;
- operation of a process plant at Boston to concentrate ore, and disposal of tailings to the Boston TMA; and
- ongoing use and maintenance of transportation infrastructure (cargo dock, jetty, roads, and quarries).

Reclamation and Closure

At Reclamation and Closure, all sites will be deactivated and reclaimed in the following manner (see Volume 3, Section 5.5):

- Camps and associated infrastructure, laydown areas and quarries, buildings and physical structures will be decommissioned. All foundations will be re-graded to ensure physical and geotechnical stability and promote free-drainage, and any obstructed drainage patterns will be re-established.
- Using non-hazardous landfill, facilities will receive a final quarry rock cover which will ensure physical and geotechnical stability.
- Mine waste rock will be used as structural mine backfill.
- The Doris TIA surface will be covered rock. : Once the water quality in the reclaim pond has reached the required discharge criteria, the North Dam will be breached and the flow returned to Doris Creek.
- The Madrid to Boston All-Weather Road and Boston Airstrip will remain in place after Reclamation and Closure. Peripheral equipment will be removed. Where rock drains, culverts, or bridges have been installed, the roadway or airstrip will be breached and the element removed. The breached opening will be sloped and armoured with rock to ensure that natural drainage can pass without the need for long-term maintenance.
- A low-permeability cover, including a geomembrane, will be placed over the Boston TMA. The contact water containment berms will be breached. The balance of the berms will be left in place to prevent localised permafrost degradation.

6.4.2 Spatial Boundaries

6.4.2.1 Project Development Area

The Project Development Area (PDA) is shown in Figure 6.2-1 and is defined as the area which has the potential for infrastructure to be developed as part of the Phase 2 Project. The PDA includes engineering buffers around the footprints of structures. These buffers allow for refinement in the final placement of a structure through detailed design and in necessary in the field modifications during construction phases. Areas with buildings and other infrastructure in close proximity are defined as pads with buffers whereas roads are defined as linear corridors with buffers. The buffers for pads varied depending on the local physiography and other buffered features such as sensitive environments or riparian areas. The average engineering buffer for roads is 100 m on either side.

Since the infrastructure for the Doris Project is in place, the PDA exactly follows the footprints of these features. In all cases, the PDA does not include the Phase 2 Project design buffers applied to potentially environmentally sensitive features. These are detailed in Volume 3 (Project Description and Alternatives).

6.4.2.2 Local Study Area

The Local Study Area (LSA) is defined as the PDA and the area surrounding the PDA within which there is a reasonable potential for immediate effects on a VEC due to an interaction with a Phase 2 Project component(s) or physical activity.

The LSA used for the assessment of effects on freshwater fish VECs for the North Belt area is 451.5 km^2 and includes the PDA and the boundaries of the Koignuk/Aimaokatalok sub-watershed, the Doris Watershed, the Windy Watershed, and the 2 – Roberts Bay Watershed (Figure 6.2-1). The LSA used for the assessment of the effects on freshwater fisheries VECs for the South Belt area is 528.5 km^2 and includes the PDA and the boundaries of the Aimaokatalok Watershed and the East Watershed (Figure 6.2-1). The total area of the LSA (North and South Belt) is 980 km^2. Overall, the outer boundary of the

LSA follows the boundaries of watersheds and sub-watersheds where direct effects of the Phase 2 Project on freshwater fish VECs are possible.

6.4.2.1 Regional Study Area

The Regional Study Area (RSA) is defined as the broader spatial area representing the maximum limit where potential direct or indirect effects may occur.

The freshwater RSA used for the assessment of effects on freshwater fisheries VECs is 4560 km^2 and includes watersheds immediately adjacent to the LSA watersheds and sub-watersheds, including the Roberts, Angimajuq, Reference B, Reference C, Upper Koignuk, and Upper Aimaokatalok watersheds (Figure 6.2-1). Overall, the outer boundary of the RSA follows the boundaries of watersheds and sub-watersheds where direct or indirect effects of the Phase 2 Project on freshwater fish VECs are possible.

6.4.3 Temporal Boundaries

The Project represents a significant development in the mining of the Hope Bay Greenstone Belt. Even though this Project spans the conventional Construction, Operation, Reclamation and Closure, and Post-closure phases of a mine project, Phase 2 is a continuation of development currently underway for the Hope Bay Project. Phase 2 has four separate operational sites: Roberts Bay, Doris, Madrid (North and South), and three mine sites: Madrid North, Madrid South, and Boston. Development, operation, and closure of the Phase 2 Project will overlap with mining and post-mining activities at the existing Doris mine. As such, the temporal boundaries of this Project overlap with a number of Existing and Approved Authorizations (EAAs) for the Hope Bay Project and the extension of activities during Phase 2.

For the purposes of the EIS, distinct phases of the Project are defined (Table 6.4-1). It is understood that construction, operation and closure activities will, in fact, overlap among sites; this is outlined in Table 6.4-1 and further described in Volume 3, Section 2 (Project Description and Alternatives).

The assessment also considers a Temporary Closure phase should there be a suspension of Project activities during periods when the Project becomes uneconomical due to market conditions. During this phase, the Project would be under care and maintenance. This could occur in any year of Construction or Operation with an indeterminate length (one to two year duration would be typical).

