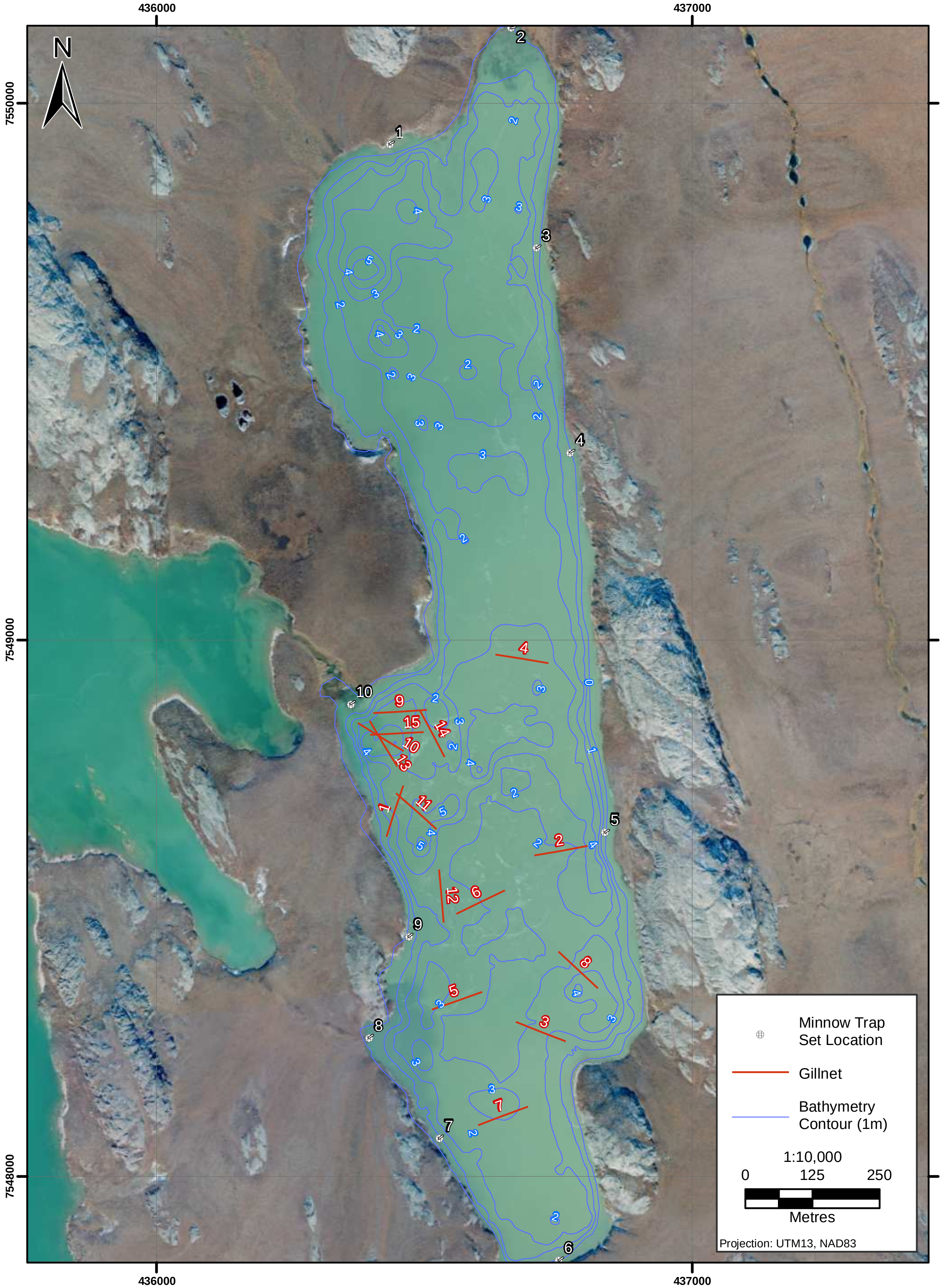
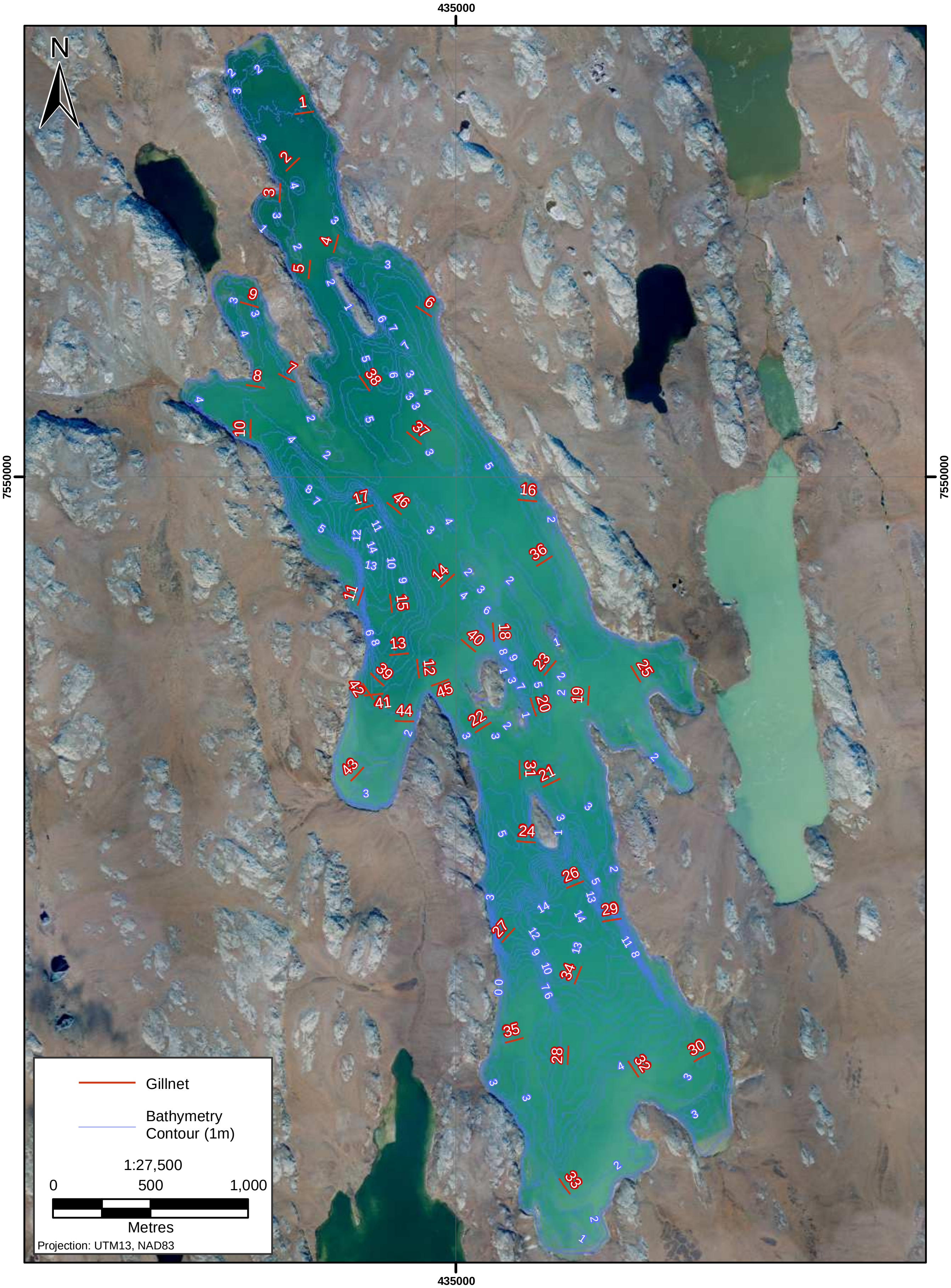


Figure 2.2-3

Gillnet and Minnow Trap Set Locations on P.O. Lake, Hope Bay Belt Project, 2009

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists



Gillnet Set Locations on Patch Lake, Hope Bay Belt Project, 2009

Figure 2.2-4

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists

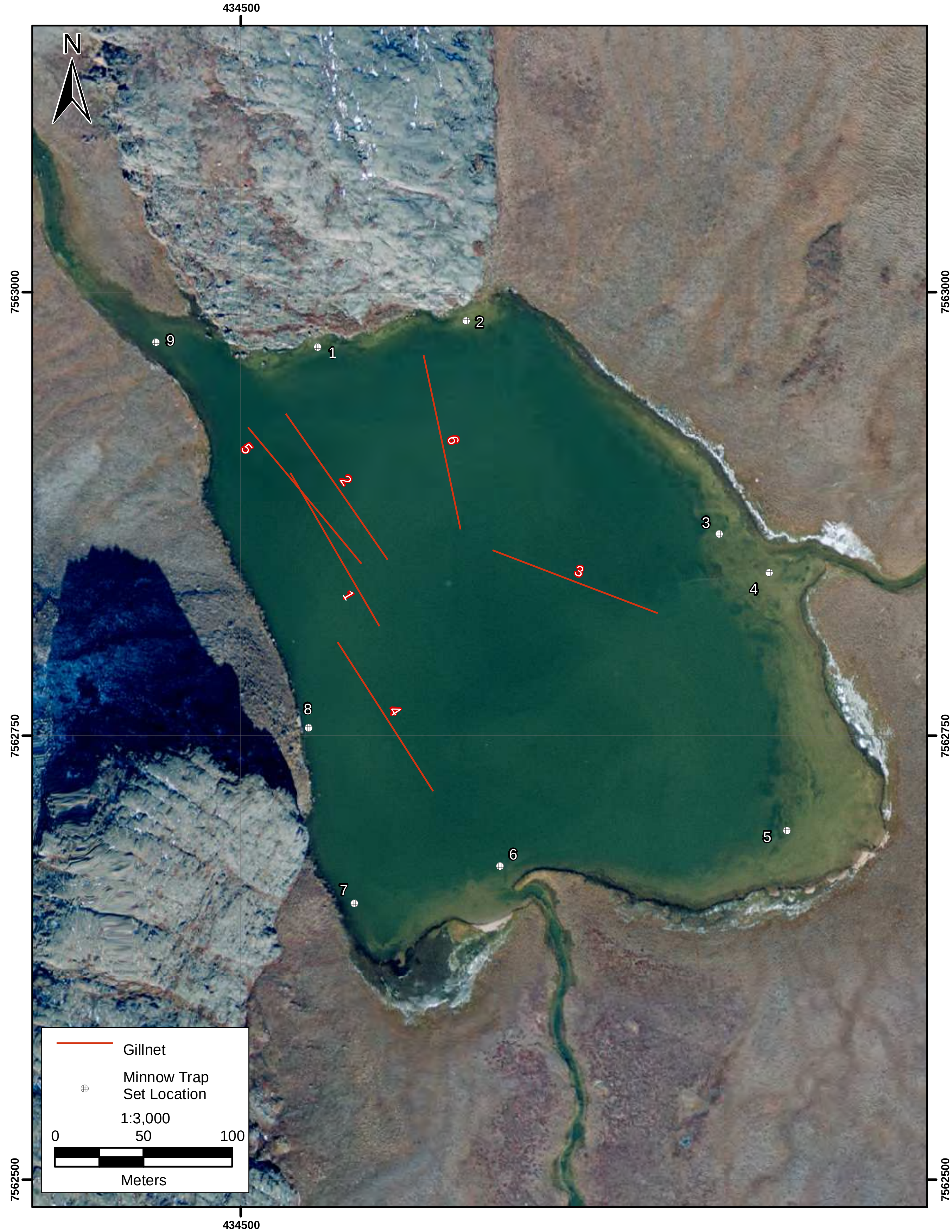


Figure 2.2-5

Gillnet and Minnow Trap Set Locations on Little Roberts Lake, Hope Bay Belt Project, 2009

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists

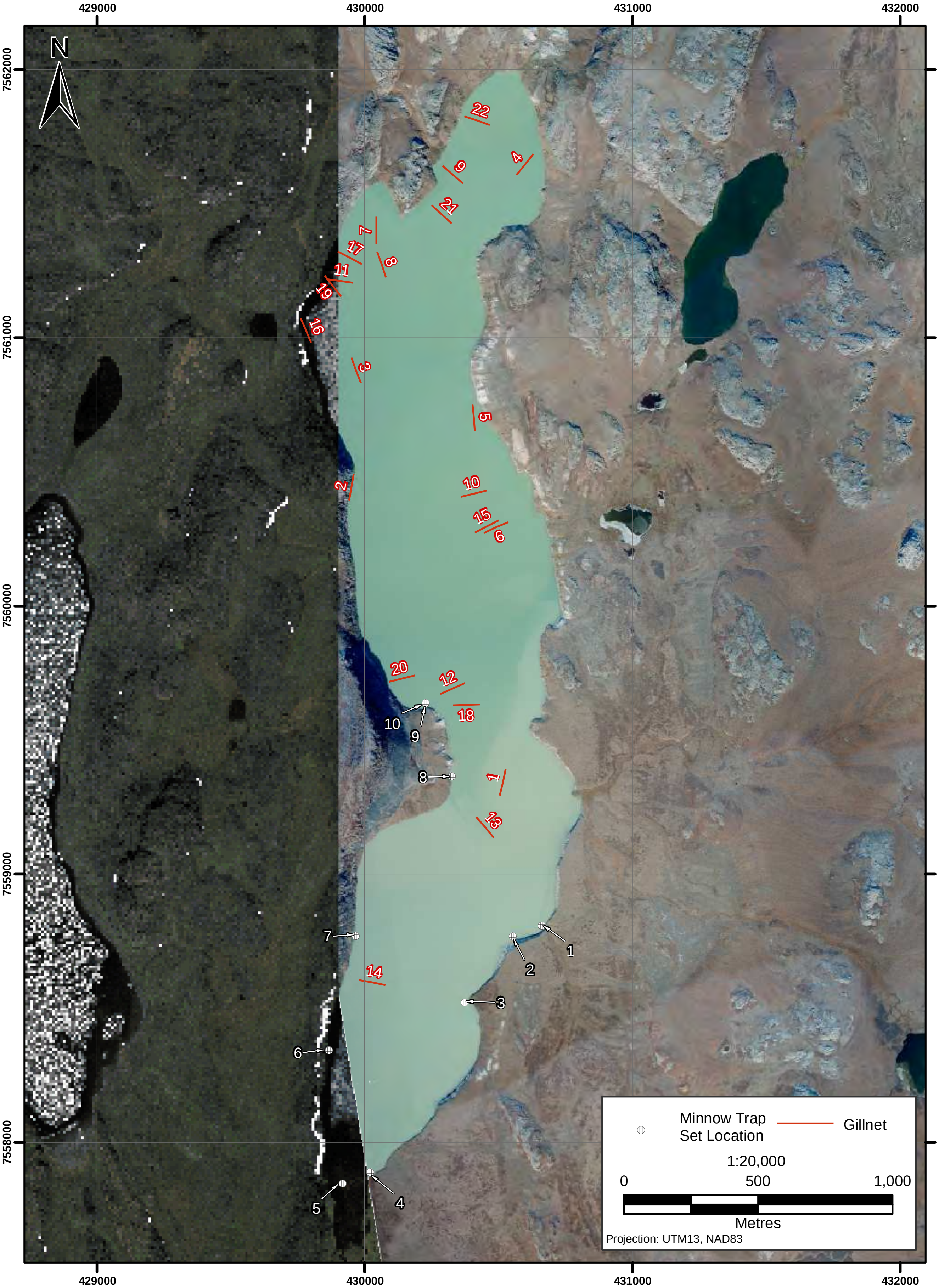


Figure 2.2-6

Gillnet and Minnow Trap Set Locations on Glenn Lake, Hope Bay Belt Project, 2009

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists

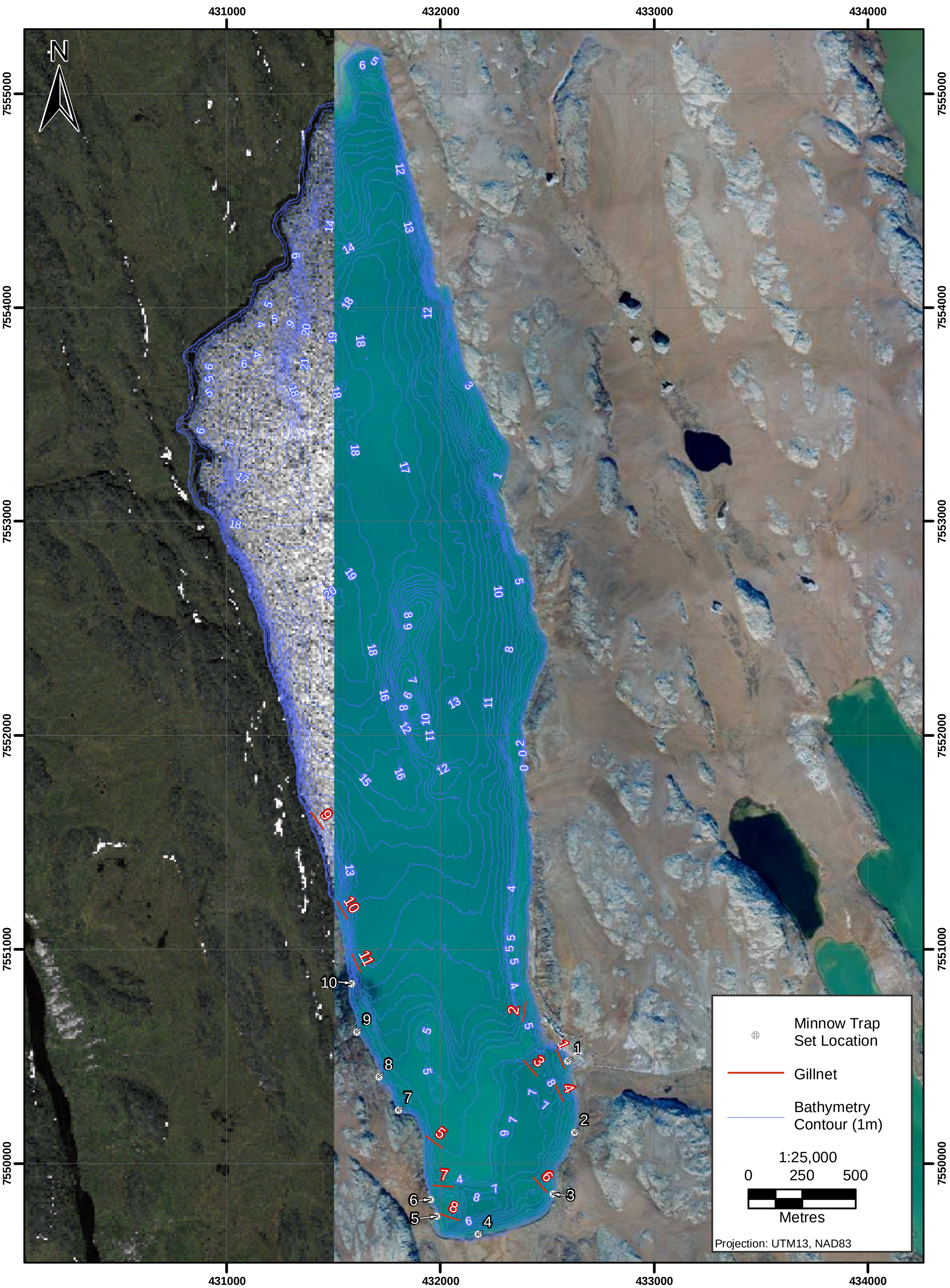
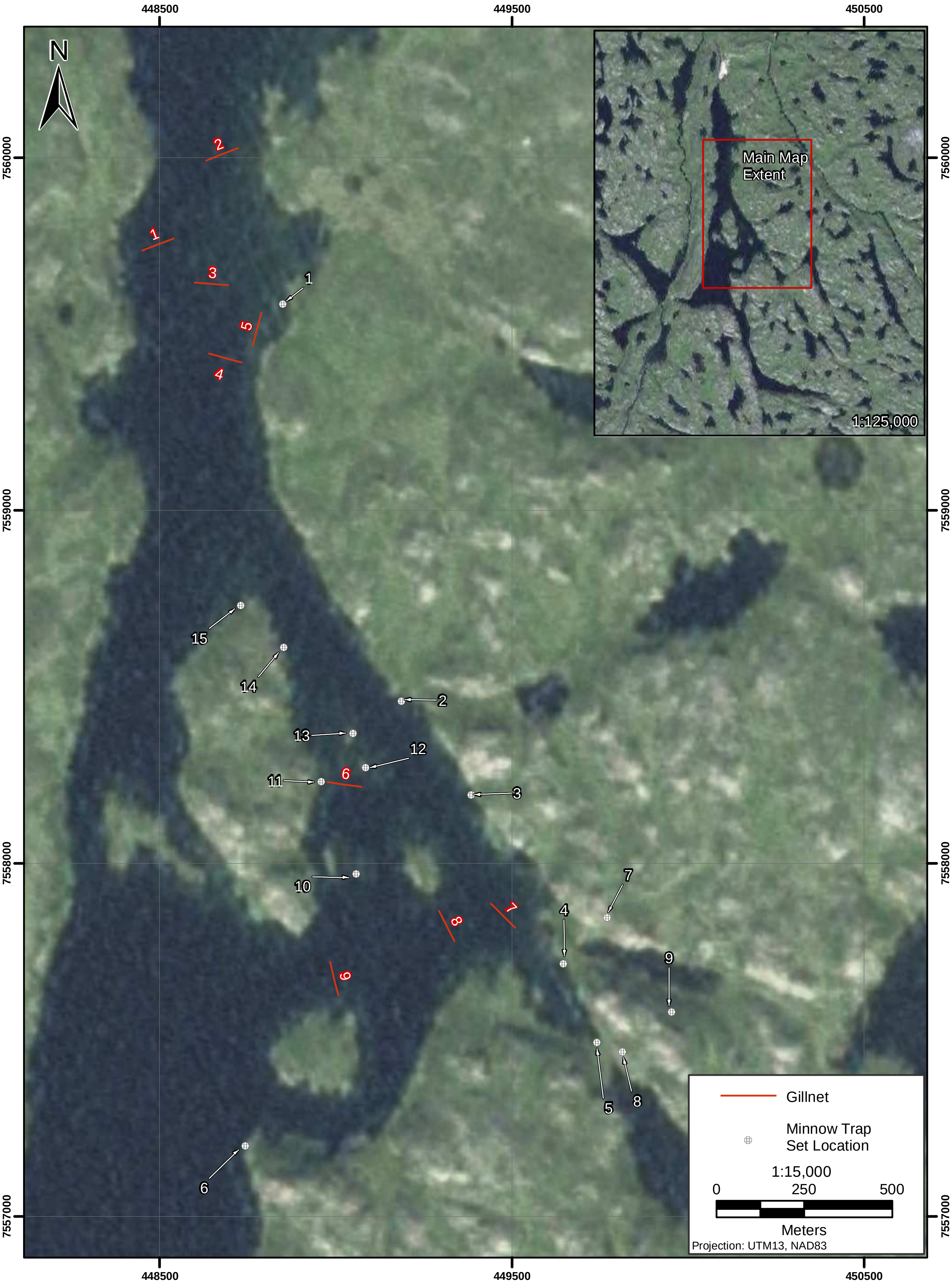


