

## Appendix V5-3J

2009 Freshwater Baseline Report, Hope Bay Belt Project



Hope Bay Mining Limited



# 2009 Freshwater Baseline Report, Hope Bay Belt Project



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# 2009 FRESHWATER BASELINE REPORT, HOPE BAY BELT PROJECT

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**Prepared for:**



Hope Bay Mining Limited

**Prepared by:**



**Engineers and Scientists**

Rescan™ Environmental Services Ltd.  
Vancouver, British Columbia

## **Executive Summary**

## Executive Summary

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Environmental baseline studies were conducted by Rescan Environmental Services Ltd. (Rescan) in 2009, on behalf of Hope Bay Mining Ltd. (HBML), for the Hope Bay Belt Project. The Hope Bay Belt Property is located approximately 125 km southwest of Cambridge Bay, Nunavut, on the south shore of Melville Sound. The nearest communities are Omingmaktok (Bay Chimo; 75 km to the southwest of the property), Cambridge Bay, and Kingaok (Bathurst Inlet; 160 km to the southwest of the property).

The environmental baseline program conducted in 2009 was based on the plan to develop multiple deposits in the belt. The 2009 program was also based on Newmont's priorities as of early 2009, which included regulatory compliance with the existing Doris North Project permits and licences. Baseline work was primarily focused on the north end of the belt in 2009. This report presents the findings of the 2009 freshwater baseline study, and includes a comparison to historically collected data. Freshwater fisheries data are presented as a separate report.

The primary objective of the 2009 freshwater program was to collect additional aquatic baseline data relevant to the planned project to support permitting and project design. This report presents the methods used to collect and analyze the freshwater aquatic data for 2009 as well as a comparison of the results to historical site data.

The 2009 aquatic baseline program involved collecting information for the following: lake water quality (winter and summer), physical limnology (winter and summer), lake sediment quality, lake phytoplankton, lake zooplankton, lake benthos, stream water quality, stream sediment quality, stream periphyton, and stream benthos. The program included collecting samples from lakes and streams in areas that could potentially be influenced by future mining activities. Two reference lakes and their associated outflows located well away from potential Project activities were also sampled, as was a reference river location on the Angimajuq River. A total of 13 lakes and 12 streams/ivers were sampled in 2009.

Analytical results from all samples collected as part of the 2009 freshwater baseline program are provided as appendices to this report. The following text provides a brief summary of the various components sampled as part of the 2009 freshwater baseline program.

### Lake Physical Limnology

During winter, the dissolved oxygen concentration in Project area lakes ranged from nearly anoxic ( $\leq 1$  mg/L) in the bottom waters of Ogama, Little Roberts, and Wolverine lakes to supersaturated in the surface waters of several lakes (maximum of 16.9 mg/L in Glenn Lake). During the summer, dissolved oxygen levels ranged from 7.8 mg/L in Patch North to 13.2 mg/L in Reference Lake A. Winter water temperatures ranged between 0.2 and 2.1°C, with coldest temperatures near the surface ice and water warming with depth. During summer, lakes were generally well-mixed or weakly stratified.

Water clarity in most lakes surveyed was relatively low, as secchi depths were typically less than 2 m. Reduced water clarity was likely attributable to the re-suspension of fine sediments along the shorelines of lakes resulting from wave action and high winds common to the area. Euphotic zone depth ranged from 3.7 to 30.4 m and extended through the entire water column at most lakes, except the deepest or most turbid.

River water temperatures during winter ranged from 0 to 0.3°C at the sites surveyed along the Koignuk River. Dissolved oxygen concentrations were extremely high (16.19 mg/L) at the upstream site of the Koignuk River, and very low (2.17 mg/L) at the downstream site.

#### Lake Water Quality

Lakes in the study area were neutral to slightly basic (with pH ranging from 6.9 to 8.3) and contained variable concentrations of metals and nutrients. Water column parameters did not vary significantly with depth, as most lakes were shallow and well-mixed to weakly stratified. Seasonal water quality trends were apparent in some lakes, with winter concentrations of certain parameters greatly exceeding summer levels. This trend was particularly evident for total dissolved solids, total organic carbon, sulphate, total phosphorus, ammonia, nitrate, and several metals (e.g., chromium, copper, iron, and lead).

Nitrate concentrations ranged from below detection in several lakes to 0.177 mg/L in Ogama Lake. Lakes within the Doris and Little Roberts watersheds contained the highest nitrate levels. Concentrations of nitrite were generally below analytical detection limits. Ammonia concentrations ranged from below detection in several lakes to 0.133 mg/L in Wolverine Lake. The highest concentrations of ammonia were measured in Wolverine and Nakhaktok lakes, which are the lakes located furthest upstream in the Doris and Windy watersheds, respectively.

Total phosphorus concentrations ranged from 0.002 mg/L at Reference Lake B to 0.095 mg/L at Nakhaktok Lake. Based on the Canadian Council of Ministers of the Environment (CCME) recommended trigger ranges for total phosphorus, Windy Lake and Reference Lakes A and B would be categorized as ultra-oligotrophic to oligotrophic (depending on the season), Imniagut, Patch North and South, P.O., and Naiqunnguut lakes would be categorized as oligotrophic, while Little Roberts Lake (during winter only) and Nakhaktok Lake would be considered eutrophic systems. Doris Lake North and South ranged from mesotrophic to meso-eutrophic depending on the season.

Glenn Lake (in the Windy Watershed) tended to contain the highest average aluminum, copper, iron, and molybdenum concentrations, and the Windy Watershed as a whole had higher molybdenum levels than the other watersheds. Nickel concentrations in Imniagut Lake were markedly higher than other lakes, while zinc levels in Doris S also tended to be higher than other lakes. Average metal concentrations in lakes were generally below CCME guidelines, with the following exceptions: aluminum in P.O., Ogama, Naiqunnguut, and Glenn lakes; chromium in Wolverine and Glenn lakes; copper in Ogama, Naiqunnguut, and Glenn lakes; iron in Wolverine and Glenn lakes; and zinc in Doris Lake South. These elevated concentrations occur naturally within study area lakes.

#### Lake Sediment Quality

Lake sediments were largely composed of clay and silt, with lesser amounts of sand and little gravel. The proportion of fine particles in sediments increased with depth, except at Nakhaktok Lake. An increase in fine sediments (clay and silt) within a lake was generally associated with an increase in all parameters evaluated with the exception of phosphorus. There were few clear trends in sediment chemistry among lake sites, though sediments from Wolverine and Imniagut lakes in the Doris Watershed contained relatively high concentrations of total organic carbon, ammonium, total nitrogen, and total sulphur. Lake sediments were naturally elevated in arsenic, chromium, and copper, and concentrations of these metals were often higher than CCME interim sediment quality guidelines. Within-site annual variability was comparable in magnitude to within-year variability observed among sites.

### Lake Phytoplankton

Lake phytoplankton biomass (as chlorophyll *a*) ranged from 0.3 to 26.9 µg chl *a*/L, and was highest in Ogama, Doris North and South, and Little Roberts lakes (in the Doris Watershed) and Nakhaktok Lake (in the Windy Watershed). Trends in phytoplankton abundance and biomass were similar. Phytoplankton taxonomic composition varied substantially among lakes, though cyanobacteria (blue-green algae) were consistently dominant at sites with high levels of phytoplankton abundance and biomass. In other lakes, the taxonomic assemblage was mainly composed of chlorophytes, cryptophytes, and diatoms. Phytoplankton richness and diversity ranged from 6 to 20 genera/sample and from 0.08 to 0.87, respectively, across all sites and seasons. Genera richness and diversity were consistently lowest at Nakhaktok and Doris North and South lake sites. Phytoplankton diversity and richness generally followed similar trends.

The taxonomic composition of epontic algae (algae living on the underside of the ice) in a particular lake was similar to the winter phytoplankton composition in that lake. The assemblage of epontic algae was mainly composed of cyanobacteria in Doris Lake North and South, chrysophytes and dinoflagellates in Little Roberts Lake, cryptophytes in Patch Lake North and South, and chrysophytes in Ogama Lake. Epontic richness ranged from 6 to 17 genera and followed a similar trend as diversity, which ranged from 0.26 to 0.88. Richness and diversity levels were consistently lowest at Doris South and highest at Ogama Lake.

### Lake Zooplankton

In general, zooplankton abundance varied widely among lakes with no obvious watershed-specific trends. Zooplankton abundance ranged from 2,200 to 282,000 organisms/m<sup>3</sup>, and Imniagut and Nakhaktok lakes contained the highest abundance levels. The zooplankton assemblage in lakes typically consisted of cladocerans, copepods, rotifers and protists. Zooplankton genera richness ranged from 3 to 12 genera/sample, and diversity ranged from 0.14 to 0.78. Richness and diversity were particularly low in Windy and Glenn lakes, but were relatively similar among the other sites surveyed.

### Lake Benthos

Lake benthos densities ranged from 116 to 23,600 organisms/m<sup>2</sup>. The highest levels of benthos density were found in Wolverine (13,300 organisms/m<sup>2</sup>), Imniagut (23,600 organisms/m<sup>2</sup>), Nakhaktok (7,700 organisms/m<sup>2</sup>), and Little Roberts lakes (11,800 organisms/m<sup>2</sup>). Lake benthic communities were generally dominated by dipterans (80% of individuals found), although pelecypods, ostracods, and oligochaetes were also prevalent. Benthic genera richness averaged 6 genera/sample, with an average diversity of 0.54. Benthic diversity and richness were generally highest in samples collected from the shallow depth zone, and Windy and Glenn lakes tended to have the lowest levels of diversity and richness.

### Stream Water Quality

Streams and rivers in the study area were neutral to slightly basic (with pH ranging from 6.9 to 8.1). Seasonal trends were apparent in some Hope Bay Belt streams and rivers. Parameters such as nitrate, ammonia, total phosphorus, copper, chromium, and nickel tended to be highest in winter or during freshet and lowest during the summer. These trends were most apparent in Glenn Outflow Downstream and the Koignuk River sites. Turbidity levels were variable across streams, and were particularly high in Glenn Outflow Downstream during freshet.

Nitrate and ammonia concentrations were frequently below detection limits, and reached a maximum of 0.56 and 0.044 mg/L (for nitrate and ammonia respectively) in Koignuk River Upstream during winter. Nitrite concentrations were always below detection limits. Total phosphorus levels were variable across stream sites, ranging from 0.002 mg/L (Wolverine Outflow in June) to 0.053 mg/L (Glenn Outflow Downstream in June). Within a watershed, total phosphorus concentrations generally increased with distance downstream. In the Doris Watershed, the lowest levels of total phosphorus were observed in Wolverine and Patch outflows, which would be categorized as ultra-oligotrophic and oligotrophic, respectively, based on the CCME trigger ranges for total phosphorus. Stream sites located furthest downstream in the Doris and Little Roberts watersheds (Doris and Little Roberts outflows) would be categorized as mesotrophic to meso-eutrophic. A similar trend was apparent in the Windy watershed, where the upstream Windy Outflow would be categorized as ultra-oligotrophic to oligotrophic, while the downstream Glenn Outflow Downstream would be considered mesotrophic to eutrophic. River sites ranged from oligotrophic to mesotrophic in the Angimajuq and from oligotrophic to meso-eutrophic in the Koignuk (depending on the season).

In general, concentrations of total metals were highest in Glenn Outflow Downstream and lowest in Windy Outflow. Molybdenum levels tended to be highest within the streams of the Windy Watershed compared to the other watersheds. These trends are consistent with the lake water quality data, indicating that the water quality of streams reflects the water quality of the upstream lakes that feed them. Average metal concentrations in streams and rivers were generally below CCME guidelines, with the following exceptions: aluminum in all streams/rivers except Wolverine, Doris, and Reference Lake A and B outflows; chromium in P.O. Outflow, Glenn Outflow Downstream, and the Koignuk River sites; copper in Glenn Outflow Downstream and Koignuk Midstream and Downstream; iron in P.O., Ogama, and Little Roberts outflows, Glenn Outflow Downstream, and the Angimajuq and Koignuk River sites; and lead in Koignuk Midstream. These elevated metal concentrations occur naturally within study area streams and rivers.

### Stream Sediment Quality

Stream sediments consisted of a highly variable mixture of gravel, sand, silt and clay. Sediments in Reference Lake A Outflow were predominantly composed of sand, while sediments in the Angimajuq River Reference and in Reference Lake B, Ogama, and Doris outflows were mainly composed of gravel and sand. In all other surveyed streams, sediments were predominantly composed of a sand-silt mixture. There were few apparent trends in sediment chemistry among streams; however, stream sediments generally contained lower metal concentrations than lake sediments. Chromium concentrations in sediments were naturally elevated and were occasionally higher than CCME interim sediment quality guidelines.

### Stream Periphyton

Periphyton biomass ranged from approximately 66 to 2,500  $\mu\text{g chl } a/\text{m}^2$ , while density ranged from 58,000 to 400,000 individuals/ $\text{cm}^2$  among stream sites. Biomass and density levels were particularly high in Ogama Outflow, the Koignuk River, and the Angimajuq River Reference. Diatoms were the dominant periphyton taxa in all streams surveyed. Genera richness ranged from 8 to 16 genera/sample and averaged 13 genera/sample. Periphyton diversity was relatively high at all sites (Simpson's diversity index between 0.57 and 0.87) except Windy Outflow (0.32).

