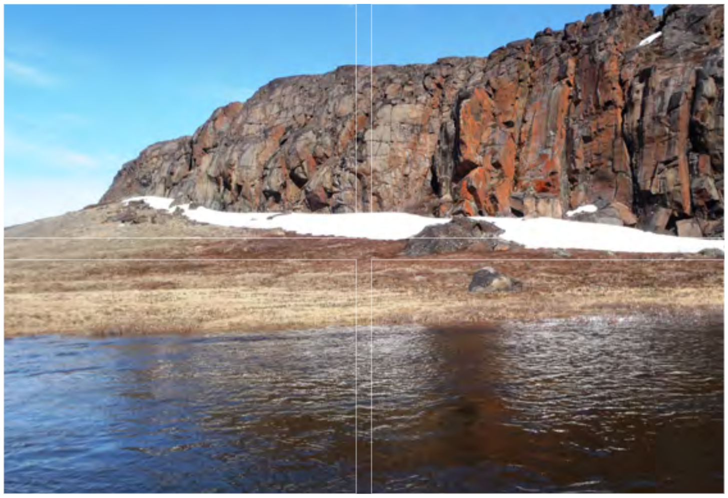
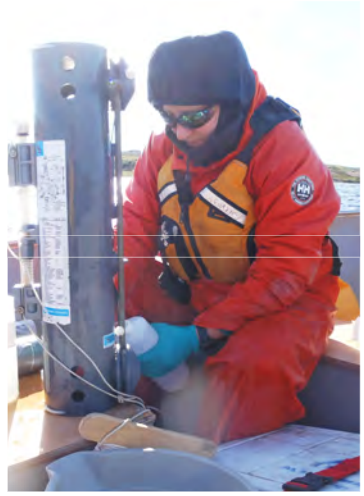




Prepared for:

DORIS NORTH PROJECT

2015 Aquatic Effects Monitoring Program Report

March 2016

The world's leading sustainability consultancy

TMAC Resources Inc.

DORIS NORTH PROJECT

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March 2016

Project #0298923-0005

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EXECUTIVE SUMMARY

The Doris North Gold Mine Project (the Project) is located on the Hope Bay Belt (the Belt), an 80 by 20 km property along the south shore of Melville Sound in Nunavut. TMAC Resources Inc. (TMAC) acquired the Belt from Newmont Corporation in March 2013. The acquisition included exploration and mineral rights over the Hope Bay Belt, including the Doris North Gold Mine and its permits, licences and authorizations for development received by previous owners. In late 2012, prior to the sale, the Hope Bay Belt Project was placed into care and maintenance, and the Project was seasonally closed during the winter of 2012/2013. TMAC re-opened the Doris North Camp in March of 2013 for the purposes of conducting site water management and environmental compliance programs and to support exploration activities which have continued through 2015. Following notification to the Nunavut Water Board (NWB) and Nunavut Impact Review Board (NIRB), construction was resumed during the summer of 2015.

This report presents the results of the Doris North Project's 2015 Aquatic Effects Monitoring Program (AEMP). The 2015 AEMP was executed in accordance with the March 25, 2010, Aquatic Effects Monitoring Plan (the Plan; Rescan 2010c). This report presents the results from the sixth year of the AEMP pre-operations. The AEMP was designed to detect effects on the aquatic environment largely due to discharge of tailings effluent from the Tailings Impoundment Area (TIA). However, to date, no mine tailings have been placed in the TIA, although site contact water is placed in the TIA. As a result, minimal effects are expected on the aquatic environment at present. Operations, and the production of mine tailings, are anticipated to commence in late 2016/early 2017.

In accordance with the Plan, five stream sites (Doris Outflow, Roberts Outflow, Little Roberts Outflow, Reference B Outflow, and Reference D Outflow), five lake sites (Doris Lake North, Doris Lake South, Little Roberts Lake, Reference Lake B, and Reference Lake D), and three marine sites (Roberts Bay East, Roberts Bay West, and REF-Marine 1) were monitored. Aquatic components evaluated in 2015 included the following: lake and marine under-ice dissolved oxygen concentrations; lake Secchi depth; stream, lake, and marine water and sediment quality; stream periphyton biomass; lake and marine phytoplankton biomass; and stream, lake, and marine benthic invertebrate community density, taxa richness, evenness, diversity, and Bray-Curtis Index. Statistical and/or graphical analyses were performed in order to determine whether Project activities had affected exposure sites in 2015. The analyses included comparisons of baseline data to current (2015) data and/or comparisons of reference sites to exposure sites through time. Data were considered to be from the baseline period if they were collected prior to 2010, except in the case of under-ice dissolved oxygen (DO) for which 2010 data were also considered baseline. Lake and marine fish communities were last surveyed in 2010 (Rescan 2011) and were not resurveyed in 2015.

<u>Streams</u>

The water quality effects analysis found that mean 2015 pH levels and concentrations of evaluated nutrients and metals in exposure streams were all below CCME guidelines (CCME 2015b), except total aluminum. However, the total aluminum guideline was frequently exceeded in all exposure streams during baseline years, suggesting that the exposure streams contain naturally high concentrations of aluminum. Based on the 18 water quality variables that were evaluated, there were no apparent adverse changes to the water quality of exposure streams as a result of 2015 Project activities.

Mean 2015 sediment quality concentrations in AEMP exposure streams were below CCME interim sediment quality guidelines (ISQGs) and probable effects levels (PELs) except chromium in the sediments of Doris Outflow, which was slightly higher than the ISQG. At Doris and Little Roberts outflows, there were some differences in the particle size composition of sediment samples collected in 2015 compared to the particle size composition of baseline samples. Variation in sediment particle size composition was likely unrelated to 2015 Project activities, and probably reflected natural spatial heterogeneity in stream sediments. At Little Roberts Outflow, sediments in 2015 contained significantly lower concentrations of total organic carbon (TOC), copper, lead, and mercury than did baseline sediments. These decreases were likely attributable to the significant decrease in the proportion of fine sediments in 2015 samples compared to baseline samples, since fine sediments tend to be associated with higher concentrations of TOC and metals than coarse sediments. Decreases in sediment metal concentrations are not of concern. Therefore, there were no apparent adverse effects of 2015 Project activities on the sediment quality of exposure streams.

There was no indication that 2015 Project activities affected periphyton biomass in the exposure streams.

There was no evidence of Project-related effects on benthos density, richness, evenness or diversity in exposure streams despite significant evidence of non-parallelism in trends in benthos family evenness and the Bray-Curtis Index between Doris Outflow and the reference streams, and total density between Little Roberts Outflow and the reference streams. Benthos community descriptors tended to be highly variable over time in both the exposure and reference streams, and the 2015 results were generally similar to previous years or within the range expected given these high levels of natural variability. The non-parallelism in trends between the exposure and reference sites was likely a result of the naturally high variability in the data, and no adverse effects of Project activities on stream benthos were found.

<u>Lakes</u>

There was no evidence of an effect of 2015 Project activities on either under-ice dissolved oxygen concentrations or Secchi depths in the exposure lakes.

The water quality effects analysis found that mean 2015 pH levels and concentrations of evaluated nutrients and metals in exposure lakes were all below CCME guidelines, except total copper which was slightly above the CCME guideline in Little Roberts Lake. However, the baseline mean total copper concentration at Little Roberts Lake was also above this CCME guideline, suggesting that copper concentrations are naturally elevated in this lake. Based on the 18 water quality variables that were evaluated, there were no apparent adverse changes to the water quality of exposure streams as a result of 2015 Project activities. Although pH increased significantly at Little Roberts Lake and hardness increased significantly at Doris Lake South in 2015, similar increases in pH and hardness occurred at Reference Lake B in 2015. This suggests that slight changes in pH and hardness can occur naturally and are not necessarily related to Project activities. There was also a slight (7%)

increase in the total molybdenum concentration in Little Roberts Lake between baseline years and 2015. Although this increase in molybdenum was statistically significant, it is not considered environmentally or biologically important, as the increase was slight and 2015 concentrations remained well below the CCME guideline concentration. Therefore, there was no evidence of adverse effects of Project activities on lake water quality.

Mean 2015 concentrations of sediment quality variables were generally below CCME ISQGs, except arsenic in Doris Lake South and Doris Lake North, chromium at all exposure and reference sites, and copper at Doris Lake North. The arsenic PEL was also slightly exceeded at Doris Lake South. At all three lake exposure sites, there were some differences in the particle size composition in the sediment samples collected in 2015 compared to the particle size composition of baseline samples. Variation in sediment particle size composition was likely unrelated to 2015 Project activities, and probably reflected natural spatial heterogeneity in lake sediments. There was evidence of a slight increase in the TOC content in Doris Lake North sediments in 2015; however, the increase was quite small (8.2%) and was likely related to natural variability rather than Project effects. Concentrations of several metals decreased in the sediments of exposure lakes in 2015 including cadmium in Doris Lake North, copper in Doris Lake South and North, lead in all three exposure sites, and zinc in Doris Lake North and Little Roberts Lake. Decreases in the concentrations of metals in sediments are not a cause for concern, so there were no apparent adverse effects of 2015 Project activities on sediment quality in exposure lake sites.

There was no indication of a Project-related effect on 2015 phytoplankton biomass in the exposure lakes.

In lake exposure sites, there was non-parallelism in 2010 to 2015 trends for nearly all benthos community descriptors when compared to the reference sites. There was evidence of significant non-parallelism for benthos density, the Simpson's Evenness Index, and the Bray Curtis Index for all exposure lakes relative to reference lakes. Benthos family richness trends were also non-parallel for Doris Lake South and Little Roberts Lake relative to the reference lakes, and Simpson's Diversity Index trends were non-parallel for Doris Lake North and South compared to the reference lakes. Benthos community descriptors tended to be highly variable over time in both the exposure and reference lakes, and the 2015 results were generally similar to previous years or within the range expected given these high levels of natural variability. The non-parallelism in trends between the exposure and reference sites was likely a result of the naturally high variability in the data, and no adverse effects of Project activities on lake benthos were found.

Marine

There was no evidence of an effect of 2015 Project activities on under-ice dissolved oxygen concentrations at the marine exposure sites in Roberts Bay, and 2015 concentrations remained above the CCME interim guideline for the minimum concentration of dissolved oxygen in marine and estuarine waters (8.0 mg/L).

The water quality effects analysis found that mean 2015 pH levels and concentrations of evaluated nutrients and metals in marine exposure sites were all below CCME guidelines. Based on the 18 water quality variables that were evaluated, there were no apparent adverse changes to the water quality of marine exposure sites that can be attributed to the Project.

Mean 2015 concentrations of sediment quality variables were generally below CCME ISQGs, except for copper at site RBW near the jetty. All sediment metal concentrations remained well below CCME PEL guidelines. Although there was no suitable baseline data to compare against 2015 sediment quality data from site RBE, concentrations of sediment quality variables were consistently lowest at this site, likely due to the greater levels of sand compared to the finer sediments at sites RBW and REF-Marine 1. At site RBW, there were significant increases in TOC and arsenic concentrations in sediments, but these increases were found to be parallel to the trends at the reference site, suggesting that the observed changes were unrelated to the Project. There were also increases in several metals in RBW sediments in 2015 that were not parallel to reference site trends, including chromium, copper, lead, and zinc. Concentrations of all these metals except for copper were higher in REF-Marine 1 sediments than RBW sediments in 2015, suggesting that concentrations of these metals in RBW sediments remained within levels expected for the region, and that Project activities did not adversely affect the sediment quality at RBW. 2015 sediment copper concentrations at RBW were within range of concentrations measured at that site since 2012, and were just slightly higher than the upper limit of the range of copper concentrations measured in reference site sediments between 2009 and 2015. Thus, it is unlikely that 2015 Project activities are responsible for the increased concentrations of copper measured in the sediments of RBW, and the difference between baseline (2002) and 2015 copper levels at RBW is probably due to natural variability.

There was no indication of a Project-related effect on 2015 phytoplankton biomass at the marine exposure sites.

In the whole benthos community (adults and juveniles) and the adult subset of the community, significant non-parallelisms were detected for all evaluated benthos community descriptors at RBW and RBE relative to the REF-Marine 1, except for whole community benthos density and Simpson's Evenness Index at RBE. Most 2015 benthos community descriptors were within range of previous years, and there was no indication that benthos communities in 2015 at RBW or RBE were adversely affected by Project activities. Non-parallelisms in trends in the benthos communities were likely attributable to high inter-annual variability of all community descriptors at the exposure and reference sites.

Mitigation measures to reduce the potential for adverse effects to stream, lake, and marine habitats in the Doris North area included surface water runoff management, dust abatement measures, site water management, quarry and waste rock management, and waste management. The 2015 results indicate that these mitigation measures were effective in preventing adverse effects to dissolved oxygen levels, water clarity (Secchi depth), water and sediment quality variables, periphyton and phytoplankton biomass levels, and benthic invertebrate communities in Project area waterbodies.