Table 6.4-1. Temporal Boundaries for the Effects Assessment for Freshwater Fish

Phase	Phase 2 Project Year	Calendar Year	Length of Phase (Years)	Description of Activities
Construction	1 - 4	2019 - 2022	4	• **Roberts Bay:** construction of marine dock and additional fuel facilities (Year 1 – Year 2); • **Doris**: expansion of the Doris TIA and accommodations (Year 1); • **Madrid North:** construction of process plant and road to Doris TIA (Year 1); • **All-weather Road**: construction (Year 1 – Year 3); • **Boston**: site preparation and installation of all infrastructures including process plant (Year 2 – Year 5).

Phase	Phase 2 Project Year	Calendar Year	Length of Phase (Years)	Description of Activities
Operation	5 - 14	2023 - 2032	14	• **Roberts Bay**: shipping operations (Year 1 – Year 14) • **Doris**: mining (Year 1 - 4); milling and infrastructure use (Year 1 – Year 14); • **Madrid North:** mining (Year 1 – 13); ore transport to Doris mill (Year 1 -13); ore processing and concentrate transport to Doris mill (Year 2 – Year 13); • **Madrid South:** mining (Year 11 – Year 14); ore transport to Doris mill (Year 11 – Year 14); • **All-weather Road**: operational (Year 4 – Year 14); • **Boston**: winter access road operating (Year 1 – Year 3); mining (Year 4 – Year 13); ore transport to Doris mill (Year 4 – Year 5); processing ore (Year 6 – Year 13); and concentrate transport to Doris mill (Year 6 – Year 13).
Reclamation and Closure	15 - 17	2033 - 2035	3	• **Roberts Bay**: facilities will be operational during closure (Year 15 – Year 17) and closed prior to post-closure; • **Doris**: accommodations and facilities will be operational during closure (Year 15 – Year 17) and closer prior to post-closure; mining, milling, and TIA decommissioning (Year 15 – Year 17); • **Madrid North:** all components decommissioned (Year 15 – Year 17); • **Madrid South:** all components decommissioned (Year 15 – Year 17); • **All-weather Road**: road will be operational (Year 15 – Year 16); decommissioning (Year 17); • **Boston**: all components decommissioned (Year 15 – Year 17).
Post-Closure	18 - 22	2036 - 2040	5	• **All Sites:** Post-closure monitoring.
Temporary Closure	NA	NA	NA	• **All Sites:** Care and maintenance activities, generally consisting of closing down operations, securing infrastructure, removing surplus equipment and supplies, and implementing on-going monitoring and site maintenance activities.

6.5 PROJECT-RELATED EFFECTS ASSESSMENT

6.5.1 Methodology Overview

This assessment follows a methodology used to identify and assess the potential environmental effects of the Phase 2 Project and is consistent with the requirements of Section 12.5.2 of the Nunavut Agreement and the EIS Guidelines. The effects assessment evaluates the potential direct and indirect effects of the Phase 2 Project on the environment and follows the general methodology provided in Volume 2, Section 4 (Effects Assessment Methodology), and comprises a number of steps that collectively assess the manner in which the Phase 2 Project will interact with VECs defined for the assessment (Section 6.3).

To provide a comprehensive understanding of the potential effects for the Project, the Phase 2 components and activities are assessed on their own as well as in the context the Approved Projects (Doris and exploration) within the Hope Bay Greenstone Belt. The effects assessment process is summarized as follows:

1. Identify potential interactions between the Phase 2 Project and the VECs
2. Identify the resulting potential effects of those interactions
3. Identify mitigation or management measures to eliminate, reduce, or offset the potential effects.
4. Identify residual effects (potential effects that would remain after mitigation and management measures have been applied) for Phase 2 in isolation.
5. Identify residual effects of Phase 2 in combination with the residual effects of Approved Projects.
6. Determine the significance of combined residual effects.

After the identification of potential interactions and potential effects (Steps 1 and 2), mitigation and management measures (including fisheries offsetting, see Section 6.2.3.1) were considered (Step 3). Phase 2 Project residual effects to freshwater fish VECs were then identified through characterization of potential effects (Step 4). If the application of mitigation and management measures were considered to effectively mitigate or offset the effect, the Phase 2 Project-related effects to freshwater fish VECs were characterized as *negligible* and not identified as residual effects. Potential effects of Phase 2 in combination with Approved Projects were also characterized to identify residual effects of the overall Hope Bay Project, and characterized as *negligible* if the mitigation and management measures were considered effective (Step 5).

The characterization of potential effects on freshwater fish VECs incorporated guidance from DFO's *Fisheries Protection Policy Statement* (DFO 2013d) and Request for Review Process (DFO 2014b) regarding the determination of whether a project is likely to cause serious harm to fish as defined in the *Fisheries Act*. This guidance from DFO recommends consideration of the duration, geographic scale, probability, and reversibility of effects, as well as the availability and condition of nearby fish habitat and effectiveness of mitigation and management measures. Overall, effects were considered *negligible* and were not carried forward in the assessment as residual effects if:

- habitat changes and/or reduction in population abundance were unlikely and were unlikely to have an effect on fisheries productivity distinguishable from natural variation; or
- effects on fisheries productivity resulting from habitat changes and/or reduction in population abundance could be feasibly and effectively mitigated or offset through mitigation, management, and fisheries offsetting measures.