Figure 2.2-7

Gillnet and Minnow Trap Set Locations on Windy Lake, Hope Bay Belt Project, 2009

NEWMONT NORTH AMERICA

Rescan™ Engineers & Scientists



NEWMONT NORTH AMERICA

Gillnet and Minnow Trap Set Locations on Reference Lake A, Hope Bay Belt Project, 2009

Figure 2.2-8

Rescan Engineers & Scientists

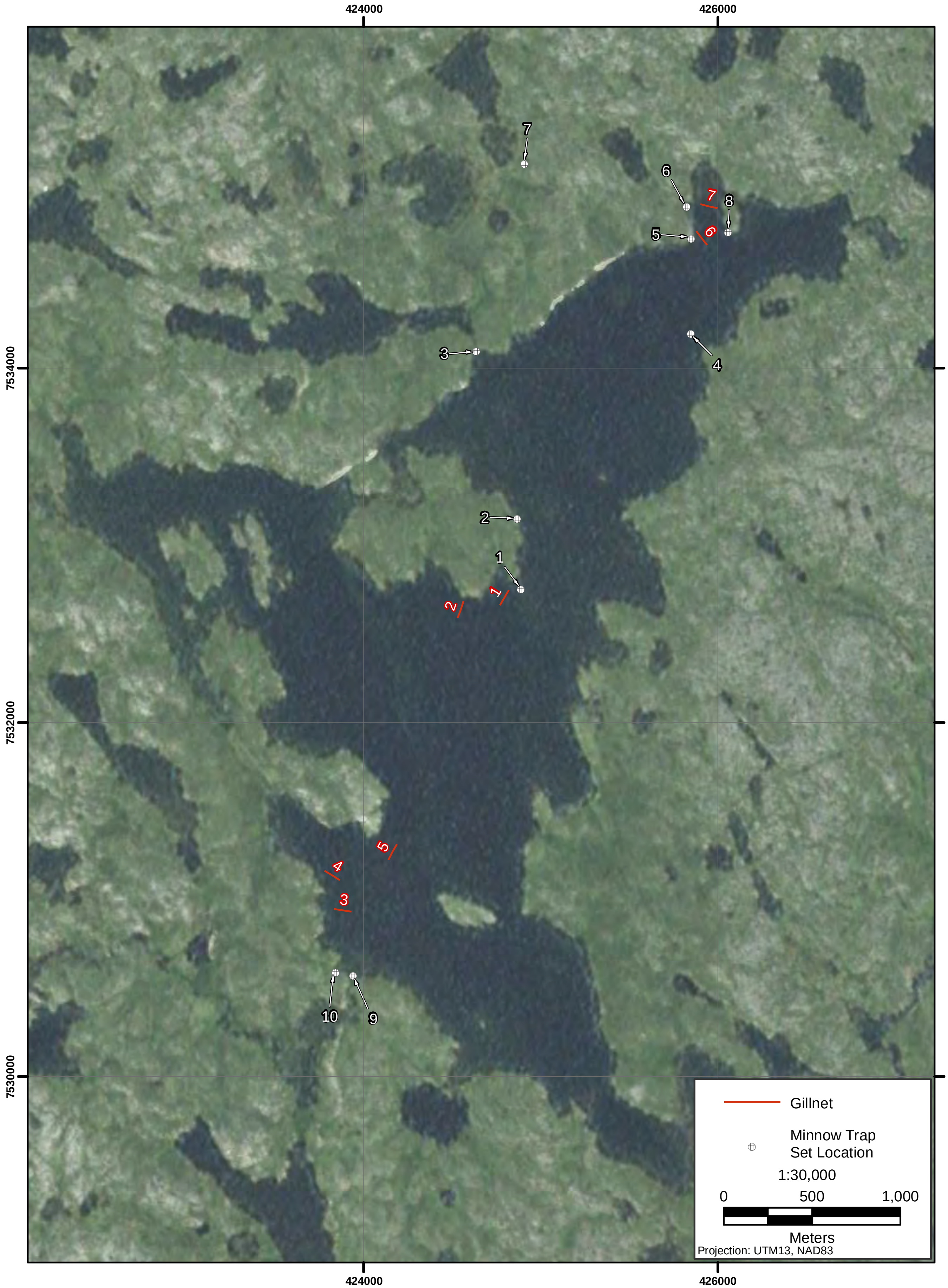


Figure 2.2-9

Gillnet and Minnow Trap Set Locations on Reference Lake B, Hope Bay Belt Project, 2009

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists

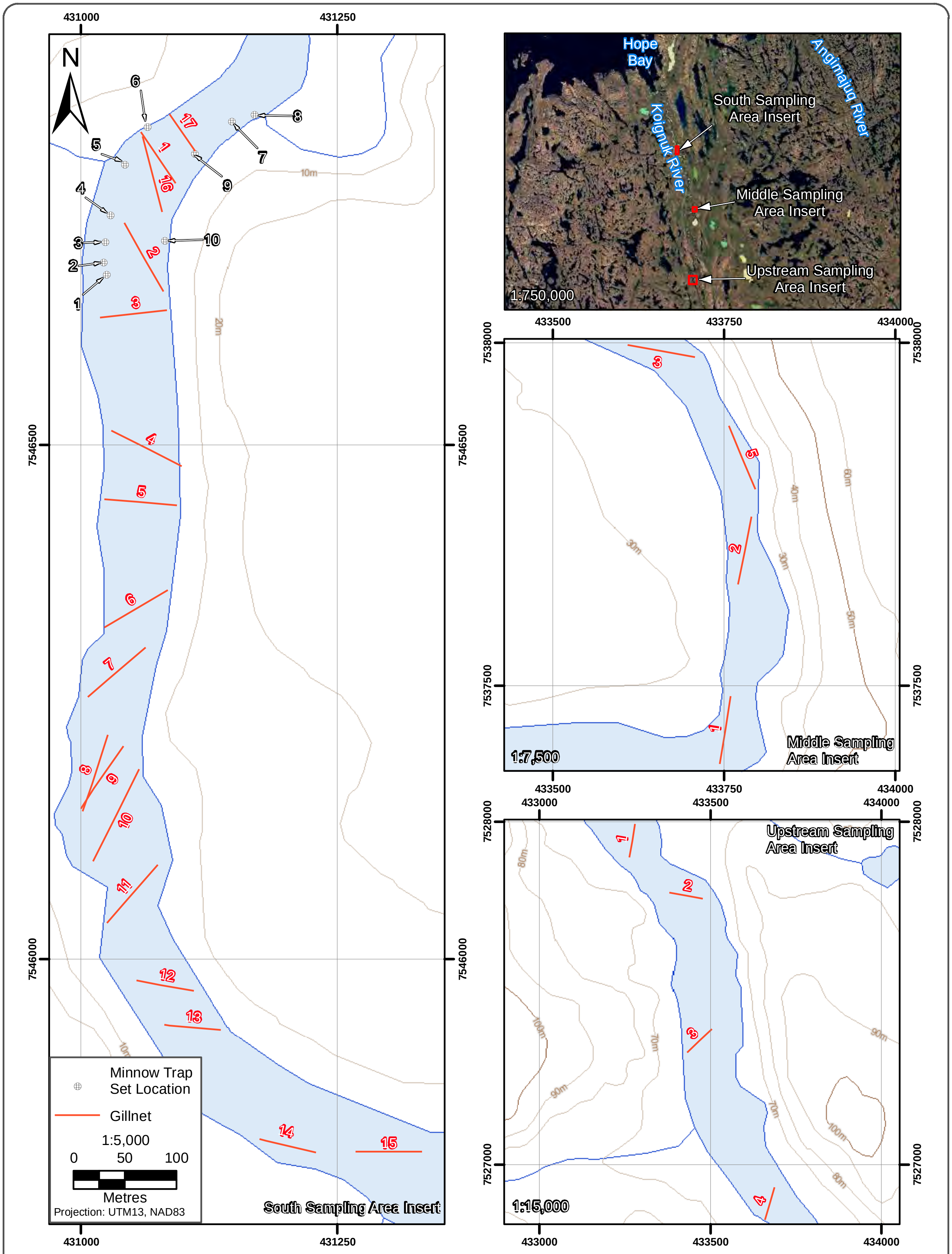


Figure 2.2-10

Gillnet and Minnow Trap Set Locations on the Koignuk River, Hope Bay Belt Project, 2009

NEWMONT NORTH AMERICA

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Plate 2.2-3. Field sampling equipment used to collect fish biological data, Hope Bay Belt Project, 2009.

Plate 2.2-4. Envelopes used for the storage of fish aging structures, Hope Bay Belt Project, 2009.

Lake trout captured from Doris and Patch lakes were marked using a T-bar tag gun, and a uniquely labelled T-bar tag was affixed at the base of the dorsal fin into the musculature of the fish. The unique tag number was then recorded. Lake trout collected from Doris and Patch lakes were also marked using Passive Integrated Transponder (PIT) tags. The use of PIT tags was necessary due to concerns about T-bar tag loss and infection caused by T-bar tags. A PIT tag gun was used to insert a uniquely numbered PIT tag under the skin at the pelvic girdle of each lake trout. The PIT tag was scanned using an AVID microchip scanner (PETIDCO, Calgary, Canada) and the unique number was recorded. Fish were then released live.

All aging analysis of scales, fin rays and otoliths was performed by John Tost of North Shore Environmental Services, Thunder Bay, Ontario. 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. The 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.

Stomachs were removed from any incidental lake trout mortalities, preserved in formalin and sent to Applied Technical Services in Victoria for detailed taxonomic analysis of their contents.

Fish are the preferred organism for tissue metal sampling in primary monitoring programs (Environment Canada 2001, 2005). Hence, fish tissue metal sampling was a key component of the 2009 baseline study of fish populations in the Hope Bay study area.

The purpose of collecting samples of fish tissue was to measure the concentrations of metals and describe their magnitudes and interrelationships. Baseline data on lake trout and lake whitefish tissue metal concentrations will also be used for future monitoring programs and human health assessments.

Metal concentrations were measured in muscle and liver tissue of lake trout collected from three lakes within the proposed area of development (Little Roberts, P.O. and Windy lakes) and from two reference lakes (Reference Lake A and Reference Lake B).

In addition, muscle and liver tissue samples were taken from four lake whitefish (*Coregonus clupeaformis*) collected from P.O. Lake. These data were not analyzed or compared with lake trout metals concentrations because of the low sample size.

The overall goal of the tissue metals study was to collect a minimum of 10 lake trout from each sampling location (where "location" is defined as an individual lake). This sample size was the maximum allowed by Fisheries and Oceans Canada (Fish Collection Licence no. S-09/10-10032-NU) for lethal sampling. In 2009, a total of 49 lake trout muscle and liver tissue samples were taken from five lakes: Little Roberts, P.O., Windy, Reference A and Reference B. The total sample numbers for each lake ranged from a low of 9 muscles and 9 livers for Little Roberts Lake, while 10 muscles and 10 livers were collected from the remaining lakes. Therefore, for muscle and liver tissues, the minimum recommended sample size of 10 was equalled by all lakes except Little Roberts Lake.

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 (Plate 2.2-5). Whole livers from each fish were collected and stored in the same manner. The tissue samples were frozen immediately and were kept frozen until they were delivered to ALS Environmental in Vancouver for analysis of metal concentrations.

Plate 2.2-5. Example of a lake trout muscle tissue sample collected for analysis of metals concentrations, Hope Bay Belt Project, 2009.

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, if required. The latter objective was considered secondary, hence percent moisture was sometimes not measured if all the sample volume was required for metals analysis. All of the 98 samples collected had sufficient volume to allow an accurate measurement of percent moisture. Since metal concentrations were measured before percent moisture, this had no effect on measurement of metal concentrations for that tissue sample.

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). The 25 metals and their analytical detection limits are shown in Table 2.2-2. Iron, phosphorus, potassium, sodium and titanium were not measured in this study.

2.2.2 Hydroacoustics

2.2.2.1 General

Mobile hydroacoustic surveys were conducted in August 2009 to describe fish population characteristics of Patch and Doris Lakes. Survey methods generally followed protocols for the sampling of fish populations with hydroacoustics described in Thorne (1983), MacLennan and Simmonds (1992), Brandt (1996) and Beauchamp et al. (2009).

Table 2.2-2. Metals and Detection Limits for Lake Trout and Lake Whitefish Tissue Analysis, Hope Bay Belt Project, 2009

Total Metal	Detection Limit (mg/kg WW)	Total Metal	Detection Limit (mg/kg WW)
Aluminum	2 to 4	Magnesium	2
Antimony	0.02	Manganese	0.02
Arsenic	0.02	Mercury	0.003
Barium	0.02	Molybdenum	0.02
Beryllium	0.2	Nickel	0.2
Bismuth	0.06	Selenium	0.4
Cadmium	0.01	Strontium	0.02
Calcium	4	Thallium	0.02
Chromium	0.2	Tin	0.1
Cobalt	0.04	Uranium	0.004
Copper	0.02	Vanadium	0.2
Lead	0.04	Zinc	0.2
Lithium	0.2		

WW = wet weight.

Main survey objectives were to: 1) estimate total fish abundance with 95% confidence intervals; 2) estimate relative abundance for each fish species in the respective fish species assemblage; and 3) describe spatial distribution of fish (vertical and horizontal) in each lake.

2.2.2.2 Data Collection

In most situations, night is the preferred time for hydroacoustic sampling to determine fish abundance (Thorne 1983); however, it was unclear which period would be best for the study lakes and their species assemblages. Therefore, Doris Lake was surveyed both during the day (August 22, 1700 to 2000 hours) and at night (August 25, 0000 to 0300 hours) to compare abundance estimates and distribution patterns between periods. Patch Lake was surveyed only at night (August 27 to 28, 2230 to 0300 hours) since wind and wave conditions were unsuitable for hydroacoustic surveys during the day. Darkness was fairly complete but not absolute during the night surveys.

Hydroacoustic sampling was conducted from a 4.3 m-long power boat traveling at 1.4 to 1.9 m/s along pre-mapped transect lines (Figure 2.1-2). The echo sounding system consisted of a dual-transducer, 200 kHz, BioSonics DT-X split-beam scientific echo sounder linked to a Garmin model 182 differential GPS. Full beam angles of the transducers (at the half power point) were 6.7° (down-looking) and 6.5° (side-looking). Other system specifications appear in Table 2.1-2. The sounder was controlled by a laptop computer that displayed electronic echograms for monitoring system performance during data collection. Hydroacoustic data merged with geo-coordinates from the GPS were logged to the computer hard disk to await processing at a later date.

The transducers were mounted on a metal pole that was attached to the boats port side (Plate 2.1-1), with one transducer aimed downward (down-looking) and the other aimed sideways (side-looking) perpendicular to the boat's direction of travel, tilted slightly downward. The down-looking transducer was aimed 1° to 3° sternward to aid in the identification of bubbles. The side-looking transducer was tilted 5° down from horizontal to reduce echoes from the lake surface as described by Yule (2000). Conditions were quite calm during the fish surveys, so a stabilizer was not required to reduce boat roll. The side-looking transducer was necessary to obtain an adequate sampling volume in the many shallow parts of the lakes and to minimize boat avoidance by fish, as recommended by Kubecka et al. (1994) and Kubecka and Whittengerova (1998). During sampling, pings (sound transmissions) alternated between transducers, giving a rate per transducer of eight pings per second. Because the lakes were shallow, all data were collected using a low transmit power setting (-10.3 dB) to avoid signal saturation. Also, a pulse width of 0.4 ms and a data collection threshold of -60 dB were used for all sampling. Other settings used for data collection appear in Table 2.1-2.

Each lake was sampled on 14 transects spaced approximately 500 m apart, perpendicular to the long axis of the lake using a systematic sampling design according to Cochran (1977). Transects covered all parts of the lakes, including shallow bays and flats, although it was expected that data from the shallowest areas would not be usable for fish abundance estimates. In the field, crews sampled to a minimum bottom depth of about 1 m and to within a few metres of shore where possible.

