MADRID-BOSTON PROJECT
FINAL ENVIRONMENTAL IMPACT STATEMENT

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
ANFO	Ammonium nitrate-fuel oil
ARD	Acid rock drainage
AWR	All-weather road
BLM	Biotic ligand model
CCME	Canadian Council of Ministers of Environment
CEA	Cumulative effects assessment
CEAA	Canadian Environmental Assessment Agency
CWP	Contact water pond
DFO	Fisheries and Oceans Canada
DO	Dissolved oxygen
DOC	Dissolved organic carbon
ECCC	Environment and Climate Change Canada
EIS	Environmental Impact Statement
GN DOE	Government of Nunavut, Department of Environment
HC	Health Canada
HDPE	High-density polyethylene
INAC	Indigenous and Northern Affairs Canada
KIA	Kitikmeot Inuit Association
LSA	Local Study Area
ML	Metal leaching
MMER	Metal Mining Effluent Regulations
MOMB	Marine outfall mixing box
NIRB	Nunavut Impact Review Board
NSA	Nunavut Settlement Area

NTKP	Naonaiyaotit Traditional Knowledge Project
NWB	Nunavut Water Board
PAH	Polycyclic aromatic hydrocarbons
PDA	Project development area
Project	Madrid-Boston Project
QA/QC	Quality assurance and quality control
RSA	Regional Study Area
SSD	Species sensitivity distribution
SSWQO	Site specific water quality objective
STP	Sewage treatment plant
TDS	Total dissolved solids
TIA	Tailings impoundment area
TK	Traditional knowledge
TMA	Tailings management area
tpd	Tonnes per day
TSS	Total suspended solids
VEC	Valued Ecosystem Component
WER	Water effects ratio
WRR	Winter road route
WTP	Water treatment plant

4. Freshwater Water Quality

Freshwater water quality is a critical component of the biological and physical environment. It constitutes the physical, chemical, biological, and aesthetic characteristics of water which are, in turn, determined by a variety of regional and local factors including rock weathering, surface transport, biological activity, and anthropogenic influences. An understanding of the freshwater quality, as well as its interactions with a project, is critical to support an environmental effects assessment as well as to contribute to engineering analysis and the design of water management features.

This section examines the potential effects of the proposed Madrid-Boston Project (the Project) on freshwater water quality. Monitoring studies of pre-development (i.e., baseline) freshwater water quality conditions were conducted to allow for the prediction, assessment, mitigation, and management of potential Project-related effects and were incorporated into mine, mine waste, and water management planning.

Alteration of freshwater water quality could potentially affect other Valued Ecological Components (VECs), and effects on these VECs are assessed in the following effects assessment sections:

- Volume 4, Chapter 9, Terrestrial Wildlife and Wildlife Habitat;
- Volume 5, Chapter 5, Freshwater Sediment Quality;
- Volume 5, Chapter 6, Freshwater Fish;
- Volume 5, Chapter 8, Marine Water Quality;
- Volume 5, Chapter 10, Marine Fish;
- Volume 5, Chapter 11, Marine Wildlife; and
- Volume 6, Chapter 5, Human Health.

This chapter follows the effects assessment methodology described in Volume 2, Chapter 4 of the Environmental Impact Statement (EIS).

4.1 INCORPORATION OF TRADITIONAL KNOWLEDGE

4.1.1 Incorporation of Traditional Knowledge for Existing Environment and Baseline Information

Available information from the *Inuit Traditional Knowledge for TMAC Resources Inc., Hope Bay Project, Naonaiyaotit Traditional Knowledge Project* (NTKP) report (Banci and Spicker 2016) was reviewed for existing environment and baseline information on freshwater water quality.

According to the information provided in the NTKP report, Inuit have seen changes in surface water quality over the past few decades. Inuit attribute recent shallower lakes and lower water flows in rivers as affecting the water quality. In general, changes to water quality in coastal areas is greater than changes in inland areas. While no specific causes of contamination have been identified, potential sources have been identified such as dust, mineral exploration and mine development, melting of permafrost, long distance transport of pollutants, too many tourists, and an overpopulation of geese.

4.1.2 Incorporation of Traditional Knowledge for VEC Selection

The NTKP report was reviewed to refine the potential VEC list for freshwater water quality. Rivers and lakes are identified in the NTKP report as Inuit's source of water and important fish habitat. Traditional knowledge was considered in addition to data from public consultation and baseline surveys to determine which valued components would potentially interact with the proposed Project, and should therefore be evaluated for inclusion in the candidate VEC list.

As a result of this process, and in consideration of the EIS guidelines (NIRB 2012a), freshwater water quality was selected as a candidate VEC for the EIS (Volume 2, Chapter 4; Effects Assessment Methodology).

4.1.3 Incorporation of Traditional Knowledge for Spatial and Temporal Boundaries

The results of the NTKP report were considered when developing the spatial and temporal boundaries for the Madrid-Boston Project. The NTKP report showed that specific and general fishing locations extend along both shores of Melville Sound, but are concentrated along the southern shore extending both east and west of Roberts Bay. General fishing areas also extend inland along the entire length of the Hope Bay Greenstone Belt. Water quality is an important component in determining the environmental quality for fish. Therefore, the entire Project area is included within the spatial boundaries of the assessment of freshwater water quality.

4.1.4 Incorporation of Traditional Knowledge for Project Effects Assessment

The results of the NTKP report were considered when developing the effects assessment for freshwater water quality. No specific references relevant to the effects assessment for water quality were included in the NTKP report. No specific drinking water sources were identified, but the potential for water use exists throughout the Project area.

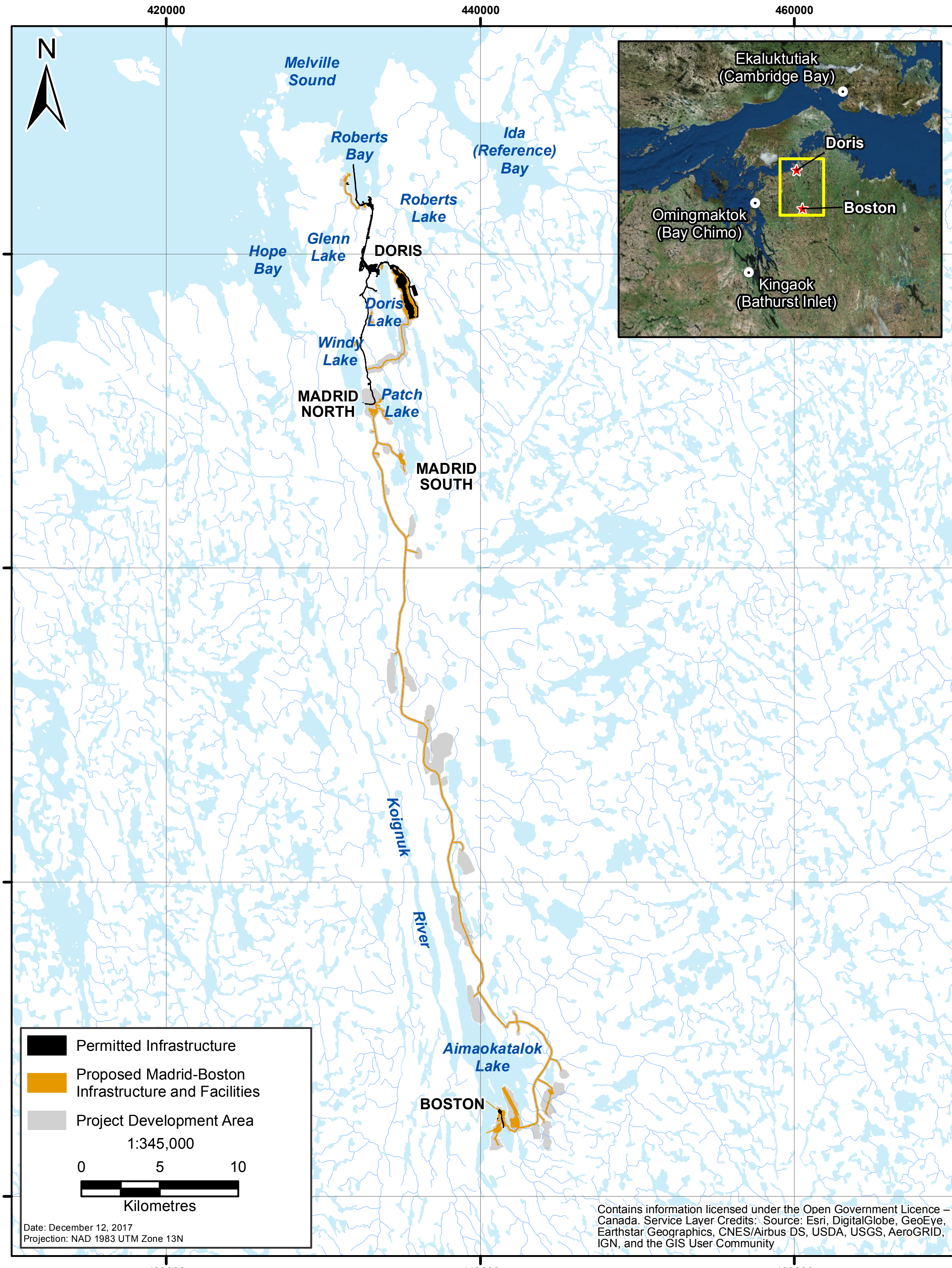
4.1.5 Incorporation of Traditional Knowledge for Mitigation and Adaptive Management

The NTKP report was considered when developing mitigation and adaptive management plans for freshwater water quality.

4.2 EXISTING ENVIRONMENT AND BASELINE INFORMATION

The Madrid-Boston Project (a component of the Hope Bay Project) is situated within the Queen Maud Gulf Lowlands, approximately 153 km southwest of Cambridge Bay on the southern shore of Melville Sound in the West Kitikmeot region of Nunavut (Figure 4.2-1). The property contains a greenstone belt running 80 km in a north-south direction that varies in width between 7 km and 20 km. The Hope Bay Project consists of three developments, with Doris being the northernmost, followed by Madrid in the north-central area, and Boston at the southern end (Figure 4.2-1). The proposed Project infrastructure in each mining district lies within a single defined Local Study Area (LSA) that is bounded by a larger Regional Study Area (RSA; see Section 4.4; Figure 4.2-2).

Figure 4.2-1
Project Location



Regionally, the Project lies entirely within the Southern Arctic Ecozone and is situated in an area of continuous permafrost. Generally, Doris has more variable relief, with exposed igneous extrusions to 160 m, and a greater marine influence than the Madrid or Boston areas, which are characterized by flat rolling bedrock covered by thin layers of moraine, lacustrine, and fluvial deposits. Winter in the Project area is characterized by extreme cold, with mean monthly temperatures ranging from -33.4ºC to -3.1ºC, and the coldest temperatures occurring in January and February. There is a short snow-free season (mid-June through September) with mean monthly temperatures ranging from -2.5ºC to 13.9ºC and the warmest temperatures typically occurring in July (Volume 4, Chapter 1). The Doris meteorological station reports total summer rainfall (June to September) ranging from 47.8 mm (2012) to 97.8 mm (2011; Volume 4, Chapter 1). The region's vegetation is characterized by shrub tundra vegetation such as dwarf birch (*Betula nana*), willow (*Salix* sp.), Labrador tea (*Ledum decumbens*), avens (*Dryas* sp.), and blueberries (*Vaccinium* sp.;Volume 4, Chapter 8).

The freshwater LSA includes the Doris, Windy, and Koignuk-Aimaokatalok sub-watersheds in the north, and the Aimaokatalok and East watersheds in the south (Figure 4.2-2). Water from the northern Doris and central Madrid watersheds flows northward into Roberts Bay via Little Roberts Outflow and Glenn Outflow, while water from the southern Boston watersheds flows into Hope Bay via the large Koignuk River system. The largest lakes in the north and central belt include Doris, Windy, Patch, Glenn, and Ogama lakes, with Aimaokatalok Lake being the largest lake in the southern belt. The hydrology in the Madrid-Boston area is dominated by snowmelt, with peak flows occurring in June in most watersheds. The lakes are typically frozen from October to June with ice thicknesses ranging between 1.5 to 2.0 m (Rescan 2010a, 2011b). Winter flow is largely absent because of negligible groundwater reserves outside of the permafrost and the lack of unfrozen surface water. Due to the influences of climate and permafrost, there is one major flood period (freshet) in June that quickly recedes into summer, with the hydrograph being punctuated with occasional high–flow events from storms during the open-water season.

Baseline freshwater water quality data have been collected within the greenstone belt since the early 1990s. The following sections provide a summary of the methods and results from the freshwater water quality sampling carried out in the Project area and surrounding region.

4.2.1 Regulatory Framework

There are several acts, regulations, and guidelines relevant to the management and preservation of freshwater water quality. Table 4.2-1 lists and provides a brief description of the key acts and regulations pertaining to freshwater water quality.

In addition to these acts and regulations, the protection of freshwater water quality is also guided by the *Canadian Environmental Quality Guidelines* (CCME 2001b), which include the *Water Quality Guidelines for the Protection of Aquatic Life* (CCME 2017) published by the Canadian Council of Ministers of the Environment (CCME). These water quality guidelines define concentrations of water quality parameters that should present a negligible risk to aquatic organisms.

Figure 4.2-2
Freshwater Water Quality Local and Regional Study Areas

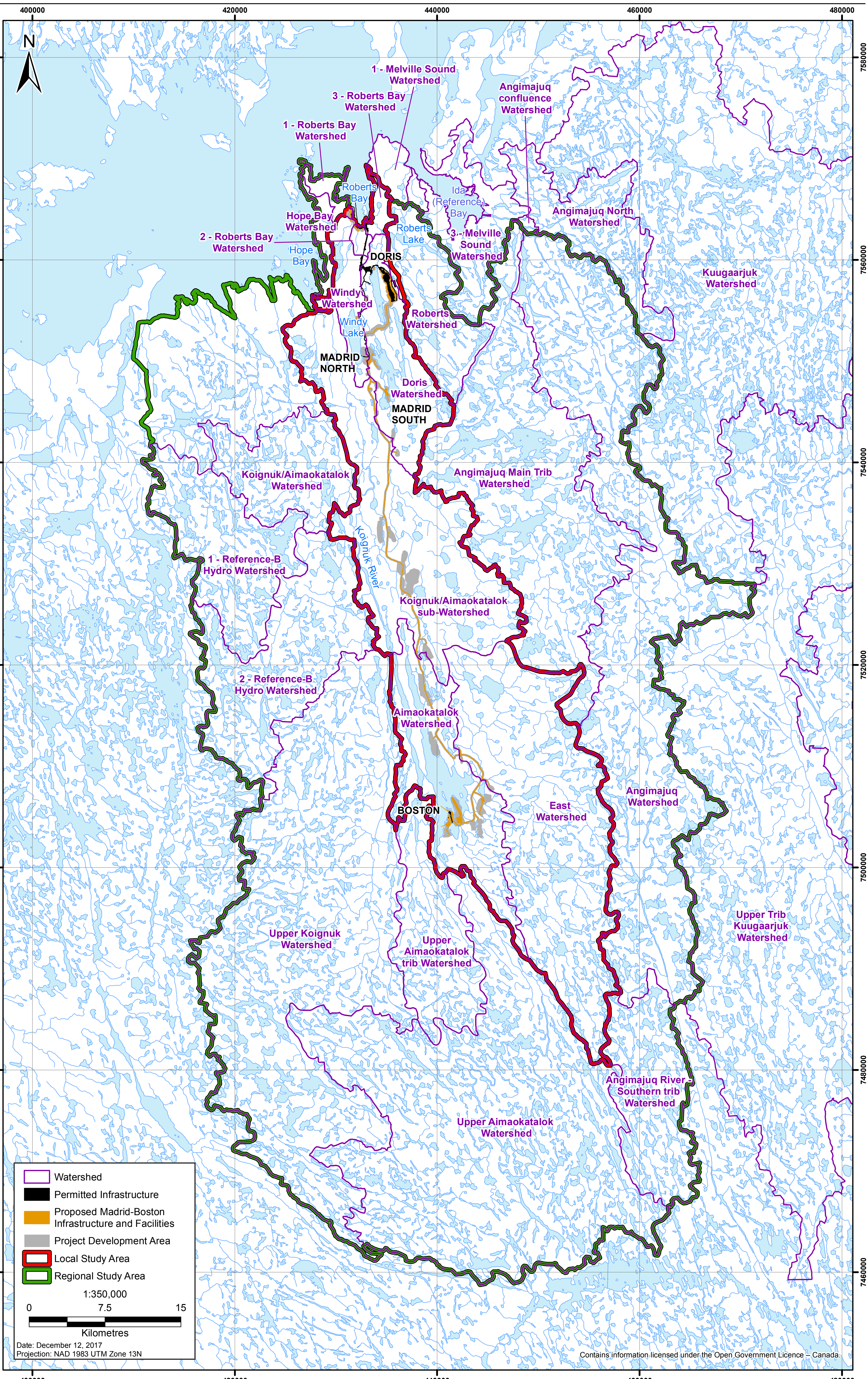


Table 4.2-1. Federal and Territorial Acts and Regulations Relevant to Freshwater Water Quality

Name of Act	Year (Year of Most Recent Amendment)	Administered by:	Relevant Regulations under the Act	Description/Purpose
Arctic Waters Pollution Prevention Act	1985 (2014)	Indigenous and Northern Affairs Canada (INAC)	Arctic Waters Pollution Prevention Regulations (C.R.C., c. 354)	• Prohibits the deposit of waste in Arctic waters unless authorized under the *Canada Water Act*, and describes limits of liability.
Fisheries Act	1985 (2016)	Fisheries and Oceans Canada (DFO); Environment and Climate Change Canada (ECCC)	Metal Mining Effluent Regulations (SOR/2002-222)	• Protects fish habitat by prohibiting any harmful alteration, disruption, or destruction of fish habitat. • Prohibits the deposition of deleterious substances into waters frequented by fish, unless authorization is granted.
Canadian Environmental Protection Act	1999 (2017)	ECCC		• Deals with the prevention of pollution and the protection of the environment and human health from toxic substances, with the goal of contributing to sustainable development. • Regulates many substances that have a deleterious effect on the environment.
Nunavut Waters and Nunavut Surface Rights Tribunal Act	2002 (2016)	INAC; NWB	Nunavut Waters Regulations (SOR/2013-69)	• Established the Nunavut Water Board (NWB) • Nunavut Waters Regulations: Establishes licensing criteria for use of waters and for deposit of waste for mining undertaking.
Environmental Protection Act	1988 (1999)	Government of Nunavut Department of Environment (GN DOE)		• Prohibits the discharge of contaminants into the environment without authorization.
Environmental Rights Act	1988 (2011)	GN DOE		• Grants all residents the ability to launch an investigation into the release of a contaminant into the environment.

4.2.2 Data Sources

The primary sources of water quality data used to describe the existing environment in lakes, streams, and rivers of the LSA and RSA are from the baseline studies conducted in 2007, 2008, 2009, 2010, and 2017, and the Aquatic Effects Monitoring Program (AEMP) for the Doris Project conducted annually from 2010 to 2017. Although water quality data have been collected historically (1992 to 2006) at some sites, only data collected from 2007 to 2017 are discussed in detail. Several activities associated with the permitted Doris Project began in 2007. Although the Doris AEMP has shown that there have been no effects of the Doris Project on the freshwater environment, data collected in the years prior to 2007 are considered representative of baseline conditions, while data collected from 2007 onward are considered representative of existing conditions. Full details of the freshwater water quality baseline programs conducted in the Hope Bay greenstone belt are described in the following reports:

- Boston Property N.W.T.: Environmental Data Report (1993) (Rescan 1993; Appendix V5-3B);
- Boston Property N.W.T.: Environmental Data Report (1994) (Rescan 1994; Appendix V5-3C);
- Doris Lake Project, Northwest Territories: 1995 Environment Study (Klohn-Crippen Consultants Ltd. 1995; Appendix V5-3D);
- Boston Property N.W.T.: Environmental Data Report 1995 (Rescan 1995; Appendix V5-3E);
- Hope Bay Belt Project: Environmental Baseline Studies Report 1996 (Rescan 1997; Appendix V5-3F);
- Hope Bay Belt Project: 1997 Environmental Data Report (Rescan 1998; Appendix V5-3G);
- Hope Bay Belt Project: 1998 Environmental Data Report (Rescan 1999a; Appendix V5-3H);
- Hope Bay Belt Site Assessment 1999 (Rescan 1999b; Appendix V5-4A);
- Hope Bay Belt Project: 2000 Supplemental Environmental Baseline Data Report (Rescan 2001; Appendix V5-3I);
- Aquatic Baseline Studies: Doris Hinge Project Data Compilation Report, 1995-2000 (RL&L / Golder 2002; Appendix V5-3J);
- Doris North Project: Aquatic Studies 2003 (RL&L / Golder 2003; Appendix V5-3K);
- Doris North Project: Aquatic Studies 2004 (Golder 2005; Appendix V5-3L);
- Doris North Project: Aquatic Studies 2005 (Golder 2006; Appendix V5-3M);
- Doris North Project: Aquatic Studies 2006 (Golder 2007; Appendix V5-3O);
- Boston and Madrid Project Areas: 2006 – 2007 Aquatic Studies (Golder Associates Ltd. 2008; Appendix V5-3P);
- Doris North Project: Aquatic Studies 2007 (Golder 2008; Appendix V5-3Q);
- Hope Bay Project: Aquatic Studies 2008 (Golder Associates Ltd. 2009; Appendix V5-3R);
- 2009 Freshwater Baseline Report, Hope Bay Belt Project (Rescan 2010a; Appendix V5-3S);
- Hope Bay Belt Project: 2010 Freshwater Baseline Report (Rescan 2011b; Appendix V5-3T);
- Doris North Gold Mine Project: 2010 Aquatic Effects Monitoring Program Report (Rescan 2011a);
- Doris North Gold Mine Project: 2011 Aquatic Effects Monitoring Program Report (Rescan 2012);
- Doris North Gold Mine Project: 2012 Aquatic Effects Monitoring Program Report (Rescan 2013);
- Doris North Project: 2013 Aquatic Effects Monitoring Program Report (ERM Rescan 2014);
- Doris North Project: 2014 Aquatic Effects Monitoring Program (ERM 2015);
- Doris North Project: 2015 Aquatic Effects Monitoring Program Report (ERM 2016);Doris Project: 2016 Aquatic Effects Monitoring Program Report (ERM 2017b);
- Doris Project: 2017 Aquatic Effects Monitoring Program Report (ERM In preparation); and
- Hope Bay Project: 2017 Madrid-Boston Freshwater Baseline Report (ERM 2017c; Appendix V5-3U).

The Doris Project Aquatic Effects Monitoring Program reports are available on the Nunavut Water Board (NWB) FTP site (ftp://ftp.nwb-oen.ca).

4.2.3 Methods

4.2.3.1 Lakes

Water quality samples and dissolved oxygen profiles were collected from 13 lakes in the LSA (10 in the North Belt and 3 in the South Belt) and 8 lakes throughout the RSA from 1992 to 2017 (Figures 4.2-3 and 4.2-4). A summary of the sampling programs from 2007 to 2017, including sampling locations and replication, is shown in Table 4.2-2.. Sampled lakes in the LSA were close to existing or proposed infrastructure, while sampled lakes in the RSA were either reference sites or far field (upstream or downstream) sites. Water quality samples were typically collected near the surface (at 1 m) and at one to two metres above the sediment-water interface; in shallow lakes, only surface or mid-column samples were collected. Dissolved oxygen profiles were collected throughout the water column. Profiles were typically collected over the deepest area of the lake or in a spatially significant location (e.g., within mine footprint, or near future tailings or waste rock piles). Multiple sites were sampled at the largest lakes including Doris, Patch, and Aimaokatalok within the LSA.

In 2007 and 2008, water quality samples were collected using a Trace Metal Acrylic Kemmerer water sampler. From 2009 to 2017, under-ice water quality samples (April, May, or June) were collected using a Niskin bottle and open-water season samples (July to September) were collected using a GO-FLO bottle. Subsamples for the various water quality parameters (e.g., nutrients, metals) were drawn from the sampling device. Lake water samples were collected from each site using clean techniques. After collection and preservation in the field, samples were transported on ice to either Maxxam Analytics Inc. (Burnaby, BC), Alberta Research Council (Vegreville, AB), or ALS Environmental (Burnaby or Vancouver, BC) for analysis of water quality parameters. Full methodologies can be found in the historical baseline and AEMP reports listed in Section 4.2.2.

Under-ice dissolved oxygen profiles were collected during late winter (April, May or June). Open-water dissolved oxygen profiles were typically collected during July, August, and September. At shallower lake stations (<10 m), dissolved oxygen values were typically recorded at 0.5 m intervals, while at deeper lake stations (>10 m), values were recorded at 1 m intervals. The profiles typically ended at approximately 0.5 to 1 m above the sediment surface to minimize the disturbance of bottom sediments.

4.2.3.2 Streams and Rivers

Water quality samples were collected from 21 streams and rivers in the LSA (11 in the North Belt and 10 in the South Belt) and 8 streams and rivers throughout the RSA from 1992 to 2017 (Figures 4.2-3 and 4.2-4). A summary of the sampling programs from 2007 to 2016 (no streams or rivers were sampled in 2017), including sampling locations and replication, is shown in Table 4.2-3. Sampled streams and rivers in the LSA were close to existing or proposed infrastructure, while sampled streams and rivers in the RSA were either reference sites or far field (upstream or downstream) sites. The Koignuk River was sampled in multiple locations within both the South Belt and the North Belt LSA.