If residual effects were identified, the significance of residual effects was determined (Step 6) by considering the characterization of each residual effect based on the primary criteria of direction and magnitude and additional attributes (Volume 2, Section 4; Table 4.3-6) including an assessment of the probability of occurrence of effects and the confidence in the baseline data and predictions of the effects of the Phase 2 Project on the freshwater fish VECs (Volume 2, Section 4; Table 4.3-7).

6.5.2 Identification of Potential Effects

The potential effects of Project activities on the VECs of fish habitat and fish community (Lake Trout, Arctic Grayling, Arctic Char, and Cisco/Whitefish) were determined using the initial matrix provided in

Volume 2, Section 4 (Table 4.3-2), and further refined using the EIS guidelines (NIRB 2012a), DFO's Pathways of Effects (DFO 2014a), available TK, professional judgement, and experience at other projects in Nunavut and the Northwest Territories. Activities throughout the duration of the Phase 2 Project were considered for their potential interactions with the fish habitat VEC and each fish community VEC.

6.5.2.1 Potential Effects on Freshwater Fish Habitat VEC

Freshwater fish habitat may interact with and be affected by Phase 2 activities along two general pathways: through a direct **loss or alteration of fish habitat** by permanent alteration or destruction (PAD), or through **changes to water quality and/or sediment quality** arising from the deposition of deleterious substances (Table 6.5-1). An alteration of fish habitat is considered a permanent alteration if the spatial scale, duration, or intensity limits or diminishes the ability of fish use the habitat to carry out one or more of their life processes. Destruction of fish habitat occurs when fish can no longer rely upon the habitat to carry out one or more of their life processes.

A PAD is a *direct* **loss or alteration of fish habitat** area potentially incurred through planned construction (e.g., encroachment of infrastructure on existing fish habitat) or water withdrawal. Direct loss or alteration of fish habitat may also occur as a result of spills, accidents or malfunctions (e.g., slope failures). Spills, accidents and malfunctions are addressed in Volume 8, Section 2.4 and Annex 4 (Spill Contingency) and Volume 7, Section 1 (Accidents and Malfunctions).

The introduction of deleterious substances could alter fish habitat *directly* by **changes in water quality and/or sediment quality** to the extent that fish health decreases and mortality occurs, or *indirectly*, through trophic interactions with biological resources used by fish. The *direct* effect on fish health and mortality potentially caused by the introduction of deleterious substances in water (e.g., via effluent discharged from site and mine contact water, accidental releases, or spills) is assessed as part of the fish habitat VEC. Spills, accidents and malfunctions that may result in changes to water and sediment quality are also addressed in Volume 7, Section 1 (Accidents and Malfunctions) and in Volume 8, Section 2.4 and Annex 4 (Spill Contingency). The *indirect* effect on fish habitat (i.e., through trophic interactions) potentially resulting from the introduction of deleterious substances into water and sediment is assessed in two chapters: Volume 5, Section 4 for Freshwater Water Quality and Volume 5, Section 5 for Freshwater Sediment Quality.

The EIS guidelines identify potential impacts on the freshwater aquatic environment for inclusion in a comprehensive impact analysis of all Phase 2 components and activities. The potential impacts identified in the EIS guidelines and the corresponding potential effects assessed in the effects assessment for the freshwater fish habitat VEC are listed in Table 6.5-2. Specific Phase 2 activities that link potential interactions/effects with the VEC freshwater fish habitat are described in Table 6.5-3.

6.5.2.2 Potential Effects on Freshwater Fish Community VECs

The freshwater fish community may interact and be affected by Phase 2 activities along two general pathways: through *direct* **mortality and changes to population abundance**, or through decreased health and *indirect* mortality resulting from **changes in water quality and/or sediment quality** (Table 6.5-1).

Table 6.5-1. Potential Effects of the Phase 2 Project on Freshwater Fish VECs

Freshwater Fish VEC	Potential Effect	Cause	Description	General Project Activity	Regulation	Effect Assessment
Fish Habitat	Loss or alteration of fish habitat	Permanent alteration or destruction (PAD) of habitat	Loss or damage of fish habitat through encroachment of infrastructure and water withdrawal.	1. Project Infrastructure Footprint 2. Water Withdrawal and Use	Fisheries Act (1985) Section 35(2)	This chapter: Vol. 5, Chapter 6 (Freshwater Fish)
	Changes in water quality and/or sediment quality resulting in: 1. Direct fish mortality or reduction in fish health 2. Indirect reduction in biological resources of fish through trophic interactions	Deposition of deleterious substances	Mine and camp effluent, hydrocarbon contaminants, accidental releases or spills, increased nutrient loading including through blasting activities, introduced sediment (increased TSS or deposition in spawning areas)	Management of Contact Water, Effluent, Dust	Metal Mining Effluent Regulations (SOR/2002-222)	1. This chapter: Vol. 5, Chapter 6 (Freshwater Fish) 2. Vol. 5, Chapters 4 and 5 (Freshwater Water Quality and Freshwater Sediment Quality)
Fish Community: Lake Trout, Arctic Grayling, Arctic Char, Cisco/Whitefish	Direct mortality and population abundance	Activities that physically harm fish or affect the ability of fish to carry out their life processes	Any impact that causes the death of fish directly (e.g., entrainment/impingement, blasting, fishing, accidental releases or spills) or reduction in population abundance (e.g., stress, effects on migration)	1. Project Infrastructure Footprint 2. Water Withdrawal and Use 3. Blasting	Fisheries Act (1985) Sections 35, 36	This chapter: Vol. 5, Chapter 6 (Freshwater Fish)
	Changes in water quality and/or sediment quality resulting in indirect mortality or reduction in fish health	Deposition of deleterious substances	Any impact that affects individual health and longevity, tissue quality, or parasite load	Management of Contact Water, Effluent, Dust	Metal Mining Effluent Regulations (SOR/2002-222)	1. Vol. 6, Chapter 5 (Human Health and Environmental Risk Assessment) 2. Vol. 5, Chapters 4 and 5 (Freshwater Water Quality and Freshwater Sediment Quality)

