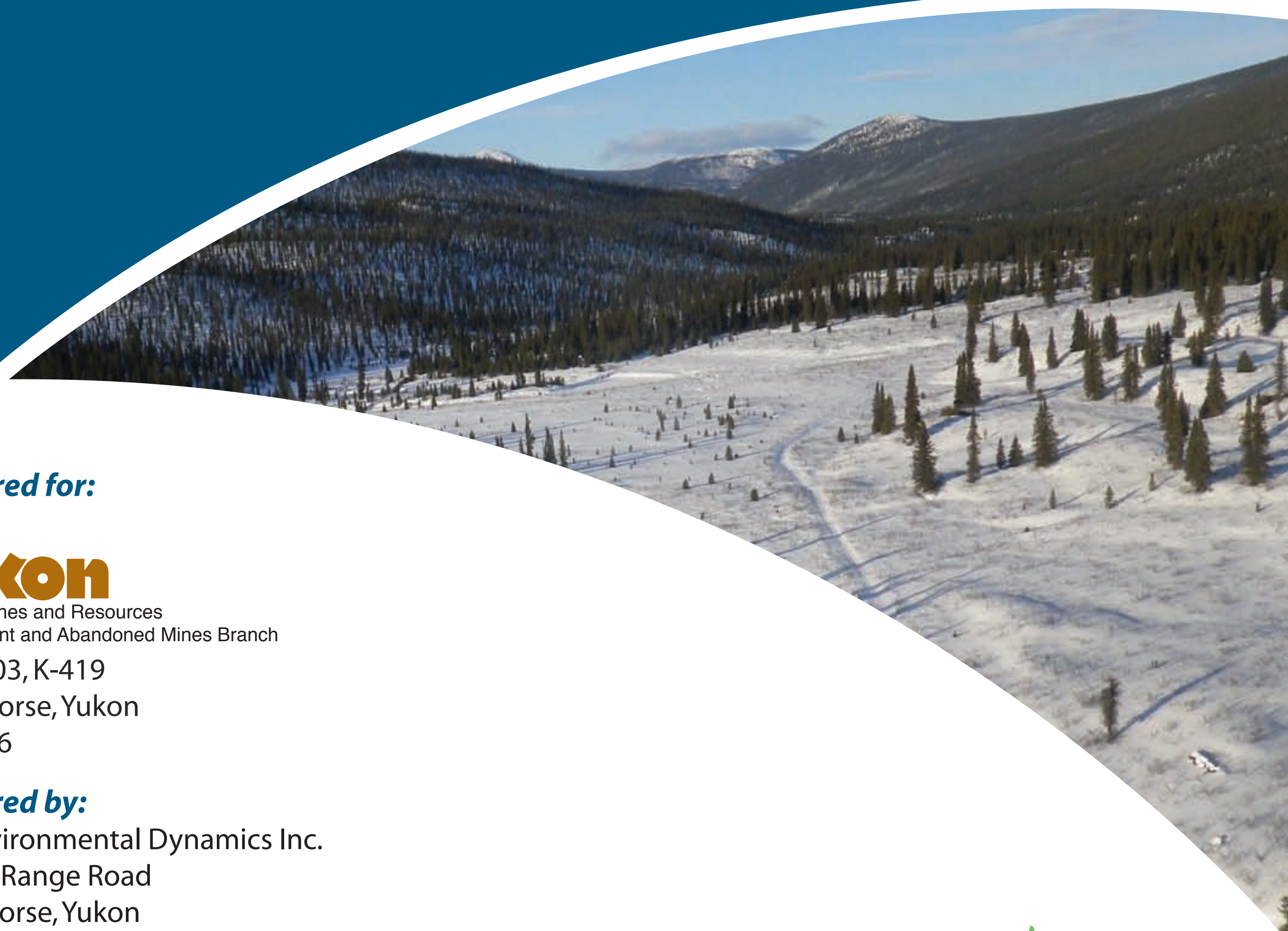
Faro Mine Fish and Fish Habitat Overwintering Study



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2012 ENVIRONMENTAL EMPLOYER OF THE YEAR

EDI ENVIRONMENTAL DYNAMICS INC.

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EXECUTIVE SUMMARY

EDI Environmental Dynamics Inc. (EDI) was retained by Assessment and Abandoned Mines (AAM) to conduct a fish overwintering study in/near the Faro Mine Complex, with a focus on Arctic grayling. While fish use has been documented in the open-water season, little information exists on overwintering fish.

EDI established 17 monitoring sites and revisited 15 of those sites during the winter for fish sampling and habitat investigations. An additional five sites in the headwater reaches were investigated via helicopter. Habitat investigations included documentation of water quality, presence of flow, and ice and water depths. Fish sampling included the use of an underwater camera, baited set-lines and angling, where appropriate.

Due to high spring flows, four temperature loggers were recovered. Temperature logger data was retrieved for the Rose Creek Diversion (RD-03), Pumphouse Pond (RP-01), the North Fork (RN-02) and the South Fork (RS-01). Temperature data for RD-03 and RS-01 maintained at or near freezing temperatures throughout most of the winter. RN-02 was also at or near freezing until the end of January, when temperatures increased and stayed above freezing. Pumphouse Pond was relatively warmer than the other sites, with temperatures consistently slightly above freezing during the winter months and warmer sooner than the stream sites.

Water quality conditions were generally suitable for fish but water depth may be a limiting factor. Specifically, dissolved oxygen levels were suitable and fast flowing water appeared to prevent freezing to the bottom substrate. Aerial observations noted the presence of open-water areas throughout Rose Creek, the Rose Creek Diversion, and the North and South Forks.

Fish sampling resulted in the documentation of a suspected Arctic grayling fry in Rose Creek, a burbot in Pumphouse Pond, slimy sculpin in the Rose Creek Diversion and North Fork pond, and four Arctic grayling in Dixon Lake. No fish were captured in the North or South Forks. Fish sampling results indicate low densities of fish utilizing the stream habitats in proximity of the site in the winter.

It was determined that although suitable overwintering conditions were present throughout the study area, deep pools were scarce and may be a limiting factor. Fish sampling conditions were difficult, due to unsafe ice conditions and shallow water. Fish may hold in specific pools through the winter that were not chosen as sample sites. Future overwintering study techniques should consider radio telemetry, as winter sampling is challenging.

AUTHORSHIP

This report was prepared by the EDI Environmental Dynamics Inc. EDI staff who contributed to this project include:

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1 INTRODUCTION

The Government of Yukon Assessment and Abandoned Mines Branch (AAM) retained EDI Environmental Dynamics Inc. (EDI) to investigate overwintering fish and fish habitat in the Faro Mine Complex.

1.1 STUDY AREA

The Faro Mine Complex is one of three Type II abandoned mines in the Yukon under the care of the AAM. The mine complex is composed of two mining areas, the Faro Mine and the Vangorda Plateau, north of the Town of Faro (Figure 1). The Faro Mine is situated within the Rose Creek drainage, a tributary to Anvil Creek, which flows into Pelly River. The Vangorda Plateau occurs in the headwaters of Vangorda Creek, a direct tributary to Pelly River.

The Rose Creek watershed is typically separated into three fish communities based on fish migration impediments throughout the study area (EDI 2012).

- Upper North Fork (upstream from the Haul Road) – possible resident population;
- Upper South Fork (upstream from the Haul Road) – resident population;
- Rose Creek – possible resident population or seasonal usage from Anvil Creek.

In Vangorda Creek fish are only documented as far as the falls, a natural barrier to upstream fish migration (EDI 2012).

1.2 STUDY RATIONALE AND OBJECTIVES

There was very little existing information on overwintering fish in/near the Faro Mine Complex. Although previous surveys typically assessed the habitat for overwintering potential, winter sampling was rare, conducted once in the North Fork of Rose Creek (White Mountain 2006). More information regarding overwintering utilization was required for fish habitat compensation planning.

The main objectives of this study were to determine if winter conditions were suitable for fish and potentially identify overwintering areas in/near the Faro Mine Complex. The primary species of interest was Arctic grayling (*Thymallus arcticus*); however, the presence of other fish species provides valuable information as well.

