Prepared for:

TMAC RESOURCES

DORIS PROJECT

2017 Aquatic Effects Monitoring Program Report

March 2018

The business of sustainability

ERM

TMAC Resources Inc.

DORIS PROJECT
2017 Aquatic Effects Monitoring Program Report

March 2018

Project #0393092-0002

Citation:
ERM. 2018. *Doris Project: 2017 Aquatic Effects Monitoring Program Report*. Prepared for TMAC Resources Inc. by ERM Consultants Canada Ltd.: Vancouver, BC.

ERM
ERM Building, 15th Floor
1111 West Hastings Street
Vancouver, BC
Canada V6E 2J3
T: (604) 689-9460
F: (604) 687-4277

EXECUTIVE SUMMARY

The Doris 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 Belt, including the Doris 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 site 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. Following notification to the Nunavut Water Board (NWB) and Nunavut Impact Review Board (NIRB), construction was resumed during the summer of 2015. The Project transitioned from a construction phase into commercial operations in early 2017.

This report presents the results of the 2017 Aquatic Effects Monitoring Program (AEMP) for the Project. This is the first year of monitoring under the revised *Hope Bay Project: Doris Aquatic Effects Monitoring Plan* (the Plan; TMAC 2016), which replaced the original AEMP Plan for the Doris Project (Rescan 2010b). In the original mine plan, the discharge of mine contact water and saline groundwater from the Tailings Impoundment Area (TIA) was to be directed to Doris Creek, a fish-bearing stream that flows from Doris Lake and eventually into Roberts Bay. However, under the terms of the current Project Certificate No. 003 and Water Licence 2AM-DOH1323, the planned discharge of TIA water has been redirected from the freshwater environment (Doris Creek) to the marine environment (Roberts Bay). Given that there is no longer anticipated to be point-source effluent discharge to the freshwater environment, the revised Plan was designed to detect effects to the freshwater environment from non-point source inputs of dust and runoff from Project-related activities. The Plan focuses on pathways of potential effects in Doris Lake, since most mine infrastructure is adjacent to Doris Lake and this waterbody has the greatest potential to be affected by the Project. Mining activities also have the potential to draw down the water level in Doris Lake due to permitted water withdrawal for Project use and water loss through the recharge of mine-intercepted groundwater (TMAC 2016).

Two lake sites were monitored as part of the 2017 AEMP in accordance with the Plan: Doris Lake North and Reference Lake B. The monitoring of Reference Lake B was retained from the original AEMP to help determine whether potential trends observed in Doris Lake are naturally occurring or Project-related. Aquatic components evaluated in 2017 included the following: under-ice water level; under-ice dissolved oxygen concentration; water temperature; water and sediment quality; phytoplankton biomass; and benthic invertebrate community density, taxa richness, diversity, and Bray-Curtis Index. Statistical and/or graphical analyses were performed in order to determine whether there were any apparent effects of Project activities on the aquatic monitoring components at the exposure site (Doris Lake North) in 2017. The analyses included comparisons of baseline data (pre-2010) to data collected during mine construction (2010 to 2016) and operations (starting in 2017) phases and comparisons between the reference site (Reference Lake B) and the potentially affected site (Doris Lake North) over time.

Table 1 presents a summary of the overall findings of the evaluation of effects for the 2017 AEMP, as well as the corresponding section in this report in which to find the discussion of the evaluation of effects for each monitoring component. Benthic invertebrate density increased over time in Doris Lake North, but a similar increase was not apparent at the reference site; therefore, the low action level was triggered for benthic invertebrate density according to the Plan (TMAC 2016). An Aquatic Response Plan for Benthos Density has been submitted as part of this AEMP report (Appendix C).

Table 1. Summary of Evaluation of Effects for 2017 Aquatic Effects Monitoring Program

Evaluated Variable	Doris Lake North (exposure site)	Low Action Level Triggered?	Report Section
Under-ice Water Level	no effect	No	3.1
Under-ice Dissolved Oxygen	no effect	No	3.2
Temperature	no effect	No	3.2
Water Quality	possible effect (total suspended solids and total molybdenum)	No	3.3
Sediment Quality	no effect	No	3.4
Phytoplankton Biomass	no effect	No	3.5
Benthic Invertebrates	possible effect (total density)	Yes	3.6

ACKNOWLEDGEMENTS

This report was prepared for TMAC Resources Inc. by ERM. The 2017 fieldwork was conducted by ERM scientists Leanne Elchyshyn (M.Sc.), Adam Chateauvert (M.Sc.), and Cameron Evans (E.I.T.), with the support of TMAC on-site environmental coordinators Kyle Conway and Sarah Warnock. Fieldwork was completed with the enthusiastic and competent support of TMAC field assistants Abe Eyegetok, Leonard Wingnek, and Jamie Ihakkaq. The report was written by Carol Adly (M.Sc.) and Leanne Elchyshyn (M.Sc.), statistical analyses were completed by Joanna Zhao (M.Sc.) and Laurie Ainsworth (Ph.D.), and the report was reviewed by Erin Forster (B.Sc., R.P.Bio) and Mike Henry (Ph.D.). The compliance program was managed by Erin Forster and Nicole Bishop (B.Sc.). Marc Wen (M.Sc., R.P.Bio.) was the Partner in Charge. Graphics production was coordinated by Francine Alford (B.F.A.), Geographical Information System (GIS) production was coordinated by Pieter van Leuzen (M.Sc.), and report publishing was coordinated by Agnes Untz (B.Tech.).

Field-related logistics support was provided by TMAC, Acasta HeliFlight, Braden Burry Expediting, and Nuna Logistics.

DORIS PROJECT
2017 Aquatic Effects Monitoring Program Report

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

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
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
BTD	Below the Dyke (mineral deposit)
CB	Comparison to benchmarks
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
D_s	Secchi depth
DO	Dissolved oxygen
ERM	ERM Consultants Canada Ltd.
Exposure site	Site anticipated to be potentially influenced by Project-related activities as part of the Doris Project (i.e., Doris Lake North).
F	Family richness
GA	Graphical analysis
HBML	Hope Bay Mining Limited
INAC	Indigenous and Northern Affairs Canada

ISQG	Interim sediment quality guideline
k	Light extinction coefficient
LME	Linear mixed effects
LOESS	Local regression
NIRB	Nunavut Impact Review Board
NTU	Nephelometric turbidity units
NWB	Nunavut Water Board
PEL	Probable effects level
the Plan	Hope Bay Project: Doris Aquatic Effects Monitoring Plan
the Project	the Doris Project
QA/QC	Quality assurance/quality control
Reference site	Site located beyond any Project influence (i.e., Reference Lake B).
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.
SA	Statistical analysis
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 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 mainland Nunavut (Figure 1-1). The Belt 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) and 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 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 site was seasonally closed during the winter of 2012/2013. TMAC re-opened the Doris Camp in March 2013 for the purposes of conducting site water management and environmental compliance programs and to support exploration activities. Following notification to the Nunavut Water Board (NWB) and Nunavut Impact Review Board (NIRB), construction was resumed during the summer of 2015. The Project transitioned from a construction phase into commercial operations in early 2017.

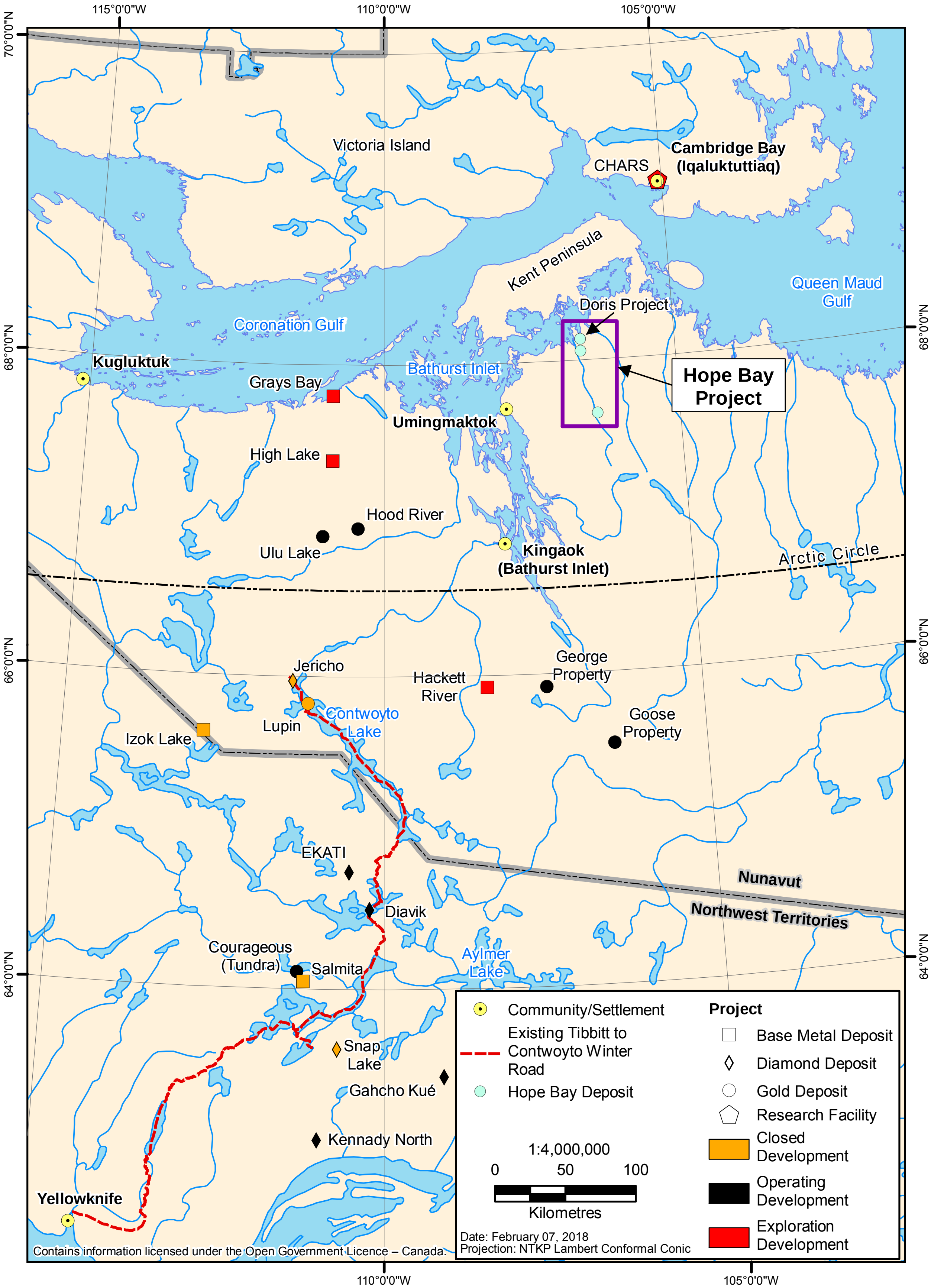
This report presents the results of the 2017 Aquatic Effects Monitoring Program (AEMP) for the Project. The AEMP was conducted according to the *Hope Bay Project: Doris Aquatic Effects Monitoring Plan* (the Plan; TMAC 2016), which was approved with the issuance of Amendment No. 1 of the Type A Water Licence (No. 2AM-DOH0713) by the Nunavut Water Board (NWB) on December 16, 2016 (Motion Number 2016-11-P7-08). This Plan replaced the original AEMP plan for the Doris Project (Rescan 2010b). In the original mine plan, the discharge of mine contact water and saline groundwater from the Tailings Impoundment Area (TIA) was to be directed to Doris Creek, a fish-bearing stream that flows from Doris Lake and eventually into Roberts Bay. However, under the terms of the current Project Certificate No. 003 and Water Licence 2AM-DOH1323, the planned discharge of TIA water has been redirected from the freshwater environment (Doris Creek) to the marine environment (Roberts Bay). Given that there is no longer anticipated to be point-source effluent discharge to the freshwater environment, the revised Plan was designed to detect effects to the freshwater environment from non-point source inputs of dust and runoff from Project-related activities. The Plan focuses on pathways of potential effects in Doris Lake, since most mine infrastructure is adjacent to Doris Lake and this waterbody has the greatest potential to be affected by the Project. Mining activities also have the potential to draw down the water level in Doris Lake due to permitted water withdrawal for Project use and water loss through the recharge of mine-intercepted groundwater (TMAC 2016).

1.1 OBJECTIVES

The objectives of the AEMP are to monitor and evaluate potential effects of Project activities on the following components of the freshwater environment in the Project area:

- under-ice water level in Doris Lake;

Figure 1-1
Doris Project Location



- dissolved oxygen concentration and water temperature;
- water quality;
- sediment quality;
- phytoplankton biomass; and
- benthic invertebrate community (various metrics).

1.2 2017 Project Activities

Existing infrastructure associated with the Doris Project is shown in Figure 1.2-1. The Project transitioned from a construction phase into commercial operations in early 2017. The mill was fully commissioned in April 2017. A fully functional Assay Lab was installed in 2017 to provide onsite monitoring of the milling processes and discharge to the TIA. Infrastructure constructed included a light duty mechanical shop, additional warehousing, and an arctic corridor to connect the main camp and the mill building. Earthworks continued in order to expand the Doris Airstrip south apron to include a lined aircraft de-icing and refueling pad. This also included the completion of another Tailings Catchment Basin, the Reagents Storage Berm, and the South Dam access road.

Underground waste development continued in 2017 with further advancement of the below the dyke (BTD) decline and necessary support infrastructure. TMAC continued to drive ore development above the dyke for long-hole drilling and blasting in Doris North, with the first ore sill for future long hole stoping blocks in BTD commencing in the second quarter. Long hole blasting continued throughout 2017, with all ore production trucked to surface and added to the stockpile. TMAC continued underground exploration diamond drilling BTD at Doris, focusing on the BTD East limb in 2017.

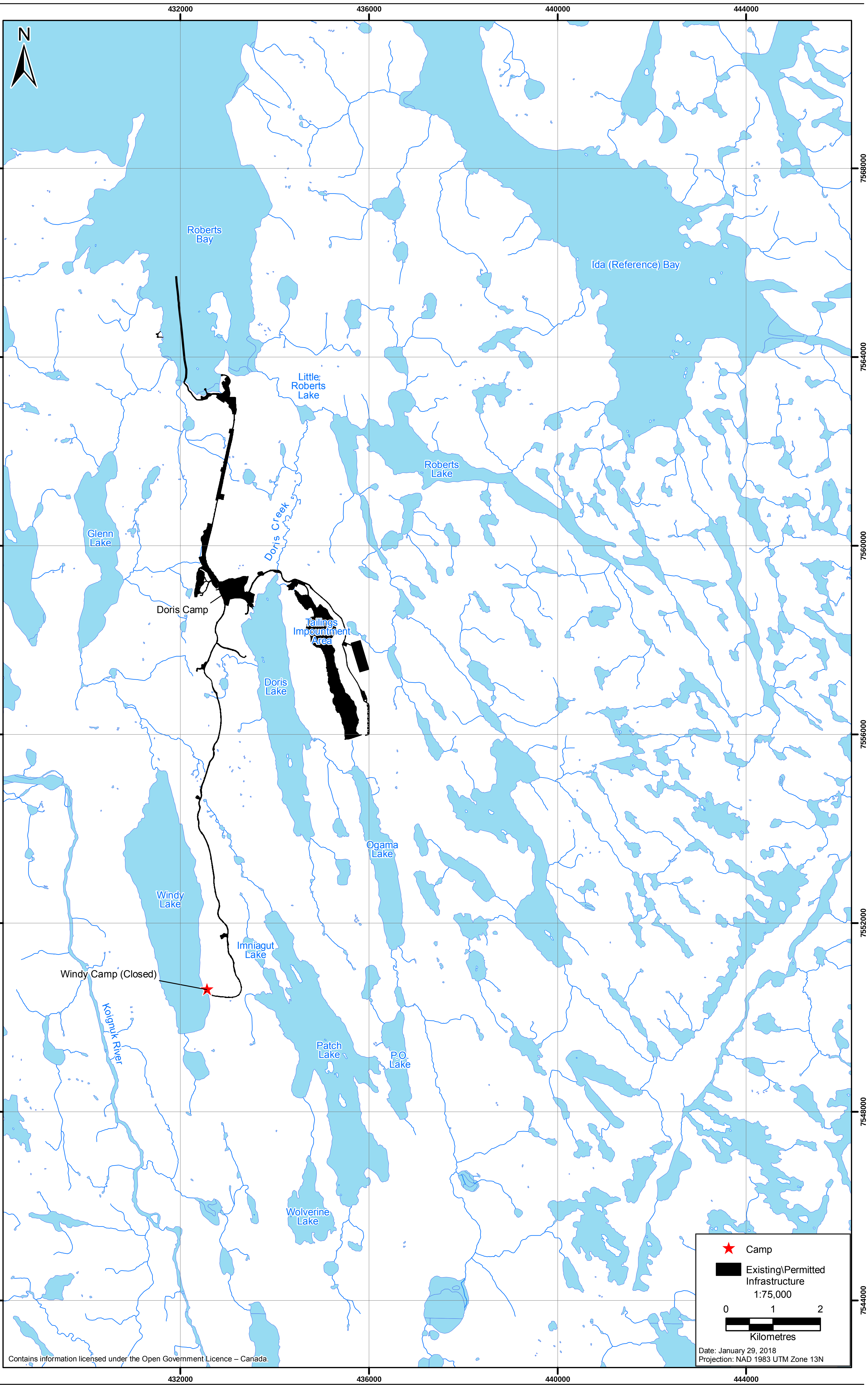
In the fall, TMAC concluded another successful sealift operation including the purchase and delivery of diesel fuel as well as explosives and reagents to support mining and milling activities. The sealift also included additional heavy equipment to support mining and construction operations as well as the acquisition of a 100-person accommodations facility to house TMAC's expanding workforce.

Project infrastructure and associated activities have the potential to affect the aquatic freshwater environment through dust generation and runoff. Mitigation measures to reduce the potential for adverse effects to freshwater habitats in the Project area include 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 2017 Doris AEMP. Detailed sampling and data analysis methodology, raw data, and results from the 2017 AEMP (including water level, ice thickness, water column structure, water quality, sediment quality, primary producers, and benthic invertebrates) are provided in Appendix A. Supplemental information relevant to the 2017 statistical analysis of effects is provided in Appendix B. The Aquatic Response Plan for Benthos Density is provided in Appendix C.

Figure 1.2-1
Existing Infrastructure, Doris Project



2. METHODS

2.1 SUMMARY OF STUDY DESIGN

The 2017 Program was conducted in accordance with the *Hope Bay Project: Doris Aquatic Effects Monitoring Plan* (TMAC 2016).

2.1.1 Sampling Locations

The AEMP study area includes two lakes sites: 1) Doris Lake North (exposure site), which has the potential to be influenced by Project-related activities, and 2) Reference Lake B (reference site), which is outside of the anticipated zone of Project influence (Table 2.1-1). Sampling sites, the aquatic components sampled, and Project infrastructure are shown in Figure 2.1-1.

Table 2.1-1. AEMP Sampling Locations, Descriptions, and Sampling Rationale, Doris Project, 2017

Sampling Location	Coordinates (13W)	Description	Sampling Rationale
<u>Lakes</u>			
Doris Lake North	433815E 7558222N	Large lake (3.4 km^2) 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 including explosives storage
Reference Lake B	424050E 7532000N	Large reference lake (7.7 km^2) located southwest of the Project	Reference lake meant to closely resemble the morphology, hydrological and habitat features of Doris Lake, but located outside of the zone of Project influence

There were no Project activities near the selected reference site. A major consideration in reference site selection was that the reference site be located beyond the reach of any potential wind-borne particulates from Project-related sources. Reference Lake B is located approximately 25 km away from Project infrastructure.

2.1.2 2017 Sampling Schedule

Sampling in 2017 was conducted in accordance with the schedule outlined in the Plan (TMAC 2016) and is summarized in Table 2.1-2. For 2017, the sampling program commenced in April with under-ice sampling and ended in September. Physical profiles (e.g., temperature, dissolved oxygen) and water quality (e.g., nutrients and metals) were collected four times during the sampling period, at least one month apart (whenever possible). Phytoplankton biomass (as chlorophyll *a*), sediment quality (e.g., total organic carbon and metals), and benthic invertebrate (benthos) samples were collected once in August. Full details of the 2017 AEMP sampling methods are provided in Appendix A.

Figure 2.1-1

AEMP Sampling Locations, Doris Project, 2017

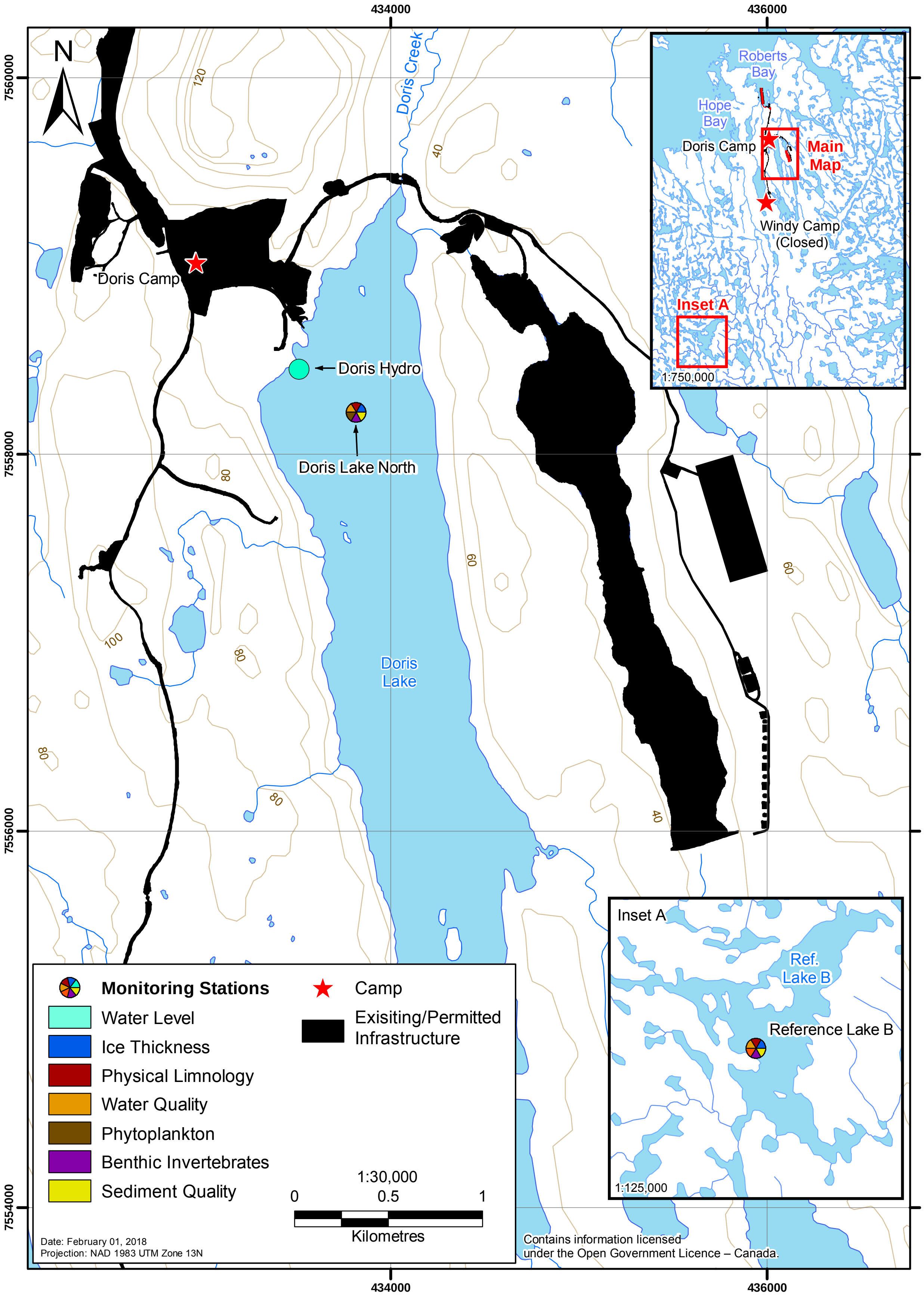


Table 2.1-2. Sampling Schedule Summary, Doris Project, 2017

Variable	Sampling Dates
Water Level in Doris Lake	Continuous from September 2016 to June 2017
Ice Thickness	April 27, 2017
Physical Limnology	April 26-27, 2017
	July 8-17, 2017
	August 17-21, 2017
	September 12, 2017
Water Quality	April 26-27, 2017
	July 8-17, 2017
	August 17-21, 2017
	September 12, 2017
Sediment Quality	August 17-21, 2017
Phytoplankton Biomass	August 17-21, 2017
Benthos	August 17-21, 2017

2.2 EVALUATION OF EFFECTS METHODOLOGY

For each variable subjected to an evaluation of effects, baseline data collected prior to 2010 in the Project area were incorporated into the analysis to determine if there were any apparent changes in the evaluated parameters over time that might be attributable to Doris Project construction and operation activities. Temporal trends in Reference Lake B were examined alongside the trends in Doris Lake to determine if potential changes over time were naturally occurring or Project-related.

2.2.1 Variables Subjected to Effects Analysis

Table 2.2-1 presents the physical, chemical, and biological variables that were evaluated in 2017. Under-ice water level in Doris Lake was included in the effects analysis to ensure that Project-related water use does not pose a risk to overwintering fish populations and fish habitat. Water and sediment quality variables for which the Canadian Council of Ministers of the Environment (CCME) has established guidelines for the protection of aquatic life were included in the effects analysis to ensure the protection of freshwater organisms residing within the zone of Project influence. Biological variables that can be used as indicators of nutrient loading or other changes to freshwater environments such as phytoplankton biomass and benthic invertebrate community metrics were also evaluated.

2.2.2 Overview of Assessment Methodology

For each variable subjected to an analysis of effects, potential mine effects were evaluated by a visual examination of graphical trends over time and, where possible, statistical analysis of trends over time. This section provides an overview of the statistical analysis methodology; a complete description of the statistical analyses, including detailed methodology and results, is presented in Appendix B. All statistical analyses were conducted using R version 3.4.3.

Table 2.2-1. Variables Subjected to Analysis of Effects, Doris Project, 2017

Category	Variable
Water Level and Ice Thickness	Winter Drawdown April Ice Thickness
Physical Limnology	Dissolved Oxygen Temperature
Water Quality	pH Total Suspended Solids (TSS) Turbidity Chloride Fluoride Ammonia Nitrate Nitrite Total Phosphorus Aluminum (Al) Arsenic (As) Boron (B) Cadmium (Cd) Chromium (Cr) Copper (Cu) Iron (Fe) Lead (Pb) Mercury (Hg) Molybdenum (Mo) Nickel (Ni) Selenium (Se) Silver (Ag) Thallium (Tl) Uranium (U) Zinc (Zn)
Sediment Quality	Total Organic Carbon (TOC) Arsenic (As) Cadmium (Cd) Chromium (Cr) Copper (Cu) Lead (Pb) Mercury (Hg) Zinc (Hg)
Phytoplankton	Phytoplankton Biomass (as Chlorophyll *a*)
Benthic Invertebrates	Density Family Richness Simpson's Diversity Index Bray-Curtis Index

Between 2010 and 2016, the Doris AEMP employed a before-after control-impact (BACI) design to assess the change in a variable between two periods defined as "before" and "after". The before period included data prior to 2010 (before initiation of construction) and the after period included data from the current assessment year. Any data between 2010 and the previous assessment year (inclusive) were removed from the analysis. The BACI approach is appropriate when limited data are available to assess long-term trends. However, the amount of information lost increases as more data are collected since only data from the current year were included in the after period of the BACI analysis conducted as part of the Doris AEMP. For the 2017 AEMP assessment year, it was concluded that sufficient data had been collected at the reference and exposure sites to estimate long-term temporal trends. The advantage of trend analysis over BACI approach is that all of the collected data would be used to estimate the effects of interest and inter-annual patterns over time can be better captured.