ACKNOWLEDGEMENTS

This report was prepared for TMAC Resources Inc. by ERM. The 2015 fieldwork was conducted by ERM scientists Erin Forster (B.Sc., R.P.Bio.), Rebecca D'Onofrio (M.Sc.), Anneli Jokela (Ph.D.), and Pascale Savage (B.Sc.) and TMAC On-site Environmental Coordinator, Clair Brown. Fieldwork was completed with the enthusiastic and competent support of TMAC field assistants Darcy Kanayok, Robert Maksagak, Lawrence Otokiak, and Warren Wourms. The report was written by Carol Adly (M.Sc.) and Erin Forster, statistical analyses were completed by Laurie Ainsworth (Ph.D.), and the report was technically reviewed by Mike Henry (Ph.D.) and Katsky Venter (M.Sc.) of TMAC. The compliance program was coordinated by Nicole Bishop (B.Sc.) and managed by April Hayward (Ph.D.) and Erin Forster. The ERM Partner in Charge was Marc Wen (M.Sc., R.P.Bio.).

Field-related logistics support was provided by TMAC, Great Slave Helicopters, Braden Burry Expediting, and Nuna Logistics.

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GLOSSARY AND ABBREVIATIONS

Terminology used in this document is defined where it is first used. The following list will assist readers who may choose to review only portions of the document.

AEMP	Aquatic Effects Monitoring Program
ALS	ALS Laboratory Group
ANOVA	Analysis of Variance
BA	Before-after
BACI	Before-after-control-impact
BC	Bray-Curtis Dissimilarity Index (also known as Bray-Curtis Similarity Index) or British Columbia
the Belt	Hope Bay Belt
Benthos	Benthic invertebrates
CCME	Canadian Council of Ministers of the Environment
Censored value	A value that is only partially known, e.g., a variable concentration that is reported as being below a specified detection limit, although the actual concentration is not known.
Chl *a*	Chlorophyll *a*
Chlorophyll *a*	An essential light-harvesting pigment for photosynthetic organisms including phytoplankton. Because of the difficulty involved in the direct measurement of plant carbon, chlorophyll *a* is routinely used as a 'proxy' estimate for plant biomass in aquatic studies.
CTD	Conductivity, temperature, depth probe
D	Simpson's Diversity Index
Degrees of Freedom	The term *degrees of freedom* refers to the number of items that can be freely varied in calculating a statistic without violating any constraints. Such items typically include observations, categories of data, frequencies, or independent variables. Because the estimation of parameters imposes constraints on a data set, a degree of freedom is generally sacrificed for each parameter that must be estimated from sample data before the desired statistic can be calculated (Eisenhauer 2011).
DO	Dissolved oxygen

D_s	Secchi depth
E	Simpson's Evenness Index
EEM	Environmental Effects Monitoring
Epontic	Occurring in or on the bottom of the ice layer.
ERM	ERM Consultants Canada Ltd.
Exposure areas	Areas anticipated to be potentially influenced by mining-related activities as part of the Doris North Project.
F	Family richness
GA	Graphical analysis
HBML	Hope Bay Mining Limited
ILBT	Impact level-by-time
INAC	Indigenous and Northern Affairs Canada
ISQG	Interim sediment quality guideline
k	Light extinction coefficient
MMER	Metal Mining Effluent Regulations
NA	Not applicable
NC	Not collected
NIRB	Nunavut Impact Review Board
NTU	Nephelometric Turbidity Units
NWB	Nunavut Water Board
OF	Outflow
PEL	Probable effects level
the Plan	the Doris North Gold Mine Project: Aquatics Effects Monitoring Plan
the Project	the Doris North Gold Mine Project
QA/QC	Quality assurance/quality control
RBE	Roberts Bay East
RBW	Roberts Bay West
RDL	Realized detection limit

Reference areas	Areas located beyond any Project influence.
Salinity	No units, dimensionless. Historically, many units have been assigned to salinity, for example, parts per thousand (ppt or ‰), Practical Salinity Units (PSU), and Practical Salinity Scale (PSS 78). Salinity is defined on the Practical Salinity Scale (PSS) as the conductivity ratio of a seawater sample to a standard KCl solution. As PSS is a ratio, it has no units.
SD	Standard deviation
SE	Standard error of the mean
TIA	Tailings Impoundment Area
TMAC	TMAC Resources Inc.
TOC	Total organic carbon
TSS	Total suspended solids
$Z_{1\%}$	The 1% euphotic depth, i.e., the depth of the water column at which 1% of the surface irradiance reaches.

1. INTRODUCTION

The Doris North Project (the Project) is located on the Hope Bay Belt (the Belt), an 80 by 20 km property along the south shore of Melville Sound in Nunavut (Figure 1-1). The property consists of a greenstone belt that contains three main gold deposits. The Doris and Madrid deposits are located in the northern portion of the belt, and the Boston deposit is at the southern end. The Project is approximately 125 km southwest of Cambridge Bay (Iqaluktuttiaq) on the southern shore of Melville Sound. The nearest communities are Umingmaktok (75 km to the southwest of the property), Cambridge Bay and Kingaok (Bathurst Inlet; 160 km to the southwest of the property).

TMAC Resources Inc. (TMAC) acquired the Belt from Newmont Corporation in March 2013. The acquisition included exploration and mineral rights over the Belt, including the Doris North Gold Mine and its permits, licences, and authorizations for development received by previous owners. In late 2012, prior to the sale, the Hope Bay Project was placed into care and maintenance, and the Project was seasonally closed during the winter of 2012/2013. TMAC re-opened the Doris Camp in March of 2013 for the purposes of conducting site water management and environmental compliance programs and to support exploration activities which continued through 2015. Following notification to the Nunavut Water Board (NWB) and Nunavut Impact Review Board (NIRB), construction was resumed during the summer of 2015.

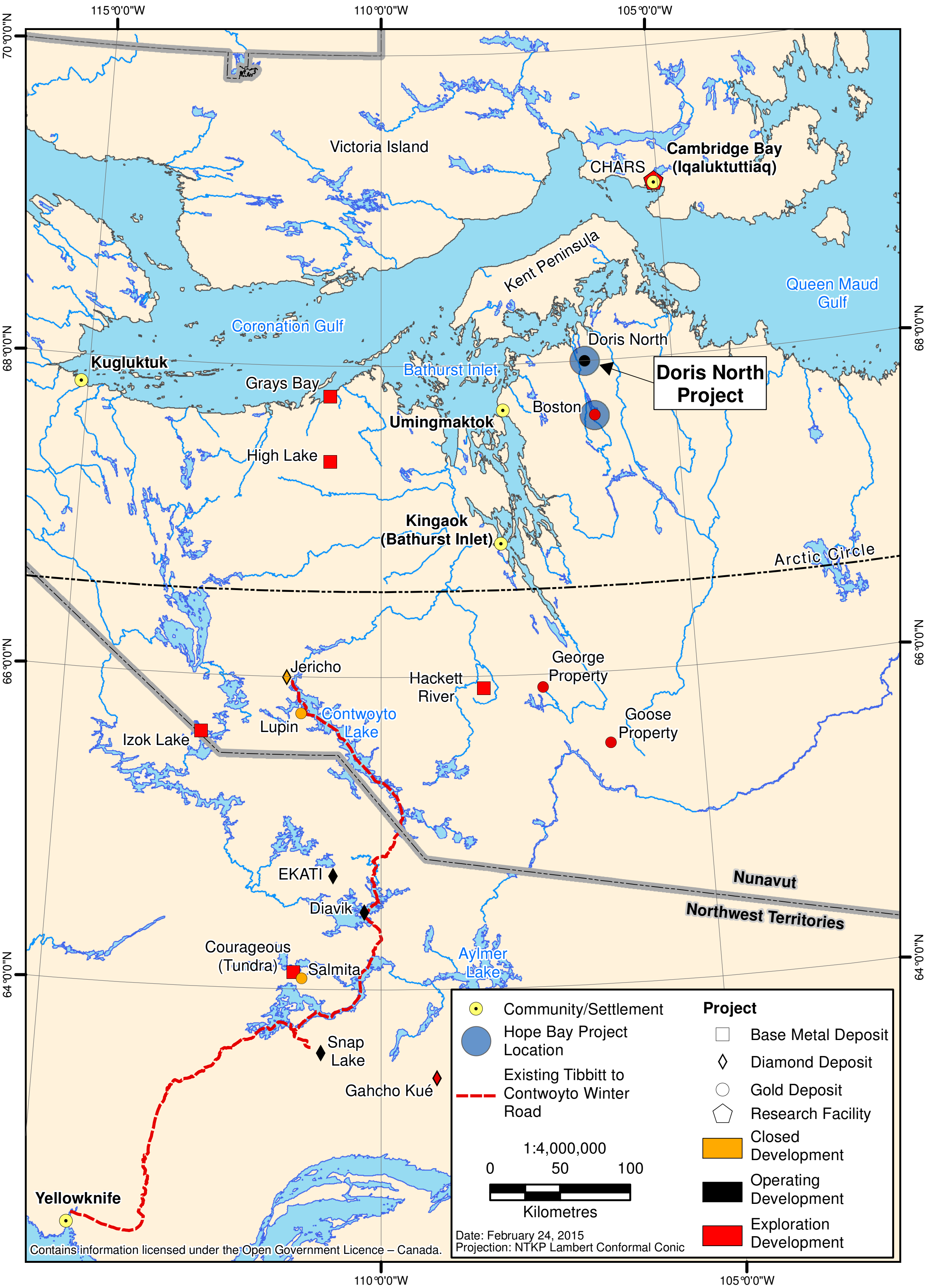
ERM Consultants Canada Ltd. (ERM) was contracted to develop an Aquatic Effects Monitoring Plan to fulfil requirements set out in the Doris North Nunavut Water Board (NWB) Type A Water Licence (No. 2AM-DOH0713 Type A, issued September 19, 2007; NWB 2007) as follows:

- Part K, Item 7. *The Licensee shall submit to the Board for approval..., a proposal for the development of an Aquatic Effects Monitoring Plan…in consultation with Environment Canada. The proposal for an [Aquatic Effects Monitoring Plan] shall consider modifications and advances in schedule which are consistent with the objectives and requirements of the Metal Mining Effluent Regulations (MMER) ;*
- Part K, Item 8. *The Licensee and Environment Canada shall coordinate with the NWB to ensure that the advanced submission of the [Aquatic Effects Monitoring Plan] meets the requirements of MMER.*

In compliance with Part K, Item 7, Hope Bay Mining Ltd. (HBML) submitted an Aquatic Effects Monitoring Plan on February 24, 2010, following consultation with Environment Canada. The *Doris North Gold Mine Project: Aquatic Effects Monitoring Plan* (the Plan; Rescan 2010c), was approved by the Nunavut Water Board (NWB) on March 25, 2010, under Motion 2009-23-L04. This document conformed to the methodologies and practices laid out in the MMER (2002), thus complying with Part K, Item 8 of the Type A Water Licence, and was designed to assess the potential effects of Project development on the aquatic environment.

On September 12, 2013, a renewed and amended Type A Water Licence was issued to TMAC. The following text outlines the requirements of the current Type A Water Licence (NWB Licence #2AM-DOH1323):

Figure 1-1
Doris North Project Location



- Part K, Item 7. *The Licensee shall submit to the Board for review, six (6) months prior to Operations, a revised Doris North Gold Mine Project: Aquatic Effects Monitoring Plan…that has been developed in consultation with Environment Canada. The revised [Aquatic Effects Monitoring Plan] shall consider modifications and advances in schedule which are consistent with the objectives and requirements of the MMER.*

The 2015 Aquatic Effects Monitoring Program (AEMP) was conducted in accordance with the Plan approved on March 25, 2010. A revised Plan will be submitted to the NWB prior to the commencement of Operations. The AEMP has been conducted annually in accordance with the Plan since 2010, and this report presents the results from the sixth year of the AEMP pre-operations. The AEMP was designed to detect effects on the aquatic environment largely due to discharge of tailings effluent from the Tailings Impoundment Area (TIA). However, to date, no mine tailings have been placed in the TIA. Site contact water is placed in the TIA as per the approved Interim Water Management Plan (SRK 2012). As a result, minimal effects are expected on the aquatic environment at present. Operations, and the production of mine tailings, are anticipated to commence in late 2016/early 2017.

This report presents the results of the 2015 Program. All other requirements pertaining to water quality monitoring (e.g., Quarry Rock Seepage Monitoring and Management) are monitored by TMAC and reported elsewhere.

1.1 OBJECTIVES

The Plan design was driven by the requirements of the MMER and the anticipated location of Project activities during the construction, operation, and closure phase of the mine. The MMER stipulates that mines are required to conduct Environmental Effects Monitoring (EEM) if effluent discharge rates exceed 50 m^3 per day and deleterious substances are discharged into any waterbody as per subsection 36(3) of the *Fisheries Act*. The primary objective of the mining EEM program is to evaluate the effects of mining effluents on fish, fish habitat, and the use of fisheries resources. Thus, the objectives of the AEMP were to monitor and evaluate potential effects of Project activities on the following components in waterbodies in the Project area:

- water quality and water column structure;
- sediment quality;
- primary producer biomass (phytoplankton and periphyton);
- benthic invertebrate community (density and taxonomy); and
- fish.

Fish were last sampled in 2010 (Rescan 2011). The second year of fish monitoring was postponed from 2013 in accordance with the modified mine development schedule. The Plan will be revised prior to the discharge of effluent from the Tailings Impoundment Area (TIA) following tailings deposition, and a new fish monitoring schedule will be outlined.