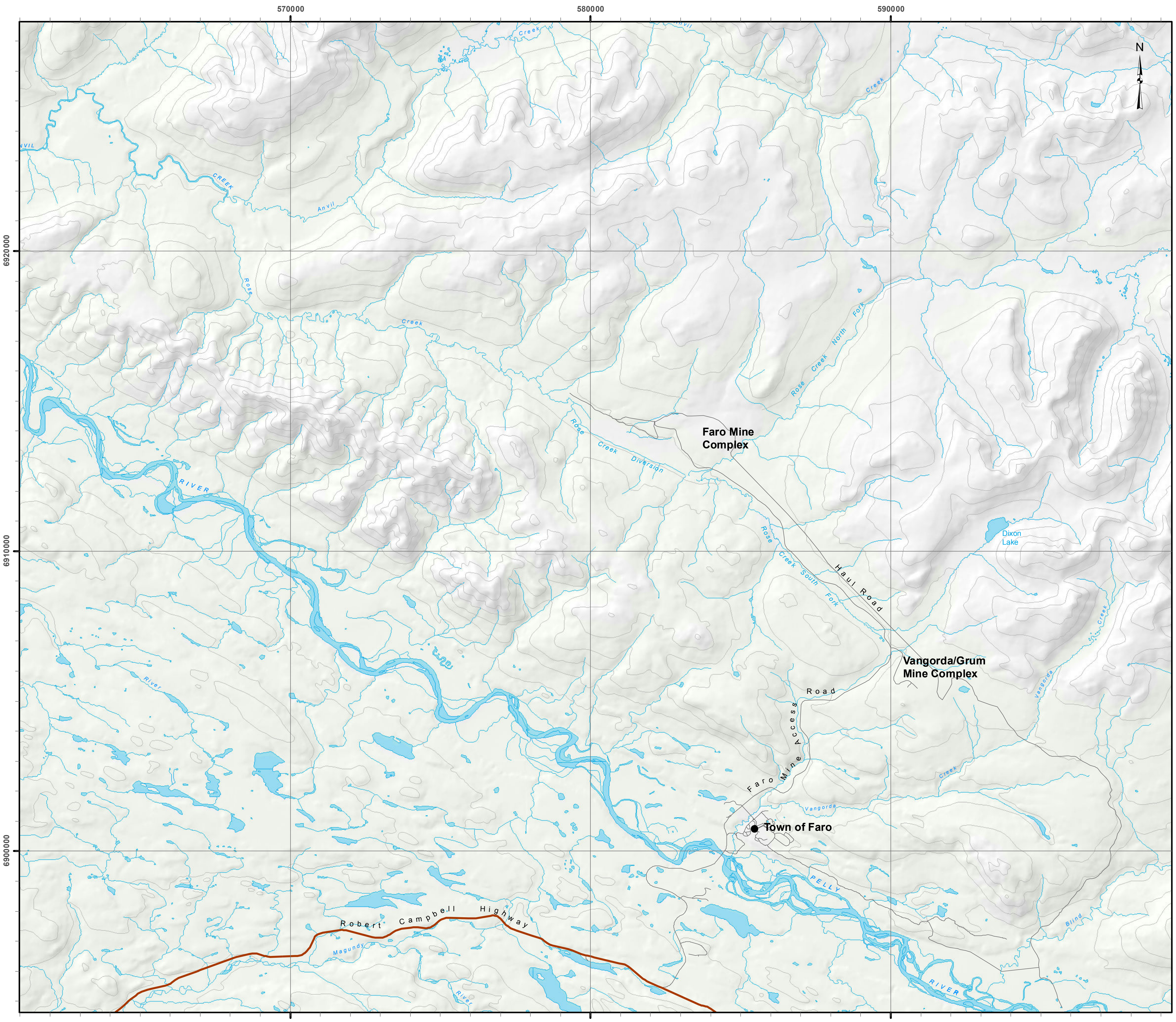
1.3 OVERWINTERING HABITAT

Arctic grayling overwintering habitat selection is variable and differs by life history type (i.e., stream-resident, fluvial, adfluvial, lacustrine) (Stewart et al. 2007; McPhail 2007). Adult Arctic grayling typically require deep pools, lakes or spring-fed areas for overwintering (Ford et al. 1995; Stewart et al. 2007; West et al. 1992). Seasonal migration from headwater summer feeding areas downstream to larger streams, rivers or lakes to overwinter is common in fluvial and adfluvial populations (Ford et al. 1995; McPhail 2007; Scott and

Crossman 1973; West et al. 1992). However, stream-resident and lacustrine Arctic grayling populations complete their entire life cycle in a small stream system or lake with no significant seasonal migrations (West et al. 1992).

Apart from deep pool habitat, dissolved oxygen (DO) can be a major limiting factor in overwintering habitat in streams and rivers. Low DO tolerance can vary by fish species, life stage, water temperature and duration of exposure. Arctic grayling fry were documented to tolerate DO as low as 1.4 mg/L in winter temperatures (Ford et al. 1995) and DO levels of 0.6 to 4.8 mg/L have been documented in known overwintering areas (Hubert et al. 1985). However, literature suggests DO values less than 2.0 mg/L are generally considered unsuitable for salmonids, including Arctic grayling (Barton and Taylor 1996; Hubert et al. 1985). Most studies agree that 5 mg/L represents a safe DO threshold for healthy salmonid populations. For example, Bjornn and Reiser (1991) state that salmonids may be able to survive when DO concentrations are relatively low (<5 mg/L), but growth, food conversion and swimming ability may be adversely affected.

Slimy sculpin are good indicators of overwintering potential because of their small home range and non-migratory nature (Cunjak et al. 2005; Gray et al. 2004). The presence of adult slimy sculpin indicates the potential for nearby overwintering habitat.



Faro Mine Complex Fish and Fish Habitat Overwintering Study Area

1:250,000 topographic spatial data and Digital Elevation Model provided by Geomatics - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.

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kilometres

Map Scale = 1:130,000 (printed on 11 x 17)
Map Projection: North American Datum 1983 UTM Zone 8N

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2 METHODS

To determine overwintering potential and use, methods were used to examine winter habitat conditions and sample for fish.

2.1 SURVEY TIMING AND SITE LOCATIONS

In the fall of 2011, a reconnaissance survey was conducted to install temperature loggers in pools or other deep water habitat throughout the study area. Sites were selected by identifying waterbodies and representative pools in watercourses throughout the study area with overwintering potential. Sites were established throughout the Rose Creek watershed and the lower reaches of Vangorda Creek (Figures 2 and 3).

Sites were revisited in mid and late winter 2012 to further investigate habitat conditions (e.g., in-situ water quality) and sample for fish, where appropriate. Site selection for resampling was dependent on access and time constraints, as not all sites could be revisited in each field trip. Sites with the highest overwintering potential were given the highest priority and all sites were revisited at least once, with the exception of two temperature logger sites. Additional sites were also visited mid-winter in the upper reaches of the North and South Forks; a helicopter was used to access these remotes areas. Tables 1 and 2 provide a summary of the field program schedule and site specific activities. Appendix A contains photos of each site established.

Table 1. Field program schedule.