Regression models were used to examine any temporal trends over the monitoring period. Linear mixed effects (LME) regression or Tobit regression analysis was used to test whether or not there was evidence of a temporal trend at each monitored lake. Tobit regression was used when a moderate amount of data (between 10 and 60%) for a given variable within a given lake was below the analytical detection limit. For profile data (dissolved oxygen and temperature) and highly censored data (i.e., datasets in which > 60% of values were below detection limits), trends were evaluated using graphical analysis alone. If 100% of concentrations of a given variable were below the detection limit for the current assessment year (i.e., 2017), it was concluded that there was no evidence of an effect of the Project on that variable, and no further analyses were performed.

The first step of the statistical analysis was to determine whether there was any evidence of a change in a given variable over time (i.e., was the slope of the trend over time significantly different from a slope of zero). This first step did not give any information about the direction of the trend (e.g., increasing or decreasing), only that there was a significant change in the variable over time. For most variables, only an increasing concentration over time would be considered an adverse mine effect (e.g., TSS in water, arsenic and copper in water and sediments), although for some variables, an increasing or decreasing trend could be of concern (e.g., phytoplankton biomass, pH in water).

If the first step of the analysis determined that there was evidence of a significant change in a variable over time in Doris Lake, the variable was carried forward to the second step of the statistical analysis where the trend in Doris Lake was compared to the trend in Reference Lake B. If the first step determined that the slope of the temporal trend was significantly different from zero, but the second step determined that the temporal trends in Doris Lake and Reference Lake B were not significantly different from each other, then it was concluded that the increasing or decreasing trend in the study lakes was naturally occurring and not related to Project activities. If, on the other hand, the second step of the analysis revealed that the trend in Reference Lake B was significantly different from the trend in Doris Lake, the differential trend in Doris Lake was carried forward as a potential mine effect and investigated further.

There are several reasons unrelated to Project activities that there could be a significant, differential trend in a variable in Doris Lake that was not paralleled in Reference Lake B. For example, trends over time could vary due to local differences in meteorological conditions, or naturally variable inputs related to weathering and erosion or runoff from the natural landscape. These changes would not necessarily affect all lakes in the region equally, and may not co-occur in Doris Lake and Reference Lake B. A difference in trends between lakes was therefore not conclusive evidence of a mine effect.

As well, any statistical analysis can result in a type I error (finding a significant effect where an effect was not present, i.e., false positive) or a type II error (failing to find a significant effect where an effect was present, i.e., false negative). In the monitoring context, a false positive is more tolerable than a false negative. 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 may be false positives in the analyses that were conducted, which is a conservative and environmentally protective approach. For this AEMP, the unadjusted type I error rate (or significance level) was set to 0.05, indicating that approximately 5% of the time, statistical results will show a significant effect (i.e., p value of < 0.05) by random chance alone where an effect is not actually present.

Any finding of a potential mine effect was interpreted using professional judgement and any other relevant information or supporting data to determine the likely cause of the effect. If the detected change was concluded to be a mine effect, the variable concentration was compared to benchmarks established through the Doris AEMP Response Framework (see Section 2.2.3) to determine what follow-up actions may be needed. If benchmarks were not exceeded and there is not considered to be ecological risk to freshwater aquatic organisms, the variables will continue to be monitored through the AEMP with no further follow-up action; however, if benchmarks were exceeded, follow-up actions are recommended as described in the Response Framework (TMAC 2016). Figure 2.2-1 illustrates the steps of the AEMP analysis and how the AEMP analysis of effects feeds into the Response Framework.

2.2.3 Doris AEMP Response Framework

Potential effects to Doris Lake and the freshwater receiving environment are adaptively managed through the Response Framework (TMAC 2016), which links the results of the AEMP effects analysis to management actions so that significant adverse effects arising from mine operation can be avoided (Figure 2.2-1). The Response Framework acts as an early-warning system with defined action levels that initiate monitoring and/or management actions within an adequate timeframe to ensure that significant adverse effects do not occur (TMAC 2016).

For each variable subjected to an analysis of effects, the Plan describes the benchmarks that will be applied to determine if potential Project-related effects could cause adverse environmental consequences. Through screening of the results of the AEMP evaluation of effects, the Plan outlines the conditions that must be met to trigger a “low action level” response. The triggers for a low action level response are designed to be conservative indicators that provide an early warning of potentially worsening conditions, before there is any exceedance of a benchmark.

2.2.3.1 Water Level and Ice Thickness

For water level and ice thickness in Doris Lake, the safe threshold or benchmark for over-wintering fish eggs is considered to be -2.74 m. This is because the winter drawdown of Doris Lake water level varied by a maximum of 0.74 m during baseline years and April ice thickness on Doris Lake varied from 1.9 to 2.0 m (Figure 2.2-2; TMAC 2015, 2016). If the combined winter drawdown and ice thickness exceeds -2.74 m (the maximum observed during baseline years), the survival of over-wintering fish eggs could be reduced. To avoid exceeding this threshold, the trigger for a low action level response according to the Response Framework is 1) identification that the water level has passed its median baseline natural drawdown and baseline ice thickness (-2.42 m), and 2) confirmation that there is a corresponding intrusion of groundwater into the mine. The low action level threshold of -2.42 m allows for adaptive management of water levels in Doris Lake while water levels are still protective of over-wintering fish eggs, in advance of reaching the potentially more consequential benchmark of -2.74 m.

Figure 2.2-1

Doris AEMP Effects Analysis and Response Framework

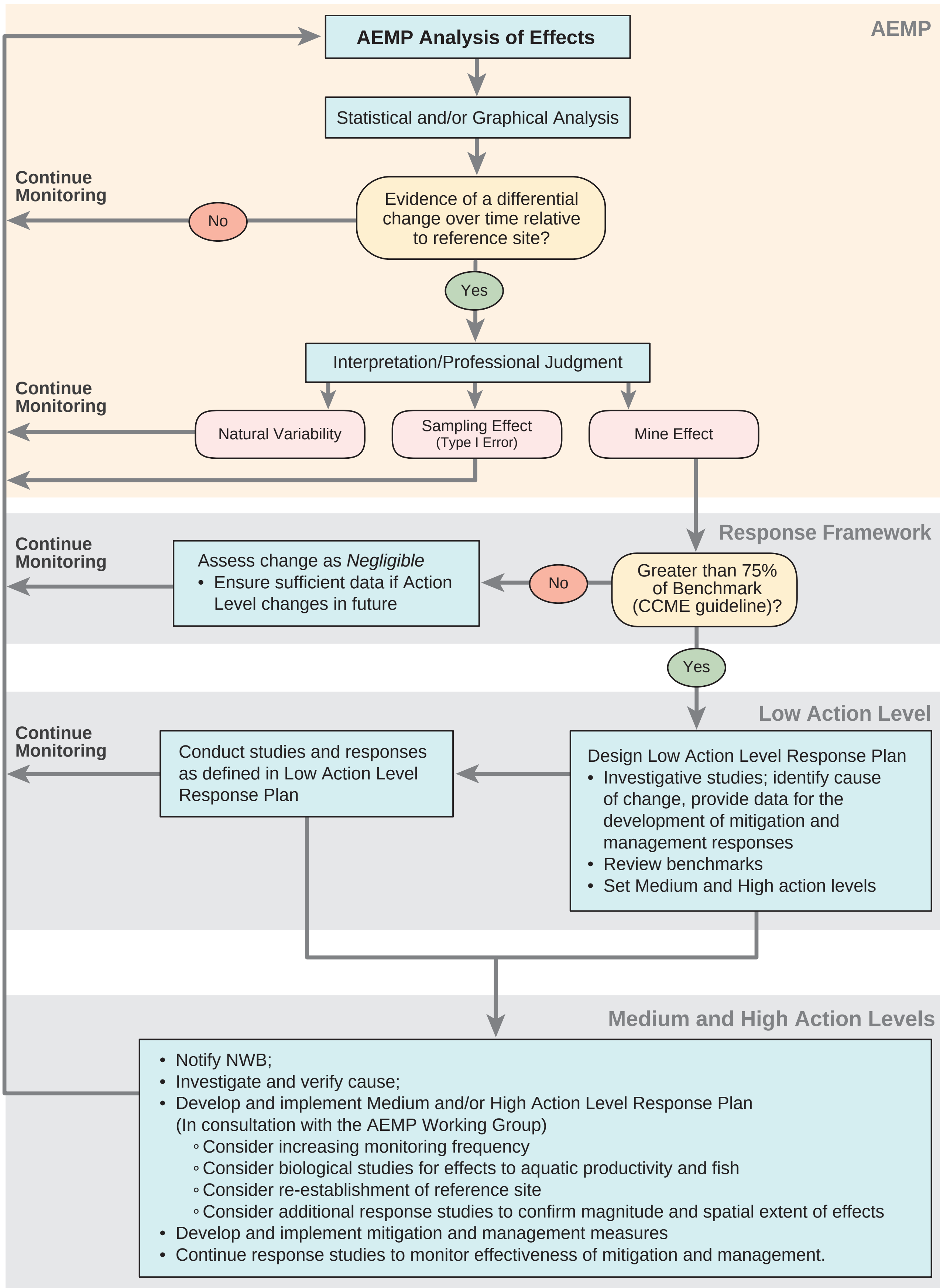
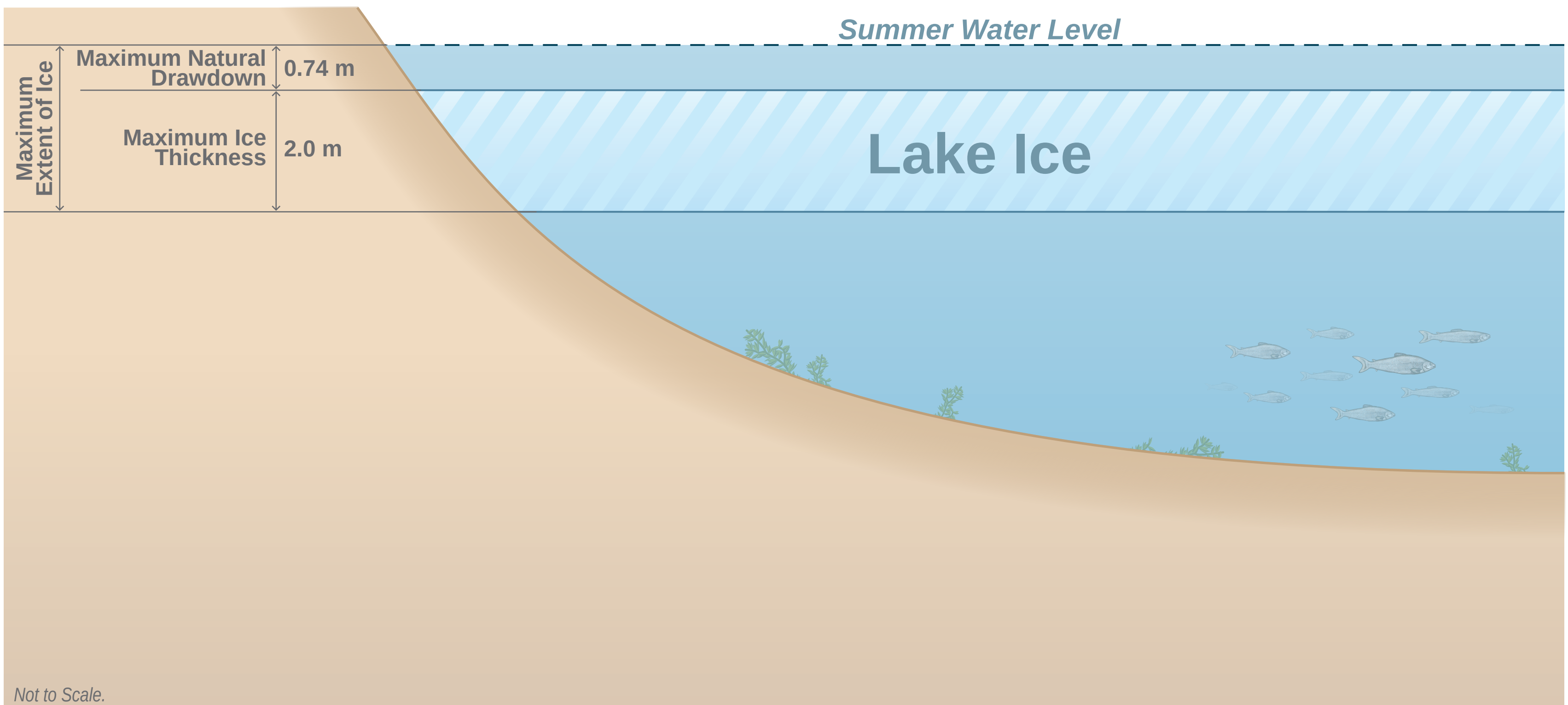


Figure 2.2-2

Schematic of Natural Water Level Drawdown and Ice Thickness on Doris Lake



2.2.3.2 Water and Sediment Quality

The benchmarks applied to water and sediment quality are the CCME freshwater water quality guidelines for the protection of aquatic life (Table 2.2-2; CCME 2018b) and the CCME freshwater sediment quality guidelines for the protection of aquatic life (Table 2.2-3; CCME 2018a). Exceedance of these benchmarks could adversely affect freshwater organisms; therefore, the trigger for a low action level is defined as 1) identification of a statistically significant increase in the AEMP effects analysis, 2) exceedance of 75% of the benchmark or CCME guideline, and 3) the absence of a similar change at the reference location (TMAC 2016). Setting the low action level trigger to 75% of the CCME guideline allows for adaptive management measures to be implemented before concentrations that could negatively affect freshwater life are reached. Tables 2.2-2 and 2.2-3 outline the water and sediment quality benchmarks as well as 75% of these benchmarks, which were used to screen the results of the AEMP analysis of effects for water and sediment quality.

Table 2.2-2. Long-term Water Quality Benchmarks for the Doris Project

Water Quality Variable	Benchmark[a]	75% of Benchmark
Dissolved Oxygen	6.5 mg/L	Not applicable
Temperature	Thermal additions must not alter thermal stratification regime, turnover date(s), and maximum weekly temperature	Not applicable
pH	6.5 – 9.0	6.62 – 8.88[b]
Total Suspended Solids (TSS)	Increase of 5 mg/L from background	Increase of 3.75 mg/L from background
Turbidity	Increase of 2 NTU from background	Increase of 1.5 NTU from background
Chloride	120 mg/L	90 mg/L
Fluoride	0.12 mg/L	0.09 mg/L
Total Ammonia-N	Temperature- and pH-dependent	Temperature- and pH-dependent
Nitrate-N	3.0 mg/L	2.25 mg/L
Nitrite-N	0.06 mg/L	0.045 mg/L
Total Phosphorus	Guidance framework: dependent on baseline conditions and ecosystem goals	Not applicable
Aluminum	0.10 mg/L if pH ≥ 6.5	0.075 mg/L if pH ≥ 6.5
Arsenic	0.005 mg/L	0.00375 mg/L
Boron	1.5 mg/L	1.125 mg/L
Cadmium	0.00004 mg/L for hardness[c] (as $CaCO_3$) of < 17 mg/L; 10(0.83[log(hardness)]-2.46)/1000 mg/L for hardness of ≥ 17 to ≤ 280 mg/L; 0.00037 mg/L for hardness of > 280 mg/L.	75% of hardness-dependent benchmark
Chromium	0.0089 mg/L for Cr (III); 0.001 mg/L for Cr (VI)	0.00668 mg/L for Cr (III); 0.00075 mg/L for Cr (VI)

(continued)

Table 2.2-2. Long-term Water Quality Benchmarks for the Doris Project (completed)

Water Quality Variable	Benchmarka	75% of Benchmark
Copper	0.002 mg/L for hardnessc (as $CaCO_3$) of <82 mg/L; e(0.8545[ln(hardness)]-1.465)/1000 mg/L for hardness of ≥ 82 to ≤ 180 mg/L; 0.004 mg/L for hardness of > 180 mg/L.	75% of hardness-dependent benchmark
Iron	0.3 mg/L	0.225 mg/L
Lead	0.001 mg/L for hardnessc (as $CaCO_3$) of ≤60 mg/L; e(1.273[ln(hardness)]-4.705)/1000 mg/L for hardness of > 60 to ≤ 180 mg/L; 0.007 mg/L for hardness of > 180 mg/L.	75% of hardness-dependent benchmark
Mercury	0.026 µg/L	0.0195 µg/L
Molybdenum	0.073 mg/L	0.055 mg/L
Nickel	0.025 mg/L for hardnessc (as $CaCO_3$) of ≤60 mg/L; e(0.76[ln(hardness)]+1.06)/1000 mg/L for hardness of > 60 to ≤ 180 mg/L; 0.15 mg/L for hardness of > 180 mg/L.	75% of hardness-dependent benchmark
Selenium	0.001 mg/L	0.00075 mg/L
Silver	0.00025 mg/L	0.0001875 mg/L
Thallium	0.0008 mg/L	0.0006 mg/L
Uranium	0.015 mg/L	0.01125 mg/L
Zinc	0.030 mg/L	0.0225 mg/L

Notes:
[a] *Source: CCME Freshwater Water Quality Guidelines for the Protection of Aquatic Life, Summary Table (CCME 2018b).*
[b] *pH benchmark values were converted to hydrogen ion concentrations for the calculations of 75% benchmark levels.*
[c] *Hardness (as $CaCO_3$) in Doris Lake North ranged from 39 to 62 mg/L between 2003 and 2017; hardness in Reference Lake B ranged from 12 to 24 mg/L between 2009 and 2017.*

Table 2.2-3. Long-term Sediment Quality Benchmarks for the Doris Project

Sediment Quality Variable	Benchmark[a] (mg/kg)		75% of Benchmark (mg/kg)	
	ISQG	PEL	ISQG	PEL
Arsenic	5.90	17.0	4.43	12.8
Cadmium	0.60	3.50	0.45	2.63
Chromium	37.3	90.0	28.0	67.5
Copper	35.7	197	26.8	148
Lead	35.0	91.3	26.3	68.5
Mercury	0.170	0.486	0.128	0.365
Zinc	123	315	92.3	236

Notes:
ISQG = Interim Sediment Quality Guideline; PEL = Probable Effects Level
[a] *Source: CCME Freshwater Sediment Quality Guidelines for the Protection of Aquatic Life, Summary Table (CCME 2018a).*

2.2.3.3 *Biological Indicators*

Potential effects to phytoplankton biomass (as chlorophyll *a*) are evaluated against existing baseline conditions. The trigger for a low action level response according to the Response Framework is 1) the identification of a significant change from baseline conditions, and 2) the absence of a similar change at the reference site (TMAC 2016).

Baseline data are not available for benthic invertebrates (benthos), so the benthos evaluation of effects is based on a comparison of trends over time from 2010 to 2017 between reference and exposure sites. The trigger for a low action level response for benthos community metrics is 1) the identification of a significant change over time between 2010 and 2017, and 2) the absence of a similar change at the reference site (TMAC 2016).

2.2.4 Historical Data

Baseline physical, chemical, and biological data have been collected in the Doris Project area since 1995. Figures 2.2-3 to 2.2-6 show the specific locations within Doris Lake and Reference Lake B where historical water quality (Figure 2.2-3), sediment quality (Figure 2.2-4), phytoplankton biomass (Figure 2.2-5), and benthic invertebrate (Figure 2.2-6) data were collected. Historical samples have been collected from a variety of locations and depths within both of the AEMP study lakes. 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 historical data that could be used in the analysis of effects.

Key determining factors for the inclusion of historical data in the evaluation of effects included the proximity of historical sampling sites to AEMP sampling sites, the depth of sampling (for sediment quality and benthos), sampling methodology, and data quality (e.g., the inclusion of historical data with poor analytical detection limits confounds the interpretation of effects and adds little value to the analysis). For the analysis of sediment quality, comparability of sampling depth was particularly important 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).

Historical data used or considered for the effects analyses were from the following reports: Klohn-Crippen Consultants Ltd. (1995), Rescan (1997, 1998, 1999, 2001, 2010a, 2011, 2012, 2013), RL&L Environmental Services Ltd. and Golder Associates Ltd. (2003), Golder Associates Ltd. (2005, 2006, 2007, 2008, 2009), ERM Rescan (2014), and ERM (2015, 2016, 2017). Full details of the rationale used in the selection of baseline data that were included in evaluation of effects are provided in Appendix B.

Figure 2.2-3
Water Quality Sampling Sites in Doris Lake and Reference Lake B, Doris Project, 1995 to 2017

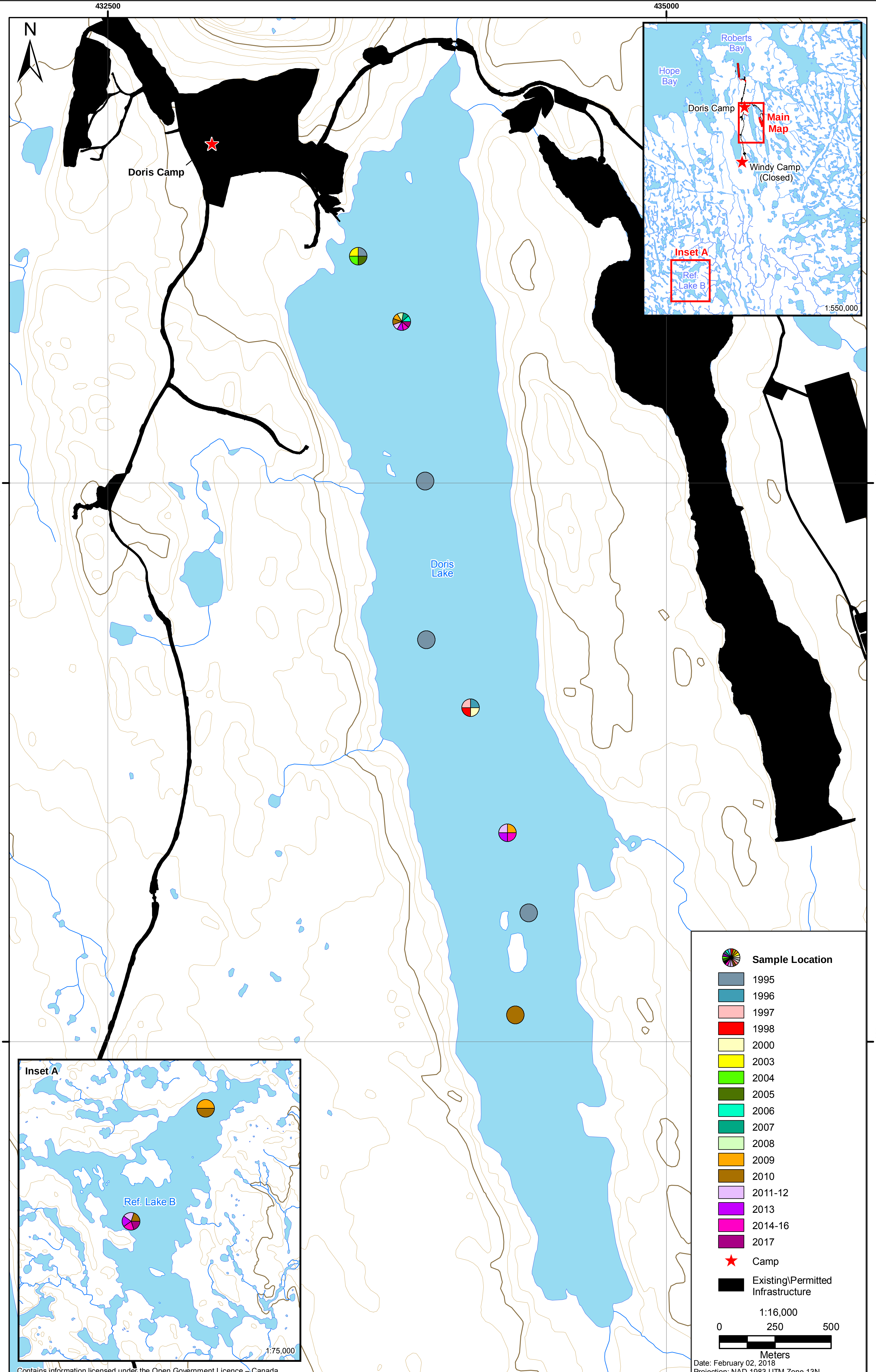


Figure 2.2-4
Sediment Quality Sampling Sites in Doris Lake and Reference Lake B, Doris Project, 1996 to 2017

TMAC RESOURCES

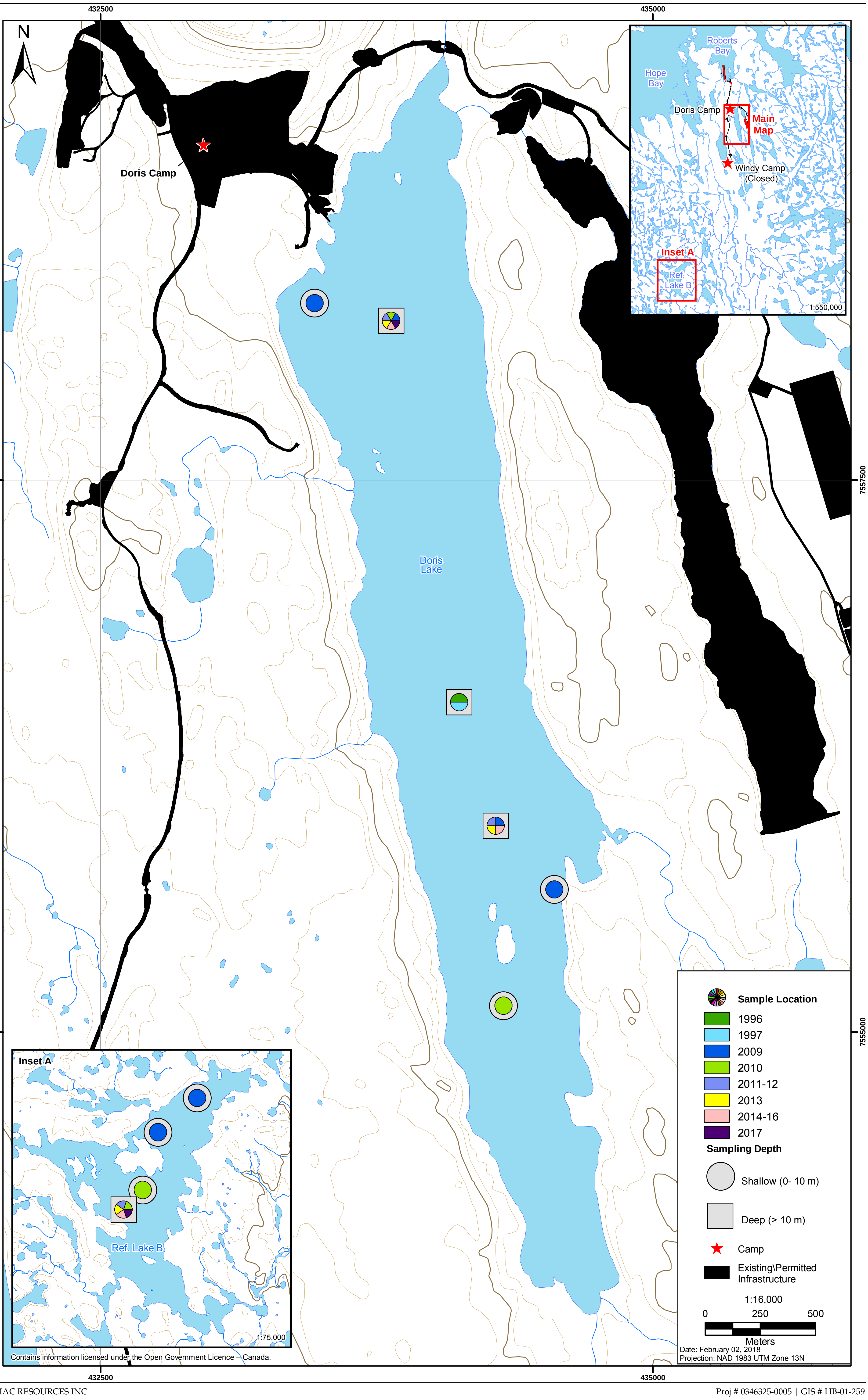


Figure 2.2-5

Phytoplankton Biomass (as Chlorophyll a) Sampling Sites in Doris Lake and Reference Lake B, Doris Project, 1997 to 2017