1.2 2015 PROJECT ACTIVITIES

As of winter 2015, existing Project infrastructure included the following: the Roberts Bay jetty, the 5,000,000 L tank and berm at Roberts Bay, the 15,000,000 L tank farm at Roberts Bay, the Roberts Bay laydown areas, the road and associated airstrip between Roberts Bay and Doris Camp, the access road to the Doris Lake pump house, the 7,500,000 L tank farm at Doris Camp, Doris Camp Pads X and Y (including the Camp, construction power house, and sewage and water treatment system), Doris Camp Pads B, C, E/P, F, G, H/J, I, Q, the helipad, the upper and lower reagent pads, the primary vent raise, permanent power house, partially developed Quarry 2, the secondary road to the TIA, and the North Dam (Figure 1.2-1). Windy Road and Quarries A, B, and D are depicted on Figure 1.2-1, but are permitted outside of the Doris North Project Certificate and Water Licence 2AM-DOH1323 (Land Use Licence KTL303C056, Quarry Permit Agreement KTP308Q010, Water Licence 2BB-HOP1222).

The Project remained in care and maintenance in early 2015 and entered construction in the summer. Construction activities included commissioning the automated controls for the existing four generator primary powerhouse, and the purchase of construction equipment to erect the processing plant building in 2016. Furthermore, TMAC designed and completed fabrication of the processing plant building, initiated on-site construction of the processing plant building foundations, and completed the Gekko processing plant flowsheet design. TMAC took advantage of the opening of quarries and the initiation of earthworks related to the process plant foundation construction to advance Doris Airstrip improvements aimed at lengthening and widening the airstrip.

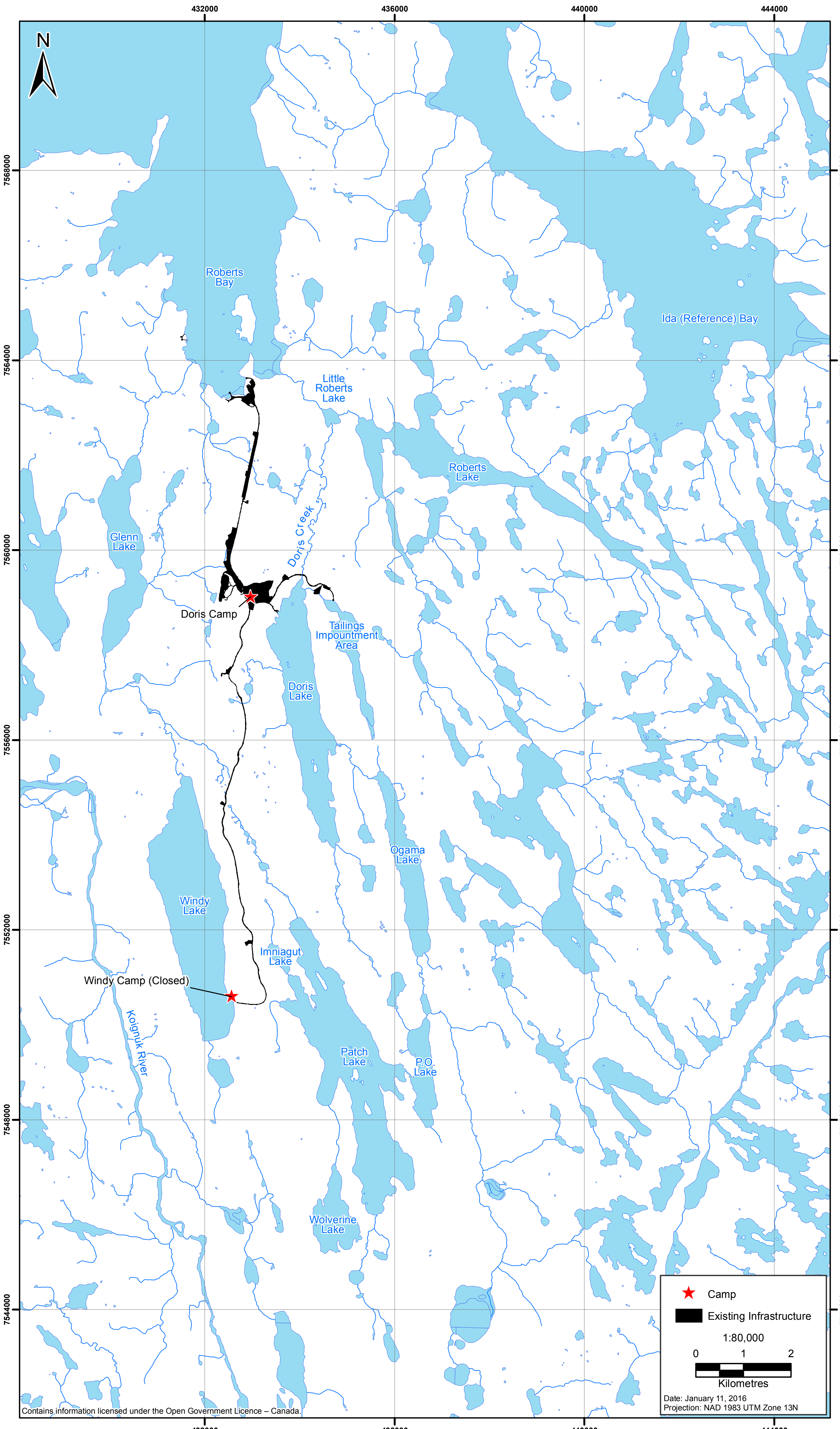
Underground development was also resumed in 2015. Significant activities included the delivery of narrow vein test mining equipment via an airlift in the spring and the purchase of mobile mine equipment capable of mining at a rate of 1,000 tonnes per day for delivery via sealift. TMAC also developed a narrow vein undercut test drift at Doris to validate the Pre-Feasibility Study mining model and cost assumptions, ordered the first year mining supplies for delivery by sealift, initiated and completed the widening of the Doris mine vent raise to incorporate escape-way infrastructure, and completed a tactical plan for mine development and production.

In the fall, TMAC successfully concluded the 2015 sealift including the purchase and delivery of 15,000,000 L of diesel fuel and delivery of the processing plant building materials to Hope Bay to allow for erection of the building in the second and third quarters of 2016.

TMAC continued with diamond-drill exploration near Doris and Madrid deposits in 2015, with the addition of an airborne geophysics program focused on nearby Elu belt crown mineral claims.

On-going site water management involved the discharge of water from the TIA into Doris Creek to manage water levels in the impoundment. This discharge has been occurring seasonally since 2011, and was unlikely to affect the aquatic environment because discharged water was closely monitored to ensure that established discharge criteria were met, and to date no mill tailings have been placed in the TIA (the mill is under construction and will only be operational in late 2016).

Figure 1.2-1
Existing Infrastructure, Doris North Project



The main potential interactions between the Project and the aquatic freshwater and marine environment relevant to the current Type A Water Licence are anticipated to be:

- the operation of the Tailings Impoundment Area (TIA; formerly Tail Lake): treated effluent from this facility is expected to be released into Doris Outflow where it would flow successively through Little Roberts Lake and into Little Roberts Outflow before entering Roberts Bay. However, no mine tailings have been placed in this facility to date and TIA discharge is monitored through the monthly site Surveillance Network Program required by the Water Licence;
- shipping activity at the marine jetty in southern Roberts Bay;
- construction of roads and infrastructure;
- runoff from site infrastructure, roads, waste rock (seepage from these sites are monitored through the Quarry and Waste Rock Monitoring Program and reported separately on an annual basis). Site contact water (including runoff from the site and waste rock) is deposited in the TIA; and
- accidental spills.

Mitigation measures to reduce the potential for adverse effects to stream, lake, and marine habitats in the Project area included surface water runoff management, dust abatement measures, site water management, tailings management, quarry and waste rock management, and waste management.

1.3 REPORT STRUCTURE

This document presents the methods, effects analysis, and conclusions of the 2015 Program. Source data and results from the 2015 Program (including water column structure, water quality, sediment quality, primary producers, and benthic invertebrates) are provided in Appendix A, and supplemental information relevant to the 2015 effects analysis is provided in Appendix B.

2. METHODS

2.1 SUMMARY OF STUDY DESIGN

The 2015 Program was conducted in accordance with the Doris North Gold Mine Project: Aquatic Effects Monitoring Plan (Rescan 2010c).

2.1.1 Study Area and Sampling Locations

The AEMP study area included those areas that may be influenced by mining-related activities as part of the Project (exposure areas) and those areas beyond any Project influence (reference areas). Three lake and three stream sites were sampled in the exposure areas and two lakes and two streams were sampled as reference sites (Table 2.1-1; Figure 2.1-1). Two marine exposure sites and one marine reference site were also sampled (Table 2.1-1; Figure 2.1-1). Sampling sites, the aquatic components sampled, Project infrastructure, and the projected flow path of the treated TIA effluent as per the current Type A Water Licence are shown in Figure 2.1-1.

2.1.1.1 Exposure Sites

The principal exposure sites in the AEMP study area are those waterbodies downstream of discharge from the TIA. From upstream to downstream, these include: Doris Outflow, Little Roberts Lake, Little Roberts Outflow, and Roberts Bay East (RBE; Figure 2.1-1). The Doris Outflow sampling site is within 100 m of the discharge location to best measure the potential effects of the TIA discharge. Little Roberts Lake, a small, shallow lake (0.1 km^2, <5 m depth) receiving outflow from Doris Lake and Roberts Lake, is the only lake along the TIA discharge path. A receiving environment site is in eastern Roberts Bay where Little Roberts Outflow enters the marine habitat (Roberts Bay East).

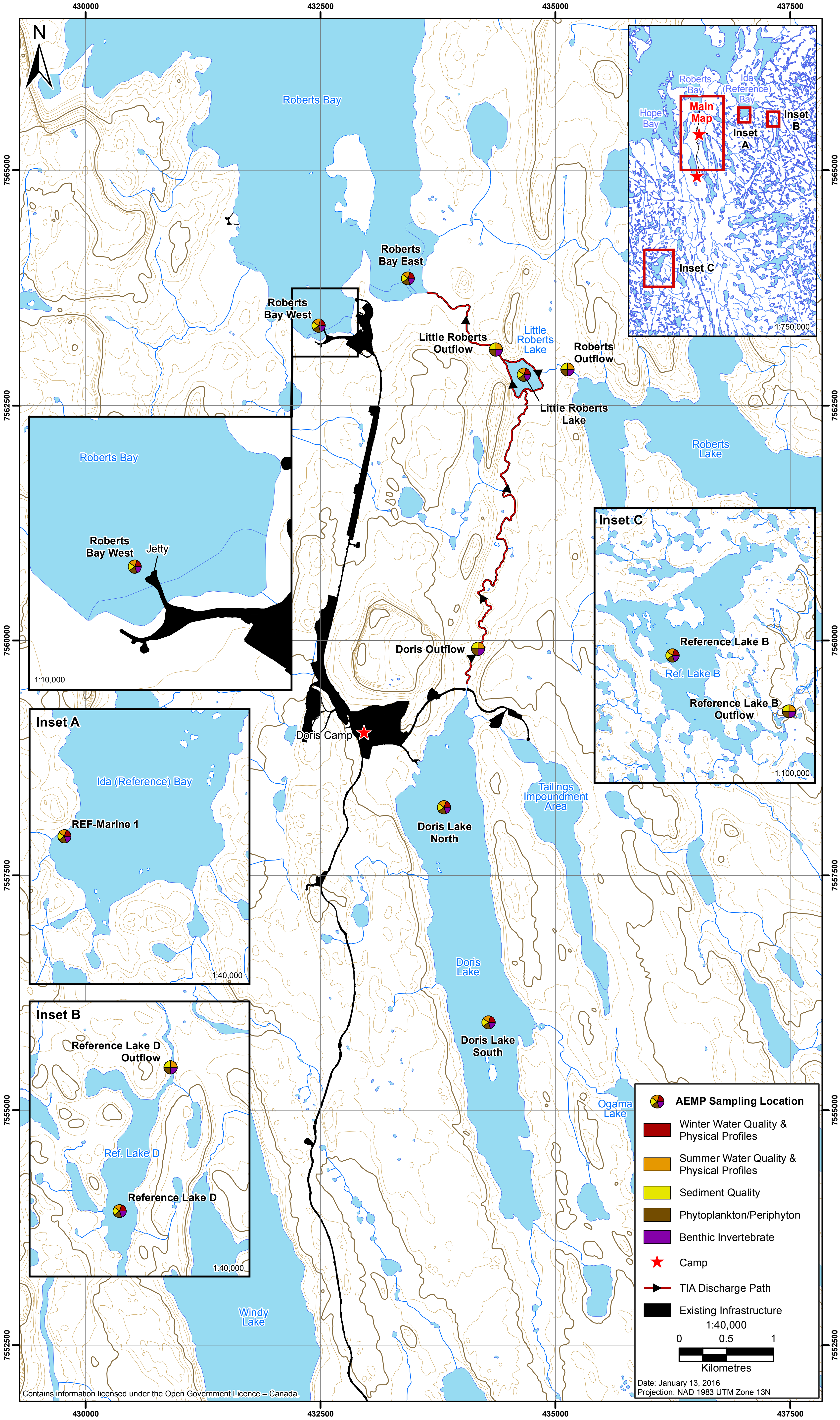
In addition to the sampling sites that could potentially be affected by TIA discharge, sites were also selected to capture other potential effects of the Project. These sites include two sampling locations in Doris Lake (adjacent to site infrastructure and roads), and a single site in western Roberts Bay (Roberts Bay West; RBW) near the marine jetty (roads, site infrastructure, marine loading/unloading activities).