Stream water samples were collected from each site using clean techniques. Samples were collected from stream banks or rocks to prevent contamination from sediments, or where sufficiently high flow was present, samples were collected while the sampler stood in the stream. In these instances, the bottles were held upstream of the sampler and care was taken to avoid disturbing bottom sediments. Samples were collected as grab samples, avoiding water from the stream surface. After collection and preservation in the field, samples were transported on ice to either Maxxam Analytics Inc. (Burnaby, BC), Alberta Research Council (Vegreville, AB), or ALS Environmental (Burnaby or Vancouver, BC) for analysis, as was done for lake water samples.

Table 4.2-2. Lake Water Quality Sampling Programs in the LSA and RSA, 2007 to 2017

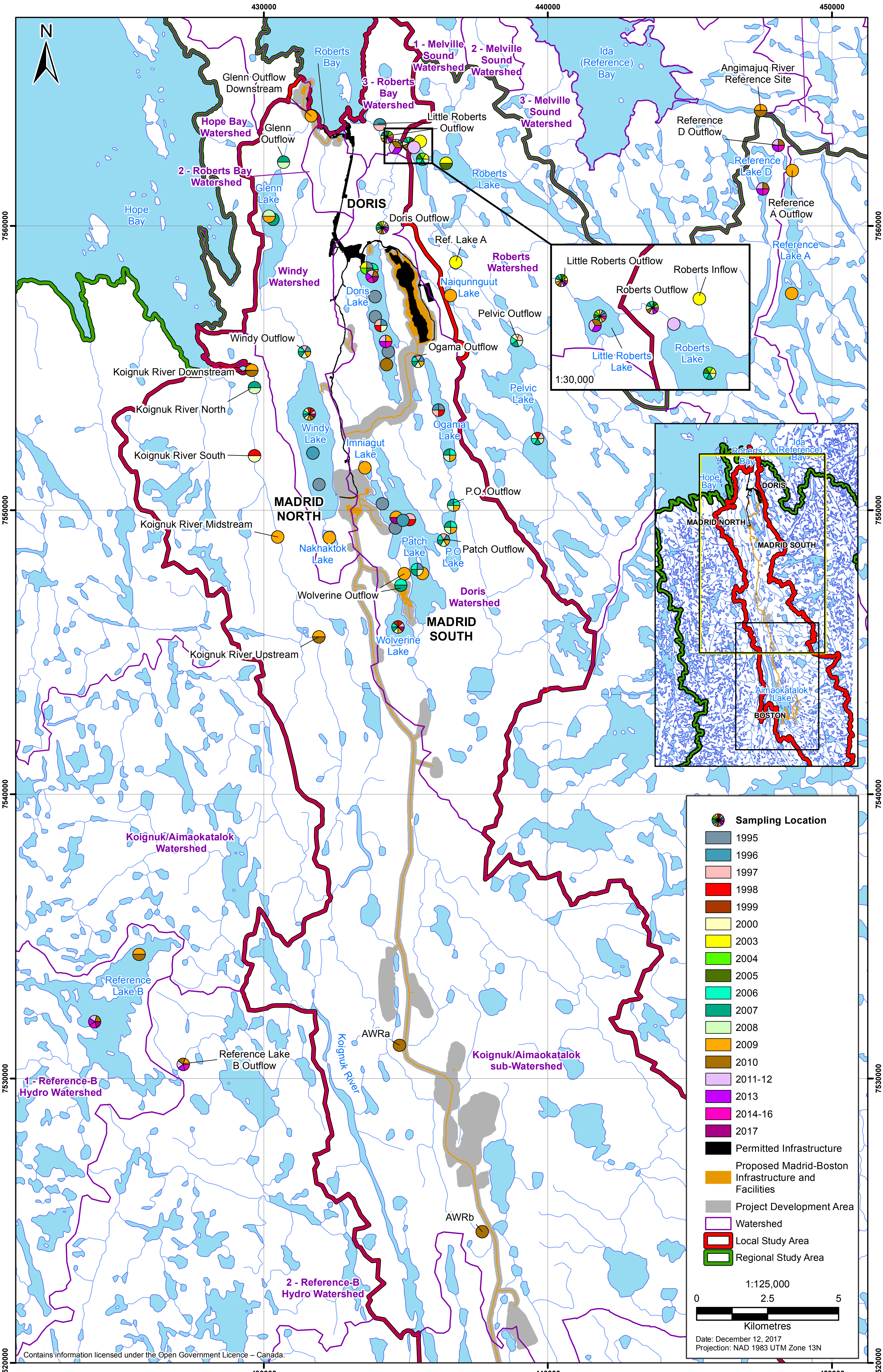
Year	2007	2008	2009	2010	2011 and 2012	2013 to 2016	2017	
Month Sampled	May July August September	May July August September	April/May August	April July August September	April July August September	April July August September	April July August September	April August
Sampling Equipment	Kemmerer Sampler, Horiba U-22 multi-parameter probe	Kemmerer Sampler, Horiba U-22 multi-parameter probe, Hach HQ40-D probe	Niskin/GO-FLO, YSI meter	Niskin/GO-FLO, YSI meter	Niskin/GO-FLO, YSI meter	Niskin/GO-FLO, YSI meter	Niskin/GO-FLO, YSI meter	Niskin/GO-FLO, YSI meter
Water Quality Parameters	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total metals	Physical parameters, anions, nutrients, total metals	Physical parameters, anions, nutrients, total metals	Physical parameters, anions, nutrients, total metals
Lakes Sampled (LSA)	North Belt Doris Glenn Little Roberts Ogama P.O. Patch Windy Wolverine South Belt Aimaokatalok Stickleback Trout	North Belt Doris Glenn Little Roberts Ogama P.O. Patch Windy Wolverine South Belt Aimaokatalok Stickleback Trout	North Belt Doris Glenn Imniagut Little Roberts Nakhaktok Ogama P.O. Patch Windy Wolverine	North Belt Doris Little Roberts Windy South Belt Aimaokatalok Stickleback Trout	North Belt Doris Little Roberts	North Belt Doris Little Roberts	North Belt Doris	North Belt Patch Windy Wolverine South Belt Aimaokatalok Stickleback

Lakes Sampled (RSA)	Boston Reference Roberts Pelvic	Boston Reference Roberts Pelvic	Naiqunnguut Reference A Reference B	Reference B Reference D	Reference B Reference D Roberts	Reference B Reference D	Reference B	
Site Replication	Duplicate samples collected at Stickleback and Doris lakes	Duplicate samples collected at Stickleback and Doris lakes	n = 1 @ shallow and deep depths + 20% replication	n = 1 @ shallow and deep depths + 20% replication	n = 1 @ shallow and deep depths + 20% replication	n = 1 @ shallow and deep depths + 20% replication	n = 1 @ shallow and deep depths + 20% replication	n = 1 @ shallow and deep depths + 10% replication

Table 4.2-3. Stream and River Water Quality Sampling Programs in the LSA and RSA, 2007 to 2016

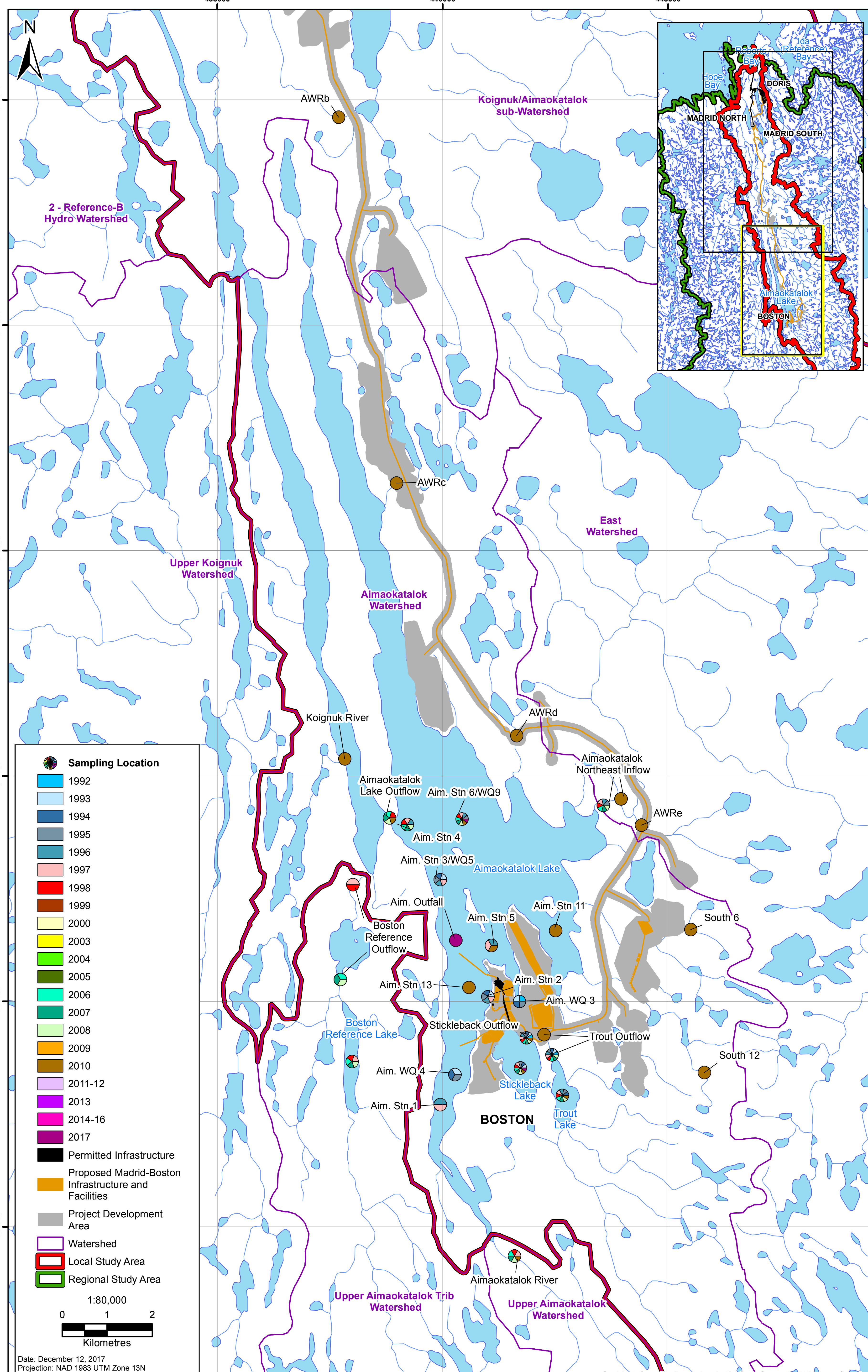
Year	2007	2008	2009	2010	2011 to 2016
Month Sampled	June July August September	June July August September	May June August September	June July August September	June July August September
Water Quality Parameters	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total metals
Sites Sampled (LSA)	North Belt Doris OF Glenn OF Koignuk River Little Roberts OF Ogama OF P.O. OF Patch OF Windy OF South Belt Aimaokatalok NE IF Aimaokatalok OF Stickleback OF Trout OF	North Belt Doris OF Glenn OF Koignuk River Little Roberts OF Ogama OF P.O. OF Patch OF Windy OF South Belt Aimaokatalok NE IF Aimaokatalok OF Stickleback OF Trout OF	North Belt Doris OF Glenn OF Koignuk River Little Roberts OF Ogama OF P.O. OF Patch OF Windy OF Wolverine OF	North Belt AWRa AWRb Doris OF Koignuk River Little Roberts OF South Belt Aimaokatalok NE IF Aimaokatalok OF AWRc AWRd AWRe Koignuk River S12 S6 Stickleback OF Trout OF	North Belt Doris OF Little Roberts OF
Sites Sampled (RSA)	Aimaokatalok River Boston Reference OF Pelvic OF Roberts OF	Aimaokatalok River Boston Reference OF Pelvic OF Roberts OF	Aimaokatalok River Angimajuk River Reference A OF Reference B OF	Aimaokatalok River Angimajuk River Reference B OF Reference D OF Roberts OF	Reference B OF Reference D OF Roberts OF
Site Replication	n = 2 at one stream (Windy, Pelvic or Ogama OF) per sampling month	n = 2 at Windy OF only	n = 2	n = 2	n = 2

Figure 4.2-3
Historical Freshwater Sampling Locations in the North Belt LSA and RSA, 1995 to 2017



Historical Freshwater Sampling Locations in the South Belt LSA and RSA, 1992 to 2017

TMAC RESOURCES



4.2.3.3 Calculation of Summary Statistics

Summary statistics were calculated for water quality parameters within the LSA (North and South belts) and the RSA. The North Belt LSA contains the Doris, Windy, and Koignuk-Aimaokatalok sub-watersheds and the South Belt LSA contains the Aimaokatalok and East watersheds (Figure 4.2-2).

For the calculation of minimum, maximum, mean, median, and the 75th and 95th percentile values for water quality parameters, one half of the value of the detection limit was substituted for sample concentrations that were below analytical detection limits.

The minimum value represents the lowest value reported for any sample after substituting one half of the detection limit for values that were below detection limits. The maximum value represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (except when all values were below detection limits, in which case the maximum represents the highest detection limit). Whenever the value of the minimum or maximum was a censored value (i.e., sample concentration below the analytical detection limit), this value was reverted back from one half of the detection limit to its raw form (i.e., reported as being less than '<' the given detection limit) in order to clearly distinguish censored values.

Water quality data collected from the same site and depth and on the same date (replicates) were averaged prior to the calculation of the mean, median, and the 75th and 95th percentiles, and for comparisons against water quality guidelines to give equal weighting to samples regardless of the degree of replication.

4.2.3.4 Quality Assurance and Quality Control

Field and equipment blanks as well as duplicate samples were collected during each lake, stream, or river survey as part of the quality assurance and quality control (QA/QC) program. All water quality samples were recorded on chain of custody forms before being sent to the analytical laboratory.

4.2.4 Characterization of Existing Conditions

Water quality is defined as a suite of chemical and physical parameters that describe the characteristics of water in terms of meeting the needs of aquatic and terrestrial organisms, ecosystem functions, human uses, and aesthetics. All water quality parameters are naturally variable due to heterogeneity in the landscape, biogeochemical cycling, weather, and climate. The baseline sampling program served to measure this natural variation such that future potential Project effects on water quality can be assessed. A summary of water quality data collected between 2007 and 2017 from the lake, stream, and river sampling program in the LSA (North and South Belt) and RSA is presented in this section.

The Canadian Council of Ministers of the Environment has established guidelines for water quality parameters to protect aquatic life (CCME 2017). The CCME guidelines are conservative empirical thresholds that are meant to be protective of all forms of aquatic life and all aspects of aquatic cycles, including the most sensitive species over the long term (CCME 2007). The water quality data are discussed within the framework of CCME guidelines where applicable.

4.2.4.1 Lakes

Lakes are important parts of the freshwater system as they are habitats for aquatic organisms, serve as water sources for many terrestrial organisms, and are significant sources of water for human uses. Lake water quality data were grouped by Project area (North Belt LSA, South Belt LSA, and RSA) to highlight general regional trends. These data are presented in Tables 4.2-4 to 4.2-9. Lake-specific data for the LSA are presented in Table 4.2-10.

Table 4.2-4. Lake Water Chemistry at LSA and RSA Sites, 2007 to 2017

Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples outside of CCME Guidelines[d]
pH									
LSA - North Belt	310	263	6.1	7.4	7.7	7.8	8.0	8.5	2.3
LSA - South Belt	67	63	6.0	6.8	7.2	7.4	7.8	8.1	11
RSA	171	131	6.1	7.1	7.3	7.4	8.0	8.2	1.5
Hardness (mg $CaCO_3$/L)									
LSA - North Belt	340	286	30.9	60.0	51.9	65.6	98.6	192	-
LSA - South Belt	82	72	9.63	32.0	14.9	24.7	103	208	-
RSA	184	142	10.7	25.6	19.6	34.4	52.1	111	-
Total Alkalinity (mg $CaCO_3$/L)									
LSA - North Belt	330	283	19.1	37.2	31.1	45.5	60.1	117	-
LSA - South Belt	76	72	7.7	20.3	10.8	19.6	84.9	125	-
RSA	179	140	8.4	16.5	13.1	20.7	30.8	51.8	-
Total Dissolved Solids (mg/L)									
LSA - North Belt	264	226	87.8	194	171	212	334	613	-
LSA - South Belt	82	72	19.9	66.3	37.9	53.0	210	436	-
RSA	125	100	17.8	81.6	58.0	119	177	417	-
Total Organic Carbon (mg/L)									
LSA - North Belt	228	203	<0.5	5.57	5.67	6.73	9.71	13.4	-
LSA - South Belt	76	72	3.90	6.14	5.15	6.05	10.6	22.4	-
RSA	96	82	2.49	5.19	4.56	6.22	9.2	18.9	-
Dissolved Organic Carbon (mg/L)									
LSA - North Belt	153	136	1.20	5.15	5.50	6.35	7.97	11.0	-
LSA - South Belt	54	48	3.60	5.38	4.68	5.11	9.80	19.7	-
RSA	69	60	1.87	5.01	4.55	5.55	7.56	16.8	-

Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples outside of CCME Guidelines[d]
Chloride (mg/L)									
LSA - North Belt	240	210	33.1	84.0	75.9	95.7	143	306	10.5
LSA - South Belt	60	50	<0.3	20.6	10.2	15.5	50.8	131	4.0
RSA	99	84	3.5	33.4	19.6	58.5	80.8	177	1.2
Fluoride (mg/L)									
LSA - North Belt	240	210	<0.01	0.068	0.060	0.080	0.120	0.25	4.8
LSA - South Belt	81	71	<0.01	0.053	0.030	0.040	0.200	0.38	8.5
RSA	103	88	<0.02	0.038	0.031	0.050	0.089	0.24	2.3
Sulphate (mg/L)									
LSA - North Belt	340	286	<0.5	4.04	2.87	4.03	10.0	15.0	-
LSA - South Belt	82	72	0.82	2.91	1.50	2.61	5.90	48.0	-
RSA	180	141	1.35	2.81	1.97	3.31	6.00	12.1	-

Notes:
'<' indicates that concentration was less than the analytical detection limit shown.
n = number of observations.
[a] *Minimum represents the lowest concentration in any sample.*
[b] *One half of the value of the analytical detection limit was substituted for values that were below detection limits, and replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, the 75th and 95th percentiles, and CCME guidelines.*
[c] *Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case maximum represents highest detection limit).*
[d] *CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed September 2017).*

Table 4.2-5. Lake Total Suspended Solids and Turbidity at LSA and RSA Sites, 2007 to 2017

Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]
TSS (mg/L)								
LSA - North Belt	340	286	<1	3.5	3.5	4.8	6.7	19.0
LSA - South Belt	82	72	<1	1.1	0.5	1.5	2.0	5.7
RSA	182	142	<1	2.1	1.2	2.0	8.9	15.3

Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]
Turbidity (NTU)								
LSA - North Belt	235	188	0.16	4.87	4.87	6.13	8.0	18.9
LSA - South Belt	28	24	0.29	1.18	1.04	1.24	2.28	5.48
RSA	145	105	0.18	1.10	0.57	1.31	3.92	5.58

Notes:
'<' indicates that concentration was less than the analytical detection limit shown.
n = number of observations.
[a] Minimum represents the lowest concentration in any sample.
[b] One half of the value of the analytical detection limit was substituted for values that were below detection limits, and replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, the 75th and 95th percentiles, and CCME guidelines.
[c] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case maximum represents highest detection limit).

Table 4.2-6. Lake Nutrient Concentrations at LSA and RSA Sites, 2007 to 2017

Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples with Concentrations above CCME Guidelines[d]
Nitrate (mg N/L)									
LSA - North Belt	336	285	<0.005	0.0152	0.0025	0.0060	0.0711	0.791	0
LSA - South Belt	82	72	<0.001	0.0379	0.0025	0.0235	0.131	1.06	0
RSA	181	141	<0.001	0.0155	0.0025	0.0124	0.0714	0.257	0
Nitrite (mg N/L)									
LSA - North Belt	340	286	<0.001	0.0007	0.0005	0.0005	0.0017	0.0080	0
LSA - South Belt	82	72	<0.001	0.0016	0.0005	0.0025	0.0025	0.0200	0
RSA	182	142	<0.001	0.0007	0.0005	0.0005	0.0018	0.0160	0
Ammonia (mg N/L)									
LSA - North Belt	340	286	0.002	0.011	0.005	0.009	0.030	0.240	0
LSA - South Belt	82	72	<0.005	0.019	0.009	0.013	0.064	0.260	0
RSA	184	142	<0.005	0.016	0.004	0.009	0.031	0.520	0

Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples with Concentrations above CCME Guidelines[d]
Total Phosphorus (mg P/L)									
LSA - North Belt	340	286	<0.002	0.0209	0.0214	0.0270	0.0350	0.188	-
LSA - South Belt	82	72	0.0028	0.0132	0.0110	0.0143	0.0268	0.039	-
RSA	182	142	0.0020	0.0137	0.0064	0.0150	0.0440	0.162	-

Notes:
'<' indicates that concentration was less than the analytical detection limit shown.
n = number of observations.
[a] Minimum represents the lowest concentration in any sample.
[b] One half of the value of the analytical detection limit was substituted for values that were below detection limits, and replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, the 75th and 95th percentiles, and CCME guidelines.
[c] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case maximum represents highest detection limit).
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed September 2017).