2.2.2.3 Data Processing and Analysis

Hydroacoustic data files were processed using Myriax Echoview software to count fish, measure target strength (TS, the hydroacoustic size of fish), and determine sampling volumes according to standard split-beam trace counting and TS methods (Thorne 1983; MacLennan and Simmonds 1992; Brandt 1996). The side-looking transducer represented the upper 5 m of the water column, so, considering the transducer deployment depth (0.55 m), beam angle (6.5°), and downward tilt (5°), data 10 to 30 m from the transducer were processed. From the down-looking transducer, data from the 2 to 20 m range were processed, but results from less than 5 m were not used for the population estimate.

Fish tracks were recognized on echograms by their shape, cohesiveness and TS. For down-looking data, at least one echo with a TS ≥ -60 dB was required for acceptance as a fish track. At least two echoes with a minimum TS of -60 dB were required for acceptance as a side-looking fish track. Additionally, only echoes within the main portion of the hydroacoustic beam (6.7° or 6.5°) were accepted. No bubbles were seen during any of the surveys, so no correction for their presence was necessary.

The accuracy of hydroacoustic measurements was verified by manufacturer and field calibration tests. The echo sounder was calibrated by its manufacturer (BioSonics) prior to the study, and in-situ TS measurements of a standard sphere were made during the survey. Results of field tests were 0.7 dB greater than the expected value (-39.5 dB) for the down-looking transducer and 0.5 dB greater than the expected value for the side-looking transducer. Corrections for these deviations were applied during processing in Echoview.

Depth intervals for data analysis were 0 to 5 m, 5 to 10 m, etc., to 20 m at the deepest parts of the lakes. Fish densities were summarized as fish/m^3 within depth intervals of transects for population estimates, and as fish/ha in 50 m-long segments of transects for spatial analysis. For each spatial cell of interest, fish/m^3 was calculated as the total number of fish counted divided by the volume sampled. The volume sampled in each spatial cell was calculated according to the wedge model (Keiser and Mulligan 1984) using the hydroacoustic beam angle, distance transected, and a correction for bottom intrusion. The effective beam angle for each depth interval was modeled considering the transducer half-power beam angle (6.7° down-looking, 6.5° side-looking), boat speed and ping rate, and the sampling volume was adjusted accordingly at ranges where the effective beam angle was less than the half-power angle. Under the conditions of the survey, the effective beam angle was never less than 6.1° for the ranges used.

Fish density estimates (fish/m^3 and fish/ha) from individual surveys were examined graphically for trends in horizontal and vertical distribution patterns. Maps using a graduated colour scale were produced to represent areas of relatively high (red) to low (purple) fish density. Based on bathymetry and fish density patterns observed with hydroacoustics and gillnetting, the lakes were divided into two horizontal and vertical strata. Vertical strata were delineated by 5 m depth intervals. Horizontal strata were defined as north (lake area north of proposed dyke) and south (lake area south of proposed dyke). Separate fish population estimates were computed for areas north and south of the proposed dyke for Doris and Patch lakes, respectively.

Each transect pass provided one replicate of each depth interval that it included (shallow transects did not contain all intervals). For each spatial cell (depth interval x lake section), mean fish density was expanded in proportion to total cell volume, and resulting abundance estimates were summed to obtain a total population estimate for all species combined. The volume of each depth interval of each lake section was estimated from a digital bathymetric map using ArcView GIS software assuming a surface elevation of 21.4 m above sea level for Doris Lake and 26.3 m above sea level for Patch Lake. Variance and 95% confidence intervals of the population estimates were calculated for a random sample stratified by horizontal and vertical strata (Cochran 1977).

Because hydroacoustics cannot differentiate fish species, gillnetting was conducted within a few days of hydroacoustic surveys to estimate species composition and other biological characteristics of the fish community (e.g., age composition). The relative catches of each species (see Section 2.4) was used as an estimate of its relative abundance for apportioning the hydroacoustic estimate. This method was only effective for fish large enough to be captured in the mesh sizes that were used (19 to 89 mm stretched mesh), and it assumes equal selectivity for all sizes and species of fish that were present.

2.3 QUALITY ASSURANCE/QUALITY CONTROL

For all fish habitat and community surveys, data sheets were reviewed at the end of each field day to ensure data were complete and collected properly. Field notes were transcribed onto electronic spreadsheets once in the office and all transcriptions were checked visually against the field forms and any errors corrected. The data were also plotted to identify any outliers that may have resulted from transcription errors that occurred in the field.

To assess the accuracy of the metal analyses, ALS conducted two measures of quality control: method blanks (or MB) and comparison with reference material (or CRM). A method blank is a test in which no tissue was added. Six method blanks were run with 25 metals measured for each blank, resulting in a total of 150 comparisons between measurements and targets. Only three of the measurements (or 2%) were above the method detection limit (or MDL) and were classified by ALS as “MB-LOR” (Appendix 2.2-3). This result was considered to be of acceptable quality (Amber Springer, ALS Environmental, pers. comm.).

To further assess the accuracy of the metal analyses, samples of a reference material, VA-NRC-TORT2 or lobster hepatopancreas, certified by the National Research Council of Canada, were subjected to the same analytical procedures as the lake trout 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. Of the 35 comparisons performed, 31 fell within the 95% confidence limits around the target value and four fell outside the limits (an incidence of 11%), but only by 0 to -4% (Appendix 2.2-3). These results are considered to be an acceptable range of analytical accuracy (Amber Springer, ALS Environmental, pers. comm.).

To assess the variability of fish tissue metal analysis, and hence the homogeneity of the samples, six of the 98 samples (or ~6% of the total 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))).

Since 26 variables were measured for each of the six samples (percent moisture and concentrations of 25 metals), this gave a total of 156 potential RPD (Appendix 2.2-4).

However, 46% of those potential RPD were not calculated because one or both of the values were less than the 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 (Table 2.2-3).

Table 2.2-3. Tests of Variability of Fish Tissue Metal Concentrations, Hope Bay Belt Project, 2009

Qualifier	Number of Potential RPD	Percent
RPD-NA	72	46
J	34	22
RPD	48	31
DUP-H	2	1
Total	**156**	**100**

RPD = Relative Percent Difference.
RPD-NA = RPD Not Available because one or both values were at or below the MDL.
J = Absolute difference between duplicates. RPD not available because one or both values were less than five times greater than the MDL.
DUP-H = Duplicate results outside of ALS data quality objectives due to sample heterogeneity.

Another 22% of those potential RPD were not calculated because both values were between one and five times higher than the MDL. The *British Columbia Field Sampling Manual* recommends that only RPD calculated from concentrations each of which is greater than five times the MDL should be used for assessing data quality (BCMWLAP 2003). Instead of an RPD, the absolute difference between the values was calculated. These results were qualified by ALS as “J” in Appendix 2.2-4.

The remaining 50 comparisons were considered to be valid RPD. They ranged from 0.06 to 68% with a median of 5%. A total of one RPD exceeded the RPD limits established by ALS (30% for percent moisture and 45% for metals). ALS interpreted these results as showing low variability of analyses (Amber Springer, ALS Environmental, pers. comm.).

2.4 DATA ANALYSIS

The variables used to assess the fish community included: relative species abundance, length, weight, condition and catch-per-unit-effort (CPUE). Data analysis and interpretation for these variables followed Guy and Brown (2007). Several of these variables required calculation. A description of the calculations undertaken is presented below.

The CPUE statistic is used as an estimate of relative abundance of fish (Hubert and Fabrizio 2007). A key factor that allows comparison of CPUE data is the standardization (type of net, mesh size, etc.) of sampling devices. The same nets, traps and amount of bait were used at all sites allowing comparisons of CPUE data to be made.

For gillnets, CPUE was the number of fish caught per 100 m^2 of net per 1 hour.

$$CPUE = \text{number of fish caught per net} \times [100/\text{total net area } (m^2)] \times [1/\text{set time (h)}]$$

For minnow traps, CPUE was calculated from the number of fish caught per trap per day.

$$CPUE = \text{number of fish} \times [\text{set time (h)}/24 \text{ h (day)}]$$

For electrofishing, CPUE was calculated as the number of fish caught per 100 s of electrofishing.

$$CPUE = \text{number of fish caught}/100 \text{ s}$$

Condition and weight-length regressions are indicators of the relative health of fish within a lake. Condition factor was based on the following formula from Ricker (1975):

$$\text{Condition} = \text{weight (g)} \times 10^5/\text{length}^3 \text{ (mm)}$$

Weight was multiplied by 10^5 to avoid fractional values, and a weight-length exponent of exactly 3 was assumed to apply to all species of fish. Weight-length relationships (Pope and Kruse 2007) were calculated for fish species captured in significant numbers (e.g., greater than 10). Logarithmic transformations were performed on the data prior to conducting the regression.

$$\ln(\text{weight}) = \ln(a) + b[\ln(\text{length})]$$

Weight is in grams, a is a coefficient, b is the slope of the regression, and length is in mm.

Length-age relationships were described with the von Bertalanffy growth model (Isley and Grabowski 2007):

$$L_t = L_\infty(1 - \exp(-K(t - t_0)))$$

where L_t = length at age (mm), L_∞ = asymptotic length (mm) (i.e., length at infinite age), K = growth rate (year^{-1}) and t_0 = age (years) at L = 0 mm. Where length and age data was limited for small and/or young fish, t_0 was fixed at zero to force the x-intercept through the graph origin and create a more realistic model of juvenile growth.

For tissue metals, metals in which 90% of the all concentrations were below the MDL were excluded from analyses. The 90% limit was calculated from muscle and liver tissues together, hence a few of the metals (e.g., arsenic, thallium, and uranium) that were enriched in livers but rare in muscle had greater than 90% of their values for muscle below the MDL. For the included metals, all values below the MDL were assigned values of one-half the MDL in order to use those values in statistical analyses.

Average metal concentrations—with standard error (SE), minimum and maximum—were calculated from that dataset for each type of tissue for each of the five lakes. To compare mean tissue metal concentrations among lakes and tissues, concentrations were ln-transformed to normalize their frequency distributions—a pre-requisite of parametric statistics. Then, mean ln(concentrations) were compared among the five lakes and the two types of tissues with two-way analysis of variance (ANOVA).

Principle Component Analysis (or PCA) was used to reduce redundancy in the tissue metals data set and to allow clearer interpretation of trends in the data. PCA is a statistical routine that reduces a dataset containing a large number of correlated observations into a smaller number of uncorrelated artificial variables called components. PCA is also called data reduction because there are always fewer components than original variables once the redundant information has been removed.

PCA was applied to a single matrix containing the ln-transformed tissue metal concentrations (in mg/kg WW) and ln-transformed fish length. Metals were excluded from the analysis if more than 90% of their values had concentrations below the MDL, and for the remaining metals, values below the MDL were replaced with one-half the detection limit. To help interpret the components, the loadings on the components (i.e., the correlation coefficients between the components and the original metal concentrations) were rotated with the Varimax option and sorted by their relative magnitude. The amounts of variance explained by each component and a scree plot (not shown here) were used to determine how many of those components were important and which were trivial. A scree plot is a plot of the variance explained by a component against the order in which the components were extracted. Important components appear as a 'cliff face' and trivial components appear as the 'scree' at the bottom of the cliff.

All statistics were conducted according to Zar (1984) using SYSTAT (2004). All linear regressions were reported with the appropriate sample size (n), coefficient of determination (r^2, the fraction of variation in the independent parameter that was explained by the dependent parameter) and P value. Only n and r^2 were reported for non-linear regressions. All r^2 for linear or non-linear regressions were not adjusted for the degrees of freedom of the regression.

3. Results and Discussion

3. Results and Discussion

3.1 FISH HABITAT

3.1.1 Lake Habitat

3.1.1.1 Visual

The littoral zones of Little Roberts Lake, Glenn Lake, Windy Lake and Reference Lake A were surveyed to document baseline fish habitat. The substrate composition of Doris Lake, Ogama Lake and P.O. Lake were surveyed in previous baseline studies. Reference Lake B was not surveyed for fish habitat due to uncertainties regarding its use as an appropriate reference (e.g., due to the lake's size and physical characteristics). Littoral zones were divided by substrate types. The substrate composition of each habitat unit is described as a percent for each substrate type, and the total area of each substrate type. These data are summarized in Table 3.1-1.

Little Roberts Lake

The littoral habitat of Little Roberts Lake was divided into eight habitat units (Figure 3.1-1). Fines were the dominant substrate observed, covering 76% of the total littoral area. Fines were particularly evident at the two inflows and at the outflow of the lake (Plate 3.1-1). Organics were also noted in 8% of the littoral zone, which was commonly found in association with fines at the inlets and outlet. Boulder and bedrock comprised 8 and 6% of the littoral area, respectively. These substrates were mainly found along the western and northern shorelines. Cobble was observed as the subdominant substrate at three habitat zones, representing 2% of the littoral area of Little Roberts Lake.

Plate 3.1-1. Organic and fine substrate observed at Little Roberts Lake, Hope Bay Belt Project, 2009.

Table 3.1-1. Littoral Zone Substrate Composition of Lakes, Hope Bay Belt Project, 2009

Habitat Number	Area (m^2)	Organics (%)	Fines (%)	Gravel (%)	Cobble (%)	Boulder (%)	Bedrock (%)	Organics (m^2)	Fines (m^2)	Gravel (m^2)	Cobble (m^2)	Boulder (m^2)	Bedrock (m^2)
Little Roberts Lake													
1	1,554	0	0	0	0	25	75	0	0	0	0	388	1,165
2	692	0	75	0	0	25	0	0	519	0	0	173	0
3	608	0	0	0	25	75	0	0	0	0	152	456	0
4	20,548	10	90	0	0	0	0	2,055	18,493	0	0	0	0
5	303	0	25	0	50	25	0	0	76	0	152	76	0
6	140	0	0	0	0	0	100	0	0	0	0	0	140
7	1,179	0	0	0	0	75	25	0	0	0	0	885	295
8	1,311	5	70	0	25	0	0	66	918	0	328	0	0
Total Littoral Zone	**26,336**						**Total**	**2,120**	**20,006**	**0**	**631**	**1,978**	**1,600**
							%	**8**	**76**	**0**	**2**	**8**	**6**
Glenn Lake													
1	35,396	0	50	0	0	50	0	0	17,698	0	0	17,698	0
2	79,903	0	0	0	0	0	100	0	0	0	0	0	79,903
3	64,035	0	0	0	5	15	80	0	0	0	3,202	9,605	51,228
4	19,987	0	0	0	0	80	20	0	0	0	0	15,990	3,997
5	13,516	0	0	0	100	0	0	0	0	0	13,516	0	0
6	51,329	0	95	0	0	5	0	0	48,763	0	0	2,566	0
7	12,397	0	10	0	0	90	0	0	1,240	0	0	11,157	0
8	36,710	0	85	0	0	15	0	0	31,204	0	0	5,507	0
9	43,272	0	97	0	0	3	0	0	41,974	0	0	1,298	0
10	17,128	0	0	0	35	20	45	0	0	0	5,995	3,426	7,708
11	37,997	0	0	0	0	0	100	0	0	0	0	0	37,997
12	13,599	0	80	0	10	10	0	0	10,879	0	1,360	1,360	0
13	8,388	0	80	5	5	10	0	0	6,710	419	419	839	0
14	14,684	0	10	0	10	20	60	0	1,468	0	1,468	2,937	8,810
15	15,187	0	100	0	0	0	0	0	15,187	0	0	0	0
16	13,138	0	80	0	0	20	0	0	10,510	0	0	2,628	0
17	8,973	0	20	0	0	0	80	0	1,795	0	0	0	7,178
18	8,797	0	60	0	20	20	0	0	5,278	0	1,759	1,759	0
19	5,489	0	100	0	0	0	0	0	5,489	0	0	0	0
20	49,332	0	40	5	25	30	0	0	19,733	2,467	12,333	14,800	0
21	13,391	0	0	0	0	10	90	0	0	0	0	1,339	12,052
22	21,379	0	0	0	5	20	75	0	0	0	1,069	4,276	16,034
23	14,728	0	0	0	3	0	97	0	0	0	442	0	14,286
24	7,879	0	0	0	20	20	60	0	0	0	1,576	1,576	4,727
25	13,137	0	90	5	0	5	0	0	11,823	657	0	657	0
26	13,997	0	0	0	0	0	100	0	0	0	0	0	13,997
27	10,342	0	0	0	0	15	85	0	0	0	0	1,551	8,791
28	10,798	0	100	0	0	0	0	0	10,798	0	0	0	0
29	11,066	0	0	0	0	0	100	0	0	0	0	0	11,066
30	48,244	0	70	0	15	15	0	0	33,771	0	7,237	7,237	0
31	50,219	0	50	0	10	30	10	0	25,110	0	5,022	15,066	5,022
Total Littoral Zone	**764,437**						**Total**	**0**	**299,429**	**3,543**	**55,398**	**123,270**	**282,797**
							%	**0**	**39**	**0**	**7**	**16**	**37**
Windy Lake													
1	35,359	0	70	10	10	10	0	0	24,751	3,536	3,536	3,536	0
2	51,735	0	15	15	40	30	0	0	7,760	7,760	20,694	15,521	0
3	24,004	0	5	5	20	30	40	0	1,200	1,200	4,801	7,201	9,602
4	40,439	0	0	10	50	30	10	0	0	4,044	20,220	12,132	4,044
5	39,696	0	25	25	25	10	15	0	9,924	9,924	9,924	3,970	5,954
6	31,315	0	25	55	10	5	5	0	7,829	17,223	3,131	1,566	1,566
7	18,157	0	16	16	36	6	26	0	2,905	2,905	6,536	1,089	4,721
8	16,491	0	30	10	30	10	20	0	4,947	1,649	4,947	1,649	3,298
9	3,789	0	0	0	10	10	80	0	0	0	379	379	3,032
10	31,336	0	70	10	10	10	0	0	21,935	3,134	3,134	3,134	0
11	21,893	0	30	20	30	10	10	0	6,568	4,379	6,568	2,189	2,189
12	18,465	0	70	0	20	10	0	0	12,926	0	3,693	1,847	0
13	33,962	0	60	10	20	5	5	0	20,377	3,396	6,792	1,698	1,698
14	10,611	0	30	20	30	15	5	0	3,183	2,122	3,183	1,592	531
15	2,116	0	0	0	10	10	80	0	0	0	212	212	1,693
16	2,574	0	0	0	10	10	80	0	0	0	257	257	2,059
17	1,749	0	0	0	10	10	80	0	0	0	175	175	1,399
18	1,721	0	0	0	10	10	80	0	0	0	172	172	1,377
19	4,503	0	0	0	10	10	80	0	0	0	450	450	3,602
20	6,683	0	5	5	10	20	60	0	334	334	668	1,337	4,010
21	43,126	0	60	10	10	10	10	0	25,876	4,313	4,313	4,313	4,313
22	8,678	0	30	10	30	0	30	0	2,603	868	2,603	0	2,603
Total Littoral Zone	**448,404**						**Total**	**0**	**153,119**	**66,787**	**106,390**	**64,417**	**57,691**
							%	**0**	**34**	**15**	**24**	**14**	**13**

(continued)

Table 3.1-1. Littoral Zone Substrate Composition of Lakes, Hope Bay Belt Project, 2009 (completed)