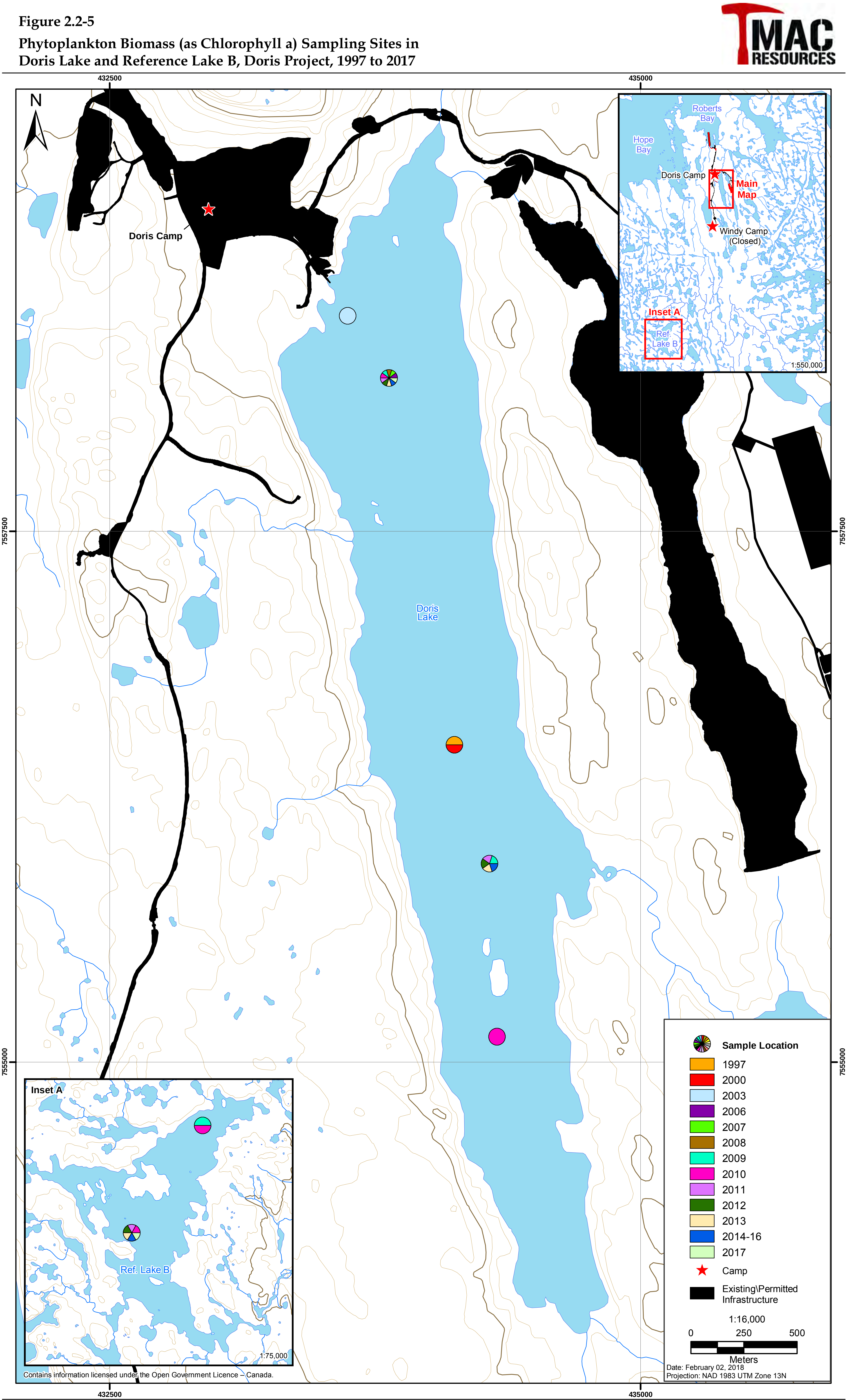
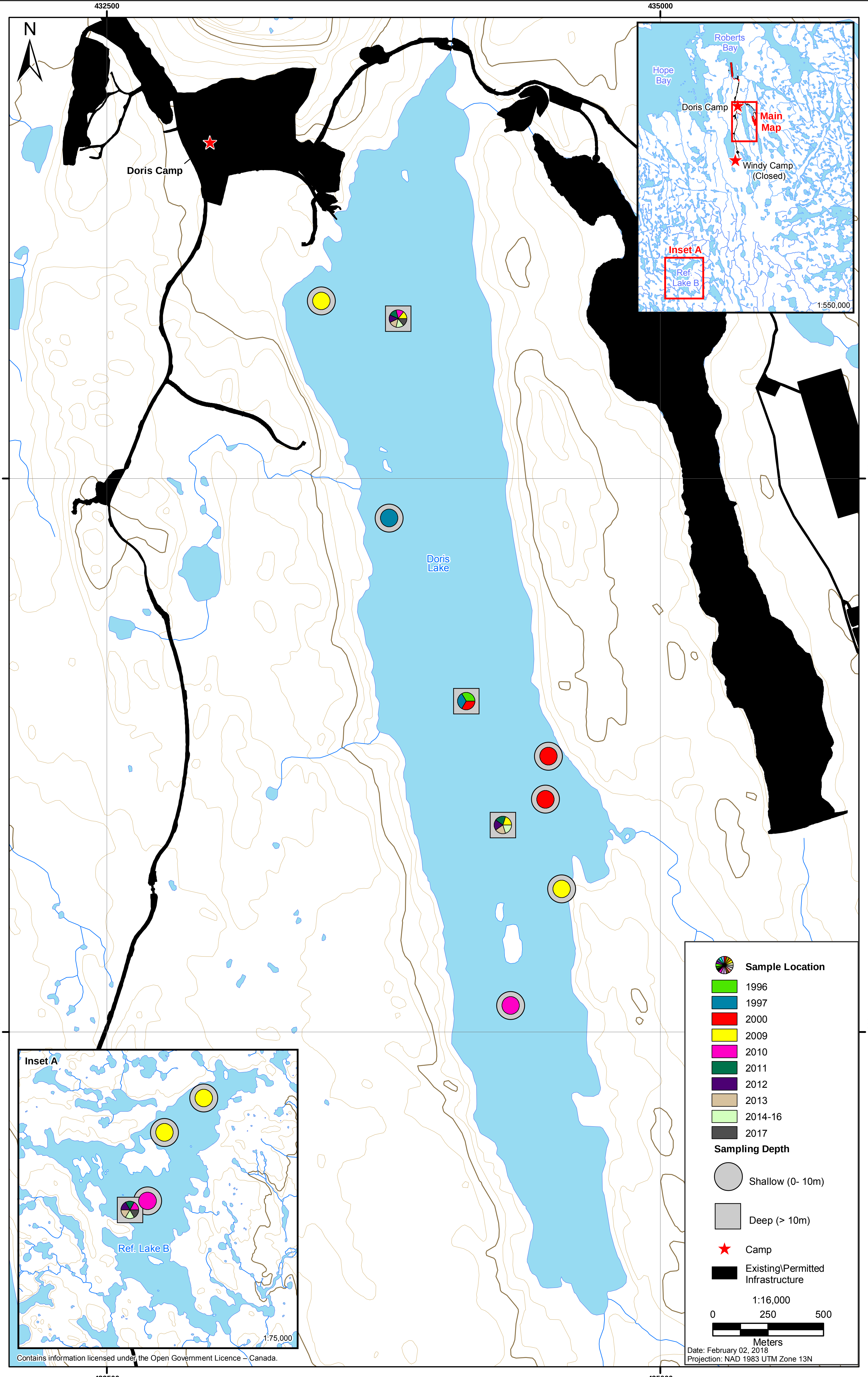


Figure 2.2-6

Benthic Invertebrate Sampling Sites in Doris Lake and Reference Lake B, Doris Project, 1996 to 2017



3. EVALUATION OF EFFECTS

In 2017, physical profiles, water and sediment samples, and biological samples were collected from one exposure lake site (Doris Lake North) and one reference lake site (Reference Lake B) to evaluate the potential for Project-related effects to the following components of the freshwater environment:

- under-ice water level in Doris Lake;
- dissolved oxygen concentration and water temperature;
- water quality;
- sediment quality;
- phytoplankton biomass; and
- benthic invertebrate community (various metrics).

Physical, chemical, and biological data from 2017 (the first year of operations with ongoing construction activities) were evaluated against historical data collected during baseline years (pre-2010) and the construction phase (2010 to 2016). The evaluation of effects was based on graphical and statistical analyses of trends over time both within Doris Lake North and between Doris Lake North and Reference Lake B, comparisons to baseline conditions, comparisons to benchmarks based on CCME water and sediment quality guidelines for the protection of aquatic life (CCME 2018b, 2018a), and professional judgement. If the evaluation of effects concluded that there may be a Project-related effect on a component of the freshwater environment, and the magnitude of the effect exceeded the low action level, further actions may be taken as described in the Response Framework within the Plan (TMAC 2016).

Details of the 2017 AEMP sampling program (including methodology and results) are provided in Appendix A, and details of the statistical analyses (including methodology and results) are provided in Appendix B.

3.1 WATER LEVEL AND ICE THICKNESS IN DORIS LAKE

Winter water-level drawdown in Doris Lake has the potential to occur from the permitted withdrawal of water from the lake and/or the movement of lake water into groundwater as a result of Project activities. Since many fish populations in Doris Lake have over-wintering eggs, a reduction in water quantity from the combined effects of winter water-level drawdown and ice penetration pose a concern for fall-spawning fish populations and spawning habitat. Potential adverse effects of water use in Doris Lake on fish habitat and populations were evaluated using continuous, daily, mean water-level data and measured April ice thickness (all raw data are provided in Appendix A). The data were assessed by comparing the winter lake drawdown and measured ice thickness to the threshold extent of ice penetration of -2.74 m (i.e., 2.74 m below the fall lake surface level). The maximum threshold of -2.74 m is based on the maximum natural ice thickness and maximum natural water-level variability over 11 years of baseline monitoring in Doris Lake (TMAC 2015).

In 2017, the maximum extent of ice penetration did not reach the maximum ice penetration benchmark of -2.74 m, nor the low action level threshold of -2.42 m. The combined winter water-level drawdown and ice depth reached -1.45 m in 2017 (Figure 3.1-1; Appendix A). Thus, there was no evidence of an adverse effect of Project-related water use on fish and fish habitat in Doris Lake.

3.2 PHYSICAL LIMNOLOGY

Dissolved oxygen and temperature profiles were collected in Doris Lake North and Reference Lake B in April, July, August, and September 2017. Raw data are provided in Appendix A, and potential Project-related effects to dissolved oxygen concentrations and water temperature are discussed in the following sections.

3.2.1 Under-ice Season Dissolved Oxygen

Potential Project-related effects on dissolved oxygen concentrations were evaluated using under-ice dissolved oxygen profiles since concentrations are lowest during the under-ice period, and therefore pose the greatest concern for aquatic life. The potential for effects to under-ice dissolved oxygen concentration was assessed by graphical analysis. To conclude that the Project had an effect on under-ice dissolved oxygen concentrations in Doris Lake, dissolved oxygen profiles from 2017 had to be noticeably different from all available baseline years. Profiles and inter-annual trends at the reference site were also considered. An adverse Project effect on under-ice season dissolved oxygen concentrations would be manifested as a decrease in dissolved oxygen concentration, since inputs of nutrients or organic carbon to a lake can fuel productivity and microbial respiration of organic matter. If dissolved oxygen concentrations drop below the CCME guidelines for the protection of aquatic life of 9.5 mg/L for early life stages or 6.5 mg/L for other life stages (CCME 2018b), this could negatively affect fish populations.

Ice cover usually forms in October or November in the Doris region, and remains until June or July of the following year. Doris Lake would not be exposed to any inputs of dust or runoff that could be generated by Project activities while it is 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 considered baseline data despite 2010 being considered year one of construction.

Under-ice dissolved oxygen concentrations in April 2017 were higher than under-ice concentrations measured during nearly all available baseline years (e.g., 2004, 2007, 2008, 2009, and 2010; Figure 3.2-1). As well, under-ice dissolved oxygen concentrations recorded at Doris Lake North since the start of Project construction and operation activities have been among the highest concentrations recorded (e.g., 2012, 2014, 2015, 2016, and 2017). A similar trend is evident in Reference Lake B, where under-ice dissolved oxygen concentrations have been relatively high in recent years (e.g., 2014 to 2017, Figure 3.2-1).

Dissolved oxygen concentrations from April 2017 in both Doris Lake North and Reference Lake B were higher than the CCME guidelines of 6.5 and 9.5 mg/L at the surface, but dropped below 9.5 mg/L at depth. In Reference Lake B, deep water dissolved oxygen concentrations also dropped below 6.5 mg/L (Figure 3.2-1). A decrease in under-ice dissolved oxygen concentrations at depth is a common phenomenon in seasonally stratified lakes, and has been observed nearly every year at both Doris Lake North and Reference Lake B (Figure 3.2-1). During baseline years, the under-ice oxygen minimum at Doris Lake North ranged from 1.8 to 9.7 mg/L; therefore, the minimum of 7.8 mg/L observed in 2017 is within this range (Figure 3.2-1).

Figure 3.1-1

Maximum Extent of Ice in Doris Lake, Doris Project, 2017

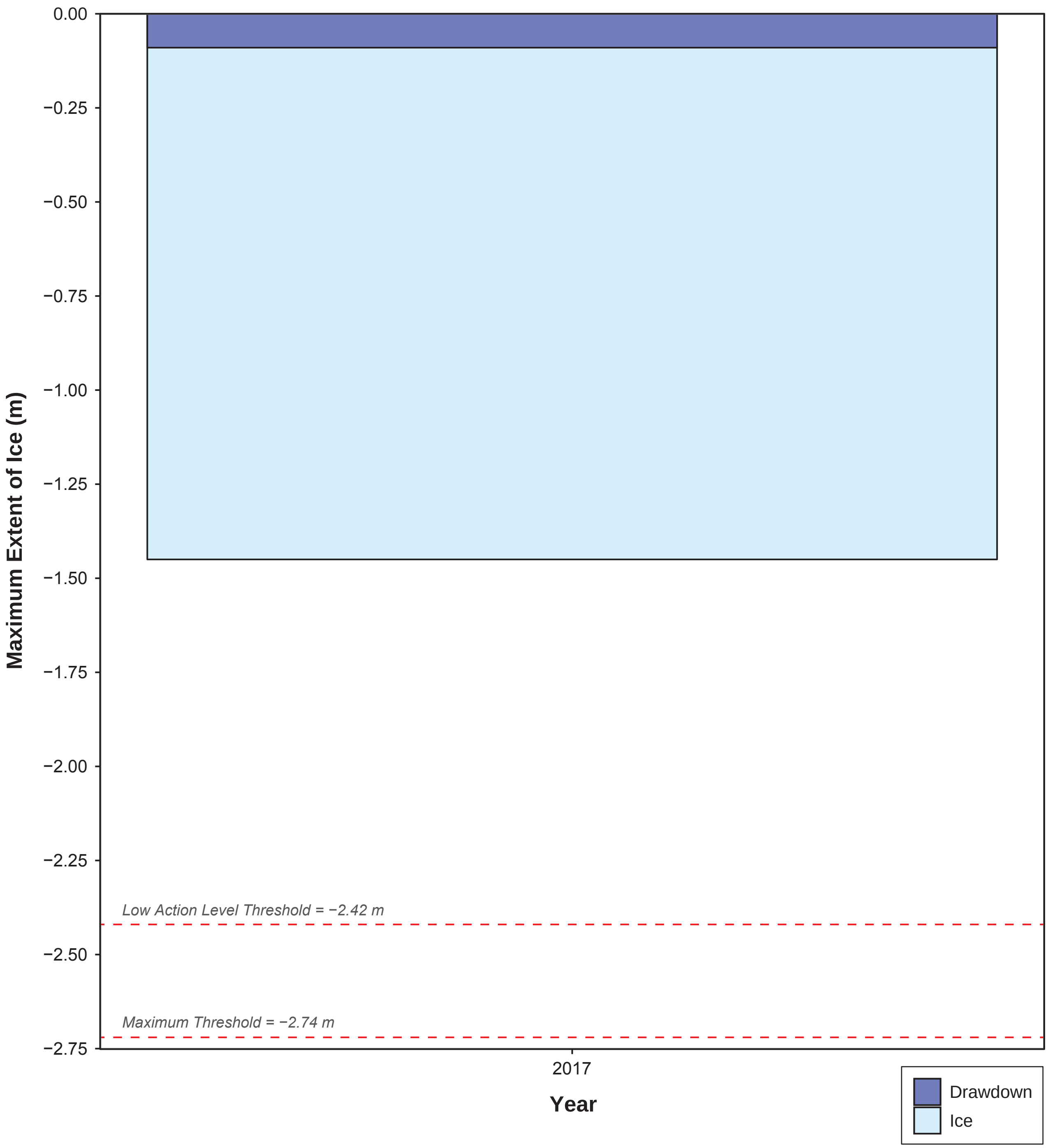
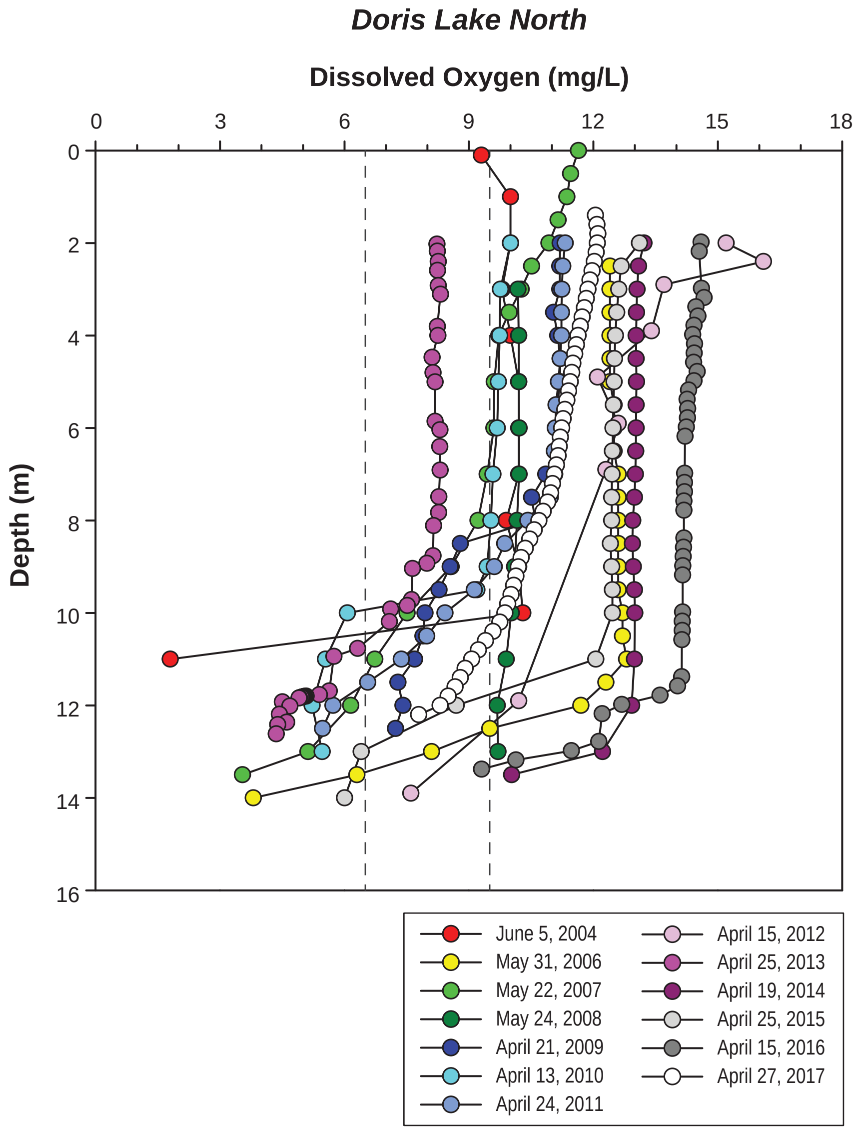
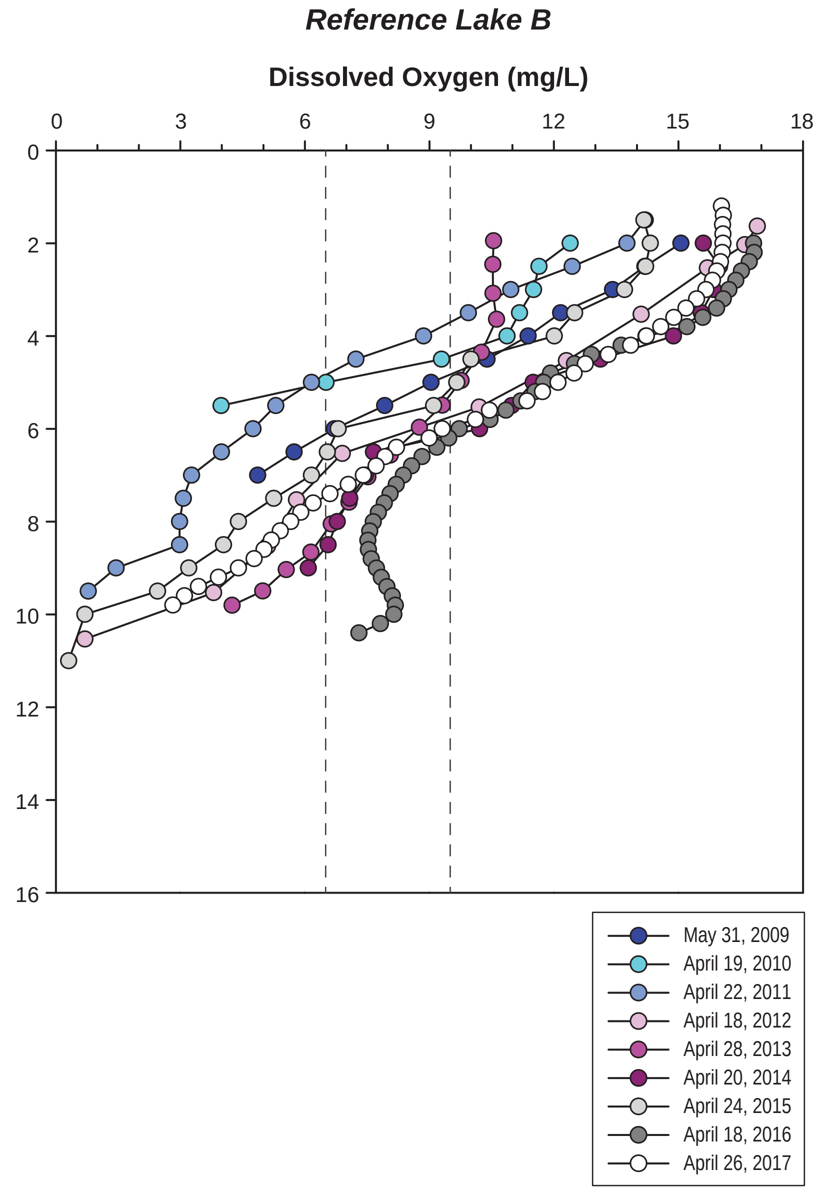


Figure 3.2-1

Under-ice Season Dissolved Oxygen Concentrations, Doris Project, 2004 to 2017





Note: Vertical dashed lines represent CCME freshwater dissolved oxygen guidelines for the protection of aquatic life: 9.5 mg/L for early life stages; 6.5 mg/L for other life stages.

Overall, there was no evidence of an adverse effect of Project activities on under-ice dissolved oxygen concentrations in Doris Lake and the low action level was not triggered.

3.2.2 Temperature

Under the terms of the current Project Certificate No. 003 and Water Licence 2AM-DOH1323, the discharge of groundwater and TIA water will be directed to the marine receiving environment, and this discharge will be at ambient temperature. There are no plans to release heated effluent to the freshwater environment, thus there are not anticipated to be Project-related changes to water temperature, thermal stratification regime, or turnover dates in Doris Lake or any other waterbody in the Project area. However, temperature is included in the evaluation of effects because there is a CCME guideline for temperature, and temperature is included in the Plan as a variable that will be evaluated.

Historical temperature profiles in Doris Lake have been collected during the under-ice season (typically in April, but sometimes in May or early June) and open-water seasons (July, August, and/or September). For the purposes of the evaluation, profiles from the under-ice season as well as August profiles from the open-water season were assessed, since the warmest water temperatures typically occur in August. Assessing under-ice and open-water (August) temperature profiles should cover the entire range of water temperatures in Doris Lake. The potential for effects on water temperature was assessed by graphical analysis. To conclude that the Project had an effect on under-ice or August water temperature in Doris Lake, temperature profiles had to be noticeably different from all available baseline years. Temperature profiles and inter-annual trends at the reference site were also considered.

At the northern end of Doris Lake, under-ice temperature profiles were collected in 2004, 2006, 2007, and annually from 2009 to 2017, and August temperature profiles were collected annually from 2003 to 2005 and from 2007 to 2017. In Reference Lake B, both under-ice and August temperature profiles were collected annually from 2009 to 2017. Under-ice temperature profiles from 2017 in Doris Lake North were similar to previous years (e.g., 2009 and 2011), and there was no evidence of a Project-related shift in under-ice water temperature (Figure 3.2-2). August temperature profiles were more variable than under-ice profiles, with surface temperatures ranging from approximately 9 to 16°C (Figure 3.2-3). August profiles from recent years (e.g., 2016 and 2017) were similar to profiles from some earlier years (e.g., 2011 and 2013), but were towards the upper end of the range of temperatures recorded in Doris Lake North. A similar trend was evident in Reference Lake B, suggesting that the trends seen in Doris Lake are not Project-related and reflect natural climatic variability (Figure 3.2-3).