Although Roberts Outflow is considered an exposure stream site, this stream is not expected to be affected by the Project but rather serves to characterize any influence of non-project related activities on Little Roberts Lake and its outflow. Non-projects influences on Little Roberts Lake and its outflow may result from an abandoned silver mine (now closed by Indigenous and Northern Affairs Canada (INAC)) and past neighbouring exploration activity (North Arrow Minerals Inc.) on the upstream Roberts Outflow. Collecting information from this Roberts Outflow location thus enables us to differentiate such non-Project effects from potential effects of TIA discharge upstream.

Table 2.1-1. AEMP Sampling Locations, Descriptions, and Purposes, Doris North Project, 2015

Sampling Location	Coordinates (13W)	Description	Purpose
Streams			
Doris Outflow	434177E 7559910N	Immediately downstream of discharge point from the TIA	First exposure site downstream of TIA discharge location
Roberts Outflow	435129E 7562881N	Stream upstream of Little Roberts Lake, which drains the much larger Roberts Lake	To characterize any influence of an abandoned silver mine and past neighbouring exploration activity (North Arrow Minerals Inc.) on Roberts Outflow and potentially downstream in Little Roberts Lake and Little Roberts Outflow, and to be able to differentiate this from potential effects of TIA discharge upstream
Little Roberts Outflow	434367E 7563094N	Stream downstream of Little Roberts Lake	Second exposure stream downstream of TIA discharge location
Reference B Outflow	427150E 7530515N	Reference outflow located southwest of the Project	Reference stream meant to closely resemble the morphology, habitat, and fish community of Doris Outflow
Reference D Outflow	448109E 7562830N	Reference outflow located west of the Project	Reference stream meant to closely resemble the morphology, habitat, and fish community of Little Roberts Outflow
Lakes			
Doris Lake South	434288E 7555935N	Large lake located south of main Project site. South part of lake is 4 km away from Project infrastructure.	South site can be used to characterize any potential changes to the lake (whether local or lake-wide)
Doris Lake North	433815E 7558222N	Large lake located south of main Project site. North part of lake is adjacent to Project infrastructure.	Potential exposure site due to close proximity of Project infrastructure and explosives storage
Little Roberts Lake	434665E 7562826N	Small lake downstream of Doris Outflow	First and only lake exposed to upstream TIA discharge
Reference Lake B	424050E 7532000N	Large reference lake located southwest of the Project	Reference lake meant to closely resemble the morphology, habitat, and fish community of Doris Lake
Reference Lake D	447566E 7561301N	Small reference lake located west of the Project	Reference lake meant to closely resemble the morphology, habitat, and fish community of Little Roberts Lake
Marine			
Roberts Bay West (Jetty; RBW)	432479E 7563346N	Small marine bay where jetty is located	Potential exposure marine area due to marine activities and infrastructure
Roberts Bay East (RBE)	433430E 7563850N	Marine bay into which Little Roberts Lake drains	Marine receiving environment for freshwater system downstream of TIA discharge location
Ida (Reference) Bay (REF-Marine 1)	441152E 7563018N	Marine bay located west of the Project	Marine reference area meant to provide a reference for the two potential marine exposure sites (Roberts Bay East, Roberts Bay West (Jetty))

Figure 2.1-1
AEMP Sampling Locations, Doris North Project, 2015



In all, there are three stream exposure sites, three lake exposure sites, and two marine exposure sites. Note that the 2010 Doris South sampling location was moved approximately 800 m to the north to a deeper basin (> 10 m deep) for 2011 to 2015 sampling for improved comparability with the Doris North sampling location, which is also in a deep basin (> 10 m deep; Figure 2.1-1). The Little Roberts Lake sampling location was moved approximately 90 m in 2014 to a deeper location so representative under-ice samples could be collected. The 2015 sampling location in Little Roberts Lake was consistent with the 1995 to 1997, 2003 to 2009, and 2014 sampling location (Figure 2.1-1).

2.1.1.2 Reference Sites

Three reference areas were included in the AEMP: two lake/stream outflow systems (Reference Lakes/Outflows B and D) and one marine site (Ida Bay; Figure 2.1-1). The two lake/stream outflow areas (Reference Lake B/Reference B Outflow and Reference Lake D/Reference D Outflow) were used as reference sites for comparability with exposure freshwater sites. Reference Lake D (area: 0.6 km^2) was selected as a suitable reference analogue for Little Roberts Lake (area: 0.1 km^2) based on its size and a direct linkage to the marine environment. Reference Lake B (7.7 km^2) was selected as a comparable lake to Doris Lake (3.4 km^2). A marine reference site in southern Ida Bay (REF-Marine 1) was selected for comparability with the two marine exposure sites in Roberts Bay. These reference areas were chosen with two features in mind:

- the reference areas were sufficiently far away from the influence of Project activity; and
- the reference areas resemble, as much as possible, the hydrological and habitat features of the exposure areas.

There were no Project activities near the selected reference sites. The major consideration in reference site selection was to ensure the reference sites were located beyond any potential wind-borne particulates from mine sources. Reference Lake D is located 15 km from Doris North infrastructure, Reference Lake B is located 25 km away, and the marine reference site in Ida Bay is 10 km away.

2.1.2 2015 Sampling Schedule

Sampling was conducted in accordance with the schedule outlined in the Plan and is summarized in Table 2.1-2 (Rescan 2010c). For 2015, sampling commenced in April with the under-ice, physical limnology/oceanography and water quality collection, and ended in late September. Physical characteristics (e.g., temperature, dissolved oxygen) and water quality (e.g., nutrients and metals) were collected in streams, lakes, and the marine environment four times during the sampling period, at least one month apart (whenever possible), thereby complying with MMER guidelines (Schedule 5, s.7 [1-2]). Phytoplankton and periphyton biomass (as chlorophyll *a*) were also collected during these surveys. Sediment quality and benthos samples were collected once in August.

2.2 DETAILED METHODS

Table 2.2-1 presents a summary of the AEMP components and methods, including: the variables assessed, the within-year sampling frequency, sampling replication, sampling dates, and the sampling devices used.

Table 2.1-2. Sampling Schedule Summary, Doris North Project, 2015

Waterbody	Variable	Sampling Dates
Streams	Water Quality	June 13-14
		July 16-18
		August 13-16
		September 16-20
	Sediment Quality	August 13-16
	Periphyton Biomass	July 16-18*
		August 13-16*
		September 16-20*
	Benthos	August 13-16, September 20**
Lakes	Physical Limnology	April 23-25
		July 15-18
		August 5-11
		September 17-19
	Water Quality	April 23-25
		July 15-18
		August 5-11
		September 17-19
	Sediment Quality	August 5-11
	Phytoplankton Biomass	April 23-25
		July 15-18
		August 5-11
		September 17-19
	Benthos	August 5-11
Marine	Physical Oceanography	April 23
		July 20
		August 6-8
		September 15-16
	Water Quality	April 23
		July 20
		August 6-8
		September 15-16
	Sediment Quality	August 6-8
	Phytoplankton Biomass	April 23
		July 20
		August 6-8
		September 15-16
	Benthos	August 6-8

** Periphyton biomass sampling dates indicate the dates of sample retrieval. Artificial samplers were installed in streams for approximately one month.*
***Doris Outflow benthos were sampled in September because the water level was too high for sampling during August due to higher than normal summer precipitation (see 2015 Hydrology Compliance Monitoring Program memorandum (ERM 2016)).*

Table 2.2-1. Sampling Program Summary, Doris North Project, 2015

Monitoring Variable	Sampling Frequency	Sample Replication and Depths	Sampling Dates / Timing	Sampling Device
Physical Limnology and Oceanography				
Dissolved oxygen/temperature profile, Secchi depth, salinity profile (marine sites only)	4×	n = 1 profile/site throughout water column	April, July, August, September	DO meter; Conductivity-Temperature-Depth (CTD) probe
Lake and Marine Water Quality				
Physical parameters, anions, nutrients, cyanides, organic carbon, total metals, radium-226	4×	Lakes: n = 1 sample/site @ 1 m below the surface and 2 m above water-sediment interface (large lakes only) + 20% replication; Marine: n = 2 samples/site @ 1 m	April, July, August, September	GO-FLO sampling bottle
Lake and Marine Phytoplankton				
Biomass (chlorophyll *a*)	4×	n = 3/site @ 1 m below the surface	April, July, August, September; coincident with lake and marine water quality	GO-FLO sampling bottle
Lake and Marine Benthos				
Density and taxonomy	1×	n = 5/site (3 composite subsamples/replicate)	August; coincident with August lake and marine survey	Ekman grab (lake); Petite Ponar grab (marine); 500 µm sieve
Lake and Marine Sediment Quality				
Physical, particle size, organic carbon, nutrients, metals	1×	n = 3/site	August; coincident with August lake and marine survey	Ekman grab (lake); Petite Ponar grab (marine)
Stream Water Quality				
Temperature, physical parameters, anions, nutrients, cyanides, organic carbon, total metals, radium-226	4×	n = 2/site	June, July, August, September	Clean water sampling bottles; temperature meter
Stream Periphyton				
Biomass (chlorophyll *a*)	3×	n = 3/site	June-July, July-August, August-September; coincident with stream water quality	Artificial samplers (Plexiglas plates) installed for ~1 month

(continued)

Table 2.2-1. Sampling Program Summary, Doris North Project, 2015 (completed)

Monitoring Variable	Sampling Frequency	Sample Replication and Depths	Sampling Dates / Timing	Sampling Device
Stream Benthos				
Density and taxonomy	1×	n = 5/site (3 composite subsamples/replicate)	August; coincident with August stream survey*	Hess sampler; 500 µm sieve
Stream Sediment Quality				
Physical, particle size, organic carbon, nutrients, metals	1×	n = 3/site	August; coincident with August lake and marine survey	Plastic bowl and spoon

**Doris Outflow benthos were sampled in September because the water level was too high for sampling during August.*

2.2.1 Physical Limnology and Oceanography

2.2.1.1 Lakes

<u>Under Ice</u>

During winter (April), the underlying lake water at the sampling sites was accessed by drilling a 25 cm diameter hole through the ice using a motorized auger. The ice thickness was then recorded and the lake bottom depth measured using a depth sounder. Water column profiling and water quality sampling depths were calculated based on bottom depth.

Measurements of water column structure (including temperature and dissolved oxygen) were collected using a YSI Pro-ODO temperature and optical dissolved oxygen meter. Temperature and dissolved oxygen values were recorded at 0.5 m intervals (depth ≤ 10 m) or 1 m intervals (depth > 10 m). The profiles extended from the surface to approximately 1 m above the sediment surface to reduce suspension of bottom sediments.

<u>Open Water</u>

Summer temperature and dissolved oxygen profiles were measured at the same sites using the same equipment as in winter, and were collected from aluminum or inflatable boats. In addition, light attenuation was estimated in each lake using a Secchi disk. Light attenuation measurements were collected at each site by lowering the 20 cm black and white Secchi disk on a metred line through the water column on the shaded side of the boat until it disappeared from sight. The depth of disappearance was recorded as the Secchi depth (D_s). The 1% euphotic zone depth ($Z_{1\%}$) was computed by first calculating the light extinction coefficient (k) from D_s, and then calculating the euphotic zone depth based on the appropriate light extinction coefficient. The 1% euphotic zone depth is the depth of the water column to which 1% of the surface irradiance reaches. It represents the depth at which the integrated gross water column photosynthetic production is equivalent to the integrated gross water column respiration; thus, there is net photosynthesis above this depth. The 1% euphotic zone depth is often referred to as the compensation depth, and is calculated as follows (Parsons, Takahashi, and Hargrave 1984):

Light extinction coefficient:

$$k\ (m^{-1}) = 1.7/D_s$$

Euphotic Depth (1%):

$$Z_{1\%}\ (m) = 4.6/k$$

2.2.1.2 Marine

Under Ice

Marine under-ice water was accessed by drilling a 25 cm diameter hole through the ice using a motorized auger. Ice thickness was recorded and the bottom depth measured using a depth sounder. A vertical profile of temperature, salinity, and conductivity was collected using an in situ conductivity, temperature, and depth probe (CTD; model RBR-420). The probe was lowered through the water column on a cable at approximately 0.5 m/s to within 1 m of the sea floor. Data from the downcast were used for physical profiles.

Measurements of temperature and dissolved oxygen were collected using a YSI Pro-ODO temperature and optical dissolved oxygen meter. Temperature and dissolved oxygen values were recorded at 0.5 m intervals. The profiles extended from the surface to approximately 1 m above the sediment surface to reduce suspension of bottom sediments.

Open Water

CTD and dissolved oxygen profiles were collected over the side of an aluminum boat using the same equipment and methods as described for the under-ice season. Light penetration at each site was measured by lowering a 30 cm white Secchi disk over the shaded side of the boat until it disappeared from sight. This was recorded as the Secchi depth. The 1% euphotic zone depth was calculated from the Secchi depth as described above for lakes.