Table 6.5-2. NIRB EIS Guidelines for Impact Assessment of the Phase 2 Project on the Freshwater Aquatic Environment and Identified Potential Effects on Freshwater Fish VECs

	Potential Effect			
	Fish Habitat VEC		Fish Community VECs	
EIS Guidelines (NIRB 2012)	Loss or alteration of fish habitat	Changes in water and/or sediment quality	Direct mortality and population abundance	Changes in water and/or sediment quality
Potential impacts to fish, invertebrates, and freshwater habitat including potential impacts to water and sediment quality. Consideration should be given to impacts associated with the following: water withdrawals; discharge; redirection of natural flows; explosives use; nutrient and contaminant inputs; and sewage and grey water effluent discharge	X	X	X	X
Potential direct or indirect effects on fish and invertebrate biota and habitat of both, including aquatic Species at Risk, from any changes to the aquatic or riparian environments, as a result of any in-water works or Project activities in close proximity to waterbodies	X	X	X	X
Potential impacts to fish due to blasting in or near waterbodies, including noise and vibration impacts	X	X	X	X
Potential impacts to fish and fish habitat from any infilling of lake, wetland or stream habitats associated with road construction(s)	X		X	
Potential impacts to freshwater fish, invertebrates and habitat from planned containment structures (e.g., sediment control structures and fuel containment structures) and potential accidental spills.	X	X	X	X
Potential impacts on identified fish habitat critical for spawning, rearing, nursery and feeding, seasonal migration, winter refuges and migration corridors.	X	X	X	X
Evaluation of the ability of fish to pass at water crossings along access roads taking into consideration periods of extreme low and extreme high stream flows	X		X	
Potential impacts to fish health, distributions and population especially taking in to consideration contamination and fugitive dust and potential impact to human health due to consumption of these fish		X	X	X
Potential impacts on contamination of traditional foods as a result of bioaccumulation, i.e., food chain uptake through air, water and soil, including a discussion of proposed monitoring		X		X
Environmental receptivity-including ecological, physical and/or climatic factors that influence exposure to harmful substances		X		X
Quantitative assessment of the ecological risks to freshwater VECs from the potential elevated contaminant loadings as a result of the Project		X	X	X

Table 6.5-3. Summary of Potential Interactions between Freshwater Fish VECs and the Phase 2 Project

		Project(s)		Fish Habitat		Fish Community (Lake Trout, Arctic Grayling, Arctic Char, Cisco/Whitefish)	
Project Phase and General Project Activity	**Specific Project Activity**	**Phase 2**	**Approved**	**Loss or alteration of fish habitat**	**Changes in water and sediment quality**	**Direct mortality and population abundance**	**Changes in water and sediment quality**
Construction							
Project Infrastructure Footprint	Water Crossings	●	●	X	X	X	X
	Infrastructure Facilities	●	●	X	X	X	X
	Madrid-Boston winter road	●		X	X	X	X
Water Use	Water use		●	X	X	X	X
Blasting	Quarry	●	●	X	X	X	X
Management of Contact Water, Effluent, and Dust	All-weather access roads	●			X		X
	Airstrip and lighting	●	●		X		X
	Road use and maintenance	●	●		X		X
	Quarry	●	●		X		X
	Fuel storage and handling	●	●	X	X	X	X
	Incinerator	●			X		X
	Construction camps	●			X		X
	Site surface infrastructure and pads	●	●		X		X
	Ore stockpiles	●	●		X		X
	Overburden pile	●			X		X
	Waste rock piles	●	●		X		X
	Water management system	●	●		X		X
	Water discharge to receiving environment	●			X		X
Operation							
Project Infrastructure Footprint	Water Crossings	●	●	X	X	X	X
	Madrid-Boston winter road	●		X	X	X	X
	Infrastructure facilities	●	●	X	X	X	X
Water use	Water use	●	●	X	X	X	X
Blasting	Quarry	●	●	X	X	X	X
Management of Contact Water, Effluent, and Dust	Quarry	●	●		X		X
	Airstrip and lighting	●	●		X		X
	Road use and maintenance	●	●		X		X