Table 4.2-7. Trophic Status of Lakes by Total Phosphorus Trigger Ranges[a], 2007 to 2017

Trophic Status	Total Phosphorus Concentration (mg/L)	LSA - North Belt	LSA - South Belt	RSA
Ultra-Oligotrophic	<0.004	Patch, Windy	Aimaokatalok	Reference A, Reference B, Reference D
Oligotrophic	0.004-0.01	Doris, Glenn, Imniagut, Patch, P.O., Windy	Aimaokatalok, Stickleback	Naiqunnguut, Reference A, Reference B, Reference D, Roberts
Mesotrophic	0.01-0.02	Doris, Glenn, Little Roberts Ogama, Patch, P.O., Windy, Wolverine	Aimaokatalok, Stickleback, Trout	Boston Reference, Reference B, Reference D, Roberts
Meso-eutrophic	0.02-0.035	Doris, Glenn, Little Roberts, Ogama, P.O.	Aimaokatalok, Stickleback, Trout	Boston Reference, Pelvic, Reference D, Roberts
Eutrophic	0.035-0.1	Doris, Little Roberts Nakhaktok, Ogama, Patch, Wolverine	Trout	Pelvic, Reference D
Hyper-eutrophic	<0.1	P.O.	-	Boston Reference, Pelvic

Notes:
Total phosphorus concentrations may vary between years and seasons; as a result, lakes may be listed under multiple trigger ranges.
[a] *Trigger ranges from Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems (CCME 2004).*

Table 4.2-8. Lake Total Metal Concentrations at LSA and RSA Sites, 2007 to 2017

Parameter	Total Metal Concentration (mg/L)						% of Samples with Concentrations greater than CCME Guidelines[d]
	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	
LSA - North Belt	**n = 340**	**n = 286**	**n = 286**	**n = 286**	**n = 286**	**n = 340**	**n = 286**
Aluminum	0.0040	0.112	0.059	0.101	0.401	1.05	25
Arsenic	<0.0004	0.00043	0.00033	0.00053	0.00082	0.00231	0
Boron	0.0142	0.0329	0.0295	0.0384	0.0568	0.0980	0
Cadmium	<0.000002	0.0000047	0.0000025	0.0000044	0.000012	0.000193	0.3
Chromium	0.00010	0.00039	0.00025	0.00043	0.00100	0.00182	4.5% (Cr (VI)); 0% (Cr (III))[e]

Parameter	Total Metal Concentration (mg/L)						% of Samples with Concentrations greater than CCME Guidelines[d]
	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	
Copper	0.000306	0.00164	0.00149	0.00175	0.00300	0.00592	16
Iron	<0.002	0.159	0.120	0.193	0.476	1.70	12
Lead	<0.000001	0.000146	0.000051	0.000130	0.000711	0.00237	2.1
Mercury	<0.0000005	0.0000017	0.0000008	0.0000023	0.0000050	0.000012	0
Molybdenum	0.000055	0.000272	0.000199	0.000244	0.000704	0.00115	0
Nickel	0.000005	0.00065	0.00057	0.00072	0.00117	0.00701	0
Selenium	<0.0001	0.00053	0.00010	0.00090	0.00160	0.00657	19
Silver	<0.0000005	0.0000033	0.0000025	0.0000037	0.0000079	0.0000681	0
Thallium	<0.0000003	0.0000094	0.0000025	0.0000050	0.0000500	0.000018	0
Uranium	0.0000205	0.000072	0.000042	0.000060	0.000253	0.000335	0
Zinc	<0.0001	0.00359	0.00150	0.00150	0.00413	0.372	1.0
LSA - South Belt	**n = 82**	**n = 72**	**n = 72**	**n = 72**	**n = 72**	**n = 82**	**n = 72**
Aluminum	0.0034	0.0485	0.0439	0.0602	0.122	0.155	21
Arsenic	0.00003	0.00024	0.00018	0.00024	0.00051	0.00121	0
Boron	0.0020	0.0089	0.0053	0.0103	0.0223	0.0450	0
Cadmium	<0.000002	0.0000032	0.0000024	0.0000038	0.0000101	0.0000240	0
Chromium	0.00004	0.00034	0.00025	0.00036	0.00100	0.00180	4.2% (Cr (VI)); 0% (Cr (III))[e]
Copper	0.000233	0.00112	0.00100	0.00128	0.00208	0.00529	5.6
Iron	0.013	0.173	0.094	0.128	0.415	2.81	13
Lead	<0.000001	0.00012	0.00003	0.00007	0.00053	0.00209	1.4
Mercury	<0.0000005	0.0000018	0.0000010	0.0000025	0.0000050	0.0000080	0
Molybdenum	0.000011	0.000051	0.000044	0.000059	0.000113	0.000260	0
Nickel	<0.000005	0.00055	0.00043	0.00060	0.00115	0.00302	0
Selenium	<0.0001	0.00035	0.00025	0.00042	0.00063	0.00436	2.8
Silver	<0.0000005	0.0000039	0.0000027	0.0000050	0.0000119	0.0000200	0
Thallium	<0.0000003	0.0000113	0.0000025	0.0000044	0.0000500	0.0000071	0
Uranium	0.000008	0.000026	0.000023	0.000029	0.000043	0.000117	0
Zinc	<0.0001	0.00230	0.00150	0.00216	0.00666	0.0208	0
RSA	**n = 184**	**n = 142**	**n = 142**	**n = 142**	**n = 142**	**n = 184**	**n = 142**
Aluminum	<0.003	0.065	0.018	0.085	0.238	0.644	21
Arsenic	<0.0001	0.00025	0.00013	0.00037	0.00080	0.00130	0
Boron	0.0031	0.0153	0.0122	0.0210	0.0339	0.0427	0
Cadmium	<0.000002	0.0000040	0.0000025	0.0000025	0.0000118	0.0000551	0
Chromium	<0.0001	0.00035	0.00025	0.00030	0.00073	0.00330	4.9% (Cr (VI)); 0% (Cr (III))[e]
Copper	<0.001	0.00131	0.00120	0.00158	0.00212	0.00726	6.3
Iron	<0.01	0.183	0.060	0.165	0.859	2.76	11
Lead	<0.000001	0.00026	0.00006	0.00010	0.00059	0.0138	4.2
Mercury	<0.0000005	0.0000017	0.0000006	0.0000015	0.0000050	0.000034	0.7

Parameter	Total Metal Concentration (mg/L)						% of Samples with Concentrations greater than CCME Guidelines[d]
	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	
Molybdenum	<0.00005	0.000086	0.000056	0.000124	0.000209	0.000288	0
Nickel	<0.0002	0.00044	0.00035	0.00054	0.00123	0.00320	0
Selenium	<0.0001	0.00029	0.00010	0.00030	0.00100	0.00210	4.9
Silver	<0.0000005	0.0000029	0.0000025	0.0000025	0.000005	0.000011	0
Thallium	<0.0000003	0.0000057	0.0000025	0.0000028	0.0000500	0.0000080	0
Uranium	0.0000194	0.000042	0.000041	0.000048	0.000063	0.000086	0
Zinc	<0.0001	0.0030	0.0015	0.0015	0.0044	0.166	0.7

Notes:
'<' indicates that concentration was less than the analytical detection limit shown.
n = number of observations.
[a] *Minimum represents the lowest concentration in any sample.*
[b] *One half of the value of the analytical detection limit was substituted for values that were below detection limits, and replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, the 75th and 95th percentiles, and CCME guidelines.*
[c] *Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case maximum represents highest detection limit).*
[d] *CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed September 2017).*
[e] *The CCME guideline for chromium is dependent on its speciation (Cr(VI) or Cr(III)). Routine metal analysis does not distinguish between chromium species,so total chromium results were used to compare with CCME guidelines to be conservative.*

General Parameters

General chemical characteristics of freshwater include: pH, alkalinity, hardness, conductivity, total dissolved solids, and major ions. pH is an important indicator that describes the acid-base balance of water and influences many chemical reactions that can, in turn, shape biological communities. Alkalinity describes the buffering capacity of water, while hardness and total dissolved solids are measures related to the quantity of dissolved ions and other materials in the water. The toxicity of some metals and compounds may depend on the pH or hardness of the water. Chloride and fluoride are also discussed among the general water quality parameters as these ions are naturally occurring in freshwater but can become toxic to aquatic organisms at high concentrations.

Between 2007 and 2017, pH levels ranged from 6.0 to 8.5 in LSA lakes and 6.1 to 8.2 in RSA lakes (Table 4.2-4). pH levels occasionally dropped below the lower limit of the CCME pH guideline range of 6.5 to 9.0 (CCME 2017).

Lake water hardness varied widely among lakes in the LSA and RSA (9.63 to 208 mg $CaCO_3$/L in the LSA and 10.7 to 111 mg $CaCO_3$/L in the RSA; Table 4.2-4). Within the LSA, Aimaokatalok Lake had particularly soft water, with an average hardness of 14.0 mg $CaCO_3$/L (Table 4.2-10). The other lakes in the LSA would generally be considered soft (< 60 mg $CaCO_3$/L) to moderately hard (60 to 120 mg $CaCO_3$/L; Table 4.2-10).

Alkalinity ranged from 7.7 to 125 mg $CaCO_3$/L in the LSA and 8.4 to 51.8 mg $CaCO_3$/L in the RSA (Table 4.2-4). Aimaokatalok Lake in the South Belt LSA was particularly acid-sensitive, with a mean alkalinity of only 10.0 mg $CaCO_3$/L (Table 4.2-10). Aimaokatalok Lake was the only LSA lake with a mean alkalinity below 20 mg $CaCO_3$/L (Table 4.2-10).

Table 4.2-9. Lake Free Cyanide Concentrations at LSA and RSA Sites, 2011 to 2017

Parameter	n (min, max)	n (mean)	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]	% of Samples with Concentrations Greater than CCME Guideline[d]
Free Cyanide (mg/L)									
LSA - North Belt	153	121	<0.001	0.0006	0.0005	0.0005	0.0012	0.0020	0
LSA - South Belt	11	10	<0.001	all concentrations below the detection limit				<0.001	0
RSA	109	74	<0.001	0.0006	0.00050	0.00050	0.0018	0.0034	0

Notes:
'<' indicates that concentration was less than the analytical detection limit shown.
n = number of observations.
[a] Minimum represents the lowest concentration in any sample.
[b] One half of the value of the analytical detection limit was substituted for values that were below detection limits, and replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, the 75th and 95th percentiles, and CCME guidelines.
[c] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case maximum represents highest detection limit).
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed September 2017).

Table 4.2-10. Lake-specific Water Quality Summary, 2007 to 2017

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Aimaokatalok	Hardness (as $CaCO_3$)	54	51	9.6	14.0	13.2	15.8	19.7	21.3	-
Aimaokatalok	pH	45	42	6.00	6.71	7.12	7.23	7.44	8.01	14%
Aimaokatalok	Total Suspended Solids	54	51	<1	0.9	0.5	1.5	2.0	4.0	-
Aimaokatalok	Total Dissolved Solids	54	51	19.9	33.4	30.0	38.6	53.0	55.0	-
Aimaokatalok	Turbidity (NTU)	20	17	0.29	0.91	1.02	1.14	1.42	1.53	-
Aimaokatalok	Total Alkalinity (as $CaCO_3$)	54	51	7.70	10.0	9.6	11.4	12.9	13.6	-
Aimaokatalok	Ammonia (as N)	54	51	<0.005	0.0097	0.0080	0.0115	0.0170	0.0830	0%
Aimaokatalok	Nitrate (as N)	54	51	<0.001	0.0275	0.0005	0.0424	0.130	0.171	0%
Aimaokatalok	Nitrite (as N)	54	51	<0.001	0.0013	0.0005	0.0025	0.0025	0.0040	0%
Aimaokatalok	Total Phosphorus	54	51	0.0028	0.0110	0.0110	0.0130	0.0210	0.0270	-
Aimaokatalok	Total Organic Carbon	54	51	3.90	5.15	4.97	5.40	7.05	8.30	-

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Aimaokatalok	Dissolved Organic Carbon	34	34	3.6	4.5	4.5	4.9	5.3	5.7	-
Aimaokatalok	Chloride	37	34	6.3	10.1	9.2	13.6	14.5	16.2	0%
Aimaokatalok	Fluoride	53	50	<0.01	0.038	0.026	0.031	0.120	0.210	6%
Aimaokatalok	Sulphate (SO_4)	54	51	1.13	2.32	1.50	2.46	4.50	12.0	-
Aimaokatalok	Free Cyanide	8	8	<0.001	all concentrations below detection limits				<0.001	0%
Aimaokatalok	Aluminum	54	51	0.011	0.045	0.048	0.057	0.073	0.086	14%
Aimaokatalok	Arsenic	54	51	0.00003	0.00017	0.00017	0.00019	0.00023	0.00033	0%
Aimaokatalok	Boron	54	51	0.0020	0.0058	0.0050	0.0072	0.0106	0.0117	0%
Aimaokatalok	Cadmium	54	51	<0.000002	0.0000030	0.0000022	0.0000035	0.0000075	0.0000240	0%
Aimaokatalok	Chromium	54	51	<0.0002	0.00029	0.00025	0.00030	0.00048	0.00120	Cr(III) 0%; Cr(VI) 2%
Aimaokatalok	Copper	54	51	<0.001	0.00107	0.00100	0.00118	0.00156	0.00230	2%
Aimaokatalok	Iron	54	51	0.013	0.080	0.083	0.111	0.141	0.153	0%
Aimaokatalok	Lead	54	51	<0.000001	0.000083	0.000025	0.000048	0.000435	0.000694	0%
Aimaokatalok	Mercury	54	51	<0.0000006	0.0000015	0.0000008	0.0000015	0.0000050	0.0000023	0%
Aimaokatalok	Molybdenum	54	51	0.000013	0.000041	0.000042	0.000053	0.000073	0.000077	0%
Aimaokatalok	Nickel	54	51	0.00027	0.00049	0.00043	0.00052	0.00085	0.00143	0%
Aimaokatalok	Selenium	54	51	<0.0001	0.00031	0.00020	0.00035	0.00050	0.00436	2%
Aimaokatalok	Silver	54	51	<0.0000005	0.0000037	0.0000025	0.0000050	0.0000106	0.0000200	0%
Aimaokatalok	Thallium	54	51	<0.0000003	0.0000102	0.0000025	0.0000036	0.0000500	0.0000049	0%
Aimaokatalok	Uranium	54	51	0.000017	0.000024	0.000023	0.000026	0.000038	0.000043	0%
Aimaokatalok	Zinc	54	51	<0.0001	0.0021	0.0015	0.0022	0.0045	0.0160	0%
Doris	Hardness (as $CaCO_3$)	164	137	42.9	50.7	49.1	53.7	61.1	64.2	-
Doris	pH	152	132	6.05	7.37	7.64	7.71	7.85	8.00	2%
Doris	Total Alkalinity (as $CaCO_3$)	156	136	23.2	30.5	29.2	32.8	37.4	40.6	-
Doris	Total Suspended Solids	164	137	<1	4.3	4.2	5.4	6.3	19.0	-
Doris	Total Dissolved Solids	106	89	118	163	162	175	200	210	-
Doris	Turbidity (NTU)	140	120	0.55	5.26	5.37	6.21	7.42	8.49	-
Doris	Ammonia (as N)	164	137	<0.005	0.0074	0.003	0.0070	0.0300	0.0907	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Doris	Nitrate (as N)	160	136	<0.005	0.0163	0.0025	0.0025	0.0753	0.791	0%
Doris	Nitrite (as N)	164	137	<0.001	0.00059	0.00050	0.00050	0.00050	0.00770	0%
Doris	Total Phosphorus	164	137	0.0047	0.0247	0.0258	0.0280	0.0322	0.0487	-
Doris	Total Organic Carbon	78	69	4.99	6.57	6.55	6.92	8.33	8.62	-
Doris	Dissolved Organic Carbon	56	49	4.50	6.16	6.04	6.54	7.63	7.86	-
Doris	Chloride	90	76	53.6	65.7	62.4	74.0	81.1	83.1	0%
Doris	Fluoride	90	76	0.037	0.056	0.053	0.060	0.070	0.180	3%
Doris	Sulphate (SO_4)	164	137	<3.00	2.82	2.70	3.11	3.58	6.00	-
Doris	Free Cyanide	102	89	<0.001	0.00061	0.0005	0.0005	0.00122	0.00200	0%
Doris	Aluminum	164	137	0.004	0.052	0.050	0.068	0.098	0.329	7%
Doris	Arsenic	164	137	<0.0004	0.00034	0.00030	0.00034	0.00059	0.00110	0%
Doris	Boron	164	137	<0.03	0.0284	0.0283	0.0315	0.0372	0.0617	0%
Doris	Cadmium	164	137	<0.000002	0.0000049	0.0000025	0.0000025	0.0000085	0.000193	1%
Doris	Chromium	164	137	0.00010	0.00028	0.00025	0.00025	0.00048	0.00120	Cr(III) 0%; Cr(VI) 1%
Doris	Copper	164	137	0.00111	0.00158	0.00151	0.00166	0.00232	0.00312	11%
Doris	Iron	164	137	<0.002	0.111	0.098	0.150	0.239	0.629	1%
Doris	Lead	164	137	<0.000001	0.000125	0.000025	0.000077	0.000614	0.00223	2%
Doris	Mercury	164	137	<0.0000005	0.0000016	0.0000008	0.0000016	0.0000050	0.0000068	0%
Doris	Molybdenum	164	137	0.00011	0.00019	0.00018	0.00021	0.00024	0.00046	0%
Doris	Nickel	164	137	0.00029	0.00057	0.00056	0.00065	0.00082	0.00135	0%
Doris	Selenium	164	137	<0.0001	0.00023	0.00010	0.00010	0.00109	0.00143	7%
Doris	Silver	164	137	<0.0000005	0.0000029	0.0000025	0.0000025	0.0000050	0.0000681	0%
Doris	Thallium	164	137	<0.0000003	0.0000046	0.0000010	0.0000025	0.0000500	0.0000098	0%
Doris	Uranium	164	137	0.000021	0.000037	0.000036	0.000040	0.000050	0.000071	0%
Doris	Zinc	164	137	<0.0001	0.0055	0.0015	0.0015	0.0036	0.372	2%
Glenn	Hardness (as $CaCO_3$)	19	18	57.1	73.1	69.0	79.8	88.6	89.6	-
Glenn	pH	14	13	7.20	7.65	7.80	8.20	8.51	8.51	0%
Glenn	Total Alkalinity (as $CaCO_3$)	17	16	41.4	51.2	48.7	57.6	60.4	60.5	-

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Glenn	Total Suspended Solids	19	18	<1	2.7	2.0	3.0	7.0	7.0	-
Glenn	Total Dissolved Solids	19	18	162	208	199	231	259	260	-
Glenn	Turbidity (NTU)	5	4	12.3	15.0	15.2	17.0	17.3	17.4	-
Glenn	Ammonia (as N)	19	18	<0.005	0.00773	0.00800	0.00968	0.0110	0.0110	0%
Glenn	Nitrate (as N)	19	18	<0.005	0.0147	0.0078	0.0215	0.0446	0.049	0%
Glenn	Nitrite (as N)	19	18	<0.001	0.00064	0.00050	0.00050	0.00115	0.00200	0%
Glenn	Total Phosphorus	19	18	0.0050	0.0137	0.0135	0.0170	0.0262	0.0270	-
Glenn	Total Organic Carbon	19	18	3.14	4.00	3.89	4.06	5.24	5.26	-
Glenn	Dissolved Organic Carbon	14	14	3.00	3.68	3.60	3.85	4.27	4.40	-
Glenn	Chloride	19	18	68.0	84.9	82.1	94.2	102	105	0%
Glenn	Fluoride	19	18	0.055	0.079	0.076	0.088	0.103	0.120	0%
Glenn	Sulphate (SO_4)	19	18	6.00	10.6	11.0	12.0	14.3	15.0	-
Glenn	Free Cyanide	0	0	-	-	-	-	-	-	-
Glenn	Aluminum	19	18	0.054	0.554	0.555	0.891	1.02	1.05	92%
Glenn	Arsenic	19	18	<0.0005	0.00057	0.00056	0.00068	0.00074	0.00077	0%
Glenn	Boron	19	18	0.0329	0.0421	0.0396	0.0472	0.0527	0.0538	0%
Glenn	Cadmium	19	18	<0.000002	0.0000063	0.0000050	0.0000096	0.0000127	0.000016	0%
Glenn	Chromium	19	18	0.00020	0.00093	0.00095	0.00132	0.00167	0.00182	Cr(III) 0%; Cr(VI) 39%
Glenn	Copper	19	18	0.00220	0.00321	0.00302	0.00364	0.00396	0.00424	100%
Glenn	Iron	19	18	<0.002	0.353	0.361	0.513	0.783	0.821	67%
Glenn	Lead	19	18	0.000020	0.000291	0.000258	0.000424	0.000567	0.00081	0%
Glenn	Mercury	19	18	<0.0000006	0.0000015	0.0000007	0.0000011	0.0000050	0.0000011	0%
Glenn	Molybdenum	19	18	0.00058	0.00071	0.00067	0.00077	0.00086	0.00086	0%
Glenn	Nickel	19	18	0.00059	0.00107	0.00100	0.00131	0.00162	0.00206	0%
Glenn	Selenium	19	18	0.00022	0.00097	0.00109	0.00134	0.00192	0.00200	56%
Glenn	Silver	19	18	<0.0000005	0.0000043	0.0000047	0.0000051	0.0000097	0.0000139	0%
Glenn	Thallium	19	18	<0.0000003	0.0000172	0.0000088	0.0000176	0.0000500	0.0000180	0%
Glenn	Uranium	19	18	0.000227	0.000289	0.000294	0.000320	0.000330	0.000335	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Glenn	Zinc	19	18	0.0007	0.0024	0.0017	0.0034	0.0048	0.005	0%
Imniagut	Hardness (as $CaCO_3$)	1	1	66.2	66.2	66.2	66.2	66.2	66.2	-
Imniagut	pH	1	1	7.63	7.63	7.63	7.63	7.63	7.63	0%
Imniagut	Total Alkalinity (as $CaCO_3$)	1	1	23.3	23.3	23.3	23.3	23.3	23.3	-
Imniagut	Total Suspended Solids	1	1	<3	1.5	1.5	1.5	1.5	<3	-
Imniagut	Total Dissolved Solids	1	1	209	209	209	209	209	209	-
Imniagut	Turbidity (NTU)	1	1	1.1	1.1	1.1	1.1	1.1	1.1	-
Imniagut	Ammonia (as N)	1	1	0.0259	0.0259	0.0259	0.0259	0.0259	0.0259	0%
Imniagut	Nitrate (as N)	1	1	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0%
Imniagut	Nitrite (as N)	1	1	<0.001	all concentrations below detection limits				<0.001	0%
Imniagut	Total Phosphorus	1	1	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	-
Imniagut	Total Organic Carbon	1	1	6.05	6.05	6.05	6.05	6.05	6.05	-
Imniagut	Dissolved Organic Carbon	0	0	-	-	-	-	-	-	-
Imniagut	Chloride	1	1	72.6	72.6	72.6	72.6	72.6	72.6	0%
Imniagut	Fluoride	1	1	0.034	0.034	0.034	0.034	0.034	0.034	0%
Imniagut	Sulphate (SO_4)	1	1	2.44	2.44	2.44	2.44	2.44	2.44	-
Imniagut	Free Cyanide	0	0	-	-	-	-	-	-	-
Imniagut	Aluminum	1	1	0.038	0.038	0.038	0.038	0.038	0.038	0%
Imniagut	Arsenic	1	1	<0.0005	all concentrations below detection limits				<0.0005	0%
Imniagut	Boron	1	1	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0%
Imniagut	Cadmium	1	1	<0.00001	all concentrations below detection limits				<0.00001	0%
Imniagut	Chromium	1	1	0.00055	0.00055	0.00055	0.00055	0.00055	0.00055	Cr(III) 0%; Cr(VI) 0%
Imniagut	Copper	1	1	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0%
Imniagut	Iron	1	1	0.106	0.106	0.106	0.106	0.106	0.106	0%
Imniagut	Lead	1	1	0.00044	0.00044	0.00044	0.00044	0.00044	0.00044	0%
Imniagut	Mercury	1	1	<0.00001	all concentrations below detection limits				<0.00001	0%
Imniagut	Molybdenum	1	1	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0%
Imniagut	Nickel	1	1	0.00447	0.00447	0.00447	0.00447	0.00447	0.00447	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Imniagut	Selenium	1	1	<0.008	0.00400	0.00400	0.00400	0.00400	<0.008	0%
Imniagut	Silver	1	1	<0.00001	all concentrations below detection limits				<0.00001	0%
Imniagut	Thallium	1	1	<0.0001	all concentrations below detection limits				<0.0001	0%
Imniagut	Uranium	1	1	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0%
Imniagut	Zinc	1	1	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0%
Little Roberts	Hardness (as $CaCO_3$)	58	37	37.2	63.0	45.5	54.1	124	192	-
Little Roberts	pH	57	36	6.42	7.30	7.58	7.68	7.92	8.12	3%
Little Roberts	Total Alkalinity (as $CaCO_3$)	58	37	23.0	36.2	26.9	29.8	69.9	105	-
Little Roberts	Total Suspended Solids	58	37	<1	3.6	3.0	4.3	7.2	12.5	-
Little Roberts	Total Dissolved Solids	40	25	122	216	154	183	562	613	-
Little Roberts	Turbidity (NTU)	50	29	0.27	4.08	4.04	4.54	6.62	7.99	-
Little Roberts	Ammonia (as N)	58	37	<0.005	0.021	0.004	0.011	0.122	0.240	0%
Little Roberts	Nitrate (as N)	58	37	<0.005	0.0175	0.0025	0.0067	0.1158	0.1550	0%
Little Roberts	Nitrite (as N)	58	37	<0.001	0.0009	0.0005	0.0005	0.0026	0.0080	0%
Little Roberts	Total Phosphorus	58	37	0.011	0.023	0.022	0.024	0.037	0.085	-
Little Roberts	Total Organic Carbon	32	22	4.73	7.12	6.33	7.96	11.4	11.8	-
Little Roberts	Dissolved Organic Carbon	24	16	4.2	6.7	5.9	7.3	10.8	11.0	-
Little Roberts	Chloride	32	22	55.6	92.5	62.4	122	179	306	27%
Little Roberts	Fluoride	32	22	<0.01	0.062	0.050	0.076	0.129	0.150	9%
Little Roberts	Sulphate (SO_4)	58	37	<3	5.31	4.00	6.00	10.6	14.0	-
Little Roberts	Free Cyanide	40	22	<0.001	0.00064	0.0005	0.0005	0.00118	0.00120	0%
Little Roberts	Aluminum	58	37	0.008	0.085	0.082	0.117	0.156	0.224	42%
Little Roberts	Arsenic	58	37	<0.0004	0.00046	0.00030	0.00048	0.00105	0.00231	0%
Little Roberts	Boron	58	37	<0.035	0.0365	0.0295	0.0446	0.0658	0.0980	0%
Little Roberts	Cadmium	58	37	<0.000002	0.0000041	0.0000025	0.0000027	0.0000119	0.0000162	0%
Little Roberts	Chromium	58	37	<0.0005	0.00033	0.00025	0.00029	0.00064	0.00159	Cr(III) 0%; Cr(VI) 0%
Little Roberts	Copper	58	37	0.00129	0.00197	0.00161	0.00234	0.00299	0.00592	22%
Little Roberts	Iron	58	37	0.060	0.286	0.186	0.287	0.610	1.70	24%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Little Roberts	Lead	58	37	<0.00005	0.000190	0.000062	0.000113	0.00108	0.00237	8%
Little Roberts	Mercury	58	37	<0.0000005	0.0000017	0.0000008	0.0000026	0.0000050	0.0000043	0%
Little Roberts	Molybdenum	58	37	0.00012	0.00021	0.00020	0.00024	0.00030	0.00038	0%
Little Roberts	Nickel	58	37	<0.0007	0.00070	0.00066	0.00078	0.00115	0.00145	0%
Little Roberts	Selenium	58	37	<0.0002	0.00044	0.00010	0.00025	0.00109	0.00657	8%
Little Roberts	Silver	58	37	<0.0000005	0.0000028	0.0000003	0.0000003	0.0000050	0.0000142	0%
Little Roberts	Thallium	58	37	0.0000003	0.0000046	0.0000023	0.0000026	0.0000150	0.0000063	0%
Little Roberts	Uranium	58	37	0.000032	0.000047	0.000043	0.000053	0.000070	0.000076	0%
Little Roberts	Zinc	58	37	<0.0001	0.00149	0.0015	0.0015	0.00237	0.00340	0%
Nakhaktok	Hardness (as $CaCO_3$)	3	3	86.8	106.9	89.8	116.9	139	144	-
Nakhaktok	pH	3	3	7.66	7.69	7.69	7.70	7.72	7.72	0%
Nakhaktok	Total Alkalinity (as $CaCO_3$)	3	3	56.0	65.8	57.7	70.7	81.1	83.7	-
Nakhaktok	Total Suspended Solids	3	3	10.0	11.6	11.0	12.4	13.5	13.8	-
Nakhaktok	Total Dissolved Solids	3	3	316	381	318	414	490	509	-
Nakhaktok	Turbidity (NTU)	3	3	14.6	16.7	16.6	17.8	18.7	18.9	-
Nakhaktok	Ammonia (as N)	3	3	<0.005	0.033	0.010	0.049	0.080	0.088	0%
Nakhaktok	Nitrate (as N)	3	3	<0.005	0.0107	0.0025	0.0148	0.0246	0.0271	0%
Nakhaktok	Nitrite (as N)	3	3	<0.001	all concentrations below detection limits				<0.001	0%
Nakhaktok	Total Phosphorus	3	3	0.054	0.068	0.056	0.075	0.091	0.095	-
Nakhaktok	Total Organic Carbon	3	3	9.66	10.93	9.72	11.56	13.0	13.4	-
Nakhaktok	Dissolved Organic Carbon	0	0	-	-	-	-	-	-	-
Nakhaktok	Chloride	3	3	135	164	138	179	212	220	100%
Nakhaktok	Fluoride	3	3	0.050	0.070	0.056	0.080	0.099	0.104	0%
Nakhaktok	Sulphate (SO_4)	3	3	3.88	5.19	3.95	5.84	7.35	7.73	-
Nakhaktok	Free Cyanide	0	0	-	-	-	-	-	-	-
Nakhaktok	Aluminum	3	3	0.0200	0.0267	0.0295	0.0300	0.0304	0.0305	0%
Nakhaktok	Arsenic	3	3	<0.0008	all concentrations below detection limits				<0.002	0%
Nakhaktok	Boron	3	3	0.0454	0.0551	0.0457	0.0600	0.0714	0.0742	0%
Nakhaktok	Cadmium	3	3	<0.00001	all concentrations below detection limits				<0.00002	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Nakhaktok	Chromium	3	3	0.00047	0.00072	0.00048	0.00084	0.00113	0.00120	Cr(III) 0%; Cr(VI) 33%
Nakhaktok	Copper	3	3	0.00092	0.00108	0.00097	0.00116	0.00131	0.00135	0%
Nakhaktok	Iron	3	3	0.122	0.229	0.281	0.283	0.285	0.285	0%
Nakhaktok	Lead	3	3	<0.0001	0.000074	0.000078	0.000086	0.000092	0.000093	0%
Nakhaktok	Mercury	3	3	<0.00001	all concentrations below detection limits				<0.00001	0%
Nakhaktok	Molybdenum	3	3	0.0002630	0.0003283	0.0002920	0.0003610	0.0004162	0.0004300	0%
Nakhaktok	Nickel	3	3	<0.0009	0.00052	0.00051	0.00056	0.00059	0.00060	0%
Nakhaktok	Selenium	3	3	<0.0005	all concentrations below detection limits				<0.0005	0%
Nakhaktok	Silver	3	3	<0.00001	all concentrations below detection limits				<0.00002	0%
Nakhaktok	Thallium	3	3	<0.0001	all concentrations below detection limits				<0.0002	0%
Nakhaktok	Uranium	3	3	0.000036	0.000045	0.000036	0.000050	0.000060	0.000063	0%
Nakhaktok	Zinc	3	3	<0.001	all concentrations below detection limits				<0.003	0%
Ogama	Hardness (as $CaCO_3$)	16	16	30.9	52.3	41.6	46.2	104.3	121	-
Ogama	pH	14	14	6.92	7.30	7.52	7.79	7.97	7.97	0%
Ogama	Total Alkalinity (as $CaCO_3$)	16	16	19.1	30.8	24.8	27.7	59.2	68.0	-
Ogama	Total Suspended Solids	16	16	<1	4.5	5.0	6.0	8.0	8.0	-
Ogama	Total Dissolved Solids	16	16	88	162	138	148	353	393	-
Ogama	Turbidity (NTU)	3	3	3.63	4.88	5.26	5.50	5.69	5.74	-
Ogama	Ammonia (as N)	16	16	<0.005	0.0072	0.0080	0.0093	0.0103	0.0110	0%
Ogama	Nitrate (as N)	16	16	<0.005	0.0267	0.0025	0.0140	0.1485	0.1770	0%
Ogama	Nitrite (as N)	16	16	<0.001	0.0007	0.0005	0.0005	0.0015	0.0030	0%
Ogama	Total Phosphorus	16	16	0.016	0.026	0.025	0.032	0.035	0.036	-
Ogama	Total Organic Carbon	16	16	5.26	7.67	7.92	8.55	10.92	11.50	-
Ogama	Dissolved Organic Carbon	13	13	4.8	6.8	6.9	7.3	8.7	10.4	-
Ogama	Chloride	16	16	42.2	76.5	63.0	74.0	151.3	197.0	19%
Ogama	Fluoride	16	16	0.040	0.066	0.060	0.068	0.120	0.120	0%
Ogama	Sulphate (SO_4)	16	16	<3	2.63	1.67	3.25	5.55	6.00	-
Ogama	Free Cyanide	0	0	-	-	-	-	-	-	-