Overall, there was no evidence of a Project-related change in water temperature, and the low action level was not triggered.

3.3 WATER QUALITY

Water quality samples were collected from one exposure lake site (Doris Lake North) and one reference lake site (Reference Lake B) in 2017. A subset of water quality variables (see Table 2.2-1) was evaluated to determine whether Project activities resulted in adverse changes to water quality over time. Statistical and graphical analyses were used to determine if there were changes in water quality variables in the Project area over time. Trends in Doris Lake North were also directly compared to trends in Reference Lake B to establish whether changes in water quality in Doris Lake were likely naturally occurring or Project-related. Water quality trends over the open-water season and under-ice season were assessed separately since large seasonal changes could confound the identification of inter-annual trends.

Figure 3.2-2

Under-ice Season Temperature Profiles, Doris Project, 2004 to 2017

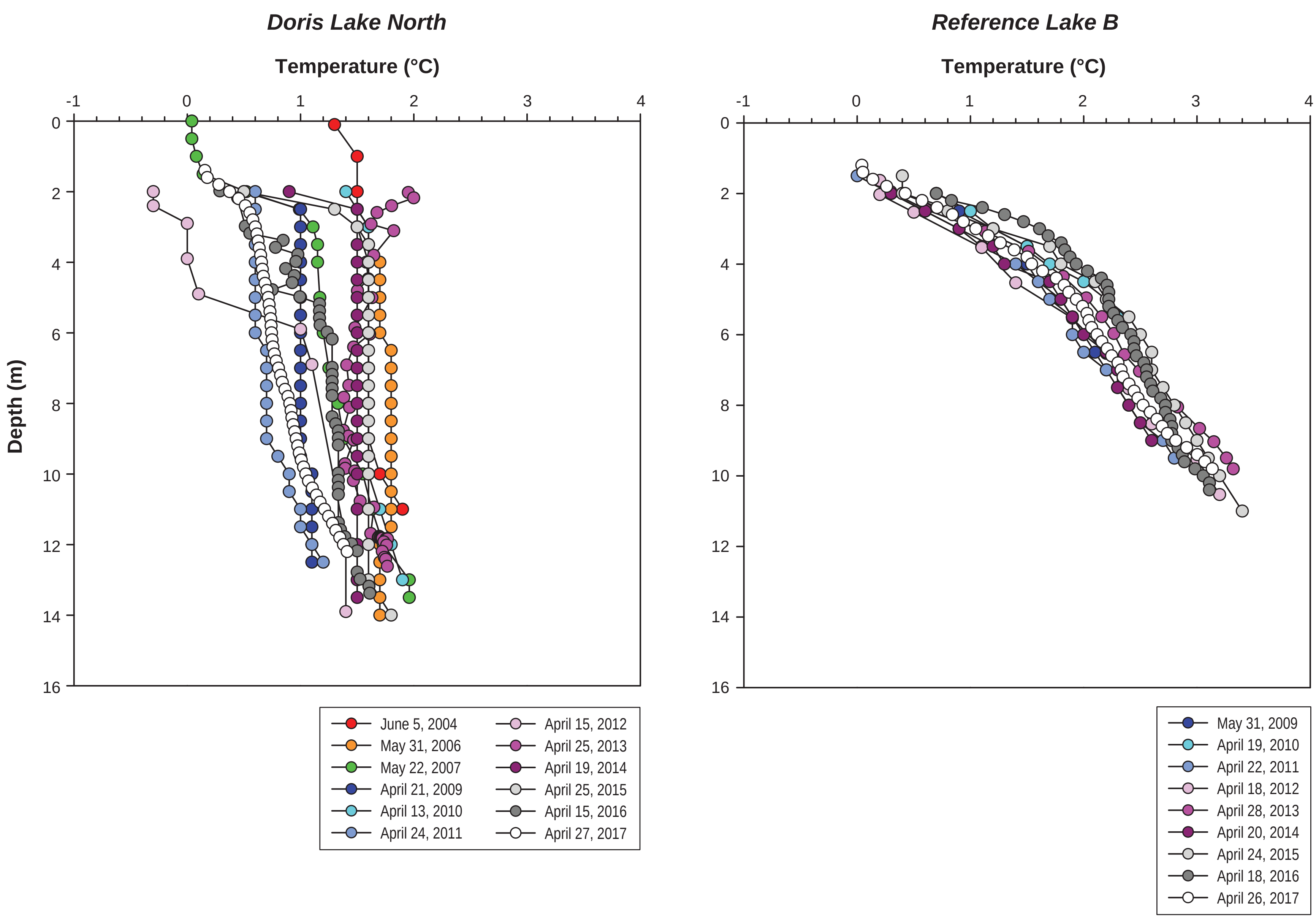
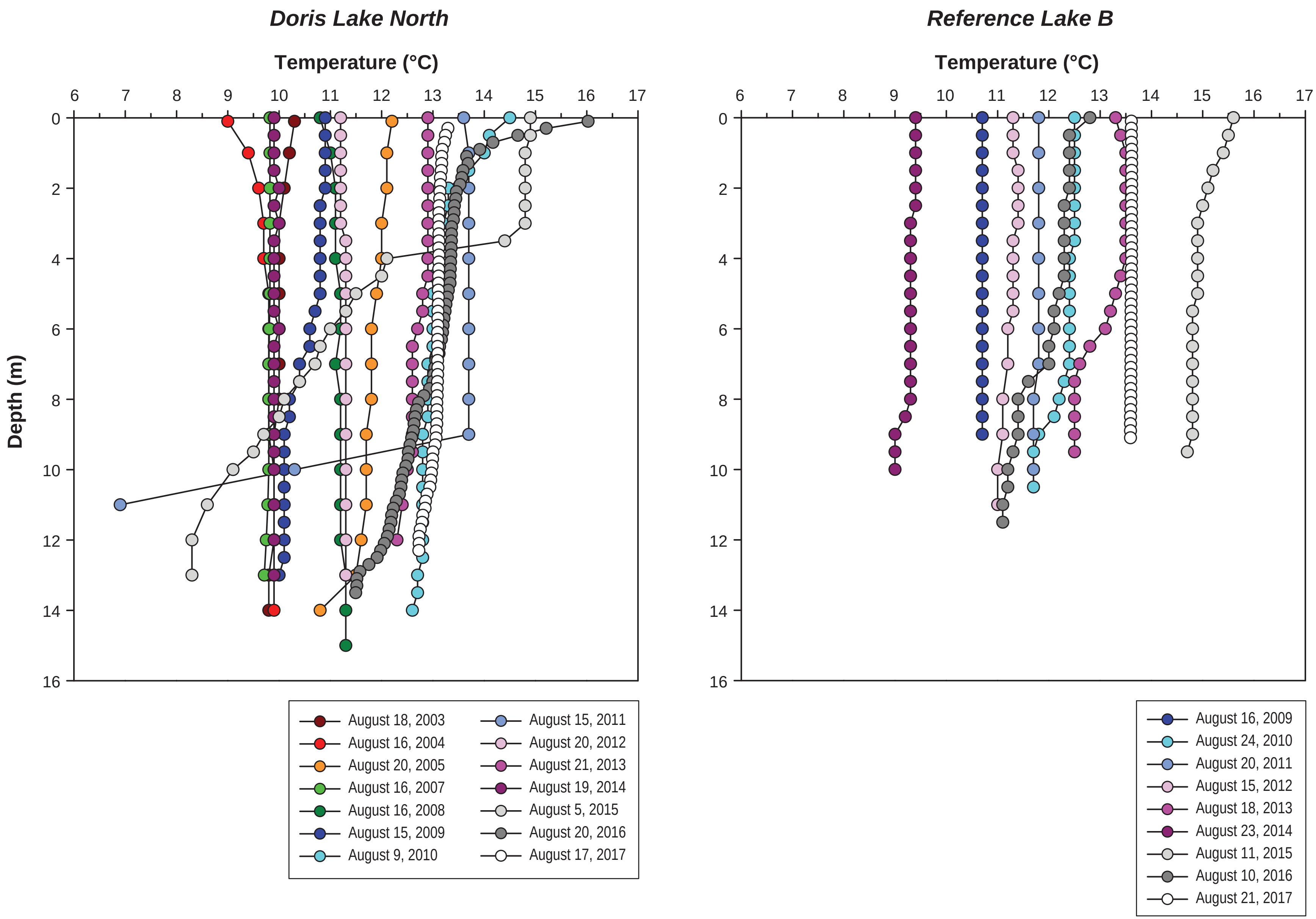


Figure 3.2-3

Open-water Season (August) Temperature Profiles, Doris Project, 2003 to 2017



Water quality variable concentrations were compared to CCME water quality guidelines for the protection of aquatic life (CCME 2018b) to assess whether existing concentrations could adversely affect freshwater biota. Water quality data were also compared against 75% of the CCME guidelines as described in Section 2.2.3 to determine whether a low action level threshold was exceeded.

Graphs showing water quality trends in lakes over time are shown in Figures 3.3-1 to 3.3-25. Raw water quality data for 2017 are presented in Appendix A, and all statistical analysis results are presented in Appendix B.

3.3.1 pH

pH levels measured in 2017 in Doris Lake North were within the recommended CCME guideline range of 6.5 to 9.0 (Figure 3.3-1; Appendix A). During the under-ice season, pH levels recorded from 2004 to 2008 were highly variable, and lower overall compared to the relatively consistent pH levels measured between 2009 and 2017 (Figure 3.3-1). During the open-water season, pH levels in Doris Lake North were generally consistent from 2003 to 2017, and did not exhibit an obvious increase or decrease over time (Figure 3.3-1).

The results of the statistical analysis were similar for under-ice and open-water season pH (Appendix B). The trends in both under-ice and open-water pH levels over time in Doris Lake North were significantly different from a slope of zero ($p = 0.0001$ for under-ice pH, $p = 0.0430$ for open-water pH); however, the pH trends in Doris Lake North were not significantly different from the corresponding trends in Reference Lake B ($p = 0.7258$ for under-ice pH, $p = 0.6841$ for open-water pH), suggesting that the observed temporal trends in under-ice and open-water pH in Doris Lake North were not Project-related.

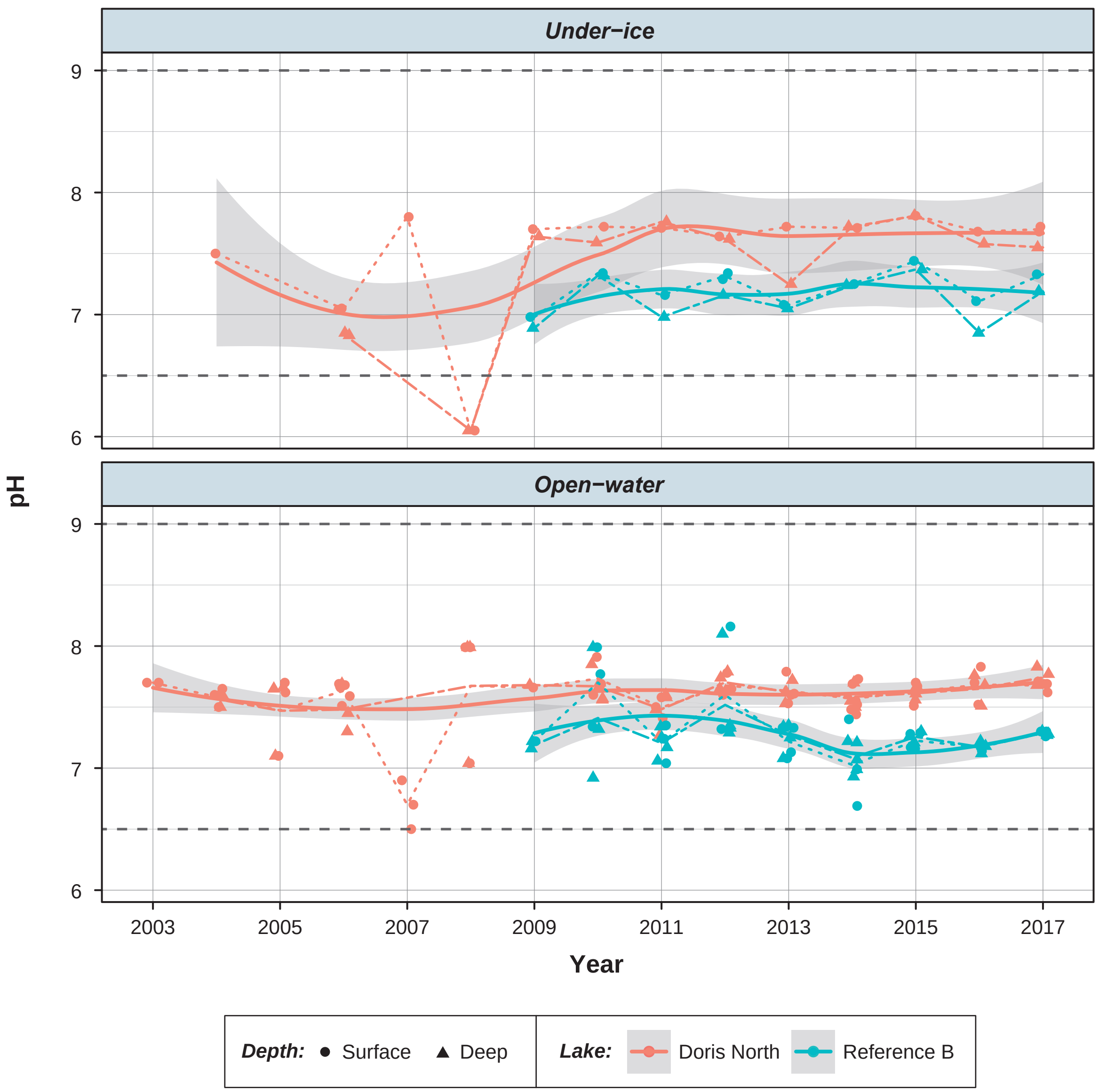
Overall, there was no evidence for a differential change in under-ice or open-water season pH over time in Doris Lake North compared to Reference Lake B. The pH levels in 2017 also remained within the CCME guideline range and the low action level threshold range described in Table 2.2-2.

3.3.2 Total Suspended Solids

Open-water TSS concentrations were relatively consistent over time in Doris Lake North (Figure 3.3-2). This was confirmed by the results of the statistical analysis, which showed that TSS concentrations over time did not significantly differ from a slope of zero ($p = 0.4833$). The CCME guideline for TSS is dependent upon background levels (for clear-flow waters with background TSS levels below 25 mg/L, a maximum increase of 25 mg/L is allowable for any short-term exposure or 5 mg/L for longer term exposure; CCME 2018b). Given that TSS concentrations did not increase over time in Doris Lake North, concentrations remained below the CCME and low action level threshold, and the low-action level for open-water TSS concentrations was not triggered.

Figure 3.3-1

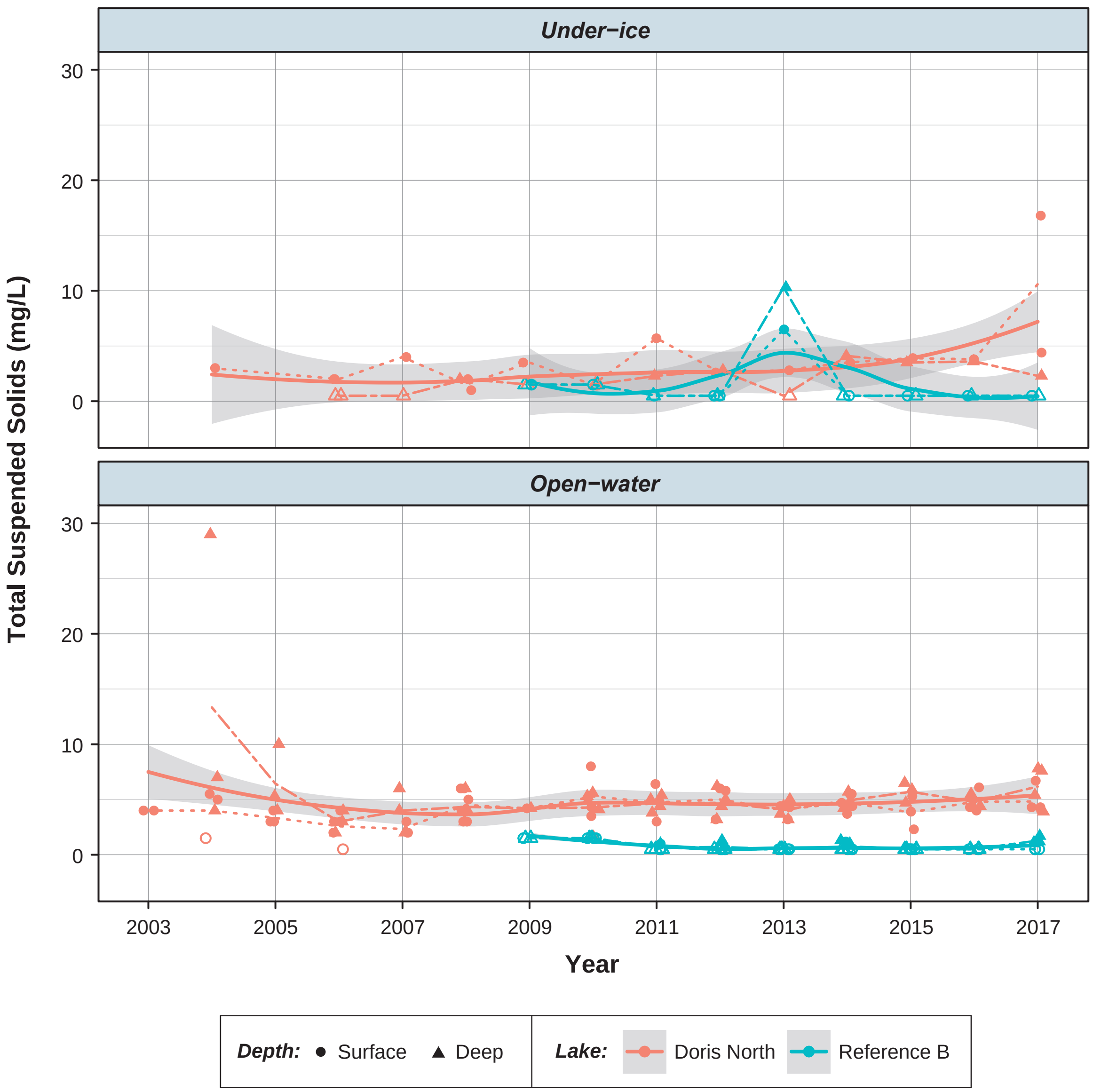
pH in Lakes,
Doris Project, 2003 to 2017



Notes: Symbols represent observed data values.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME guideline pH range (6.5 to 9.0).

Figure 3.3-2

Total Suspended Solids Concentrations in Lakes, Doris Project, 2003 to 2017



Notes: Symbols represent observed data values.
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
The CCME guideline for total suspended solids is dependent upon background levels.

Under-ice TSS concentrations in Doris Lake North showed some evidence of an increase over time (Figure 3.3-2); however, this was mainly driven by a single high concentration measured in April 2017 of 16.8 mg/L at 2.5 m depth. The TSS concentration in the replicate sample collected on the same date and at the same depth was 4.4 mg/L, while the sample collected on the same date at 11 m depth contained 2.3 mg/L TSS. The large difference between replicates suggests potential data quality or contamination issues. With no corresponding increase during the open-water season, there would be no reason to expect an increase in TSS during the under-ice season when the ice cover over Doris Lake isolates the water column from potential effects of dust or runoff. The potential increasing trend in under-ice TSS concentrations will need to be confirmed by continued monitoring. Under-ice TSS concentrations in baseline samples ranged from < 1.0 to 3.5 mg/L, which is similar to the concentrations of 2.3 and 4.4 mg/L measured in two out of three of the 2017 under-ice samples.

Statistical analysis confirmed that the under-ice TSS trend over time in Doris Lake North was significantly different from a slope of zero ($p = 0.0020$); however, due to the high proportion of censored values (i.e., concentrations below detection limits) within the TSS dataset for Reference Lake B, statistical results for Reference Lake B could not be compared to Doris Lake North results. Therefore, a naturally occurring increase in under-ice TSS could not be ruled out. However, the analysis of turbidity (a parameter closely related to TSS; Section 3.3.3) showed that turbidity trends were similar between Doris Lake North and Reference Lake B, which further supports the notion that the increase in TSS in Doris Lake North was unrelated to the Project.

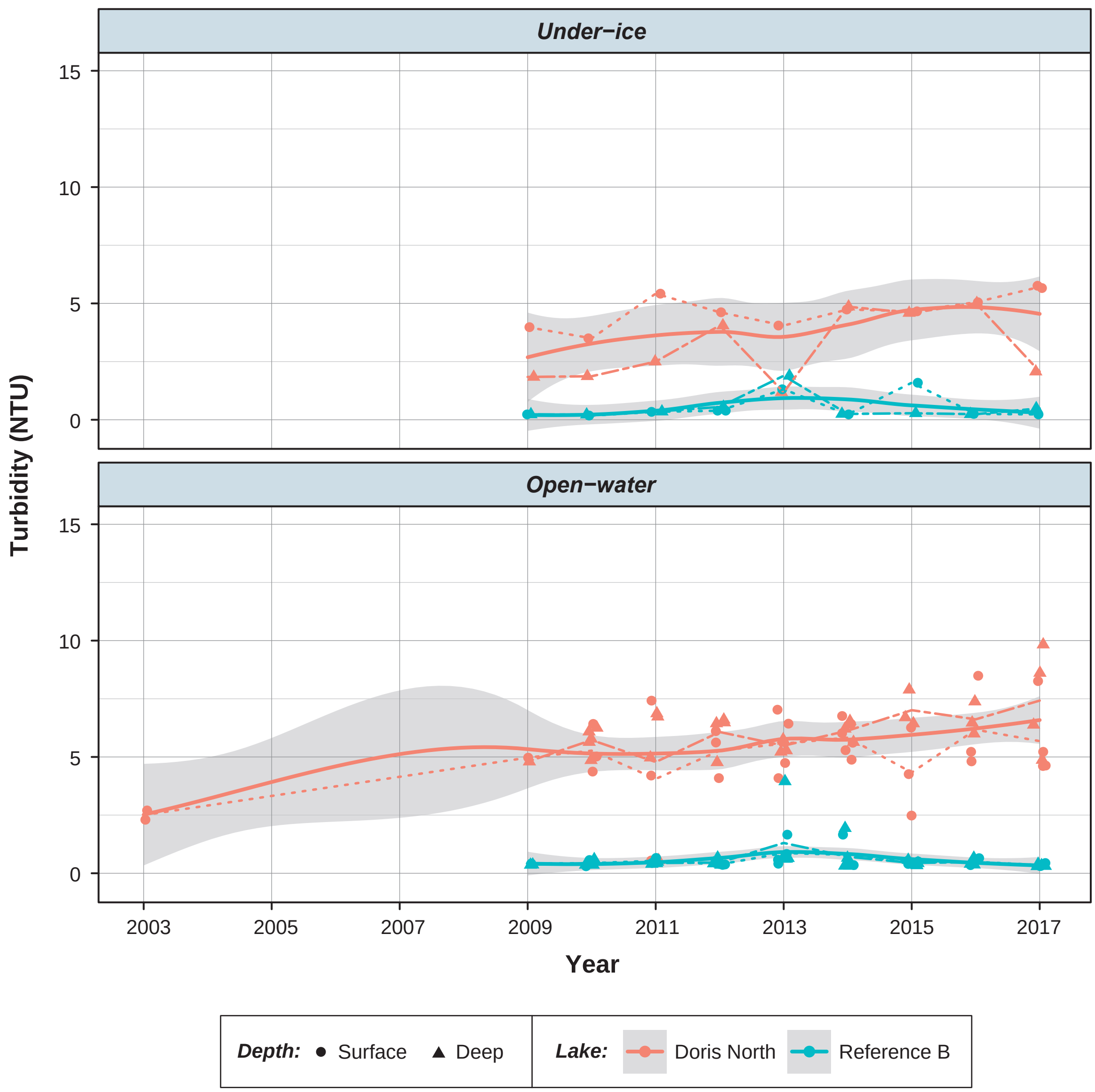
The baseline (2003 to 2009) mean under-ice TSS concentration in Doris Lake North was 1.9 mg/L (below detection limit concentrations were substituted with half the detection limit for the calculation of the mean). The mean under-ice TSS concentration increased to 3.4 mg/L (net increase of 1.5 mg/L) in 2017 if the questionable concentration of 16.8 mg/L is excluded, or to 7.8 mg/L (net increase of 5.9 mg/L) if the potentially contaminated sample is included. The inclusion or exclusion of this anomalous sample therefore determines whether the low action level threshold for TSS (i.e., of 75% of the CCME guideline or an increase of 3.75 mg/L from baseline levels) was exceeded in 2017. At present the low action level for under-ice TSS is not considered to have been triggered due to limited evidence for a Project-related increase in under-ice TSS concentrations and the low magnitude of the overall increase if the questionable sample is excluded. However, the potential for a Project-related increase in under-ice TSS concentrations in Doris Lake North and the potential magnitude of this increase will need to be further evaluated through continued monitoring.

3.3.3 Turbidity

Turbidity trends generally followed trends in TSS. Like TSS, under-ice turbidity increased slightly over time in Doris Lake North (Figure 3.3-3); and this trend was significantly different from a slope of zero ($p = 0.0093$). For TSS, it was not possible to compare trends between Doris Lake North and Reference Lake B because of the high proportion of censored data, but for turbidity the statistical analysis showed that there was no significant difference between the Doris Lake North and Reference Lake B trends ($p = 0.2284$). This suggests that the slight increase in under-ice turbidity over time was unlikely related to the Project. During the open-water season, the turbidity trend over time was not significantly different from a slope of zero ($p = 0.7044$), suggesting that there was no change in open-water turbidity over time.

Figure 3.3-3

Turbidity in Lakes, Doris Project, 2003 to 2017



Notes: Symbols represent observed data values.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
The CCME guideline for turbidity is dependent upon background levels.

The CCME guideline for turbidity is dependent upon background levels (for clear-flow waters with background turbidity levels below 8 NTU, a maximum increase of 8 NTU is allowable for any short-term exposure or 2 NTU for longer term exposure; CCME 2018b). There was no evidence for a Project-related increase in turbidity in Doris Lake North; therefore concentrations remained below the CCME guideline and the low-action level threshold.

3.3.4 Chloride

Chloride concentrations recorded between 2010 and 2017 were within the range of baseline concentrations recorded between 2003 and 2009 (Figure 3.3-4). However, the statistical analysis showed that the under-ice and open-water chloride trends were significantly different from a slope of zero ($p < 0.0001$ for both under-ice and open-water). The under-ice trend was also significantly different from the Reference Lake B trend ($p < 0.0001$) while the open-water trends between Doris Lake North and Reference Lake B were not significantly different ($p = 0.3429$). Although the under-ice season chloride trend over time in Doris Lake North was not the same as the trend in Reference Lake B, the graphical analysis showed that this trend was not an increase (Figure 3.3-4). Therefore, there was no evidence of Project-related adverse change in chloride concentrations (Figure 3.3-4), and all chloride concentrations remained below the CCME guideline of 120 mg/L and the low action level threshold of 90 mg/L.