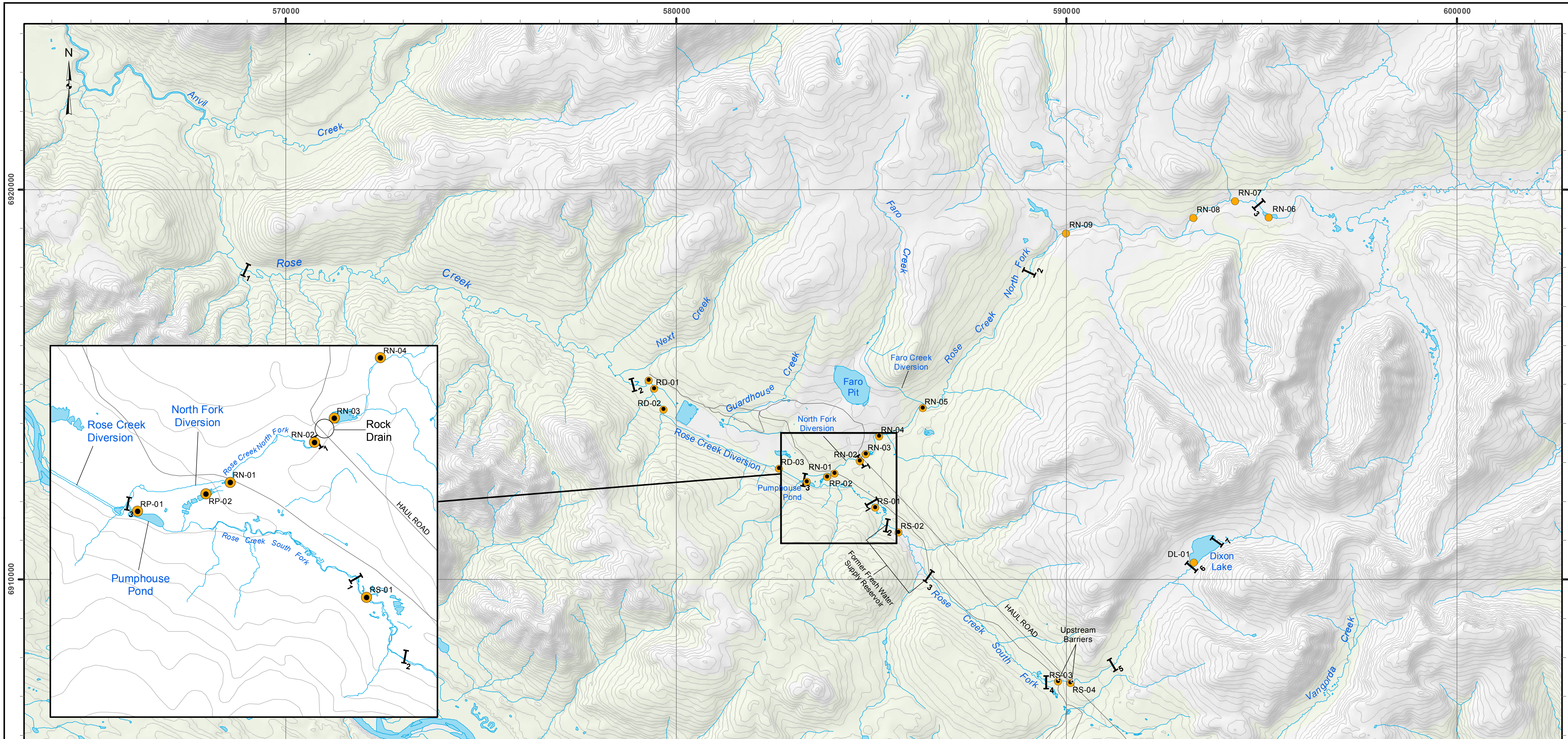
Season	Specific Dates	Field Tasks
Late fall	October 25 – 27, 2011	Reconnaissance, site selection; temperature logger installations
Mid winter	February 13 – 16, 2012	Investigate headwater areas; revisit established sites to document habitat conditions and fish sampling
Late winter	March 26 – 28, 2012	Revisit established sites to document habitat conditions and fish sampling
Early summer	July 05 – 06, 2012	Temperature data retrieval

Table 2. Site locations and field activities.

Watercourse / Waterbody	Site	UTM Coordinates [a]		Site Visited			Temperature Logger	Fish Sampling		
		E	N	Late Fall	Mid Winter	Late Winter		Angling	Set Lines	Video
Rose Creek	RC-01	579287	6915105	✓	- [b]	✓	✓	-	-	✓
Rose Creek Diversion	RD-01	579425	6914891	✓	- [b]	✓	✓	-	-	✓
	RD-02	579673	6914355	✓	✓	✓	✓	-	-	✓
	RD-03	582632	6912837	✓	- [d]	✓	✓	-	-	- [c]
Pumphouse Pond	RP-01	583345	6912499	✓	✓	✓	✓	✓	✓	✓
North Fork pond	RP-02	583867	6912633	✓	✓	✓	✓	-	-	✓
North Fork	RN-01	584052	6912721	✓	✓	✓	✓	-	-	✓
	RN-02	584697	6913028	✓	✓	✓	✓	-	-	✓
	RN-03	584847	6913212	✓	✓	-	✓	-	-	✓
	RN-04	585200	6913675	✓	✓	✓	✓	-	-	✓
	RN-05	586309	6914387	✓	✓	✓	✓	-	-	✓
	RN-06	595184	6919284	- [f]	✓	- [f]	- [f]	-	-	- [c]
	RN-07	594312	6919697	- [f]	✓	- [f]	- [f]	-	-	- [c]
	RN-08	593246	6919270	- [f]	✓	- [f]	- [f]	-	-	- [c]
	RN-09	589981	6918875	- [f]	✓	- [f]	- [f]	-	-	- [c]
South Fork	RS-01	585095	6911843	✓	✓	-	✓	-	-	✓
	RS-02	585690	6911204	✓	✓	-	✓	-	-	-
	RS-03	589779	6907377	✓	-	✓	✓	-	-	✓
	RS-04	590102	6907344	✓	- [e]	- [e]	✓	-	-	-
Dixon Lake	DL-01	593263	6910425	- [f]	✓	- [f]	- [f]	✓	✓	✓
Vangorda Creek	VC-01	584768	6899988	✓	✓	✓	✓	-	-	✓
	VC-02	585064	6900898	✓	- [e]	- [e]	✓	-	-	-

Where, ✓ = site sampled; - = not sampled; E = Easting; N = Northing

Notes: [a] Universal Transverse Mercator (UTM) coordinates in North American Datum (NAD) 83; [b] Unsafe ice conditions; [c] Conditions not suitable for underwater video (e.g., turbid, shallow); [d] Conditions were not suitable for ice auger (shallow); [e] Not accessible in winter, temperature data site only; [f] Not easily accessible



Fish and Fish Habitat Winter Site Locations, Rose Creek Watershed

Legend

- Temperature Logger Location
- Fish & Fish Habitat Site
- Stream Reach Breaks
- Road (mine access/haul)
- Contours
- Waterbody (natural/man-made)

0 1 2 3 4 5

kilometres

Map Scale = 1:100,000 (printed on 11 x 17)
Map Projection: North American Datum 1983 UTM Zone 8N

Data sources
1:50,000 topographic spatial data provided by Geomatics - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.

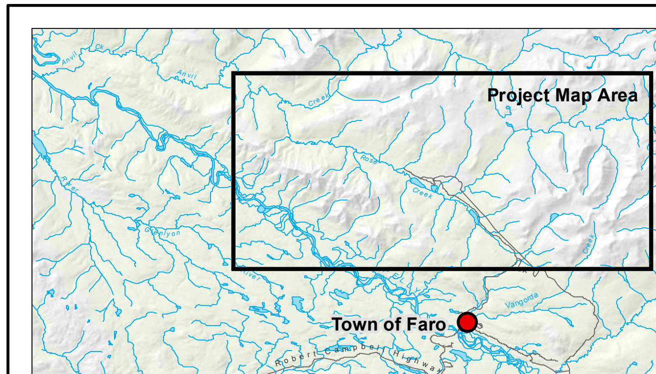
National Road Network courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Detailed toppgraphic features of the Faro, Grum and Vangorda mine sites was provided by Yukon Government - Energy, Mines and Resources - Assessment and Abandoned Mines Branch (March 2012).

Reach Breaks were based on Gartner Lee (2003). Locations are approximated.

Project data displayed is site specific. Data collected by EDI Environmental Dynamics Inc. was obtained using Garmin GPS technology.

This document is not an official land survey and the spatial data presented is subject to change.