2.2.2 Water Quality

Water quality samples were collected at the lake and marine sites during the under-ice season in April, and the open-water season in July, August, and September 2015. Stream water quality samples were collected during the June freshet and the three open-water months listed above. Whenever possible, samples at a specific site were collected at least one month apart to conform to MMER/EEM recommendations. The sampling dates and depths for all sites are presented in Table 2.2-2 and the analyzed variables are summarized in Table 2.2-3. Sampling locations are presented in Figure 2.1-1. The sampling procedures used for each aquatic habitat are described below.

2.2.2.1 Streams

During the open-water season, water quality samples were collected from three streams within the Doris and Roberts watersheds (Doris, Roberts, and Little Roberts outflows), and two reference streams far from Project activities (Reference B and Reference D outflows). Samples were collected on four occasions (June, July, August, and September) at each sampling site from June 13 to September 20, 2015. Stream sampling locations are presented in Figure 2.1-1.

Table 2.2-2. Stream, Lake, and Marine Physical Limnology, Oceanography and Water Quality Sampling Dates and Depths, Doris North Project, 2015

Habitat	Site	Sampling Date	Water Quality Sampling Depth(s) (m)	Physical Limnology and Oceanography Sampling Depths
Stream	Doris Outflow	14-Jun-15	Surface	Surface
		17-Jul-15	Surface	Surface
		15-Aug-15	Surface	Surface
		17-Sep-15	Surface	Surface
	Roberts Outflow	13-Jun-15	Surface	Surface
		18-Jul-15	Surface	Surface
		15-Aug-15	Surface	Surface
		20-Sep-15	Surface	Surface
	Little Roberts Outflow	13-Jun-15	Surface	Surface
		17-Jul-15	Surface	Surface
		14-Aug-15	Surface	Surface
		16-Sep-15	Surface	Surface
	Reference B Outflow	14-Jun-15	Surface	Surface
		16-Jul-15	Surface	Surface
		13-Aug-15	Surface	Surface
		18-Sep-15	Surface	Surface
	Reference D Outflow	14-Jun-15	Surface	Surface
		17-Jul-17	Surface	Surface
		16-Aug-15	Surface	Surface
		16-Sep-15	Surface	Surface
Lake	Doris Lake North	25-Apr-15	3.0, 12	Throughout water column
		18-Jul-15	1.0, 12.0	Throughout water column
		5-Aug-15	1.0, 12.0	Throughout water column
		17-Sep-15	1.0, 12.0	Throughout water column
	Doris Lake South	25-Apr-15	3.0, 9.0	Throughout water column
		18-Jul-15	1.0, 9.0	Throughout water column
		5-Aug-15	1.0, 9.0	Throughout water column
		17-Sep-15	1.0, 9.0	Throughout water column
	Little Roberts Lake	24-Apr-15	2.25	Throughout water column
		15-Jul-15	1.0	Throughout water column
		10-Aug-15	1.0	Throughout water column
		19-Sep-15	0	Throughout water column
	Reference Lake B	24-Apr-15	2.5, 9.0	Throughout water column
		16-Jul-15	1.0, 8.0	Throughout water column
		11-Aug-15	1.0, 8.0	Throughout water column
		18-Sep-15	1.0, 8.0	Throughout water column

(continued)

Table 2.2-2. Stream, Lake, and Marine Physical Limnology, Oceanography and Water Quality Sampling Dates and Depths, Doris North Project, 2015 (completed)

Habitat	Site	Sampling Date	Water Quality Sampling Depth(s) (m)	Physical Limnology and Oceanography Sampling Depths
Lake (*cont'd*)	Reference Lake D	23-Apr-15	2.0	Throughout water column
		16-Jul-15	1.0	Throughout water column
		9-Aug-15	1.0	Throughout water column
		19-Sep-15	1.0	Throughout water column
Marine	RBE (Roberts Bay)	23-Apr-15	2.0	Throughout water column
		20-Jul-15	0	Throughout water column
		6-Aug-15	0	Throughout water column
		16-Sep-15	0.1	Throughout water column
	RBW (Roberts Bay)	23-Apr-15	3.0	Throughout water column
		20-Jul-15	1.0	Throughout water column
		6-Aug-15	1.0	Throughout water column
		15-Sep-15	1.0	Throughout water column
	REF-Marine 1 (Ida Bay)	23-Apr-15	3.0	Throughout water column
		20-Jul-15	1.0	Throughout water column
		8-Aug-15	1.0	Throughout water column
		16-Sep-15	1.0	Throughout water column

Note: April sample depths are recorded as depths below the water surface and are equal to approximately 0-1 m below the bottom of the ice.

Stream water quality samples were collected at one midstream point in the cross section of the flow, with care being taken to prevent sampling artifacts associated with disturbing bottom sediments and collecting particulate material. Sampling personnel stood facing upstream to minimize sample contamination from re-suspended sediments. Samples were collected using appropriate verified-clean bottles provided by ALS Laboratory Group, Burnaby, BC (ALS). Samples were collected in duplicate and the appropriate preservatives provided by ALS were added in the field after sample collection.

All samples were kept cold and in the dark while in the field, and were refrigerated at Doris Camp prior to transport. Samples were transported in coolers with freezer packs to ALS in Burnaby, BC for analysis. The analyzed variables and their realized detection limits are presented in Table 2.2-3.

2.2.2.2 Lakes and Marine

Lake water quality were collected from three sites in two lakes within the Doris and Roberts watersheds (Doris Lake South, Doris Lake North, Little Roberts Lake), and from two reference lakes (Reference Lake B and Reference Lake D). Marine water quality samples were collected from two near-shore sites in Roberts Bay (RBE and RBW) and at one reference site in the adjacent inlet, Ida (Reference) Bay (REF-Marine 1). Lake and marine sampling sites are presented in Figure 2.1-1.

Table 2.2-3. Water Quality Variables and Realized Detection Limits, Doris North Project, 2015

Variable	Units	Realized Detection Limits		Variable	Units	Realized Detection Limits	
		Freshwater	Marine			Freshwater	Marine
Physical Tests				**Organic Carbon**			
pH	pH	0.1	0.1	Dissolved Organic Carbon	mg/L	0.5	0.5
Alkalinity, Total (as $CaCO_3$)	mg/L	1.0	1.0 to 2.0	Total Organic Carbon	mg/L	0.5	0.5
Hardness (as $CaCO_3$)	mg/L	0.5	4.3	**Total Metals**			
Conductivity	μS/cm	2.0	-	Aluminum (Al)	mg/L	0.003	0.005
Total Suspended Solids	mg/L	1.0	2.0	Antimony (Sb)	mg/L	0.00003	0.0005
Total Dissolved Solids	mg/L	10 to 20	20 to 80	Arsenic (As)	mg/L	0.00005	0.0004
Turbidity	NTU	0.1	0.1	Barium (Ba)	mg/L	0.0001	0.001
Salinity		-	1.0	Beryllium (Be)	mg/L	0.000005	0.0005
Anions				Bismuth (Bi)	mg/L	0.00005	0.0005
Bromide (Br)	mg/L	0.05	1.0 to 5.0	Boron (B)	mg/L	0.01	0.1
Chloride (Cl)	mg/L	0.5	10 to 50	Cadmium (Cd)	mg/L	0.000005	0.00002
Fluoride (F)	mg/L	0.02	0.4 to 2.0	Calcium (Ca)	mg/L	0.05	0.5
Sulphate (SO_4)	mg/L	0.3	10 to 50	Cesium (Cs)	mg/L	0.000005	0.0005
Nutrients				Chromium (Cr)	mg/L	0.0005	0.0005
Ammonia (as N)	mg/L	0.005	0.005	Cobalt (Co)	mg/L	0.00005	0.00005
Nitrate (as N)	mg/L	0.005	0.006	Copper (Cu)	mg/L	0.0005	0.00005
Nitrite (as N)	mg/L	0.001	0.002	Gallium (Ga)	mg/L	0.00005	0.0005
Total Kjeldahl Nitrogen	mg/L	0.05	0.05	Iron (Fe)	mg/L	0.03	0.01
Orthophosphate-Dissolved (as P)	mg/L	0.001	0.001	Lead (Pb)	mg/L	0.00005	0.00005 to 0.0003
Total Phosphorus	mg/L	0.002	0.01	Lithium (Li)	mg/L	0.0004	0.02
Cyanides				Magnesium (Mg)	mg/L	0.1	1.0
Cyanide Total	mg/L	0.001	0.001	Manganese (Mn)	mg/L	0.0002	0.00005
Cyanide, Free	mg/L	0.001	0.001	Mercury (Hg)	μg/L	0.0005	0.0005

(continued)

Table 2.2-3. Water Quality Variables and Realized Detection Limits, Doris North Project, 2015 (completed)

Variable	Units	Realized Detection Limits		Variable	Units	Realized Detection Limits	
		Freshwater	Marine			Freshwater	Marine
Total Metals *(cont'd)*				**Total Metals *(cont'd)***			
Molybdenum (Mo)	mg/L	0.00005	0.002	Thallium (Tl)	mg/L	0.000005	0.00005
Nickel (Ni)	mg/L	0.0002	0.00005	Thorium (Th)	mg/L	0.000005	0.0005
Phosphorus (P)	mg/L	0.30	1.0	Tin (Sn)	mg/L	0.0002	0.001
Potassium (K)	mg/L	2.0	20	Titanium (Ti)	mg/L	0.0002	0.005
Rhenium (Re)	mg/L	0.000005	0.0005	Tungsten (W)	mg/L	0.00001	0.001
Rubidium (Rb)	mg/L	0.00002	0.005	Uranium (U)	mg/L	0.000002	0.00005
Selenium (Se)	mg/L	0.0002	0.0005	Vanadium (V)	mg/L	0.00005	0.0005
Silicon (Si)	mg/L	0.05	0.5	Yttrium (Y)	mg/L	0.000005	0.0005
Silver (Ag)	mg/L	0.000005	0.0001	Zinc (Zn)	mg/L	0.003	0.0008
Sodium (Na)	mg/L	2.0	20	Zirconium (Zr)	mg/L	0.00005	0.0005
Strontium (Sr)	mg/L	0.0002	0.05	**Radiochemistry**			
Tellurium (Te)	mg/L	0.00001	0.0005	Radium-226	Bq/L	0.001 to 0.01	0.001 to 0.01

Note:
"-" indicates not applicable (variable not measured)

Samples were collected once during the ice-covered season (April), and three times during the open-water season (July, August, September) from April 23 to September 19, 2015. Within each lake, samples were collected at approximately 1 m depth over the deepest part of the lake. At the deepest lake sites (Doris Lake North, Doris Lake South, and Reference Lake B), samples were collected both at approximately 1 m below the surface and 2 m above the sediment.

In April, the underlying water was accessed through a hole in the ice following the temperature, CTD, and dissolved oxygen profiles. An adapted 2.5 L Niskin bottle was used to collect water during winter sampling. This bottle was designed to "trip" and collect discrete samples during freezing temperatures. To avoid metal contamination, the tripping mechanism used acid-cleaned silicone tubing within the interior of the bottle. A dual rope system was used to trigger the bottle to close and to ensure the collection of discrete samples.

During open-water season sampling, water samples were collected using an acid-washed, Teflon-lined 5 L GO-FLO sampling bottle. The GO-FLO was securely attached to a metred line and lowered to the appropriate sampling depth. It was then triggered to close using a Teflon-coated brass messenger and brought aboard the boat for distribution of the collected water into sample containers.

Samples for the various water quality components (e.g., physical variables/major ions, nutrients, and total metals) were drawn from the GO-FLO/Niskin bottles, with care being taken not to bring the bottle or cap into contact with the plastic spigot or other possible sources of contamination. The appropriate preservatives provided by ALS were added in the field after sample collection.

All samples were kept cold and in the dark while in the field and were refrigerated at Doris Camp prior to transport. Samples were transported in coolers with freezer packs to ALS, Burnaby for analysis as described for stream water quality samples. The variables analyzed and their realized detection limits are summarized in Table 2.2-3. Realized detection limits were occasionally higher than the theoretical detection limits in freshwater samples due to interference from other variables. Marine samples were consistently diluted to reduce matrix effects from the high concentrations of cations (e.g., sodium).

2.2.2.3 Quality Assurance and Quality Control

The quality assurance and quality control (QA/QC) program for water quality sampling included the collection of replicates to account for within-site variability and the use of chain of custody forms to track samples. A set of travel, field, and equipment blanks (~20% of total samples) was also processed during each trip and submitted with the water samples as part of the QA/QC program. These blanks were used to identify potential sources of contamination to the field samples. Results for water quality QA/QC blanks are provided in Appendix A.

2.2.3 Sediment Quality

Sediment quality samples were collected at stream, lake, and marine sites during the open-water season in August 2015. This sampling coincided with benthic invertebrate sampling (with the exception of Doris Outflow; Table 2.2-4). Sampling dates and depths for all sites are presented in Table 2.2-4 and the analyzed variables are summarized in Table 2.2-5. Sampling locations are presented in Figure 2.1-1. Sampling procedures for each aquatic habitat are described below.