Project Phase and General Project Activity	Specific Project Activity	Project(s)		Fish Habitat		Fish Community (Lake Trout, Arctic Grayling, Arctic Char, Cisco/Whitefish)	
		Phase 2	Approved	Loss or alteration of fish habitat	Changes in water and sediment quality	Direct mortality and population abundance	Changes in water and sediment quality
Operation (cont'd)							
	Fuel storage and handling	●	●	X	X	X	X
	Storage and handling of explosives		●	X	X	X	X
	Chemical and hazardous material management		●	X	X	X	X
	Incinerator	●	●		X		X
	Site surface infrastructure and pads	●	●		X		X
	Ore stockpiles	●	●		X		X
	Overburden pile	●			X		X
	Waste rock piles	●	●		X		X
	Water management system	●	●		X		X
	Water discharge to receiving environment	●	●		X		X
Reclamation and Closure							
Project Infrastructure Footprint	Water Crossings	●	●	X	X	X	X
	Madrid-Boston winter road	●		X	X	X	X
	Inter-site roads	●	●		X		X
Water use	Water use	●	●	X	X	X	X
Management of Contact Water, Effluent, and Dust	Quarry	●			X		X
	All-weather access roads	●	●		X		X
	Airstrips		●		X		X
	Construction camps		●		X		X
	Surface and mining infrastructure	●	●		X		X
	TIA/TMA and associated infrastructure	●			X		X
	Water management system	●	●		X		X
	Water discharge to receiving environment	●	●		X		X
Post-closure							
	Post-closure monitoring	●		X	X	X	X
Temporary Closure							
	Care and maintenance	●		X	X	X	X

The effects assessment for freshwater fish community VECs focuses on the interactions and potential effects associated with the pathway of *direct* **mortality and changes to population abundance** of the VECs Lake Trout, Arctic Grayling, Arctic Char, and Cisco/Whitefish. Direct mortality and changes to population abundance may potentially occur during the construction of in-water infrastructure and any Phase 2 activities that physically harm fish through blasting, water withdrawal, impact injury (e.g., interactions with industrial equipment), and spills, accidents and malfunctions. Spills, accidents, and malfunctions are addressed in Volume 7, Section 1 (Accidents and Malfunctions) and in Volume 8, Section 2.4 and Annex 4 (Spill Contingency). Fishing activities can also physically harm fish due to handling and hook and release mortality. However, although fish mortality rates may increase with increased fishing pressure, a "no fishing" policy for personnel and contractors while on site will be in place. On-site monitoring activities targeting fish will also take the least invasive approach as appropriate to minimize impacts on fish. This policy/approach will remove potential effects on fish communities that may result from an increase in fishing pressure, therefore the effects of fishing are not discussed any further in the assessment for fish community VECs.

For the pathway of decreased health and *indirect* mortality, potential **changes in water quality and/or sediment quality** resulting from contact water, fugitive dust, and planned discharge of water/effluent to the receiving environment could have chronic effects on fish community VECs. The potential effects of these Phase 2 activities are assessed as part of the VECs of Freshwater Water Quality and Sediment Quality in Volume 5, Sections 4 and 5, respectively. The potential effects on fish health due to bioaccumulation of contaminants in Lake Trout, Arctic Grayling, Arctic Char, and Cisco/Whitefish is quantitatively assessed in the Human Health and Environmental Risk Assessment (Volume 6, Section 5) using receptor fish species representative of different freshwater trophic levels and habitat preferences (i.e., Lake Trout, Whitefish, and Ninespine Stickleback). Spills, accidents and malfunctions may also result in changes to water and sediment quality and are addressed in Volume 7, Section 1 (Accidents and Malfunctions) and in Volume 8, Section 2.4 and Annex 4 (Spill Contingency).

The EIS guidelines identify potential impacts on the freshwater aquatic environment for inclusion in a comprehensive impact analysis of all Phase 2 components and activities. The potential impacts identified in the EIS guidelines and the corresponding potential interactions/effects assessed in the effects assessment for freshwater fish community VECs are listed in Table 6.5-2. Specific Phase 2 activities that link potential interactions/effects with freshwater fish community VECs (Lake Trout, Arctic Grayling, Arctic Char, and Cisco/Whitefish) are described in Table 6.5-3.

6.5.3 Mitigation and Adaptive Management for Freshwater Fish VECs

Mitigation and adaptive management measures applicable to freshwater fish VECs were identified through a review of best management practices at similar mining projects in the Arctic (including the Doris Project), available TK, regulatory guidance and considerations, scientific literature, and professional judgement. Mitigation and monitoring specific to potential effects on individual freshwater fish VECs are identified where necessary in the individual VEC effects assessments in Section 6.5.4 and Section 6.5.5.

6.5.3.1 Mitigation by Project Design

Phase 2 has been designed to avoid impacts on freshwater fish habitat and freshwater fish community VECs where possible. The major aspects of mitigation by design include:

- Where possible, Phase 2 infrastructure has been located outside of fish bearing water;

- Minimum 31 m setbacks, and 51 m setbacks where possible were applied near water features to avoid affecting riparian functions;
- Roads were routed, as far as was practical, to avoid streams, channel crossings, and wet, boggy areas where fish habitat may be disturbed;
- Fish-bearing streams will be spanned using bridge structures (clear span bridge structures will be used where practical). Fish-bearing streams of very low flow will be spanned using culverts sized for fish passage provided the required conditions necessary to sustain fish habitat can be achieved;
- Road rights-of-way will cross each stream as close to perpendicular as possible to minimize the amount of riparian vegetation that may be disturbed during construction;
- Where pumps/intakes are used in fish-bearing watercourses or where fish salvage has not occurred, intakes will be screened following DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013g); and
- Water will be recycled where possible to reduce the demand for water withdrawals (Volume 3, Project Description and Alternatives; Section 4.4.5 Water Management)