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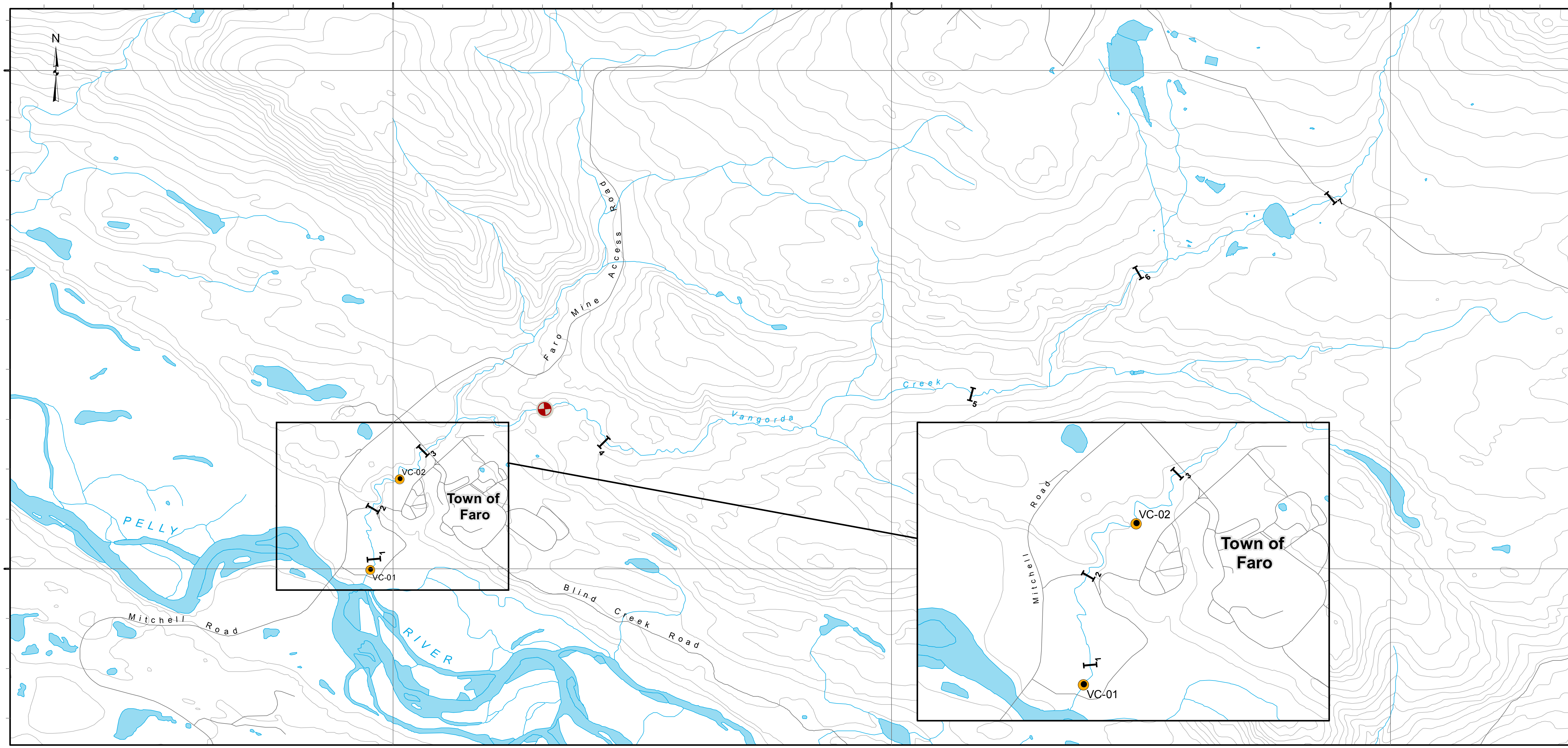

Fish and Fish Habitat Winter Site Locations, Lower Vangorda Creek

Legend

- Temperature Logger Location
- Fish & Fish Habitat Site
- Upstream Barrier- Vangorda Falls
- I_1 Stream Reach Breaks
- Road
- Contours

0 0.5 1 1.5 2

kilometres

Map Scale = 1:40,000 (printed on 11 x 17)
Map Projection: North American Datum 1983 UTM Zone 8N

Data sources
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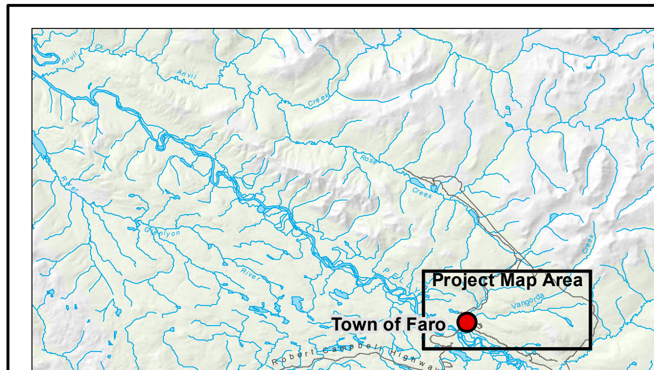

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2.2 TEMPERATURE DATA LOGGERS

In the fall 2011, Onset HOBO TidbiT v2 temperature data loggers were deployed at 17 sites (Table 2). Sites were selected to provide broad coverage throughout the study area. Where present, pools with a maximum depth greater than 1 m were targeted. Data loggers were housed within an elbow PVC pipe joint, anchored to heavy rocks found on site and secured with plastic coated cable to a T-bar installed in the stream bank or a large mature tree. Each site was flagged and GPS coordinates were recorded. Temperature loggers were programed to record hourly. Due to high flows in the spring, temperature data was retrieved in the early summer 2012. Data was downloaded into MS Excel format. Loggers were left in place to record additional temperature data for future use.

2.3 HABITAT SURVEYS

Winter surveys were conducted in mid and late winter 2012. A helicopter was used in the mid winter survey to access the upper reaches of the North and South Forks. Additionally, an aerial flight of the lower reaches of Rose Creek was conducted.

In general, the winter field surveys included the following:

- Measurement of in-situ water quality parameters (temperature, pH, specific conductivity and dissolved oxygen) with a YSI multi-meter;
- Measurement of snow, ice and water depth;
- Investigation of the presence or absence of flow;
- Description of under ice conditions (e.g., substrate, cover, bottom ice);
- Observation of open-water; and,
- Photographic documentation of each site.

2.4 FISH SAMPLING

Methods used to document fish presence included:

- Underwater video camera (Aqua-Vu 740c) set at a fixed location for a minimum of 20 minutes;
- Set lines, baited, bottom overnight set (as per DFO and YTG license requirements); and
- Under-ice angling, with a variety of lures, some baited.

The underwater video camera was used at almost all sites, it is appropriate for both waterbodies and watercourses. Set lines and under-ice angling are more appropriate for waterbodies and require more time; these methods were deployed at Pumphouse Pond and Dixon Lake, two waterbodies with the highest overwintering potential.

3 RESULTS

3.1 TEMPERATURE DATA

High spring flows resulted in the unfortunate loss of all but four temperature loggers: RD-03, RN-02, RP-01 and RS-01. Table 3 summarizes monthly mean, minimum and maximum temperatures by watercourse. Mean daily temperatures for each temperature logger are summarized in Figures 4 through 7.

At the Rose Creek Diversion site (RD-03), a minimum recorded temperature of 0.00˚C occurred throughout December to March. The maximum temperature recorded was 10.71˚C on June 25, 2012.

At the Pumphouse Pond site (RP-01), the minimum temperature recorded was 0.05˚C on December 27, 2011 and the maximum temperature recorded was 11.49˚C on June 25, 2012. Comparatively, this site remained the warmest through the winter months.

At the North Fork site (RN-02), a minimum recorded temperature of 0.00˚C occurred throughout November to January. Temperatures increased at the end of January and maintained an above freezing daily average with the exception of a few occurrences in the spring. The maximum recorded temperature was 10.15˚C on June 23, 2012.

At the South Fork site (RS-01), a minimum temperature of 0.05˚C occurred throughout November to April; however, the minimum temperature recorded was 0.02˚C in May. The maximum temperature recorded at this site was 10.12 ˚C on June 25, 2012.

Table 3. Minimum, maximum and mean monthly water temperatures, sites RP-01, RD-03 and RS-01.