Habitat Number	Area (m^2)	Organics (%)	Fines (%)	Gravel (%)	Cobble (%)	Boulder (%)	Bedrock (%)	Organics (m^2)	Fines (m^2)	Gravel (m^2)	Cobble (m^2)	Boulder (m^2)	Bedrock (m^2)
Reference Lake A													
1	10,357	0	10	0	30	60	0	0	1,036	0	3,107	6,214	0
2	1,372	0	0	0	0	15	85	0	0	0	0	206	1,166
3	6,076	0	25	0	30	45	0	0	1,519	0	1,823	2,734	0
4	3,270	0	65	0	20	15	0	0	2,125	0	654	490	0
5	1,889	0	0	0	0	15	85	0	0	0	0	283	1,605
6	3,292	0	70	0	0	30	0	0	2,305	0	0	988	0
7	782	0	0	0	0	0	100	0	0	0	0	0	782
8	4,691	0	0	0	15	70	15	0	0	0	704	3,284	704
9	755	0	0	0	0	20	80	0	0	0	0	151	604
10	36,468	0	10	0	0	80	10	0	3,647	0	0	29,175	3,647
11	18,286	0	0	0	0	5	95	0	0	0	0	914	17,372
12	13,811	0	0	0	70	10	20	0	0	0	9,667	1,381	2,762
13	28,560	0	0	0	0	10	90	0	0	0	0	2,856	25,704
14	30,777	0	85	0	0	5	10	0	26,160	0	0	1,539	3,078
15	7,952	0	0	0	30	60	10	0	0	0	2,386	4,771	795
16	4,424	0	0	0	10	35	55	0	0	0	442	1,548	2,433
17	18,003	0	0	0	0	5	95	0	0	0	0	900	17,103
18	16,451	0	0	0	30	60	10	0	0	0	4,935	9,871	1,645
19	3,773	0	80	0	0	20	0	0	3,019	0	0	755	0
20	6,126	0	0	0	0	0	100	0	0	0	0	0	6,126
21	2,828	0	85	0	0	15	0	0	2,404	0	0	424	0
22	15,315	0	0	0	0	10	90	0	0	0	0	1,532	13,784
23	11,030	0	0	0	10	70	20	0	0	0	1,103	7,721	2,206
24	1,158	0	90	0	0	10	0	0	1,042	0	0	116	0
25	455	0	0	0	0	0	100	0	0	0	0	0	455
26	944	0	90	0	0	10	0	0	850	0	0	94	0
27	5,492	0	0	0	0	10	90	0	0	0	0	549	4,943
28	31,440	0	0	0	20	70	10	0	0	0	6,288	22,008	3,144
29	1,239	0	0	0	0	10	90	0	0	0	0	124	1,115
30	8,132	0	0	0	40	60	0	0	0	0	3,253	4,879	0
31	5,059	0	0	0	10	90	0	0	0	0	506	4,553	0
32	1,975	0	0	75	25	0	0	0	0	1,481	494	0	0
33	3,554	0	0	0	0	25	75	0	0	0	0	889	2,666
34	25,865	0	0	0	15	75	10	0	0	0	3,880	19,399	2,587
35	9,462	0	0	0	0	15	85	0	0	0	0	1,419	8,043
36	4,616	0	0	0	0	100	0	0	0	0	0	4,616	0
37	58,361	0	0	0	10	20	70	0	0	0	5,836	11,672	40,852
38	39,713	0	75	0	10	15	0	0	29,784	0	3,971	5,957	0
39	81,277	0	0	0	25	0	75	0	0	0	20,319	0	60,958
Total Littoral Zone	**525,030**						**Total**	**0**	**73,891**	**1,481**	**69,368**	**154,012**	**226,277**
							%	**0**	**14**	**0**	**13**	**29**	**43**

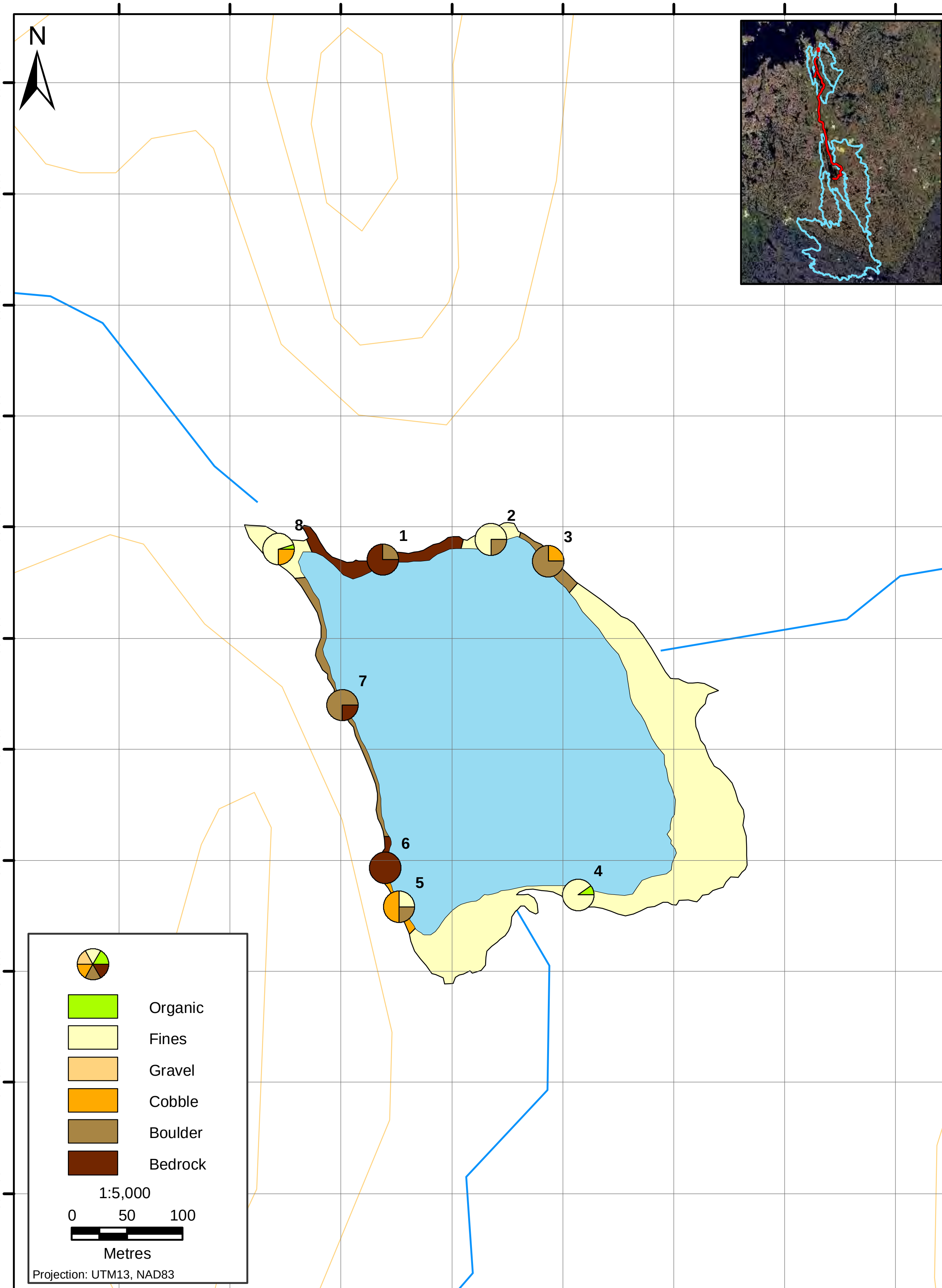

Figure 3.1-1

Fish Habitat Map of Little Roberts Lake Littoral Zone, Hope Bay Belt Project, 2009

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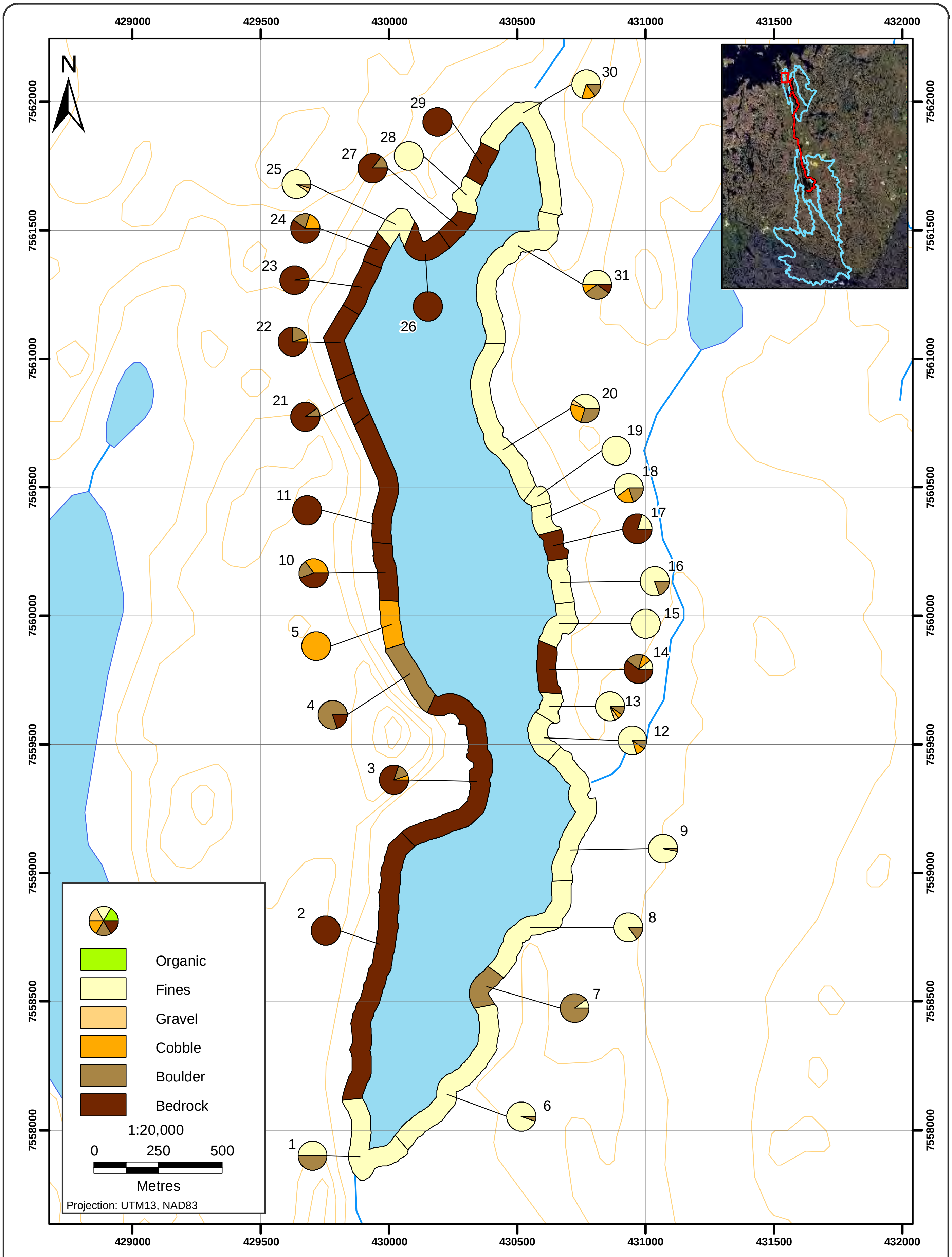
Glenn Lake

Glenn Lake was divided into 31 littoral habitat units (Figure 3.1-2). The dominant substrate type was fines and bedrock, representing 39 and 37% of the total littoral area, respectively. Bedrock substrate was primarily observed along the steep western shoreline (Plate 3.1-2), while fines formed the dominant substrate type along the eastern shoreline (Plate 3.1-3). Boulder and cobble were observed as the subdominant forms of substrate, usually in association with bedrock along the western shoreline. These substrates formed 16 and 7% of the total littoral habitat, respectively. Gravel was also observed in very small proportions in three habitat units.

Windy Lake

The littoral habitat of Windy Lake was divided into 22 habitat units (Figure 3.1-3). The littoral habitat of the lake was distributed relatively evenly amongst the five substrate categories. Fines formed the dominant substrate type, representing 34% of the total littoral habitat. Cobble was identified as the subdominant substrate type at 24% of the total littoral habitat. Gravel, boulder and bedrock represented 15%, 14%, and 13%, respectively. As with Glenn Lake, the majority of bedrock substrate was located in the western littoral zone, while the eastern littoral zone was predominately fine substrate. Due to the content of round cobble observed at habitat zones 12 and 14, these areas may be suitable as lake trout spawning habitat (Plate 3.1-4).

Plate 3.1-2. Bedrock along the western shoreline of Glenn Lake, Hope Bay Belt Project, 2009.



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Fish Habitat Map of Glenn Lake Littoral Zone, Hope Bay Belt Project, 2009

Figure 3.1-2

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Plate 3.1-3. Fine substrate along the eastern shoreline of Glenn Lake, Hope Bay Belt Project, 2009.

Plate 3.1-4. Clean cobble suitable for lake trout spawning habitat at habitat zone 14 of Windy Lake, Hope Bay Belt Project, 2009.

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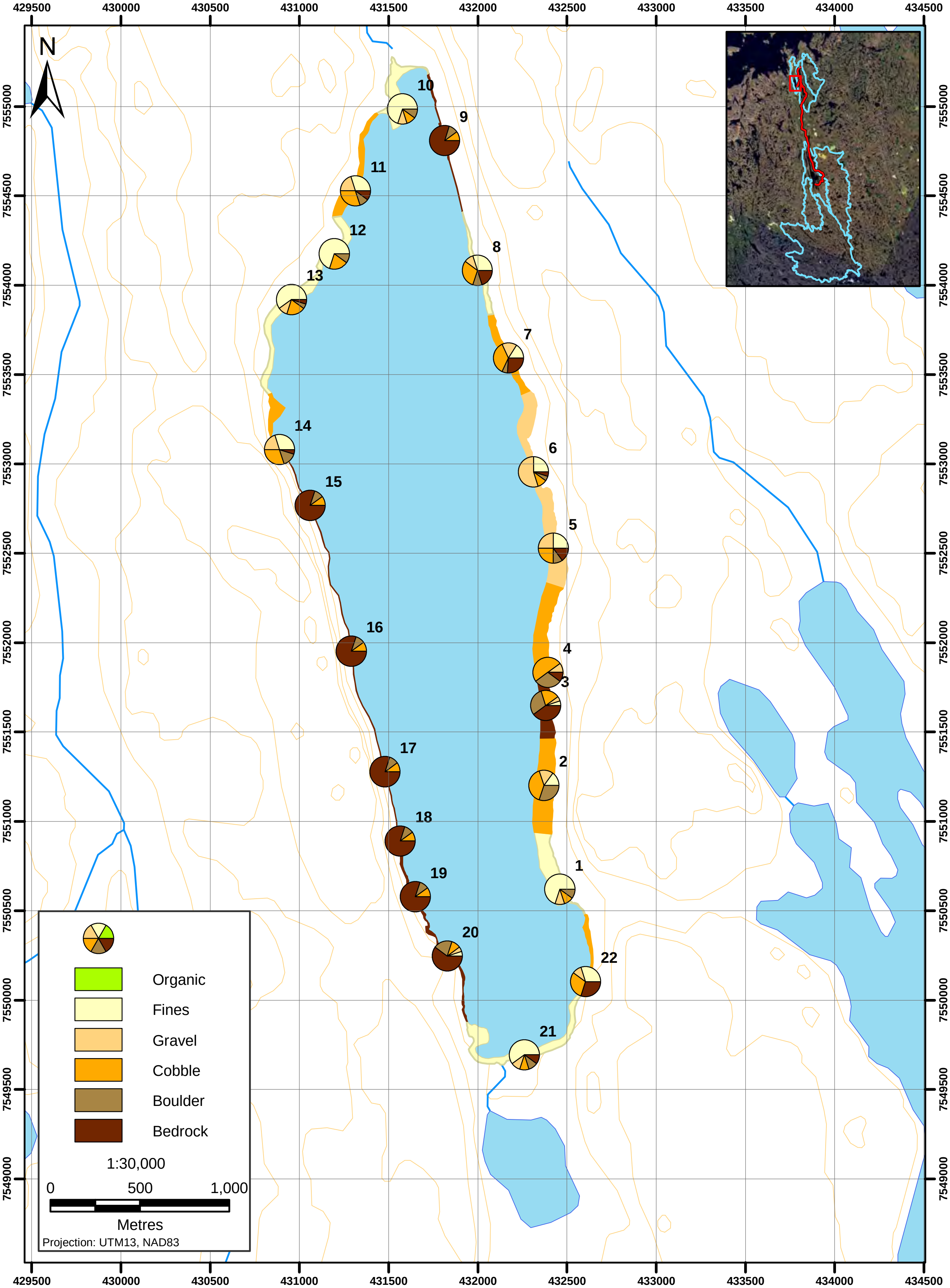

Figure 3.1-3

Fish Habitat Map of Windy Lake Littoral Zone, Hope Bay Belt Project, 2009

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Reference Lake A

Reference Lake A was divided into 39 littoral habitat zones (Figure 3.1-4). Bedrock was identified as the dominant substrate type, representing 43% of the total littoral area. Again, much of the bedrock substrate was found on the western shore of this lake. Bedrock substrate was also found in conjunction with minimal littoral zone due to the steep shoreline. Boulder accounted for 29% of the total littoral area and represented the subdominant substrate type. The remaining substrate composition was represented as fines (14%) and cobble (13%). Several potential lake trout spawning shoals were identified in Reference Lake A. These sites included habitat zones 1, 12, 15, 18 and 30. Generally, these locations were characterized by clean, round cobble and boulder with large interstitial spaces within the substrate.

3.1.1.2 Hydroacoustics and Underwater Video

Appendices 3.1-1 and 3.1-2 present data collected from hydroacoustics surveys of Doris and Patch lakes, respectively. Figures 3.1-5 and 3.1-6 illustrate the distribution of substrates in Doris and Patch lakes, respectively. The predominant substrate category found at Doris Lake was 'very soft fines', representing 53% of the overall bottom area. The subdominant bottom types were comprised of hard substrate (gravel, cobble, boulder) and mud. These categories represented 25% and 22% of the overall bottom type. Very soft fines and mud were generally associated with the deep water sections of Doris Lake. Hard substrates such as gravel, cobble and boulder were associated with near-shore locations and around islands. Underwater video was not used at Doris Lake due to very poor visibility caused by high turbidity.

The predominant substrate type found at Patch Lake was mud, representing 41% of the total bottom area. Hard substrates (gravel, cobble, boulder) were similarly abundant, representing 37% of the total bottom area. Very soft fines represented 22% of the total bottom area. As with Doris Lake, fines and mud were associated with deeper portions of the lake, particularly in the mid-basin. Hard substrates were also found most commonly along shorelines, bays and near off-shore islands. Underwater video was able to be used at Patch Lake to calibrate hydroacoustic signals. The underwater video footage showed that nearly all mud and fine substrates were covered with green algae and some larger aquatic plant life (Plate 3.1-5).

Underwater video footage showed substrates ranging from fines (<2 mm) to boulders (>256 mm), including some >1 m in diameter, in Patch Lake. Video footage confirmed that fines and mud predominated in deeper parts of the lake (Figure 3.1-6 and Plate 3.1-5a). Rocky substrates (gravel, cobble, boulder) occurred near shore (Plates 3.1-5b and 3.1-5c) and in off shore areas near the proposed dyke (Plate 3.1-5d). Hard substrates were rounded in some locations and highly angular in others (Plates 3.1-5b and 3.1-5c). In many places, rocky substrates were coated with silt or algae or embedded with fines, especially in off-shore locations (Plates 3.1-5b and 3.1-5d). Typically, there was a zone of cobble and boulder interspersed among fines between a rocky shoreline and fine sediment in deeper water. Gravel, cobble and boulders were often mixed together or occurred in patches.