3.3.5 Fluoride

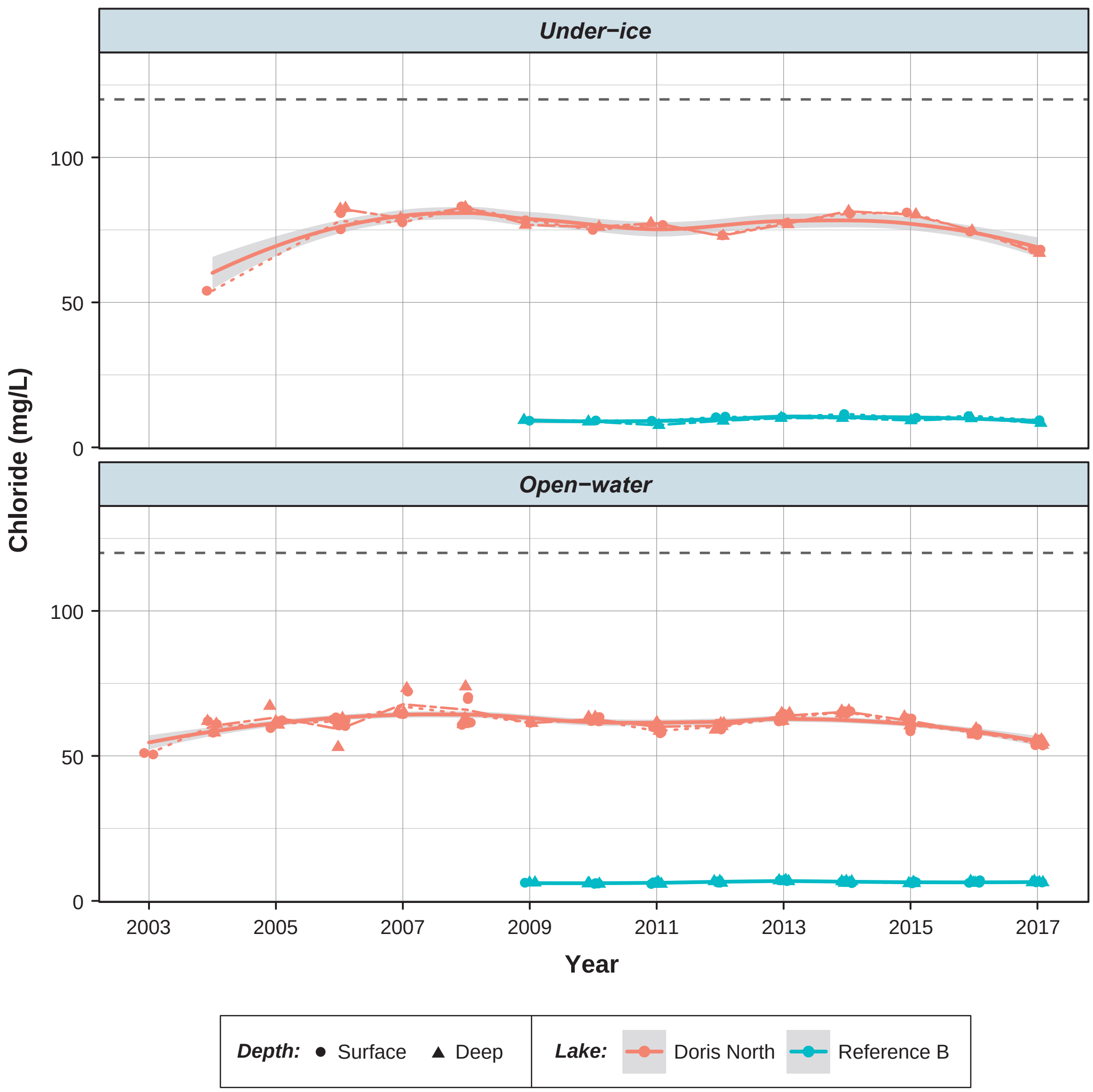
Under-ice and open-water fluoride concentrations changed little over time in Doris Lake North (Figure 3.3-5), and there was no significant difference between fluoride trends over time and a slope of zero ($p = 0.5632$ for under-ice, and $p = 0.6136$ for open-water). Therefore, there was no evidence of a Project-related effect on fluoride concentrations in Doris Lake North. Fluoride concentrations recorded since the start of Project construction in 2010 also remained below the CCME guideline of 0.12 mg/L and the low action level threshold of 0.90 mg/L in Doris Lake North.

3.3.6 Total Ammonia

During the under-ice season, total ammonia concentrations in Doris Lake North were variable over time (Figure 3.3-6). The trend in under-ice total ammonia concentrations in Doris Lake North was significantly different from a slope of zero ($p = 0.0243$), though not significantly different from the trend in Reference Lake B ($p = 0.0760$), suggesting that changes in under-ice total ammonia concentrations were unrelated to the Project. During the open-water season, most total ammonia concentrations were below analytical detection limits, including the total ammonia concentration in five of eight samples collected in 2017 (Appendix A). Because of the high proportion of censored data, statistical analysis of open-water season total ammonia trends could not be conducted. However, total ammonia concentrations do not appear to be increasing over time (Figure 3.3-6), so there was no evidence of a Project-related effect on total ammonia concentrations in Doris Lake North. All ammonia concentrations in Doris Lake North remained well below the pH- and temperature-dependent CCME guideline and low action level threshold.

Figure 3.3-4

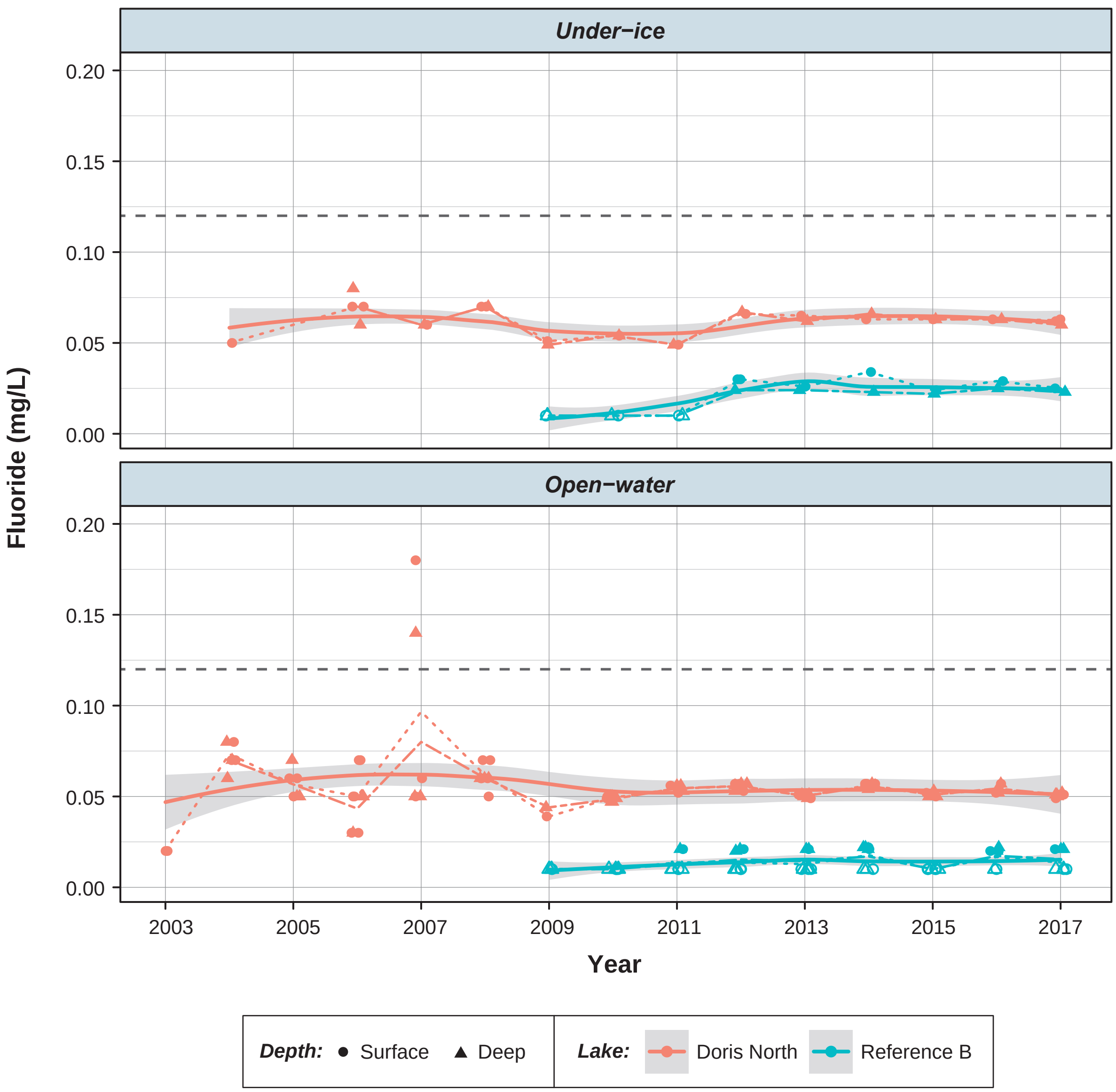
Chloride Concentrations in Lakes, Doris Project, 2003 to 2017



Notes: *Symbols represent observed data values.*
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME long-term guideline for chloride (120 mg/L).

Figure 3.3-5

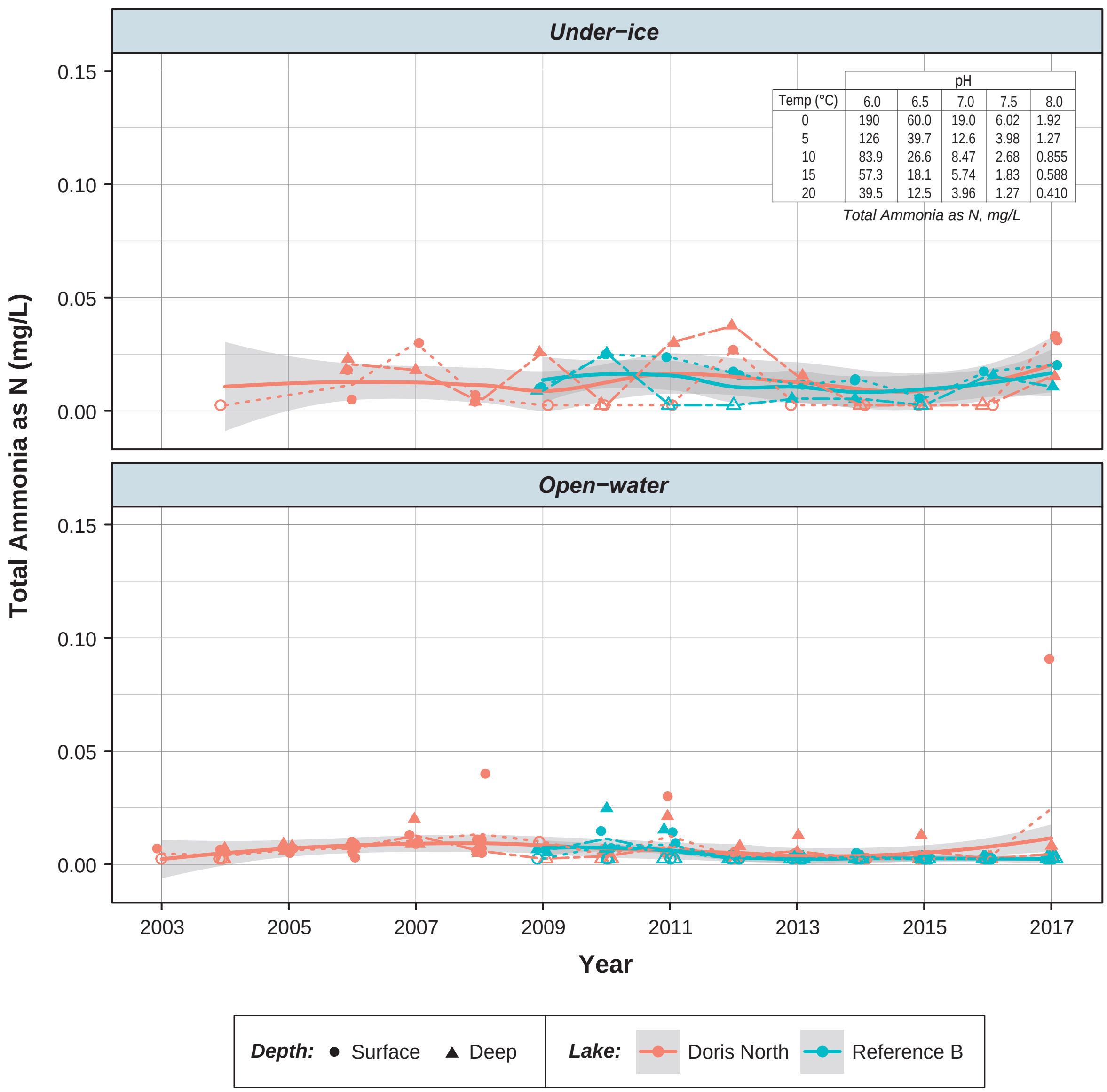
Fluoride Concentrations in Lakes, Doris Project, 2003 to 2017



Notes: *Symbols represent observed data values.*
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME interim guideline for fluoride (0.120 mg/L).

Figure 3.3-6

Total Ammonia Concentrations in Lakes, Doris Project, 2003 to 2017



	pH				
Temp (°C)	6.0	6.5	7.0	7.5	8.0
0	190	60.0	19.0	6.02	1.92
5	126	39.7	12.6	3.98	1.27
10	83.9	26.6	8.47	2.68	0.855
15	57.3	18.1	5.74	1.83	0.588
20	39.5	12.5	3.96	1.27	0.410

Total Ammonia as N, mg/L

Notes: *Symbols represent observed data values.*
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Inset table shows the pH- and temperature-dependent CCME guideline for total ammonia as N.

3.3.7 Nitrate

During the under-ice season, nitrate concentrations between 2010 and 2017 in Doris lake North remained within the range of concentrations measured during baseline years (Figure 3.3-7). Although the trend over time in under-ice nitrate concentrations was significantly different from a slope of zero ($p = 0.0002$) and from the trend in Reference Lake B ($p < 0.0001$), there was no indication of an increase in concentrations over time (Figure 3.3-7) suggesting that Project activities have not adversely affected under-ice nitrate concentrations in Doris Lake North. During the open-water season, most historical nitrate concentrations and all 2017 nitrate concentrations were below analytical detection limits, so there was no evidence of a Project effect on open-water season nitrate concentrations in Doris Lake North (statistical analysis not performed). Under-ice and open-water nitrate concentrations in Doris Lake North remained well below the long-term CCME guideline of 3.0 mg nitrate-N/L and the low action level threshold of 2.25 mg nitrate-N/L.

3.3.8 Nitrite

All 2017 concentrations of nitrite in Doris Lake North were below analytical detection limits and well below the CCME guideline of 0.06 mg nitrite-N/L and the low action level threshold of 0.045 mg nitrite-N/L (Figure 3.3-8). Therefore, there was no evidence of an adverse Project effect on nitrite concentrations in the exposure lake.

3.3.9 Total Phosphorus

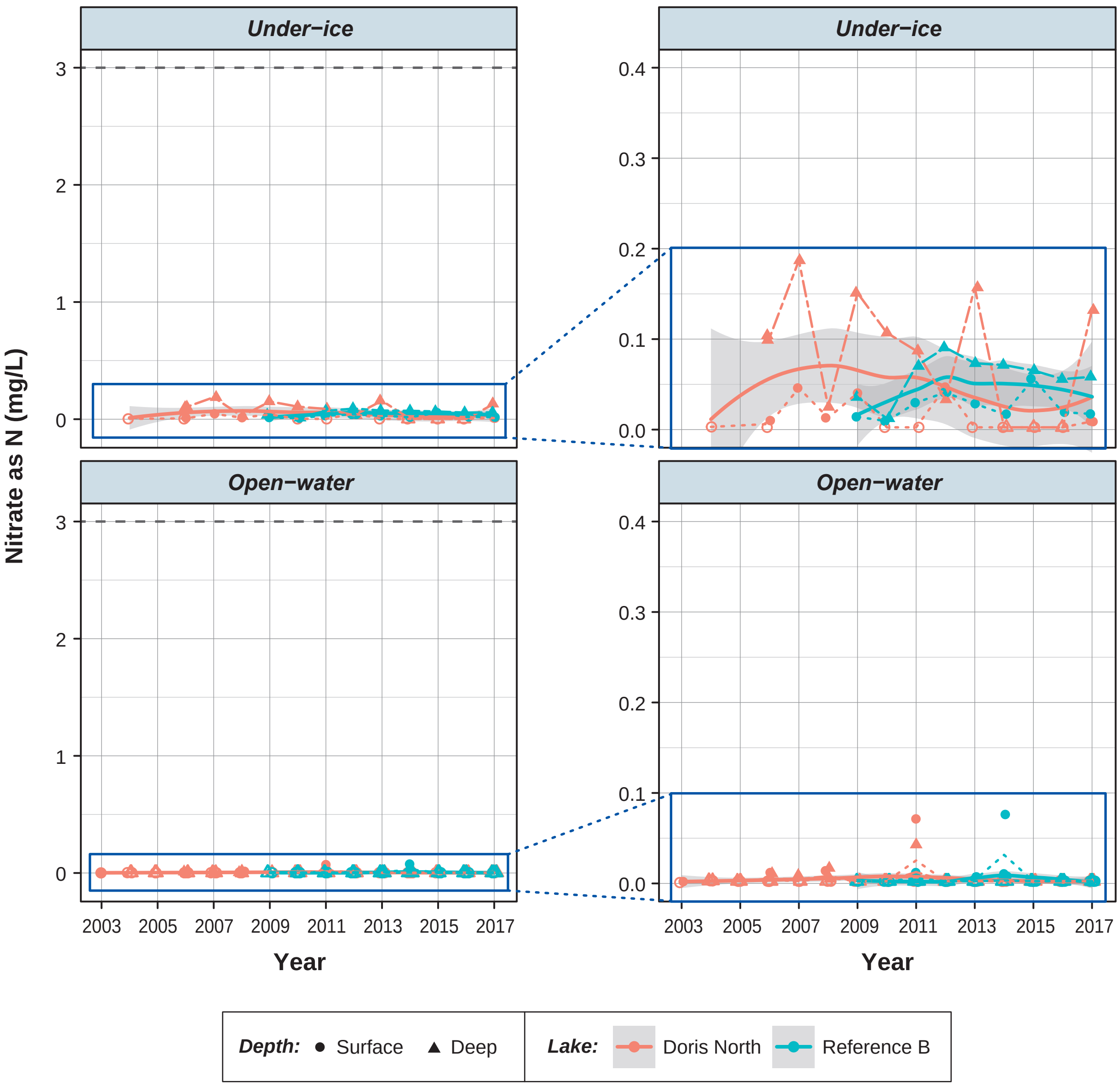
Total phosphorus concentrations measured in Doris Lake North ranged from 0.01 to 0.05 mg/L (characteristic of a mesotrophic to eutrophic lake; CCME 2018b) and averaged 0.026 mg/L (Figure 3.3.-9). Under-ice and open-water season total phosphorus concentrations changed little over time in Doris Lake North (Figure 3.3-9). This was confirmed by the statistical analysis, which showed that there was no significant difference between total phosphorus trends over time and a slope of zero ($p = 0.1004$ for under-ice, and $p = 0.7523$ for open-water). Overall, there was no evidence of a change in total phosphorus concentrations in Doris Lake North due to Project activities, and the low action level for total phosphorus was not triggered.

3.3.10 Total Aluminum

Under-ice and open-water season total aluminum concentrations changed little over time in Doris Lake North (Figure 3.3-10). This was confirmed by the statistical analysis, which showed that there was no significant difference between total aluminum trends over time and a slope of zero ($p = 0.3730$ for under-ice, and $p = 0.6871$ for open-water). Total aluminum concentrations measured in 2017 remained below the CCME guideline of 0.1 mg/L (for waters with pH above 6.5); however, concentrations were sporadically elevated above this guideline during baseline years (2004 to 2009), the construction phase (2010 to 2016) in Doris Lake North, and in Reference Lake B (2013). Total aluminum concentrations in Doris Lake North were also occasionally higher than the low action level threshold of 0.075 mg/L in 2017 as well as in baseline years; however, the low action level was not triggered because there was no evidence of a Project-related change in total aluminum concentrations in Doris Lake North.

Figure 3.3-7

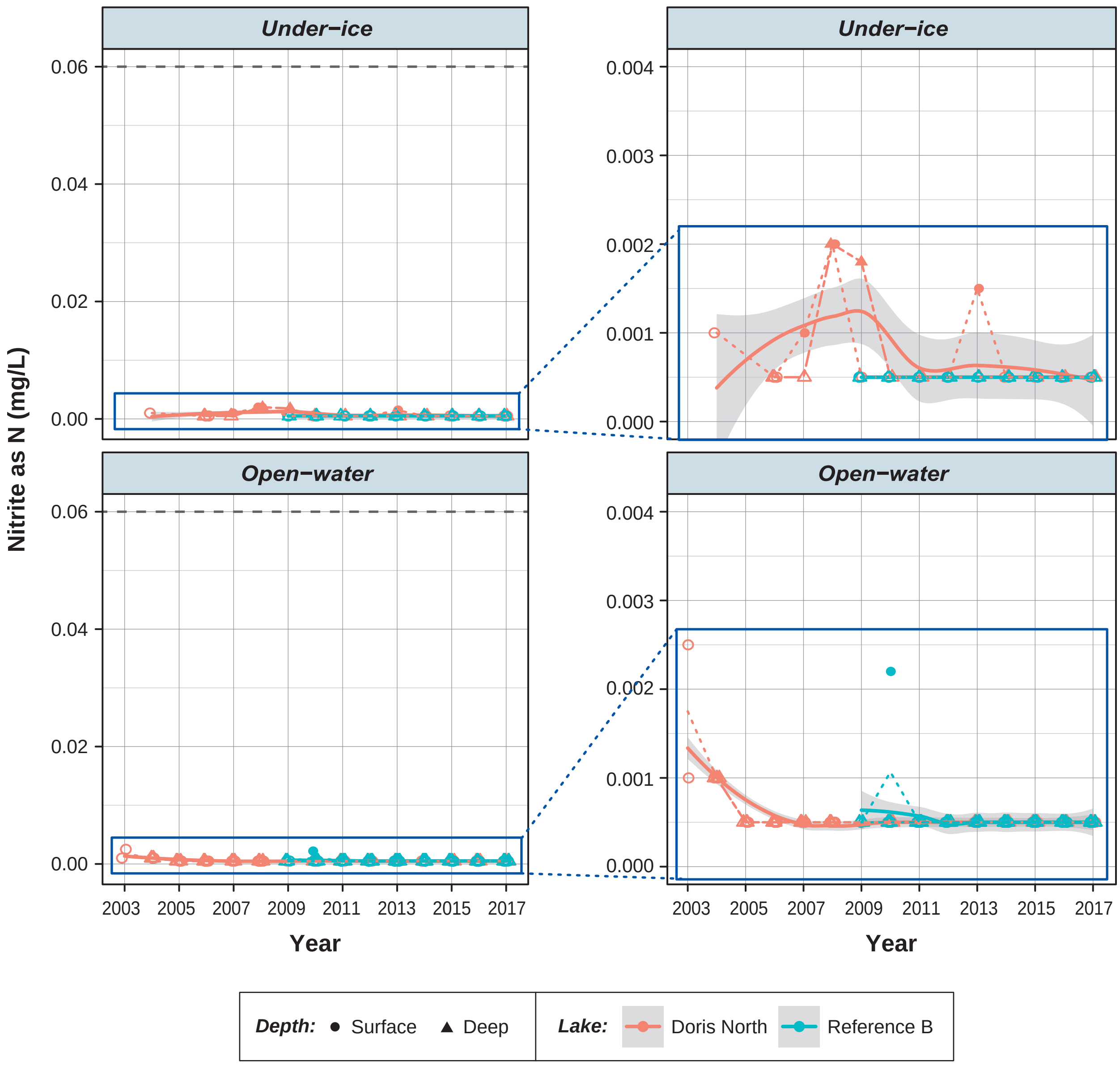
Nitrate Concentrations in Lakes, Doris Project, 2003 to 2017



Notes: *Symbols represent observed data values.*
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME long-term guideline for nitrate as N (3.0 mg/L).
Graphs on the left show the same data as graphs on the right, but at different y-axis scales.
A larger scale is used for the left side graphs to show the data relative to CCME guidelines.

Figure 3.3-8

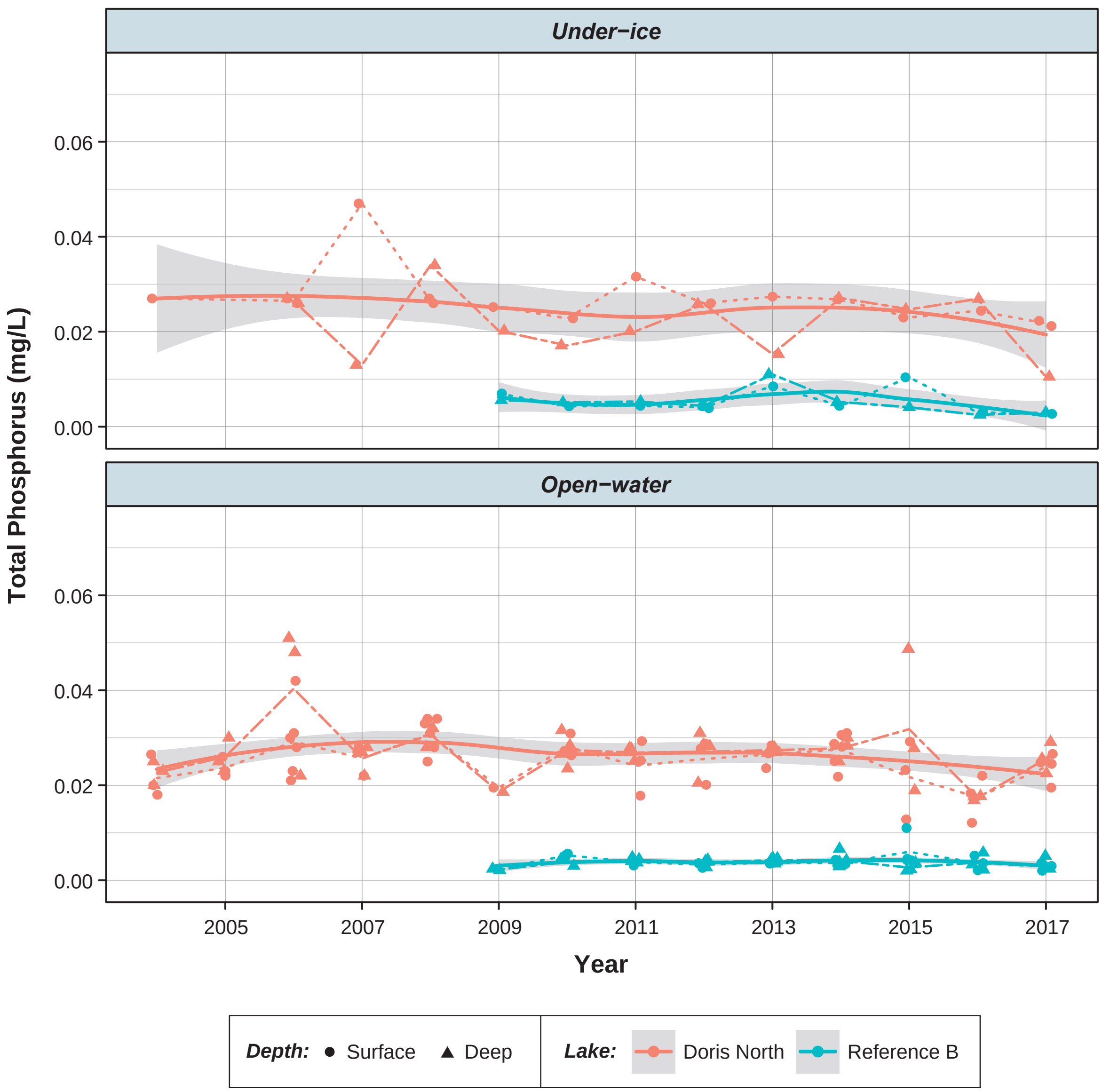
Nitrite Concentrations in Lakes, Doris Project, 2003 to 2017



Notes: Symbols represent observed data values.
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME long-term guideline for nitrite as N (0.06 mg/L).
Graphs on the left show the same data as graphs on the right, but at different y-axis scales.
A larger scale is used for the left side graphs to show the data relative to CCME guidelines.