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Ogama	Aluminum	16	16	0.046	0.231	0.209	0.314	0.384	0.403	86%
Ogama	Arsenic	16	16	<0.0004	0.00056	0.00051	0.00056	0.00121	0.00136	0%
Ogama	Boron	16	16	0.0142	0.0254	0.0222	0.0256	0.0473	0.0558	0%
Ogama	Cadmium	16	16	<0.000002	0.0000037	0.0000031	0.0000050	0.0000094	0.0000120	0%
Ogama	Chromium	16	16	0.00038	0.00059	0.00051	0.00076	0.00084	0.00095	Cr(III) 0%; Cr(VI) 0%
Ogama	Copper	16	16	0.00120	0.00192	0.00185	0.00227	0.00278	0.00333	25%
Ogama	Iron	16	16	0.165	0.261	0.242	0.321	0.355	0.365	38%
Ogama	Lead	16	16	0.000004	0.000179	0.000125	0.000152	0.000584	0.000862	0%
Ogama	Mercury	16	16	<0.0000006	0.0000016	0.0000010	0.0000016	0.0000050	0.0000020	0%
Ogama	Molybdenum	16	16	0.000128	0.000210	0.000203	0.000239	0.000305	0.000319	0%
Ogama	Nickel	16	16	0.00069	0.00094	0.00092	0.00107	0.00126	0.00153	0%
Ogama	Selenium	16	16	<0.0005	0.00094	0.00090	0.00100	0.00159	0.00310	25%
Ogama	Silver	16	16	<0.0000005	0.0000039	0.0000037	0.0000050	0.0000103	0.0000173	0%
Ogama	Thallium	16	16	<0.0000003	0.0000132	0.0000054	0.0000085	0.0000500	0.0000103	0%
Ogama	Uranium	16	16	0.000039	0.000053	0.000052	0.000056	0.000078	0.000081	0%
Ogama	Zinc	16	16	<0.0001	0.0023	0.0016	0.0023	0.0057	0.0111	0%
P.O.	Hardness (as $CaCO_3$)	7	7	38.2	50.4	51.9	54.2	56.7	57.4	-
P.O.	pH	7	7	7.00	7.38	7.65	7.73	7.89	7.92	0%
P.O.	Total Alkalinity (as $CaCO_3$)	7	7	21.8	30.2	30.4	33.1	34.5	34.6	-
P.O.	Total Suspended Solids	7	7	<1	3.6	3.0	4.9	5.9	6.0	-
P.O.	Total Dissolved Solids	7	7	104	146	142	163	175	177	-
P.O.	Turbidity (NTU)	1	1	7.02	7.02	7.02	7.02	7.02	7.02	-
P.O.	Ammonia (as N)	7	7	<0.005	0.0089	0.0080	0.0115	0.0154	0.0160	0%
P.O.	Nitrate (as N)	7	7	<0.005	0.0032	0.0025	0.0038	0.0050	0.0050	0%
P.O.	Nitrite (as N)	7	7	<0.001	0.0014	0.0005	0.0005	0.0051	0.0070	0%
P.O.	Total Phosphorus	7	7	0.007	0.039	0.014	0.021	0.138	0.188	-
P.O.	Total Organic Carbon	7	7	3.60	4.14	4.09	4.36	4.69	4.74	-
P.O.	Dissolved Organic Carbon	6	6	3.4	4.0	4.0	4.2	4.4	4.4	-

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
P.O.	Chloride	7	7	51.1	71.7	69.1	80.0	85.5	85.7	0%
P.O.	Fluoride	7	7	0.035	0.065	0.060	0.060	0.123	0.150	14%
P.O.	Sulphate (SO_4)	7	7	<3	1.93	1.50	1.76	3.40	4.00	-
P.O.	Free Cyanide	0	0	-	-	-	-	-	-	-
P.O.	Aluminum	7	7	0.121	0.385	0.369	0.461	0.804	0.923	100%
P.O.	Arsenic	7	7	<0.0005	0.00050	0.00059	0.00060	0.00061	0.00061	0%
P.O.	Boron	7	7	0.0176	0.0250	0.0248	0.0274	0.0314	0.0324	0%
P.O.	Cadmium	7	7	<0.000002	0.0000041	0.0000041	0.0000047	0.0000103	0.0000125	0%
P.O.	Chromium	7	7	<0.0005	0.00067	0.00052	0.00085	0.00138	0.00154	Cr(III) 0%; Cr(VI) 14%
P.O.	Copper	7	7	0.00080	0.00144	0.00140	0.00170	0.00199	0.00200	0%
P.O.	Iron	7	7	0.162	0.273	0.207	0.300	0.501	0.581	29%
P.O.	Lead	7	7	0.000070	0.000271	0.000208	0.000277	0.000654	0.000787	0%
P.O.	Mercury	7	7	<0.0000006	0.0000019	0.0000015	0.0000026	0.0000045	0.0000034	0%
P.O.	Molybdenum	7	7	0.00012	0.00028	0.00021	0.00025	0.00064	0.00080	0%
P.O.	Nickel	7	7	0.00047	0.00068	0.00059	0.00079	0.00100	0.00109	0%
P.O.	Selenium	7	7	<0.0009	0.00105	0.00120	0.00130	0.00131	0.00131	71%
P.O.	Silver	7	7	<0.0000005	0.0000039	0.0000030	0.0000045	0.0000105	0.0000128	0%
P.O.	Thallium	7	7	0.0000030	0.0000128	0.0000054	0.0000105	0.0000395	0.0000150	0%
P.O.	Uranium	7	7	0.000046	0.000060	0.000064	0.000067	0.000077	0.000080	0%
P.O.	Zinc	7	7	0.0010	0.0026	0.0023	0.0027	0.0049	0.0059	0%
Patch	Hardness (as $CaCO_3$)	28	27	46.6	71.5	62.8	84.9	101	103	-
Patch	pH	23	22	6.60	7.31	7.66	7.77	7.98	8.28	0%
Patch	Total Alkalinity (as $CaCO_3$)	28	27	28.5	42.7	36.5	52.8	58.0	59.2	-
Patch	Total Suspended Solids	28	27	<1	1.7	1.5	2.5	4.0	5.7	-
Patch	Total Dissolved Solids	28	27	129	208	191	252	290	309	-
Patch	Turbidity (NTU)	12	11	0.79	1.81	1.65	2.27	3.02	3.22	-
Patch	Ammonia (as N)	28	27	0.002	0.009	0.008	0.012	0.017	0.022	0%
Patch	Nitrate (as N)	28	27	<0.005	0.0106	0.0025	0.0075	0.0465	0.0562	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Patch	Nitrite (as N)	28	27	<0.001	0.0006	0.0005	0.0005	0.0010	0.0020	0%
Patch	Total Phosphorus	28	27	0.0030	0.0086	0.0060	0.0085	0.0120	0.0600	-
Patch	Total Organic Carbon	28	27	<0.5	4.42	4.26	4.80	7.04	7.33	-
Patch	Dissolved Organic Carbon	16	16	3.1	4.0	4.0	4.3	4.7	4.8	-
Patch	Chloride	28	27	63.6	93.3	82.3	114	131	136	22%
Patch	Fluoride	28	27	0.044	0.070	0.062	0.079	0.111	0.180	4%
Patch	Sulphate (SO_4)	28	27	<3	2.65	2.20	3.58	5.00	6.00	-
Patch	Free Cyanide	5	4	<0.001	all concentrations below detection limits				<0.001	0%
Patch	Aluminum	28	27	0.018	0.113	0.084	0.142	0.296	0.351	27%
Patch	Arsenic	28	27	<0.0004	0.00047	0.00043	0.00061	0.00079	0.00081	0%
Patch	Boron	28	27	0.0214	0.0323	0.0288	0.0382	0.0432	0.0439	0%
Patch	Cadmium	28	27	<0.000002	0.0000039	0.0000025	0.0000050	0.0000096	0.0000120	0%
Patch	Chromium	28	27	0.00020	0.00041	0.00038	0.00052	0.00070	0.00070	Cr(III) 0%; Cr(VI) 0%
Patch	Copper	28	27	0.00096	0.00146	0.00128	0.00166	0.00212	0.00380	7%
Patch	Iron	28	27	0.010	0.092	0.071	0.119	0.211	0.257	0%
Patch	Lead	28	27	<0.000001	0.000140	0.000088	0.000141	0.000259	0.00149	0%
Patch	Mercury	28	27	<0.0000005	0.0000018	0.0000003	0.0000044	0.0000050	0.0000038	0%
Patch	Molybdenum	28	27	0.00011	0.00019	0.00017	0.00021	0.00026	0.00029	0%
Patch	Nickel	28	27	0.00023	0.00081	0.00056	0.00070	0.00091	0.00701	0%
Patch	Selenium	28	27	<0.0001	0.00090	0.00090	0.00137	0.00197	0.00210	42%
Patch	Silver	28	27	<0.0000005	0.0000032	0.0000025	0.0000050	0.0000063	0.0000110	0%
Patch	Thallium	28	27	<0.0000003	0.0000151	0.0000040	0.0000281	0.0000500	0.0000062	0%
Patch	Uranium	28	27	0.000048	0.000059	0.000060	0.000062	0.000065	0.000071	0%
Patch	Zinc	28	27	<0.0001	0.0020	0.0015	0.0018	0.0040	0.0178	0%
Stickleback	Hardness (as $CaCO_3$)	19	12	63.1	100.9	70.2	101	205	208	-
Stickleback	pH	13	12	6.50	7.23	7.70	7.77	7.98	8.08	0%
Stickleback	Total Alkalinity (as $CaCO_3$)	13	12	31.7	53.3	35.2	54.4	115	125	-
Stickleback	Total Suspended Solids	19	12	<1	1.4	0.9	1.5	3.7	5.7	-

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Stickleback	Total Dissolved Solids	19	12	105	197	136	208	430	436	-
Stickleback	Turbidity (NTU)	6	5	0.49	1.79	0.67	1.70	4.72	5.48	-
Stickleback	Ammonia (as N)	19	12	0.005	0.040	0.013	0.019	0.178	0.193	0%
Stickleback	Nitrate (as N)	19	12	<0.001	0.0080	0.0025	0.0025	0.0352	0.0720	0%
Stickleback	Nitrite (as N)	19	12	<0.001	0.0015	0.0008	0.0025	0.0032	0.0040	0%
Stickleback	Total Phosphorus	19	12	0.007	0.013	0.012	0.015	0.022	0.026	-
Stickleback	Total Organic Carbon	13	12	4.01	6.59	5.34	6.67	12.22	13.70	-
Stickleback	Dissolved Organic Carbon	13	7	3.7	5.3	4.7	5.0	8.6	10.1	-
Stickleback	Chloride	18	11	<0.3	57.3	47.0	50.7	127.5	131.0	18%
Stickleback	Fluoride	19	12	0.020	0.080	0.044	0.087	0.221	0.380	8%
Stickleback	Sulphate (SO_4)	19	12	0.82	1.50	1.50	1.50	2.40	2.74	-
Stickleback	Free Cyanide	3	2	<0.001	all concentrations below detection limits				<0.001	0%
Stickleback	Aluminum	19	12	0.003	0.011	0.009	0.015	0.028	0.050	0%
Stickleback	Arsenic	19	12	<0.0003	0.00050	0.00043	0.00048	0.00103	0.00121	0%
Stickleback	Boron	19	12	0.0142	0.0236	0.0194	0.0260	0.0409	0.0450	0%
Stickleback	Cadmium	19	12	<0.000002	0.0000040	0.0000025	0.0000045	0.0000115	0.0000160	0%
Stickleback	Chromium	19	12	0.00004	0.00027	0.00022	0.00026	0.00066	0.00100	Cr(III) 0%; Cr(VI) 0%
Stickleback	Copper	19	12	0.00023	0.00052	0.00046	0.00058	0.00097	0.00133	0%
Stickleback	Iron	19	12	0.040	0.238	0.088	0.169	0.883	1.26	25%
Stickleback	Lead	19	12	0.000002	0.000237	0.000025	0.000052	0.001180	0.002090	8%
Stickleback	Mercury	19	12	<0.0000005	0.0000026	0.0000024	0.0000050	0.0000052	0.0000080	0%
Stickleback	Molybdenum	19	12	0.000011	0.000068	0.000044	0.000072	0.000193	0.000260	0%
Stickleback	Nickel	19	12	<0.000005	0.00030	0.00023	0.00046	0.00071	0.00080	0%
Stickleback	Selenium	19	12	<0.0002	0.00057	0.00055	0.00063	0.00131	0.00200	8%
Stickleback	Silver	19	12	<0.0000005	0.0000026	0.0000025	0.0000035	0.0000050	0.0000038	0%
Stickleback	Thallium	19	12	<0.0000003	0.0000142	0.0000031	0.0000161	0.0000500	0.0000071	0%
Stickleback	Uranium	19	12	0.000008	0.000015	0.000010	0.000014	0.000035	0.000038	0%
Stickleback	Zinc	19	12	0.0004	0.0030	0.0015	0.0019	0.0109	0.0208	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Trout	Hardness (as $CaCO_3$)	9	9	16.3	42.1	26.5	30.7	103	104	-
Trout	pH	9	9	6.60	7.10	7.51	7.52	7.65	7.72	0%
Trout	Total Alkalinity (as $CaCO_3$)	9	9	13.8	34.2	20.7	24.9	86.7	91.4	-
Trout	Total Suspended Solids	9	9	<1	1.5	1.5	2.0	2.0	2.0	-
Trout	Total Dissolved Solids	9	9	25	78	42	57	213	221	-
Trout	Turbidity (NTU)	2	2	1.54	1.96	1.96	2.17	2.34	2.38	-
Trout	Ammonia (as N)	9	9	0.004	0.044	0.012	0.028	0.175	0.260	0%
Trout	Nitrate (as N)	9	9	<0.001	0.137	0.0025	0.0025	0.700	1.06	0%
Trout	Nitrite (as N)	9	9	<0.001	0.0032	0.0005	0.0025	0.013	0.020	0%
Trout	Total Phosphorus	9	9	0.013	0.026	0.024	0.033	0.039	0.039	-
Trout	Total Organic Carbon	9	9	5.41	11.15	9.09	10.3	21.6	22.4	-
Trout	Dissolved Organic Carbon	7	7	5.0	9.5	8.4	9.8	16.7	19.7	-
Trout	Chloride	5	5	5.5	11.7	7.1	9.8	26.1	30.2	0%
Trout	Fluoride	9	9	0.020	0.099	0.040	0.067	0.326	0.370	22%
Trout	Sulphate (SO_4)	9	9	0.96	8.16	3.00	4.00	31.8	48.0	-
Trout	Free Cyanide	0	0	-	-	-	-	-	-	-
Trout	Aluminum	9	9	0.044	0.116	0.119	0.142	0.154	0.155	78%
Trout	Arsenic	9	9	0.00023	0.00034	0.00025	0.00030	0.00070	0.00081	0%
Trout	Boron	9	9	0.0036	0.0071	0.0053	0.0119	0.0128	0.0132	0%
Trout	Cadmium	9	9	<0.000002	0.0000033	0.0000020	0.0000040	0.0000094	0.0000120	0%
Trout	Chromium	9	9	0.00030	0.00072	0.00061	0.00069	0.00148	0.00180	Cr(III) 0%; Cr(VI) 22%
Trout	Copper	9	9	0.00100	0.00218	0.00183	0.00230	0.00421	0.00529	33%
Trout	Iron	9	9	0.228	0.611	0.357	0.401	1.86	2.81	67%
Trout	Lead	9	9	0.000052	0.000158	0.000088	0.000104	0.000488	0.000707	0%
Trout	Mercury	9	9	<0.0000006	0.0000021	0.0000014	0.0000034	0.0000050	0.0000034	0%
Trout	Molybdenum	9	9	0.00005	0.00009	0.00008	0.00009	0.00015	0.00016	0%
Trout	Nickel	9	9	0.00060	0.00125	0.00107	0.00116	0.00254	0.00302	0%
Trout	Selenium	9	9	<0.0001	0.00028	0.00027	0.00030	0.00056	0.00060	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Trout	Silver	9	9	0.0000012	0.0000067	0.0000050	0.0000096	0.0000126	0.0000137	0%
Trout	Thallium	9	9	<0.0000003	0.0000136	0.0000040	0.0000057	0.0000500	0.0000057	0%
Trout	Uranium	9	9	0.000025	0.000049	0.000036	0.000045	0.000098	0.000117	0%
Trout	Zinc	9	9	0.0009	0.0024	0.0015	0.0026	0.0059	0.0080	0%
Windy	Hardness (as $CaCO_3$)	31	28	53.5	71.9	70.4	78.7	81.8	82.5	-
Windy	pH	27	24	6.40	7.30	7.89	7.96	8.36	8.43	8%
Windy	Total Alkalinity (as $CaCO_3$)	31	28	23.2	51.8	49.4	57.6	63.2	68.9	-
Windy	Total Suspended Solids	31	28	<1	1.2	0.5	1.5	3.8	5.0	-
Windy	Total Dissolved Solids	31	28	89	228	227	256	266	268	-
Windy	Turbidity (NTU)	15	12	0.16	0.64	0.54	0.96	1.32	1.46	-
Windy	Ammonia (as N)	31	28	0.002	0.005	0.005	0.007	0.012	0.014	0%
Windy	Nitrate (as N)	31	28	<0.005	0.0048	0.0025	0.0031	0.0150	0.0162	0%
Windy	Nitrite (as N)	31	28	<0.001	0.0007	0.0005	0.0005	0.0013	0.0020	0%
Windy	Total Phosphorus	31	28	<0.002	0.005	0.004	0.006	0.008	0.011	-
Windy	Total Organic Carbon	31	28	1.23	1.82	1.76	1.98	2.32	2.71	-
Windy	Dissolved Organic Carbon	16	16	1.2	1.6	1.6	1.8	2.0	2.2	-
Windy	Chloride	31	28	33.1	99.9	96.9	111	117	119	0%
Windy	Fluoride	31	28	0.060	0.088	0.080	0.083	0.152	0.250	7%
Windy	Sulphate (SO_4)	31	28	4.00	7.85	8.00	9.13	10.0	10.0	-
Windy	Free Cyanide	4	4	<0.001	all concentrations below detection limits				<0.001	0%
Windy	Aluminum	31	28	0.004	0.049	0.039	0.075	0.109	0.146	13%
Windy	Arsenic	31	28	<0.0004	0.00046	0.00046	0.00062	0.00076	0.00083	0%
Windy	Boron	31	28	0.0349	0.0513	0.0513	0.0546	0.0611	0.0680	0%
Windy	Cadmium	31	28	<0.000002	0.0000046	0.0000030	0.0000050	0.0000120	0.0000170	0%
Windy	Chromium	31	28	0.00012	0.00036	0.00030	0.00040	0.00087	0.00148	Cr(III) 0%; Cr(VI) 7%
Windy	Copper	31	28	0.00035	0.00097	0.00093	0.00103	0.00144	0.00190	0%
Windy	Iron	31	28	<0.002	0.037	0.035	0.049	0.085	0.125	0%
Windy	Lead	31	28	<0.000001	0.000066	0.000028	0.000049	0.000219	0.00102	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Windy	Mercury	31	28	<0.0000005	0.0000018	0.0000003	0.0000050	0.0000050	0.0000019	0%
Windy	Molybdenum	31	28	0.00046	0.00068	0.00067	0.00071	0.00079	0.00115	0%
Windy	Nickel	31	28	0.00001	0.00020	0.00021	0.00028	0.00035	0.00042	0%
Windy	Selenium	31	28	<0.0002	0.00083	0.00069	0.00112	0.00223	0.00230	31%
Windy	Silver	31	28	<0.0000005	0.0000046	0.0000033	0.0000050	0.0000080	0.0000400	0%
Windy	Thallium	31	28	<0.0000003	0.0000162	0.0000034	0.0000500	0.0000500	0.0000070	0%
Windy	Uranium	31	28	0.000137	0.000183	0.000185	0.000198	0.000212	0.000220	0%
Windy	Zinc	31	28	<0.0001	0.0013	0.0012	0.0015	0.0035	0.0042	0%
Wolverine	Hardness (as $CaCO_3$)	13	12	48.9	88.2	58.5	132	165	181	-
Wolverine	pH	12	11	6.66	7.24	7.71	7.80	8.01	8.25	0%
Wolverine	Total Alkalinity (as $CaCO_3$)	13	12	25.3	56.6	38.7	86.7	107	117	-
Wolverine	Total Suspended Solids	13	12	<1	1.9	1.8	2.1	5.0	5.0	-
Wolverine	Total Dissolved Solids	13	12	147	272	190	378	515	560	-
Wolverine	Turbidity (NTU)	5	4	0.97	1.41	1.36	1.62	1.87	1.93	-
Wolverine	Ammonia (as N)	13	12	<0.005	0.036	0.009	0.012	0.167	0.216	0%
Wolverine	Nitrate (as N)	13	12	<0.005	0.0241	0.0038	0.0092	0.115	0.186	0%
Wolverine	Nitrite (as N)	13	12	<0.001	0.0012	0.0005	0.0008	0.0041	0.0060	0%
Wolverine	Total Phosphorus	13	12	0.011	0.019	0.015	0.018	0.041	0.048	-
Wolverine	Total Organic Carbon	13	12	4.37	7.41	5.86	9.76	12.5	13.4	-
Wolverine	Dissolved Organic Carbon	8	8	4.1	6.0	5.1	6.6	9.4	9.7	-
Wolverine	Chloride	13	12	72.0	122	87.3	160	237	275	33%
Wolverine	Fluoride	13	12	0.043	0.084	0.075	0.100	0.133	0.140	17%
Wolverine	Sulphate (SO_4)	13	12	<0.5	1.42	1.50	1.50	2.63	4.00	-
Wolverine	Free Cyanide	2	2	<0.001	all concentrations below detection limits				<0.001	0%
Wolverine	Aluminum	13	12	0.009	0.066	0.043	0.074	0.185	0.205	18%
Wolverine	Arsenic	13	12	<0.0005	0.00075	0.00058	0.00074	0.00177	0.00182	0%
Wolverine	Boron	13	12	0.0167	0.0277	0.0210	0.0412	0.0456	0.0498	0%
Wolverine	Cadmium	13	12	<0.000002	0.0000048	0.0000033	0.0000047	0.0000145	0.0000201	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Wolverine	Chromium	13	12	0.00010	0.00043	0.00031	0.00050	0.00105	0.00153	Cr(III) 0%; Cr(VI) 8%
Wolverine	Copper	13	12	0.00031	0.00078	0.00069	0.00107	0.00118	0.00130	0%
Wolverine	Iron	13	12	0.062	0.242	0.151	0.269	0.670	0.729	25%
Wolverine	Lead	13	12	0.000020	0.000116	0.000065	0.000108	0.000375	0.000551	0%
Wolverine	Mercury	13	12	<0.0000005	0.0000026	0.0000011	0.0000030	0.0000081	0.0000120	0%
Wolverine	Molybdenum	13	12	0.00006	0.00009	0.00008	0.00010	0.00013	0.00015	0%
Wolverine	Nickel	13	12	0.00024	0.00062	0.00054	0.00071	0.00125	0.00137	0%
Wolverine	Selenium	13	12	<0.0002	0.00105	0.00092	0.00115	0.00278	0.00440	33%
Wolverine	Silver	13	12	<0.0000005	0.0000038	0.0000025	0.0000053	0.0000114	0.0000132	0%
Wolverine	Thallium	13	12	<0.0000003	0.0000144	0.0000025	0.0000044	0.0000725	0.0000045	0%
Wolverine	Uranium	13	12	0.000025	0.000032	0.000031	0.000034	0.000044	0.000048	0%
Wolverine	Zinc	13	12	0.0002	0.0017	0.0017	0.0027	0.0032	0.0035	0%