Table 2.2-4. Stream, Lake, and Marine Sediment Quality and Benthic Invertebrate Sampling Dates and Depths, Doris North Project, 2015

Habitat	Site	Sampling Date	Depth (m)
Stream	Doris Outflow	15-Aug-15* 20-Sep-15**	NA
	Roberts Outflow	15-Aug-15	NA
	Little Roberts Outflow	14-Aug-15	NA
	Reference B Outflow	13-Aug-15	NA
	Reference D Outflow	16-Aug-15	NA
Lake	Doris Lake North	5-Aug-15	14
	Doris Lake South	5-Aug-15	10
	Little Roberts Lake	10-Aug-15	3
	Reference Lake B	11-Aug-15	10
	Reference Lake D	9-Aug-15	3
Marine	RBE (Roberts Bay)	7-Aug-15	1
	RBW (Roberts Bay)	6-Aug-15	5
	REF-Marine-1 (Ida Bay)	8-Aug-15	8

Note: NA = not applicable
** Sediment quality sampling date*
*** Benthic invertebrate sampling date*

2.2.3.1 Streams

Three replicate sediment samples were collected at each stream site. At each site, a replicate sample consisted of a 1 L composite of several (plastic) spoonsful of sediments, with replicates collected three times the channel width apart from each other whenever possible. The sediment was fully homogenized, slowly drained of excess water, and transferred into separate pre-labelled Whirl-Pak bags: one for particle size analysis, and one for sediment chemistry analysis. Each bag was then placed into another Whirl-Pak bag as a protective measure.

Samples were refrigerated (in darkness) until they were shipped to ALS (Burnaby, BC). The sediment quality variables that were analyzed and their corresponding detection limits are presented in Table 2.2-5.

2.2.3.2 Lakes

Lake sediments were obtained in the deepest section of the lake (except Doris Lake South) using an Ekman grab sampler with the replicates collected approximately 5 to 20 m apart. Sampling depths are provided in Table 2.2-4. The Ekman was carefully set open, lowered gradually onto the sediment surface using a metred cable line, and triggered to close with a messenger. The sample was carefully raised and inspected to ensure the collection of an intact, undisturbed sample. Each sediment sample was carefully transferred onto a tray, and the top 2 to 3 cm of sediment was homogenized in a plastic bowl using a plastic spoon and placed into two Whirl-Pak bags: one for particle size, and one for sediment chemistry. Samples were refrigerated (in darkness) until they were shipped to ALS (Burnaby, BC). The sediment quality variables that were analyzed and their corresponding detection limits are presented in Table 2.2-5.

Table 2.2-5. Sediment Quality Variables and Realized Detection Limits, Doris North Project, August 2015

Variable	Units	Realized Detection Limit		Variable	Units	Realized Detection Limit	
		Freshwater	Marine			Freshwater	Marine
Physical Tests				**Total Metals** ***(cont'd)***			
Moisture	%	0.25	0.25	Chromium (Cr)	mg/kg	0.5	0.5
pH	pH	0.1	0.1	Cobalt (Co)	mg/kg	0.1	0.1
Particle Size				Copper (Cu)	mg/kg	0.5	0.5
% Gravel (>2 mm)	%	0.1	0.1	Iron (Fe)	mg/kg	50	50
% Sand (2.0 - 0.063 mm)	%	0.1	0.1	Lead (Pb)	mg/kg	0.5	0.5
% Silt (0.063 mm - 4 µm)	%	0.1	0.1	Lithium (Li)	mg/kg	2.0	2.0
% Clay (<4 µm)	%	0.1	0.1	Magnesium (Mg)	mg/kg	20	20
Organic Carbon				Manganese (Mn)	mg/kg	1.0	1.0
Total Organic Carbon	%	0.1	0.1	Mercury (Hg)	mg/kg	0.01	0.01
Leachable Nutrients				Molybdenum (Mo)	mg/kg	0.1	0.1
Total Nitrogen	%	0.02	0.02	Nickel (Ni)	mg/kg	0.5	0.5
Plant Available Nutrients				Phosphorus (P)	mg/kg	50	50
Available Ammonium-N	mg/kg	1.0 to 1.6	1.0 to 1.6	Potassium (K)	mg/kg	100	100
Available Nitrate-N	mg/kg	2.0 to 4.0	2.0 to 4.0	Selenium (Se)	mg/kg	0.2	0.2
Available Nitrite-N	mg/kg	0.4 to 0.8	0.4 to 0.8	Silver (Ag)	mg/kg	0.1	0.1
Available Phosphate-P	mg/kg	2.0	2.0	Sodium (Na)	mg/kg	50	50
Total Metals				Strontium (Sr)	mg/kg	0.5	0.5
Aluminum (Al)	mg/kg	50	50	Sulphur (S)	mg/kg	500	500
Antimony (Sb)	mg/kg	0.1	0.1	Thallium (Tl)	mg/kg	0.05	0.05
Arsenic (As)	mg/kg	0.1	0.1	Tin (Sn)	mg/kg	2.0	2.0
Barium (Ba)	mg/kg	0.5	0.5	Titanium (Ti)	mg/kg	1.0	1.0
Beryllium (Be)	mg/kg	0.1	0.1	Uranium (U)	mg/kg	0.05	0.05
Bismuth (Bi)	mg/kg	0.2	0.2	Vanadium (V)	mg/kg	0.2	0.2
Cadmium (Cd)	mg/kg	0.05	0.05	Zinc (Zn)	mg/kg	2	2
Calcium (Ca)	mg/kg	50	50				

2.2.3.3 *Marine*

Marine sediment quality samples were collected in triplicate using a Petite Ponar grab sampler (surface sampling area of 0.023 m^2), with replicates spaced approximately 5 to 20 m apart. Sampling depths are provided in Table 2.2-4. Each sediment sample was carefully transferred onto a tray, and the top 2 to 3 cm of sediment was homogenized in a plastic bowl using a plastic spoon and placed into two Whirl-Pak bags: one for particle size, and one for sediment chemistry. Samples were refrigerated (in darkness) until they were shipped to ALS (Burnaby, BC). The sediment quality variables that were analyzed and their corresponding detection limits are presented in Table 2.2-5.

2.2.3.4 *Quality Assurance and Quality Control*

The QA/QC program for sediment quality sampling included the collection of replicates to account for within-site variability and the use of chain of custody forms to track samples.

2.2.4 Primary Producers

Primary producer biomass (as chlorophyll *a*) samples were collected in streams, lakes, and the marine habitat to assess potential changes in their standing stocks due to eutrophication (i.e., excess nutrients) or toxicity (i.e., presence of deleterious substances). Periphyton biomass samples were collected in streams during the open-water season in July, August, and September. Phytoplankton biomass samples were collected in lakes and the marine environment both under-ice (April) and during the open-water season (July, August, and September).

2.2.4.1 *Stream Periphyton*

Stream periphyton samples were collected using artificial substrate samplers. The samplers were installed in each study stream for approximately one month before sample collection and processing (i.e., the plates collected in July, August, and September, were installed in June, July, and August, respectively). The complete installation and retrieval schedule is outlined in Table 2.2-6.

The samplers were 10 cm × 10 cm Plexiglas® plates that were affixed to rocks with fishing line and placed in the stream such that they remained submerged until retrieval. Overall, six plates were submerged per site, but only three plates were processed. These extra plates were used to increase the likelihood that at least three plates were available to process after a month's time. The plates were installed a minimum distance of three times the channel width apart from each other whenever possible. Only two plates were processed in Little Roberts Outflow in July as the remaining plates were found flipped over and were not considered appropriate for sampling.

Upon collection, the sample plates were scraped using a razor blade, and rinsed into a 500 mL wide-mouth plastic jar. The samples were then filtered at Doris Camp onto 47 mm diameter, 0.45 µm pore-size membrane filters, folded carefully in half and placed into a black plastic tube to prevent light penetration. A label was then attached to the tube indicating sampling information. The filters were kept frozen and sent to ALS Burnaby for analysis.

Table 2.2-6. Periphyton Sampling Dates, Doris North Project, 2015

Stream Site	Installation Date	Retrieval Date	# of Days Submerged
Doris Outflow	14-Jun-15	17-Jul-15	33
	17-Jul-15	15-Aug-15	29
	15-Aug-15	17-Sep-15	33
Roberts Outflow	13-Jun-15	18-Jul-15	35
	18-Jul-15	15-Aug-15	28
	15-Aug-15	20-Sep-15	36
Little Roberts Outflow	13-Jun-15	17-Jul-15	34
	17-Jul-15	14-Aug-15	28
	14-Aug-15	16-Sep-15	33
Reference B Outflow	14-Jun-15	16-Jul-15	32
	16-Jul-15	13-Aug-15	28
	13-Aug-15	18-Sep-15	36
Reference D Outflow	14-Jun-15	17-Jul-15	33
	17-Jul-15	16-Aug-15	30
	16-Aug-15	16-Sep-15	31

2.2.4.2 *Lake and Marine Phytoplankton*

Lake and marine phytoplankton biomass samples were collected in triplicate at approximately 1 m depth using a 5 L GO-FLO water sampler during July, August, and September. In April, a 2.5 L Niskin bottle was used to collect a sample from approximately 1 m beneath the ice layer. For each sample, the water sampler was lowered to the appropriate depth using a metred cable line and triggered to close with a messenger. Once retrieved, a subsample was drawn for a chlorophyll *a* sample. The GO-FLO/Niskin was set, lowered, and triggered three times (i.e., once for each replicate).

Subsamples for chlorophyll *a* were obtained by rinsing and filling a clean 1 L bottle. The samples were kept cold and dark and transported to Doris Camp, where the samples were filtered using gentle vacuum filtration (hand pump). The samples were filtered onto 47-mm diameter, 0.45-µm pore size nitrocellulose membrane filters, folded carefully in half, and placed into a black plastic tube to prevent light penetration. A label was then attached to the tube indicating sampling information. The filters were kept frozen and sent to ALS Burnaby for analysis.

2.2.4.3 *Quality Assurance and Quality Control*

The QA/QC program for phytoplankton and periphyton biomass sampling included the collection of replicates to account for within-site variability and the use of chain of custody forms to track samples.

2.2.5 Benthos

Benthic invertebrate (benthos) samples were collected at the stream, lake, and marine sites during the open-water season in August 2015. This coincided with the sediment quality sampling. Doris Outflow was too deep to collect benthic invertebrate samples in August 2015, so samples from this stream were collected in September 2015. Sampling dates and depths for all sites are presented in Table 2.2-4 and sampling locations are indicated in Figure 2.1-1.

All field sampling devices and methods for the AEMP benthos sampling were designed to comply with EEM guidance documents (Environment Canada 2011). Sampling procedures for each aquatic habitat are described below.

2.2.5.1 Streams

With the exception of Doris Outflow, benthos samples were collected at AEMP streams from August 13 to August 16, 2015. The water was too deep for benthos sampling during August at Doris Outflow; therefore, samples from this stream were collected on September 20, 2015. To comply with EEM requirements, three separate subsamples were collected and pooled for each replicate sample; five replicates were collected at each site. Samples were collected in riffle habitats using a Hess sampler (surface sampling area of 0.096 m^2) fitted with a 500 µm mesh net and terminal cod-end. Replicate samples were collected a minimum distance of three times the channel width apart from each other whenever possible.

For each subsample, the bottom of the Hess sampler was placed firmly on the sediment bottom making sure sediment contact was continuous along the bottom rim. The encircled sediment was then swept by hand and all rocks lifted and scrubbed to make sure the entire sediment surface was agitated. After sweeping, the collected debris was transferred from the cod-end into a 500 mL wide-mouthed plastic jar. Three subsamples were combined to make one sample and this was preserved with buffered formalin to a final concentration of 10%. Benthos samples were sent to Dr. Jack Zloty (Summerland, BC) for enumeration and identification.

Several community descriptors were calculated from the taxonomic results, including benthos density, family richness, Simpson’s Diversity and Evenness indices, and the Bray-Curtis Index. Cladocerans and cyclopoid and calanoid copepods were not included in the community metrics as these groups are generally planktonic. Nematodes were also excluded from the community metrics as they are typically considered to be meiofauna (invertebrates ranging in size between 63 µm and 500 µm) and are not adequately sampled using a 500-µm sieve bucket. Immature or damaged organisms that were not identifiable to the family level were excluded from the community analysis. Organisms belonging to the groups Ostracoda and Microturbellaria were not identifiable to the family level but were included in the community metrics at the next lowest taxonomic category. Any terrestrial organisms that were identified in the benthos samples were excluded from the calculations of community descriptors.

Benthos counts were normalized to three times the surface area of the of the Hess sampler (i.e., 3×0.096 m^2) to determine the benthos density in units of organisms/m^2 (because each replicate consisted of three pooled Hess samples).

Family richness was calculated as the total number of benthic invertebrate families present in each replicate sample.