Figure 3.3-9

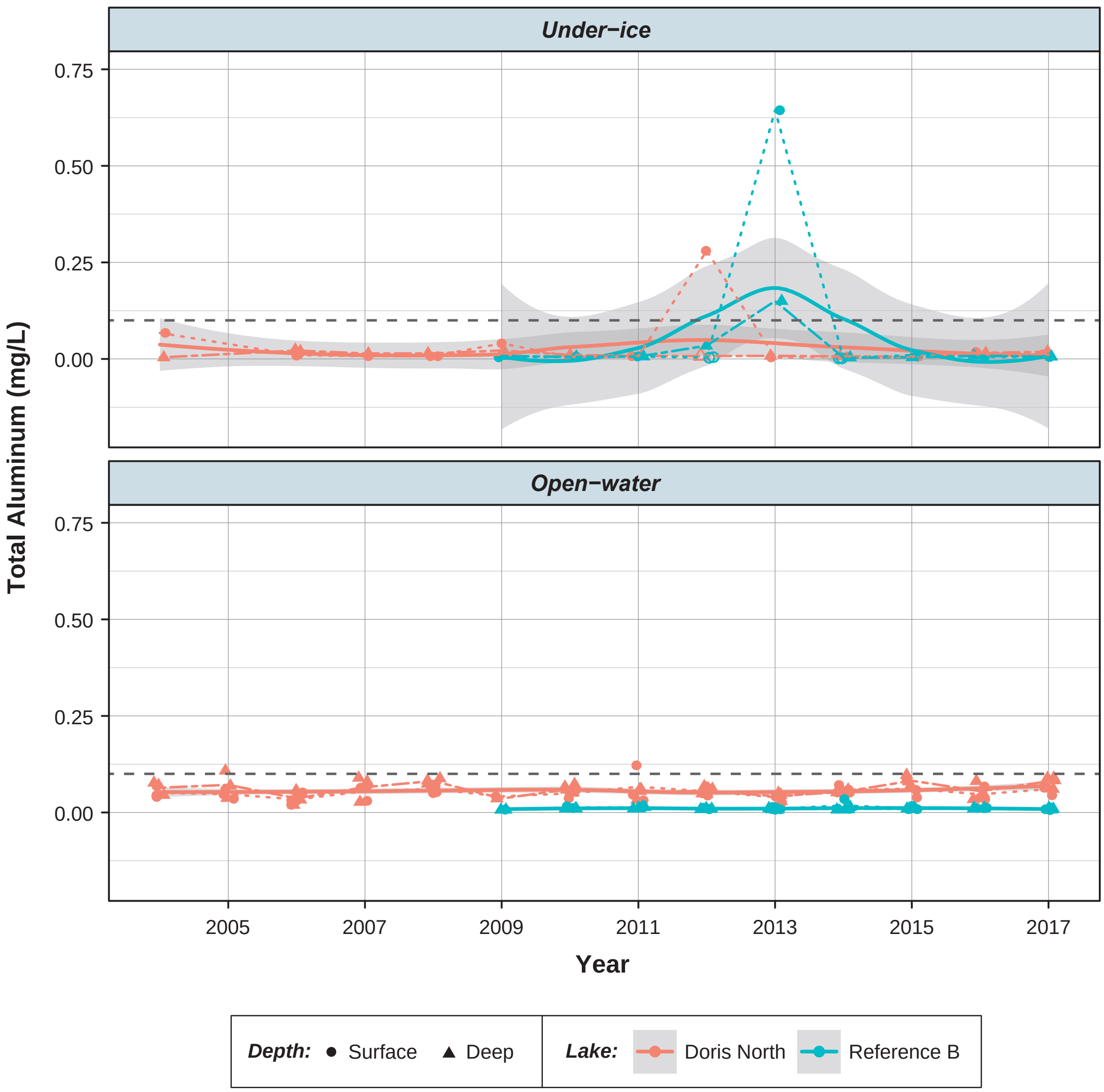
Total Phosphorus Concentrations in Lakes, Doris Project, 2004 to 2017



Notes: *Symbols represent observed data values.*
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Total phosphorus trigger ranges from CCME guidance framework: <0.004 mg/L = ultra-oligotrophic; 0.004 to 0.010 mg/L = oligotrophic; 0.01 to 0.02 mg/L = mesotrophic; 0.02 to 0.035 mg/L = meso-eutrophic; 0.035 to 0.1 mg/L = eutrophic; >0.1 mg/L = hyper-eutrophic.

Figure 3.3-10

Total Aluminum Concentrations in Lakes, Doris Project, 2004 to 2017



Notes: Symbols represent observed data values.
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the pH-dependent CCME guideline for aluminum (0.1 mg/L at pH ≥ 6.5; 0.05 mg/L at pH < 6.5);
pH was greater than 6.5 in all lake samples in 2017.

3.3.11 Total Arsenic

Both under-ice and open-water season total arsenic concentrations have decreased over time in Doris Lake North (Figure 3.3-11). These total arsenic trends were significantly different from a slope of zero ($p < 0.0001$ for under-ice, and $p = 0.0262$ for open-water). The under-ice trend also differed from the Reference B under-ice trend ($p < 0.0001$) while the open-water season trends between lakes were not significantly different ($p = 0.7868$). Since the change in total arsenic concentrations over time was a decrease compared to baseline concentrations and a decrease is not an environmental concern, there was no apparent adverse effect of the Project on total arsenic concentrations in Doris Lake North. Arsenic concentrations remained well below the CCME guideline of 0.005 mg/L and the low action level threshold of 0.00375 mg/L.

3.3.12 Total Boron

Both under-ice and open-water season total boron concentrations in Doris Lake North increased slightly from 2004 to 2015, and decreased back to baseline concentrations between 2015 and 2017 (Figure 3.3-12); these trends were significantly different from a slope of zero ($p < 0.0001$ for under-ice, and $p = 0.0128$ for open-water). The under-ice trend in Doris Lake North also differed from the Reference B under-ice trend ($p = 0.0054$) while the open-water season trends between lakes were not significantly different ($p = 0.4662$). Concentrations in 2017 were within the range of baseline concentrations; therefore, there was no evidence of an adverse change in total boron concentrations as a result of Project activities. Total boron concentrations remained well below the CCME long-term guideline of 1.5 mg/L and the low action level threshold of 1.125 mg/L.

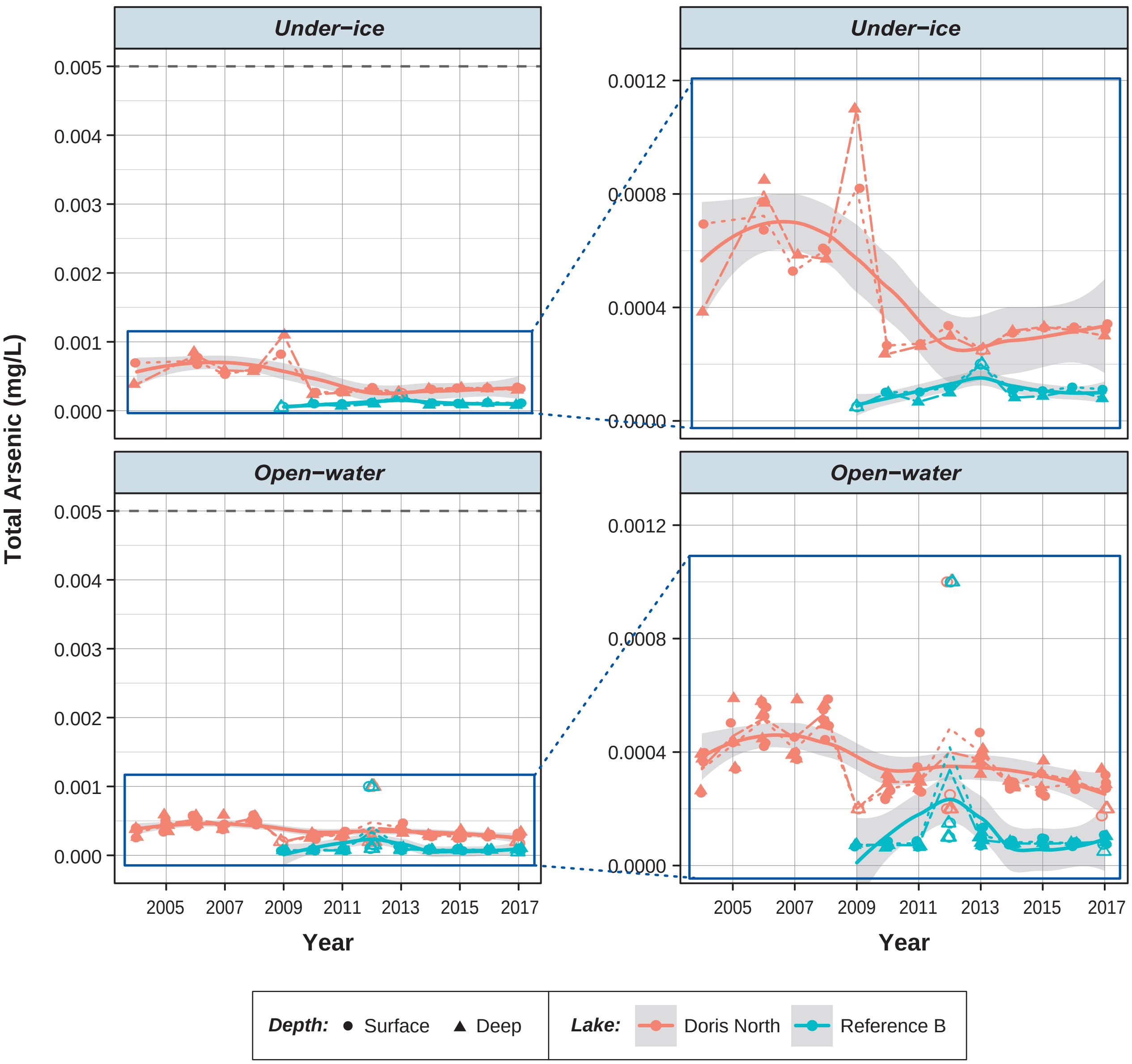
3.3.13 Total Cadmium

Total cadmium concentrations in Doris Lake North were generally consistent from 2004 to 2017, with most concentrations below analytical detection limits (Figure 3.3-13). In 2017, only 1 out of 11 samples collected in Doris Lake North between April and September contained a detectable concentration of cadmium (0.0000084 mg/L on July 18, deep sample; Appendix A). Because of the high proportion of censored data, it was not possible to perform a statistical analysis of the total cadmium dataset; however, the trend over time suggests that the Project has not adversely affected total cadmium concentrations in Doris Lake North. All total cadmium concentrations remained below the hardness-dependent CCME guideline and low action level threshold.

3.3.14 Total Chromium

Total chromium concentrations in Doris Lake North changed little over time from 2004 to 2017, with most concentrations below analytical detection limits (Figure 3.3-14). In 2017, only 2 out of 11 samples collected at Doris Lake North contained detectable concentrations of total chromium (0.00062 and 0.00215 mg/L on September 12, shallow and deep sample, respectively; Appendix A). The concentration of 0.00215 mg/L was higher than the CCME guideline of 0.001 mg/L and the low action level threshold of 0.00075 mg/L for hexavalent chromium but lower than the CCME guideline of 0.0089 mg/L and the low action level threshold of 0.0068 mg/L for trivalent chromium. Sporadic increases above the CCME guideline and low action level for hexavalent chromium have also been observed in samples from Reference Lake B (e.g., 2013 and 2014), and are therefore not necessarily indicative of a Project effect. Because of the high proportion of censored data, it was not possible to perform a statistical analysis of the total chromium dataset; however, the trend over time suggests that the Project has not adversely affected total chromium concentrations in Doris Lake North, and the low action level for total chromium was not triggered.

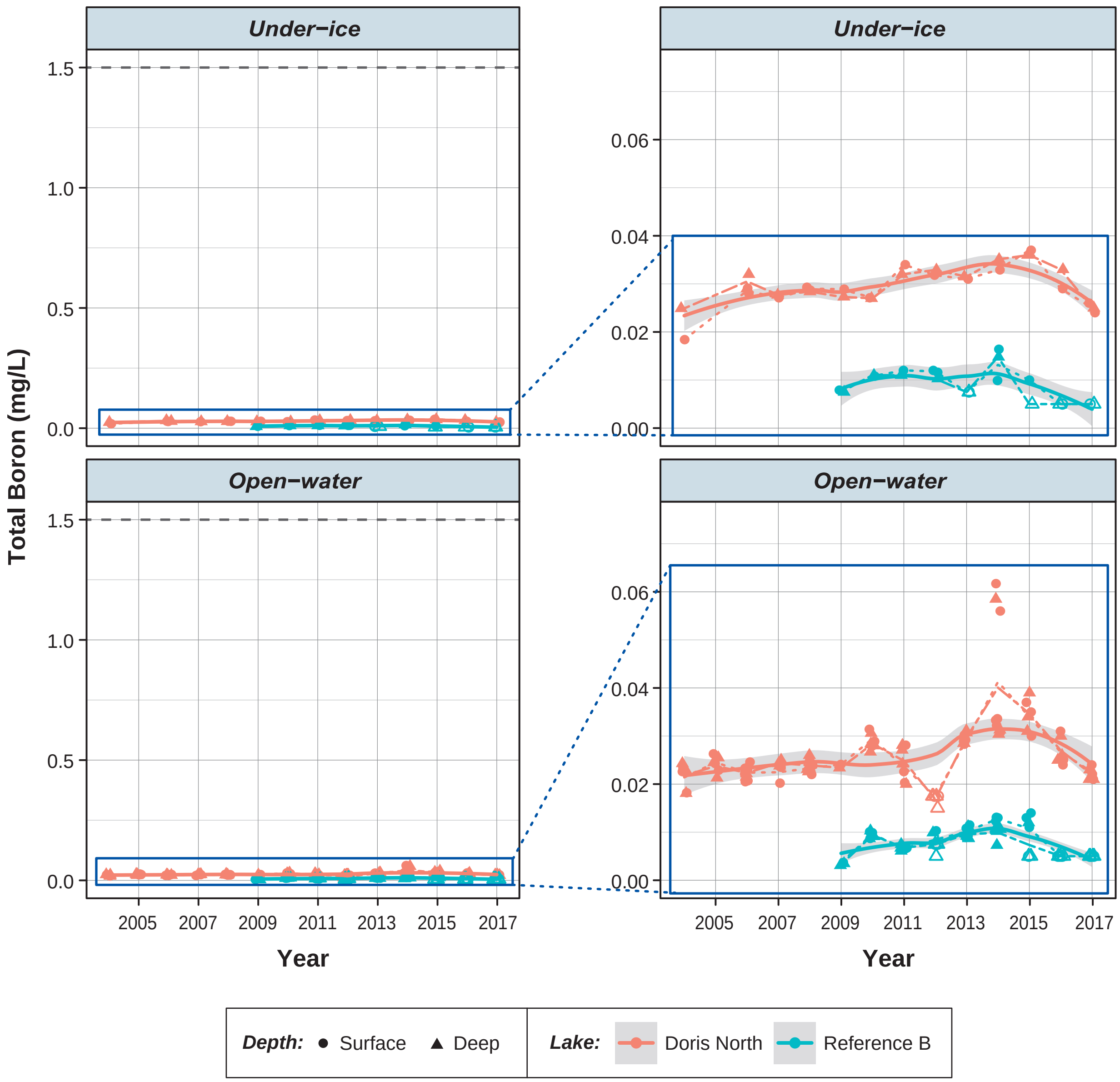
Arsenic Concentrations in Lakes, Doris Project, 2004 to 2017



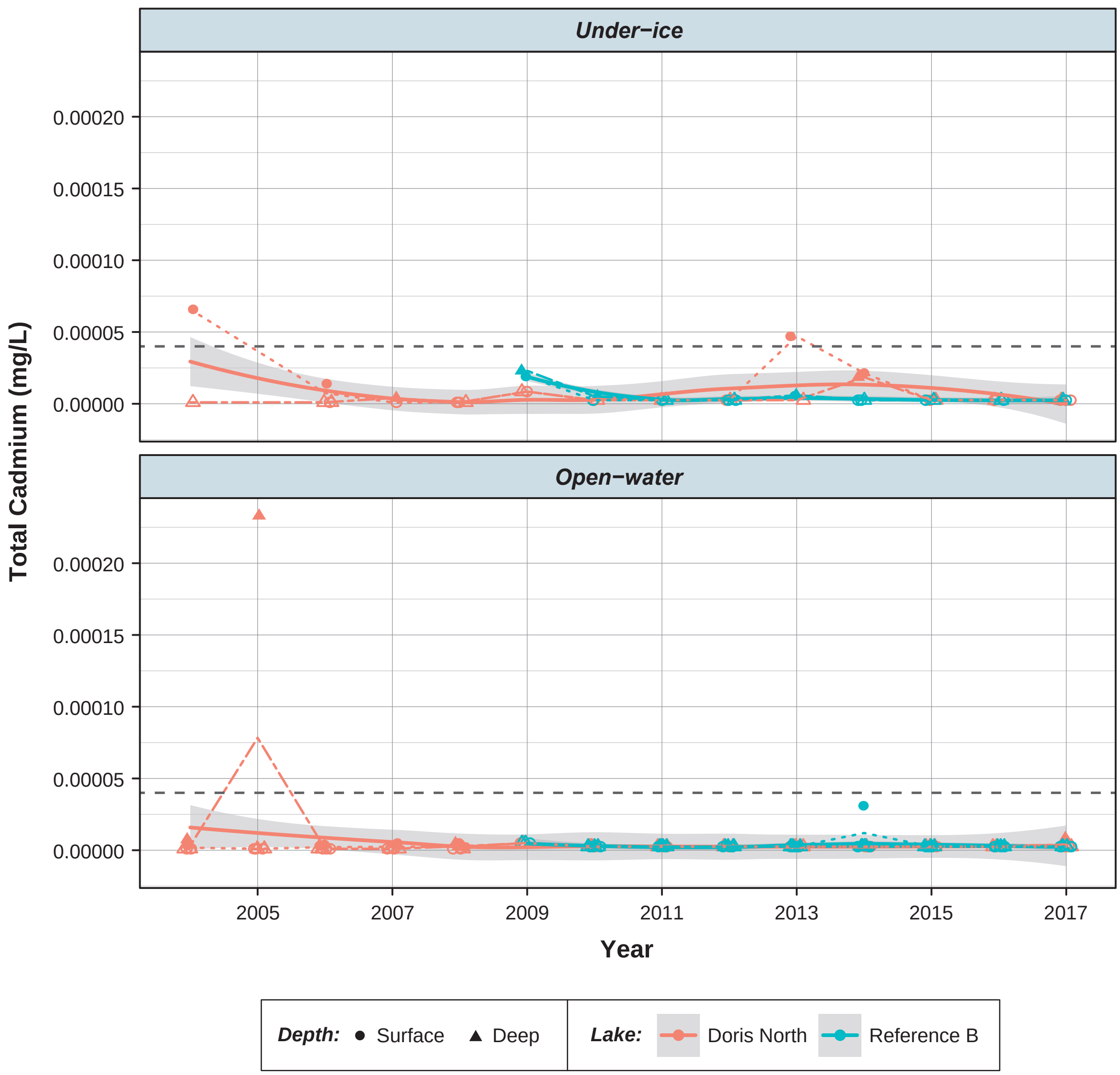
Notes: *Symbols represent observed data values.*
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME guideline for arsenic (0.005 mg/L).
Graphs on the left show the same data as graphs on the right, but at different y-axis scales.
A larger scale is used for the left side graphs to show the data relative to CCME guidelines.

Figure 3.3-12

Boron Concentrations in Lakes, Doris Project, 2004 to 2017



Notes: *Symbols represent observed data values.*
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME long-term guideline for boron (1.5 mg/L).
Graphs on the left show the same data as graphs on the right, but at different y-axis scales.
A larger scale is used for the left side graphs to show the data relative to CCME guidelines.

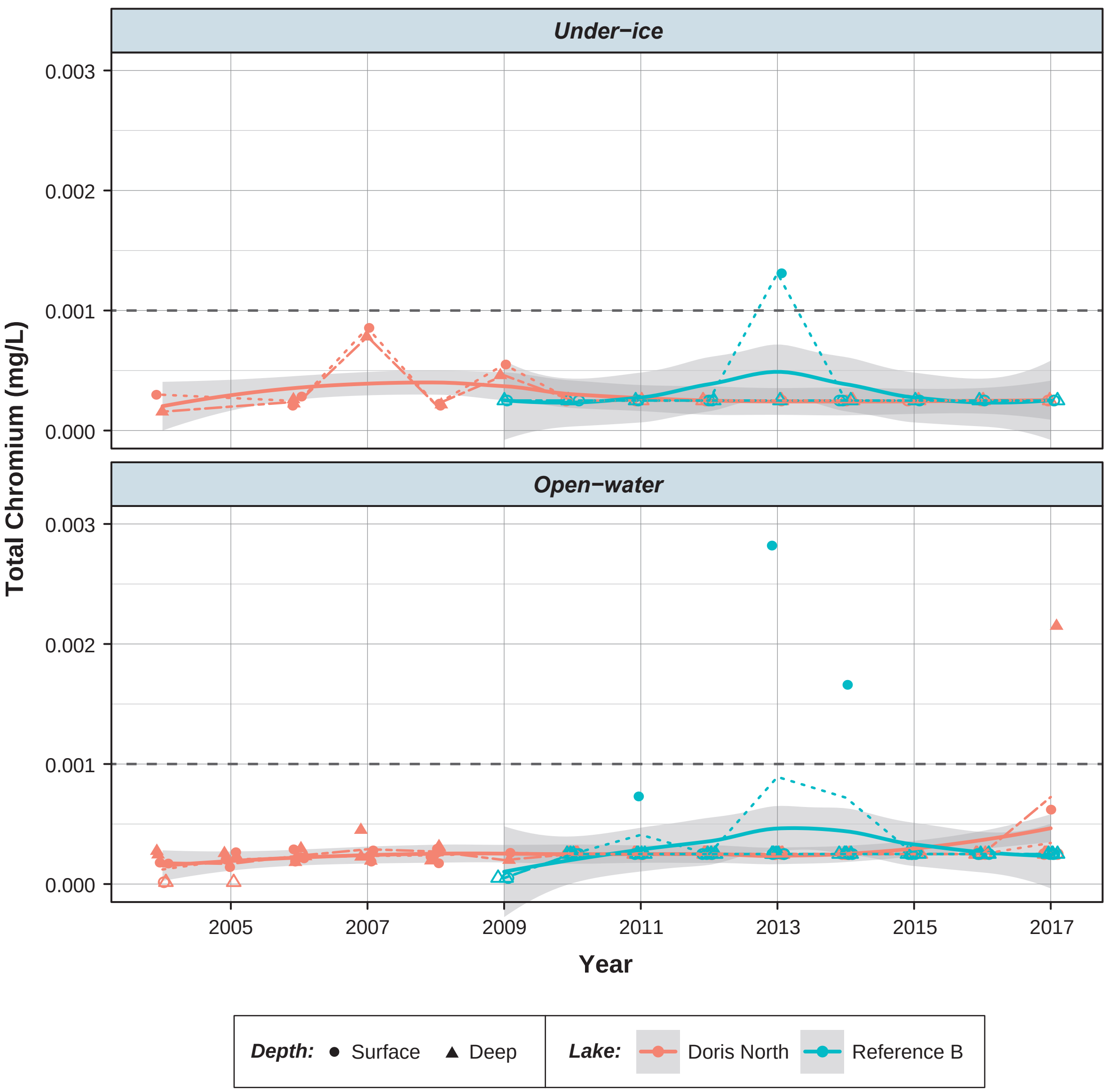


Notes: *Symbols represent observed data values.*
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the minimum hardness-dependent CCME long-term guideline for cadmium of 0.00004 mg/L (for hardness as $CaCO_3$ of < 17 mg/L); the CCME guideline increases with increasing hardness.

Figure 3.3-14

Chromium Concentrations in Lakes, Doris Project, 2004 to 2017

ERM



Notes: Symbols represent observed data values.
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME guideline for hexavalent chromium (0.001 mg/L);
the CCME interim guideline for trivalent chromium (0.0089 mg/L) is not shown.

3.3.15 Total Copper

Under-ice and open-water total copper concentrations in Doris Lake North changed little over time (Figure 3.3-15). This was confirmed by the statistical analysis, which showed that the total copper trends over time were not significantly different from a slope of zero ($p = 0.3812$ for under-ice, and $p = 0.8848$ for open-water). Thus, the data suggest that the Project has not adversely affected total copper concentrations in Doris Lake North. All 2017 total copper concentrations remained below the minimum hardness-dependent CCME guideline of 0.002 mg/L, but most concentrations were higher than the hardness-dependent low action level threshold of 0.0015 mg/L. However, total copper concentrations in Doris Lake North did not trigger the low action level since concentrations did not change from baseline levels.

3.3.16 Total Iron

Total iron concentrations in Doris Lake North were relatively consistent over time in both the under-ice and open-water sseasons (Figure 3.3-16). This was confirmed by the statistical analysis, which showed that the total iron trends over time were not significantly different from a slope of zero ($p = 0.7483$ for under-ice, and $p = 0.8980$ for open-water). Therefore, total iron concentrations did not trigger the low action level since there was no significant change from baseline levels. All 2017 total iron concentrations in Doris Lake North remained below the CCME guideline of 0.3 mg/L, but some concentrations were higher than the low action level threshold of 0.225 mg/L.