Watercourse / Waterbody	Site	Temp (˚C)	2011		2012					
			Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Rose Creek Diversion	RD-03	Mean	0.02	0.00	0.00	0.00	0.00	0.03	1.17	5.72
		Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.51
		Max	0.19	0.02	0.02	0.02	0.05	0.58	4.56	10.71
Pumphouse Pond	RP-01	Mean	0.23	0.31	0.25	0.41	0.36	1.47	2.04	5.90
		Min	0.08	0.05	0.08	0.30	0.30	0.50	0.38	1.29
		Max	0.47	0.63	0.50	0.52	0.55	2.26	4.97	11.49
North Fork	RN-02	Mean	0.02	0.01	0.28	1.67	1.63	1.55	1.43	5.20
		Min	0.00	0.00	0.00	1.15	1.59	1.37	0.02	1.51
		Max	0.02	0.02	1.56	1.70	1.67	1.59	3.17	10.15
South Fork	RS-01	Mean	0.06	0.05	0.05	0.05	0.05	0.07	1.25	5.36
		Min	0.05	0.05	0.05	0.05	0.05	0.05	0.02	5.36
		Max	0.08	0.05	0.05	0.05	0.05	0.30	4.61	10.12

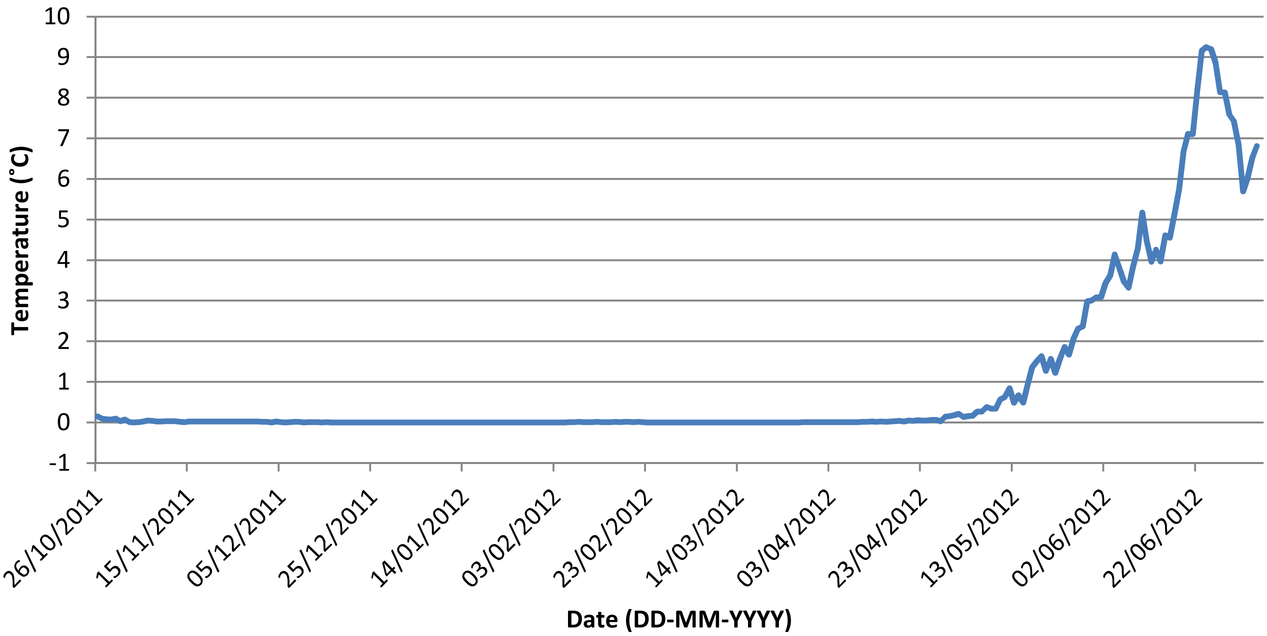

Figure 4. **Mean daily water temperature, Rose Creek Diversion (RD-03).**

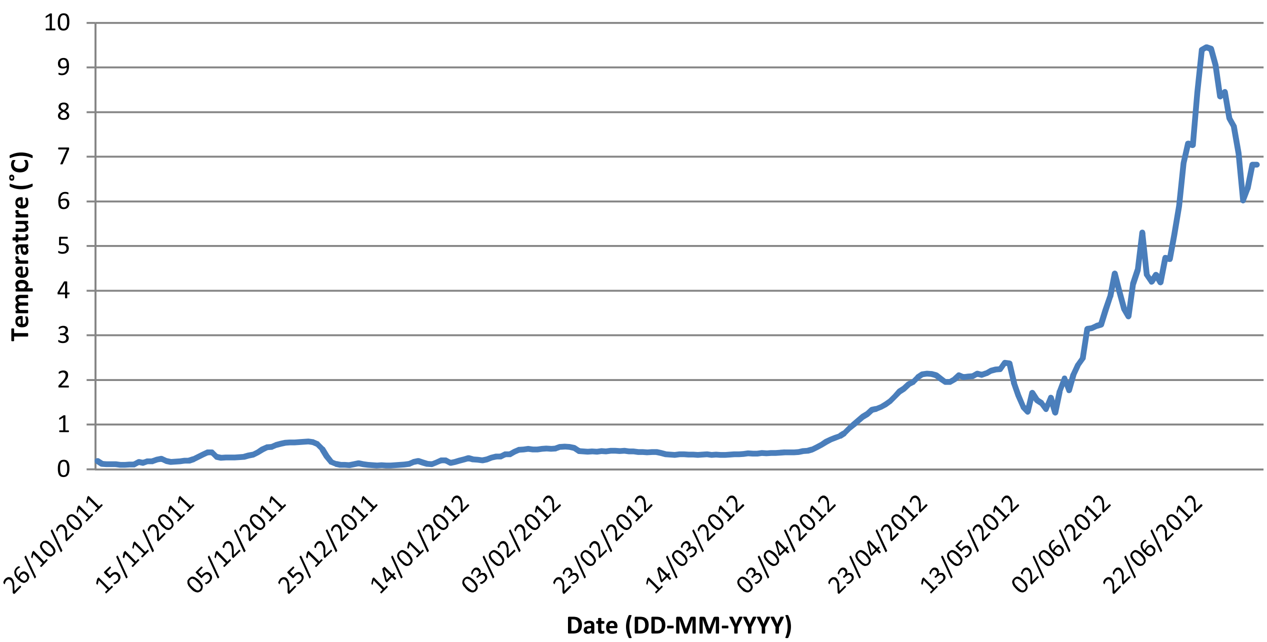

Figure 5. **Mean daily water temperature, Pumphouse Pond (RP-01).**

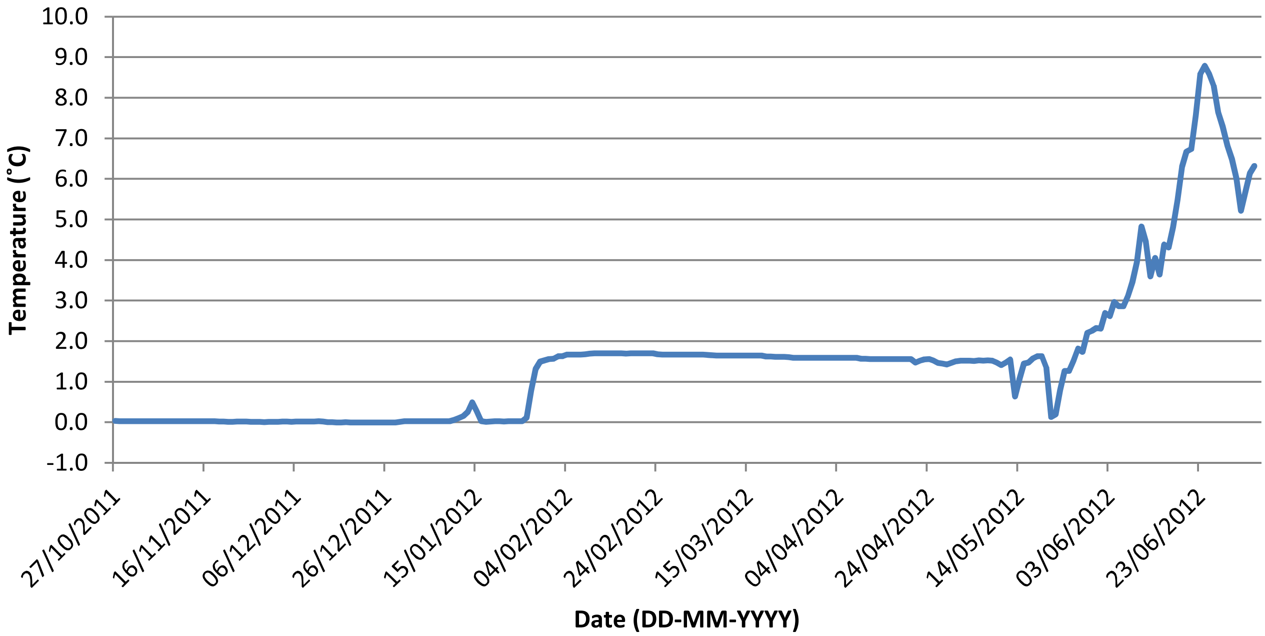

Figure 6. Mean daily water temperature, North Fork (RN-02).