6.5.3.2 Best Management Practices

The Phase 2 Project will be constructed and managed following government guidelines and industrial best management practices as much as possible to avoid unnecessary impacts to freshwater fish habitat and fish communities. Government guidelines to avoid harm to fish habitat and fish communities include DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013g), federal and territorial guidelines to preserve water and air quality (e.g., CCME guidelines for the protection of aquatic life; CCME 2016), and federal and territorial environmental protection regulations. In addition, standard industrial best management practices will be implemented, many of which are featured in water management plans (Volume 8, Management Plans; Annex 5 to Annex 11). General best management practices are as follows:

- Prevent the release of sediment or sediment laden water into water frequented by fish by employing erosion and sediment control measures;
- Discharge of compliant water to the receiving environment; and
- Vehicular access across a watercourse or waterbody will be by road or bridge, or other acceptable method according to DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat.

Mitigation measures from DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013g) that will be implemented to ensure that fish and fish habitat are not adversely affected by development include:

<u>Timing</u>

- Timing of in-water construction activities will conform, when possible, to Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat (DFO 2013h; May 1 to July 15 for spring spawning fish, e.g., Arctic Grayling and August 15 to June 30 for fall spawning fish, e.g., Lake Trout, Arctic Char, cisco and whitefish) of May 1 to July 15 for spring spawning fish (Arctic Grayling) and August 15 to June 30 for fall spawning fish (Lake Trout, Arctic Char, cisco and whitefish); and
- The duration of in-water work will be minimized to the extent possible.

Site Selection

- In-water works will be designed and planned such that loss or disturbance to aquatic habitat is minimized and sensitive spawning habitats are avoided;
- Where possible, approaches will be designed to be perpendicular to the watercourse to minimize loss or disturbance to riparian vegetation;
- Where possible, crossing locations will avoid unstable areas such as meander bends, braided sections, and active floodplains to avoid introduction of sediments to the watercourse; and
- Instream activities will be undertaken, where possible, in isolation of open or flowing water, or when frozen, to maintain the natural flow of water downstream and avoid introducing sediment into the watercourse.

Contaminant and Spill Management

- A spill response plan will be in place that will be implemented in the event of a sediment release or spill of a deleterious substance and emergency spill kits will be available (Volume 8, Management Plans; Section 2.4 and Annex 4);
- Construction materials will have been handled and treated to prevent the release or leaching of deleterious substances into the waterbody; and
- Excess materials will be removed from the construction site upon project completion.

Erosion and Sediment Control

- Effective erosion and sediment control measures will be installed before starting work to prevent sediment from entering the waterbody;
- Where practical, site isolation measures (e.g., silt boom or silt curtain) will be used to contain suspended sediment where in-water work is required;
- Regular inspection and maintenance of erosion and sediment control measures and structures will be conducted during the course of construction and until disturbed ground has been stabilized;
- Repairs to erosion and sediment control measures and structures will be promptly completed if damage occurs; and
- Removal of non-biodegradable erosion and sediment control materials will be completed once site is stabilized.

Shoreline/Bank Re-vegetation and Stabilization

- Clearing of riparian vegetation will be kept to a minimum to avoid disturbance to the riparian vegetation and prevent soil compaction;
- Shorelines or banks disturbed by any activity will be stabilized promptly to prevent erosion and/or sedimentation;
- Where disturbed, the bed and banks of waterbodies will be restored to their original contour and gradient, where possible, or to a stable gradient that does not obstruct fish passage; and

If rock is required to stabilize eroding or exposed areas, appropriately-sized, clean rock will be used and it will be installed at a similar slope to maintain a uniform bank/shoreline and natural stream/shoreline alignment.

Fish Protection

- In-water activities or associated in-water structures (i.e., culverts and bridges) will not interfere with fish passage, constrict channel width, or reduce flows; and
- A qualified professional will be retained, where needed, to ensure applicable permits for relocating fish are obtained and to capture any fish trapped within an isolated/enclosed area and safely relocate them to an appropriate location in the same waterbody (i.e., fish salvage activities).

Operation of Machinery

- Machinery undertaking in-water work will be in a clean condition and maintained free of fluid leaks, invasive species, and noxious weeds;
- Whenever possible, machinery will be operated on land above the high water mark or on ice in a manner that minimizes disturbance to the banks and bed of the waterbody;
- Whenever possible, machine fording of a watercourse will be limited to a one-time event (i.e., over and back), and only if no alternative crossing method is available. If repeated crossings of the watercourse are required, a temporary crossing structure will be constructed;
- Service machinery will be washed, refueled and fuel and other materials for the machinery stored in such a way as to prevent any deleterious substances from entering the water;
- If minor rutting is likely to occur, stream bank and bed protection methods (e.g., swamp mats, pads) will be used, provided they do not constrict flows or block fish passage; and
- If the stream bed and banks are steep and highly erodible (e.g., dominated by organic materials and silts) and erosion and degradation are likely to occur as a result of equipment fording, then a temporary bridge will be used in order to protect these areas.