3.3.17 Total Lead

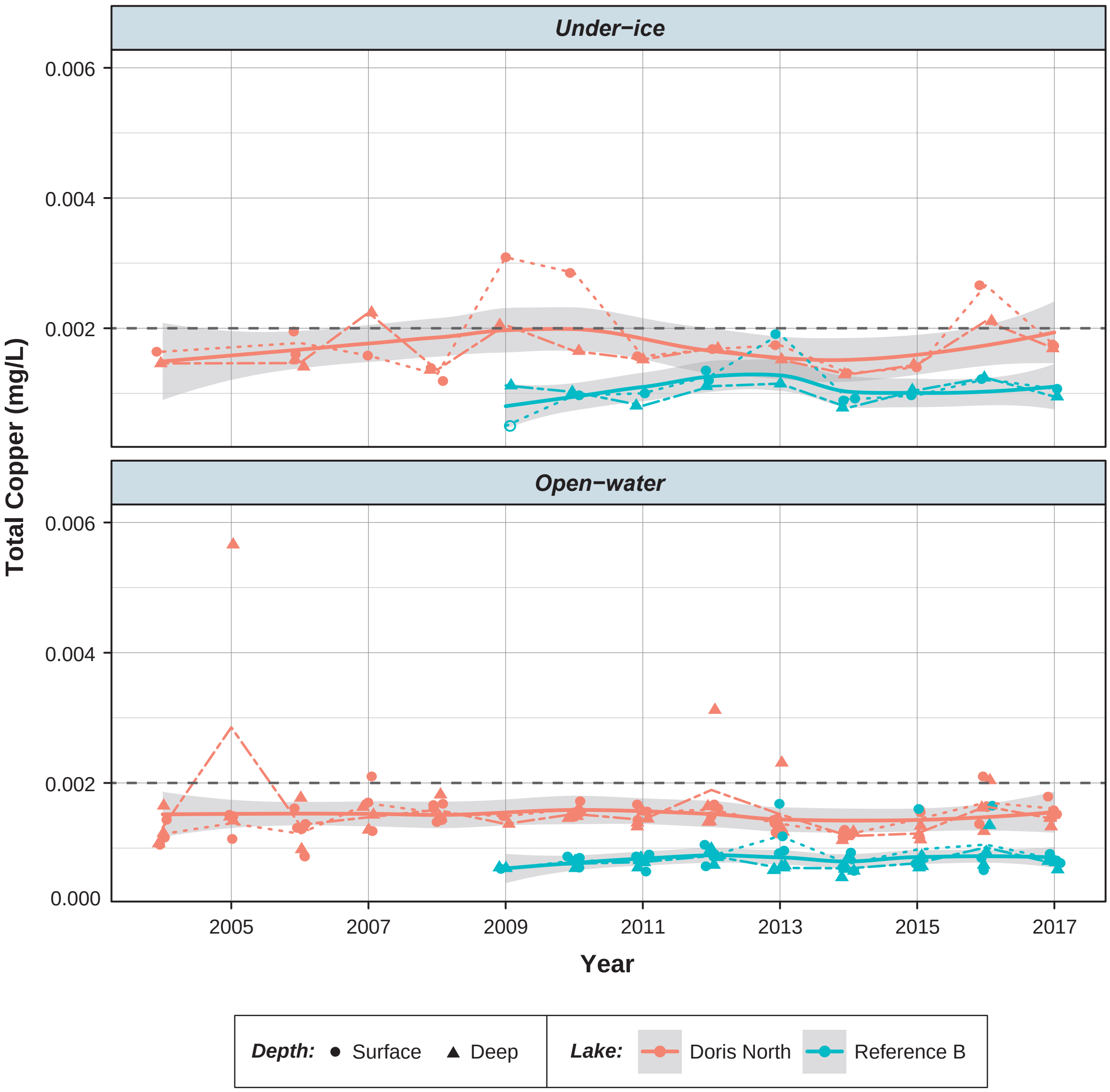
Total lead concentrations in Doris Lake North changed little over time from 2004 to 2017, with most concentrations below analytical detection limits (Figure 3.3-17). In 2017, only 3 out of 11 samples collected at Doris Lake North contained detectable concentrations of total lead, and these concentrations were slightly higher than the analytical detection limit of 0.00005 mg/L (range of detectable concentrations: 0.000051 to 0.000086 mg/L; Appendix A). Although historical total lead concentrations in both Doris Lake North and Reference Lake B were sporadically elevated above the minimum hardness-dependent CCME guideline of 0.001 mg/L, all 2017 concentrations remained well below this guideline, and well below the low action level threshold.

Because of the high proportion of censored data, it was not possible to perform a statistical analysis of total lead concentrations; however, the trend over time suggests that the Project has not adversely affected total lead concentrations in Doris Lake North, and the low action level for total lead was not triggered.

3.3.18 Total Mercury

Under-ice and open-water total mercury concentrations were variable over time in Doris Lake North, and were similar to Reference B concentrations (Figure 3.3-18). The results of the statistical analysis showed that mercury trends over time were not significantly different from a slope of zero for under-ice season concentrations ($p = 0.9398$) as well as open-water season concentrations ($p = 0.9979$), suggesting that mercury concentrations have been unaffected by Project activities. Total mercury concentrations were also well below the CCME guideline of 0.026 µg/L and the low action level benchmark of 0.0195 µg/L.

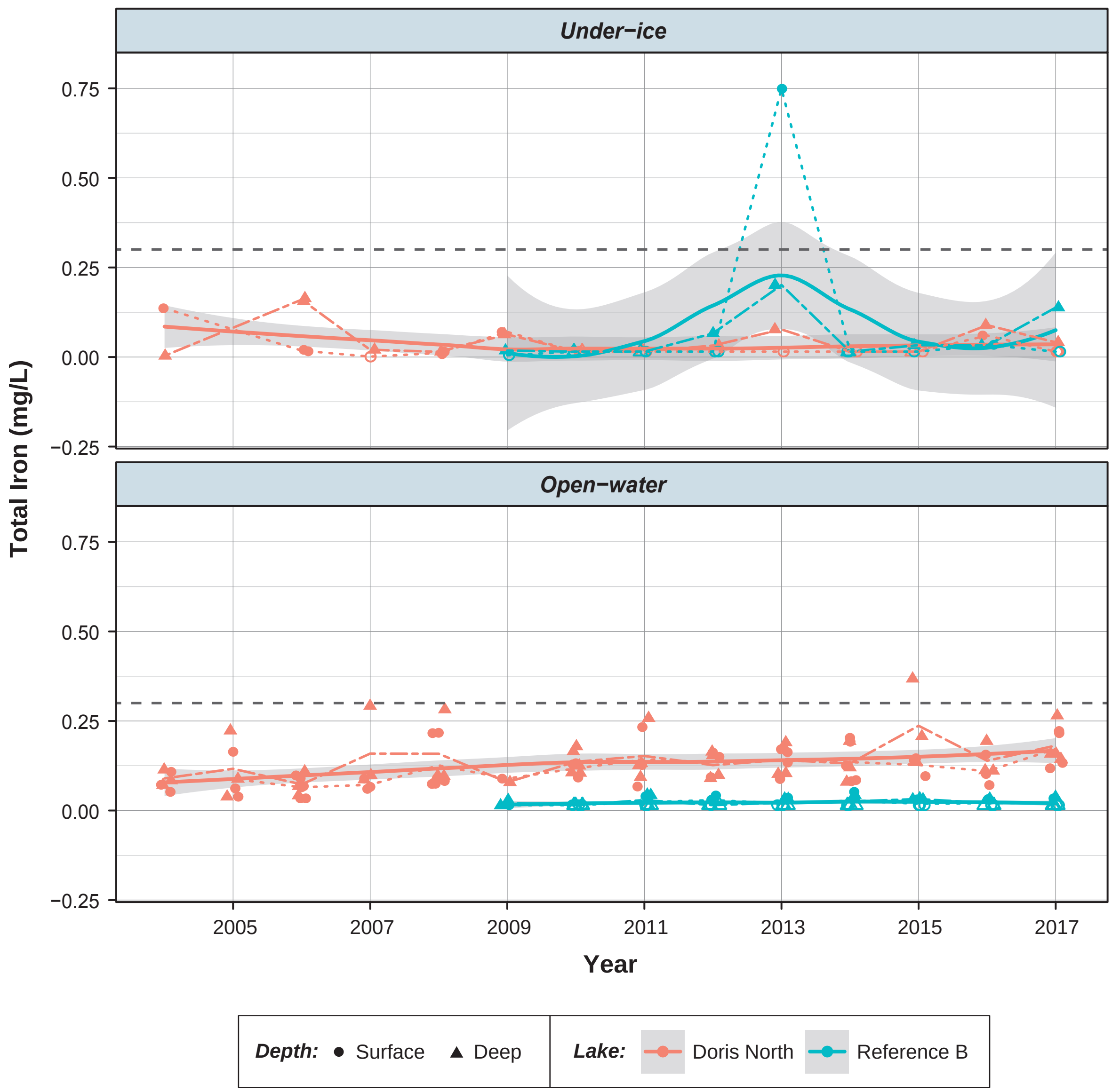
Copper Concentrations in Lakes, Doris Project, 2004 to 2017



Notes: *Symbols represent observed data values.*
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the minimum hardness-dependent CCME guideline for copper of 0.002 mg/L
(for hardness as $CaCO_3$ of < 82 mg/L); the CCME guideline increases with increasing hardness.

Figure 3.3-16

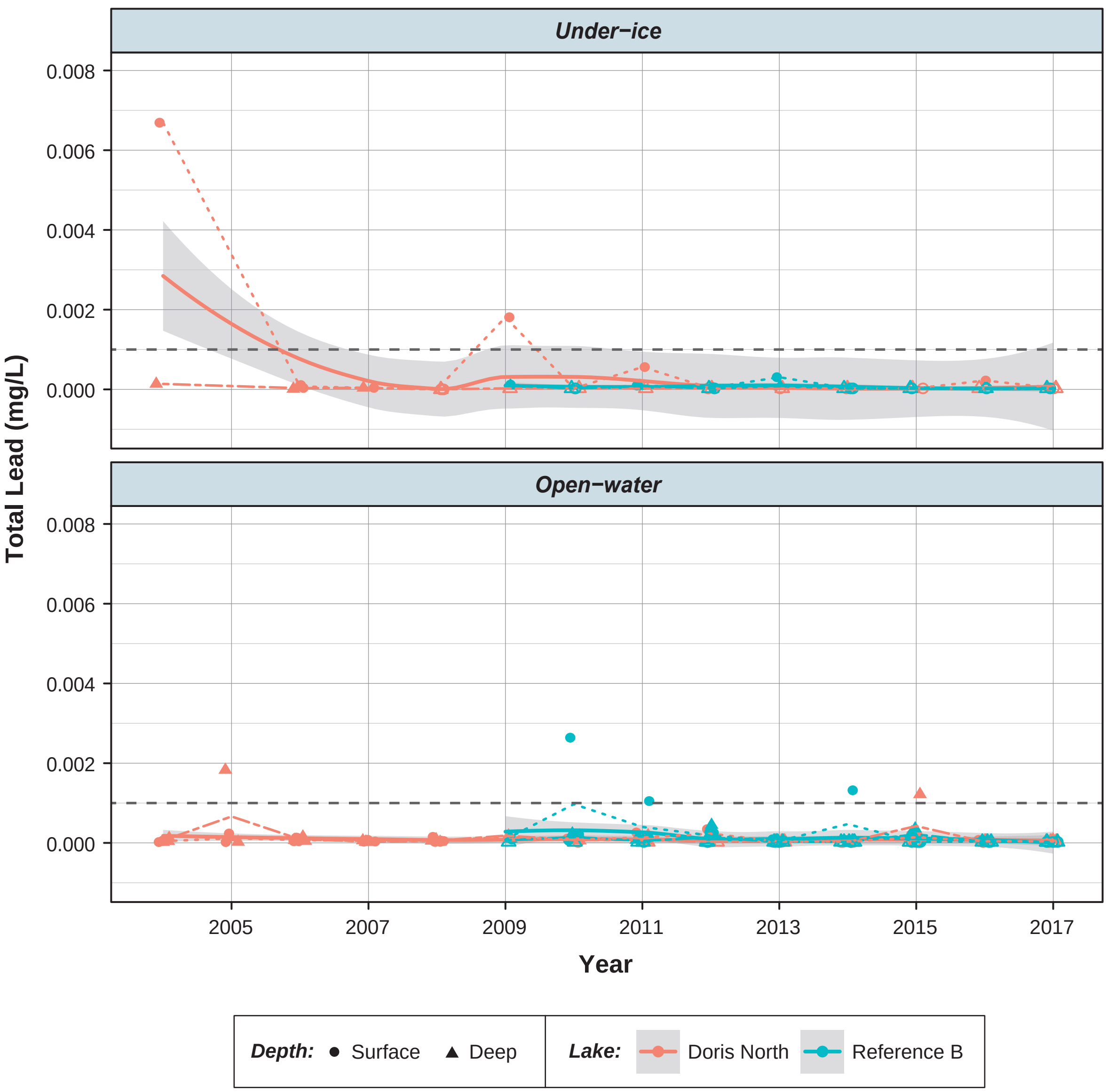
Iron Concentrations in Lakes, Doris Project, 2004 to 2017



Notes: Symbols represent observed data values.
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME guideline for iron (0.3 mg/L).

Figure 3.3-17

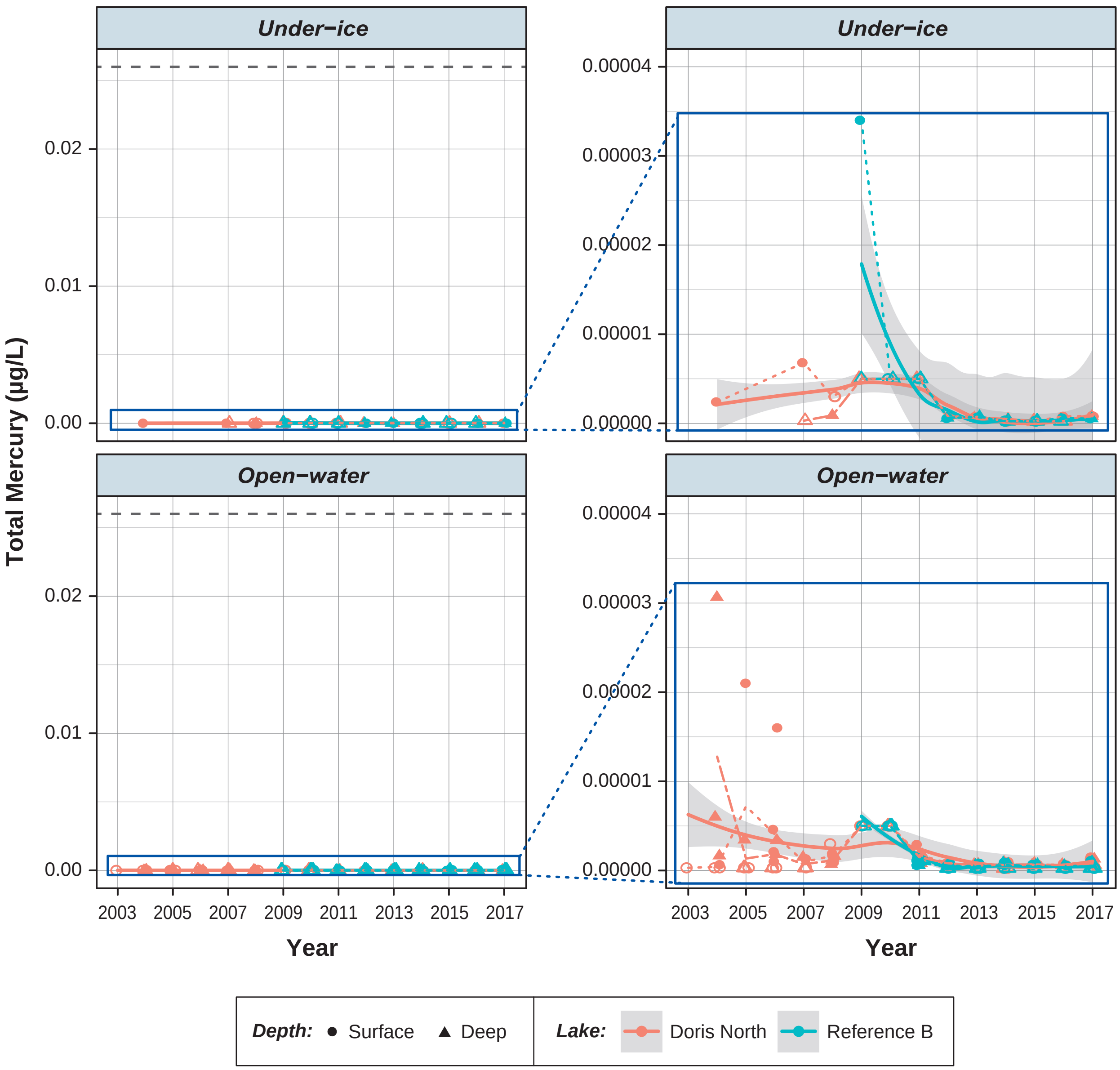
Lead Concentrations in Lakes, Doris Project, 2004 to 2017



Notes: *Symbols represent observed data values.*
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the minimum hardness-dependent CCME guideline for lead of 0.001 mg/L (for hardness as $CaCO_3$ of ≤ 60 mg/L); the CCME guideline increases with increasing hardness.

Figure 3.3-18

Mercury Concentrations in Lakes, Doris Project, 2003 to 2017



Notes: *Symbols represent observed data values.*
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME guideline for mercury (0.026 µg/L).
Graphs on the left show the same data as graphs on the right, but at different y-axis scales.
A larger scale is used for the left side graphs to show the data relative to CCME guidelines.

3.3.19 Total Molybdenum

Total molybdenum concentrations in Doris Lake North increased slightly over time in both the under-ice and open water seasons (Figure 3.3-19). This trend was significantly different from a slope of zero for both under-ice ($p < 0.0001$) and open water seasons ($p = 0.0061$). Because of the high proportion of censored data in the dataset for total molybdenum in Reference Lake B, it was not possible to statistically compare the trends between the exposure and reference lake to determine whether this increase in total molybdenum could be naturally occurring rather than Project related. However, even if the slight increase was due to the Project, total molybdenum concentrations remained well below the CCME guideline of 0.073 mg/L and the low action level threshold of 0.055 mg/L; therefore, total molybdenum concentrations remain protective of aquatic life. Although a Project effect on total molybdenum concentrations in Doris Lake North cannot be discounted, the low action level was not triggered because molybdenum concentrations remained well below the low action level threshold.

3.3.20 Total Nickel

Under-ice and open-water total nickel concentrations in Doris Lake North changed little over time (Figure 3.3-20). This was confirmed by the statistical analysis, which showed that the total nickel trends over time were not significantly different from a slope of zero ($p = 0.3006$ for under-ice, and $p = 0.8646$ for open-water). Therefore, there was no apparent Project effect on total nickel concentrations in Doris Lake North. All 2017 total nickel concentrations remained below the minimum hardness-dependent CCME guideline of 0.025 mg/L and the low action level threshold.

3.3.21 Total Selenium

All 2017 total selenium concentrations were below the analytical detection limit of 0.0002 mg/L, the CCME guideline of 0.001 mg/L, and the low action level threshold of 0.00075 mg/L. Statistical analysis of total selenium trends was not conducted because of the high proportion of censored data. Total selenium concentrations measured during baseline years (2004 to 2009) were generally higher than total selenium concentrations measured since the start of Project construction in 2010 (Figure 3.3-21). Overall, there was no evidence of a Project effect on total selenium concentrations in Doris Lake North.

3.3.22 Total Silver

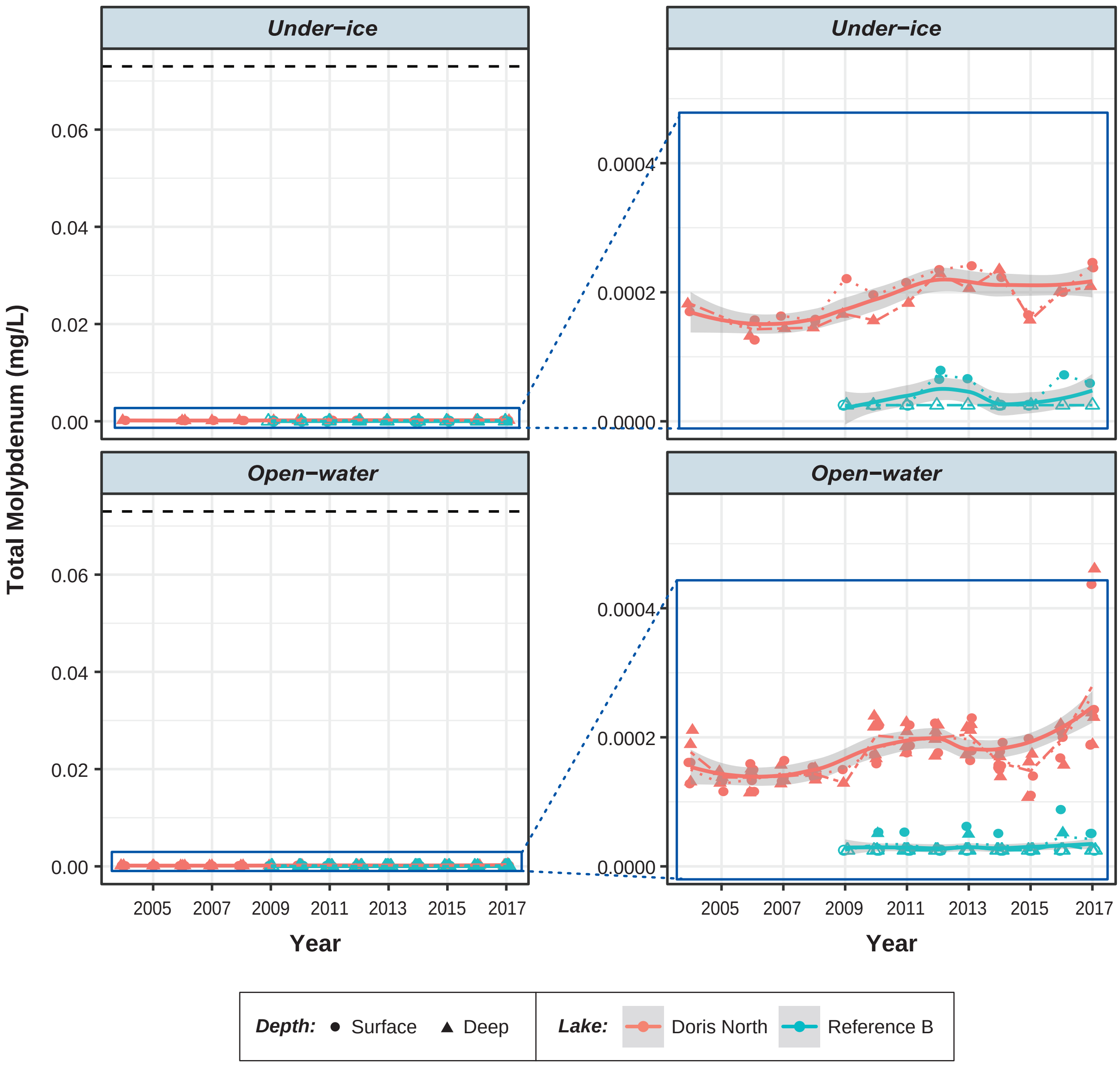
All total silver concentrations in Doris Lake North in 2017 were below the analytical detection limit of 0.000005 mg/L, the CCME guideline of 0.00025 mg/L, and the low action threshold of 0.00019 mg/L. Statistical analysis of total silver trends was not conducted, but there was no apparent increase in concentrations over time (Figure 3.3-22). There was no evidence of a Project effect on total silver concentrations in Doris Lake North.

3.3.23 Total Thallium

All 2017 total thallium concentrations in Doris Lake North were below the analytical detection limit of 0.000005 mg/L, the CCME guideline of 0.0008 mg/L, and the low action level threshold of 0.0006 mg/L. Statistical analysis was not conducted, but there was no apparent increase in concentrations over time (Figure 3.3-23). There was no evidence of a Project effect on total thallium concentrations in Doris Lake North.

Figure 3.3-19

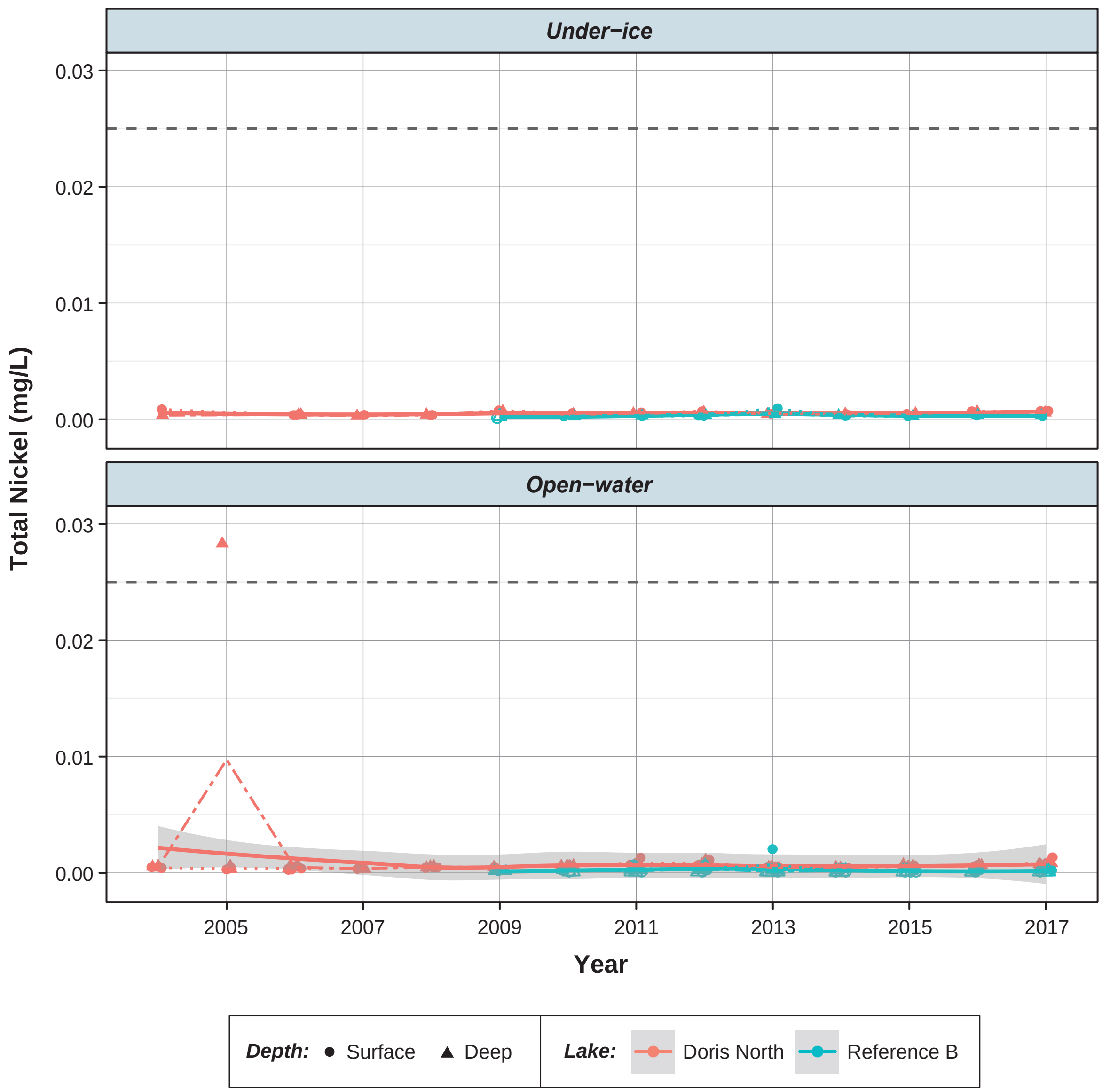
Molybdenum Concentrations in Lakes, Doris Project, 2004 to 2017



Notes: Symbols represent observed data values.
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME interim guideline for molybdenum (0.073 mg/L).
Graphs on the left show the same data as graphs on the right, but at different y-axis scales.
A larger scale is used for the left side graphs to show the data relative to CCME guidelines.