**Stream Benthos**

Stream benthos density ranged from 770 to 25,100 organisms/m<sup>2</sup>. Benthos density was highest in Doris Outflow. Ogama Outflow, Little Roberts Outflow, and the midstream portion of the Koignuk River also contained dense benthos communities. Stream benthos assemblages were dominated by dipterans, which represented ~70% of the stream benthic organisms. Nematodes, oligochaetes, and ostracods were also common in study area streams. Benthic community richness ranged from 9 to 21 genera/sample, with an average of 15 genera/sample. Dipteran richness generally corresponded closely with community richness, and averaged 10 genera/sample. Simpson's diversity index averaged 0.73 for the entire benthic community, and 0.66 for dipterans.

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## **Table of Contents**

# 2009 FRESHWATER BASELINE REPORT, HOPE BAY BELT PROJECT

## Table of Contents

---

Executive Summary .....	i
Acknowledgements .....	xi
Table of Contents .....	xi
List of Appendices.....	xiii
List of Figures.....	xiv
List of Tables .....	xx
List of Plates .....	xxi
1. Introduction .....	1-1
2. Methods .....	2-1
2.1 Monitoring Locations and Sampling Program.....	2-1
2.2 Physical Limnology.....	2-1
2.2.1 Winter Lake Physical Limnology .....	2-4
2.2.2 Summer Lake Physical Limnology.....	2-4
2.3 Lake Water Quality.....	2-22
2.3.1 Winter Lake Water Quality .....	2-22
2.3.2 Summer Lake Water Quality.....	2-24
2.3.3 Quality Assurance/Quality Control (QA/QC).....	2-24
2.4 Stream and River Water Quality .....	2-26
2.4.1 Winter River Water Quality and Limnology.....	2-26
2.4.2 Summer Stream Water Quality.....	2-26
2.4.3 Quality Assurance/Quality Control (QA/QC).....	2-27
2.5 Lake Sediment Quality .....	2-27
2.6 Stream Sediment Quality .....	2-29
2.7 Phytoplankton.....	2-29
2.7.1 Winter Phytoplankton and Epontic Algal Sampling .....	2-29
2.7.2 Summer Phytoplankton Sampling.....	2-29
2.8 Periphyton.....	2-30
2.9 Zooplankton .....	2-30
2.10 Lake Benthos .....	2-30
2.11 Stream Benthos .....	2-31
2.12 Data Management and Analysis .....	2-31
2.12.1 Physical Limnology.....	2-31

2.12.2	Water Quality.....	2-31
2.12.3	Sediment Quality .....	2-31
2.12.4	Aquatic Biology.....	2-32
2.13	Historical Data .....	2-32
3.	Results and Discussion .....	3-1
3.1	Physical Limnology.....	3-1
3.1.1	Winter .....	3-1
3.1.1.1	Lakes .....	3-1
3.1.1.2	Rivers.....	3-6
3.1.2	Summer - Lakes .....	3-7
3.1.3	Physical Limnology Summary.....	3-7
3.2	Lake Water Quality.....	3-11
3.2.1	Depth Variation .....	3-49
3.2.2	Seasonal Variation .....	3-49
3.2.3	Spatial Variation .....	3-49
3.2.4	Comparison with CCME Guidelines .....	3-50
3.2.5	2009 Lake Water Quality Assurance/Quality Control.....	3-51
3.2.6	Annual Variation.....	3-51
3.2.7	Lake Water Quality Summary.....	3-56
3.3	Stream Water Quality.....	3-57
3.3.1	Seasonal Variation .....	3-57
3.3.2	Spatial Variation .....	3-94
3.3.3	Comparison with CCME Guidelines .....	3-95
3.3.4	2009 Stream Water Quality Assurance/Quality Control.....	3-95
3.3.5	Annual Variation.....	3-95
3.3.6	Stream Water Quality Summary.....	3-96
3.4	Lake Sediment Quality .....	3-101
3.4.1	Depth Variation .....	3-101
3.4.2	Spatial Variation .....	3-101
3.4.3	Comparison with CCME Guidelines .....	3-127
3.4.4	Annual Variation.....	3-127
3.4.5	Lake Sediment Quality Summary .....	3-127
3.5	Stream and River Sediment Quality.....	3-127
3.5.1	Spatial Variation .....	3-128
3.5.2	Comparison with CCME Guidelines .....	3-128
3.5.3	Annual Variation.....	3-128
3.5.4	Stream and River Sediment Quality Summary.....	3-128
3.6	Phytoplankton.....	3-128
3.6.1	Phytoplankton Biomass.....	3-145
3.6.2	Phytoplankton Abundance .....	3-145
3.6.3	Phytoplankton Taxonomic Composition.....	3-145
3.6.4	Phytoplankton Richness and Diversity .....	3-145

3.6.5	Epontic Algae Taxonomic Composition and Diversity.....	3-149
3.6.6	Annual Comparison .....	3-149
3.6.7	Phytoplankton Summary .....	3-154
3.7	Periphyton.....	3-154
3.7.1	Periphyton Biomass .....	3-154
3.7.2	Periphyton Density.....	3-156
3.7.3	Periphyton Taxonomic Composition .....	3-156
3.7.4	Periphyton Richness and Diversity.....	3-156
3.7.5	Annual Comparison .....	3-156
3.7.6	Periphyton Summary.....	3-160
3.8	Zooplankton .....	3-160
3.8.1	Zooplankton Abundance .....	3-160
3.8.2	Zooplankton Taxonomic Composition.....	3-160
3.8.3	Zooplankton Richness and Diversity.....	3-160
3.8.4	Annual Comparison .....	3-163
3.8.5	Zooplankton Summary .....	3-163
3.9	Lake Benthos .....	3-163
3.9.1	Lake Benthos Density .....	3-165
3.9.2	Lake Benthos Taxonomic Composition.....	3-165
3.9.3	Lake Benthos Diversity .....	3-165
3.9.3.1	Community Diversity.....	3-165
3.9.3.2	Dipteran Diversity.....	3-165
3.9.4	Annual Comparison .....	3-172
3.9.5	Lake Benthos Summary .....	3-172
3.10	Stream Benthos .....	3-174
3.10.1	Stream Benthos Density .....	3-174
3.10.2	Stream Benthos Taxonomic Composition.....	3-174
3.10.3	Stream Benthos Diversity.....	3-174
3.10.3.1	Community Diversity.....	3-174
3.10.3.2	Dipteran Diversity.....	3-174
3.10.4	Annual Comparison .....	3-178
3.10.5	Stream Benthos Summary .....	3-178
	References.....	R-1

### **List of Appendices**

Appendix 3.1-1 - Lakes Dissolved Oxygen/Temperature Profiles, Hope Bay Belt Project, 2009

Appendix 3.1-2 - River Dissolved Oxygen/Temperature Profiles, Hope Bay Belt Project, 2009

Appendix 3.2-1 - Winter Lake Water Quality Analytical Results, Hope Bay Belt Project, 2009

Appendix 3.2-2 - Summer Lake Water Quality Analytical Results, Hope Bay Belt Project, 2009

Appendix 3.2-3 - Lake Water Quality QA/QC, Hope Bay Belt Project, 2009

Appendix 3.3-1 - Stream Water Quality Analytical Results, Hope Bay Belt Project, 2009

Appendix 3.3-2 - Stream Water Quality QA/QC, Hope Bay Belt Project, 2009

Appendix 3.4-1 - Lake Sediment Quality Descriptions, Hope Bay Belt Project, 2009

Appendix 3.4-2 - Lake Sediment Quality Photographs, Hope Bay Belt Project, 2009

Appendix 3.4-3 - Lake Sediment Quality Analytical Results, Hope Bay Belt Project, 2009

Appendix 3.5-1 - Stream Sediment Quality Analytical Results, Hope Bay Belt Project, 2009

Appendix 3.6-1 - Phytoplankton Biomass Results, Hope Bay Belt Project, 2009

Appendix 3.6-2 - Summer Phytoplankton Abundance and Taxonomic Results, Hope Bay Belt Project, 2009

Appendix 3.6-3 - Winter Phytoplankton Abundance and Taxonomic Results, Hope Bay Belt Project, 2009

Appendix 3.6-4 - Winter Epontic Algae Taxonomic Results, Hope Bay Belt Project, 2009

Appendix 3.7-1 - Periphyton Biomass Results, Hope Bay Belt Project, 2009

Appendix 3.7-2 - Periphyton Density and Taxonomic Results, Hope Bay Belt Project, 2009

Appendix 3.8-1 - Zooplankton Abundance and Taxonomic Results, Hope Bay Belt Project, 2009

Appendix 3.9-1 - Lake Benthos and Taxonomic Results, Hope Bay Belt Project, 2009

Appendix 3.10-1 - Stream Benthos Density and Taxonomic Results, Hope Bay Belt Project, 2009

### **List of Figures**

<b>FIGURE</b>	<b>PAGE</b>
Figure 1-1. Hope Bay Belt Project Location .....	1-3
Figure 1-2. Site Layout Options Considered for 2009 Baseline Program.....	1-5
Figure 2.1-1. Water Quality, Sediment Quality, and Aquatic Biology Sampling Locations, Hope Bay Belt Project, 2009 .....	2-7
Figure 2.1-2a. Environmental Sampling Locations for Wolverine Lake .....	2-9
Figure 2.1-2b. Environmental Sampling Locations for Patch Lake.....	2-10
Figure 2.1-2c. Environmental Sampling Locations for Imniagut Lake.....	2-11
Figure 2.1-2d. Environmental Sampling Locations for P.O. Lake .....	2-12

Figure 2.1-2e. Environmental Sampling Locations for Ogama Lake .....	2-13
Figure 2.1-2f. Environmental Sampling Locations for Doris Lake .....	2-14
Figure 2.1-2g. Environmental Sampling Locations for Little Roberts Lake .....	2-15
Figure 2.1-2h. Environmental Sampling Locations for Naiqunnguut Lake.....	2-16
Figure 2.1-2i. Environmental Sampling Locations for Nakhaktok Lake .....	2-17
Figure 2.1-2j. Environmental Sampling Locations for Windy Lake.....	2-18
Figure 2.1-2k. Environmental Sampling Locations for Glenn Lake.....	2-19
Figure 2.1-2l. Environmental Sampling Locations for Reference Lake A.....	2-20
Figure 2.1-2m. Environmental Sampling Locations for Reference Lake B .....	2-21
Figure 2.13-1. Historical Water Quality Sampling Locations, Hope Bay Belt Project .....	2-39
Figure 2.13-2. Historical Sediment Quality Sampling Locations, Hope Bay Belt Project.....	2-41
Figure 2.13-3. Historical Phytoplankton and Periphyton Sampling Locations, Hope Bay Belt Project .....	2-43
Figure 2.13-4. Historical Zooplankton Sampling Locations, Hope Bay Belt Project.....	2-45
Figure 2.13-5. Historical Benthic Invertebrate Sampling Locations, Hope Bay Belt Project.....	2-47
Figure 3.1-1a. Winter Dissolved Oxygen and Temperature Profiles, Hope Bay Lakes, April/May 2009 .....	3-2
Figure 3.1-1b. Winter Dissolved Oxygen and Temperature Profiles, Hope Bay Lakes, April/May 2009 .....	3-3
Figure 3.1-1c. Winter Dissolved Oxygen and Temperature Profiles, Hope Bay Lakes, April/May 2009 .....	3-4
Figure 3.1-2a. Summer Dissolved Oxygen and Temperature Profiles, Hope Bay Lakes, August 2009.....	3-8
Figure 3.1-2b. Summer Dissolved Oxygen and Temperature Profiles, Hope Bay Lakes, August 2009 .....	3-9
Figure 3.1-2c. Summer Dissolved Oxygen and Temperature Profiles, Hope Bay Lakes, August 2009.....	3-10
Figure 3.2-1a. Average pH, Hope Bay Lakes, 2009 .....	3-12
Figure 3.2-1b. Average Turbidity, Hope Bay Lakes, 2009.....	3-13
Figure 3.2-1c. Average Total Dissolved Solids, Hope Bay Lakes, 2009 .....	3-14
Figure 3.2-1d. Average Total Organic Carbon, Hope Bay Lakes, 2009.....	3-15
Figure 3.2-1e. Average Ammonia, Hope Bay Lakes, 2009.....	3-16
Figure 3.2-1f. Average Nitrate, Hope Bay Lakes, 2009.....	3-17
Figure 3.2-1g. Average Total Phosphorus, Hope Bay Lakes, 2009 .....	3-18
Figure 3.2-1h. Average Sulphate, Hope Bay Lakes, 2009 .....	3-19
Figure 3.2-1i. Average Aluminum, Hope Bay Lakes, 2009 .....	3-20
Figure 3.2-1j. Average Chromium, Hope Bay Lakes, 2009 .....	3-21
Figure 3.2-1k. Average Copper, Hope Bay Lakes, 2009.....	3-22