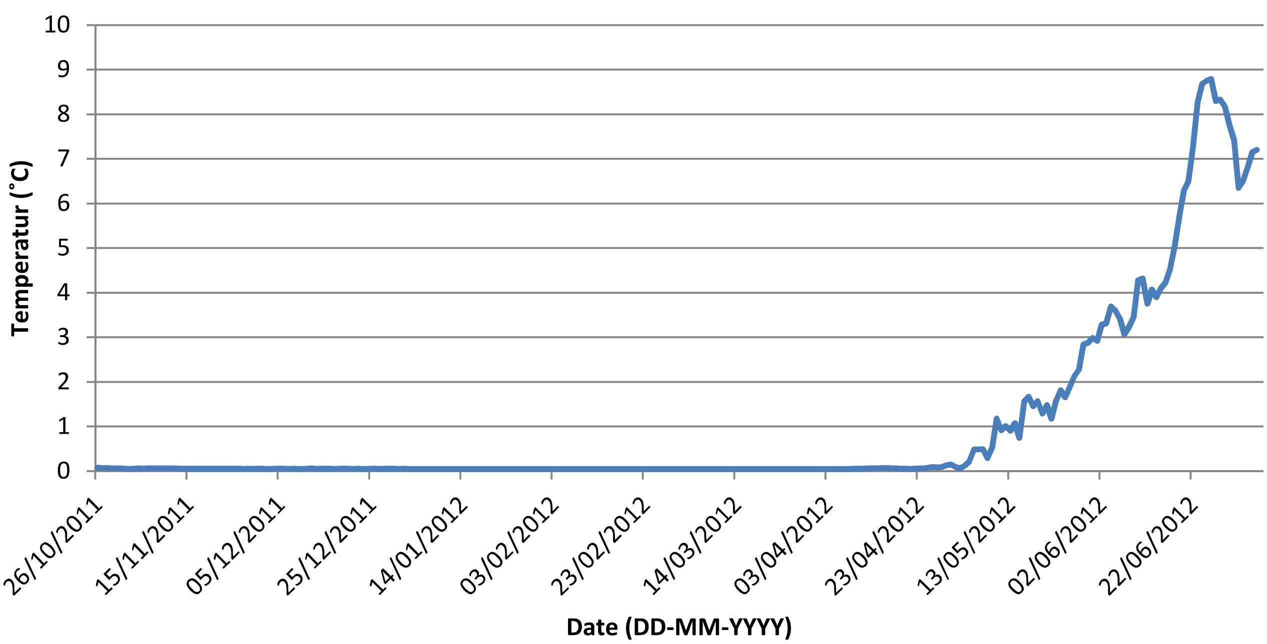

Figure 7. Mean daily water temperature, South Fork (RS-01).

3.2 HABITAT CONDITIONS

3.2.1 Water Quality and Ice Conditions

In-situ water quality and ice conditions are summarized in Table 4 by watercourse. As described in the methods, sites not sampled were either difficult to access, ice conditions were unsafe, or site conditions were not suitable for augering (i.e., shallow depth).

Table 4. In-situ water quality, ice thickness and water depth.

Watercourse/ Waterbody	Site	Season	Depth (m) Ice	Water	Total	Water Quality Temp (˚C)	Spec Cond (µS/cm)	DO (mg/L)	pH
Rose Creek	RC-01	late fall	0.00	1.20	1.20	0.28	362	13.52	7.62
		mid winter	0.00	0.26	0.26	0.20	510	11.00	6.90
		late winter	0.05	1.00	1.05	0.60	878	11.10	7.24
Rose Creek Diversion	RD-01	late fall	1.04	0.06	1.10	0.07	249	13.71	7.91
		late winter	0.05	0.29	0.34	0.00	324	12.32	8.28
	RD-02	late fall	0.00	0.64	0.64	0.05	460	12.21	7.47
		mid winter	0.00	0.50	0.50	0.00	281	11.31	8.03
		late winter	0.06	0.43	0.49	0.00	322	12.33	8.10
	RD-03	late fall	0.71	0.00	0.71	1.12	451	12.86	7.20
		late winter	0.65	0.00	0.65	N/A	N/A	N/A	N/A
Pumphouse Pond	RP-01	late fall	2.10	0.10	2.20	0.10	427	12.71	7.30
		mid winter	0.58	0.56	1.14	0.10	290	10.00	-
		mid winter	0.60	0.22	0.82	0.00	293	-	6.23
		mid winter	0.60	0.22	0.82	1.60	305	9.44	6.21
		late winter	0.54	0.33	0.87	0.00	313	11.1	7.23
North Fork pond	RP-02	late fall	1.50	0.08	1.58	0.06	379	13.16	7.19
		mid winter	0.62	0.25	0.87	0.00	260	10.00	6.58
		late winter	0.50	0.13	0.63	0.00	315	11.78	7.15
North Fork	RN-01	late fall	1.14	0.00	1.14	0.05	404	12.68	6.99
		mid winter	0.00	0.34	0.34	0.00	215	11.31	6.80
		late winter	0.10	0.81	0.91	0.00	316	11.58	7.11
	RN-02	late fall	1.38	0.00	1.38	0.07	389	14.24	6.86
		mid winter	0.00	0.18	0.18	0.00	284	14.10	7.10
		late winter	0.07	0.23	0.30	0.00	300	11.51	6.85
	RN-03	late fall	0.62	0.03	0.65	0.07	397	10.82	6.97
		mid winter	0.72	2.58	3.30	0.20	284	11.88	7.49

Table continued on next page.

Table 4. Continued.

Watercourse/ Waterbody	Site	Season	Depth (m) Ice	Depth (m) Water	Depth (m) Total	Water Quality Temp (˚C)	Water Quality Spec Cond (µS/cm)	Water Quality DO (mg/L)	Water Quality pH
North Fork	RN-04	late fall	0.00	1.02	1.02	0.05	377	14.60	7.49
		mid winter	0.70	0.10	0.80	0.00	278	12.26	7.68
		late winter	0.30	0.66	0.96	0.00	294	11.81	7.67
	RN-05	late fall	0.09	1.20	1.29	0.05	327	13.48	7.41
		mid winter	0.48	0.76	1.24	0.00	282	12.95	7.66
		late winter	0.35	0.63	0.98	0.00	207	11.20	7.67
	RN-06	mid winter	0.60	0.05	0.65	0.00	266	7.51	6.43
	RN-07	mid winter	0.99	0.17	1.16	0.00	295	8.70	11.30
	RN-08	mid winter	0.00	0.25	0.25	0.10	282	11.00	11.98
	RN-09	mid winter	0.30	0.10	0.40	0.00	251	11.47	7.27
South Fork	RS-01	late fall	0.10	1.30	1.40	0.08	430	12.15	7.09
		mid winter	1.05	0.65	1.70	0.00	296	10.70	7.62
	RS-02	late fall	0.00	1.22	1.22	0.37	409	11.43	7.21
		mid winter	0.44	0.42	0.86	0.00	280	10.62	7.71
	RS-03	late fall	0.00	1.12	1.12	0.18	131	11.74	7.12
		late winter	0.08	0.42	0.50	0.00	109	11.69	7.47
	RS-04	late fall	0.00	1.09	1.09	0.11	121	13.61	7.41
Dixon Lake	DL-01	mid winter	0.70	0.14	0.84	0.00	208	0.60	8.54
		mid winter	0.89	0.12	1.01	0.00	128	7.97	7.66
		mid winter	1.15	6.05	7.20	-	-	-	-
Vangorda Creek	VC-01	late fall	0.00	0.94	0.94	0.04	944	13.72	8.13
		mid winter	0.65	0.35	1.00	0.00	777	11.30	8.40
		late winter	0.56	0.33	0.89	0.00	755	12.46	8.01
	VC-02	late fall	0.00	0.68	0.68	0.06	927	12.92	8.03

Water quality conditions recorded were suitable for overwintering fish (Table 4). In-situ water temperatures were commonly at or near freezing. In general, DO declined in the winter months from the initial fall survey. However, winter DO levels were still considered high, likely saturated from fast flowing water, and suitable for overwintering fish. Rose Creek and the Diversion DO levels ranged from 11.00 to 13.71 mg/L. Pumphouse Pond and the North Fork pond site maintain DO levels between 9.44 and 13.16 mg/L. The North Fork DO levels ranged from 7.51 to 14.60 mg/L; the lower values were recorded in the headwater reaches. South Fork DO levels ranged from 10.62 to 13.61 mg/L. Dixon Lake had acceptable DO near the inlet at 7.97 mg/L, but not at another station near the east shore, with a value of 0.60 mg/L.