Figure 3.3-20

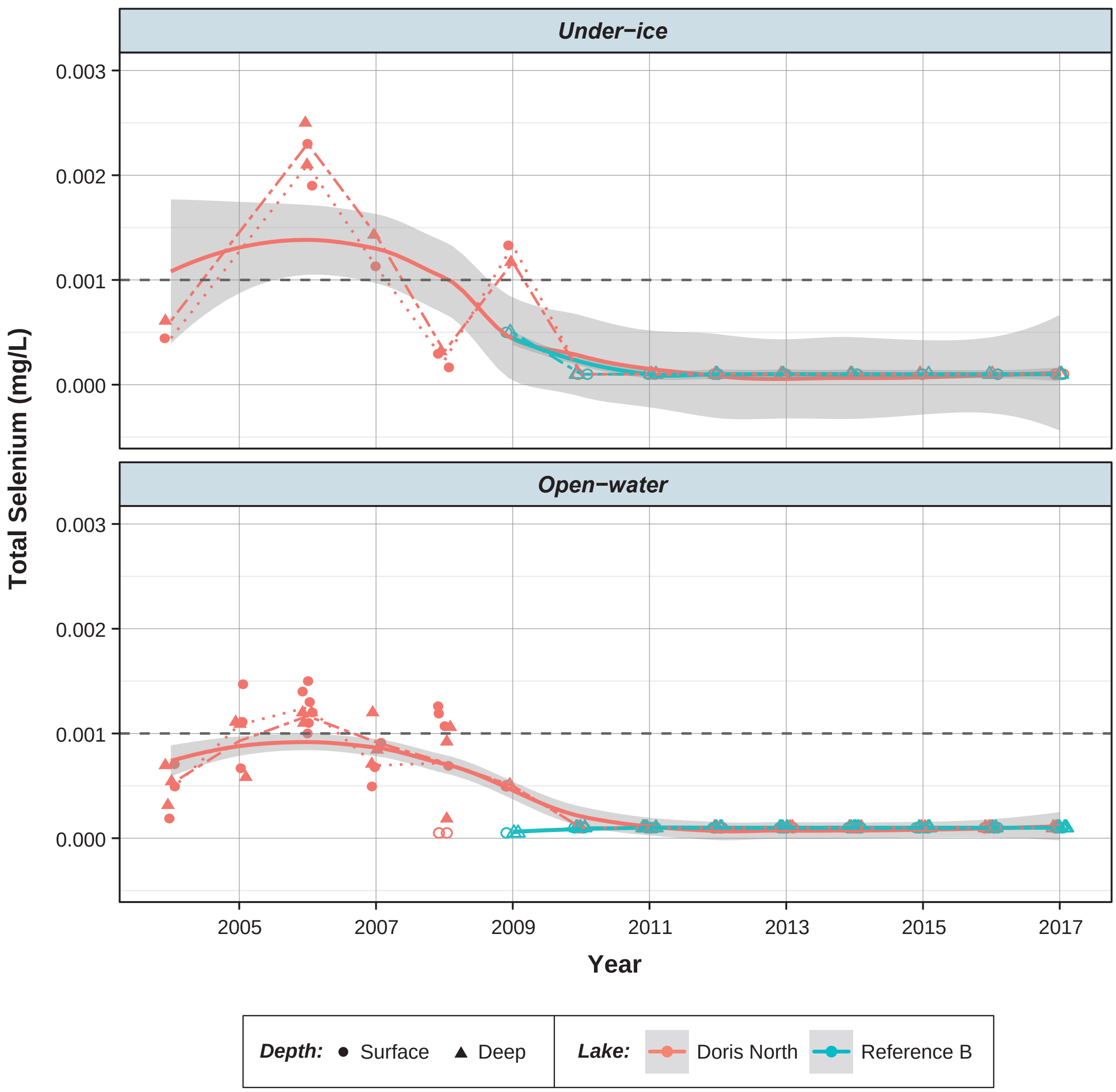
Nickel Concentrations in Lakes, Doris Project, 2004 to 2017



Notes: Symbols represent observed data values.
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the minimum hardness-dependent CCME guideline for nickel of 0.025 mg/L
(for hardness as $CaCO_3$ of ≤ 60 mg/L); the CCME guideline increases with increasing hardness.

Figure 3.3-21

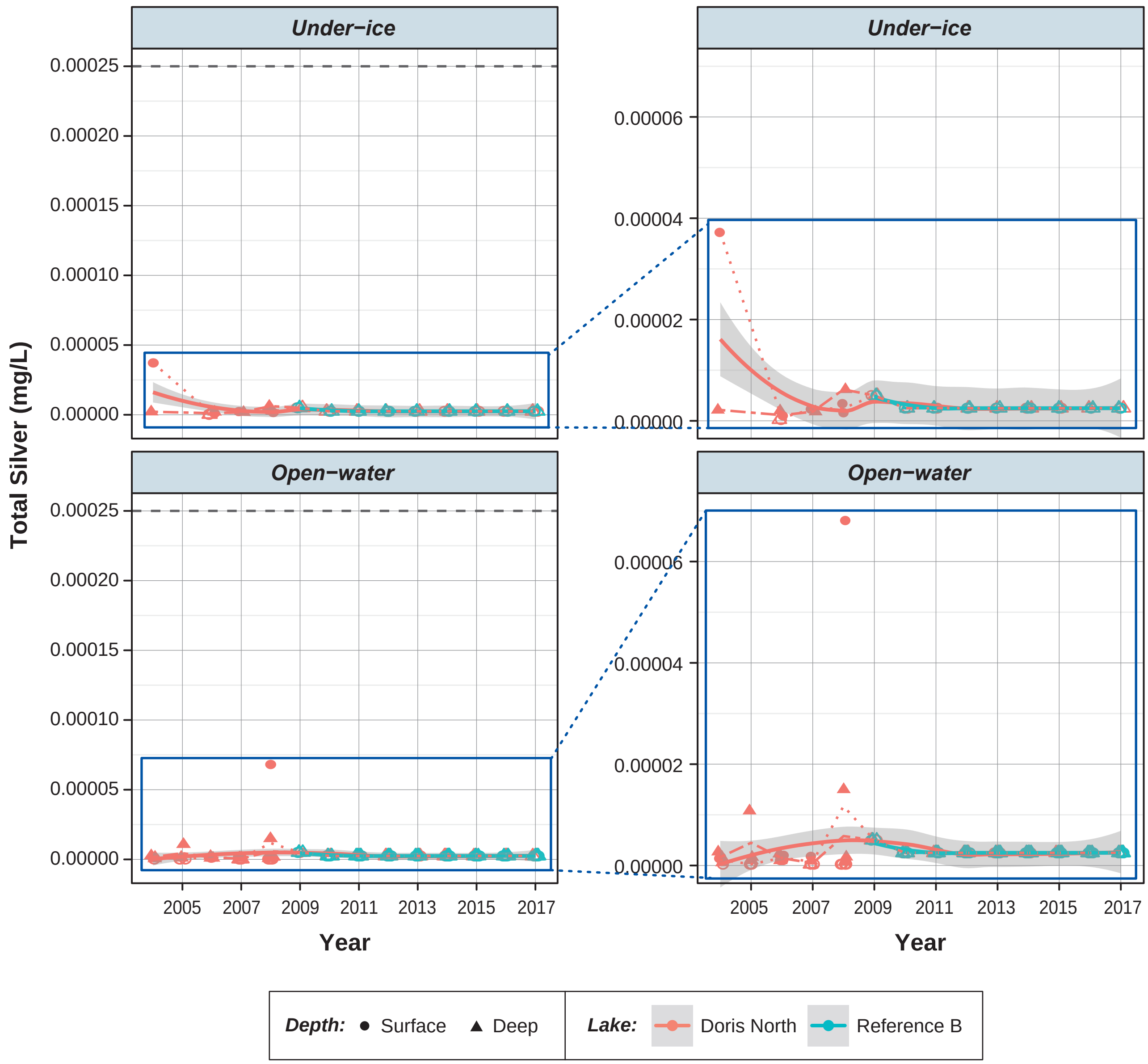
Selenium Concentrations in Lakes, Doris Project, 2004 to 2017



Notes: *Symbols represent observed data values.*
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME guideline for selenium (0.001 mg/L).

Figure 3.3-22

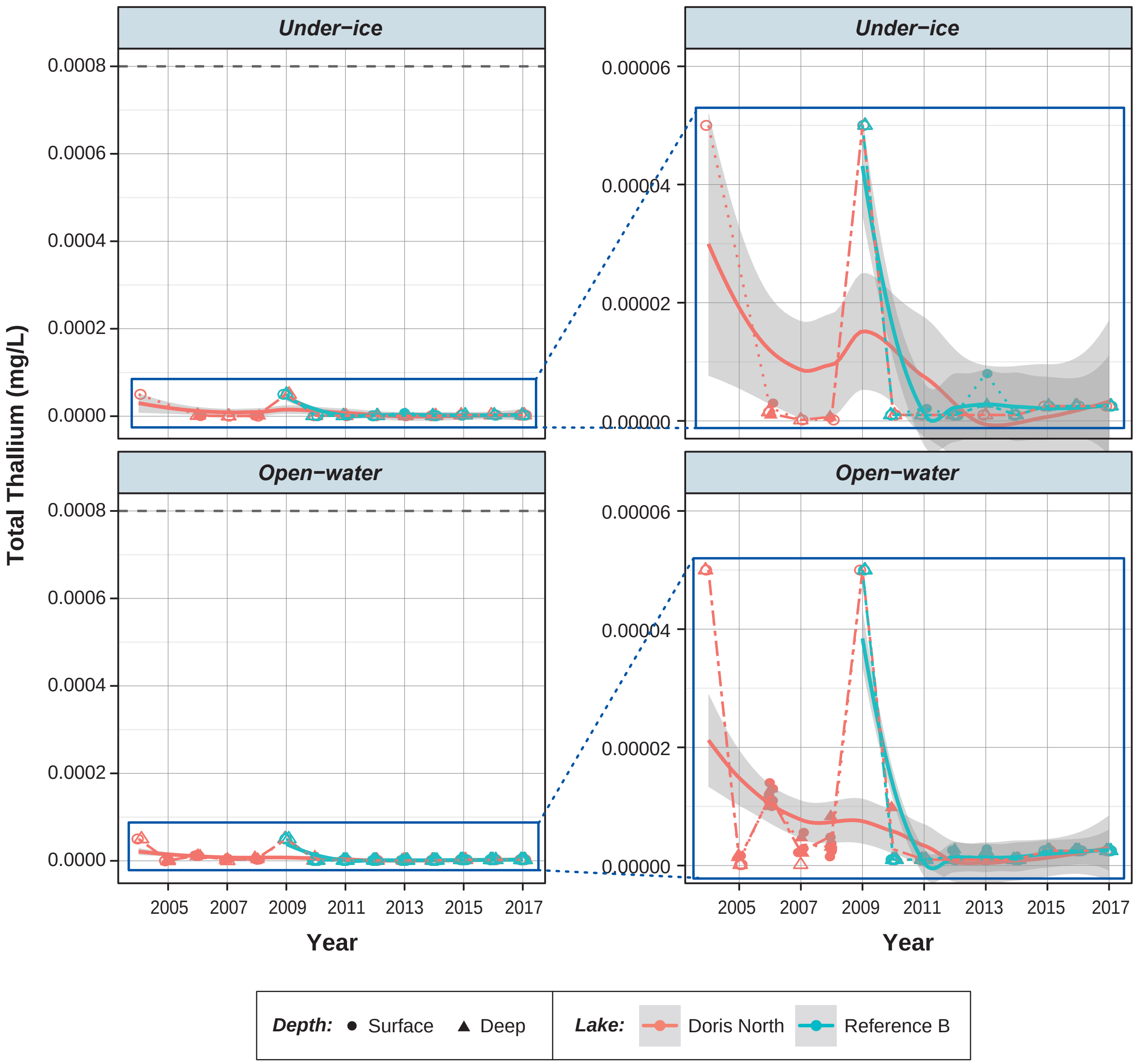
Silver Concentrations in Lakes, Doris Project, 2004 to 2017



Notes: Symbols represent observed data values.
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME long-term guideline for silver (0.00025 mg/L).
Graphs on the left show the same data as graphs on the right, but at different y-axis scales.
A larger scale is used for the left side graphs to show the data relative to CCME guidelines.

Figure 3.3-23

Thallium Concentrations in Lakes, Doris Project, 2004 to 2017



Notes: *Symbols represent observed data values.*
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME guideline for thallium (0.0008 mg/L).
Graphs on the left show the same data as graphs on the right, but at different y-axis scales.
A larger scale is used for the left side graphs to show the data relative to CCME guidelines.

3.3.24 Total Uranium

Under-ice and open-water total uranium concentrations increased over time in Doris Lake North (Figure 3.3-24). The statistical analysis confirmed that the total uranium trends were significantly different from a slope of zero for both the under-ice season ($p < 0.0001$) and the open-water season ($p = 0.0296$). However, the comparison of trends between Doris Lake North and Reference Lake B revealed that the trends between lakes were not significantly different ($p = 0.1139$ for under-ice, and $p = 0.1327$ for open-water), suggesting that the increasing total uranium concentrations were naturally occurring and unrelated to Project activities. There is therefore no evidence of a Project-related adverse effect on total uranium concentration in Doris Lake North. All total uranium concentrations in Doris Lake North were well below the CCME long-term guideline of 0.015 mg/L and the low action level threshold of 0.01125 mg/L.

3.3.25 Total Zinc

All 2017 total zinc concentrations in Doris Lake North were below the analytical detection limit of 0.003 mg/L, the CCME guideline of 0.03 mg/L, and the low action level threshold of 0.0225 mg/L. Statistical analysis was not conducted, but there was no apparent increase in total zinc concentrations over time (Figure 3.3-25). Overall, there was no evidence of a change in total zinc concentrations in Doris Lake North due to the Project.

3.4 Sediment Quality

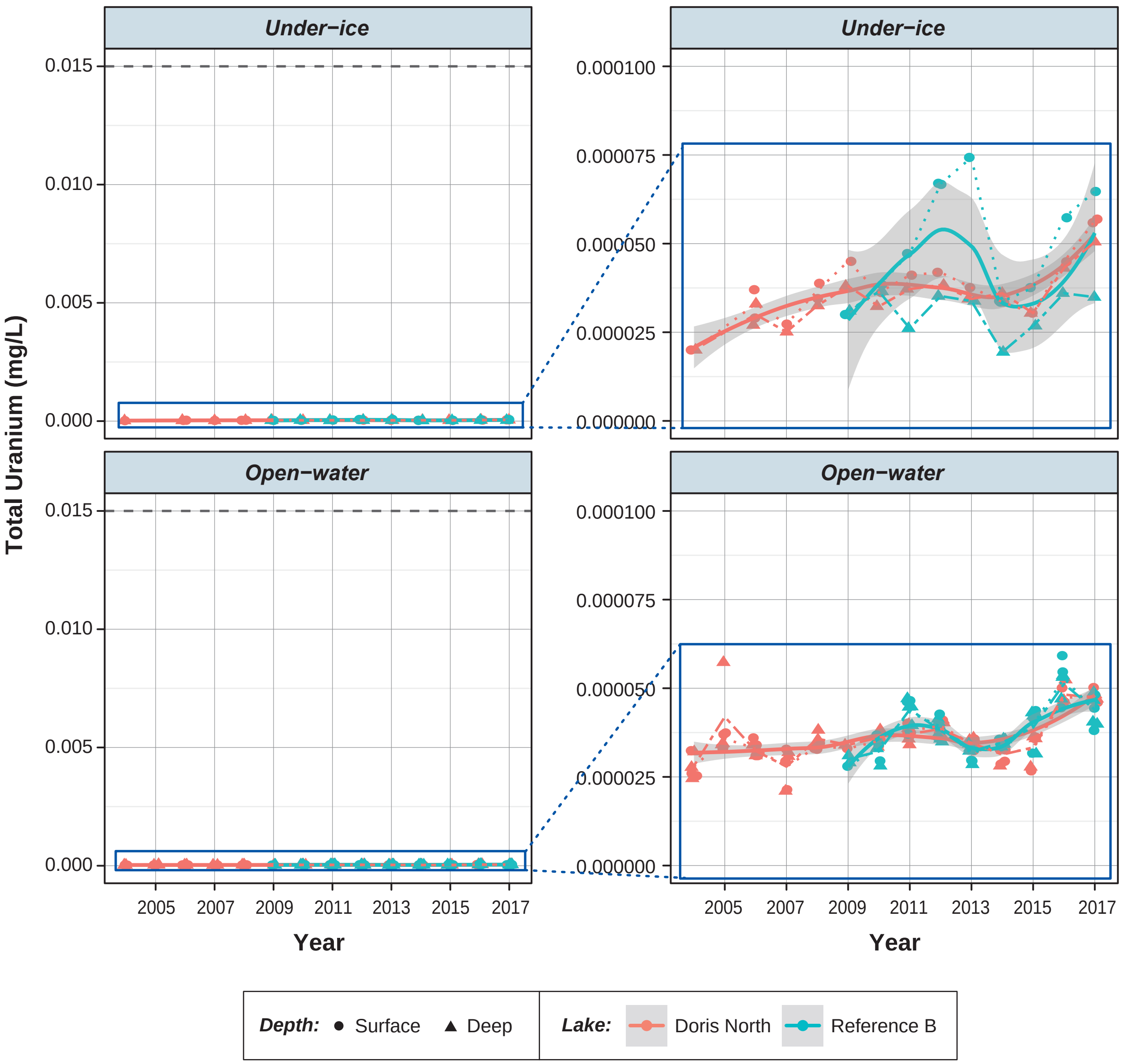
Sediment quality samples were collected from one exposure lake site (Doris Lake North) and one reference lake site (Reference Lake B) in August 2017. A subset of sediment quality variables (see Table 2.2-1) was evaluated to determine whether Project activities resulted in adverse changes to sediment quality over time. Statistical and graphical analyses were used to determine if there were changes in sediment quality variables in the Project area over time. Trends in Doris Lake North were also directly compared to trends in Reference Lake B to establish whether changes in sediment quality in Doris Lake were likely naturally occurring or Project related.

Sediment quality variable concentrations were compared to CCME sediment quality guidelines for the protection of aquatic life (CCME 2018a) to assess whether existing concentrations could adversely affect freshwater aquatic life. CCME guidelines for sediments include interim sediment quality guidelines (ISQGs) and probable effects levels (PELs). The more conservative ISQGs are levels below which adverse biological effects are rarely observed. The higher PELs correspond to concentrations above which negative effects would be expected (CCME 2018a). Sediment quality data were also compared against 75% of the ISQG and PEL guidelines as described in Section 2.2.3 to determine whether a low action level threshold was exceeded.

Graphs showing sediment quality trends in lakes over time are shown in Figures 3.4-1 to 3.4-8. Raw sediment quality data for 2017 are presented in Appendix A, and all statistical analysis results are presented in Appendix B.

Figure 3.3-24

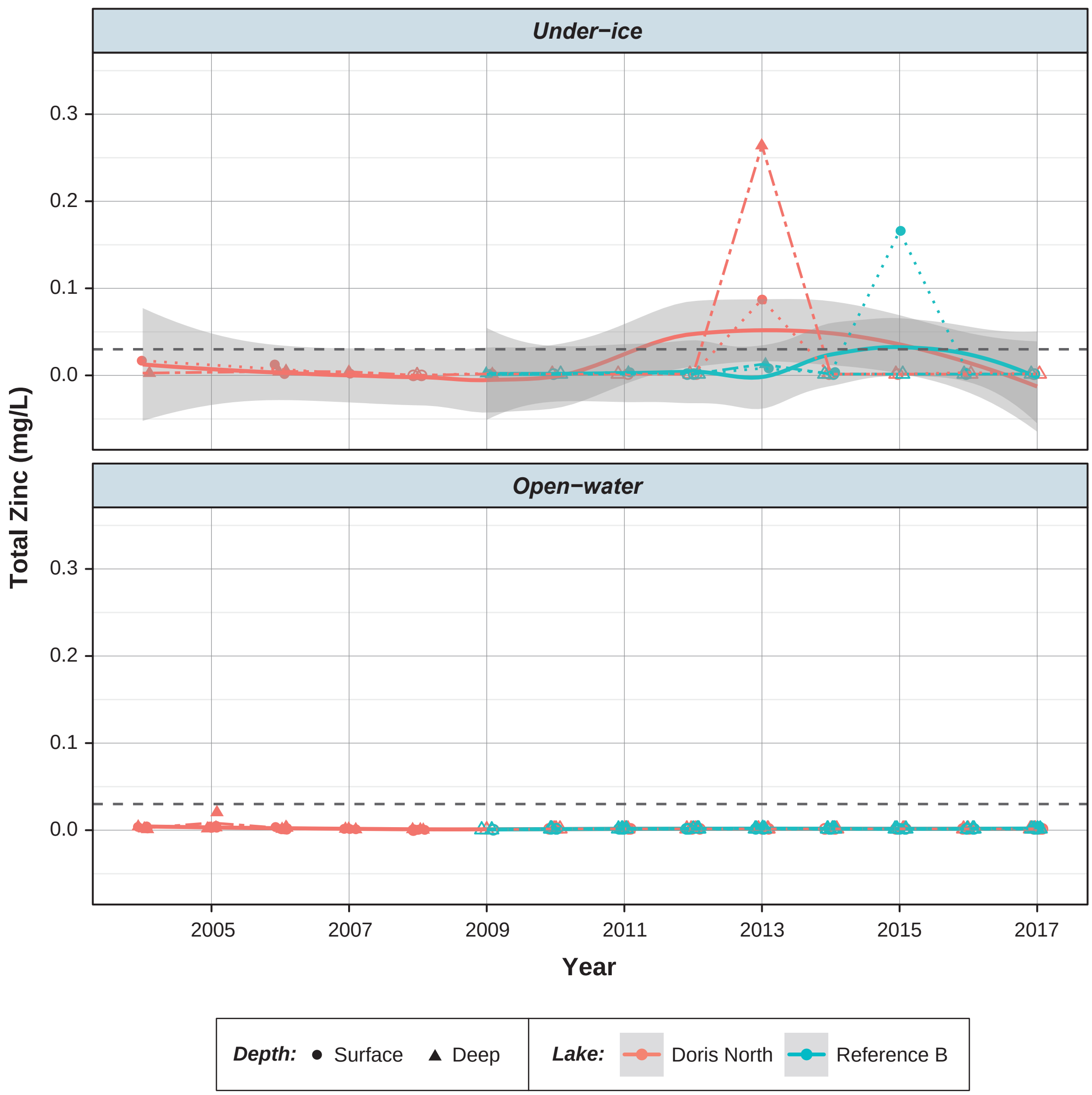
Uranium Concentrations in Lakes, Doris Project, 2004 to 2017



Notes: Symbols represent observed data values.
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME long-term guideline for uranium (0.015 mg/L).
Graphs on the left show the same data as graphs on the right, but at different y-axis scales.
A larger scale is used for the left side graphs to show the data relative to CCME guidelines.

Zinc Concentrations in Lakes, Doris Project, 2004 to 2017

ERM



Notes: Symbols represent observed data values.
Observations below the analytical detection limit are represented by open symbols and plotted at half the detection limit.
Observations are slightly jittered along the x-axis for legibility.
Dashed or dotted lines drawn through the scatter plots represent the annual means.
LOESS smoothing curves and corresponding 95% confidence intervals are represented by solid lines and grey shading, respectively.
Black dashed lines represent the CCME guideline for zinc (0.03 mg/L).

3.4.1 Total Organic Carbon

The total organic carbon (TOC) content of sediments is used an indicator of increased primary production, and is often positively correlated with heavy metals or other pollutants in sediments (e.g., Yang, Xiong, and Yang 2010). The TOC content of sediments in Doris Lake North remained nearly constant between 2009 and 2017 (Figure 3.4-1). The statistical analysis confirmed that the TOC trend over time was not significantly different from a slope of zero ($p = 0.9973$), indicating that there was no change in this variable due to Project activities.

3.4.2 Arsenic

Sediment arsenic concentrations in Doris Lake North were variable over time, with mean concentrations always higher than the ISQG of 5.9 mg/kg and lower than the PEL of 17 mg/kg (Figure 3.4-2). Elevated concentrations of arsenic are naturally occurring as concentrations measured during the baseline year (2009) were also higher than the ISQG guideline. The sediment arsenic trend over time in Doris Lake North was significantly different from a slope of zero ($p = 0.0008$), but not significantly different from the trend in Reference Lake B ($p = 0.4279$). This suggests that there were parallel changes in arsenic over time between Doris Lake North and Reference Lake B, and the Project likely did not affect sediment arsenic concentrations in Doris Lake North. Although arsenic concentrations in Doris Lake North sediments were higher than 75% of the ISQG guideline, the low action level was not triggered because there was no evidence of a Project-related change in arsenic concentrations.

3.4.3 Cadmium

Sediment cadmium concentrations were nearly constant over time in Doris Lake North and tended to be lower than cadmium concentrations in Reference Lake B sediments (Figure 3.4-3). The statistical analysis confirmed that the cadmium trend over time was not significantly different from a slope of zero ($p = 0.5530$). Thus, Project activities had no apparent adverse effect on cadmium concentrations in Doris Lake North sediments. Sediment cadmium concentrations in Doris Lake North also remained below the CCME ISQG of 0.6 mg/kg, the PEL of 3.5 mg/kg, and the low action level thresholds of 75% of the ISQG and PEL guidelines between 2009 and 2017 (Figure 3.4-3).

3.4.4 Chromium

Sediment chromium concentrations were relatively consistent over time, with mean concentrations always greater than the CCME ISQG of 37.3 mg/kg and slightly below the PEL of 90 mg/kg (Figure 3.4-4). Elevated concentrations of chromium are naturally occurring as concentrations measured during the baseline year (2009) were also higher than the ISQG guideline. The statistical analysis showed that that the chromium trend over time was not significantly different from a slope of zero ($p = 0.1917$). Although chromium concentrations in Doris Lake North were consistently higher than the low action level thresholds of 75% of the ISQG and PEL guidelines, the low action level for chromium was not triggered because there was no evidence of Project-related change in chromium concentrations over time.