## 2009 FRESHWATER BASELINE REPORT, HOPE BAY BELT PROJECT

Figure 3.2-1l. Average Iron, Hope Bay Lakes, 2009 .....	3-23
Figure 3.2-1m. Average Lead, Hope Bay Lakes, 2009 .....	3-24
Figure 3.2-1n. Average Molybdenum, Hope Bay Lakes, 2009 .....	3-25
Figure 3.2-1o. Average Nickel, Hope Bay Lakes, 2009 .....	3-26
Figure 3.2-1p. Average Zinc, Hope Bay Lakes, 2009 .....	3-27
Figure 3.2-2a. Average Annual pH, Hope Bay Lakes, 1995–2009 .....	3-28
Figure 3.2-2b. Average Annual Turbidity, Hope Bay Lakes, 1995–2009 .....	3-29
Figure 3.2-2c. Average Annual Total Dissolved Solids, Hope Bay Lakes, 1995–2009 .....	3-30
Figure 3.2-2d. Average Annual Total Organic Carbon, Hope Bay Lakes, 1995–2009 .....	3-31
Figure 3.2-2e. Average Annual Ammonia, Hope Bay Lakes, 1995–2009 .....	3-32
Figure 3.2-2f. Average Annual Nitrite, Hope Bay Lakes, 1995–2009 .....	3-33
Figure 3.2-2g. Average Annual Nitrate, Hope Bay Lakes, 1995–2009 .....	3-34
Figure 3.2-2h. Average Annual Total Phosphorus, Hope Bay Lakes, 1995–2009 .....	3-35
Figure 3.2-2i. Average Annual Sulphate, Hope Bay Lakes, 1995–2009 .....	3-36
Figure 3.2-2j. Average Annual Aluminum, Hope Bay Lakes, 1995–2009 .....	3-37
Figure 3.2-2k. Average Annual Arsenic, Hope Bay Lakes, 1995–2009 .....	3-38
Figure 3.2-2l. Average Annual Cadmium, Hope Bay Lakes, 1995–2009 .....	3-39
Figure 3.2-2m. Average Annual Chromium, Hope Bay Lakes, 1995–2009 .....	3-40
Figure 3.2-2n. Average Annual Copper, Hope Bay Lakes, 1995–2009 .....	3-41
Figure 3.2-2o. Average Annual Iron, Hope Bay Lakes, 1995–2009 .....	3-42
Figure 3.2-2p. Average Annual Lead, Hope Bay Lakes, 1995–2009 .....	3-43
Figure 3.2-2q. Average Annual Mercury, Hope Bay Lakes, 1995–2009 .....	3-44
Figure 3.2-2r. Average Annual Molybdenum, Hope Bay Lakes, 1995–2009 .....	3-45
Figure 3.2-2s. Average Annual Nickel, Hope Bay Lakes, 1995–2009 .....	3-46
Figure 3.2-2t. Average Annual Selenium, Hope Bay Lakes, 1995–2009 .....	3-47
Figure 3.2-2u. Average Annual Zinc, Hope Bay Lakes, 1995–2009 .....	3-48
Figure 3.3-1a. Average pH, Hope Bay Streams, 2009 .....	3-58
Figure 3.3-1b. Average Turbidity, Hope Bay Streams, 2009 .....	3-59
Figure 3.3-1c. Average Total Dissolved Solids, Hope Bay Streams, 2009 .....	3-60
Figure 3.3-1d. Average Total Organic Carbon, Hope Bay Streams, 2009 .....	3-61
Figure 3.3-1e. Average Ammonia, Hope Bay Streams, 2009 .....	3-62

Figure 3.3-1f. Average Nitrate, Hope Bay Streams, 2009.....	3-63
Figure 3.3-1g. Average Total Phosphorus, Hope Bay Streams, 2009 .....	3-64
Figure 3.3-1h. Average Sulphate, Hope Bay Streams, 2009 .....	3-65
Figure 3.3-1i. Average Aluminum, Hope Bay Streams, 2009 .....	3-66
Figure 3.3-1j. Average Chromium, Hope Bay Streams, 2009 .....	3-67
Figure 3.3-1k. Average Copper, Hope Bay Streams, 2009.....	3-68
Figure 3.3-1l. Average Iron, Hope Bay Streams, 2009 .....	3-69
Figure 3.3-1m. Average Lead, Hope Bay Streams, 2009.....	3-70
Figure 3.3-1n. Average Molybdenum, Hope Bay Streams, 2009 .....	3-71
Figure 3.3-1o. Average Nickel, Hope Bay Streams, 2009.....	3-72
Figure 3.3-1p. Average Zinc, Hope Bay Streams, 2009 .....	3-73
Figure 3.3-2a. Average Annual pH, Hope Bay Streams, 1996-2009 .....	3-74
Figure 3.3-2b. Average Annual Turbidity, Hope Bay Streams, 1996-2009 .....	3-75
Figure 3.3-2c. Average Annual Total Dissolved Solids, Hope Bay Streams, 1996-2009 .....	3-76
Figure 3.3-2d. Average Annual Total Organic Carbon, Hope Bay Streams, 1996-2009 .....	3-77
Figure 3.3-2e. Average Annual Ammonia, Hope Bay Streams, 1996-2009 .....	3-78
Figure 3.3-2f. Average Annual Nitrite, Hope Bay Streams, 1996-2009 .....	3-79
Figure 3.3-2g. Average Annual Nitrate, Hope Bay Streams, 1996-2009.....	3-80
Figure 3.3-2h. Average Annual Total Phosphorus, Hope Bay Streams, 1996-2009.....	3-81
Figure 3.3-2i. Average Annual Sulphate, Hope Bay Streams, 1996-2009 .....	3-82
Figure 3.3-2j. Average Annual Aluminum, Hope Bay Streams, 1996-2009 .....	3-83
Figure 3.3-2k. Average Annual Arsenic, Hope Bay Streams, 1996-2009 .....	3-84
Figure 3.3-2l. Average Annual Cadmium, Hope Bay Streams, 1996-2009.....	3-85
Figure 3.3-2m. Average Annual Chromium, Hope Bay Streams, 1996-2009 .....	3-86
Figure 3.3-2n. Average Annual Copper, Hope Bay Streams, 1996-2009.....	3-87
Figure 3.3-2o. Average Annual Iron, Hope Bay Streams, 1996-2009.....	3-88
Figure 3.3-2p. Average Annual Lead, Hope Bay Streams, 1996-2009.....	3-89
Figure 3.3-2q. Average Annual Molybdenum, Hope Bay Streams, 1996-2009.....	3-90
Figure 3.3-2r. Average Annual Nickel, Hope Bay Streams, 1996-2009 .....	3-91
Figure 3.3-2s. Average Annual Selenium, Hope Bay Streams, 1996-2009.....	3-92
Figure 3.3-2t. Average Annual Zinc, Hope Bay Streams, 1996-2009 .....	3-93

Figure 3.4-1. Sediment Particle Size Composition, Hope Bay Lakes, August 2009 .....	3-102
Figure 3.4-2a. Average Concentrations of Total Organic Carbon in Lake Sediments, Hope Bay Belt Project, 2009 .....	3-103
Figure 3.4-2b. Average Concentrations of Available Phosphorus in Lake Sediments, Hope Bay Belt Project, 2009 .....	3-104
Figure 3.4-2c. Average Concentrations of Available Ammonia as N in Lake Sediments, Hope Bay Belt Project, 2009 .....	3-105
Figure 3.4-2d. Average Concentrations of Total Nitrogen in Lake Sediments, Hope Bay Belt Project, 2009 ....	3-106
Figure 3.4-2e. Average Concentrations of Total Sulphur in Lake Sediments, Hope Bay Belt Project, 2009.....	3-107
Figure 3.4-2f. Average Concentrations of Arsenic in Lake Sediments, Hope Bay Belt Project, 2009.....	3-108
Figure 3.4-2g. Average Concentrations of Cadmium in Lake Sediments, Hope Bay Belt Project, 2009 .....	3-109
Figure 3.4-2h. Average Concentrations of Chromium in Lake Sediments, Hope Bay Belt Project, 2009.....	3-110
Figure 3.4-2i. Average Concentrations of Copper in Lake Sediments, Hope Bay Belt Project, 2009.....	3-111
Figure 3.4-2j. Average Concentrations of Lead in Lake Sediments, Hope Bay Belt Project, 2009.....	3-112
Figure 3.4-2k. Average Concentrations of Mercury in Lake Sediments, Hope Bay Belt Project, 2009 .....	3-113
Figure 3.4-2l. Average Concentrations of Zinc in Lake Sediments, Hope Bay Belt Project, 2009 .....	3-114
Figure 3.4-3a. Average Annual Concentrations of Total Organic Carbon in Lake Sediments, Hope Bay Belt Project, 1996–2009 .....	3-115
Figure 3.4-3b. Average Annual Concentrations of Arsenic in Lake Sediments, Hope Bay Belt Project, 1996–2009 .....	3-116
Figure 3.4-3c. Average Annual Concentrations of Cadmium in Lake Sediments, Hope Bay Belt Project, 1996–2009 .....	3-117
Figure 3.4-3d. Average Annual Concentrations of Chromium in Lake Sediments, Hope Bay Belt Project, 1996–2009 .....	3-118
Figure 3.4-3e. Average Annual Concentrations of Copper in Lake Sediments, Hope Bay Belt Project, 1996–2009 .....	3-119
Figure 3.4-3f. Average Annual Concentrations of Lead in Lake Sediments, Hope Bay Belt Project, 1996–2009 .....	3-120
Figure 3.4-3g. Average Annual Concentrations of Mercury in Lake Sediments, Hope Bay Belt Project, 1996–2009 .....	3-121
Figure 3.4-3h. Average Annual Concentrations of Zinc in Lake Sediments, Hope Bay Belt Project, 1996–2009 .....	3-122
Figure 3.5-1. Sediment Particle Size Composition, Hope Bay Streams, 2009.....	3-129
Figure 3.5-2a. Average Concentrations of Total Organic Carbon in Stream Sediments, Hope Bay Belt Project, 2009 .....	3-130

Figure 3.5-2b. Average Concentrations of Available Phosphorus in Stream Sediments, Hope Bay Belt Project, 2009 .....	3-131
Figure 3.5-2c. Average Concentrations of Available Ammonia as N in Stream Sediments, Hope Bay Belt Project, 2009 .....	3-132
Figure 3.5-2d. Average Concentrations of Total Nitrogen in Stream Sediments, Hope Bay Belt Project, 2009 .....	3-133
Figure 3.5-2e. Average Concentrations of Total Sulphur in Stream Sediments, Hope Bay Belt Project, 2009..	3-134
Figure 3.5-2f. Average Concentrations of Arsenic in Stream Sediments, Hope Bay Belt Project, 2009.....	3-135
Figure 3.5-2g. Average Concentrations of Chromium in Stream Sediments, Hope Bay Belt Project, 2009.....	3-136
Figure 3.5-2h. Average Concentrations of Copper in Stream Sediments, Hope Bay Belt Project, 2009 .....	3-137
Figure 3.5-2i. Average Concentrations of Lead in Stream Sediments, Hope Bay Belt Project, 2009 .....	3-138
Figure 3.5-2j. Average Concentrations of Mercury in Stream Sediments, Hope Bay Belt Project, 2009 .....	3-139
Figure 3.5-2k. Average Concentrations of Zinc in Stream Sediments, Hope Bay Belt Project, 2009 .....	3-140
Figure 3.6-1. Winter and Summer Phytoplankton Biomass and Abundance, Hope Bay Lakes, 2009.....	3-146
Figure 3.6-2. Winter and Summer Phytoplankton Taxonomic Composition, Hope Bay Lakes, 2009 .....	3-147
Figure 3.6-3. Winter and Summer Phytoplankton Richness and Diversity, Hope Bay Lakes, 2009.....	3-148
Figure 3.6-4. Epontic Algal Taxonomic Composition, Hope Bay Lakes, April/May 2009.....	3-150
Figure 3.6-5. Epontic Algal Richness and Diversity, Hope Bay Lakes, April/May 2009 .....	3-151
Figure 3.6-6. Average Annual Phytoplankton Biomass, Hope Bay Lakes, 1996-2009 .....	3-152
Figure 3.6-7. Average Annual Phytoplankton Abundance, Hope Bay Lakes, 1996-2009.....	3-153
Figure 3.7-1. Average Stream Periphyton Biomass, Hope Bay, 2009 .....	3-155
Figure 3.7-2. Periphyton Density and Taxonomic Composition, Hope Bay Streams, 2009.....	3-157
Figure 3.7-3. Periphyton Richness and Diversity, Hope Bay Streams, 2009.....	3-158
Figure 3.7-4. Average Annual Periphyton Density, Hope Bay Streams, 1996-2009 .....	3-159
Figure 3.8-1. Zooplankton Abundance and Taxonomic Composition, Hope Bay Lakes, August 2009.....	3-161
Figure 3.8-2. Zooplankton Richness and Diversity, Hope Bay Lakes, August 2009.....	3-162
Figure 3.8-3. Average Annual Zooplankton Abundance, Hope Bay Lakes, 1996-2009 .....	3-164
Figure 3.9-1. Average Benthos Densities by Depth Strata, Hope Bay Lakes, August 2009.....	3-166
Figure 3.9-2a. Taxonomic Composition of Benthos Assemblages, Hope Bay Lakes, August 2009 .....	3-167
Figure 3.9-2b. Taxonomic Composition of Benthos Assemblages, Hope Bay Lakes, August 2009.....	3-168
Figure 3.9-2c. Taxonomic Composition of Benthos Assemblages, Hope Bay Lakes, August 2009.....	3-169
Figure 3.9-2d. Taxonomic Composition of Benthos Assemblages, Hope Bay Lakes, August 2009.....	3-170