Aquatic plants were also observed using underwater video in Patch Lake. Two general forms of algae were observed: "filamentous" (Plate 3.1-6a) and "globular" (Plate 3.1-6b). These algae covered large areas of the lake bottom, with the exception of the deep basins and close to shore. Algal coverage was intermediate (25 to 75%) to extensive (75 to 100%) at many locations. Underwater video was unable to identify or confirm substrate composition at locations with 100% algae coverage.

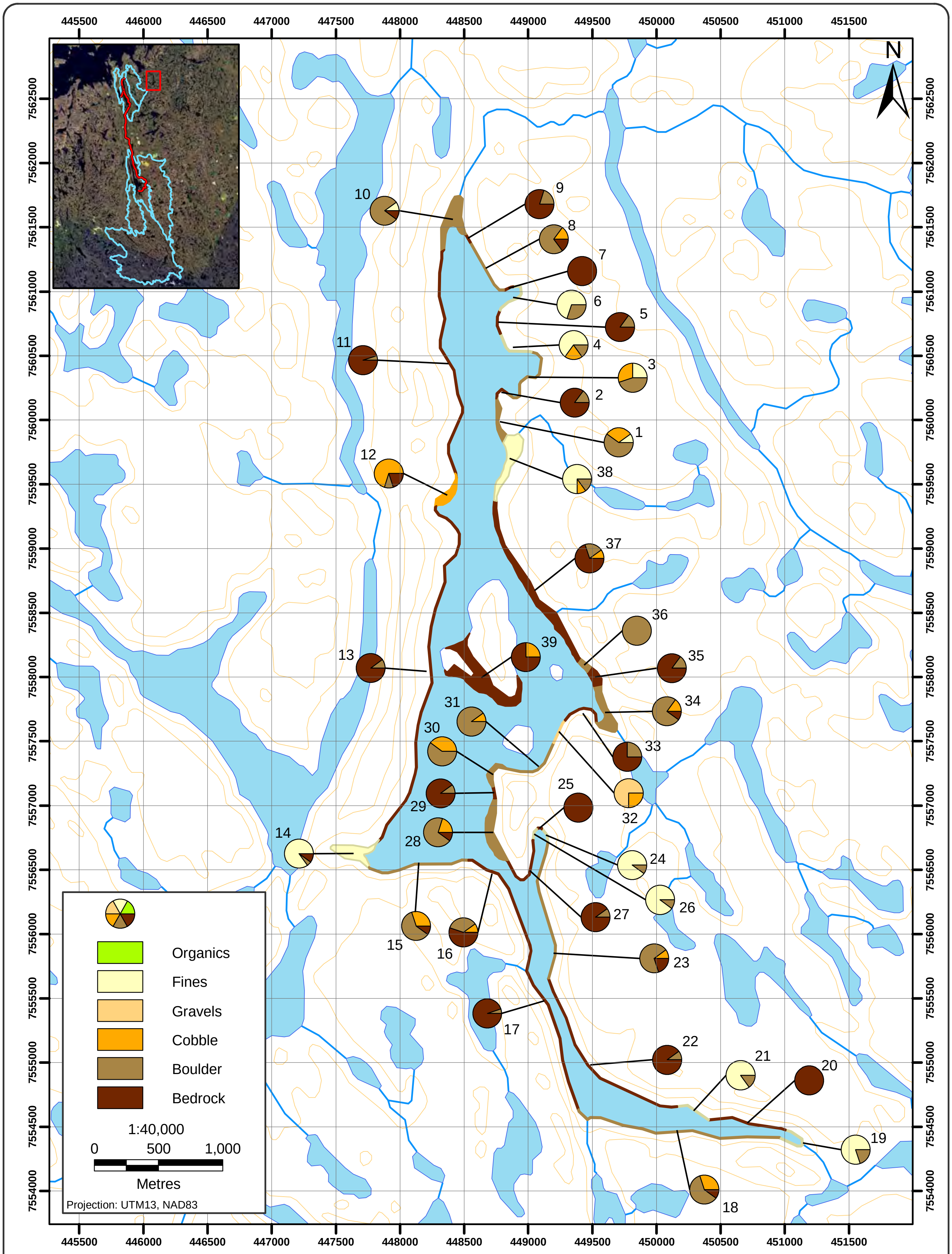

Figure 3.1-4

Fish Habitat Map of Reference Lake A Littoral Zone, Hope Bay Belt Project, 2009

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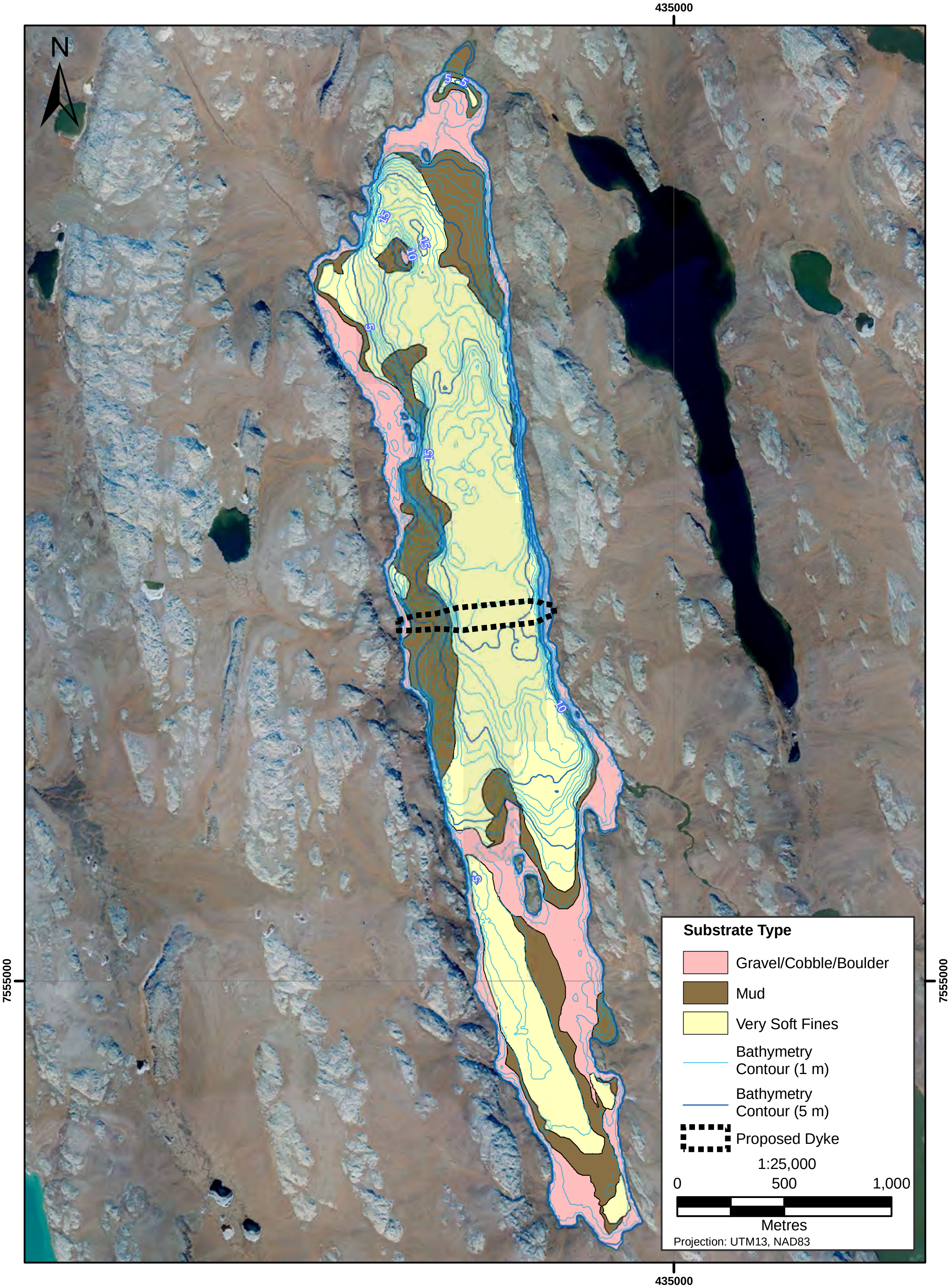

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Substrate Composition of Doris Lake Derived from Hydroacoustic Surveys, Hope Bay Belt Project, 2009

Figure 3.1-5

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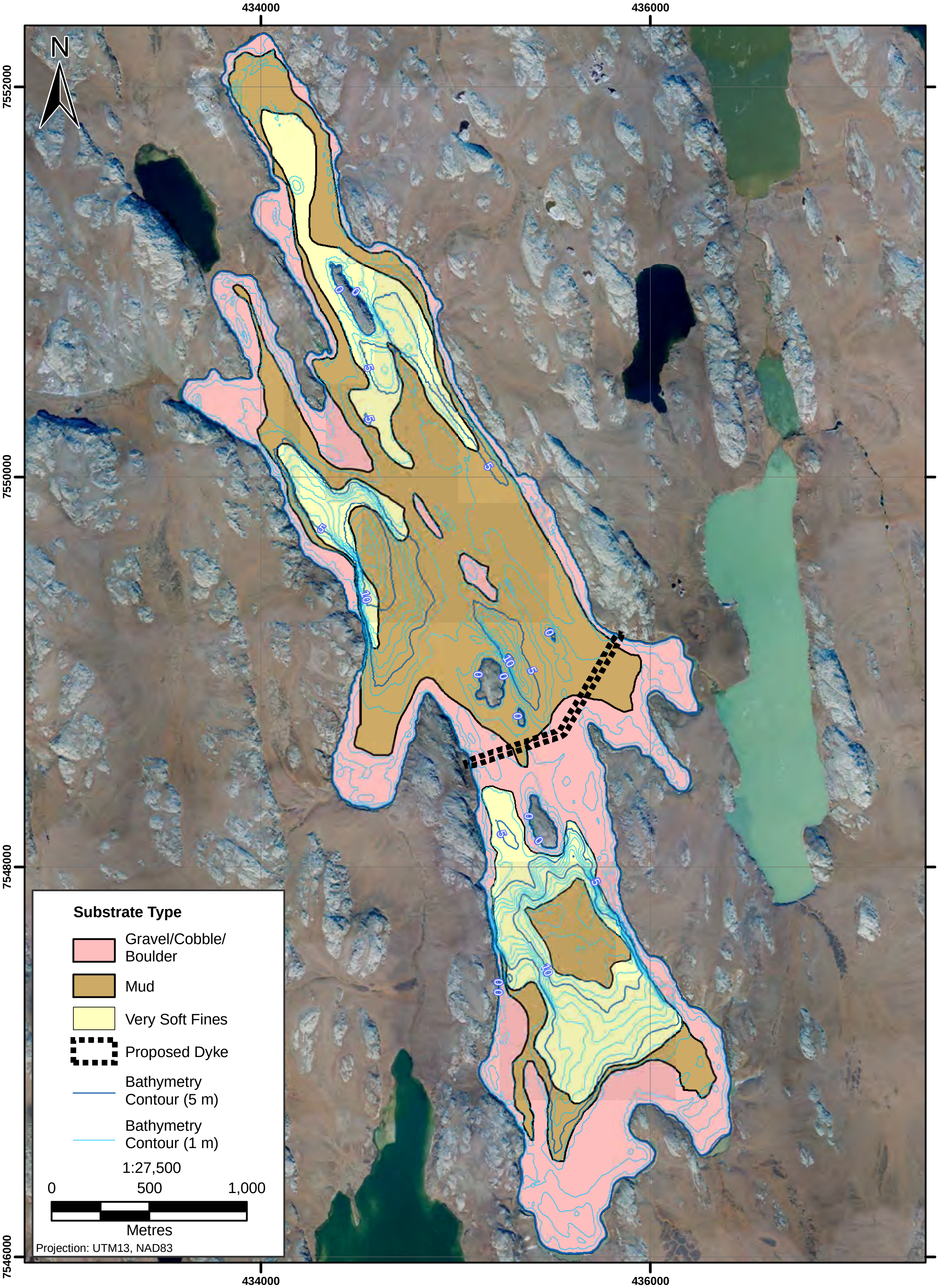

Substrate Composition of Patch Lake Derived from Hydroacoustic and Underwater Video Surveys, Hope Bay Belt Project, 2009

Figure 3.1-6

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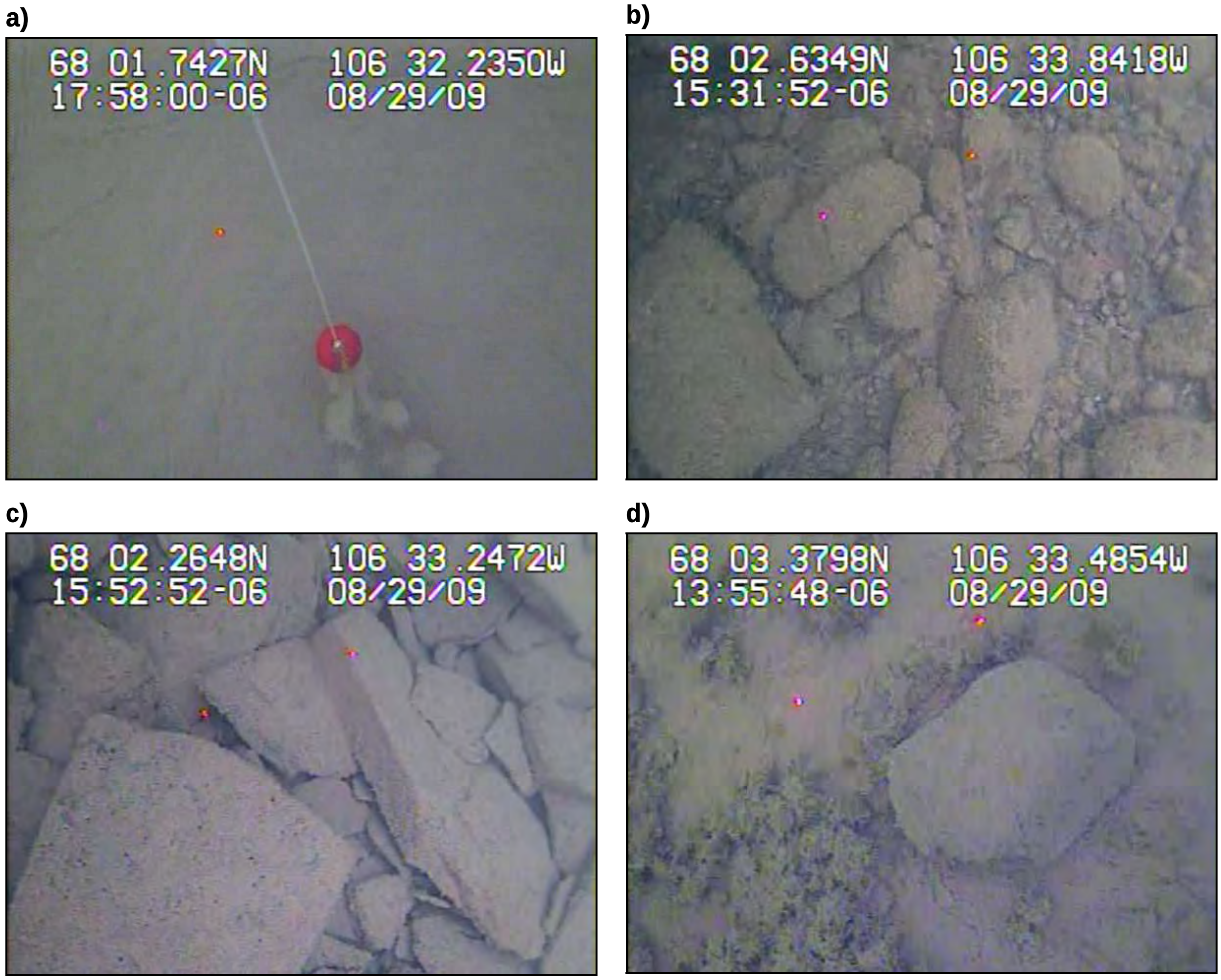


Plate 3.1-5. Examples of substrate types in Patch Lake: a) fines in the deepwater main basin; b) gravel and cobble in the near shore; c) angular cobbles in the near shore; and d) a piece of cobble among algae and fines in the off shore. Note: the red dots represent a distance of 10 cm.

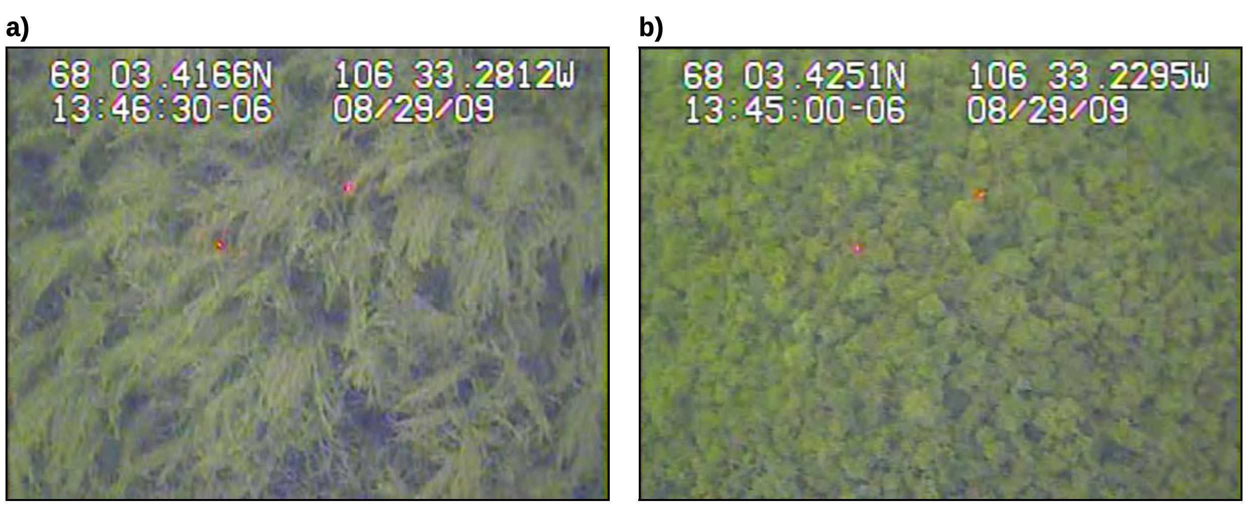


Plate 3.1-6. Filamentous (a) and globular (b) forms of algae on the bottom of Patch Lake. Note: the red dots represent a distance of 10 cm.

3.1.2 Stream Habitat

Detailed fish habitat surveys were completed at 27 sites in the Project area. Surveys were conducted from June to August 2009. Thirteen potential receiving environment streams were surveyed from four different watersheds (Doris, Koignuk, Windy and Roberts), while three reference environment streams were surveyed from three different watersheds. Fish habitat data sheets and photos are listed in Appendix 3.1-3. The data is summarized in Appendix 3.1-4.

Sections of streams assessed in the study area consisted of glide, riffle, pool and cascade habitat. Mean gradients, ranged from 0.8 to 10.6% (Figure 3.1-7). Reference B outflow, Angimajug River and Koignuk River were the largest systems surveyed, ranging in bankfull channel width from 40.5 m to 137.0 m (Figure 3.1-8). Streams within the Doris, Windy and Roberts Bay watersheds were considerably smaller, ranging from 1.0 m (Doris I/F) to 15.7 m (P.O. O/F). Mean bankfull depth ranged from 0.3 m (Doris I/F) to 2.4 (Doris I/F) (Figure 3.1-9). The bed material was primarily composed of fines and secondarily composed of varied amounts of bedrock, boulders, cobble and gravel (Figure 3.1-10). Fines were the dominant substrate for all streams within the receiving environment, while the bed material of the reference environment sites was a mixture of gravel, cobble, boulders and bedrock.