Notes:
'<' indicates that concentration was less than the analytical detection limit shown.
n = number of observations.
[a] Minimum represents the lowest concentration in any sample.
[b] One half of the value of the analytical detection limit was substituted for values that were below detection limits, and replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, the 75th and 95th percentiles, and CCME guidelines.
[c] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case maximum represents highest detection limit).
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed September 2017).
The CCME guideline for chromium is dependent on its speciation (Cr(VI) or Cr(III)). Routine metal analysis does not distinguish between chromium species, so total chromium results were used to compare with CCME guidelines to be conservative.

Similar to the trends seen for alkalinity and hardness, total dissolved solid (TDS) concentrations were higher in the North Belt LSA (mean: 194 mg/L) than in the RSA (mean: 81.6 mg/L; Table 4.2-4). TDS concentrations were lowest in the South Belt LSA (mean 66.3 mg/L; Table 4.2-4). This was driven by Aimaokatalok Lake, where TDS concentrations were markedly lower than other LSA lakes (mean: 33.4 mg/L; Table 4.2-10), and were comparable to several of the reference lakes in the RSA.

Chloride concentrations in both LSA and RSA lakes were occasionally greater than the CCME long-term guideline concentration of 120 mg/L (CCME 2017; Table 4.2-4). Within the LSA, baseline concentrations were greater than the chloride CCME guideline in some samples from Patch, Wolverine, Nakhaktok, Ogama, Little Roberts, and Stickleback lakes (Table 4.2-10). Within the RSA, chloride concentrations were sometimes higher than the CCME guideline in Naiqunnguut Lake, which is near the edge of the LSA. All chloride concentrations were consistently below the CCME short-term concentration guideline of 640 mg/L (CCME 2017).

Fluoride concentrations within each study area were occasionally higher than the CCME interim guideline of 0.12 mg/L (CCME 2017; Table 4.2-4). Baseline fluoride concentrations were greater than the CCME guideline in some samples from Doris, P.O., Patch, Windy, Wolverine, Little Roberts, Aimaokatalok, Stickleback, and Trout lakes in the LSA (Table 4.2-10). Within the RSA, fluoride concentrations were sometimes higher than the CCME guideline in Boston Reference and Pelvic lakes.

Total Suspended Solids and Turbidity

The concentration of total suspended solids (TSS) and turbidity are related measures describing the quantity of particulate material, primarily sediment, suspended in the water. These parameters are also related to water clarity as high concentrations of TSS and high turbidity levels are associated with reduced water clarity. Natural variation in TSS concentrations and turbidity result from spatial differences in terrestrial runoff, surrounding cover, bathymetry, and mixing due to temporal changes from season and weather.

Lakes in the LSA and RSA had variable TSS and turbidity levels. TSS concentrations ranged from below the analytical detection limit (< 1.0 mg/L) to 19.0 mg/L in the LSA lakes, and < 1.0 mg/L to 15.3 mg/L in the RSA lakes (Table 4.2-5). Turbidity ranged from 0.16 to 18.9 NTU in the LSA lakes, and 0.18 to 5.58 NTU in RSA lakes (Table 4.2-5). TSS and turbidity levels were sporadically elevated and highly variable over time and across lakes (Table 4.2-10).

Lake Dissolved Oxygen

Dissolved oxygen (DO) concentration is an important environmental parameter that has major effects on the chemistry and aquatic life of freshwater ecosystems. Redox chemistry can affect the solubility and availability of nutrients and metals, which can be released from or precipitated onto the sediments under low DO conditions. Low DO concentrations can also inhibit growth and reproduction in zooplankton, benthic invertebrates, and fish, and may lead to mortalities if low DO impedes respiration. The CCME guideline for DO concentrations for cold-water organisms is 9.5 mg/L for early life stages and 6.5 mg/L for other life stages (CCME 2017).

Lakes in the LSA and RSA were typically ice-covered from October into June, with ice thicknesses of around 2 m in late winter. Between 2007 and 2017, the winter DO profiles were typical of ice-covered Arctic lakes, with concentrations being highest near the water-ice interface (maximum of 18 mg/L at Doris Lake in 2012 and Little Roberts Lake in 2012 and 2015) and gradually declining with depth, particularly in deeper lakes. The amount of oxygen depletion at depth varied among lakes and across years. Bottom waters in some lakes (i.e., Ogama, Wolverine, Stickleback, and Trout lakes in the LSA, and Reference Lake B, Little Roberts and Pelvic lakes in the RSA) were nearly anoxic (DO ≤ 1 mg/L) on some winter sampling occasions, indicating that there was oxygen-consuming decomposition occurring in bottom waters or sediments and limited vertical mixing to replenish the oxygen supply.

Winter DO concentrations in the upper portion of the water column of most lakes were above the CCME guideline for the protection of cold-water aquatic life of 9.5 mg/L for early life stages and 6.5 mg/L for other life stages (CCME 2017). However, bottom water DO concentrations were often below one or both guideline levels (e.g., Doris, Windy, and Nakhaktok lakes in the North Belt LSA; Aimaokatalok Lake in the South Belt LSA; and Reference Lake A, Reference Lake B, and Pelvic Lake in the RSA). DO concentrations were lower than 6.5 mg/L throughout the water column at some shallow lakes of all three study areas (e.g., Ogama, Wolverine, Stickleback, Trout, Little Roberts lakes and Reference Lake D). However, DO concentrations varied widely among years in some lakes such as Ogama, Little Roberts Lake, and Reference Lake D, and DO concentrations were not below guideline levels during all years. The oxygen depletion observed in the deep waters of the sampled lakes is a common phenomenon in Arctic lakes, and is a result of respiration and a lack of exchange with atmospheric oxygen.

Open-water season DO concentrations were also typical of Arctic lakes. Summer DO concentrations changed little throughout the water columns of all lakes, and temperature profiles generally showed that lakes were well mixed during the summer. Overall, lakes were well oxygenated, with surface water column oxygen concentrations ranging from 8 to 15 mg/L. Most lakes had DO concentrations above CCME guidelines of 6.5 mg/L and 9.5 mg/L throughout the water column. Some oxygen depletion occasionally occurred near the lake bottom at Aimaokatalok, Doris, Imniagut, Ogama, Patch, Pelvic, and Nakhaktok lakes, likely due to respiratory oxygen consumption. In many lakes, including reference lakes, summer DO concentrations occasionally dropped slightly below 9.5 mg/L throughout the water column; however, DO concentrations during these periods typically approached or exceeded 100% saturation, indicating that DO was at maximal levels for the physical conditions in those lakes (e.g., temperature). Summer bottom water concentrations in Doris, Ogama, and Pelvic lakes occasionally dropped below the 6.5 mg/L guideline. Conversely, a few lakes exhibited a slight increase in oxygen with depth. These increases were typically inversely related to water temperature, and likely reflected the increased oxygen carrying capacity of colder water.

Nutrients

Nutrients are the chemicals required by photosynthetic organisms for growth and productivity and ultimately serve as building blocks for organic matter flowing through aquatic food webs. Variation in nutrient concentrations can be caused by periodic mixing, terrestrial runoff events, changes in allochthonous inputs from the surrounding terrestrial environment, and variations in nutrient uptake and remineralization by primary producers and microbes, respectively.

Ammonia and nitrate concentrations in LSA and RSA lakes were often below analytical detection limits and were usually lowest during the open-water season, likely due to uptake by primary producers. Mean nitrate concentrations were highest in the South Belt LSA (0.0379 mg nitrate-N/L) and similar between the North Belt LSA (0.0152 mg nitrate-N/L) and the RSA (0.0155 mg nitrate-N/L; Table 4.2-6). Mean ammonia concentrations were similar among areas (Table 4.2-6).). Nitrate concentrations in all surveyed lakes were always well below the CCME guideline of 3.0 mg nitrate-N/L, and ammonia concentrations were always below the pH- and temperature-dependent CCME guideline for total ammonia (CCME 2017). Nitrite concentrations in LSA and RSA lakes were typically below analytical detection limits (< 0.001 mg nitrite-N/L; Table 4.2-6) and reached a maximum concentration of 0.02 mg nitrite-N/L in Trout Lake in 2007 (Table 4.2-10). All nitrite concentrations in study area lakes were below the CCME guideline of 0.06 mg nitrite-N/L (CCME 2017).

Total phosphorus concentrations varied seasonally and across lakes, but tended to be highest in North Belt LSA lakes (Table 4.2-6). All lakes in the LSA were assigned a trophic status based on the CCME trigger ranges for total phosphorus concentrations in freshwater systems (CCME 2004a); Table 4.2-7 provides a listing of all study lakes by trophic status. Lakes were often assigned more than one trophic status because of the seasonal variability of total phosphorus concentrations. Within the North Belt LSA, lake trophic status covered the entire spectrum from ultra-oligotrophic to hyper-eutrophic. Windy Lake had the lowest mean total phosphorus concentration (mean: 0.005 mg/L; Table 4.2-10), and varied from ultra-oligotrophic to mesotrophic (Table 4.2-7). P.O. was the only lake with total phosphorus concentrations that reached the hyper-eutrophic range (Table 4.2-7). In the South Belt LSA, Aimaokatalok ranged from ultra-oligotrophic to meso-eutrophic, Stickleback lake was classified as oligotrophic to meso-eutrophic, and Trout Lake was considered mesotrophic to eutrophic (Table 4.2-7). In the RSA, Reference lakes A, B, and D were classified as ultra-oligotrophic during some sampling periods, but reached oligotrophic (Reference A), mesotrophic (Reference B), or eutrophic (Reference D) status depending on the year or season. Boston Reference and Pelvic lakes were the only RSA lakes that seasonally reached hyper-eutrophic status (Table 4.2-7).

<u>Metals</u>

Many metals are biologically significant chemical constituents of water because they are required nutritional co-factors for organisms. However, some metals may become toxic to aquatic organisms at elevated concentrations, particularly in acidic, soft-water environments. Understanding the natural variability in metal concentrations is an important component of the baseline water quality sampling program. Table 4.2-8 presents the summary statistics for lake metal concentrations in each study area, and the percentage of sample metal concentrations that were above CCME guidelines. Table 4.2-10 presents lake-specific metal concentrations and CCME guideline comparisons.

Metal concentrations were sometimes highest during the ice-covered season due to solute extrusion during ice formation, changes in redox chemistry, increased remineralization, and/or decreased biological uptake. Between 2007 and 2017, concentrations of metals such as cadmium, selenium, silver, and thallium were frequently near or less than analytical detection limits (Table 4.2-8). Some metals such as aluminum, chromium, copper, iron, lead, and selenium were occasionally naturally elevated in LSA and RSA lakes. These naturally-elevated metal concentrations were greater than CCME guideline levels in some lake samples collected from all study areas (North Belt LSA, South Belt LSA, and RSA; Table 4.2-8). The highest mean concentrations of these metals tended to occur in Glenn Lake, though concentrations were also relatively high in Trout and P.O. lakes (Table 4.2-10).

There were also some metal concentrations that were sporadically higher than CCME guidelines, including cadmium, mercury, and zinc. The cadmium concentration was higher than the hardness-dependent, long-term CCME guideline in one sample collected from Doris Lake (North Belt LSA; Table 4.2-10). The mercury concentration in a single sample collected from Reference Lake B (RSA) was higher than the CCME guideline of 0.000026 mg/L (Table 4.2-8). Zinc concentrations in three samples collected from Doris Lake and one sample from Reference Lake B were higher than the CCME guideline concentration of 0.03 mg/L (Tables 4.2-8 and 4.2-10).

<u>Cyanide</u>

Cyanide is a naturally-occurring organic nitrogen compound produced by micro-organisms and plants. Free cyanide concentrations were occasionally measured in lakes for comparison with the CCME guideline for the protection of aquatic life of 0.005 mg/L (CCME 2017). Free cyanide concentrations in LSA and RSA lakes were usually below the analytical detection limit (<0.001 or <0.005 mg/L; Tables 4.2-9 and 4.2-10). Maximum concentrations of 0.0020 and 0.0034 mg/L were measured in the North Belt LSA and RSA, respectively, while concentrations in the South Belt LSA were always below the detection limit of 0.001 mg/L (Table 4.2-9). Concentrations of free cyanide in all lakes remained below the CCME guideline of 0.005 mg/L (CCME 2017).

4.2.4.2 Streams and Rivers

Streams and rivers are the other significant component of freshwater environments in the Madrid-Boston area. Streams and rivers are hosts to many aquatic organisms, serve as water sources for many terrestrial organisms, and are valuable sources of water for human uses. Streams in the Madrid-Boston Project area are seasonal and usually flow between June and September.

Like lakes, all water quality indicators in streams and rivers are naturally variable due to heterogeneity in the landscape, biogeochemical cycling, weather, and climate. The baseline sampling program served to measure this natural variation to identify any future Madrid-Boston Project effects on water quality. Stream and river water quality data were grouped by Project area (North Belt LSA, South Belt LSA, and RSA) to highlight general regional trends. These data are presented in Tables 4.2-11 to 4.2-16. Stream- and river-specific data for the LSA are presented in Table 4.2-17.

<u>General Parameters</u>

Between 2007 and 2016, pH levels in streams and rivers ranged from 5.6 to 8.4 in the LSA and 6.0 to 8.7 in the RSA (Table 4.2-11). Some pH levels in all study areas fell below the lower limit of the CCME pH guideline range of 6.5 to 9.0 (CCME 2017).

Water in the streams and rivers of the LSA and RSA can generally be characterized as soft (hardness of less than 60 mg $CaCO_3$/L), though hardness sometimes increased seasonally to levels that would be considered moderately hard (maximum of 81.9 mg $CaCO_3$/L in the North Belt LSA, 75.2 mg $CaCO_3$/L in the South Belt LSA, and 60.3 mg $CaCO_3$/L in the RSA; Table 4.2-11). Within the LSA, mean water hardness was highest at Glenn Outflow (62.8 mg $CaCO_3$/L) and lowest at Aimaokatalok Outflow (12.6 mg $CaCO_3$/L; Table 4.2-17).

The acid-sensitivity of streams and rivers in the LSA and RSA was generally high. Alkalinity levels of less than 20 mg $CaCO_3$/L (indicating sensitivity to acid because of poor buffering capacity) occurred seasonally in nearly all streams of the LSA and RSA (Table 4.2-11). The only streams of the LSA in which alkalinity remained higher than 20 mg $CaCO_3$/L during all sampling periods were Ogama and Windy outflows in the North Belt LSA (Table 4.1-17). Within the LSA, mean alkalinity was highest at Glenn Outflow (42.6 mg $CaCO_3$/L) followed by Windy Outflow (40.3 mg $CaCO_3$/L), and lowest at Aimaokatalok Outflow (9.1 mg $CaCO_3$/L) and Wolverine Outflow (10.6 mg $CaCO_3$/L; Table 4.2-17).

Stream and river TDS concentrations were higher in the North Belt LSA (mean: 134 mg/L) than in the South Belt LSA (mean: 57.8 mg/L) or the RSA (mean: 70.2 mg/L; Table 4.2-11). Among the streams and rivers of the LSA, Glenn and Windy outflows had the highest mean TDS concentrations (178 and 170 mg/L, respectively), and stream AWRc had the lowest mean TDS concentration (2.3 mg/L; Table 4.2-17).

Mean concentrations of total and dissolved organic carbon were higher in streams and rivers of the LSA than in the RSA (Table 4.2-11). Within the LSA, total organic carbon concentrations were highest at streams AWRa and AWRe (mean: 14.9 mg/L) and lowest at Windy Outflow (2.5 mg/L; Table 4.2-17).

Chloride concentrations in streams of the LSA and RSA were always below the CCME long-term guideline concentration of 120 mg/L for the protection of freshwater aquatic life (CCME 2017; Table 4.2-11). Mean chloride concentrations were higher in the North Belt LSA (56.8 mg/L) than in the other areas (15.6 mg/L in the South Belt LSA and 28.0 mg/L in the RSA; Table 4.2-11), and concentrations were highest at Glenn and Windy outflows (mean: 71.4 and 74.5 mg/L, respectively; Table 4.2-17).

Table 4.2-11. Stream and River Water Chemistry at LSA and RSA Sites, 2007 to 2016

Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]	% of Samples with Concentrations above CCME Guidelines[d]
pH									
LSA - North Belt	265	159	5.6	7.0	7.5	7.7	8.0	8.3	3.8
LSA - South Belt	98	65	6.0	6.7	7.2	7.4	7.7	8.4	20
RSA	224	129	6.0	7.1	7.3	7.5	7.8	8.7	5.4
Hardness (mg $CaCO_3$/L)									
LSA - North Belt	267	160	12.1	44.8	46.2	52.6	69.9	81.9	-
LSA - South Belt	99	66	2.2	26.2	19.8	29.3	71.1	75.2	-
RSA	225	129	7.3	23.1	19.2	33.5	40.8	43.6	-
Total Alkalinity (mg $CaCO_3$/L)									
LSA - North Belt	267	160	9.0	27.6	27.5	31.6	48.2	56.4	-
LSA - South Belt	99	66	<2	17.5	13.8	21.2	35.5	54.0	-
RSA	224	129	5.2	14.6	12.6	20.7	23.6	25.6	-
Total Dissolved Solids (mg/L)									
LSA - North Belt	219	136	27.9	134	142	162	211	278	-
LSA - South Belt	99	66	<10	57.8	43.9	66.4	125	187	-
RSA	156	95	15.5	70.2	53.0	112	142	156	-
Total Organic Carbon (mg/L)									
LSA - North Belt	267	160	1.58	6.24	5.93	6.58	10.1	46.3	-
LSA - South Belt	99	66	0.90	7.02	6.25	8.08	12.1	18.4	-
RSA	225	129	2.43	4.93	4.70	5.52	7.76	14.0	-
Dissolved Organic Carbon (mg/L)									
LSA - North Belt	131	100	1.50	5.63	5.43	6.13	8.44	44.7	-
LSA - South Belt	32	32	1.70	6.18	5.45	7.90	10.9	11.5	-
RSA	127	80	2.27	4.80	4.72	5.54	7.21	7.90	-

Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]	% of Samples with Concentrations above CCME Guidelines[d]
Chloride (mg/L)									
LSA - North Belt	267	160	4.39	56.8	60.3	69.6	89.8	112	0
LSA - South Belt	83	50	1.39	15.6	10.4	17.9	50.8	52.1	0
RSA	216	121	3.30	28.0	20.4	53.7	60.7	66.8	0
Fluoride (mg/L)									
LSA - North Belt	267	160	<0.02	0.076	0.053	0.060	0.111	1.65	5.0
LSA - South Belt	98	65	<0.01	0.042	0.033	0.040	0.088	0.38	3.1
RSA	224	129	<0.02	0.037	0.033	0.043	0.078	0.33	1.6
Sulphate (mg/L)									
LSA - North Belt	267	160	0.68	3.7	3.0	4.0	9.0	18.0	-
LSA - South Belt	99	66	<0.5	2.1	1.5	1.8	6.0	12.0	-
RSA	223	128	0.95	2.6	2.1	4.0	5.0	7.61	-

Notes:
'<' indicates that concentration was less than the analytical detection limit shown.
n = number of observations.
[a] *Minimum represents the lowest concentration in any sample.*
[b] *One half of the value of the analytical detection limit was substituted for values that were below detection limits, and replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, the 75th and 95th percentiles, and CCME guidelines.*
[c] *Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case maximum represents highest detection limit).*
[d] *CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed October 2016).*

Table 4.2-12. Stream and River Total Suspended Solids and Turbidity at LSA and RSA Sites, 2007 to 2016

Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]
TSS (mg/L)								
LSA - North Belt	267	160	<1	6.2	3.6	5.1	19.6	198
LSA - South Belt	99	66	<1	3.0	1.5	3.1	11.3	23.0
RSA	224	129	<1	2.6	1.7	3.0	8.3	17.0

Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]
Turbidity (NTU)								
LSA - North Belt	198	91	0.36	10.3	5.2	7.1	29.0	218
LSA - South Belt	67	34	0.25	2.7	1.6	2.8	10.0	12.1
RSA	192	97	0.28	2.5	1.6	2.8	9.4	15.3

Notes:
'<' indicates that concentration was less than the analytical detection limit shown.
n = number of observations.
[a] Minimum represents the lowest concentration in any sample.
[b] One half of the value of the analytical detection limit was substituted for values that were below detection limits, and replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, the 75th and 95th percentiles, and CCME guidelines.
[c] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case maximum represents highest detection limit).

Table 4.2-13. Stream and River Nutrient Concentrations at LSA and RSA Sites, 2007 to 2016

Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples with Concentrations above CCME Guidelines[d]
Nitrate (mg N/L)									
LSA - North Belt	267	160	<0.005	0.0111	0.0025	0.0025	0.0141	0.556	0
LSA - South Belt	99	66	<0.001	0.0085	0.0025	0.0060	0.0284	0.181	0
RSA	224	129	<0.001	0.0080	0.0025	0.0085	0.0203	0.268	0
Nitrite (mg N/L)									
LSA - North Belt	267	160	<0.001	0.0007	0.0005	0.0005	0.0020	0.0030	0
LSA - South Belt	99	66	<0.001	0.0010	0.0005	0.0010	0.0025	0.0030	0
RSA	224	129	<0.001	0.0007	0.0005	0.0005	0.0020	0.0031	0
Total Ammonia (mg N/L)									
LSA - North Belt	267	160	<0.005	0.0077	0.0060	0.0100	0.0191	0.044	0
LSA - South Belt	99	66	<0.005	0.0145	0.0120	0.0154	0.0305	0.238	0
RSA	225	129	<0.005	0.0079	0.0041	0.0080	0.0178	0.239	0

Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples with Concentrations above CCME Guidelines[d]
Total Phosphorus (mg P/L)									
LSA - North Belt	267	160	<0.002	0.0209	0.0198	0.0262	0.0370	0.0650	-
LSA - South Belt	99	66	0.0029	0.0169	0.0143	0.0200	0.0338	0.0990	-
RSA	225	129	0.0023	0.0136	0.0108	0.0170	0.0332	0.0670	-

Notes:
'<' indicates that concentration was less than the analytical detection limit shown.
n = number of observations.
[a] Minimum represents the lowest concentration in any sample.
[b] One half of the value of the analytical detection limit was substituted for values that were below detection limits, and replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, the 75th and 95th percentiles, and CCME guidelines.
[c] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case maximum represents highest detection limit).
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed October 2016).