Figure 3.9-3. Average Benthos Richness and Diversity by Depth Strata, Hope Bay Lakes, August 2009.....	3-171
Figure 3.9-4. Average Annual Benthos Densities by Depth Strata, Hope Bay Lakes, 1996-2009 .....	3-173
Figure 3.10-1. Average Benthos Densities, Hope Bay Streams, July 2009 .....	3-175
Figure 3.10-2. Taxonomic Composition of Benthos Assemblages, Hope Bay Streams, July 2009.....	3-176
Figure 3.10-3. Average Benthos Richness and Diversity, Hope Bay Streams, July 2009 .....	3-177

### **List of Tables**

<b>TABLE</b>	<b>PAGE</b>
Table 2.1-1. Lake Water, Sediment, and Aquatic Biology Sampling Locations, Hope Bay Belt Project, 2009 .....	2-2
Table 2.1-2. Stream Water, Sediment and Aquatic Biology Sampling Locations, Hope Bay Belt Project, 2009 .....	2-2
Table 2.1-3. Sampling Details for Water Quality, Sediment Quality, and Aquatic Biology, Hope Bay Belt Project, 2009 .....	2-3
Table 2.1-4. Lake Sampling Dates, Hope Bay Belt Project, 2009.....	2-5
Table 2.1-5. Stream Sampling Dates, Hope Bay Belt Project, 2009.....	2-6
Table 2.3-1. Water Quality Parameters and Detection Limits, Hope Bay Belt Project, 2009 .....	2-23
Table 2.5-1. Sediment Quality Parameters and Detection Limits, Hope Bay Belt Project, 2009 .....	2-27
Table 2.13-1. Summary of Historical Lake Water Quality Sampling Conducted for the Hope Bay Belt Project ..	2-33
Table 2.13-2. Summary of Historical Stream Water Quality Sampling Conducted for the Hope Bay Belt Project .....	2-34
Table 2.13-3. Summary of Historical Lake Sediment Quality Sampling Conducted for the Hope Bay Belt Project .....	2-35
Table 2.13-4. Summary of Historical Stream Sediment Quality Sampling Conducted for the Hope Bay Belt Project .....	2-35
Table 2.13-5. Summary of Historical Lake Phytoplankton Sampling Conducted for the Hope Bay Belt Project .....	2-35
Table 2.13-6. Summary of Historical Stream Periphyton Sampling Conducted for the Hope Bay Belt Project....	2-36
Table 2.13-7. Summary of Historical Lake Zooplankton Sampling Conducted for the Hope Bay Belt Project....	2-36
Table 2.13-8. Summary of Historical Lake Benthos Sampling Conducted for the Hope Bay Belt Project .....	2-37
Table 2.13-9. Summary of Historical Stream Benthos Sampling Conducted for the Hope Bay Belt Project .....	2-37
Table 3.1-1. Lake Dissolved Oxygen Concentrations, Winter and Summer 2009.....	3-5
Table 3.1-2. River Dissolved Oxygen and Temperature Profiles, Winter 2009 .....	3-7
Table 3.1-3. Secchi Depths for Hope Bay Belt Lakes, August 2009 .....	3-11

Table 3.2-1. Lake Water Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009.....	3-52
Table 3.3-1. Stream Water Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009.....	3-97
Table 3.3-2. Stream Water Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009.....	3-99
Table 3.4-1. Lake Sediment Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009.....	3-123
Table 3.4-2. Lake Sediment Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009.....	3-125
Table 3.5-1. Stream Sediment Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009.....	3-141
Table 3.5-2. Stream Sediment Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009.....	3-143

### **List of Plates**

<b>PLATE</b>	<b>PAGE</b>
Plate 2.3-1. Lake water quality sampling with the use of a 5L GO-FLO.....	2-25
Plate 3.1-1. Little Roberts Lake looking towards the outflow (NW), May 5 2009. ....	3-5
Plate 3.1-2. Epontic algal sample collected from Little Roberts Lake, May 5 2009.....	3-6

# **1. Introduction**

# 1. Introduction

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The Hope Bay Belt Property is located approximately 125 km southwest of Cambridge Bay, Nunavut, on the south shore of Melville Sound (Figure 1-1). The nearest communities are Omingmaktok (75 km to the southwest of the property), Cambridge Bay, and Kingaok (Bathurst Inlet; 160 km to the southwest of the property).

The property consists of a greenstone belt running in a north/south direction, approximately 80 km long, with three main gold deposit areas. The Doris and Madrid deposits are located in the northern portion of the belt, and the Boston deposit is located in the southern end. The northern portion of the property consists of several watershed systems that drain into Roberts Bay, and a large river (Koignuk River) that drains into Hope Bay. Watersheds in the southern portion of the belt ultimately drain into the upper Koignuk, which drains into Hope Bay.

Newmont Mining Corporation (Newmont) acquired the property in 2008, and initially decided to consider the property as a whole to evaluate various options for responsible, long-term development of the belt. However, as of the fall of 2009, Hope Bay Mining Ltd. (HBML), a fully owned subsidiary of Newmont, has decided to proceed with developing the already-permitted Doris North Project, which consists of a two-year underground gold mine in the north end of the belt.

The environmental baseline program conducted in 2009 was based on the plan to develop multiple deposits in the belt, as indicated in Figure 1-2. The 2009 program was also based on HBML's priorities as of early 2009, which included regulatory compliance with the existing Doris North Project permits and licences. Baseline programs for ecosystem mapping, vegetation, soils, and socio-community were deferred to 2010. Baseline work was primarily focused on the north end of the belt in 2009.

Results from the 2009 environmental baseline program are being reported in a series of reports, as follows:

- 2009 Hydrology Baseline Report;
- 2009 Meteorology Baseline Report;
- 2009 Freshwater Baseline Report;
- 2009 Freshwater Fish and Fish Habitat Baseline Report;
- 2009 Marine Baseline Report; and
- 2009 Marine Fish and Fish Habitat Baseline Report.

In addition, baseline information obtained during 2009 was used to generate various compliance reports as specified in the Doris North Project Certificate (e.g. the Wildlife Monitoring & Mitigation Program Report), the Doris North Type A Water Licence, and the Doris North Roberts Bay Jetty Fisheries Authorization. Archaeology work was also conducted in 2009 and is being reported separately.

This report presents the results from the 2009 Freshwater Baseline Report portion of the 2009 environmental baseline program. Results from the freshwater fish community and habitat work are provided in a separate report.

The 2009 freshwater baseline program involved collecting information for the following: lake water quality (both winter and summer), lake physical limnology (both winter and summer), lake sediment quality, lake phytoplankton (both winter and summer), lake zooplankton, lake benthos, stream water quality, stream sediment quality, stream periphyton, and stream benthos. Aquatic components were sampled from numerous lakes and streams contained within three drainage basins in the northern portion of the belt that could potentially be influenced by future Project activities. Aquatic components were also sampled in the Koignuk River, a major river adjacent to the property. Two reference lakes and their associated outflows located well away from potential Project activities were also included in the 2009 program, as was a reference river location on the Angimajuq River.

Analytical results from all samples collected as part of the 2009 freshwater baseline program are provided as appendices to this report. Chapter 2 of this report presents the sampling locations and methods used for the 2009 freshwater baseline work, and results from the samples collected are presented in graphical and tabular form in Chapter 3.



Figure 1-1

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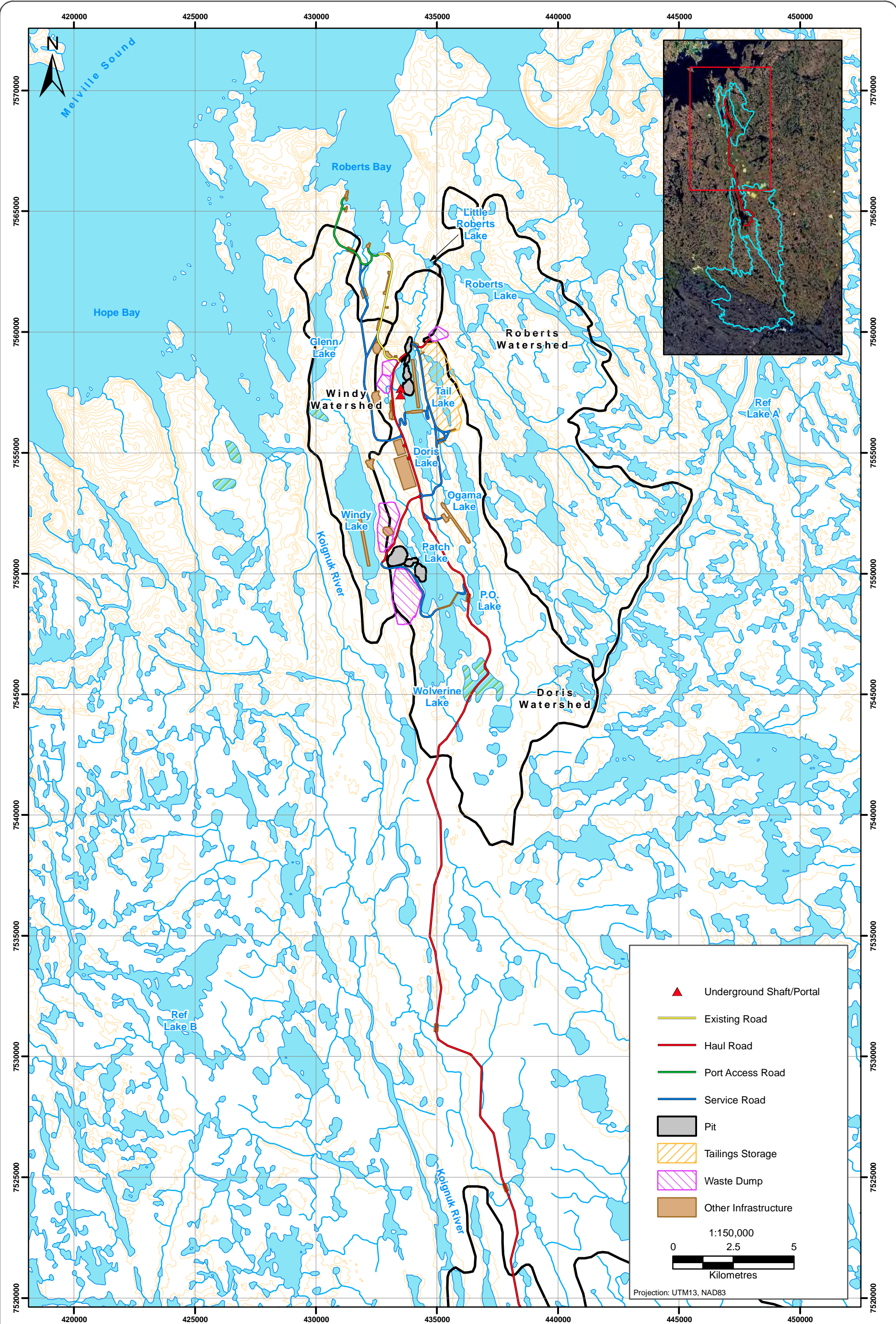


Figure 1-2



Site Layout Options Considered for 2009 Baseline Program

Figure 1-2



## **2. Methods**

## 2. Methods

---

### 2.1 MONITORING LOCATIONS AND SAMPLING PROGRAM

In 2009, baseline studies were conducted to complement existing data in preparation for an Environmental Impact Statement. These studies focused on the northern portion of the belt as well as reference areas well away from future Project activities.

The following components were sampled as part of the 2009 freshwater baseline program:

#### *Lakes:*

- Winter Lake Water Quality & Limnology;
- Winter Phytoplankton and Epontic Algal sampling;
- Open-water Season Lake Water Quality & Limnology;
- Lake Sediment Quality;
- Lake Phytoplankton Assemblages;
- Lake Zooplankton Assemblages; and
- Lake Benthic Invertebrate Communities.

#### *Streams:*

- Winter Stream Water Quality;
- Open-water Season Stream Water Quality;
- Stream Sediment Quality;
- Stream Periphyton Assemblages; and
- Stream Benthic Invertebrate Communities.

Tables 2.1-1 and 2.1-2 present the lakes and streams sampled, along with the aquatic components examined in 2009. Table 2.1-3 provides a summary of the sampling details for each aquatic component, including the sampling frequency and replication. Table 2.1-4 and 2.1-5 presents the dates each aquatic component was sampled at each site. Figure 2.1-1 presents an overview of the study area sampling locations in 2009 along with the major drainage basins. Figures 2.1-2a to 2.1-2m present lake maps depicting lake bathymetry (where available) and 2009 sampling locations.

### 2.2 PHYSICAL LIMNOLOGY

In 2009, physical limnology measurements were taken from both lakes and rivers in late April/early May and again from lakes in August. Sampling locations were selected from one of the following: a previously sampled site, the deepest section in the lake, or a spatially significant location (i.e., within and outside of mine footprints, or near future on-shore tailings or waste rock piles). In lakes with no bathymetric information or prior sampling history, winter sampling occurred near the middle of the lake, or in the middle of any obvious basins as estimated by the surrounding topography. At such sites, course-level bathymetry (using a depth sounder) was carried out prior to summer sampling and the sampling location moved if deeper areas were found.