The Simpson’s Diversity Index (D) was calculated as:

$$\textit{Simpson Diversity Index (D)} = 1 - \sum_{i=1}^{F} p_i^2$$

where F was the number of families present (i.e., family richness), and p_i was the relative abundance of each family calculated as n_i/N, where n_i is the number of individuals in family i, and N was the total number of individuals. Simpson's Evenness Index (E) was calculated as:

$$\textit{Simpson Evenness Index (E)} = 1/\sum_{i=1}^{F} p_i^2/F$$

A complete dissimilarity matrix was also generated that included pairwise comparisons of all samples using the Bray-Curtis Index. The Bray-Curtis Index compares the community composition within a benthos sample to the median reference community composition (Environment Canada 2011). This reference composition is generated from the median abundance of each represented family from all of the reference site replicates. Since the median reference composition is generated from the combined reference site replicates, the comparison of a single reference site replicate community to the median reference community composition will produce a dissimilarity value (although generally a much lower value than exposure sites). Because the Bray-Curtis Index measures the percent difference between sites, the greater the dissimilarity value between a site and the median reference community, the more dissimilar those benthos communities are. The Bray-Curtis Index ranges from 0 to 1, with 1 representing completely dissimilar communities, and 0 representing identical communities. This index is calculated as:

$$\textit{Bray-Curtis Index (BC)} = \sum_{i=1}^{n} |y_{i1} - y_{i2}| \,/\, \sum_{i=1}^{n} (y_{i1} + y_{i2})$$

where BC is the Bray-Curtis distance between sites 1 and 2, n is the total number of families present at the two sites, y_{i1} is the count for family i at site 1, and y_{i2} is the count for family i at site 2. Replicate data from the two reference locations (Reference B and D outflows) were combined for the determination of the "median reference composition".

Standard summary statistics (minimum, maximum, median, mean, standard deviation, and standard error) were calculated for all 2015 benthic invertebrate endpoints described above. These summary statistics are presented in Appendix A.

2.2.5.2 Lakes

Lake benthos samples were collected during the open-water season from August 5 to August 11, 2015. Like in streams, lake benthos sampling was designed to meet EEM criteria (i.e., three subsamples/replicate; five replicates/site). With the exception of Doris Lake South, lake benthos samples were obtained in the deepest section of the lake using an Ekman grab sampler (surface sampling area of 0.0225 m^2), with replicates collected approximately 5 to 20 m apart. The Ekman was carefully set open, lowered gradually onto soft sediment using a metred cable line, and triggered to close with a messenger. Sampling depths are provided in Table 2.2-4.

At the surface, each sediment sample was transferred into a 500 µm sieve bucket and rinsed with site-specific water until free of sediments. The material retained within the sieve was then placed into a labelled plastic jar and preserved with buffered formalin to a final concentration of 10%. Benthos samples were sent to Dr. Jack Zloty (Summerland, BC) for enumeration and identification. Benthos counts were normalized to three times the surface area of the Ekman sampler (i.e., 3 × 0.0225 m^2) to determine the benthos density in units of organisms/m^2 (because each replicate consisted of three pooled Ekman samples). Community descriptors, Bray-Curtis dissimilarity distances, and summary statistics were calculated as described for stream benthos with the following exception: because lakes can have dramatically different physico-chemical and biological function based on their morphologies (Cole 1983), median reference compositions were created for each reference lake (large lake: Reference Lake B; small lake: Reference Lake D) for Bray-Curtis analysis. Bray-Curtis distances were then calculated by comparing the Reference Lake B median community to the large lake sites, Doris Lake North and Doris Lake South, and the Reference Lake D median community to Little Roberts Lake.

2.2.5.3 Marine

Benthos samples were collected at the two sites in Roberts Bay (RBW and RBE) and at the reference site in Ida Bay (REF-Marine 1) from August 6 to 8, 2015. Samples were collected with a Petite Ponar grab sampler (surface sampling area of 0.023 m^2). Five replicates were collected approximately 5 to 20 m apart at each site, with each replicate consisting of three pooled grab samples. Each sediment sample was transferred into a 500 µm sieve bucket and rinsed with site-specific water until free of sediments. The material retained within the sieve was then placed into a labelled plastic jar and preserved with saline, buffered formalin to a final concentration of 10%. Benthos samples were sent to Columbia Science (Courtenay, BC) for enumeration and identification. Benthos counts were normalized to three times the surface area of the of the Petite Ponar sampler (i.e., 3 × 0.023 m^2) to determine the benthos density in units of organisms/m^2 (because each replicate consisted of three pooled Petite Ponar grab samples).

Community descriptors and summary statistics were calculated as described for stream benthos. Nematodes and harpacticoid copepods were excluded from the calculations of density and community metrics as these groups are typically considered to be meiofauna (invertebrates ranging in size between 63 µm and 500 µm) and are not adequately sampled using a 500 µm sieve bucket. Individuals that were not identifiable to the family level were excluded from the community analysis. Any fish or fish eggs that were identified in the benthos samples were also excluded from the calculations of community descriptors. Community descriptors, Bray-Curtis dissimilarity distances, and summary statistics were calculated as described for stream benthos, with the REF-Marine 1 median community composition compared to the RBW and RBE benthos communities in the Bray-Curtis analysis.

2.2.5.4 Quality Assurance and Quality Control

The QA/QC program for benthos sampling included the collection of replicates to account for within-site variability and the use of chain of custody forms to track samples.

A re-sorting of randomly selected sample residues was conducted by taxonomists on a minimum of 10% of the benthos samples to determine the level of sorting efficiency. The criterion for an acceptable sorting was that more than 90% of the total number of organisms was recovered during the initial sort. The number of organisms initially recovered from the sample was expressed as a percentage of the total number after the re-sort (total of initial and re-sort count). Any sample not meeting the 90% removal criterion was re-sorted a third time. The 90% minimum efficiency was always attained. Results for benthos QA/QC are provided in Appendix A.

2.3 EVALUATION OF EFFECTS

Select baseline data collected between 1995 and 2009 in the Project area were compared against 2015 data to determine whether there were adverse changes to the aquatic environment that could be directly attributed to Project activities. Data from 2010 to 2014 were not included in the baseline years for the effects analysis because Project construction began in 2010. The only exception to this was for the evaluation of under-ice dissolved oxygen concentrations in lake and marine sites; 2010 was considered a baseline year for this assessment for reasons described below. No suitable baseline data were available for benthos, so the benthos evaluation of effects was based on a comparison of trends over time from 2010 to 2015 between reference and exposure sites.

2.3.1 Variables Subjected to Evaluation

Table 2.3-1 presents the physical, chemical, and biological variables that were evaluated for 2015. Water quality variables associated with the various components of the MMER (e.g., Schedule 4 Deleterious Substances, Effluent Monitoring Conditions (Division 2), EEM's Effluent Characterization) were assessed for potential effects. Canadian Council of Ministers of the Environment (CCME) water quality guidelines for the protection of aquatic life exist for many of the assessed variables. As per the MMER and EEM requirements, the benthic invertebrate community and associated sediment variables (sediment particle size and total organic carbon content) were evaluated. Additional sediment variables for which there are CCME sediment quality guidelines for the protection of aquatic life were also included in the assessment. Periphyton and phytoplankton biomass were also evaluated.

Table 2.3-1. Variables Subjected to Effects Analysis, Doris North Project, 2015[a]

Category	Variable
Physical Limnology	
Effluent Characterization and Water Quality Variables[c]	Dissolved Oxygen[d] Secchi Depth
Water Quality	
Deleterious Substances[b]	Total Suspended Solids[d] Cyanide, Total[d] Arsenic, Total[d] Copper, Total[d] Lead, Total[d] Nickel, Total[d] Zinc, Total[d] Radium-226

(continued)

Table 2.3-1. Variables Subjected to Effects Analysis, Doris North Project, 2015[a] (completed)

Category	Variable
Water Quality (*cont'd*)	
Effluent Characterization and Water Quality Variables[c]	pH[d] Alkalinity, Total Hardness Ammonia (as N)[d] Nitrate (as N)[d] Aluminum, Total[d] Cadmium, Total[d] Iron, Total[d] Mercury, Total[d] Molybdenum, Total[d]
Sediment Quality	
	Particle Size[e] Total Organic Carbon[e] Arsenic[d] Cadmium[d] Chromium[d] Copper[d] Lead[d] Mercury[d] Zinc[d]
Biology	
	Phytoplankton and Periphyton Biomass Benthic Invertebrate Density[e] Taxa Richness[e] Simpson's Evenness Index[e] Simpson's Diversity Index[e] Bray-Curtis Index[e]

Notes:
[a] *2010 was year 1 of fish data collection. Fish sampling was not undertaken in 2015.*
[b] *Variables regulated as deleterious substances as per Schedule 4 of the MMER.*
[c] *Variables required for effluent characterization and water quality monitoring as per Schedule 5 of the MMER.*
[d] *Variables that have CCME water or sediment quality guidelines for the protection of aquatic life.*
[e] *Variables required as part of the benthic invertebrate surveys as per Schedule 5 of the MMER.*

2.3.2 Baseline Data and Effects Analysis

Baseline physical, chemical, and biological data have been collected in the Doris North Project area since 1995. Historical samples have been collected from a variety of locations and depths within each of the AEMP stream, lake, and marine environments. The frequency and seasonal timing of sampling has also varied since 1995, as have sampling methodologies. For these reasons, professional judgment was used in the selection of baseline data that could be used for comparison with the 2015 data.

The approaches used to assemble the appropriate baseline datasets and to determine whether there were any effects on evaluated variables in 2015 are discussed below. Key determining factors for the inclusion of baseline data included the proximity of baseline sampling sites to 2015 sampling sites, the depth of sampling (for sediment quality and benthos), and sampling methodology (for sediment quality, periphyton, phytoplankton, and benthos). In the case of benthos, pre-2010 baseline data were not considered comparable because of methodological differences; therefore, 2010 to 2014 data were incorporated into the effects analysis for 2015. Historical data used for the effects analyses were from the following reports: Klohn-Crippen Consultants Ltd. (1995), Rescan (1997, 1998, 1999, 2001, 2010a, 2010b, 2011, 2012, 2013), RL&L Environmental Services Ltd. and Golder Associates Ltd. (2003a, 2003b), and Golder Associates Ltd. (2005, 2006, 2007, 2008, 2009), ERM Rescan (2014), and ERM (2015). Full details of the rationale used in the selection of baseline data that could be used for comparison with the 2015 data are provided in Appendix B.

All statistical analyses were run using R version 3.1.3. A complete description of the statistical analyses used to assess the evaluated variables, including lists of outliers and detailed methodology and results, is presented in Appendix B.

2.3.2.1 Under-ice Dissolved Oxygen

<u>Data Selection</u>

Potential effects on physical limnology and oceanography were evaluated using April, May, or early June under-ice dissolved oxygen since concentrations are lowest during this period, and therefore pose the greatest concern for aquatic life. Although temperature and salinity (marine) were also measured, they were not evaluated for effects since they are largely determined by climatic variability, and no mine tailings-related TIA effluent has been discharged to the aquatic environment to date.

Ice cover usually forms in October or November in the Doris North region, and remains until June or July of the following year. Waterbodies in the Doris North area would not be exposed to any atmospheric inputs such as dust that could be generated by Project activities while they are covered in ice. Therefore, the under-ice water column that is profiled in April or May reflects activities from the previous year. For example, profiles collected in April 2010 reflect activities from 2009 rather than 2010. For this reason, profiles collected in the spring of 2010 are included in the baseline dataset despite 2010 being considered year one of construction.

Baseline under-ice dissolved oxygen measurements have been collected several times at the exposure lake sites since 1998. Under-ice dissolved oxygen data are available from 2009 and 2010 for Reference Lake B, and from 2010 for Reference Lake D.

In the marine environment, baseline under-ice dissolved oxygen profiles were collected at RBE in 2006 and 2010, and at RBW in 2009 and 2010. No pre-2011 under-ice dissolved oxygen data exists for REF-Marine 1.

<u>Effects Analysis</u>

The potential for effects on under-ice dissolved oxygen concentrations was assessed by graphical analysis. For winter dissolved oxygen concentrations to warrant concern and be considered an effect, concentrations from 2015 had to be noticeably different from all available baseline years. For example, if 2015 dissolved oxygen concentrations were different from 2005, but similar to 2007, it was concluded that there were no 2015 Project effects at that exposure site. Dissolved oxygen concentrations and inter-annual trends at the reference sites were also considered in the effects analysis. Dissolved oxygen concentrations were compared against CCME guidelines for the protection of aquatic life (CCME 2015b) to determine if baseline or 2015 concentrations dropped below recommended levels.

2.3.2.2 Secchi Depth

<u>Data Selection</u>

Secchi depths have been measured at lake sites in the Doris North Project area since 1995. The selection of historical lake data to include in the effects analysis was based on similarity of baseline sampling locations to 2015 sampling locations. At least three years of baseline Secchi depth data are available for Doris Lake South, Doris Lake North, and Little Roberts Lake. Pre 2010 Secchi depth was recorded once in August 2009 at Reference Lake B, and no pre-2010 data were available for Reference Lake D.

Marine sites RBE and RBW are shallow (< 5 m) and typically contain low levels of phytoplankton biomass. At site RBE, all Secchi depths measured in 2015 reached the bottom sediments (Appendix A), indicating that the euphotic zone typically extended throughout the entire shallow water column. Although Secchi depths did not reach the bottom sediments at site RBW in 2015, this was a common occurrence historically and the euphotic zone extended throughout the water column during the August 2015 sampling event. The purpose of evaluating Secchi depth is to determine whether there is any evidence of reduced water clarity caused by either an increase in phytoplankton biomass as a result of eutrophication or an increase in suspended sediments. As there was no indication of water clarity concerns, Secchi depth was not evaluated for the Roberts Bay sites RBW and RBE.