The Koignuk River was observed as having the least amount of total fish cover present (7%), while the Doris I/F and Windy I/F were observed as having the greatest amount of total fish cover present (100%) (Figure 3.1-11). Overall, instream cover (in the form of small woody debris) was identified as the primary cover type. Boulder and pool cover was the secondary type, while overhanging vegetation, undercut banks, large woody debris and small woody debris contributed small proportions of the available fish habitat.

<u>Doris Watershed</u>

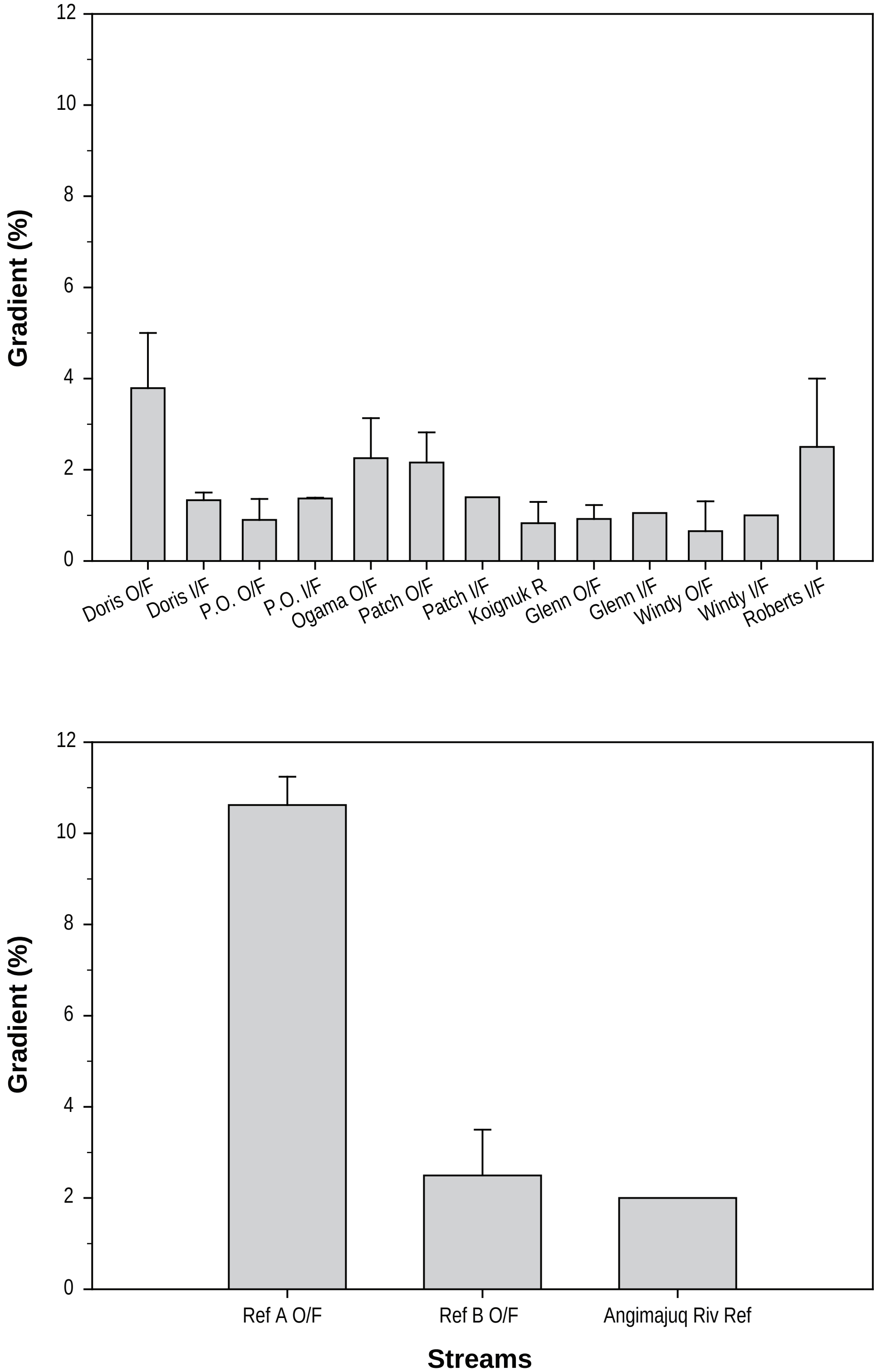
A total of 17 fish habitat surveys for seven different streams were completed within the Doris Watershed.

Doris Outflow

Three sections of Doris Outflow (Doris O/F1, Doris, O/F2 and Doris O/F3), covering a total of 800 m, were surveyed. Doris Outflow is characterized by long glide and riffle habitats with a mean gradient ranging from 1.4 to 5.0%. The mean bankfull depth ranged from 0.8 to 5.0 m, while the mean bankfull width ranged from 3.5 to 15.2 m. The primary substrate type present was fines, while gravel, cobble and boulders were less abundant. Fish habitat was present in the form of pools, boulders, instream vegetation and overhanging vegetation. A 3 m-high falls was identified downstream of Doris O/F1 as a barrier to fish migration. Several lake trout were observed holding in Doris Outflow in deep areas with relatively light flow. Fish habitat was rated as good due to the presence of adult lake trout using the habitat for feeding.

Doris Inflow

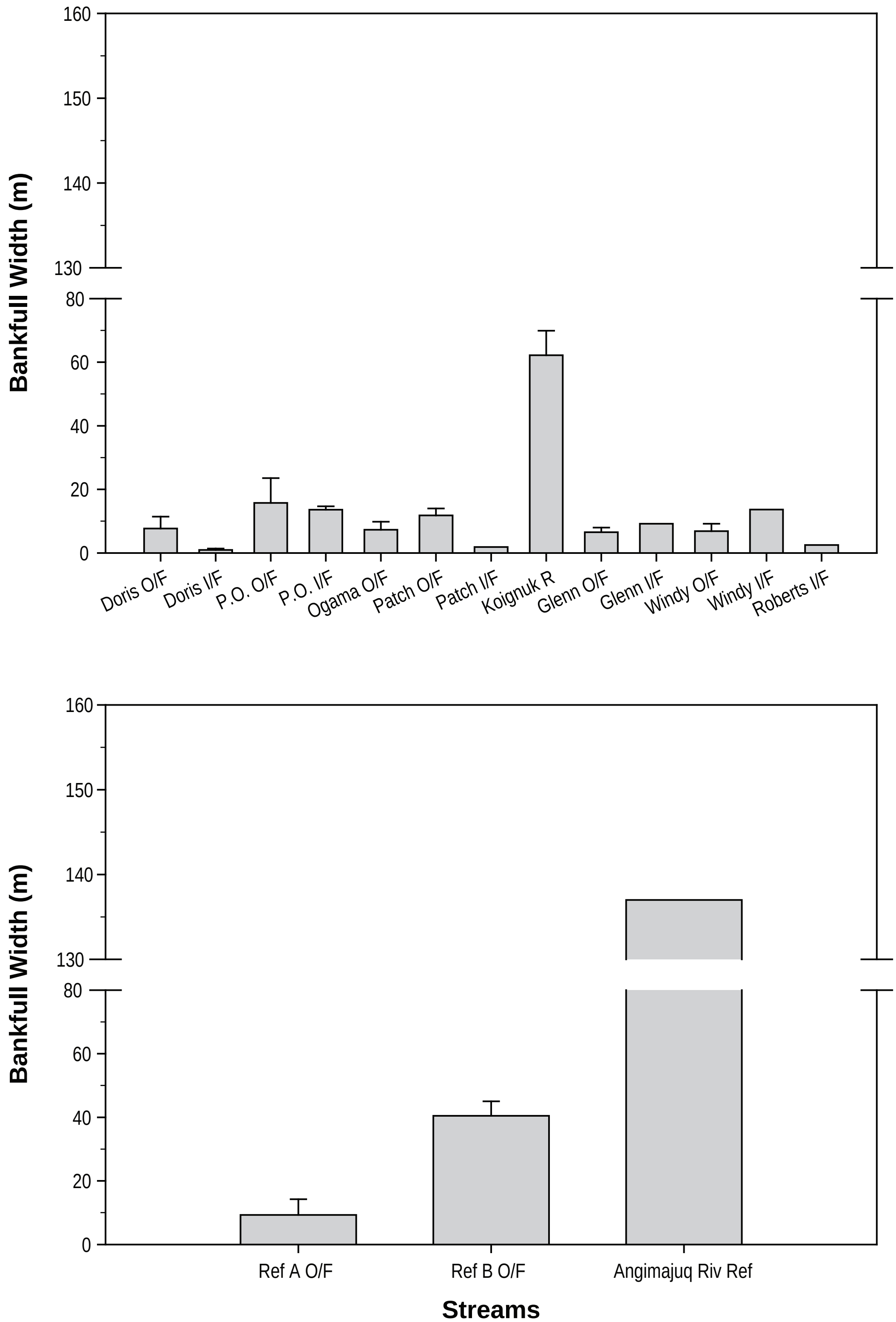
A total of 600 m of Doris Inflow was assessed for fish habitat. Doris Inflow was characterized as an ephemeral stream with a predominance of overland flow, which was observed during the freshet period. Stream gradient ranged from 1.0 to 1.5%. Bankfull width ranged from 0.3 m to 1.8 m, and bankfull depth ranged from 0.26 m to 0.30 m. The bed material of the stream was 100% composed of fines. Terrestrial vegetation was observed throughout the stream bed, which offered 100% of the stream area as cover for fish in the wetted portion of the stream. The predominance of fines and terrestrial vegetation is typical of ephemeral streams. Fish habitat was classified as none to marginal.



Note: Error bars represent the one standard error of the mean

Figure 3.1-7

Mean Gradient of Streams Surveyed for Fish Habitat, Hope Bay Belt Project, 2009



Note: Error bars represent the one standard error of the mean

Figure 3.1-8

Mean Bankfull Widths of Streams Surveyed for Fish Habitat, Hope Bay Belt Project, 2009

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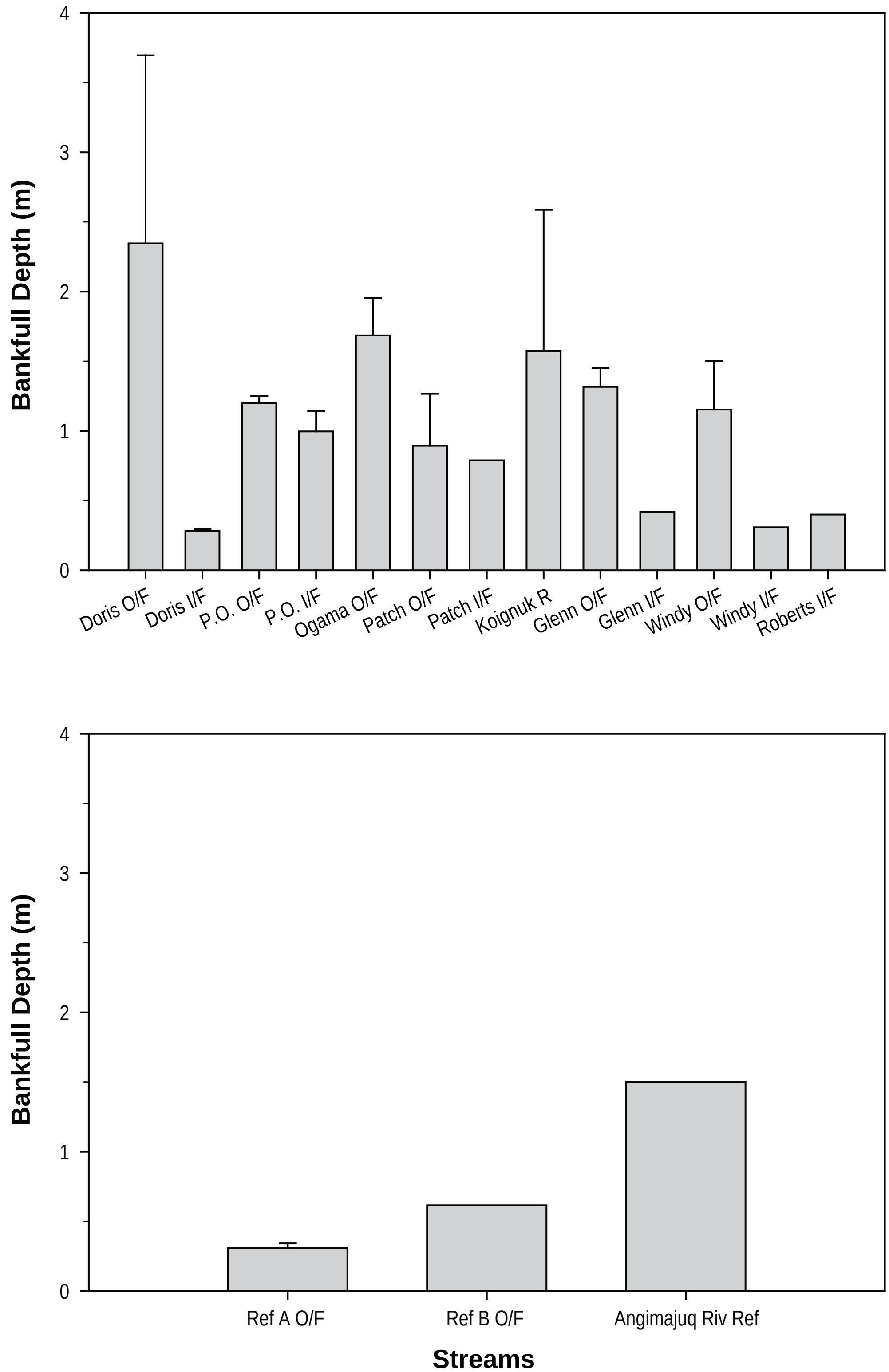

Note: Error bars represent the one standard error of the mean

Figure 3.1-9

Mean Bankfull Depths of Streams Surveyed for Fish Habitat, Hope Bay Belt Project, 2009

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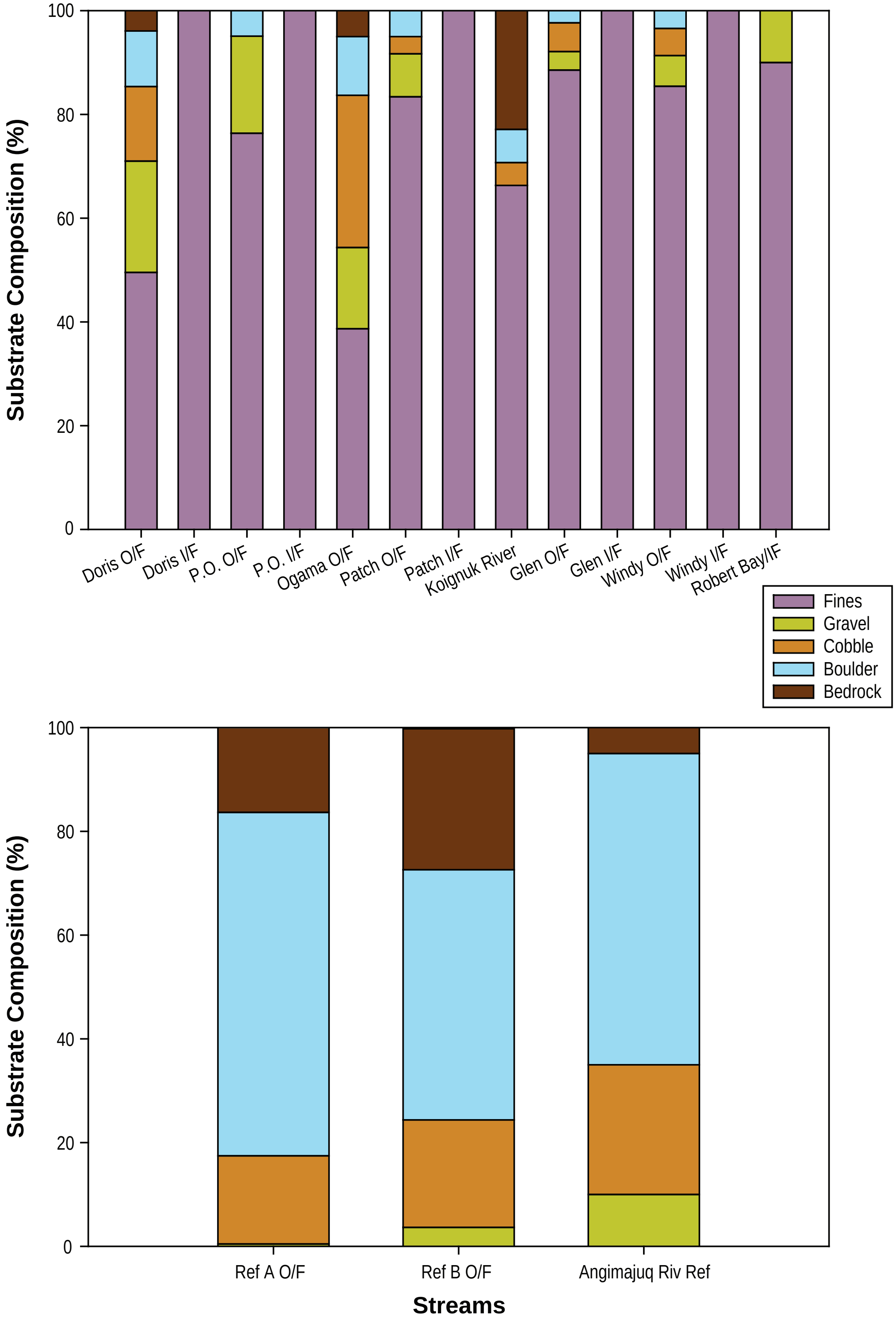

Figure 3.1-10

Cover for Fish in Streams Surveyed for Fish Habitat, Hope Bay Belt Project, 2009

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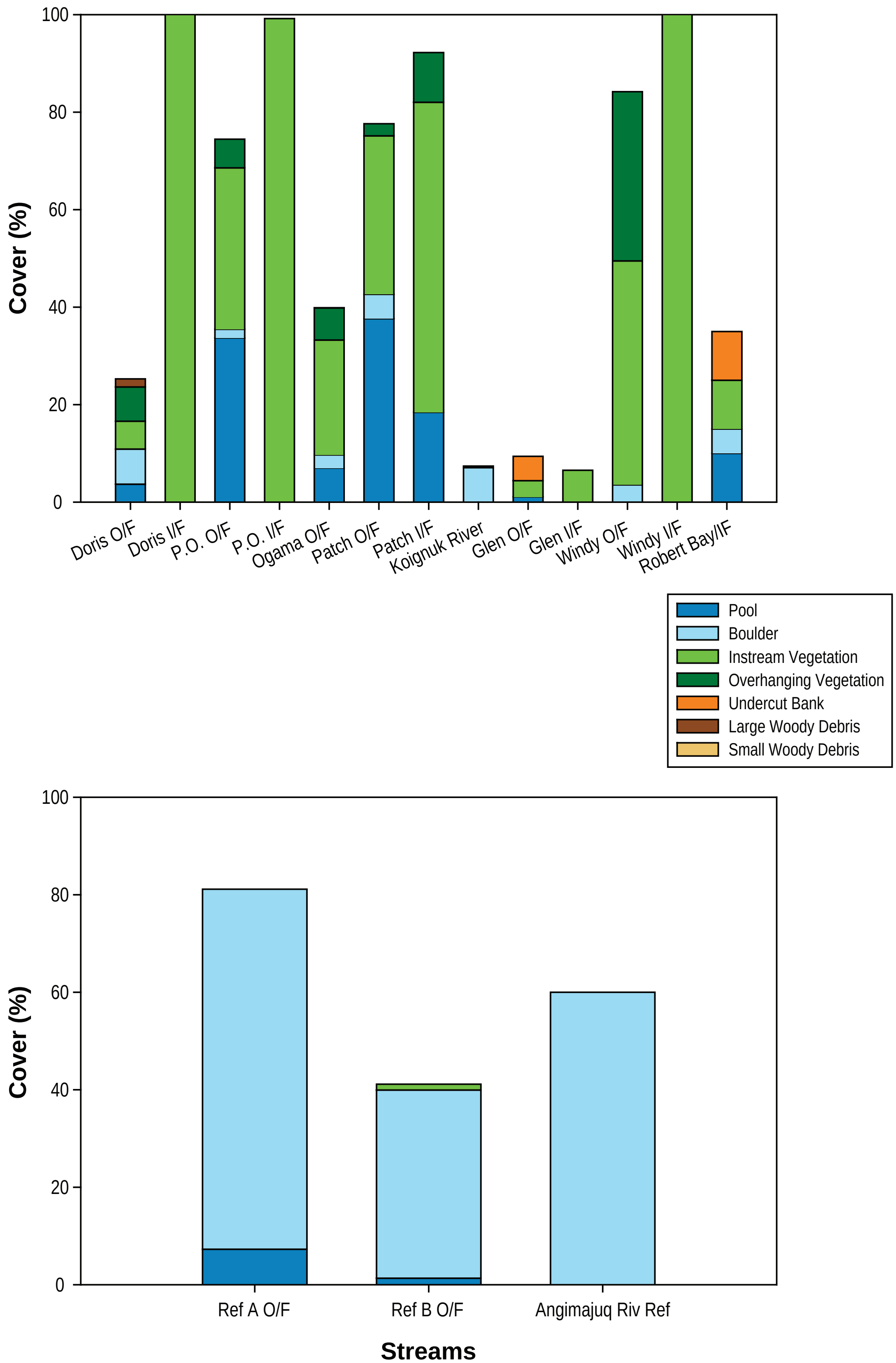

Figure 3.1-11

Substrate Composition of Streams Surveyed for Fish Habitat, Hope Bay Belt Project, 2009

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P.O. Outflow

Two surveys of P.O. Outflow were completed in June during the freshet period and one survey was completed in July during the low-flow summer period. Of the seven habitat units identified, three were glides, two were riffles, one was a cascade and one was a pool. The stream gradient ranged from 0 to 1.5%. Stream channel dimensions ranged from 1.3 m to 17.9 m for bankfull width, and 1.1 to 1.3 m for bankfull depth. Substrate was predominantly fines. Gravel and boulders were present in trace amounts. Instream vegetation and pools were noted as the predominant source of cover for fish. A small proportion of boulder and overhanging vegetation cover was observed. Overall fish habitat was rated as important.