**Table 2.1-1. Lake Water, Sediment, and Aquatic Biology Sampling Locations, Hope Bay Belt Project, 2009**

Watershed	Site Name	Abbreviated Name	Winter Water Quality & Limnology	Winter Algal Sampling	Summer Water Quality & Limnology	Sediment Quality	Aquatic Biology
Doris	Wolverine Lake	Wolverine	X		X	X (1)	X (1)
	Imniagut Lake	Imniagut			X	X (1)	X (1)
	Patch Lake South	Patch S	X	X	X	X (2)	X (2)
	Patch Lake North	Patch N	X	X	X	X (2)	X (2)
	P.O. Lake	P.O.			X	X (1)	X (1)
	Ogama Lake	Ogama	X	X	X	X (1)	X (1)
	Doris Lake South	Doris S	X	X	X	X (2)	X (2)
	Doris Lake North	Doris N	X	X	X	X (2)	X (2)
Little Roberts	Little Roberts Lake	Little Roberts	X	X	X	X (1)	X (1)
Roberts	Naiqunnguut Lake	Naiqunnguut	X		X	X (1)	X (1)
Windy	Nakhaktok Lake	Nakhaktok	X		X	X (2)	X (2)
	Windy Lake	Windy	X		X	X (2)	X (2)
	Glenn Lake	Glenn	X		X	X (2)	X (2)
Ref A	Reference Lake A	Ref Lk A	X		X	X (2)	X (2)
Ref B	Reference Lake B	Ref Lk B	X		X	X (2)	X (2)
Ref C	Reference Lake C	Ref Lk C	X				

Note: Values in parenthesis for lake benthos and sediment quality indicate the number of sampling depths per lake. Although sampled as indicated, data for Reference Lake C (discontinued reference site) are only presented in the appendices.

**Table 2.1-2. Stream Water, Sediment and Aquatic Biology Sampling Locations, Hope Bay Belt Project, 2009**

Watershed	Site Name	Abbreviated Name	Winter Water Quality & Limnology	Summer Water Quality	Sediment Quality	Aquatic Biology
Doris	Wolverine Outflow	Wolverine OF		X	X	X
	Patch Outflow	Patch OF		X	X	X
	P.O. Outflow	P.O. OF		X	X	X
	Ogama Outflow	Ogama OF		X	X	X
	Doris Outflow	Doris OF		X	X	X
Little Roberts	Little Roberts Outflow	Little Roberts OF		X	X	X
Windy	Windy Outflow	Windy OF		X	X	X
	Glenn Outflow Downstream	Glenn OF D/S		X	X	X
Koignuk River	Koignuk River Upstream	Koignuk U/S	X	X	X	X
	Koignuk River Midstream	Koignuk M/S	X	X	X	X
	Koignuk River Downstream	Koignuk D/S	X	X	X	X
Ref A	Reference Lake A Outflow	Ref Lk A OF		X	X	X
Ref B	Reference Lake B Outflow	Ref Lk B OF		X	X	X
Ref C	Reference Lake C Outflow	Ref Lk C OF		X		
Angimajuq	Angimajuq River Reference Site	Angimajuq R. Ref		X	X	X
Aimaokatalok River	Aimaokatalok River Reference Site	Aim. R. Ref	X			

Note: Although sampled as indicated, data from Ref C OF and Aim. R. Ref. (discontinued reference sites) are only presented in the appendices.

**Table 2.1-3. Sampling Details for Water Quality, Sediment Quality, and Aquatic Biology, Hope Bay Belt Project, 2009**

<b>Monitoring Parameter</b>	<b>Sampling Frequency</b>	<b>Sample Replication and Depths</b>	<b>Sampling Dates/Timing</b>
<b><u>Lakes</u></b>			
<b><u>Winter Lake Water Quality</u></b>			
Physical, nutrients, total & dissolved metals	1 x	n=1 @ 1 m below the ice and 2 m above water-sediment interface + 20% replication	April/early May; coincident with winter DO/T profiles
<b><u>Summer Lake Water Quality</u></b>			
Physical, nutrients, total & dissolved metals	1 x	n=1 @ 1 m below the surface and 2 m above water-sediment interface + 20% replication	August; coincident with biological lake surveys
<b><u>Winter Limnology</u></b>			
Dissolved oxygen/temperature profile	1 x	once over deepest area of lake, or at lake station	April/early May; coincident with winter water quality
<b><u>Summer Limnology</u></b>			
Dissolved oxygen/temperature profile; Secchi depth	1 x	once over deepest area of lake, or at lake station	August; coincident with biological lake surveys
<b><u>Lake Sediment Quality</u></b>			
Physical, nutrients, metals	1 x	n=3 @ shallow and mid or deep depth strata	August; coincident with lake surveys
<b><u>Winter Phytoplankton*</u></b>			
Microcystin concentrations	1 x	n= 1@ 1 m below ice	April/early May; coincident with winter water quality
Biomass (as chlorophyll <i>a</i> )	1 x	n= 1@ 1 m below ice	April/early May; coincident with winter water quality
Abundance and taxonomy	1 x	n= 1@ 1 m below ice	April/early May; coincident with winter water quality
<b><u>Winter Epontic Algae*</u></b>			
Taxonomy	1 x	n= 1; scraping from bottom of ice (qualitative sample)	April/early May; coincident with winter water quality
<b><u>Summer Phytoplankton</u></b>			
Biomass (as chlorophyll <i>a</i> )	1 x	n=3 @ 1 m	August; coincident with lake surveys
Abundance and taxonomy	1 x	n=3 @ 1 m	August; coincident with lake surveys
<b><u>Zooplankton</u></b>			
Abundance and taxonomy	1 x	n=3 vertical hauls from 1 m above bottom	August coincident with lake surveys
<b><u>Lake Benthos</u></b>			
Density and taxonomy	1 x	n=3 @ shallow and mid or deep depth strata	August coincident with lake surveys
<b><u>Streams/Rivers</u></b>			
<b><u>Winter River Water Quality</u></b>			
Physical, nutrients, total & dissolved metals	1 x	n=2	Late April/early May

(continued)

**Table 2.1-3. Sampling Details for Water Quality, Sediment Quality, and Aquatic Biology, Hope Bay Belt Project, 2009 (completed)**

Monitoring Parameter	Sampling Frequency	Sample Replication and Depths	Sampling Dates/Timing
<u>Summer Stream Water Quality</u>			
Physical, nutrients, total & dissolved metals	3 x	n=2	freshet (early June), summer (August), fall (September)
<u>Stream Sediment Quality</u>			
Physical, nutrients, metals	1 x	n=3	July; coincident with stream water quality and periphyton plate installation
<u>Periphyton</u>			
Biomass (as chlorophyll <i>a</i> )	1 x	n=3	artificial samplers installed in July; retrieved in August
Density and taxonomy	1 x	n=3	artificial samplers installed in July; retrieved in August
<u>Stream Benthos</u>			
Density and taxonomy	1 x	n=3	July; coincident with stream water quality and periphyton plate installation

\*At Patch (N and S), Ogama, Doris (N and S), and Little Roberts lakes only.

### 2.2.1 Winter Lake Physical Limnology

Before collecting the physical profiles (and later water samples), a 10-inch diameter ice auger was used to drill a hole through the ice. Once the hole was drilled, a weighted metered line was used to measure the bottom depth, with extreme care taken to minimize any disturbance to lake sediments. Water column profiling and water quality sampling depths were calculated based on bottom depth.

Measurements for water column structure (including temperature and dissolved oxygen) were collected using a YSI dissolved oxygen/temperature meter. At shallow lake stations (<20 m), temperature and dissolved oxygen values were recorded at 0.5 m intervals, while at deep lake stations (>20 m), values were recorded at 1 m intervals. As the meter consumes oxygen while taking a reading, the probe was gently agitated to ensure a continual flushing of 'new' water. The profiles ended at ~1 m above the sediment surface to reduce suspension of bottom sediments.

### 2.2.2 Summer Lake Physical Limnology

Summer temperature and dissolved oxygen profiles were measured at the same locations that winter samples were collected, unless new bathymetric data prompted the relocation of a sampling site. Summer water column temperature and dissolved oxygen data were collected using the same equipment employed during winter sampling.

Light attenuation was estimated in each lake using a Secchi Disk. Measurements were collected at each site by lowering the disk (20-cm diameter, black and white) on a metered line through the water column on the shaded side of the boat until it disappeared from sight. The depth of disappearance was identified as the Secchi depth ( $D_s$ ), which was then used to calculate the depth of the euphotic zone.

**Table 2.1-4. Lake Sampling Dates, Hope Bay Belt Project, 2009**

Watershed	Lake	Winter			Summer					
		DO/Temp	Water Quality	Phytoplankton and Epontic	DO/Temp & Secchi Depth	Water Quality	Sediment Quality	Phytoplankton	Zooplankton	Benthos
Doris	Wolverine	Apr. 26	Apr. 26 (3)	NC	Aug. 6	Aug. 6 (1)	Aug. 6 (3.5)	Aug. 6	Aug. 6	Aug. 6 (3.6)
	Imniagut	NC	NC	NC	Aug. 7	Aug. 8 (1)	Aug. 8 (3)	Aug. 7	Aug. 8	Aug. 8 (3)
	Patch S	Apr. 24	Apr. 23 (3, 12.5)	Apr. 24	Aug. 11	Aug. 14 (1)	Aug. 11 (3, 14)	Aug. 11	Aug. 11	Aug. 11 & 12 (3, 13.7)
	Patch N	Apr. 23	Apr. 23 & 24 (3)	Apr. 23	Aug. 9	Aug. 9 (1, 6)	Aug. 9 & 11 (2.6, 8.2)	Aug. 9	Aug. 9	Aug. 9 & 11 (2.7, 8.2)
	P.O.	Apr. 26	NC	NC	Aug. 10	Aug. 14 (1)	Aug. 10 (3)	Aug. 10	Aug. 10	Aug. 10 (3.3)
	Ogama	May 5	May 5 (3)	Apr. 26	Aug. 14	Aug. 14 (1, 3)	Aug. 15 (4.3)	Aug. 14	Aug. 14	Aug. 14 (4.3)
	Doris S	Apr. 22	Apr. 22 & 24 (3, 4)	Apr. 21	Aug. 17	Aug. 17 (1, 8)	Aug. 17 (4.3, 10.9)	Aug. 16	Aug. 17	Aug. 17 (4.3, 10.9)
	Doris N	Apr. 21	Apr. 21 & 24 (3, 11.5)	Apr. 22	Aug. 15	Aug. 15 (1, 11.5)	Aug. 15 (4.1, 14.2)	Aug. 15	Aug. 16	Aug. 15 (4.1, 14.2)
Little Roberts	Little Roberts	May 5	May 5 (3)	May 5	Aug. 7	Aug. 9 (1)	Aug. 7 (2.6)	Aug. 7	Aug. 7	Aug. 7 (2.6)
Roberts	Naiqunnguut	Apr. 26	Apr. 26 (2)	NC	Aug. 10	Aug. 14 (1)	Aug. 10 (4.4)	Aug. 10	Aug. 10	Aug. 10 (4.4)
Windy	Nakhaktok	Apr. 27	Apr. 27 (4)	NC	Aug. 6	Aug. 6 (1, 6)	Aug. 6 (3.5, 7.5)	Aug. 6	Aug. 6	Aug. 6 (3.5, 7.6)
	Windy	Apr. 27	Apr. 27 (4, 15.5)	NC	Aug. 9	Aug. 10 (1, 16)	Aug. 9 (3.7, 18)	Aug. 6	Aug. 9	Aug. 9 (3.4, 18)
	Glenn	May 6	May 3 (3, 9.5)	NC	Aug. 8	Aug. 9 (1, 17.5)	Aug. 8 (4.5, 19.5)	Aug. 8	Aug. 8	Aug. 8 (4.5, 19.5)
Ref A	Ref Lk A	May 31	May 31 (3, 26)	NC	Aug. 13	Aug. 14 (1, 29)	Aug. 12 & 13 (3.4, 31.5)	Aug. 12	Aug. 12 & 13	Aug. 13 (3.4, 31.5)
Ref B	Ref Lk B	May 31	May 31 (3, 6)	NC	Aug. 16	Aug. 16 (1, 7.5)	Aug. 16 (4.7, 9.4)	Aug. 16	Aug. 16	Aug. 16 (4.7, 9.4)
Ref C	Ref Lk C	May 31	May 31 (3, 11)	NC	NC	NC	NC	NC	NC	NC

Values in parenthesis are the approximate sampling depths in meters

NC - Not Collected

Note that data collected for Ref Lk C are not discussed in this report; this was a discontinued reference site.