A limiting factor for overwintering fish may be water depths, as there was an overall low density of pools and depth decreased with ice development. Anchor ice (i.e., submerged ice that is anchored to the stream bed) was also observed, which would decrease habitat and food availability for overwintering fish (Photo 1).

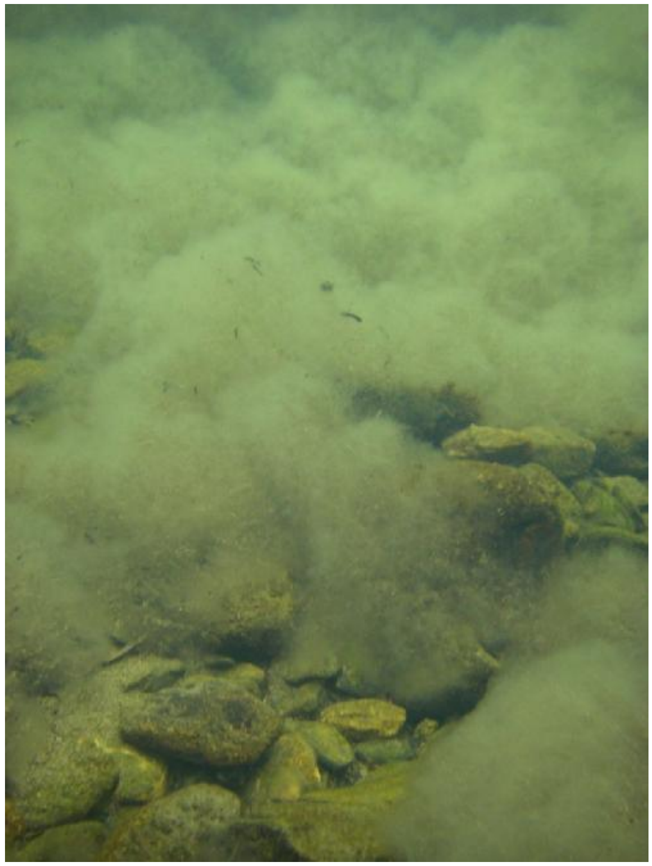

Photo 1. Underwater view of anchor ice near RN-04 (North Fork), October 27, 2011.

3.2.2 Aerial Observations

Aerial observations during the mid-winter survey noted the presence of open-water areas throughout the study area. Open-water indicates the stream does not freeze through to the bottom substrate, could have groundwater influence and has dissolved oxygen inputs from the surface. An aerial flight of lower Rose Creek downstream from the mine site to its confluence revealed many open-water areas (Photo 2). Open-water was also noted in the Rose Creek Diversion (Photo 3), North Fork (Photo 4), South Fork and Vangorda Creek while accessing sites by helicopter.

Photo 2. Open water observed in lower Rose Creek, February 14, 2012.

Photo 3. Open water observed in the Rose Creek and North Fork diversions downstream from Pumphouse Pond, February 14, 2012.

Photo 4. Open water noted in the upper North Fork, February 14, 2012.

3.3 FISH SAMPLING

Fish sampling via underwater video, baited set-lines and angling resulted in the documentation of Arctic grayling, burbot and slimy sculpin in the study area (Table 5). Underwater camera efforts documented one fry, likely an Arctic grayling, in Rose Creek; two slimy sculpin in the Rose Creek Diversion and the North Fork pond sites; and three Arctic grayling in Dixon Lake. Baited overnight set-lines in Pumphouse Pond captured one burbot (33 cm total length; Photo 5). Angling in Dixon Lake captured an Arctic grayling (23 cm fork length; Photo 6). No fish were documented in the North or South Forks. No fish were documented in Vangorda Creek; however, sampling effort was low, due to the lack of pools and dominant riffle and shallow run habitat.

Table 5. Fish sampling effort and catch.

Watercourse / Waterbody	Site	Station	Season	Underwater Camera Effort (hrs)	Underwater Camera Observ	Baited Set-lines Effort (hrs)	Baited Set-lines Catch	Angling Effort (hrs)	Angling Catch
Rose Creek	RC-01	A	late winter	0.45	1 fry [(a)]	-	-	-	-
		B	late winter	0.33	0	-	-	-	-
Rose Creek Diversion	RD-01	A	late winter	0.35	1 CCG	-	-	-	-
		B	late winter	0.32	0	-	-	-	-
	RD-02	-	late winter	0.33	0	-	-	-	-
Pumphouse Pond	RP-01	A	mid winter	0.25	0	17.17	0	-	-
		B	mid winter	0.25	0	17.25	1 BB [(b)]	-	-
		C	mid winter	1.67	0	-	-	1.67	0
		D	mid winter	-	-	-	-	1.67	0
		-	late winter	0.50	0	-	-	-	-
North Fork pond	RP-02	-	late winter	0.50	1 CCG	-	-	-	-
North Fork	RN-01	-	late winter	0.38	0	-	-	-	-
	RN-02	-	late winter	0.33	0	-	-	-	-
	RN-03	-	mid winter	0.42	0	-	-	-	-
	RN-04	A	late winter	0.30	0	-	-	-	-
		B	late winter	0.37	0	-	-	-	-
	RN-05	-	mid winter	0.33	0	-	-	-	-
		A	late winter	0.30	0	-	-	-	-
		B	late winter	0.23	0	-	-	-	-
South Fork	RS-01	-	mid winter	0.33	0	-	-	-	-
	RS-03	-	late winter	0.42	0	-	-	-	-
Dixon Lake	DL-01	B	mid winter	-	-	19.0	0	-	-
		C	mid winter	-	-	19.3	0	-	-
		D	mid winter	-	-	19.7	0	-	-
		E	mid winter	0.83	3 GR	-	-	0.8	1 GR [(c)]
Vangorda Creek	VC-01		late winter	0.50	0	-	-	-	-

Where BB = burbot, CCG = slimy sculpin, GR = Arctic grayling

Notes: (a) Could not be determined, likely GR; (b) BB total length = 33 cm; (c) GR fork length = 23 cm

Photo 5. Burbot captured in Pumphouse Pond (RP-01), February 14, 2012.

Photo 6. Arctic grayling captured in Dixon Lake (DL-01), February 15, 2012.

4 DISCUSSION

This study confirmed that fish utilize the Rose Creek watershed for overwintering but the extent of utilization is unclear. The Rose Creek mainstem is likely utilized for overwintering, based on the presence of the fry at RC-01 and the slimy sculpin at the downstream end of the diversion channel at RD-01. The density and quality of deep pools likely increases in lower Rose Creek and the observed open-water areas are an indicator of well oxygenated, flowing water.

The Rose Creek Diversion was generally characterized by shallow depths and potential barriers (i.e., engineered steps and cascades), with the exception of the downstream end, which is likely the original channel. Anchor ice was observed throughout the upper end of the diversion during the fall reconnaissance survey. Overwintering potential was considered poor and unlikely; however, this could not be adequately confirmed because sampling was difficult due to unsafe ice conditions and shallow depths.

Pumphouse Pond water quality was suitable for fish but may be limited by depth. The small burbot captured demonstrates its use but no additional fish were captured or observed. Temperature data shows this site was not at risk to freeze through to the bottom. Comparatively, the North Fork pond is similar but may be additionally limited in its capacity due to access (steep cascades between each pond).

Historically, the upper North Fork was assumed to provide overwintering fish habitat (Harder and Bustard 1991). While on site in mid-winter, it was noted that the upper ponds suspected to provide overwintering habitat appear lower than historically noted, possibly the result of a washed out beaver dam(s). No fish were captured in the North Fork.

The lower South Fork water quality was suitable for fish but may be limited by lack of deep pools. No fish were captured but sampling efforts were low and only two sites were established in potential fish habitat; RS-04 was located between two culvert barriers for temperature monitoring only. It should be noted that the removal of the Freshwater Supply Dam effectively removed a very large area of overwintering habitat. No sites were situated in the upper South Fork but fish were captured and observed in Dixon Lake, the headwaters of the South Fork.