P.O. Inflow

P.O. Inflow is characterized by long stretches of glide and riffle habitat (i.e., 25 to 65 m long) followed by shorter stretches of pool habitat (i.e., 19 to 22 m long). Mean stream gradient was 1.4%, while the stream channel dimensions ranged from 12.5 m to 14.7 m for bankfull width, and 0.9 m to 1.1 m for bankfull depth. Bed material was composed of 100% fines. Instream vegetation was the only source of cover for fish. The total amount of cover present was relatively high, ranging from 98 to 100%. Overall habitat quality was rated as important because of the presence of rare glide-pool habitat complexes.

Ogama Outflow

Ogama Outflow is characterized by long stretches (i.e., 100 m) of riffle and glide habitat, and short stretches (i.e., 10 m) of pool habitat. Stream gradient ranged from 1.2 to 4.0%. Stream channel dimensions ranged from 4.0 m to 12.2 m for bankfull width, and 1.5 m to 2.2 m for bankfull depth. While the primary bed material present was fines, there was a diverse mixture of substrates, at least relative to other streams within the Project area. The major source of cover for fish within Ogama Outflow was instream cover. Trace amounts of overhanging vegetation and large woody debris were also present. Overall habitat quality was rated as marginal.

Patch Outflow

Two surveys of Patch Outflow were completed. The first survey was completed in June during the freshet period, while the second survey was completed in July during the low-flow summer period. Habitat types were pools, riffles and glides. Stream gradient ranged from 1.5 to 2.8%, while the stream bank dimensions ranged from 9.6 m to 14.0 m for bankfull width, and 0.5 m to 1.3 m for bankfull depth. The primary substrate type was fines. A diverse range of cover types were observed at these sites. Pools and instream vegetation were noted as the dominant cover types. Trace amounts of boulder and overhanging vegetation were also present. Overall habitat quality was rated as important due to the observation of lake trout holding in pool areas and habitat use by ninespine stickleback in downstream sections of this stream. The majority of important fish habitat is located in the downstream section of this site where the stream flows into P.O. Lake. Present site designs indicate that a road may cross the Patch Lake Outflow. To protect important fish habitat, the road crossing should be situated immediately downstream of Patch Lake, if possible.

Patch Inflow

A total of nine habitat units were identified within a 200 m-long section of Patch Inflow. Of the nine habitat units, five were pools, two were glides and two were riffles. The mean stream gradient was 1.4%. The mean bankfull width was 1.9 m and the mean bankfull depth was 0.8 m. The bed material was composed of 100% fines. The primary source of cover was instream vegetation, while pool and overhanging vegetation were present in lesser abundances. Overall habitat quality as rated as marginal.

Koignuk Watershed

Koignuk River

Koignuk River is characterized as a large river with stream bank dimensions ranging from 44.0 to 80.0 m for bankfull width, and 0.6 m to 2.6 m for bankfull depth. Stream gradient ranged from 0 to 1.5%. The substrate type present was primarily fines with lesser amounts of cobble, boulders, and bedrock. The amount of total cover ranged from 1 to 10%, with insteam cover being the dominant cover type. Overall habitat quality was rated as important.

Windy Watershed

Glenn Outflow

Glenn Outflow was composed of pool, riffle and glide habitat types. The stream gradient ranged from 0 to 3.2%. Stream bank dimensions ranged from 5.1 m to 8.0 m for bankfull width, and 1.1 m to 1.5 m for bankfull depth. Fines were the predominant substrate type present. Cover available for fish in the outflow ranged from 3.2 to 20%. Instream cover and undercut banks were the primary cover types present. Overall habitat quality was rated as important because Glenn Outflow is a migratory route for anadromous lake trout moving to and from Glenn Lake and Roberts Bay. Juvenile Arctic char, lake trout, whitefish spp. and cisco have also been captured near Roberts Bay.

A road is presently proposed to cross at Glenn Outflow. It is important to note that any development should avoid disrupting habitat at this site for the protection of anadromous lake trout and other fish populations.

Glenn Inflow

Glide and riffle habitat units were identified within a 195 m section of Glenn Inflow. Stream gradient was 1.0%. Stream channel dimensions were 9.2 m for bankfull width and 0.4 m for bankfull depth. The stream bed material was composed of 100% fines. Instream vegetation was the sole source of cover, totalling 7%. Overall habitat quality was rated as marginal.

Windy Outflow

Windy Outflow is composed of pool, riffle and glide habitat types. Stream gradient ranged from 0 to 1.3%, while the stream bank dimensions ranged from 4.5 m to 9.2 m, for bankfull width, and 0.8 m to 1.5 m, for bankfull depth. The stream bed material was predominantly composed of fines. The total amount of cover available for fish within the stream was abundant, ranging from 78 to 90%. Overall habitat quality was rated as marginal.

Windy Inflow

Windy Inflow was characterized as wetland habitat. Field crews observed sculpin (*Cottus* sp.) within the shallow wetland section of the inflow. Mean stream gradient was 1.0%. Stream dimensions were 13.6 m for bankfull width and 0.3 m for bankfull depth. The stream bed material was composed of 100% fines. The total amount of cover present was 100%, which was exclusively instream vegetation. Overall habitat quality was rated as important.

Roberts Bay Watershed

Roberts Bay Inflow

Two surveys were completed for the Roberts Bay Inflow in June and August. During the June survey, fish habitat was limited to a section from the ocean coastline to a point 300 m upstream. Within this section the stream gradient ranged from 1 to 4%. Stream dimensions were 2.5 m for bankfull width and 0.4 m for bankfull depth. Cover for fish populations were present in the form of pools, boulders, instream vegetation and undercut banks. Overall habitat quality was rated as marginal.

Reference Watersheds

Reference A Outflow

Two branches of Reference A Outflow were surveyed in July. The two branches are characterized primarily as riffle habitat with a steep gradient up to 11%. The stream bank channel dimensions ranged from 4.3 to 14.3 m, for bankfull channel width, and the bankfull depth was 0.3 m. The stream bed material was a mixture of gravel, cobble, boulder and bedrock. While boulders were observed as the predominant substrate type, they were also identified as the greatest source of cover for fish populations within the outflow. Reference A Outflow was identified as a stream with a relatively high amount of total cover, ranging from 76 to 86%.

Reference B Outflow

Reference B Outflow is characterized as a stream with various types of pool, glide, riffle and cascade habitats. Stream gradient ranged from 1.5 to 3.5%. The bankfull channel width ranged from 35.9 m to 45.0 m while the mean bankfull channel depth was 0.6 m. The stream bed material was composed of gravel, cobble, boulders and bedrock. The total amount of cover ranged from 24.8 to 57.5% which was comprised of pool, boulders and instream vegetation. Similar to Reference A Outflow, boulders were identified as the primary source of cover for fish populations. Overall habitat quality was rated as important.

Angimajug River Reference

A 200 m-long section of the Angimajug River was surveyed for fish habitat. The river is a large system with a mean bankfull width of 137 m and a gradient of 2%. A single habitat unit was identified within the section of river surveyed – a 200 m-long glide. The mean bankfull depth was 1.5 m. The stream bed material was comprised of a mixture of gravel, cobble, boulder and bedrock substrates. Boulders were the single source of cover identified within the habitat unit. The total amount of cover available for fish in the Angimajug River was 60%. Overall habitat quality was rated as important because the site may be used by Arctic grayling (*Thymallus arcticus*) and Arctic char (*Salvelinus alpinus*) for spawning habitat.

3.2 FISH COMMUNITY

3.2.1 Lake Fish Community

3.2.1.1 Composition and CPUE

Biological data for fish sampled from lakes in the Project area are presented in Appendix 3.2-1. The fish assemblages in all lakes in the Project area displayed very low diversity. Most lakes contained only three species, including: lake trout (Plate 3.2-1), lake whitefish (Plate 3.2-2) and cisco (*Coregonus artedii)*; Plate 3.2-3). Arctic char (Plate 3.2-4) were captured only in Little Roberts Lake and Reference Lake B.

A total of 1,243 fish were captured using gillnets from lakes in the Project area. Of this number, 730 (59%) were cisco, 312 (25%) were lake whitefish, 186 (15%) were lake trout and 16 (1%) were Arctic char.

Plate 3.2-1. Lake trout captured by gillnetting from Ogama Lake, Hope Bay Belt Project, 2009.

Plate 3.2-2. Lake whitefish captured by gillnetting from Doris Lake, Hope Bay Belt Project, 2009.

Plate 3.2-3. Cisco captured by gillnetting from Windy Lake, Hope Bay Belt Project, 2009.

Plate 3.2-4. Arctic char captured by gillnetting from Little Roberts Lake, Hope Bay Belt Project, 2009.

Table 3.2-1 summarizes the total number of gillnet sets, total catch and mean total CPUE (defined as the mean of total CPUE from all gillnet sets). The total number of gillnets set ranged from six at Little Roberts Lake to 55 at Doris Lake, with an average of 19 sets per lake. The number of gillnets set per lake was dependant on lake size and assessment purpose (i.e., population assessment for Doris and Patch lakes). This trend was also reflected in total gillnet effort for each lake. All gillnet set locations are shown in Section 2.2.

Table 3.2-1. Total Lake Gillnet Sets, Catch and CPUE, Hope Bay Belt Project, 2009

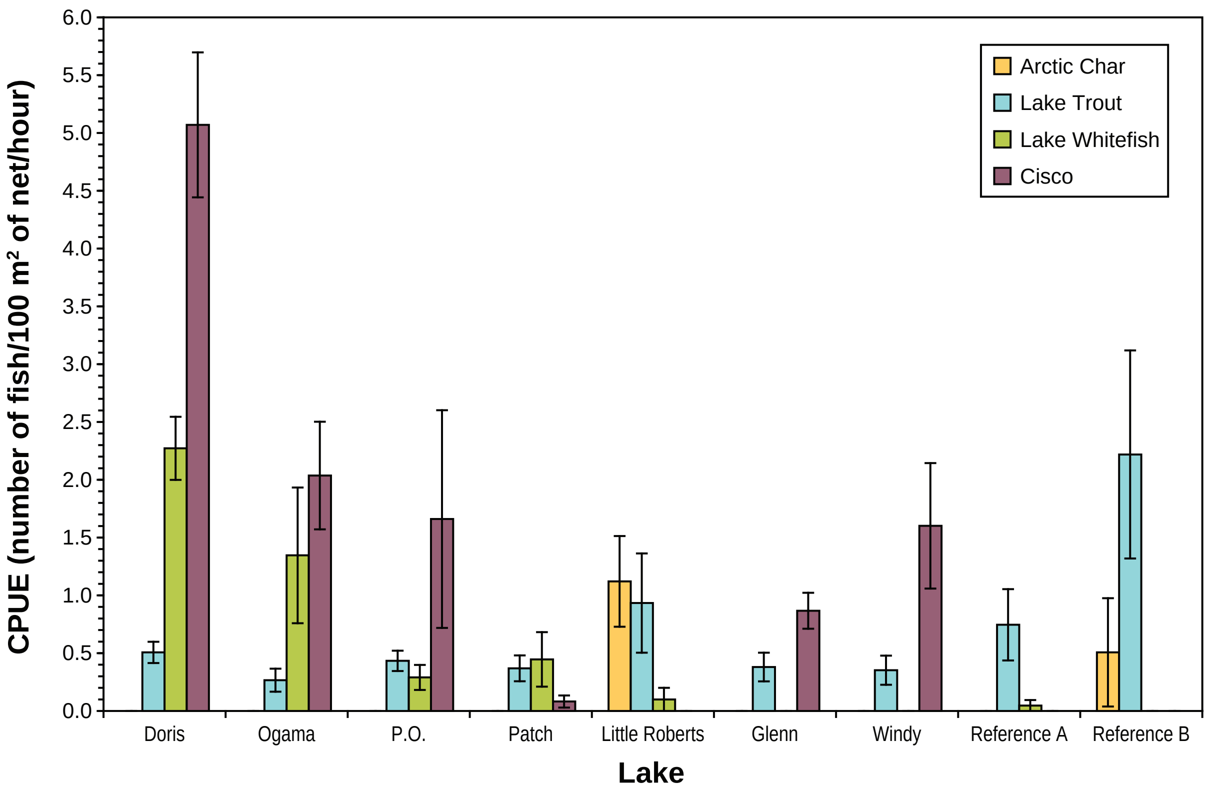
Lake	Watershed	Number of Sets	Catch (Number of fish)				Total Catch	Mean Total CPUE	SE
			ARCH	LKTR	LKWH	LCIS			
Doris	Doris	55	0	47	218	481	746	7.85	0.83
Ogama	Doris	11	0	7	42	65	114	3.65	0.96
P.O.	Doris	15	0	16	10	73	99	2.38	0.94
Patch	Doris	37	0	31	40	6	77	0.90	0.32
Little Roberts	Doris/Roberts	6	12	10	1	0	23	2.15	0.90
Glenn	Windy	22	0	20	0	45	65	1.25	0.19
Windy	Windy	11	0	14	0	60	73	1.91	0.62
Reference A	Reference A	9	0	16	1	0	17	0.79	0.33
Reference B	Reference B	7	4	25	0	0	29	2.73	1.31
Totals		**173**	**16**	**186**	**312**	**730**	**1,243**	**3.63**	**0.37**

Notes:
Species code: ARCH = Arctic char, LKTR = lake trout, LKWH = lake whitefish, LCIS = cisco
CPUE = number of fish/100 m^2 of net/hour
SE = standard error

Figure 3.2-1 shows mean RISC standard gillnet CPUE for each fish species for all lakes assessed in the Project area. Doris Lake had the highest mean CPUE for cisco and lake whitefish. Reference Lake B displayed the highest mean CPUE for lake trout, while Little Roberts Lake had the highest mean CPUE for Arctic char.

Table 3.2-2 summarizes the total effort, total catch and CPUE for minnow traps used at lakes in the Project area. The total minnow trap catch included 317 (99%) ninespine stickleback (*Pungitius pungitius*), three (1%) slimy sculpin and one (<1%) Arctic char. Minnow traps generally captured very few fish from lakes and had very low CPUE. Minnow traps were most successful in capturing ninespine stickleback from P.O. Lake and Reference Lake B.

Table 3.2-3 shows the CPUE of fish captured by RISC standard gillnets from the north and south basins and from three depth ranges. Figure 3.2-2 shows the distribution of RISC standard gillnet CPUE for Doris Lake. Lake trout CPUE showed a clear trend of increased CPUE with depth, with the highest CPUE from the 15 to 20 m depth range. Lake trout CPUE was relatively consistent between the north and south basins in depths ranging from 0 to 10 m. Lake whitefish also showed relatively consistent CPUE at all depth ranges and basins, with the highest CPUE coming from the 5 m to 10 m depth range in the southern basin. The highest CPUE for cisco occurred in the 10 to 15 m range in the southern basin and in the 15 to 20 m range in the northern basin.