Table 4.2-14. Trophic Status of Streams and Rivers by Total Phosphorus Trigger Ranges[a], 2007 to 2016

Trophic Status	Total Phosphorus Concentration (mg/L)	LSA - North Belt	LSA - South Belt	RSA
Ultra-Oligotrophic	<0.004	Windy OF, Wolverine OF	S6	Reference B OF
Oligotrophic	0.004-0.01	Koignuk River, P.O. OF, Patch OF, Windy OF	Aimaokatalok OF, AWRc, AWRe, Koignuk River, S12, Stickleback OF	Aimaokatalok River, Angimajuq River, Boston Reference OF, Reference A OF, Reference B OF, Reference D OF
Mesotrophic	0.01-0.02	AWRb, Doris OF, Glenn OF, Koignuk River, Little Roberts OF, P.O. OF, Patch OF, Windy OF	Aimaokatalok OF, AWRc, AWRd, AWRe, Koignuk River, Stickleback OF, Trout OF	Aimaokatalok River, Angimajuq River, Boston Reference OF, Reference D OF, Roberts OF
Meso-eutrophic	0.02-0.035	AWRa, AWRb, Doris OF, Glenn OF, Koignuk River, Little Roberts OF, Ogama OF, P.O. OF	Aimaokatalok NE IF, AWRd, Stickleback OF, Trout OF	Aimaokatalok River, Boston Reference OF, Pelvic OF, Roberts OF
Eutrophic	0.035-0.1	AWRa, Doris OF, Glenn OF, Koignuk River, Little Roberts OF, Ogama OF, P.O. OF, Patch OF	Aimaokatalok NE IF, Trout OF	Pelvic OF
Hyper-eutrophic	<0.1	-	-	-

Notes:
OF = Outflow, IF = Inflow, NE = Northeast
Total phosphorus concentrations may vary between years and seasons; as a result, streams may be listed under multiple trigger ranges.
[a] Trigger ranges from Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems (CCME 2004).

Table 4.2-15. Stream and River Total Metal Concentrations at LSA and RSA Sites, 2007 to 2016

Parameter	Total Metal Concentration (mg/L)						% of Samples with Concentrations Greater than CCME Guidelines[d]
	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]	
LSA - North Belt	**n = 267**	**n = 160**	**n = 160**	**n = 160**	**n = 160**	**n = 267**	**n = 160**
Aluminum	0.022	0.281	0.140	0.317	0.878	3.90	61
Arsenic	<0.0001	0.00041	0.00032	0.00047	0.00065	0.00493	0
Boron	0.0043	0.0245	0.0243	0.0289	0.0461	0.0526	0

Parameter	Total Metal Concentration (mg/L)						% of Samples with Concentrations Greater than CCME Guidelines[d]
	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]	
Cadmium	<0.000002	0.0000055	0.0000025	0.0000050	0.0000121	0.000165	0.6
Chromium	<0.0001	0.00067	0.00035	0.00074	0.00215	0.00739	18% (Cr (VI)); 0% (Cr (III))[e]
Copper	0.00057	0.00175	0.00151	0.00182	0.00332	0.00948	21
Iron	0.015	0.338	0.199	0.401	0.941	3.97	34
Lead	0.000008	0.000146	0.000062	0.000150	0.000346	0.00528	1.3
Mercury	<0.0000005	0.0000021	0.0000011	0.0000050	0.0000050	0.0000039	0
Molybdenum	<0.00005	0.000216	0.000175	0.000213	0.000637	0.000720	0
Nickel	0.000005	0.00086	0.00065	0.00097	0.00206	0.00529	0
Selenium	<0.0001	0.00051	0.00050	0.00078	0.00131	0.00216	18
Silver	<0.0000005	0.0000043	0.0000025	0.0000050	0.0000134	0.000117	0
Thallium	<0.0000003	0.0000137	0.0000040	0.0000107	0.0000500	0.0000172	0
Uranium	0.000013	0.000072	0.000045	0.000064	0.000234	0.000447	0
Zinc	<0.0001	0.0020	0.0015	0.0022	0.0047	0.0180	0
LSA - South Belt	**n = 99**	**n = 66**	**n = 66**	**n = 66**	**n = 66**	**n = 99**	**n = 66**
Aluminum	0.011	0.121	0.069	0.125	0.409	0.836	45
Arsenic	<0.00005	0.00027	0.00020	0.00037	0.00070	0.00097	0
Boron	0.00209	0.00997	0.0103	0.0133	0.0177	0.0265	0
Cadmium	<0.000002	0.0000047	0.0000050	0.0000050	0.0000089	0.0000255	0
Chromium	<0.00003	0.00047	0.00037	0.00064	0.00110	0.00135	11% (Cr (VI)); 0% (Cr (III))[e]
Copper	0.000093	0.00124	0.00108	0.00151	0.00221	0.0156	6.1
Iron	0.026	0.421	0.285	0.508	1.17	3.46	48
Lead	0.0000071	0.000065	0.000029	0.000084	0.000203	0.000860	0
Mercury	<0.0000006	0.0000030	0.0000050	0.0000050	0.0000050	0.0000029	0
Molybdenum	0.0000022	0.0000683	0.0000612	0.0000788	0.000154	0.000482	0
Nickel	<0.0001	0.00073	0.00065	0.00101	0.00144	0.00226	0
Selenium	<0.0001	0.00029	0.00025	0.00050	0.00059	0.000754	0
Silver	<0.0000005	0.0000045	0.0000050	0.0000050	0.0000094	0.000023 0	0
Thallium	<0.0000003	0.0000272	0.0000500	0.0000500	0.0000500	0.0000125	0
Uranium	<0.00001	0.000049	0.000024	0.000045	0.000085	0.00112	0
Zinc	<0.0001	0.0019	0.0015	0.0021	0.0043	0.0175	0
RSA	**n = 225**	**n = 129**	**n = 129**	**n = 129**	**n = 129**	**n = 225**	**n = 129**
Aluminum	0.0044	0.108	0.073	0.133	0.370	0.717	41
Arsenic	<0.00005	0.00032	0.00015	0.00028	0.00058	0.00517	0.8
Boron	0.0012	0.0156	0.0134	0.0228	0.0328	0.0542	0
Cadmium	<0.000002	0.0000040	0.0000025	0.0000025	0.0000055	0.000213	0.8
Chromium	<0.0001	0.00035	0.00025	0.00038	0.00075	0.00258	2.3% (Cr (VI)); 0% (Cr (III))[e]
Copper	<0.0005	0.00129	0.00120	0.00148	0.00185	0.00804	3.9

Parameter	Total Metal Concentration (mg/L)						% of Samples with Concentrations Greater than CCME Guidelines[d]
	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]	
Iron	<0.03	0.194	0.141	0.253	0.518	1.09	18
Lead	0.000022	0.000060	0.000025	0.000066	0.000159	0.00136	0.8
Mercury	<0.0000005	0.0000027	0.0000010	0.0000023	0.0000050	0.000106	0.8
Molybdenum	0.000019	0.000093	0.000070	0.000159	0.000207	0.000270	0
Nickel	<0.0002	0.00048	0.00049	0.00062	0.00087	0.00219	0
Selenium	<0.0001	0.00022	0.00010	0.00016	0.00096	0.00142	3.9
Silver	<0.0000005	0.0000036	0.0000025	0.0000028	0.0000069	0.000104	0
Thallium	<0.0000003	0.0000075	0.0000025	0.0000040	0.0000500	0.0000077	0
Uranium	0.000019	0.000048	0.000044	0.000054	0.000075	0.000176	0
Zinc	<0.0001	0.0017	0.0015	0.0015	0.0035	0.0102	0

Notes:
'<' indicates that concentration was less than the analytical detection limit shown.
n = number of observations.
[a] *Minimum represents the lowest concentration in any sample.*
[b] *One half of the value of the analytical detection limit was substituted for values that were below detection limits, and replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, the 75th and 95th percentiles, and CCME guidelines.*
[c] *Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case maximum represents highest detection limit).*
[d] *CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed October 2016).*
[e] *The CCME guideline for chromium is dependent on its speciation (Cr(VI) or Cr(III)). Routine metal analysis does not distinguish between chromium species, so total chromium results were used to compare with CCME guidelines to be conservative.*

Fluoride concentrations in stream and river samples collected in 2007 from all of the study areas were occasionally higher than the CCME interim guideline of 0.12 mg/L; however, all fluoride concentrations in samples collected from 2008 to 2016 were below this guideline (CCME 2017; Table 4.2-11).

Total Suspended Solids and TurbidityStreams and rivers in the LSA and RSA had highly variable TSS and turbidity levels. TSS concentrations ranged widely from below the analytical detection limit (< 1.0 mg/L) to 198 mg/L in LSA streams, and < 1.0 mg/L to 17 mg/L in RSA streams. Turbidity ranged from 0.25 to 218 NTU in LSA streams, and 0.28 to 15.3 NTU in RSA streams. Mean and maximum TSS and turbidity levels were highest in the North Belt LSA (Table 4.2-12), and were particularly high in Glenn Outflow (Table 4.2-17).

Nutrients

Nitrate concentrations in streams and rivers ranged from below the analytical detection limit (< 0.001 mg/L) to 0.556 mg/L in the LSA and from < 0.001 mg/L to 0.268 mg/L in the RSA (Table 4.2-13). All concentrations remained well below the CCME guideline of 3.0 mg nitrate-N/L (CCME 2017). Nitrite concentrations throughout the LSA and RSA were near or below the analytical detection limit (< 0.001 mg/L; Table 4.2-13) and well below the CCME guideline of 0.06 mg nitrite-N/L (CCME 2017). Ammonia concentrations were similar in the LSA and RSA, ranging from below the detection limit (<0.005 mg/L) to 0.24 mg/L in both the LSA and RSA streams (Table 4.2-13). Concentrations always remained below the pH- and temperature-dependent CCME guideline for total ammonia (CCME 2017).

Table 4.2-16. Stream and River Free Cyanide Concentrations at LSA and RSA Sites, 2011 to 2016

Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples with Concentrations greater than CCME Guidelined
Free Cyanide (mg/L)									
LSA - North Belt	95	48	<0.001	all concentrations below detection limit				<0.005	0
LSA - South Belt	-	-	-	-	-	-	-	-	-
RSA	144	72	<0.001	all concentrations below detection limit				<0.005	0

Notes:
'<' indicates that concentration was less than the analytical detection limit shown.
n = number of observations.
[a] Minimum represents the lowest concentration in any sample.
[b] One half of the value of the analytical detection limit was substituted for values that were below detection limits, and replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, the 75th and 95th percentiles, and CCME guidelines.
[c] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case maximum represents highest detection limit).
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed October 2016).

Table 4.2-17. Stream- and River-specific Water Quality Summary, 2007 to 2016

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Aimaokatalok NE IF	Hardness (as $CaCO_3$)	14	11	9.6	18.5	19.6	21.6	24.7	25.2	-
Aimaokatalok NE IF	pH	13	10	6.10	6.72	7.09	7.31	7.78	8.35	20%
Aimaokatalok NE IF	Total Alkalinity (as $CaCO_3$)	14	11	6.6	12.2	13.4	14.0	16.2	17.7	-
Aimaokatalok NE IF	Total Suspended Solids	14	11	<3	6.6	4.0	7.0	18.0	23.0	-
Aimaokatalok NE IF	Total Dissolved Solids	14	11	22.4	49.3	49.2	54.5	77.5	84.0	-
Aimaokatalok NE IF	Turbidity (NTU)	6	3	4.85	6.90	6.26	7.90	9.22	9.73	-
Aimaokatalok NE IF	Ammonia (as N)	14	11	<0.005	0.019	0.015	0.024	0.036	0.040	0%
Aimaokatalok NE IF	Nitrate (as N)	14	11	<0.001	0.0034	0.0025	0.0038	0.0070	0.0080	0%
Aimaokatalok NE IF	Nitrite (as N)	14	11	<0.001	0.0010	0.0005	0.0015	0.0023	0.0020	0%
Aimaokatalok NE IF	Total Phosphorus (as P)	14	11	0.023	0.032	0.031	0.034	0.043	0.047	-

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Aimaokatalok NE IF	Total Organic Carbon	14	11	5.25	9.47	10.55	11.16	12.41	12.67	-
Aimaokatalok NE IF	Dissolved Organic Carbon	8	8	6.00	8.33	8.40	9.68	10.9	11.0	-
Aimaokatalok NE IF	Chloride	10	7	7.6	14.4	15.9	18.2	18.8	18.8	0%
Aimaokatalok NE IF	Fluoride	14	11	<0.01	0.039	0.040	0.041	0.075	0.100	0%
Aimaokatalok NE IF	Sulphate (SO_4)	14	11	0.88	3.04	1.50	3.00	8.50	12.00	-
Aimaokatalok NE IF	Free Cyanide	0	0	-	-	-	-	-	-	-
Aimaokatalok NE IF	Aluminum	14	11	0.087	0.315	0.206	0.386	0.782	0.836	90%
Aimaokatalok NE IF	Arsenic	14	11	0.00019	0.00040	0.00037	0.00041	0.00063	0.00097	0%
Aimaokatalok NE IF	Boron	14	11	0.0049	0.0084	0.0063	0.0110	0.0143	0.0148	0%
Aimaokatalok NE IF	Cadmium	14	11	<0.000002	0.0000065	0.0000046	0.0000058	0.0000178	0.0000255	0%
Aimaokatalok NE IF	Chromium	14	11	0.00045	0.00086	0.00074	0.00113	0.00135	0.00135	Cr(III) 0%; Cr(VI) 36%
Aimaokatalok NE IF	Copper	14	11	0.00093	0.00146	0.00160	0.00168	0.00183	0.00184	0%
Aimaokatalok NE IF	Iron	14	11	0.33	0.63	0.64	0.77	0.95	1.02	100%
Aimaokatalok NE IF	Lead	14	11	0.000049	0.000141	0.000114	0.000173	0.000279	0.000295	0%
Aimaokatalok NE IF	Mercury	14	11	<0.0000006	0.0000022	0.0000016	0.0000040	0.0000050	0.0000029	0%
Aimaokatalok NE IF	Molybdenum	14	11	0.00006	0.00012	0.00010	0.00015	0.00018	0.00019	0%
Aimaokatalok NE IF	Nickel	14	11	0.00055	0.00105	0.00103	0.00112	0.00141	0.00158	0%
Aimaokatalok NE IF	Selenium	14	11	<0.0001	0.00036	0.00040	0.00049	0.00056	0.00062	0%
Aimaokatalok NE IF	Silver	14	11	<0.0000005	0.0000052	0.0000050	0.0000075	0.0000107	0.0000116	0%
Aimaokatalok NE IF	Thallium	14	11	<0.0000003	0.000016	0.000005	0.000031	0.000050	0.000013	0%
Aimaokatalok NE IF	Uranium	14	11	0.000036	0.000057	0.000051	0.000066	0.000080	0.000094	0%
Aimaokatalok NE IF	Zinc	14	11	0.0011	0.0038	0.0027	0.0036	0.0110	0.0175	0%
Aimaokatalok OF	Hardness (as $CaCO_3$)	15	12	10.1	12.6	12.7	13.1	15.1	16.8	-
Aimaokatalok OF	pH	15	12	6.03	6.48	6.89	7.15	7.30	7.44	33%
Aimaokatalok OF	Total Alkalinity (as $CaCO_3$)	15	12	7.7	9.1	9.1	9.9	10.7	10.9	-
Aimaokatalok OF	Total Suspended Solids	15	12	<1	1.1	1.0	1.5	2.0	2.0	-
Aimaokatalok OF	Total Dissolved Solids	15	12	20.8	30.0	29.1	32.1	43.5	48.0	-