**Table 2.1-5. Stream Sampling Dates, Hope Bay Belt Project, 2009**

Watershed	Stream	Winter			Summer				
		DO/Temp	Water Quality		Water Quality	Sediment Quality	Periphyton		
							Installation	Retrieval	Benthos
<i>Doris</i>	Wolverine OF	NC	NC		Jun.21	NC	NC	NC	NC
	Patch OF	NC	NC		Jun. 21, Aug. 18, Sep. 14	Jul. 23	Jul. 23	Aug. 18	Jul. 23
	P.O. OF	NC	NC		Jun. 21, Aug. 18, Sep. 14	Jul. 23	Jul. 23	Aug. 18	Jul. 23
	Ogama OF	NC	NC		Jun. 21, Aug. 18, Sep. 15	Jul.22 & 23	Jul. 23	Aug. 18	Jul. 23
	Doris OF	NC	NC		Jun. 21, Aug. 18, Sep. 15	Jul. 21	Jul. 21	Aug. 18	Jul. 21
<i>Little Roberts</i>	Little Rob. OF	NC	NC		Jun. 21, Aug. 18, Sep. 14	Jul. 22	Jul. 21	Aug. 18	Jul. 22
<i>Windy</i>	Windy OF	NC	NC		Jun. 21, Aug. 18, Sep. 15	Jul.22 & 23	Jul. 22	Aug. 18	Jul. 22
	Glenn OF D/S	NC	NC		Jun. 21, Aug. 18, Sep. 15	Jul. 23	Jul. 21	Aug. 18	Jul. 23
<i>Koignuk River</i>	Koignuk U/S	May 4	May 4		Jun. 21, Aug. 21, Sep. 14	Jul. 24	Jul. 26	Aug. 21	Jul. 24
	Koignuk M/S	May 23	May 23		Jun. 21, Aug. 22, Sep. 14	Jul. 24	Jul. 24	Aug. 22	Jul. 24
	Koignuk D/S	May 4	May 4		Jun. 21, Aug. 21, Sep. 14	Jul. 24	Jul. 24	Aug. 21	Jul. 24
<i>Ref A</i>	Ref Lk A OF	NC	NC		Jun. 21, Aug. 23, Sep. 15	Jul. 26	Jul. 26	Aug. 23	Jul. 26
<i>Ref B</i>	Ref Lk B OF	NC	NC		Jun. 21, Aug. 23, Sep. 14	Jul. 26	Jul. 26	Aug. 23	Jul. 26
<i>Angimajuq</i>	Angimajuq R. Ref	NC	NC		Jun. 21, Aug. 23, Sep. 15	Jul. 26	Jul. 26	Aug. 23	Jul. 26
<i>Aimaokatolok River</i>	Aim. R. Ref	May 1	May 1		NC	NC	NC	NC	NC

NC - Not Collected

Note that data collected for Aim. R. Ref are not discussed in this report; this was a discontinued reference site.

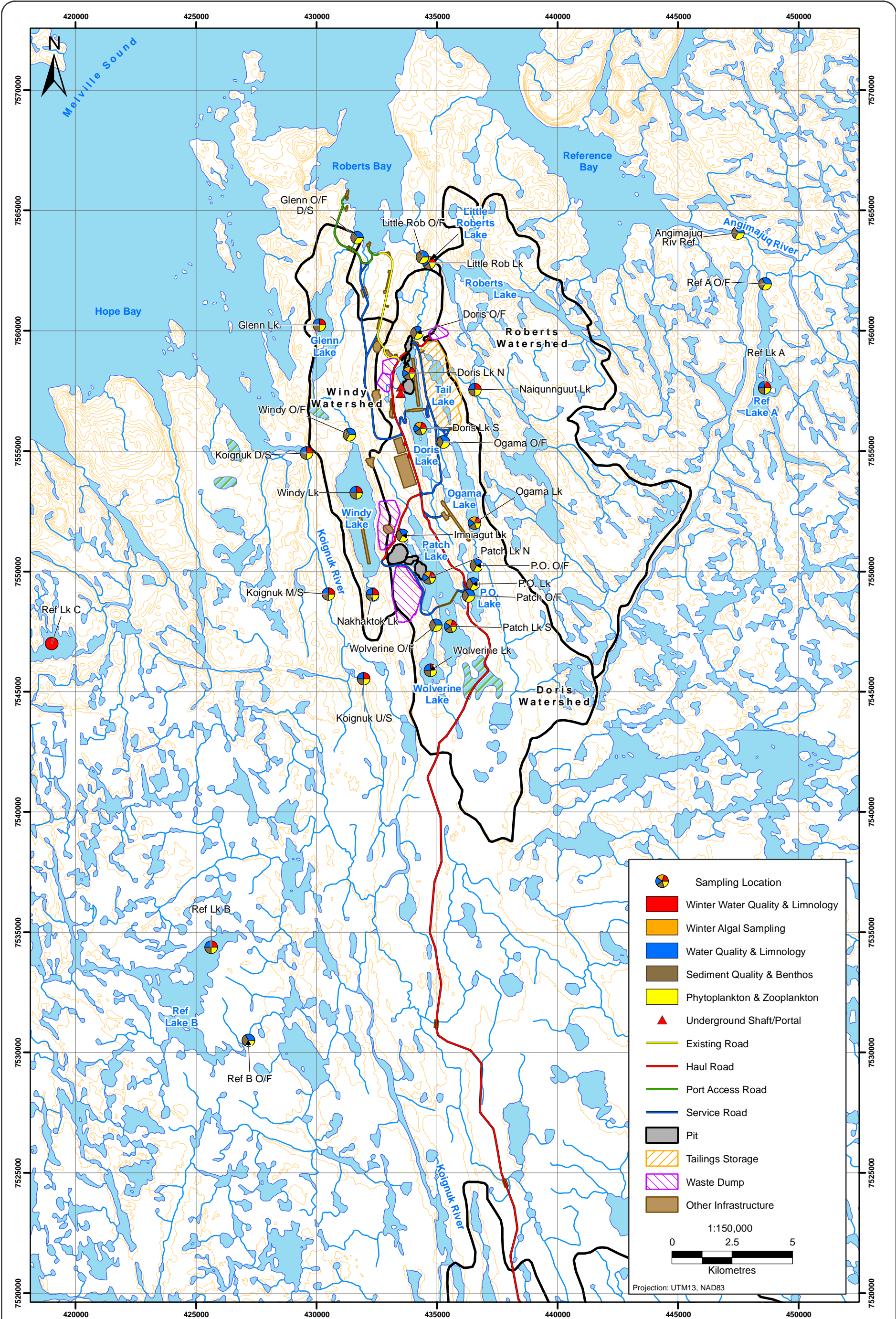


Figure 2.1-1



Water Quality, Sediment Quality, and Aquatic Biology  
Sampling Locations, Hope Bay Belt Project, 2009