<u>Effects Analysis</u>

Graphical analysis of annual mean Secchi depths were used to compare before (baseline) and after (2015) data at the exposure sites to before and after data at the reference sites and to supplement the results of the statistical analyses.

For each lake site, a before-after comparison between the mean baseline Secchi depth and the mean Secchi depth for 2015 was conducted. A mixed model ANOVA was used for this before-after comparison. This model included fixed effects of *period* (before vs. after) and *season*, and a random effect of *year* to account for variability in the Secchi depth data. For the *period* effect, data were grouped into one of two periods: *before* the start of construction (1995 to 2009) or *after* the start of construction (2015). For the *season* effect, data were grouped into one of three seasons depending on the timing of Secchi depth measurement: 1) July, 2) August, 3) September, since Secchi depth can vary over the open-water season depending on sediment and nutrient inputs and phytoplankton growth.

A significance level of 0.05 was used when reviewing the results. In the monitoring context, a false positive (i.e., type I error, determining impact when none exists) is more tolerable than a false negative (i.e., type II error, determining no effect when in fact there is one). There is a direct trade-off between the two error rates, as reducing one type of error generally results in an increase in the other type of error. No correction for the large number of statistical tests was applied to the false positive (type I) error rate. Therefore, there are likely false positives in the analyses that were conducted, which is a conservative and environmentally protective approach.

If the before-after comparison revealed that the mean Secchi depth in 2015 was significantly different (or marginally non-significant) from the baseline mean, a before-after-control-impact (BACI) analysis, which is a standard method used to assess an environmental effect, was conducted. The BACI analysis compares the mean before and after at the exposure site with the mean before and after at a corresponding reference site, to see if there is a parallel change and, thus, trends which are attributable to a natural process. A significance level of 0.05 was used when reviewing the results. A BACI analysis could only be performed if baseline and 2015 data were available for both the exposure site and the reference site. Because there was no baseline data available for Secchi depth in Reference Lake D, it was not possible to conduct a BACI analysis for Secchi depth in Little Roberts Lake.

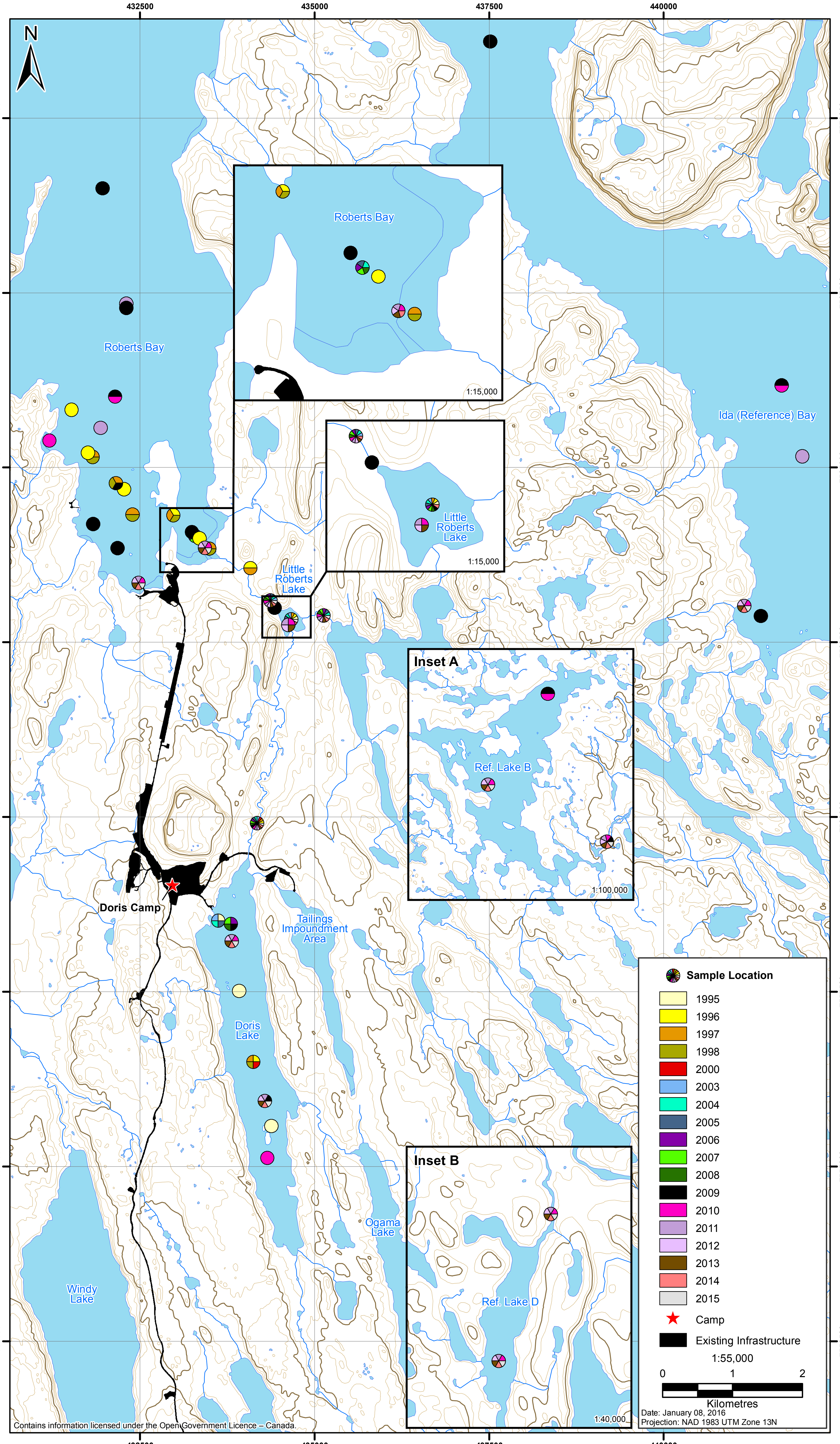
The BACI analysis introduces a *class* effect to the mixed model ANOVA, which is the classification of the waterbody as an exposure or a reference site. The interaction between the *period* (before vs. after) and *class* (exposure vs. reference) effects reveals whether any before-after change in the mean Secchi depth that occurred in the exposure site also occurred in the reference site. If a change in the mean was detected by the before-after comparison, but the BACI analysis revealed that a parallel change also occurred at the reference site, the change likely resulted from a natural phenomenon and was unrelated to the 2015 Project activities. Note that BACI results are only discussed in the text if a significant difference was detected by the before-after analysis for exposure sites, but all BACI results are included in Appendix B and presented in the report figures.

2.3.2.3 Water Quality

Data Selection

Water quality samples have been collected in the Project area since 1995 (Figure 2.3-1). The selection of historical data to include in the effects analysis was based on the similarity of baseline sampling locations to 2015 sampling locations, methodology (e.g., lake shoreline grabs were excluded from dataset), sampling depth (e.g., for marine data, baseline samples collected from just above the sediment were excluded because all 2015 samples were collected from the surface zone), and professional judgement. Note that for Doris Lake South, historical water quality data collected between 1996 and 2000 were excluded from the effects analysis presented in the 2010 Program report (Rescan 2011) because the 1996 to 2000 sampling site was more than 1 km north of the 2010 Doris Lake South sampling site (Figure 2.3-1). In 2011, the Doris Lake South sampling site was moved into deeper water approximately 500 m away from the 1996 to 2000 sampling site, and has remained at this location for 2015 sampling. Therefore, the historical 1996 to 2000 data were considered comparable to the 2015 water quality data and were included in the 2015 effects analysis for Doris Lake South. The Little Roberts Lake sampling location was moved approximately 90 m in 2014 to a deeper location to improve the ability to obtain representative samples under-ice. The 2015 sampling location was consistent with the 1995 to 1997, 2003 to 2009, and 2014 baseline sampling location for Little Roberts Lake and all baseline data were therefore retained in the effects analysis (except for some shoreline grabs collected in 1995; see Appendix B).

Figure 2.3-1
Waer Quality Sampling Stations, Doris North Project, 1995 to 2015



Effects Analysis

All 18 evaluated water quality variables presented in Table 2.3-1 were screened against relevant CCME guidelines for the protection of freshwater and marine aquatic life (CCME 2015b). For each variable, a graph showing annual mean variable concentrations for all available years is presented alongside a graph comparing before-after means at the exposure sites to before-after means at the reference sites. This graphical analysis was used to identify trends and to supplement the results of the statistical analyses. Relevant CCME guidelines were included on these graphs and also in Appendix A.

For each waterbody, a before-after comparison between the baseline mean and the 2015 mean was conducted for each of the 18 evaluated variables (provided that baseline data were available). A mixed model ANOVA was used for this before-after comparison. This model included fixed effects of *period* (before vs. after) and *season* (early vs. late, see below), and a random effect of *year* to account for variability in water quality data. For the *period* effect, data were grouped into one of two periods: *before* the start of construction (1995 to 2009) or *after* the start of construction (2015). For the *season* effect, samples were grouped into one of two seasons depending on the timing of sampling: *early* (i.e., June or earlier, which included freshet or under-ice sampling) or *late* (i.e., July or later, which included open-water season sampling). A significance level of 0.05 was used when reviewing the results.

The interpretation of the before-after analyses, the conditions under which a subsequent BACI analyses was conducted, the BACI methodology, and the interpretation and presentation of the BACI results are described in Section 2.3.2.2. Details specific to the water quality analyses are described below.

For lake and marine water quality variables, the before-after change for each exposure site was compared against the change at the corresponding reference site for the BACI analysis. For stream water quality variables, the before-after change for each exposure site was compared against the change obtained using data from both reference streams (Reference B Outflow and Reference D Outflow). Although no baseline data was available for Reference D Outflow, data collected from this site in 2015 contributed some information on the year effect, which improved the precision of the BACI analysis.

All sample replicates collected on the same date and from the same depth in the water quality dataset were treated as pseudo-replicates and were averaged prior to graphical and statistical analysis. In some large lake sites, the dataset included samples that were collected from multiple depths within the water column. Because there was little evidence of vertical chemical stratification, the data were pooled for the calculation of the variable mean regardless of sampling depth. For all effects analyses, statistical results were considered unreliable if > 70% of the values in the dataset for a variable were less than analytical detection limits (i.e., censored data). These statistical results are not presented in this report (though statistical results for these data do appear in the statistical outputs provided in Appendix B).

A value equal to half of the detection limit was substituted for censored data that were included in the analyses. Similar results were obtained regardless of whether half the detection limit or the full detection limit was substituted for these censored values. If the substitution of half versus the full detection limit affected the conclusions of the effects assessment, differences were discussed in the text. Values determined to be outliers were excluded from the statistical analyses. In most cases, outliers were baseline values that were less than very high detection limits. These and other anomalous historical values were removed to reduce artificial inflation of the variance, which would lead to reduced power to detect effects. Lists of outliers identified for water quality variables are available in Appendix B.

2.3.2.4 Sediment Quality

Data Selection

Baseline sediment quality sampling has been conducted six times in the freshwater and marine study area since 1997 (Figure 2.3-2). The selection of historical data was based partially on the proximity of baseline sampling sites to the 2015 sites and the similarity of sampling techniques. However, the most important criterion in the historical sediment quality data selection process was that baseline (1995-2009) samples had to be collected from the same depth strata as the 2015 samples, since greater metal concentrations are often associated with greater proportions of fine sediments (silts and clays; e.g., Lakhan, Cabana, and LaValle 2003), and this, in turn, is affected by the depth of sampling (i.e., deeper samples tend to contain greater proportions of fine sediments). Because the Doris Lake South sampling location was moved from a shallow site in 2010 (< 5 m deep) to a deep site in 2011 (> 10 m deep) for improved comparability with the Doris Lake North site (which is also a deep site), only baseline data collected from the deep depth strata were included in the comparison to 2015 Doris Lake South data. The sediment samples collected from the marine reference site (REF-Marine 1) in 2015 were collected from an average depth of 8 m, so site REF-Marine 1 would be categorized as a mid-depth (5 to 10 m) site in 2015. Between 2010 and 2014, sampling depths for individual replicates at this site have ranged from 3.9 to 8.5 m; therefore, some samples were collected from shallow (0 to 5 m) depth zones, while others were collected from mid-depth zones. Because 2015 samples were clearly within the mid-depth category, the 2009 baseline data used for the effects analysis were from a mid-depth site located near the REF-Marine 1 site (Figure 2.3-2). This differs from previous AEMP reports in which 2009 data from a shallow site near REF-Marine 1 were used for the effects analysis.

Effects Analysis

The nine sediment quality variables presented in Table 2.3-1 were evaluated using graphical analysis, before-after comparisons, and BACI analysis. All evaluated sediment quality variables were screened against relevant CCME guidelines for the protection of freshwater and marine aquatic life (CCME 2015a). Relevant CCME guidelines were included on effects analysis graphs, and also in Appendix A.

Before-after comparisons were used to determine if mean 2015 sediment quality concentrations differed from baseline means. A mixed model ANOVA was used for this before-after comparison. This model included fixed effects of *period* (before vs. after) and a random effect of *year* to account for variability in sediment quality data. For the *period* effect, data were grouped into one of two periods: *before* the start of construction (1996 to 2009) or *after* the start of construction (2015). Each waterbody was treated independently and each variable was treated separately. A significance level of 0.05 was used when reviewing the results.