Vangorda Creek maintained suitable water quality for overwintering fish. Existing information on the diversity of fish captured in Vangorda Creek (Arctic grayling, burbot, Chinook, lake chub, longnose sucker, slimy sculpin, and round whitefish; EDI 2012) suggest it is likely utilized for overwintering.

In conclusion, suitable overwintering conditions were present throughout the study area but deep pools were scarce and may be a limiting factor. Fish sampling results indicate low densities of fish. Fish were captured in each of the waterbodies sampled (Pumphouse Pond, North Fork pond, Dixon Lake) with the exception of RN-03; these are considered important habitat types. It is also possible that fish may hold in specific pools through the winter that were not chosen as sample sites. Future overwintering study techniques to consider include radio telemetry, as winter sampling is challenging. Future compensation works at site should maintain flow in the winter season and consider improving overwintering habitat by providing deep pool or pond habitat.

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5.2 SPATIAL DATA

1:50,000 CanVec topographic data from Government of Canada, Natural Resources Canada, Earth Sciences Sector, Centre for Topographic Information. Geogratis website (http://geogratis.cgdi.gc.ca).

1:20,000 TRIM positional files from the Land and Resource Data Warehouse (http://lrdw.ca). Copyright belongs to Her Majesty the Queen in Right of the Province of British Columbia.

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APPENDIX A SITE PHOTOS AND DESCRIPTION

RC-01 – Rose Creek	Site Description
	- Rose Creek, Reach 3 - Located just downstream from mine discharge in the natural channel - Vehicle accessible with short walk - Deep run habitat - Cover provided in large woody debris and cobble - Max depth 1.20 m (Oct 2011)
RD-01 – Rose Creek Diversion	**Site Description**
	- Rose Creek, Reach 3 - Located in the downstream end of the diversion channel - Vehicle accessible - Natural stream characteristics - Pool habitat - Gravel/cobble substrate - Maximum depth 1.04 m (Oct 2011)

RD-02 – Rose Creek Diversion	Site Description
	- Rose Creek, Reach 3 - Located in diversion channel midway through series of engineered step-pools - Pool habitat - Cover provided in cobble/boulder substrate - Maximum depth 0.64 m (Oct 2011)

RD-03 – Rose Creek Diversion	Site Description
	- Rose Creek, Reach 3 - Located in the upper end of the diversion channel - Vehicle accessible - Run habitat - Cover provided in a few cobble - Substrate mainly gravel/sand - Maximum depth 0.71 m (Oct 2011)

<table>
<tr><th>RP-01 – Pumphouse Pond</th><th>Site Description</th></tr>
<tr><td></td><td>
- Immediately upstream from the Rose Creek Diversion and North Fork Diversion confluence
- Receives inflow from North Fork ponds and South Fork
- Vehicle accessible
- Substrate mainly fine sediments
- Maximum depth 2.10 m; ice depth 0.10 m (Oct 2011; temperature logger station)
</td></tr>
<tr><th>RP-02 – North Fork pond</th><th>Site Description</th></tr>
<tr><td></td><td>
- Constructed series of ponds receiving water from the North Fork
- Located in a pond mid-way in the series of ponds
- Vehicle accessible
- Substrate mainly fine sediments
- Cover provided by overhanging vegetation and small woody debris
- Maximum depth 1.50 m; ice depth 0.08 m (Oct 2011; temperature logger station)
</td></tr>
</table>

RN-01 – North Fork	Site Description
	- North Fork, Reach 1 - Located on the downstream side of the mine access road crossing - Vehicle accessible - Culvert plunge pool habitat - Cover in cobble and overhanging vegetation - Maximum depth 1.14 m (Oct 2011)
RN-02 – North Fork	**Site Description**
	- North Fork, Reach 1 - Downstream side of the Haul Road rock drain; upper end of reach - Vehicle access with walk - Site located in side channel flowing out of rock drain rubble - Pool habitat - Cover provided in banks, small woody debris, vegetation - Maximum depth 1.38 m (Oct 2011)

<table>
<tr><th>RN-03 – North Fork</th><th>Site Description</th></tr>
<tr><td></td><td>
- North Fork, Reach 2
- Upstream side of the Haul Road rock drain; lower end of reach
- All-terrain vehicle access seasonally
- Site located at the rock drain end of the pond
- Cover provided in small woody debris and large angular rock drain rubble
- Maximum depth 0.62 m ice depth 0.03 m (Oct 2011; temperature logger station)
</td></tr>
<tr><th>RN-04 – North Fork</th><th>Site Description</th></tr>
<tr><td></td><td>
- North Fork, Reach 2
- All-terrain or vehicle access seasonally
- Pool habitat
- Anchor ice observed upstream and downstream of site and along banks
- Cover provided by cobble and overhanging vegetation
- Maximum depth 1.02 m (Oct 2011)
</td></tr>
</table>

<table>
<tr><th>RN-05 – North Fork</th><th>Site Description</th></tr>
<tr><td></td><td>
- North Fork, Reach 2
- All-terrain or vehicle access seasonally
- Backwater pool habitat
- Anchor ice observed upstream and downstream of site
- Cover provided by woody debris and overhanging vegetation vegetation
- Substrate mainly fines in the pool, gravel/cobble in the main channel
- Maximum depth 1.20 m ice depth 0.09 m (Oct 2011; temperature logger station)
</td></tr>
<tr><th>RN-06 – North Fork</th><th>Site Description</th></tr>
<tr><td></td><td>
- North Fork, Reach 4
- Helicopter access
- Large headwater pond
- Fine substrate with aquatic vegetation
- Not suitable for overwintering habitat
- Water depth 0.05 m, ice depth 0.60 m (Feb 2012)
</td></tr>
</table>

RN-07 – North Fork	Site Description
	- North Fork, Reach 3 - Helicopter access - Beaver pond - Fine substrate with aquatic vegetation - Low overwintering habitat potential - Water depth 0.17 m, ice depth 0.99 m (Feb 2012)
RN-08 – North Fork	**Site Description**
	- North Fork, Reach 3 - Helicopter access - Open-water in riffle/ run habitat - Fine substrate with aquatic vegetation - Low overwintering habitat potential - Water depth 0.25 m, (Feb 2012)

RN-09 – North Fork	Site Description
	- North Fork, Reach 3 - Helicopter access - Site located at old deactivated road / trail crossing - Run habitat - Gravel / small cobble substrate - Water depth 0.10 m, ice depth 0.30 m (Feb 2012)
RS-01 – South Fork	**Site Description**
	- South Fork, Reach 2 - Access by foot - Site located in side channel - Pool habitat - Fines/ sand dominated substrate - Maximum depth 1.30 m ice depth 0.10 m (Oct 2011)

RS-02 – South Fork	Site Description
	- South Fork, Reach 3 - Site located just upstream of the former dam, within the former Fresh Water Reservoir - Access by foot - Pool habitat within main channel - Cover available in overhanging banks, cobble and small woody debris - Maximum depth 1.22 m (Oct 2011)
RS-03 – South Fork	**Site Description**
	- South Fork, Reach 5 - Site located in culvert plunge pool at mine access road crossing - Access by vehicle - Culvert is a barrier to upstream fish passage - Cover provided by cobble - Maximum depth 1.12 m (Oct 2011)

<table>
<tr><th>RS-04 – South Fork</th><th>Site Description</th></tr>
<tr><td></td><td>
- South Fork, Reach 5
- Site located in culvert plunge pool at Haul Road crossing
- Vehicle access
- Culvert is a barrier to upstream fish passage
- Site is between two fish barriers
- Established site for temperature logging
- Maximum depth 1.09 m (Oct 2011)
</td></tr>
<tr><th>DL-01 – Dixon Lake</th><th>Site Description</th></tr>
<tr><td></td><td>
- Dixon Lake
- Headwaters of the South Fork
- Helicopter access
- Substrate dominated by fines
- Max depth near the inlet 6.05 m with ice depth 1.15 m
</td></tr>
</table>

VC-01 – Vangorda Creek	Site Description
	- Vangorda Creek, Reach 1 - Site located upstream from deactivated road crossing - Vehicle access with short walk - Cover available in cobble, overhanging vegetation and small woody debris - Pool habitat - Maximum depth 0.94 m Oct (2011)
VC-02 – Vangorda Creek	**Site Description**
	- Vangorda Creek, Reach 3 - Access by foot - Established site for temperature logging - Step-pool habitat - Maximum depth 0.68 m (Oct 2011)