Figure 2.1-1



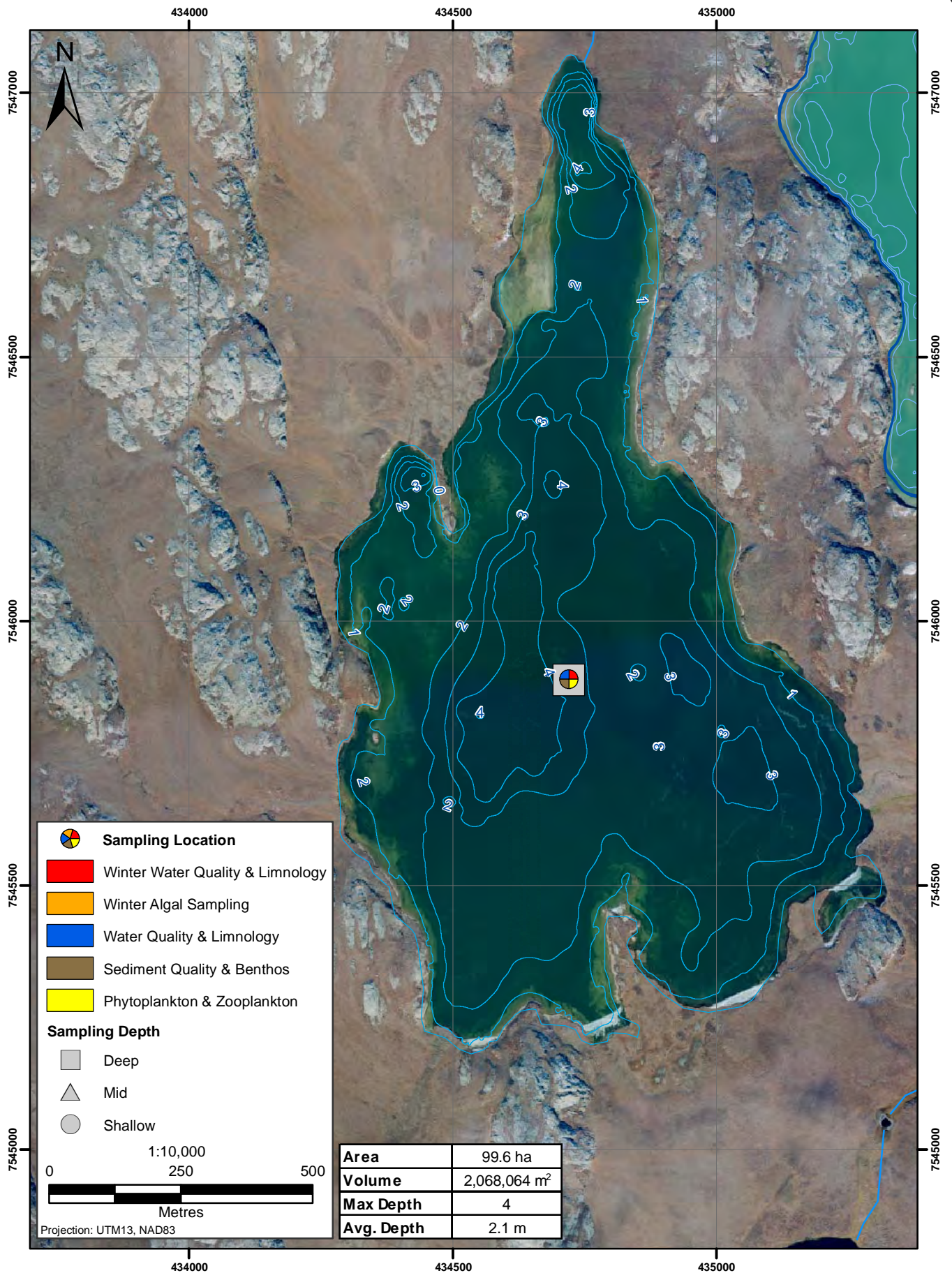


Figure 2.1-2a

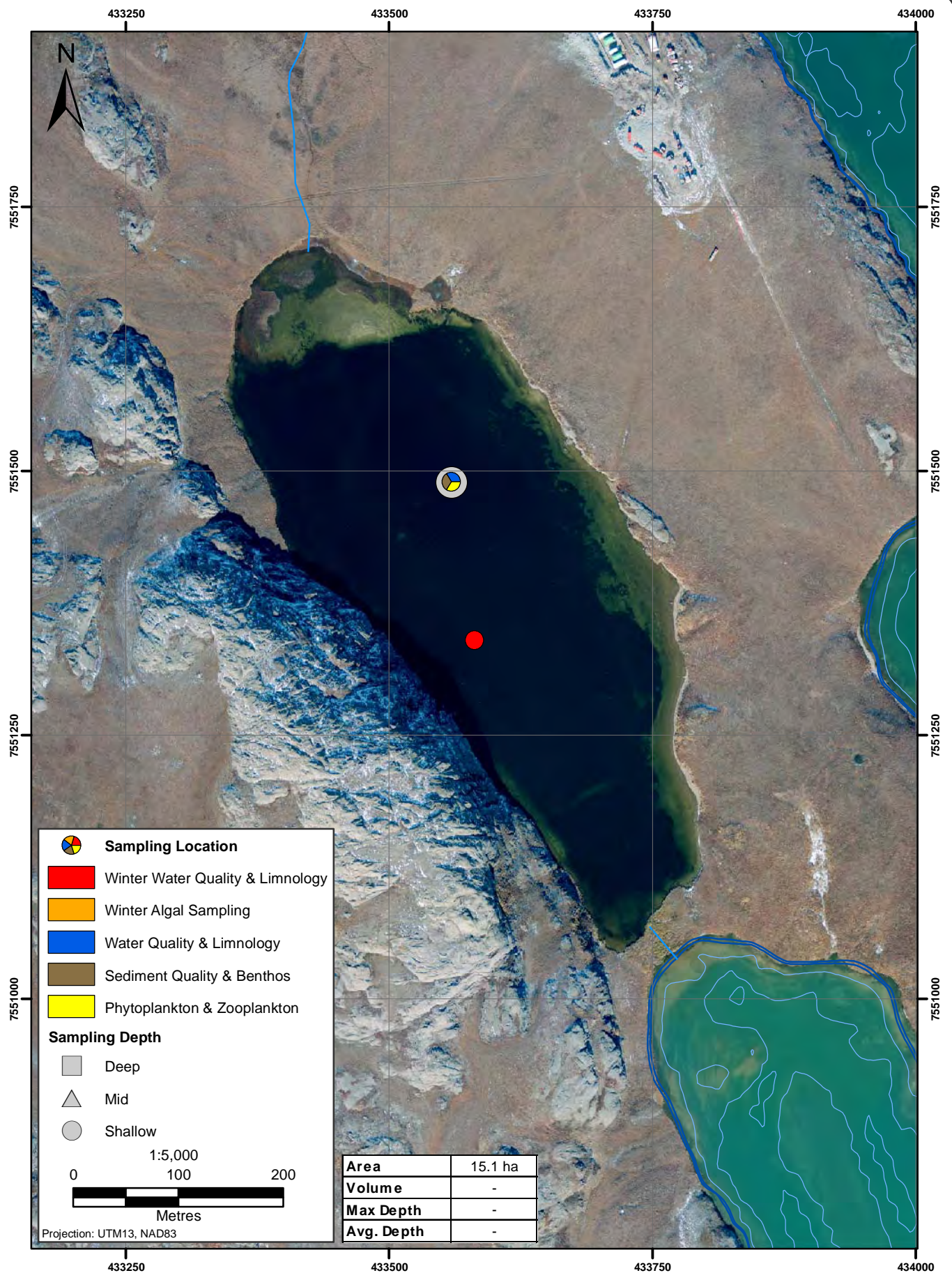


Figure 2.1-2b

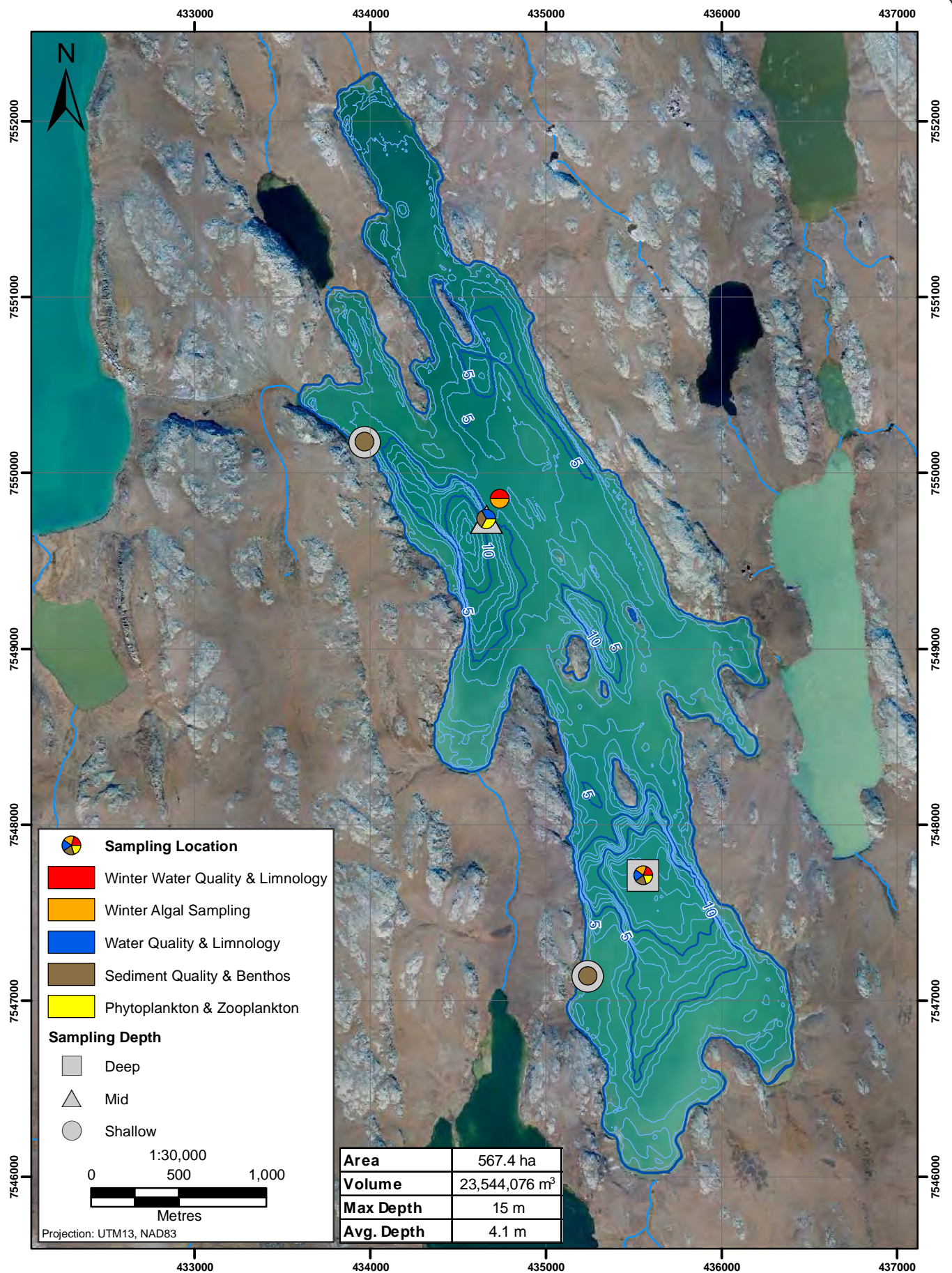


Figure 2.1-2c

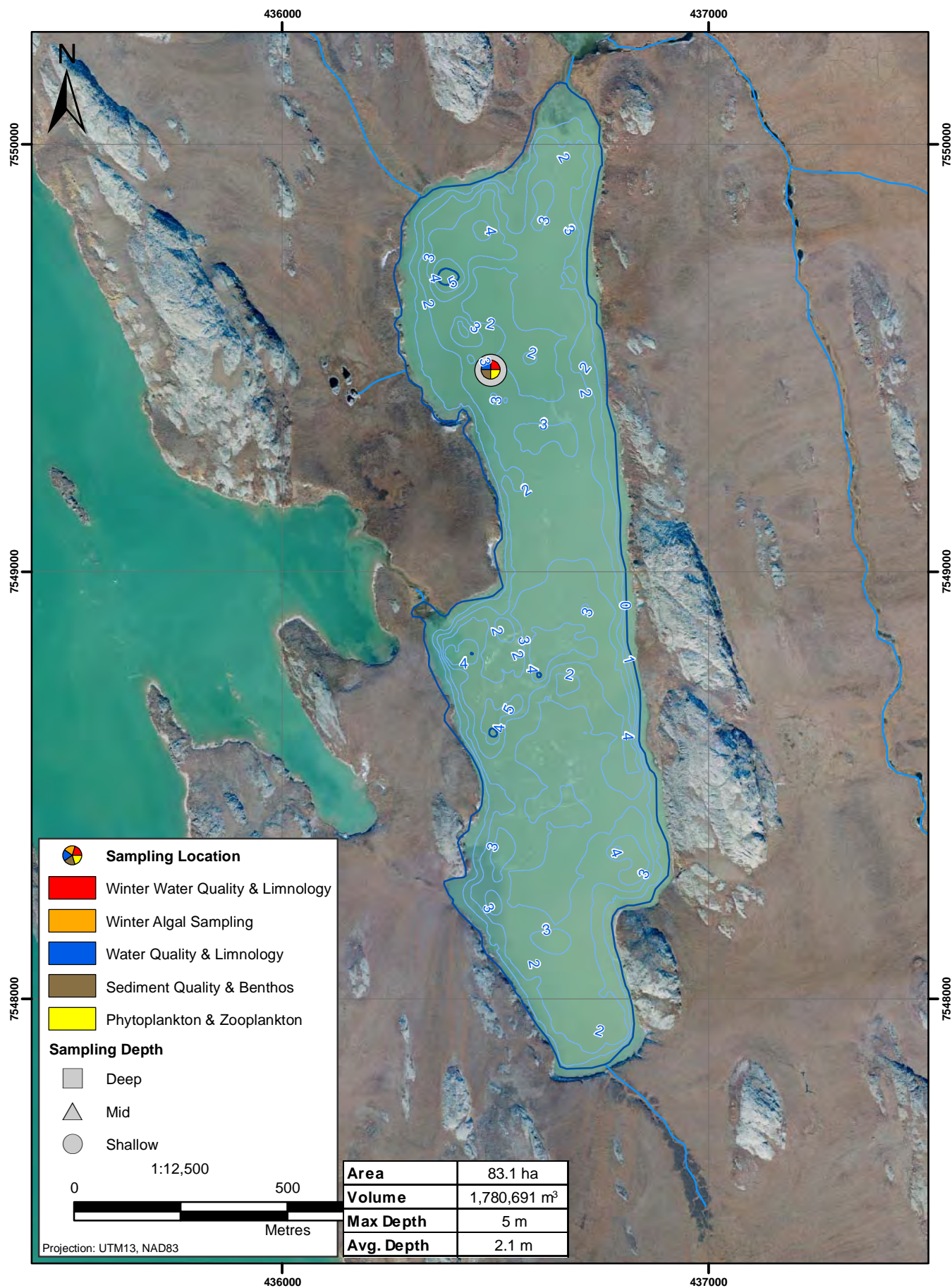


Figure 2.1-2d