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Aimaokatalok OF	Turbidity (NTU)	7	4	0.37	1.19	1.22	1.49	1.84	1.98	-
Aimaokatalok OF	Ammonia (as N)	15	12	<0.005	0.008	0.008	0.009	0.016	0.017	0%
Aimaokatalok OF	Nitrate (as N)	15	12	<0.001	0.0108	0.0033	0.0188	0.0338	0.0396	0%
Aimaokatalok OF	Nitrite (as N)	15	12	<0.001	0.0013	0.0008	0.0025	0.0025	0.0010	0%
Aimaokatalok OF	Total Phosphorus (as P)	15	12	0.007	0.010	0.010	0.011	0.012	0.013	-
Aimaokatalok OF	Total Organic Carbon	15	12	3.69	4.90	4.77	5.42	6.20	6.60	-
Aimaokatalok OF	Dissolved Organic Carbon	8	8	3.50	4.60	4.60	5.08	5.43	5.5	-
Aimaokatalok OF	Chloride	11	8	6.8	8.1	7.8	8.2	10.2	11.1	0%
Aimaokatalok OF	Fluoride	14	11	0.020	0.032	0.028	0.030	0.065	0.090	0%
Aimaokatalok OF	Sulphate (SO_4)	15	12	1.19	2.07	1.50	1.63	4.90	6.00	-
Aimaokatalok OF	Free Cyanide	0	0	-	-	-	-	-	-	-
Aimaokatalok OF	Aluminum	15	12	0.019	0.055	0.046	0.062	0.106	0.122	42%
Aimaokatalok OF	Arsenic	15	12	0.00012	0.00021	0.00016	0.00018	0.00046	0.00080	0%
Aimaokatalok OF	Boron	15	12	0.0021	0.0067	0.0050	0.0083	0.0133	0.0151	0%
Aimaokatalok OF	Cadmium	15	12	<0.000002	0.0000037	0.0000036	0.0000050	0.0000067	0.0000087	0%
Aimaokatalok OF	Chromium	15	12	0.00016	0.00028	0.00027	0.00030	0.00044	0.00047	Cr(III) 0%; Cr(VI) 0%
Aimaokatalok OF	Copper	15	12	0.00071	0.00098	0.00091	0.00106	0.00136	0.00152	0%
Aimaokatalok OF	Iron	15	12	0.03	0.10	0.08	0.13	0.22	0.23	0%
Aimaokatalok OF	Lead	15	12	0.000011	0.000030	0.000025	0.000038	0.000057	0.000065	0%
Aimaokatalok OF	Mercury	15	12	<0.0000006	0.0000022	0.0000016	0.0000050	0.0000050	0.0000017	0%
Aimaokatalok OF	Molybdenum	15	12	0.00000	0.00004	0.00003	0.00005	0.00006	0.00007	0%
Aimaokatalok OF	Nickel	15	12	0.00033	0.00042	0.00042	0.00046	0.00056	0.00057	0%
Aimaokatalok OF	Selenium	15	12	<0.0001	0.00016	0.00017	0.00020	0.00026	0.00027	0%
Aimaokatalok OF	Silver	15	12	<0.0000005	0.0000028	0.0000026	0.0000050	0.0000050	0.0000047	0%
Aimaokatalok OF	Thallium	15	12	<0.0000003	0.000018	0.000002	0.000050	0.000050	0.000003	0%
Aimaokatalok OF	Uranium	15	12	0.000014	0.000023	0.000022	0.000025	0.000030	0.000030	0%
Aimaokatalok OF	Zinc	15	12	<0.001	0.0012	0.0011	0.0014	0.0024	0.0024	0%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
AWRa	Hardness (as $CaCO_3$)	6	3	20.5	39.3	44.9	48.6	51.6	52.8	-
AWRa	pH	6	3	7.28	7.47	7.57	7.59	7.61	7.62	0%
AWRa	Total Alkalinity (as $CaCO_3$)	6	3	12.3	25.9	29.6	32.7	35.2	36.0	-
AWRa	Total Suspended Solids	6	3	<3	14.8	4.0	21.1	34.8	38.5	-
AWRa	Total Dissolved Solids	6	3	92.0	144	153	169	182	190	-
AWRa	Turbidity (NTU)	6	3	17.3	26.8	21.1	31.0	39.0	41.1	-
AWRa	Ammonia (as N)	6	3	<0.005	0.008	0.011	0.011	0.011	0.012	0%
AWRa	Nitrate (as N)	6	3	<0.005	all concentrations below detection limits				<0.025	0%
AWRa	Nitrite (as N)	6	3	<0.001	all concentrations below detection limits				<0.005	0%
AWRa	Total Phosphorus (as P)	6	3	0.0248	0.0404	0.0359	0.0479	0.0575	0.0624	-
AWRa	Total Organic Carbon	6	3	9.20	14.9	17.1	17.3	17.5	18.0	-
AWRa	Dissolved Organic Carbon	0	0	-	-	-	-	-	-	-
AWRa	Chloride	6	3	29.3	41.8	38.9	48.0	55.4	58.2	0%
AWRa	Fluoride	6	3	<0.1	0.066	0.068	0.075	0.080	0.082	0%
AWRa	Sulphate (SO_4)	6	3	0.68	1.05	1.23	1.24	1.25	1.24	-
AWRa	Free Cyanide	0	0	-	-	-	-	-	-	-
AWRa	Aluminum	6	3	0.55	1.20	1.05	1.52	1.89	2.05	100%
AWRa	Arsenic	6	3	0.00043	0.00049	0.00045	0.00052	0.00058	0.00062	0%
AWRa	Boron	6	3	0.0127	0.0163	0.0137	0.0177	0.0209	0.0221	0%
AWRa	Cadmium	6	3	<0.00001	0.0000062	0.0000050	0.0000068	0.0000082	0.0000120	0%
AWRa	Chromium	6	3	0.00173	0.00267	0.00215	0.00313	0.00391	0.00422	Cr(III) 0%; Cr(VI) 100%
AWRa	Copper	6	3	0.00293	0.00300	0.00295	0.00302	0.00308	0.00316	100%
AWRa	Iron	6	3	0.91	1.44	1.18	1.68	2.09	2.23	100%
AWRa	Lead	6	3	0.000285	0.000495	0.000337	0.000595	0.000801	0.000861	0%
AWRa	Mercury	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRa	Molybdenum	6	3	0.00013	0.00015	0.00015	0.00016	0.00017	0.00018	0%
AWRa	Nickel	6	3	0.00353	0.00420	0.00429	0.00450	0.00466	0.00484	0%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
AWRa	Selenium	6	3	<0.0005	all concentrations below detection limits				<0.001	0%
AWRa	Silver	6	3	<0.00001	0.000027	0.000016	0.000038	0.000056	0.000117	0%
AWRa	Thallium	6	3	<0.0001	all concentrations below detection limits				<0.0001	0%
AWRa	Uranium	6	3	0.000087	0.000121	0.000126	0.000137	0.000146	0.000149	0%
AWRa	Zinc	6	3	0.0019	0.0031	0.0025	0.0037	0.0047	0.0051	0%
AWRb	Hardness (as $CaCO_3$)	6	3	16.6	26.8	29.8	31.9	33.5	34.2	-
AWRb	pH	6	3	7.17	7.38	7.34	7.43	7.50	7.54	0%
AWRb	Total Alkalinity (as $CaCO_3$)	6	3	13.2	18.4	19.8	21.0	21.9	22.2	-
AWRb	Total Suspended Solids	6	3	<3	3.2	1.5	4.1	6.2	6.7	-
AWRb	Total Dissolved Solids	6	3	51.0	93.0	104	113	121	127	-
AWRb	Turbidity (NTU)	6	3	2.0	5.4	3.4	7.1	10.1	11.0	-
AWRb	Ammonia (as N)	6	3	<0.005	0.009	0.003	0.013	0.021	0.025	0%
AWRb	Nitrate (as N)	6	3	<0.005	all concentrations below detection limits				<0.005	0%
AWRb	Nitrite (as N)	6	3	<0.001	all concentrations below detection limits				<0.001	0%
AWRb	Total Phosphorus (as P)	6	3	0.0142	0.0167	0.0153	0.0177	0.0195	0.0204	-
AWRb	Total Organic Carbon	6	3	6.42	7.18	7.05	7.51	7.88	8.0	-
AWRb	Dissolved Organic Carbon	0	0	-	-	-	-	-	-	-
AWRb	Chloride	6	3	14.6	31.6	39.7	40.1	40.4	40.5	0%
AWRb	Fluoride	6	3	0.036	0.038	0.040	0.040	0.040	0.040	0%
AWRb	Sulphate (SO_4)	6	3	<0.5	0.57	0.61	0.74	0.84	0.87	-
AWRb	Free Cyanide	0	0	-	-	-	-	-	-	-
AWRb	Aluminum	6	3	0.10	0.23	0.16	0.30	0.41	0.46	100%
AWRb	Arsenic	6	3	0.00012	0.00022	0.00021	0.00026	0.00030	0.00032	0%
AWRb	Boron	6	3	0.0116	0.0146	0.0142	0.0159	0.0172	0.0176	0%
AWRb	Cadmium	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRb	Chromium	6	3	<0.0005	0.00060	0.00038	0.00073	0.00101	0.00113	Cr(III) 0%; Cr(VI) 33%
AWRb	Copper	6	3	<0.0009	0.00087	0.00083	0.00106	0.00125	0.00139	0%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
AWRb	Iron	6	3	0.34	0.46	0.41	0.51	0.59	0.62	100%
AWRb	Lead	6	3	0.000052	0.000091	0.000058	0.000109	0.000151	0.000163	0%
AWRb	Mercury	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRb	Molybdenum	6	3	0.00006	0.00007	0.00007	0.00008	0.00008	0.00009	0%
AWRb	Nickel	6	3	0.00078	0.00102	0.00087	0.00113	0.00134	0.00142	0%
AWRb	Selenium	6	3	<0.0002	all concentrations below detection limits				<0.001	0%
AWRb	Silver	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRb	Thallium	6	3	<0.0001	all concentrations below detection limits				<0.0001	0%
AWRb	Uranium	6	3	0.000017	0.000027	0.000025	0.000031	0.000037	0.000040	0%
AWRb	Zinc	6	3	<0.001	0.0010	0.0011	0.0013	0.0015	0.0016	0%
AWRc	Hardness (as $CaCO_3$)	6	3	12.5	23.5	23.3	28.9	33.3	34.6	-
AWRc	pH	6	3	7.29	7.43	7.48	7.51	7.54	7.55	0%
AWRc	Total Alkalinity (as $CaCO_3$)	6	3	10.3	21.6	20.3	27.2	32.7	34.1	-
AWRc	Total Suspended Solids	6	3	<3	3.2	1.5	4.1	6.2	6.7	-
AWRc	Total Dissolved Solids	6	3	<3	2.3	1.5	2.8	3.8	6.5	-
AWRc	Turbidity (NTU)	6	3	1.3	1.7	1.7	1.9	2.0	2.1	-
AWRc	Ammonia (as N)	6	3	<0.005	0.0081	0.0059	0.0103	0.0137	0.0147	0%
AWRc	Nitrate (as N)	6	3	<0.005	all concentrations below detection limits				<0.005	0%
AWRc	Nitrite (as N)	6	3	<0.001	all concentrations below detection limits				<0.001	0%
AWRc	Total Phosphorus (as P)	6	3	0.0064	0.0094	0.0083	0.0104	0.0120	0.0128	-
AWRc	Total Organic Carbon	6	3	5.81	6.65	6.95	7.07	7.17	7.2	-
AWRc	Dissolved Organic Carbon	0	0	-	-	-	-	-	-	-
AWRc	Chloride	6	3	7.7	9.5	10.2	10.5	10.7	10.7	0%
AWRc	Fluoride	6	3	0.025	0.029	0.028	0.031	0.033	0.035	0%
AWRc	Sulphate (SO_4)	6	3	<0.5	0.34	0.25	0.39	0.49	0.52	-
AWRc	Free Cyanide	0	0	-	-	-	-	-	-	-
AWRc	Aluminum	6	3	0.023	0.045	0.048	0.054	0.060	0.069	0%
AWRc	Arsenic	6	3	0.00009	0.00014	0.00015	0.00016	0.00016	0.00017	0%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
AWRc	Boron	6	3	0.0107	0.0112	0.0110	0.0113	0.0116	0.0126	0%
AWRc	Cadmium	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRc	Chromium	6	3	<0.0005	0.00033	0.00029	0.00037	0.00044	0.00048	Cr(III) 0%; Cr(VI) 0%
AWRc	Copper	6	3	<0.0006	0.00298	0.00067	0.00431	0.00722	0.0156	33%
AWRc	Iron	6	3	0.24	0.43	0.44	0.53	0.60	0.62	67%
AWRc	Lead	6	3	<0.00005	0.000169	0.000025	0.000241	0.000414	0.000860	0%
AWRc	Mercury	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRc	Molybdenum	6	3	<0.00005	all concentrations below detection limits				<0.00005	0%
AWRc	Nickel	6	3	0.00038	0.00059	0.00066	0.00068	0.00070	0.00073	0%
AWRc	Selenium	6	3	<0.0002	all concentrations below detection limits				<0.001	0%
AWRc	Silver	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRc	Thallium	6	3	<0.0001	all concentrations below detection limits				<0.0001	0%
AWRc	Uranium	6	3	<0.00001	0.0000058	0.0000050	0.0000063	0.0000073	0.0000100	0%
AWRc	Zinc	6	3	0.0011	0.0026	0.0016	0.0032	0.0044	0.0084	0%
AWRd	Hardness (as $CaCO_3$)	6	3	16.5	21.3	20.0	23.7	26.7	27.4	-
AWRd	pH	6	3	7.04	7.23	7.28	7.34	7.39	7.42	0%
AWRd	Total Alkalinity (as $CaCO_3$)	6	3	13.8	18.8	15.9	21.3	25.6	27.0	-
AWRd	Total Suspended Solids	6	3	<3	5.3	1.5	7.2	11.7	15.1	-
AWRd	Total Dissolved Solids	6	3	56.0	63.7	61.0	65.8	69.6	71.0	-
AWRd	Turbidity (NTU)	6	3	1.2	4.6	1.8	6.3	9.8	12.1	-
AWRd	Ammonia (as N)	6	3	<0.005	0.0482	0.0187	0.0695	0.110	0.238	0%
AWRd	Nitrate (as N)	6	3	<0.005	0.0061	0.0025	0.0080	0.0123	0.0243	0%
AWRd	Nitrite (as N)	6	3	<0.001	all concentrations below detection limits				<0.001	0%
AWRd	Total Phosphorus (as P)	6	3	0.0110	0.0190	0.0148	0.0229	0.0293	0.0353	-
AWRd	Total Organic Carbon	6	3	5.69	6.59	6.21	6.97	7.58	8.3	-
AWRd	Dissolved Organic Carbon	0	0	-	-	-	-	-	-	-
AWRd	Chloride	6	3	17.1	18.1	18.0	18.6	19.0	19.2	0%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
AWRd	Fluoride	6	3	0.031	0.033	0.033	0.034	0.034	0.035	0%
AWRd	Sulphate (SO_4)	6	3	<0.5	0.68	0.84	0.90	0.94	0.96	-
AWRd	Free Cyanide	0	0	-	-	-	-	-	-	-
AWRd	Aluminum	6	3	0.011	0.030	0.032	0.038	0.043	0.047	0%
AWRd	Arsenic	6	3	0.00011	0.00035	0.00023	0.00046	0.00065	0.00070	0%
AWRd	Boron	6	3	0.0121	0.0155	0.0163	0.0170	0.0176	0.0201	0%
AWRd	Cadmium	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRd	Chromium	6	3	0.00022	0.00030	0.00025	0.00033	0.00039	0.00043	Cr(III) 0%; Cr(VI) 0%
AWRd	Copper	6	3	<0.0002	0.00047	0.00038	0.00065	0.00087	0.0011	0%
AWRd	Iron	6	3	0.26	1.38	1.23	1.94	2.51	3.04	67%
AWRd	Lead	6	3	<0.00005	all concentrations below detection limits				<0.00005	0%
AWRd	Mercury	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRd	Molybdenum	6	3	<0.00005	all concentrations below detection limits				<0.00005	0%
AWRd	Nickel	6	3	0.00036	0.00045	0.00044	0.00048	0.00051	0.00055	0%
AWRd	Selenium	6	3	<0.0005	all concentrations below detection limits				<0.001	0%
AWRd	Silver	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRd	Thallium	6	3	<0.0001	all concentrations below detection limits				<0.0001	0%
AWRd	Uranium	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRd	Zinc	6	3	<0.001	0.0011	0.0011	0.0015	0.0017	0.0021	0%
AWRe	Hardness (as $CaCO_3$)	6	3	22.6	38.4	44.8	46.2	47.4	47.8	-
AWRe	pH	6	3	7.35	7.50	7.53	7.57	7.60	7.64	0%
AWRe	Total Alkalinity (as $CaCO_3$)	6	3	17.5	29.5	30.9	35.4	39.0	39.9	-
AWRe	Total Suspended Solids	6	3	<3	4.9	1.5	6.7	10.8	22.1	-
AWRe	Total Dissolved Solids	6	3	58.0	95.7	105	113	120	122	-
AWRe	Turbidity (NTU)	6	3	0.25	0.91	0.61	1.23	1.73	3.24	-
AWRe	Ammonia (as N)	6	3	<0.005	0.0058	0.0025	0.0074	0.011	0.013	0%
AWRe	Nitrate (as N)	6	3	<0.005	all concentrations below detection limits				<0.005	0%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
AWRe	Nitrite (as N)	6	3	<0.001	all concentrations below detection limits				<0.001	0%
AWRe	Total Phosphorus (as P)	6	3	0.0046	0.0092	0.0074	0.0115	0.0147	0.0237	-
AWRe	Total Organic Carbon	6	3	10.0	14.9	16.5	17.4	18.1	18.4	-
AWRe	Dissolved Organic Carbon	0	0	-	-	-	-	-	-	-
AWRe	Chloride	6	3	13.5	19.3	18.7	22.2	25.0	25.8	0%
AWRe	Fluoride	6	3	0.049	0.051	0.051	0.052	0.053	0.054	0%
AWRe	Sulphate (SO_4)	6	3	<0.5	0.42	0.25	0.51	0.72	0.78	-
AWRe	Free Cyanide	0	0	-	-	-	-	-	-	-
AWRe	Aluminum	6	3	0.038	0.048	0.042	0.053	0.062	0.075	0%
AWRe	Arsenic	6	3	<0.00025	0.00019	0.00014	0.00022	0.00028	0.00031	0%
AWRe	Boron	6	3	0.0080	0.0105	0.0114	0.0115	0.0117	0.0122	0%
AWRe	Cadmium	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRe	Chromium	6	3	0.00044	0.00080	0.00081	0.00096	0.00108	0.00112	Cr(III) 0%; Cr(VI) 33%
AWRe	Copper	6	3	0.00051	0.00087	0.00103	0.00104	0.00104	0.0011	0%
AWRe	Iron	6	3	0.09	0.24	0.27	0.31	0.35	0.49	33%
AWRe	Lead	6	3	<0.00005	all concentrations below detection limits				<0.00005	0%
AWRe	Mercury	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRe	Molybdenum	6	3	0.000062	0.000090	0.000084	0.000100	0.000113	0.000121	0%
AWRe	Nickel	6	3	0.00118	0.00181	0.00208	0.00211	0.00214	0.00226	0%
AWRe	Selenium	6	3	<0.0002	all concentrations below detection limits				<0.001	0%
AWRe	Silver	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
AWRe	Thallium	6	3	<0.0001	all concentrations below detection limits				<0.0001	0%
AWRe	Uranium	6	3	0.000011	0.0000147	0.0000115	0.0000163	0.0000201	0.0000230	0%
AWRe	Zinc	6	3	0.0017	0.0025	0.0026	0.0029	0.0031	0.0034	0%
Doris OF	Hardness (as $CaCO_3$)	75	44	28.3	46.7	47.1	50.8	54.9	56.6	-
Doris OF	pH	75	44	5.73	6.93	7.60	7.69	7.85	7.96	7%
Doris OF	Total Alkalinity (as $CaCO_3$)	75	44	16.4	27.8	28.6	29.9	32.4	33.0	-

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Doris OF	Total Suspended Solids	75	44	<1	4.5	3.7	5.5	10.4	20.3	-
Doris OF	Total Dissolved Solids	51	32	83	139	141	152	173	189	-
Doris OF	Turbidity (NTU)	62	31	1.81	5.39	5.29	6.42	9.18	12.1	-
Doris OF	Ammonia (as N)	75	44	<0.005	0.0090	0.0077	0.0118	0.0199	0.0360	0%
Doris OF	Nitrate (as N)	75	44	<0.005	0.0027	0.0025	0.0025	0.0036	0.0061	0%
Doris OF	Nitrite (as N)	75	44	<0.001	0.0006	0.0005	0.0005	0.0018	0.0030	0%
Doris OF	Total Phosphorus (as P)	75	44	0.011	0.025	0.025	0.028	0.037	0.043	-
Doris OF	Total Organic Carbon	75	44	3.91	7.24	6.33	6.76	9.42	46.3	-
Doris OF	Dissolved Organic Carbon	45	29	4.09	7.16	5.70	6.26	9.26	44.7	-
Doris OF	Chloride	75	44	36.0	60.1	61.3	64.7	71.7	73.3	0%
Doris OF	Fluoride	75	44	0.029	0.054	0.054	0.058	0.069	0.130	2%
Doris OF	Sulphate (SO_4)	75	44	<3	2.74	2.64	2.95	5.62	7.00	-
Doris OF	Free Cyanide	48	24	<0.001	all concentrations below detection limits				<0.005	0%
Doris OF	Aluminum	75	44	0.022	0.098	0.066	0.079	0.371	0.633	23%
Doris OF	Arsenic	75	44	0.00017	0.00038	0.00029	0.00039	0.00052	0.00372	0%
Doris OF	Boron	75	44	<0.025	0.0249	0.0244	0.0283	0.0335	0.0503	0%
Doris OF	Cadmium	75	44	<0.000002	0.0000033	0.0000025	0.0000026	0.0000107	0.0000201	0%
Doris OF	Chromium	75	44	0.00017	0.00037	0.00025	0.00028	0.00084	0.00228	Cr(III) 0%; Cr(VI) 5%
Doris OF	Copper	75	44	0.00099	0.00156	0.00150	0.00164	0.00259	0.00400	14%
Doris OF	Iron	75	44	0.062	0.189	0.142	0.177	0.471	0.830	16%
Doris OF	Lead	75	44	0.000017	0.000045	0.000025	0.000039	0.000168	0.000219	0%
Doris OF	Mercury	75	44	<0.0000006	0.0000016	0.0000010	0.0000017	0.0000050	0.0000036	0%
Doris OF	Molybdenum	75	44	0.000102	0.000163	0.000163	0.000184	0.000216	0.000232	0%
Doris OF	Nickel	75	44	0.00029	0.00061	0.00056	0.00066	0.00101	0.00136	0%
Doris OF	Selenium	75	44	<0.0002	0.00037	0.00010	0.00064	0.00117	0.00126	9%
Doris OF	Silver	75	44	<0.0000005	0.0000031	0.0000025	0.0000025	0.0000050	0.0000357	0%
Doris OF	Thallium	75	44	<0.0000003	0.0000056	0.0000025	0.0000038	0.0000435	0.0000068	0%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Doris OF	Uranium	75	44	0.000019	0.000035	0.000034	0.000038	0.000054	0.000059	0%
Doris OF	Zinc	75	44	<0.0001	0.0016	0.0015	0.0015	0.0037	0.0055	0%
Glenn OF	Hardness (as $CaCO_3$)	14	11	25.4	62.8	68.9	73.4	80.2	81.9	-
Glenn OF	pH	13	10	6.84	7.31	7.54	7.96	8.21	8.34	0%
Glenn OF	Total Alkalinity (as $CaCO_3$)	14	11	17.7	42.6	48.2	48.9	49.7	49.8	-
Glenn OF	Total Suspended Solids	14	11	1.0	24.4	7.0	8.5	111	198	-
Glenn OF	Total Dissolved Solids	14	11	90	178	180	196	264	278	-
Glenn OF	Turbidity (NTU)	6	3	28	102	62	138	199	218	-
Glenn OF	Ammonia (as N)	14	11	<0.005	0.0061	0.0070	0.0080	0.0095	0.0110	0%
Glenn OF	Nitrate (as N)	14	11	<0.005	0.0047	0.0025	0.0043	0.0130	0.0170	0%
Glenn OF	Nitrite (as N)	14	11	<0.001	0.00086	0.00050	0.00050	0.00250	0.00300	0%
Glenn OF	Total Phosphorus (as P)	14	11	0.0120	0.0217	0.0170	0.0210	0.0452	0.0585	-
Glenn OF	Total Organic Carbon	14	11	2.98	4.23	4.09	4.72	5.74	6.69	-
Glenn OF	Dissolved Organic Carbon	8	8	2.80	3.88	3.55	4.05	5.74	6.40	-
Glenn OF	Chloride	14	11	27.2	71.4	77.8	82.2	103	112	0%
Glenn OF	Fluoride	14	11	0.033	0.083	0.080	0.080	0.155	0.180	18%
Glenn OF	Sulphate (SO_4)	14	11	4.18	10.1	10.0	13.2	17.4	18.0	-
Glenn OF	Free Cyanide	0	0	-	-	-	-	-	-	0%
Glenn OF	Aluminum	14	11	0.195	0.974	0.694	1.02	2.52	3.90	100%
Glenn OF	Arsenic	14	11	<0.00057	0.000559	0.000583	0.000680	0.000737	0.000777	0%
Glenn OF	Boron	14	11	0.0186	0.0375	0.0384	0.0426	0.0473	0.0486	0%
Glenn OF	Cadmium	14	11	<0.000002	0.0000054	0.0000050	0.0000054	0.0000131	0.0000200	0%
Glenn OF	Chromium	14	11	0.00051	0.00185	0.00117	0.00178	0.00521	0.00739	Cr(III) 0%; Cr(VI) 64%
Glenn OF	Copper	14	11	0.00243	0.00379	0.00314	0.00400	0.00688	0.00898	100%
Glenn OF	Iron	14	11	0.117	0.901	0.535	0.808	2.83	3.97	82%
Glenn OF	Lead	14	11	0.000063	0.000430	0.000249	0.000374	0.00132	0.00204	9%
Glenn OF	Mercury	14	11	<0.0000006	0.0000021	0.0000014	0.0000041	0.0000050	0.0000032	0%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Glenn OF	Molybdenum	14	11	0.000103	0.000570	0.000603	0.000673	0.000709	0.000720	0%
Glenn OF	Nickel	14	11	0.00072	0.00160	0.00111	0.00154	0.00395	0.00529	0%
Glenn OF	Selenium	14	11	<0.0005	0.00097	0.00094	0.00135	0.00159	0.00170	45%
Glenn OF	Silver	13	10	<0.0000005	0.0000056	0.0000046	0.0000069	0.0000151	0.0000200	0%
Glenn OF	Thallium	14	11	0.0000010	0.0000185	0.0000111	0.0000308	0.0000500	0.0000115	0%
Glenn OF	Uranium	14	11	0.000155	0.000289	0.000299	0.000320	0.000405	0.000447	0%
Glenn OF	Zinc	14	11	0.0010	0.0035	0.0024	0.0031	0.0095	0.0134	0%
Koignuk River	Hardness (as $CaCO_3$)	52	31	12.6	22.4	17.5	20.7	54.7	78.5	-
Koignuk River	pH	52	31	6.50	7.10	7.19	7.38	7.68	8.00	3%
Koignuk River	Total Alkalinity (as $CaCO_3$)	52	31	9.0	15.7	11.9	14.7	37.3	56.4	-
Koignuk River	Total Suspended Solids	52	31	1.0	9.6	4.0	13.0	36.1	57.5	-
Koignuk River	Total Dissolved Solids	52	31	26	58	45	56	140	237	-
Koignuk River	Turbidity (NTU)	44	23	0.52	9.48	5.78	12.5	27.3	37.4	-
Koignuk River	Ammonia (as N)	52	31	<0.005	0.008	0.007	0.010	0.016	0.044	0%
Koignuk River	Nitrate (as N)	52	31	<0.005	0.0581	0.0025	0.0139	0.391	0.556	0%
Koignuk River	Nitrite (as N)	52	31	<0.001	0.00061	0.00050	0.00050	0.00125	0.00200	0%
Koignuk River	Total Phosphorus (as P)	52	31	0.0073	0.0174	0.0150	0.0196	0.0330	0.0429	-
Koignuk River	Total Organic Carbon	52	31	3.98	6.81	5.89	6.41	14.2	22.6	-
Koignuk River	Dissolved Organic Carbon	8	8	3.80	4.99	4.95	5.70	6.00	6.00	-
Koignuk River	Chloride	52	31	6.19	15.7	10.8	15.2	38.0	61.1	0%
Koignuk River	Fluoride	52	31	<0.02	0.031	0.028	0.031	0.063	0.110	0%
Koignuk River	Sulphate (SO_4)	52	31	1.15	3.49	2.21	4.18	9.32	12.6	-
Koignuk River	Free Cyanide	0	0	-	-	-	-	-	-	-
Koignuk River	Aluminum	52	31	0.020	0.432	0.304	0.638	1.10	1.43	90%
Koignuk River	Arsenic	52	31	<0.0002	0.00028	0.00025	0.00033	0.00046	0.00089	0%
Koignuk River	Boron	52	31	0.0045	0.0103	0.0087	0.0139	0.0186	0.0291	0%
Koignuk River	Cadmium	52	31	<0.000002	0.000012	0.000005	0.000005	0.000030	0.000165	3%
Koignuk River	Chromium	52	31	<0.0005	0.00116	0.00095	0.00188	0.00259	0.00387	Cr(III) 0%;

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
										Cr(VI) 45%
Koignuk River	Copper	52	31	0.00098	0.00216	0.00177	0.00233	0.00459	0.00948	35%
Koignuk River	Iron	52	31	0.062	0.467	0.315	0.633	1.15	1.52	61%
Koignuk River	Lead	52	31	<0.00005	0.000318	0.000132	0.000307	0.000509	0.00528	3%
Koignuk River	Mercury	52	31	<0.0000006	0.0000039	0.0000050	0.0000050	0.0000050	0.0000017	0%
Koignuk River	Molybdenum	52	31	<0.00005	0.0000974	0.0000835	0.0000998	0.000268	0.000365	0%
Koignuk River	Nickel	52	31	0.00037	0.00117	0.00104	0.00165	0.00242	0.00343	0%
Koignuk River	Selenium	52	31	<0.0001	0.00036	0.00045	0.00050	0.00050	0.00112	3%
Koignuk River	Silver	52	31	<0.0000005	0.0000060	0.0000050	0.0000050	0.0000132	0.0000430	0%
Koignuk River	Thallium	52	31	0.0000041	0.000039	0.000050	0.000050	0.000050	0.000017	0%
Koignuk River	Uranium	52	31	0.000022	0.000062	0.000044	0.000077	0.000131	0.000251	0%
Koignuk River	Zinc	52	31	<0.001	0.0029	0.0022	0.0034	0.0054	0.0180	0%
Little Roberts OF	Hardness (as $CaCO_3$)	70	39	25.4	43.4	44.4	47.6	51.8	60.3	-
Little Roberts OF	pH	70	39	6.82	7.36	7.55	7.67	7.83	7.86	0%
Little Roberts OF	Total Alkalinity (as $CaCO_3$)	70	39	14.2	25.0	26.1	26.9	29.0	29.8	-
Little Roberts OF	Total Suspended Solids	70	39	1.0	4.7	3.6	4.6	14.0	20.0	-
Little Roberts OF	Total Dissolved Solids	46	27	70	140	139	151	170	180	-
Little Roberts OF	Turbidity (NTU)	62	31	2.05	5.80	4.66	6.00	13.0	19.0	-
Little Roberts OF	Ammonia (as N)	70	39	<0.005	0.006	0.004	0.007	0.017	0.030	0%
Little Roberts OF	Nitrate (as N)	70	39	<0.005	0.0034	0.0025	0.0025	0.0059	0.0256	0%
Little Roberts OF	Nitrite (as N)	70	39	<0.001	0.0006	0.0005	0.0005	0.0006	0.0020	0%
Little Roberts OF	Total Phosphorus (as P)	70	39	0.012	0.021	0.020	0.024	0.031	0.036	-
Little Roberts OF	Total Organic Carbon	70	39	3.66	5.91	5.99	6.37	6.99	8.56	-
Little Roberts OF	Dissolved Organic Carbon	38	23	4.10	5.73	5.70	6.17	7.27	7.9	-
Little Roberts OF	Chloride	70	39	35.0	58.6	59.9	62.7	67.3	70.9	0%
Little Roberts OF	Fluoride	70	39	0.027	0.050	0.050	0.053	0.062	0.090	0%
Little Roberts OF	Sulphate (SO_4)	70	39	<3	3.51	3.49	4.00	5.01	5.24	-
Little Roberts OF	Free Cyanide	47	24	<0.001	all concentrations below detection limits				<0.005	0%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Little Roberts OF	Aluminum	70	39	0.045	0.169	0.110	0.176	0.564	0.655	56%
Little Roberts OF	Arsenic	70	39	0.00018	0.00044	0.00030	0.00038	0.00055	0.00493	0%
Little Roberts OF	Boron	70	39	<0.025	0.0262	0.0251	0.0292	0.0366	0.0518	0%
Little Roberts OF	Cadmium	70	39	<0.000002	0.0000039	0.0000025	0.0000026	0.0000085	0.0000339	0%
Little Roberts OF	Chromium	70	39	0.00019	0.00038	0.00025	0.00033	0.00095	0.00134	Cr(III) 0%; Cr(VI) 5%
Little Roberts OF	Copper	70	39	0.00105	0.00158	0.00153	0.00167	0.00202	0.00353	8%
Little Roberts OF	Iron	70	39	0.06	0.28	0.21	0.30	0.68	0.83	26%
Little Roberts OF	Lead	70	39	0.000023	0.000066	0.000039	0.000077	0.000199	0.000246	0%
Little Roberts OF	Mercury	70	39	<0.0000005	0.0000016	0.0000008	0.0000019	0.0000050	0.0000026	0%
Little Roberts OF	Molybdenum	70	39	0.00012	0.00018	0.00018	0.00020	0.00022	0.00022	0%
Little Roberts OF	Nickel	70	39	0.00037	0.00067	0.00062	0.00075	0.00109	0.00128	0%
Little Roberts OF	Selenium	70	39	<0.0002	0.00031	0.00010	0.00050	0.00111	0.00121	10%
Little Roberts OF	Silver	70	39	<0.0000005	0.0000026	0.0000025	0.0000025	0.0000050	0.0000094	0%
Little Roberts OF	Thallium	70	39	<0.000002	0.000006	0.000003	0.000004	0.000050	0.000008	0%
Little Roberts OF	Uranium	70	39	0.000030	0.000045	0.000043	0.000050	0.000061	0.000080	0%
Little Roberts OF	Zinc	70	39	<0.0001	0.0014	0.0015	0.0015	0.0022	0.0031	0%
Ogama OF	Hardness (as $CaCO_3$)	14	11	33.5	43.6	45.1	46.3	54.9	61.7	-
Ogama OF	pH	14	11	6.80	7.14	7.27	7.63	8.14	8.27	0%
Ogama OF	Total Alkalinity (as $CaCO_3$)	14	11	20.0	25.5	25.4	27.4	31.8	36.0	-
Ogama OF	Total Suspended Solids	14	11	3.0	4.8	4.8	5.6	6.6	7.7	-
Ogama OF	Total Dissolved Solids	14	11	94	138	138	143	196	249	-
Ogama OF	Turbidity (NTU)	6	3	6.17	9.13	9.75	10.6	11.3	11.7	-
Ogama OF	Ammonia (as N)	14	11	<0.005	0.009	0.008	0.014	0.016	0.017	0%
Ogama OF	Nitrate (as N)	14	11	<0.005	0.0045	0.0025	0.0025	0.0137	0.0232	0%
Ogama OF	Nitrite (as N)	14	11	<0.001	0.0009	0.0005	0.0010	0.0020	0.0030	0%
Ogama OF	Total Phosphorus (as P)	14	11	0.021	0.031	0.028	0.031	0.050	0.065	-
Ogama OF	Total Organic Carbon	14	11	5.37	7.66	7.40	9.22	9.70	9.87	-