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Mean CPUE for All Fish Species Captured using RISC Standard Gillnets from Lakes, Hope Bay Project Area, 2009

Figure 3.2-1

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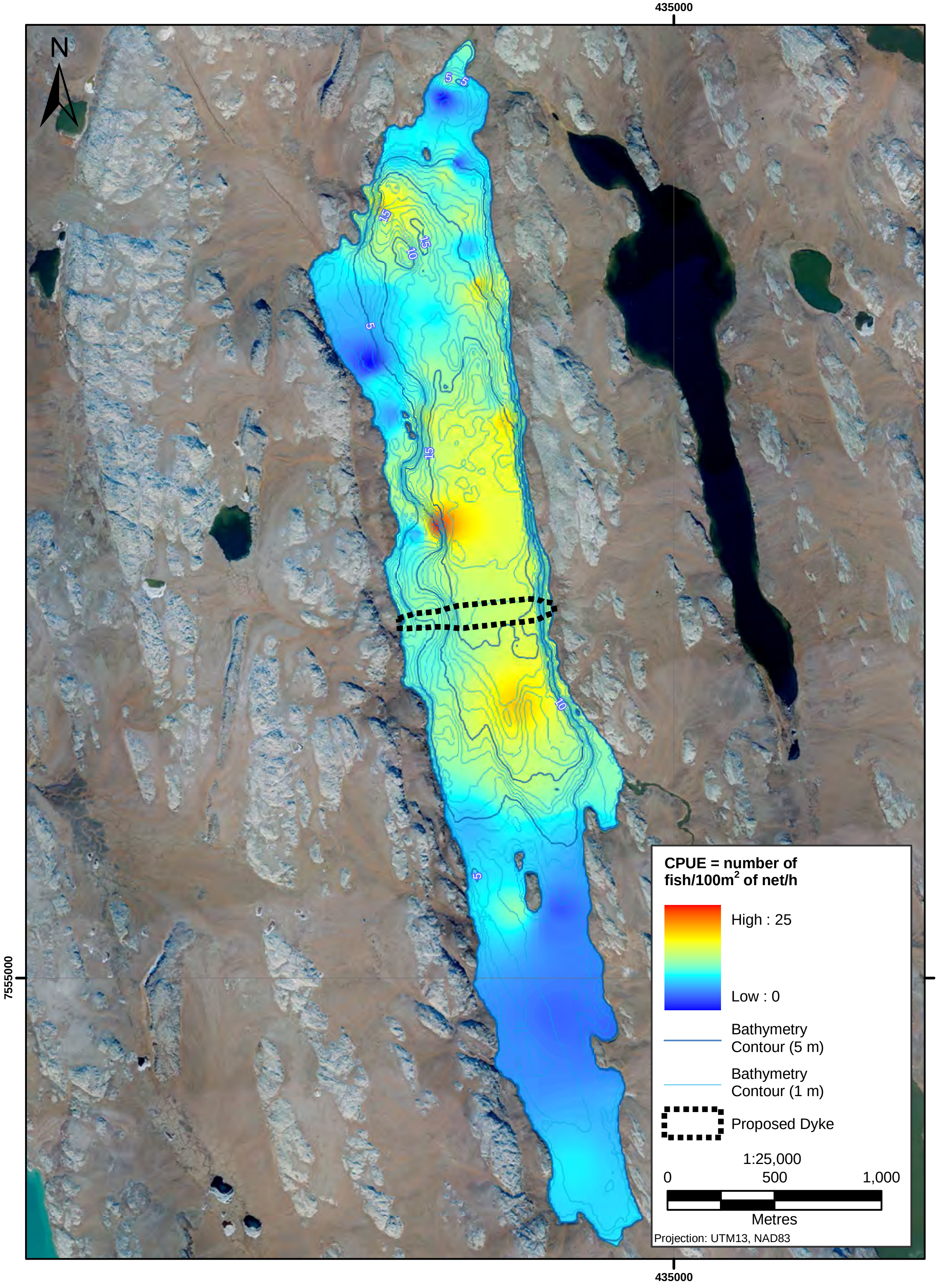

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Distribution of RISC Standard Gillnet CPUE in Doris Lake, Hope Bay Belt Project, 2009

Figure 3.2-2

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Table 3.2-2. Minnow Trap Effort, Catch and CPUE for Lakes, Hope Bay Belt Project, 2009

Lake	Watershed	Number of Traps Set	Total Effort (h)	Catch (Number of fish)			Total Catch	Mean Total CPUE	SE
				ARCH	NSSB	SLSC			
Doris	Doris	50	1,107.4	0	2	0	2	0.04	0.03
Ogama	Doris	9	243.5	0	0	0	0	0.00	0.00
P.O.	Doris	10	251.2	0	231	0	231	22.08	5.36
Little Roberts	Doris/Roberts	9	214.2	0	3	0	3	0.34	0.24
Glenn	Windy	10	240.0	0	0	1	1	0.10	0.10
Windy	Windy	10	240.0	0	1	0	1	0.10	0.10
Reference A	Reference A	15	391.6	0	7	0	7	0.42	0.42
Reference B	Reference B	10	250.2	1	73	2	76	7.22	3.57
Totals		**123**	**2,938.0**	**1**	**317**	**3**	**321**	**2.49**	**0.75**

Notes:
Fish Species Codes: ARCH = Arctic char, NSSB = ninespine stickleback, SLSC = slimy sculpin
CPUE = number of fish/24 h
SE = standard error

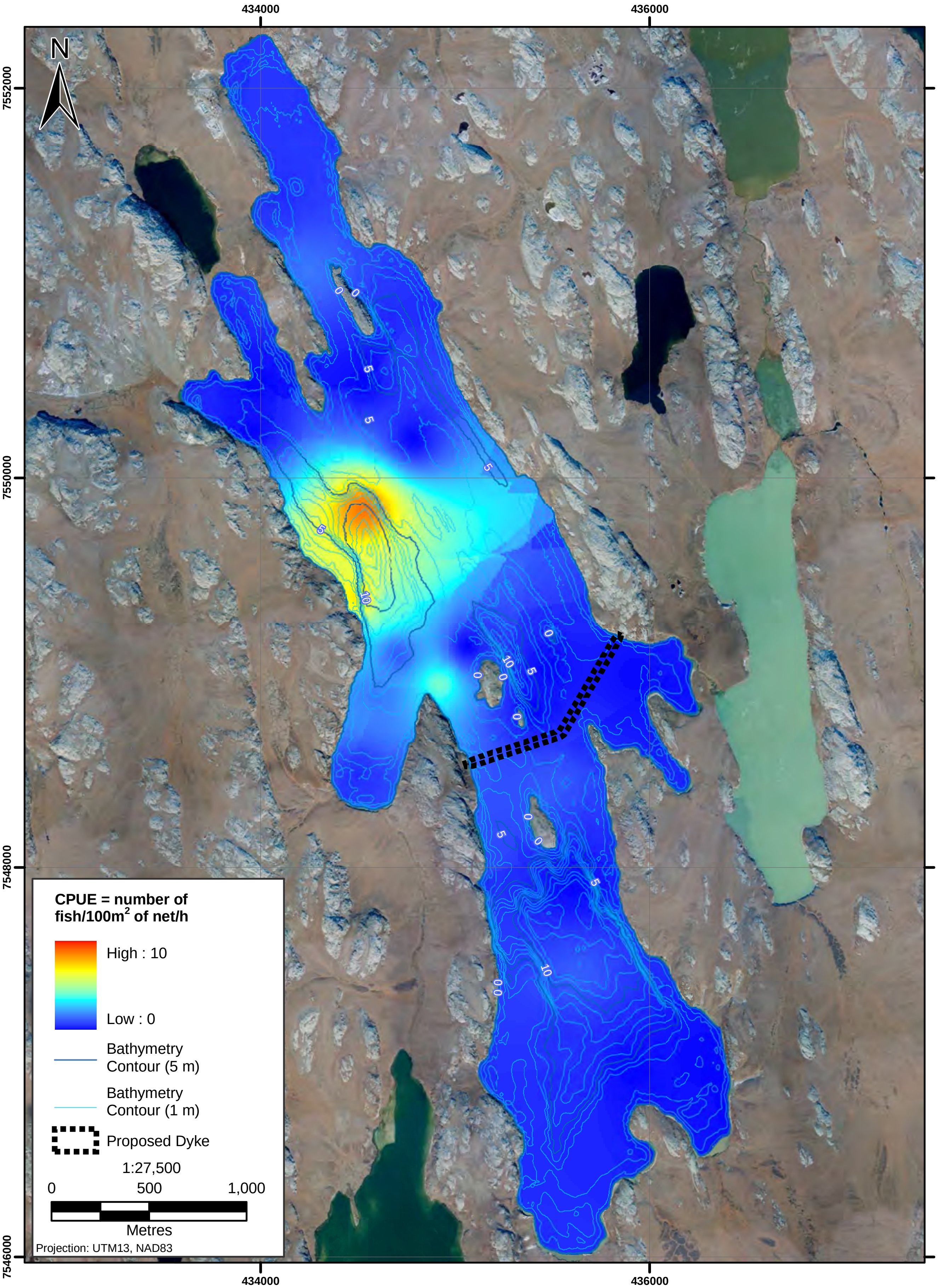
Table 3.2-3. Mean CPUE for Fish Species Captured by RISC Standard Sinking Gillnets in Vertical and Horizontal Strata of Doris Lake, Hope Bay Belt Project, 2009

Lake Basin	Depth Range (m)	LKTR		LKWH		LCIS	
		CPUE	SE	CPUE	SE	CPUE	SE
North	0-5	0.44	0.19	3.12	0.90	3.15	1.01
	5-10	0.53	0.26	2.19	0.28	7.54	2.10
	10-15	0.91	0.31	2.37	0.41	7.45	0.93
	15-20	1.26	0.39	2.95	0.59	9.17	1.74
South	0-5	0.41	0.21	3.15	0.69	2.00	0.56
	5-10	0.50	0.50	4.82	1.16	10.60	0.86

Notes:
Fish Species Codes: LKTR = lake trout, LKWH = lake whitefish, LCIS = cisco.
CPUE = number of fish/100 m^2 of net/hour.
SE = standard error.

Figure 3.2-3 shows the distribution of RISC standard gillnet CPUE for Patch Lake. Areas of relatively high CPUE were adjacent to the deepest portion of Patch Lake along the western shoreline. Relatively low CPUE was associated with areas of shallow depth and the southern basin of Patch Lake.

Table 3.2-4 shows the CPUE of fish captured by RISC standard gillnets from the north and south basins and from three depth ranges of Patch Lake. Relative to Doris Lake, patterns of CPUE were less clearly defined, and CPUE was much lower for each species. Lake trout, lake whitefish and cisco CPUE was highest in the 5 to 10 m range at the northern basin of Patch Lake. The CPUE for cisco was the lowest for the three species.



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Distribution of RISC Standard Gillnet CPUE in Patch Lake, Hope Bay Belt Project, 2009

Figure 3.2-3

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Table 3.2-4. Mean CPUE for Fish Species Captured by RISC Standard Sinking Gillnets in Vertical and Horizontal Strata of Patch Lake, Hope Bay Belt Project, 2009

Lake Basin	Depth Range (m)	LKTR		LKWH		LCIS	
		CPUE	SE	CPUE	SE	CPUE	SE
North	0-5	0.39	0.14	0.24	0.24	0.00	0.00
	5-10	1.26	0.59	2.32	1.45	0.61	0.32
South	0-5	0.00	0.00	0.34	0.34	0.00	0.00
	5-10	0.44	0.00	0.00	0.00	0.00	0.00
	10-15	0.27	0.27	0.27	0.27	0.00	0.00

Notes:
Fish Species Codes: LKTR = lake trout, LKWH = lake whitefish, LCIS = cisco
CPUE = number of fish/100 m^2 of net/hour
SE = standard error

Hydroacoustics

Doris Lake

Appendix 3.2-2 presents fish density data collected during hydroacoustic surveys of Doris Lake. Figure 3.2-4 shows an example echogram from the down-looking transducer at a portion of Transects 5 and 9 showing the majority of fish below a depth of 5 m. Figure 3.2-5 illustrates patterns of fish density at Doris Lake. The highest density of fish observed in Doris Lake was 0.02 fish/m^3 or greater than 1,050 fish/ha. Areas of high fish density were most frequently observed below 10 m in depth in the main basin.

Relatively few fish were detected by either down-looking or side-looking transducers in shallow (<5 m deep) areas such as the southern (Transects 1 to 4) and northern (Transect 14) portions of Doris Lake. These patterns of fish density are similar to those of relative abundance derived from gillnet CPUE data, which showed the highest CPUE occurred in the relatively deep main basin and the lowest CPUE in the shallow north and south portions of Doris Lake.

Table 3.2-5 shows the estimated absolute abundance of fish in 5 m depth ranges, and between the north and south portions of Doris Lake. The total number of fish in Doris Lake was estimated at 55,806 with the 95% confidence limits ranging from 41,982 to 69,629. The northern portion of Doris Lake had an estimated 33,746 fish, while the southern portion of the lake had an estimated 22,060 fish. This difference was attributed to the greater proportion of deep water habitat available in the northern half of Doris Lake. The 10 to 15 m depth range in the northern portion of Doris Lake had the greatest number of fish (14,211). The 15 to 20 m depth ranged showed the highest density of fish at 0.00878 fish/m^3. These data lend further support to the fish density pattern illustrated in Figure 3.2-5, suggesting that fish density increases with increasing depth.

Table 3.2-6 shows the population estimates for lake trout, lake whitefish and cisco in Doris Lake. The species composition and proportions were derived from RISC standard sinking gillnet catches. Lake trout were relatively evenly distributed among depth ranges; however, greater total numbers of lake trout were estimated for the northern portion of Doris Lake. Lake whitefish estimates were highest in the 0 to 5 m depth range. The estimated lake whitefish population was nearly identical for the northern and southern portions at 8,018 and 7,795 fish, respectively. This observation suggests that although distribution patterns of fish density are highest in the deep basins, the shallow portions of Doris Lake may be important specifically for lake whitefish. In contrast, cisco were the predominant species in nearly all depth ranges and locations. The greatest proportion and numbers of cisco were found in the 10 to 15 m depth range at the northern portion of Doris Lake. These observations suggest that cisco are driving the trend of greater density of fish with increasing depth illustrated in Figures 3.2-2, 3.2-4, and 3.2-5.

Table 3.2-5. Fish Density and Estimate of Absolute Abundance (All Species Combined) Derived from Hydroacoustics Data for Doris Lake, Hope Bay Project, 2009

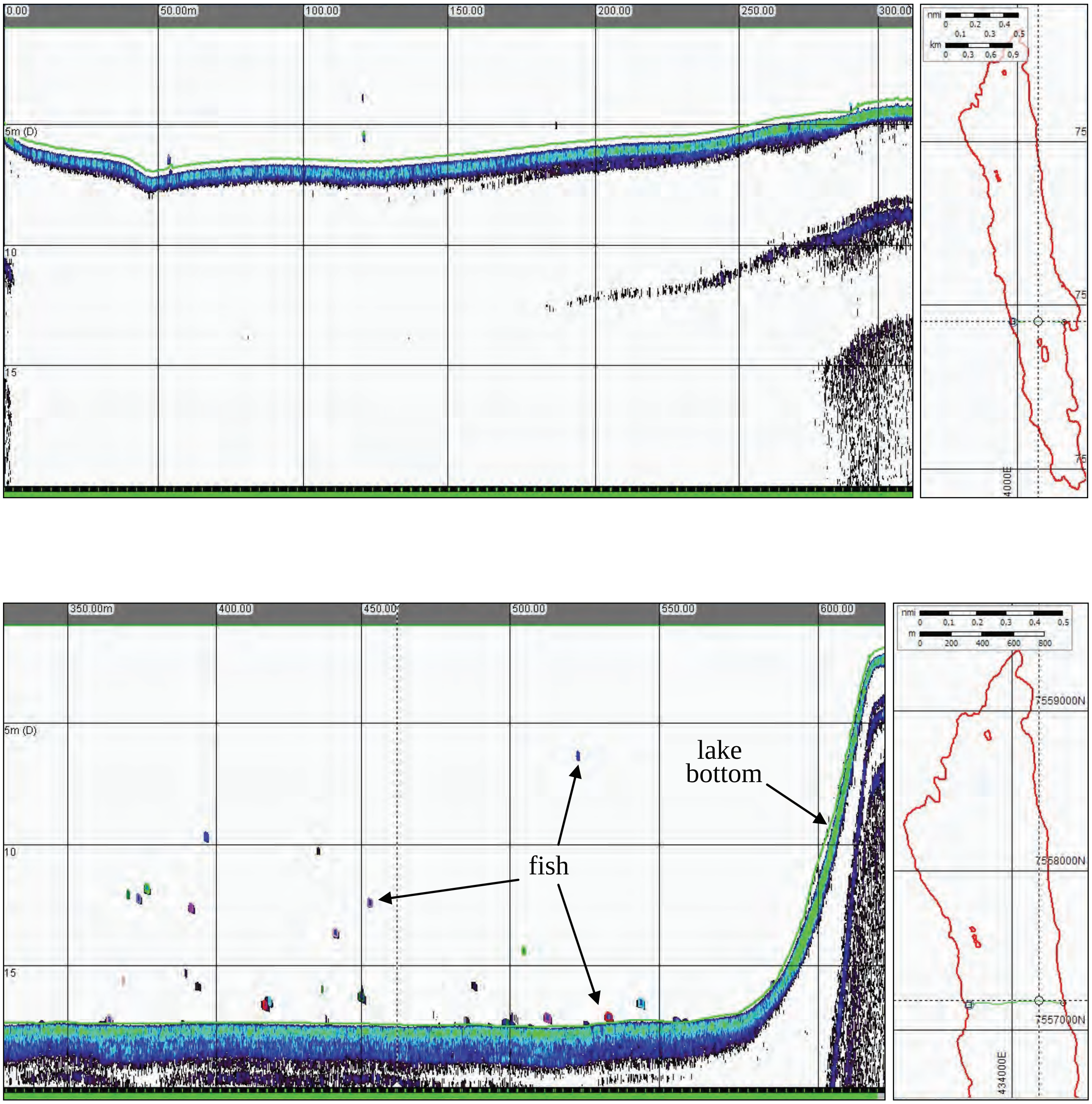
Lake Basin	Depth Range (m)	Mean Number/m^3	Variance	Sample Size **	Stratum Volume (m^3)	Estimate of Absolute Abundance	SE	95% CL	
								Lower	Upper
North	0-5	0.00037	3.2E-08	7	7.2E+06	2,640	489	1,443	3,837
	5-10	0.00190	7.5E-07	6	5.3E+06	10,152	1,891	5,292	15,013
	10-15	0.00418	1.1E-05	6	3.4E+06	14,211	4,621	2,333	26,089
	15-20	0.00878	6.0E-05	5	7.7E+05	6,743	2,667	-662	14,147
	Basin Total			**24**	**1.7E+07**	**33,746**	**5,681**	**21,895**	**45,597**
South	0-5	0.00073	3.1E-07	7	5.9E+06	4,246	1,235	1,225	7,267
	5-10	0.00585	4.5E-06	3	2.4E+06	13,760	2,867	1,426	26,095
	10-15	0.00432	8.5E-06	2	9.3E+05	4,000	1,913	-20,311	28,312
	15-20*	0.00432	8.5E-06	1	1.2E+04	53	36	-403	509
	Basin Total			**13**	**9.1E+06**	**22,060**	**3,661**	**13,777**	**30,342**
Total (North + South Basins)						**55,806**	**6,759**	**41,982**	**69,629**

Notes:
** Variance estimated by regression using data from other depths.*
*** Number of transects with corresponding depth interval.*
CL = confidence limit; SE = standard error

Table 3.2-6. Relative Abundance and Population Estimates for Individual Fish Species Derived from Hydroacoustics Data for Doris Lake, Hope Bay Project, 2009

Lake Basin	Depth Range (m)	Percent by Species			Number by Species			Total Number
		LKTR	LKWH	LCIS	LKTR	LKWH	LCIS	
North	0-5	6.6	46.4	47.0	174	1,226	1,240	2,640
	5-10	5.2	21.3	73.5	527	2,167	7,458	10,152
	10-15	8.5	22.1	69.5	1,203	3,137	9,871	14,211
	15-20	9.4	22.1	68.5	633	1,487	4,622	6,743
	Basin Total				**2,537**	**8,018**	**23,191**	**33,746**
South	0-5	7.4	56.6	36.0	313	2,405	1,528	4,246
	5-10	3.1	30.3	66.6	431	4,164	9,166	13,760
	10-15	3.1	30.3	66.6	125	1,211	2,665	4,000
	15-20*	3.1	30.3	66.6	2	16	35	53
	Basin Total				**871**	**7,795**	**13,394**	**22,060**
Total (North + South Basins)					**3,408**	**15,813**	**36,584**	**55,806**

Notes:
** None of the acoustic transects were greater than 15 m deep. Density and variance of the 10 to 15 m layer were used as estimates of 15 to 20 m layer density and variance.*
Fish Species Codes: LKTR = lake trout; LKWH = lake whitefish; LCIS = cisco



Notes: *Crosshairs on the maps to the right show the locations of the data illustrated.*
The grid spacing on the ecograms is 5 m vertically and 50 m horizontally.

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Example Echogram Produced from Hydroacoustic Surveys of Doris Lake, Hope Bay Belt Project, 2009

Figure 3.2-4

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