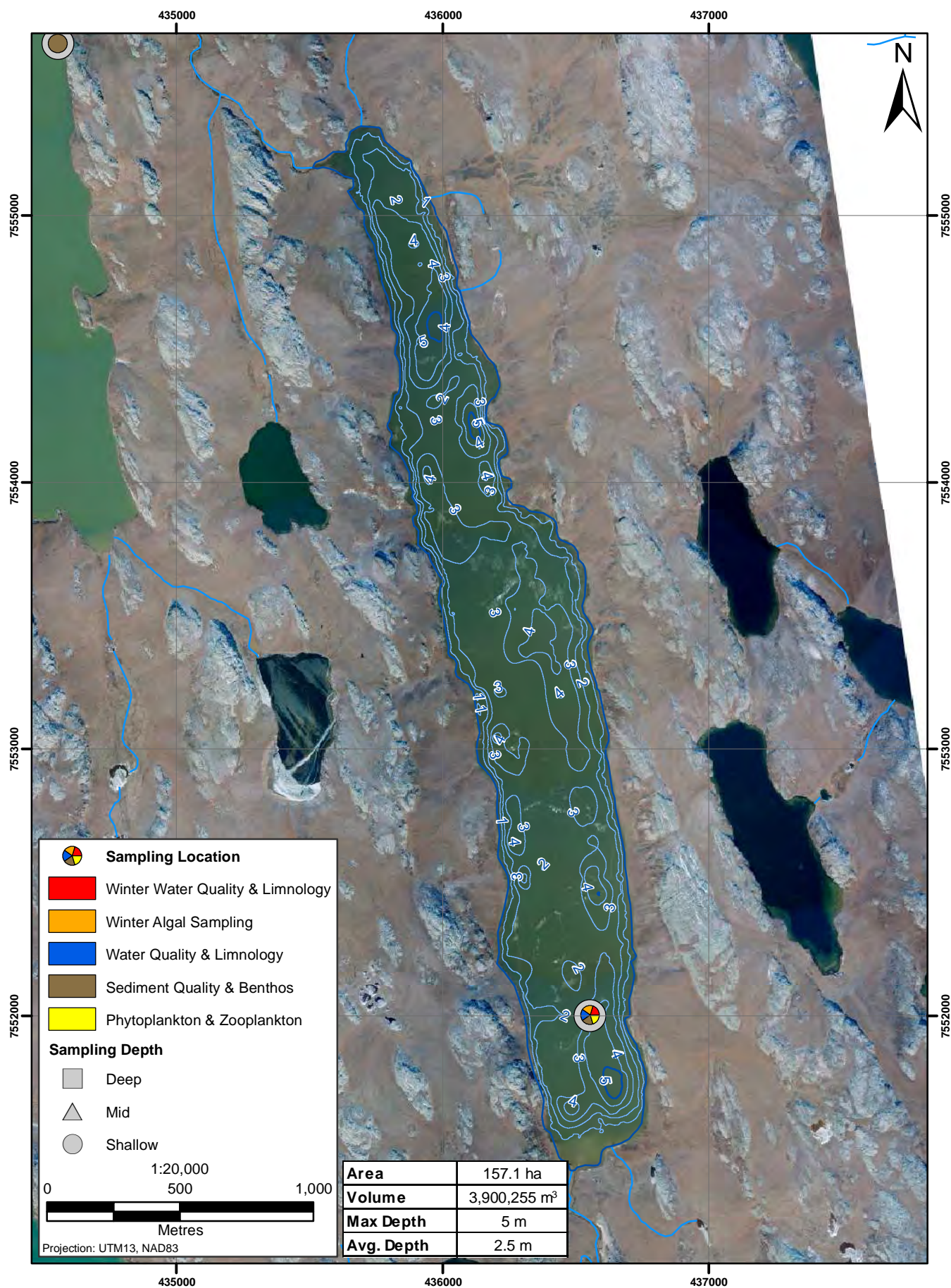


Figure 2.1-2e

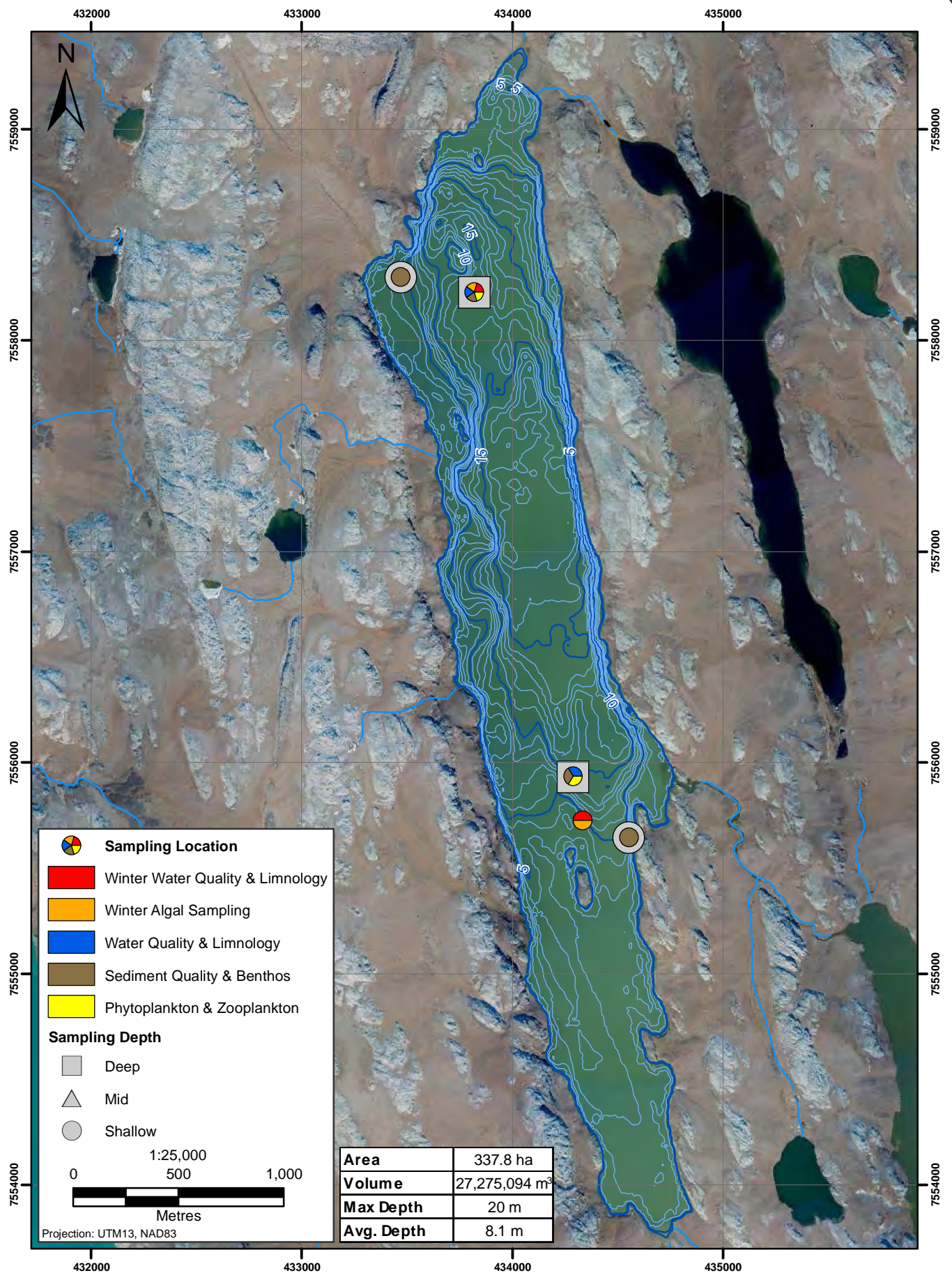


Figure 2.1-2f

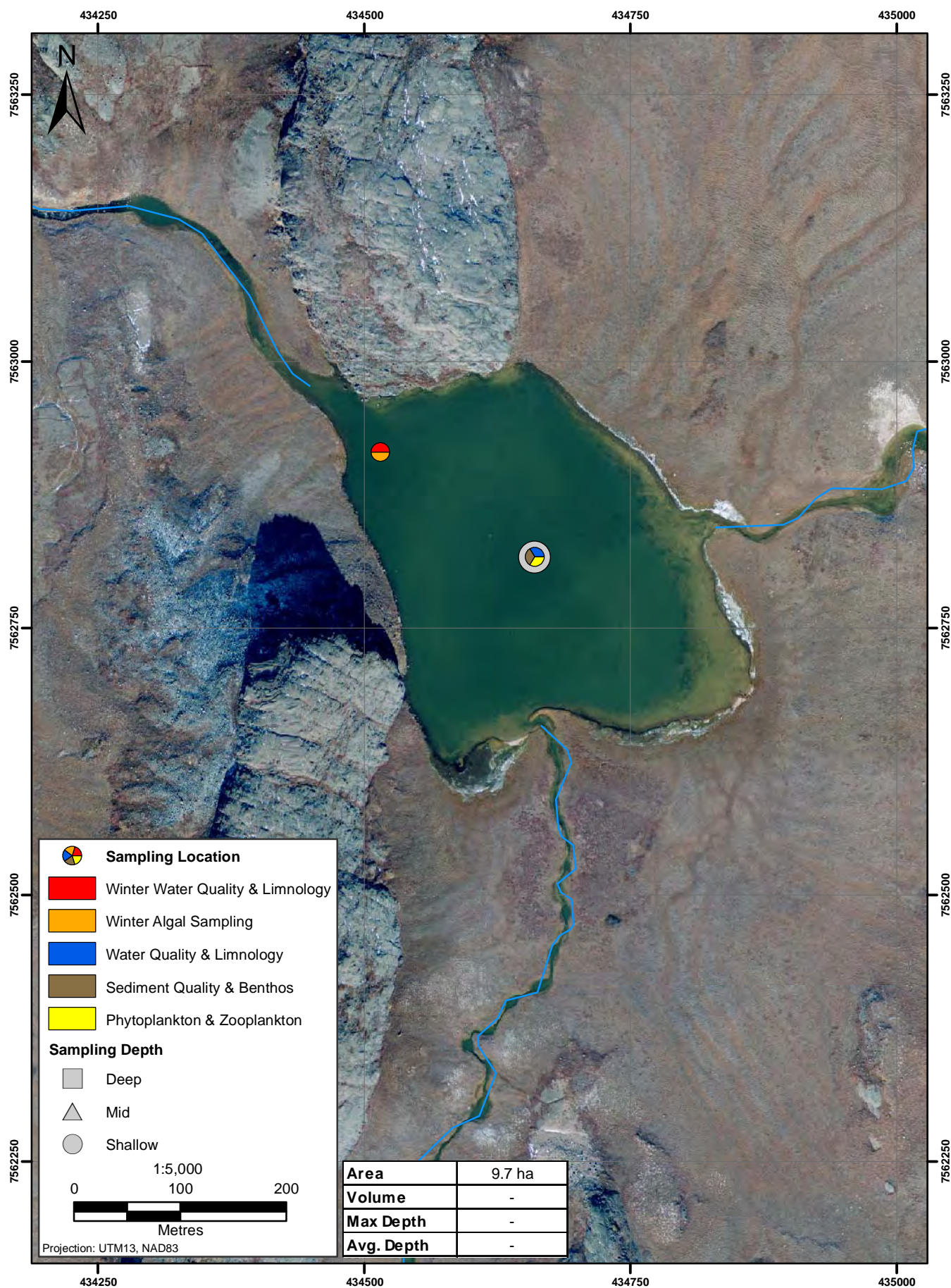


Figure 2.1-2g

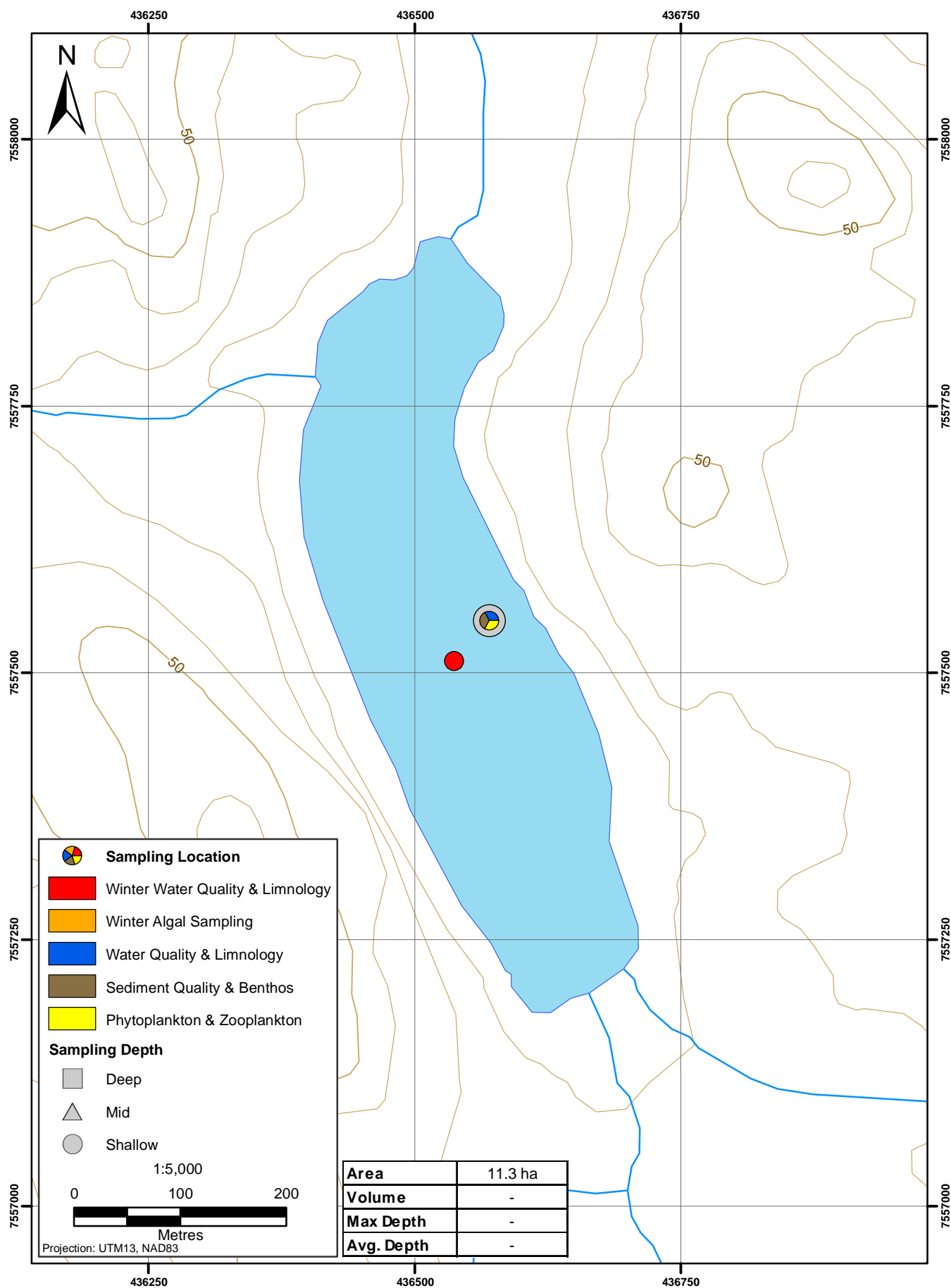


Figure 2.1-2h

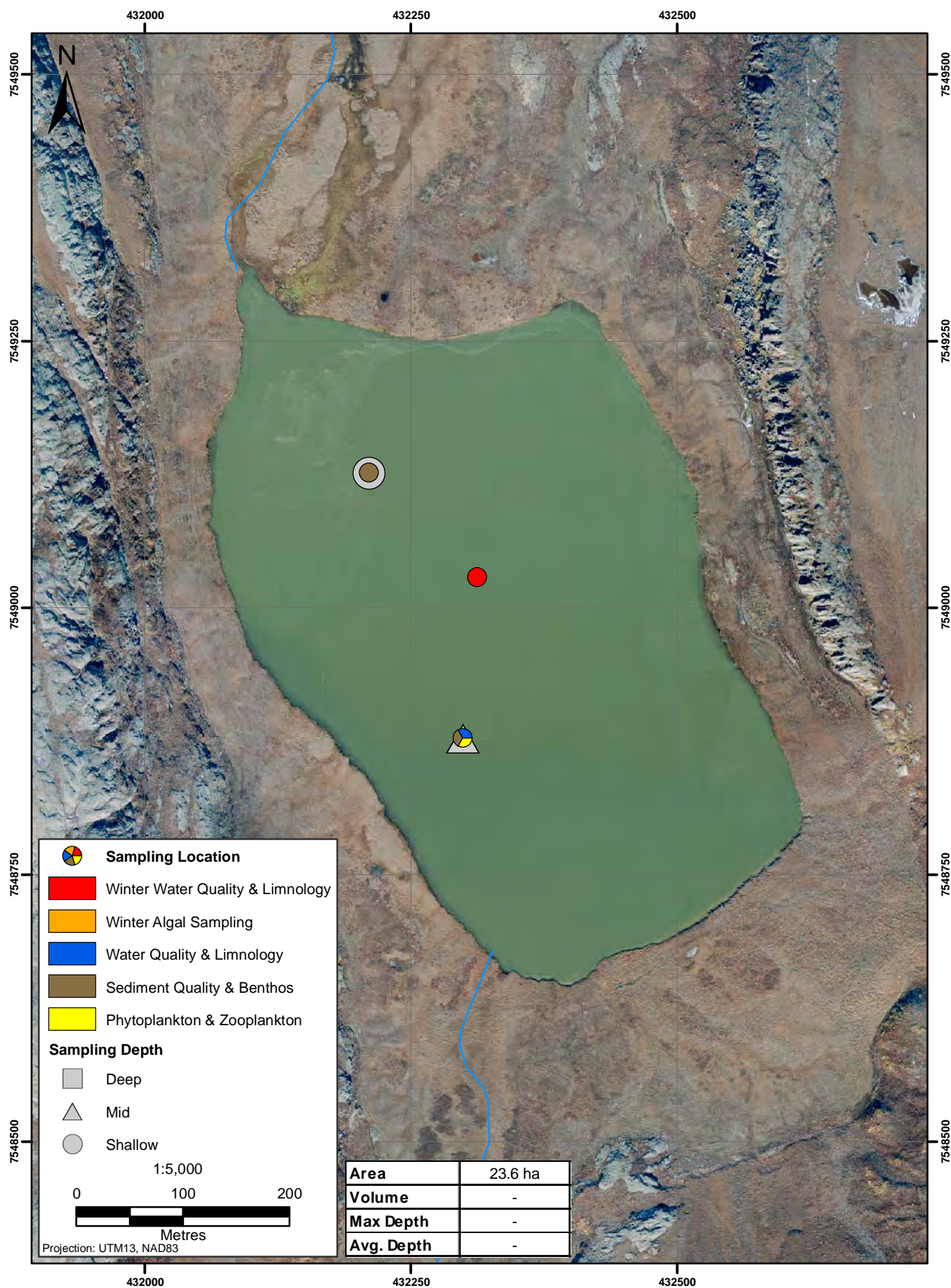


Figure 2.1-2i