Detailed best management practices for specific project activities are described in sections 6.5.4 and 6.5.5 under Mitigation and Management Measures for Specific Potential Effects.

6.5.3.3 Proposed Monitoring Plans and Adaptive Management

Proposed Monitoring Plans

Aquatic Effects Monitoring Program

The Aquatic Effects Monitoring Plan (Volume 8, Management Plans; Section 2.17 and Annex 21) will be in place that outlines the Aquatic Effects Monitoring Program (AEMP) that will be carried out during all phases of the Project. The AEMP will include the following:

- monitoring the freshwater environment at locations potentially affected by the Phase 2 Project and a reference area well away from Phase 2 activities;
- monitoring freshwater water quality, sediment quality, and aquatic biology; and
- monitoring fish populations and fish tissues if and where required based on monitoring results and as required under the MMER.

Fisheries Offsetting Plan

A Fisheries Offsetting Plan typically contains the design, implementation, and monitoring actions required to offset potential serious harm to CRA fisheries resulting from a project, as concluded by DFO and as per the guidance provided in DFO's *Fisheries Protection Policy Statement* (DFO 2013d). If deemed necessary by DFO through the *Fisheries Authorization* process, the Fisheries Offsetting Plan will address all potential serious harm to CRA fish through mitigation and/or offsetting using methods from DFO's *Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting* (DFO 2013c) such as the restoration or enhancement of habitats or the creation of habitat elsewhere in the landscape. A monitoring program will be developed to monitor the effectiveness of the Fisheries Offsetting Plan. The monitoring program will be developed in conjunction with regulatory agencies, and will assess the effectiveness of the offsetting activities over time in reference to specific performance objectives. These performance objectives may include:

- stability of constructed habitat;
- primary productivity;
- benthic invertebrate community;
- fish presence/habitat use; and
- local density, production, or population size estimated for fish species.

For the purposes of this EIS, where the effects conclusion relies on the successful implementation of a Fisheries Offsetting Plan to mitigate potential residual effects resulting from Phase 2, a conceptual approach to developing a Fisheries Offsetting Plan is provided in Appendix V5-6V. If required, a final Fisheries Offsetting Plan will be developed and submitted in conjunction with the FEIS, satisfying the requirements of the EIS guidelines (NIRB 2012a; refer to Volume 8, Section 1 for additional information).

Other Management Plans

Other management plans which form the Environmental Management System (Volume 8; Management Plans) address particular issues through specific mitigation and management measures to maintain air and water quality through the management of contaminants and waste. These plans, presented in Volume 8 (Management Plans), address spills and contingencies, management of water, waste, waste rock, ore, and tailings, as well as air quality management and monitoring.

Adaptive Management

The need for any corrective actions to on-site emission management or installation of additional control or mitigation measures will be determined on a case-by-case basis. Indications of the need for corrective actions and additional control or mitigation measures may include:

- results from the Aquatic Effects Monitoring Program, which will monitor the receiving environment around the mine infrastructure and activities, show adverse effects to fish habitat and/or fish communities; and
- if a Fisheries Offsetting Plan and Monitoring Plan are deemed necessary by DFO through the *Fisheries Authorization* process, results from the Fisheries Offsetting Monitoring Program show that the offsetting program is not successful.

6.5.4 Characterization of Potential Effects - Fish Habitat VEC

Project residual effects are the effects that are remaining after mitigation and management measures are taken into consideration. If the implementation of mitigation measures eliminates a potential effect and no residual effect is identified on that VEC, the effect is eliminated from further analyses. If the proposed implementation controls and mitigation measures are not sufficient to eliminate an effect, a residual effect is identified and carried forward for additional characterization and a significance determination. Residual effects of the Project can occur directly or indirectly. Direct effects result from specific Project/environment interactions between Project activities and components, and VECs. Indirect effects are the result of direct effects on the environment that lead to secondary or collateral effects on VECs.

The following characterization of specific potential Project effects on the fish habitat VEC describes the potential effects of interactions of fish habitat with the Phase 2 Project and the Hope Bay Project (including Phase 2 activities), identifies mitigation measures (including fisheries offsetting), and assesses whether residual effects remain after mitigation and management measures are taken into consideration. Residual effects from project-related interactions associated with the fish habitat VEC may be avoided and/or considered mitigable even when serious harm (as per the *Fisheries Act*) may be concluded by DFO, as long as it is considered feasible to offset the serious harm.

6.5.4.1 Loss or Alteration of Fish Habitat: Project Infrastructure Footprint

Characterization of Phase 2 Potential Effects

Phase 2 Project infrastructure has the potential to interact with the VEC freshwater fish habitat wherever the locations of infrastructure overlap with fish-bearing freshwater. Effects on the VEC freshwater fish habitat may occur during all phases of the Phase 2 Project, beginning in Construction when the building of most infrastructure will take place, and occurring through Post-Closure (Table 6.5-3). Figures 6.5-1 and 6.5-2 indicate the waterbodies in the LSA and RSA where there is the potential for freshwater fish habitat loss or alteration as a result of interaction with the Phase 2 Project. Waterbodies with the for potential effects from the Phase 2 infrastructure footprint include waterbodies crossed by all-weather roads and Aimaokatalok Lake, where a water intake and discharge pipe will be constructed. Waterbodies with the potential for effects on the fish habitat VEC due to water withdrawal/use are discussed further in section 6.5.4.2.

Water Crossings

Fish habitat loss or alteration related to Phase 2 Project infrastructure may occur at locations where Phase 2 roads cross freshwater fish habitats. Four all-weather roads (AWRs) are proposed that will cross stream habitats including the Roberts Bay Cargo Dock Access Road, Madrid North-TIA AWR, , the Madrid South AWR, and the Madrid-Boston AWR. Various crossing types have been proposed including culverts, fish-bearing culverts, and bridges (see Section 3.7.4.3; Volume 3, Project Description and Alternatives).

Culvert crossings (non-fish-bearing) will be used at crossing locations confirmed not to be fish habitat. Streams with non-fish-bearing culverts will be spanned using 1 m diameter culverts. Culvert crossings (fish-bearing; CRA fish species or forage fish species that support CRA species) will be used for fish-bearing streams with minimal flow, and culverts will be sized to allow fish passage during normal flow conditions (1:2 year, 24-hour storm event). A typical fish-bearing culvert will have a minimum diameter of 1 m and riprap will be placed inside the culvert to dampen the flow velocity to allow the passage of fish. Culvert diameter and rip-rap size will vary depending on the catchment area reporting to the crossing, the species of fish present in the waterbody being crossed, and the water depth within the culvert required to maintain fish passage. Bridges will be constructed at stream crossings that are fish-bearing and free flowing. Bridge structures will be preferentially constructed above the ordinary high water mark (HWM). The HWM is the usual or average level to which a body of water rises at its highest point and remains at this level long enough to change the land characteristics. For rivers and streams, this is the flow generated from a 1:2 year, 24-hour storm. Crossing locations and fish-bearing status (based on available fish and fish habitat information) for each crossing site are presented in Table 6.5-4. Crossing locations identified as fish-bearing are those where fish have been captured during fish community surveys. Crossing locations identified as assumed fish-bearing are those where fish have been captured upstream or downstream in fish community surveys, and where there are no known barriers that may prevent fish access to the crossing site. Crossings identified as likely non-fish-bearing were in generally wet areas with no preferential flow plan and identified as having no or marginal fish habitat potential in fish habitat surveys. Prior to construction, the fish-bearing status will be confirmed at each crossing location (by fish community and/or habitat surveys). Crossing types will be selected based on stream flow characteristics, to maintain fish passage and, to the extent possible, to minimize alteration of fish habitat through effects on stream beds and banks.

The fish species that utilize streams being crossed by AWRs include juvenile rearing and migrating Lake Trout, Arctic Char, Lake Whitefish, Cisco, and Burbot as well as all life stages of Arctic Grayling, and forage fish species such as Ninespine Stickleback and Slimy Sculpin. Culverts and bridges located in or over fish-bearing habitats will be constructed during the Construction Phase and will be breached during the Reclamation and Closure Phase. During closure, breached openings will be sloped and armoured with rock to ensure natural drainage and stability. Therefore, habitat losses and other potential alterations will be initiated during the Construction Phase and will persist through Post-Closure.

Fish habitat loss (PAD) will be incurred at fish-bearing culvert sites, in the area under the culvert footprints and at bridges which contain any in-stream supports as determined in the design phase. The area of habitat loss at fish-bearing culvert sites will be determined based on the bankfull wetted width of the waterbody at the crossing location and the length of the culvert. The area of habitat loss at bridge sites will be determined based on the area lost to the placement of material or structures below the HWM. Additional habitat loss outside of the infrastructure footprint may occur if any of the crossing structures are improperly sized or installed. Improperly sized or installed crossing structures could create physical or flow barriers to fish passage, altering access to habitats by fish. Both construction and closure activities in and near water may alter riparian and aquatic vegetation, mobilize sediment, destabilize stream banks, and change streambed substrate composition. At stream crossing sites, these impacts could alter or eliminate spawning, rearing, feeding, and/or migration habitat for fish.

Culverts and bridges located in or over fish-bearing habitats may also require maintenance over their period of operation. Materials may accumulate (i.e., vegetation, ice build-up, etc.) inside culverts or on bridge structures, potentially preventing the passage of water and/or fish through the structure. Flooding may occur upstream of blocked water crossings or downstream of crossings when materials and debris are removed. This flooding could result in alteration of riparian habitat, stream bank destabilization, and/or erosion and mobilization of sediments. The accumulation of debris at water crossings could alter access to habitats by fish by creating physical or flow barriers. It could also alter the composition of substrates that comprise spawning, rearing, feeding, and/or migration habitats. Water crossing structures will be monitored regularly for blockages and material and debris removal will be performed as required.

Water Intakes and Discharge Pipes

Water intakes will be used to withdraw water from lakes in the LSA for domestic and industrial uses. Water discharge pipes will be used to discharge compliant effluent to the receiving environment. The Phase 2 Project will continue to use existing water intake points in Doris and Windy Lakes in addition to the TIA discharge line, which discharges TIA and groundwater effluent to Roberts Bay. Water intake and discharge lines will also be established in Aimaokatalok Lake. All water intakes will be screened to prevent the entrainment or impingement of fish.

Figure 6.5-1
Phase 2 Infrastructure Footprint and Waterbodies with Potential Habitat Loss or Alteration, North Belt

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