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Ogama OF	Dissolved Organic Carbon	8	8	5.00	6.83	6.55	8.10	8.92	9.2	-
Ogama OF	Chloride	14	11	45.9	63.1	58.9	71.0	83.7	93.9	0%
Ogama OF	Fluoride	14	11	0.040	0.069	0.060	0.060	0.135	0.140	18%
Ogama OF	Sulphate (SO_4)	14	11	<3	2.79	1.73	3.18	6.50	9.00	-
Ogama OF	Free Cyanide	0	0	-	-	-	-	-	-	-
Ogama OF	Aluminum	14	11	0.150	0.268	0.240	0.341	0.401	0.448	100%
Ogama OF	Arsenic	14	11	<0.00042	0.00045	0.00047	0.00055	0.00059	0.00060	0%
Ogama OF	Boron	14	11	0.0156	0.0221	0.0225	0.0247	0.0281	0.0310	0%
Ogama OF	Cadmium	14	11	<0.000002	0.0000037	0.0000040	0.0000050	0.0000054	0.0000056	0%
Ogama OF	Chromium	14	11	0.00040	0.00059	0.00049	0.00071	0.00097	0.00145	Cr(III) 0%; Cr(VI) 9%
Ogama OF	Copper	14	11	0.00119	0.00162	0.00167	0.00174	0.00207	0.00238	9%
Ogama OF	Iron	14	11	0.173	0.349	0.333	0.403	0.650	0.679	55%
Ogama OF	Lead	14	11	0.000052	0.000102	0.000088	0.000118	0.000168	0.000210	0%
Ogama OF	Mercury	14	11	<0.0000006	0.0000023	0.0000014	0.0000041	0.0000050	0.0000031	0%
Ogama OF	Molybdenum	14	11	0.00014	0.00020	0.00021	0.00023	0.00027	0.00033	0%
Ogama OF	Nickel	14	11	0.00055	0.00100	0.00092	0.00109	0.00160	0.00224	0%
Ogama OF	Selenium	14	11	0.00024	0.00075	0.00067	0.00104	0.00137	0.00163	36%
Ogama OF	Silver	14	11	<0.0000005	0.0000033	0.0000017	0.0000050	0.0000092	0.0000134	0%
Ogama OF	Thallium	14	11	<0.0000003	0.0000161	0.0000040	0.0000283	0.0000500	0.0000066	0%
Ogama OF	Uranium	14	11	0.000035	0.000052	0.000053	0.000059	0.000069	0.000079	0%
Ogama OF	Zinc	14	11	<0.001	0.0017	0.0017	0.0021	0.0027	0.0029	0%
P.O. OF	Hardness (as $CaCO_3$)	14	11	23.4	46.9	52.3	53.4	57.0	57.9	-
P.O. OF	pH	14	11	5.61	6.57	7.38	7.70	7.98	8.07	9%
P.O. OF	Total Alkalinity (as $CaCO_3$)	14	11	16.7	28.0	29.8	30.8	33.0	33.5	-
P.O. OF	Total Suspended Solids	14	11	<1	5.2	3.3	4.5	16.1	28.7	-
P.O. OF	Total Dissolved Solids	14	11	66	144	151	165	181	201	-
P.O. OF	Turbidity (NTU)	6	3	5.19	21.9	6.28	30.2	49.3	54.80	-

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
P.O. OF	Ammonia (as N)	14	11	<0.005	0.008	0.006	0.010	0.019	0.022	0%
P.O. OF	Nitrate (as N)	14	11	<0.005	0.0046	0.0025	0.0025	0.0143	0.0260	0%
P.O. OF	Nitrite (as N)	14	11	<0.001	0.0009	0.0005	0.0005	0.0025	0.0030	0%
P.O. OF	Total Phosphorus (as P)	14	11	0.007	0.017	0.014	0.018	0.034	0.040	-
P.O. OF	Total Organic Carbon	14	11	3.37	5.49	4.35	7.21	9.32	10.2	-
P.O. OF	Dissolved Organic Carbon	8	8	3.10	5.19	4.05	6.40	9.05	9.50	-
P.O. OF	Chloride	14	11	30.5	66.5	70.0	77.1	83.4	84.3	0%
P.O. OF	Fluoride	14	11	0.042	0.070	0.060	0.066	0.130	0.180	9%
P.O. OF	Sulphate (SO_4)	14	11	<3	2.67	1.50	2.34	7.00	11.00	-
P.O. OF	Free Cyanide	0	0	-	-	-	-	-	-	-
P.O. OF	Aluminum	14	11	0.106	0.493	0.299	0.443	1.417	2.130	100%
P.O. OF	Arsenic	14	11	<0.0003	0.00046	0.00048	0.00054	0.00060	0.00062	0%
P.O. OF	Boron	14	11	0.0153	0.0231	0.0244	0.0251	0.0302	0.0335	0%
P.O. OF	Cadmium	14	11	<0.000002	0.0000050	0.0000050	0.0000064	0.0000119	0.0000140	0%
P.O. OF	Chromium	14	11	0.00034	0.00097	0.00062	0.00091	0.00263	0.00421	Cr(III) 0%; Cr(VI) 27%
P.O. OF	Copper	14	11	0.00071	0.00145	0.00146	0.00167	0.00225	0.00276	9%
P.O. OF	Iron	14	11	0.18	0.48	0.35	0.48	1.20	1.94	55%
P.O. OF	Lead	14	11	0.000043	0.000204	0.000184	0.000224	0.000516	0.000733	0%
P.O. OF	Mercury	14	11	<0.0000006	0.0000022	0.0000003	0.0000045	0.0000050	0.0000039	0%
P.O. OF	Molybdenum	14	11	0.00012	0.00019	0.00019	0.00021	0.00027	0.00029	0%
P.O. OF	Nickel	14	11	0.00024	0.00101	0.00084	0.00115	0.00214	0.00264	0%
P.O. OF	Selenium	14	11	<0.0007	0.00085	0.00077	0.00117	0.00133	0.00136	36%
P.O. OF	Silver	14	11	<0.0000005	0.0000096	0.0000034	0.0000050	0.0000422	0.0000500	0%
P.O. OF	Thallium	14	11	<0.0000003	0.000018	0.000007	0.000032	0.000050	0.000013	0%
P.O. OF	Uranium	14	11	0.000041	0.000065	0.000061	0.000064	0.000112	0.000163	0%
P.O. OF	Zinc	14	11	<0.001	0.0029	0.0026	0.0038	0.0059	0.0066	0%
Patch OF	Hardness (as $CaCO_3$)	14	11	12.1	50.1	59.3	63.6	66.7	68.6	-

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Patch OF	pH	14	11	5.60	6.55	7.50	7.73	8.10	8.20	9%
Patch OF	Total Alkalinity (as $CaCO_3$)	14	11	10.0	28.7	33.6	35.5	36.1	36.3	-
Patch OF	Total Suspended Solids	14	11	<1	2.2	1.5	3.0	5.9	7.0	-
Patch OF	Total Dissolved Solids	14	11	28	137	163	168	185	190	-
Patch OF	Turbidity (NTU)	6	3	1.66	3.47	2.67	4.37	5.73	6.14	-
Patch OF	Ammonia (as N)	14	11	<0.005	0.008	0.006	0.007	0.022	0.033	0%
Patch OF	Nitrate (as N)	14	11	<0.005	0.0043	0.0025	0.0038	0.0110	0.0140	0%
Patch OF	Nitrite (as N)	14	11	<0.001	0.0008	0.0005	0.0005	0.0020	0.0020	0%
Patch OF	Total Phosphorus (as P)	14	11	0.005	0.012	0.008	0.011	0.031	0.048	-
Patch OF	Total Organic Carbon	14	11	3.16	4.63	3.91	4.39	8.38	11.1	-
Patch OF	Dissolved Organic Carbon	8	8	3.10	4.68	4.05	4.53	8.17	9.6	-
Patch OF	Chloride	14	11	8.8	63.4	77.5	78.8	81.7	82.4	0%
Patch OF	Fluoride	14	11	0.021	0.203	0.061	0.070	0.865	1.63	9%
Patch OF	Sulphate (SO_4)	14	11	0.71	2.32	1.50	2.43	5.50	7.00	-
Patch OF	Free Cyanide	0	0	-	-	-	-	-	-	-
Patch OF	Aluminum	14	11	0.068	0.215	0.159	0.221	0.542	0.763	64%
Patch OF	Arsenic	14	11	<0.0001	0.00040	0.00041	0.00052	0.00063	0.00065	0%
Patch OF	Boron	14	11	0.0070	0.0218	0.0240	0.0273	0.0300	0.0304	0%
Patch OF	Cadmium	14	11	<0.000002	0.0000034	0.0000034	0.0000050	0.0000063	0.0000076	0%
Patch OF	Chromium	14	11	<0.0001	0.00052	0.00045	0.00064	0.00107	0.00120	Cr(III) 0%; Cr(VI) 9%
Patch OF	Copper	14	11	0.00066	0.00123	0.00106	0.00120	0.00231	0.00298	9%
Patch OF	Iron	14	11	0.082	0.203	0.165	0.199	0.494	0.497	18%
Patch OF	Lead	14	11	<0.00005	0.000086	0.000081	0.000106	0.000177	0.000234	0%
Patch OF	Mercury	14	11	<0.0000006	0.0000021	0.0000019	0.0000038	0.0000050	0.0000026	0%
Patch OF	Molybdenum	14	11	0.00006	0.00016	0.00016	0.00019	0.00025	0.00025	0%
Patch OF	Nickel	14	11	0.00022	0.00064	0.00048	0.00062	0.00146	0.00197	0%
Patch OF	Selenium	14	11	0.00020	0.00075	0.00050	0.00104	0.00144	0.00160	36%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Patch OF	Silver	14	11	<0.0000005	0.0000035	0.0000023	0.0000050	0.0000090	0.0000110	0%
Patch OF	Thallium	14	11	<0.0000003	0.0000168	0.0000056	0.0000294	0.0000500	0.0000087	0%
Patch OF	Uranium	14	11	0.000019	0.000062	0.000062	0.000072	0.000092	0.000106	0%
Patch OF	Zinc	14	11	<0.001	0.0015	0.0012	0.0021	0.0031	0.0039	0%
S12	Hardness (as $CaCO_3$)	4	2	8.0	34.4	34.4	47.5	58.1	60.8	-
S12	pH	4	2	7.03	7.27	7.27	7.48	7.77	7.91	0%
S12	Total Alkalinity (as $CaCO_3$)	4	2	6.6	30.3	30.3	42.0	51.4	54.0	-
S12	Total Suspended Solids	4	2	<3	all concentrations below detection limits				<3	-
S12	Total Dissolved Solids	4	2	29	68	68	86	100	108	-
S12	Turbidity (NTU)	4	2	0.69	1.15	1.15	1.38	1.56	1.62	-
S12	Ammonia (as N)	4	2	0.0159	0.0170	0.0170	0.0174	0.0177	0.0187	0%
S12	Nitrate (as N)	4	2	<0.005	0.092	0.092	0.136	0.172	0.181	0%
S12	Nitrite (as N)	4	2	<0.001	all concentrations below detection limits				<0.001	0%
S12	Total Phosphorus (as P)	4	2	0.0049	0.0055	0.0055	0.0058	0.0060	0.0067	-
S12	Total Organic Carbon	4	2	4.57	6.19	6.19	6.97	7.59	7.87	-
S12	Dissolved Organic Carbon	0	0	-	-	-	-	-	-	-
S12	Chloride	4	2	1.6	7.0	7.0	9.8	12.0	12.5	0%
S12	Fluoride	4	2	0.023	0.030	0.030	0.034	0.036	0.037	0%
S12	Sulphate (SO_4)	4	2	1.05	5.49	5.49	7.71	9.49	9.96	-
S12	Free Cyanide	0	0	-	-	-	-	-	-	-
S12	Aluminum	4	2	0.0679	0.0725	0.0725	0.0740	0.0752	0.0756	0%
S12	Arsenic	4	2	<0.00005	0.000073	0.000073	0.000096	0.000115	0.000130	0%
S12	Boron	4	2	0.0104	0.0129	0.0129	0.0132	0.0134	0.0140	0%
S12	Cadmium	4	2	<0.00001	0.0000095	0.0000095	0.0000118	0.0000136	0.0000160	0%
S12	Chromium	4	2	<0.0004	0.00042	0.00042	0.00053	0.00061	0.00067	Cr(III) 0%; Cr(VI) 0%
S12	Copper	4	2	0.00242	0.00405	0.00405	0.00482	0.00544	0.00561	100%
S12	Iron	4	2	0.115	0.243	0.243	0.305	0.355	0.390	50%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
S12	Lead	4	2	<0.00005	0.000060	0.000060	0.000077	0.000091	0.000096	0%
S12	Mercury	4	2	<0.00001	all concentrations below detection limits				<0.00001	0%
S12	Molybdenum	4	2	0.00007	0.00026	0.00026	0.00036	0.00044	0.00048	0%
S12	Nickel	4	2	0.00051	0.00089	0.00089	0.00107	0.00121	0.00127	0%
S12	Selenium	4	2	<0.0002	all concentrations below detection limits				<0.001	0%
S12	Silver	4	2	<0.00001	0.0000120	0.0000120	0.0000155	0.0000183	0.0000230	0%
S12	Thallium	4	2	<0.0001	all concentrations below detection limits				<0.0001	0%
S12	Uranium	4	2	0.000241	0.000675	0.000675	0.000887	0.00106	0.00112	0%
S12	Zinc	4	2	0.0010	0.0017	0.0017	0.0020	0.0022	0.0023	0%
S6	Hardness (as $CaCO_3$)	6	3	7.9	19.5	25.3	25.3	25.4	25.4	-
S6	pH	6	3	6.79	7.14	7.41	7.43	7.45	7.46	0%
S6	Total Alkalinity (as $CaCO_3$)	6	3	5.7	15.2	18.6	19.9	20.9	21.5	-
S6	Total Suspended Solids	6	3	<3	2.1	1.5	2.3	3.0	4.8	-
S6	Total Dissolved Solids	6	3	39	53	51	59	65	67	-
S6	Turbidity (NTU)	6	3	0.28	0.61	0.63	0.78	0.89	1.00	-
S6	Ammonia (as N)	6	3	<0.005	0.0053	0.0055	0.0068	0.0078	0.0104	0%
S6	Nitrate (as N)	6	3	<0.005	all concentrations below detection limits				<0.005	0%
S6	Nitrite (as N)	6	3	<0.001	all concentrations below detection limits				<0.001	0%
S6	Total Phosphorus (as P)	6	3	0.0029	0.0035	0.0034	0.0036	0.0037	0.0041	-
S6	Total Organic Carbon	6	3	5.26	9.10	9.37	10.4	11.2	11.6	-
S6	Dissolved Organic Carbon	0	0	-	-	-	-	-	-	-
S6	Chloride	6	3	2.06	4.69	4.69	6.00	7.05	7.33	0%
S6	Fluoride	6	3	0.037	0.047	0.048	0.052	0.056	0.057	0%
S6	Sulphate (SO_4)	6	3	0.83	2.68	2.84	3.61	4.22	4.40	-
S6	Free Cyanide	0	0	-	-	-	-	-	-	-
S6	Aluminum	6	3	0.0286	0.0670	0.0846	0.0854	0.0860	0.115	0%
S6	Arsenic	6	3	0.00008	0.000115	0.000100	0.000130	0.000154	0.000169	0%
S6	Boron	6	3	0.0076	0.0100	0.0101	0.0109	0.0116	0.0122	0%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
S6	Cadmium	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
S6	Chromium	6	3	<0.0005	0.00053	0.00044	0.00064	0.00080	0.00086	Cr(III) 0%; Cr(VI) 0%
S6	Copper	6	3	0.00097	0.00142	0.00158	0.00164	0.00168	0.00185	0%
S6	Iron	6	3	0.136	0.612	0.382	0.850	1.22	2.40	67%
S6	Lead	6	3	<0.00005	all concentrations below detection limits				<0.00005	0%
S6	Mercury	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
S6	Molybdenum	6	3	<0.00005	0.00008	0.00007	0.00010	0.00013	0.00015	0%
S6	Nickel	6	3	0.00071	0.00089	0.00085	0.00098	0.00109	0.00118	0%
S6	Selenium	6	3	<0.0002	0.000137	0.000100	0.000155	0.000199	0.000320	0%
S6	Silver	6	3	<0.00001	all concentrations below detection limits				<0.00001	0%
S6	Thallium	6	3	<0.0001	all concentrations below detection limits				<0.0001	0%
S6	Uranium	6	3	0.000053	0.000073	0.000060	0.000083	0.000101	0.000113	0%
S6	Zinc	6	3	0.00150	0.00217	0.00215	0.00235	0.00251	0.00310	0%
Stickleback OF	Hardness (as $CaCO_3$)	14	11	2.2	54.3	68.4	72.6	75.0	75.2	-
Stickleback OF	pH	14	11	6.04	6.62	6.75	7.48	7.79	7.86	27%
Stickleback OF	Total Alkalinity (as $CaCO_3$)	14	11	<2	25.3	32.0	34.0	37.8	39.7	-
Stickleback OF	Total Suspended Solids	14	11	<1	1.2	1.0	1.5	2.3	3.0	-
Stickleback OF	Total Dissolved Solids	14	11	<10	102	114	127	180	187	-
Stickleback OF	Turbidity (NTU)	6	3	0.36	1.58	1.42	2.17	2.77	2.95	-
Stickleback OF	Ammonia (as N)	14	11	<0.005	0.013	0.013	0.017	0.025	0.029	0%
Stickleback OF	Nitrate (as N)	14	11	<0.001	0.0057	0.0025	0.0060	0.0160	0.0240	0%
Stickleback OF	Nitrite (as N)	14	11	<0.001	0.0012	0.0005	0.0023	0.0025	0.0020	0%
Stickleback OF	Total Phosphorus (as P)	14	11	0.006	0.013	0.014	0.016	0.019	0.020	-
Stickleback OF	Total Organic Carbon	14	11	0.90	4.07	4.50	5.10	5.64	5.85	-
Stickleback OF	Dissolved Organic Carbon	8	8	1.70	3.88	4.10	4.60	5.23	5.4	-
Stickleback OF	Chloride	10	7	1.4	38.3	50.0	51.7	52.1	52.1	0%
Stickleback OF	Fluoride	14	11	<0.02	0.070	0.040	0.050	0.230	0.380	9%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Stickleback OF	Sulphate (SO_4)	14	11	<0.5	1.40	1.50	1.50	2.25	3.00	-
Stickleback OF	Free Cyanide	0	0	-	-	-	-	-	-	-
Stickleback OF	Aluminum	14	11	0.0118	0.0247	0.0225	0.0273	0.0461	0.0620	27%
Stickleback OF	Arsenic	14	11	<0.00005	0.00039	0.00043	0.00048	0.00066	0.00082	0%
Stickleback OF	Boron	14	11	0.0036	0.0149	0.0164	0.0186	0.0230	0.0265	0%
Stickleback OF	Cadmium	14	11	<0.000002	0.0000037	0.0000029	0.0000050	0.0000078	0.0000090	0%
Stickleback OF	Chromium	14	11	<0.00003	0.000176	0.000180	0.000235	0.000307	0.000370	Cr(III) 0%; Cr(VI) 0%
Stickleback OF	Copper	14	11	0.00009	0.00037	0.00031	0.00040	0.00077	0.00108	0%
Stickleback OF	Iron	14	11	0.026	0.175	0.126	0.176	0.429	0.624	9%
Stickleback OF	Lead	14	11	0.000007	0.000027	0.000025	0.000029	0.000051	0.000062	0%
Stickleback OF	Mercury	14	11	<0.0000006	0.0000017	0.0000003	0.0000031	0.0000050	0.0000011	0%
Stickleback OF	Molybdenum	14	11	0.000015	0.000035	0.000030	0.000041	0.000057	0.000067	0%
Stickleback OF	Nickel	14	11	<0.0001	0.00024	0.00020	0.00032	0.00049	0.00067	0%
Stickleback OF	Selenium	14	11	<0.0002	0.00043	0.00050	0.00058	0.00068	0.00075	0%
Stickleback OF	Silver	14	11	<0.0000005	0.0000033	0.0000036	0.0000050	0.0000056	0.0000061	0%
Stickleback OF	Thallium	14	11	<0.0000003	0.0000163	0.0000047	0.0000288	0.0000500	0.0000076	0%
Stickleback OF	Uranium	14	11	<0.00001	0.000009	0.000009	0.000010	0.000013	0.000013	0%
Stickleback OF	Zinc	14	11	<0.0001	0.0008	0.0007	0.0010	0.0017	0.0018	0%
Trout OF	Hardness (as $CaCO_3$)	14	11	14.5	23.7	25.8	29.4	32.0	32.8	-
Trout OF	pH	14	11	5.97	6.57	6.85	7.33	7.53	7.66	36%
Trout OF	Total Alkalinity (as $CaCO_3$)	14	11	12.3	19.8	20.0	23.0	29.1	31.6	-
Trout OF	Total Suspended Solids	14	11	<1	2.8	2.0	4.0	6.3	8.0	-
Trout OF	Total Dissolved Solids	14	11	26	41	38	49	61	68	-
Trout OF	Turbidity (NTU)	6	3	1.37	3.79	2.37	4.98	7.06	7.90	-
Trout OF	Ammonia (as N)	14	11	<0.005	0.020	0.014	0.015	0.057	0.097	0%
Trout OF	Nitrate (as N)	14	11	<0.001	0.0035	0.0025	0.0038	0.0080	0.0090	0%
Trout OF	Nitrite (as N)	14	11	<0.001	0.0012	0.0010	0.0015	0.0028	0.0030	0%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Trout OF	Total Phosphorus (as P)	14	11	0.010	0.024	0.017	0.020	0.060	0.099	-
Trout OF	Total Organic Carbon	14	11	5.49	8.12	8.06	8.94	11.22	12.12	-
Trout OF	Dissolved Organic Carbon	8	8	5.30	7.90	7.85	8.73	10.9	11.5	-
Trout OF	Chloride	10	7	2.9	6.7	6.5	9.0	10.4	10.5	0%
Trout OF	Fluoride	14	11	0.020	0.039	0.030	0.036	0.085	0.130	9%
Trout OF	Sulphate (SO_4)	14	11	0.95	2.87	1.50	4.00	7.00	8.00	-
Trout OF	Free Cyanide	0	0	-	-	-	-	-	-	-
Trout OF	Aluminum	14	11	0.079	0.173	0.108	0.299	0.328	0.352	73%
Trout OF	Arsenic	14	11	0.00009	0.00029	0.00024	0.00026	0.00065	0.00070	0%
Trout OF	Boron	14	11	0.0034	0.0061	0.0047	0.0073	0.0115	0.0133	0%
Trout OF	Cadmium	14	11	<0.000002	0.0000038	0.0000037	0.0000050	0.0000061	0.0000071	0%
Trout OF	Chromium	14	11	0.00025	0.00057	0.00059	0.00070	0.00093	0.00114	Cr(III) 0%; Cr(VI) 9%
Trout OF	Copper	14	11	0.00115	0.00151	0.00150	0.00165	0.00205	0.00233	9%
Trout OF	Iron	14	11	0.16	0.66	0.38	0.51	2.00	3.46	73%
Trout OF	Lead	14	11	<0.00005	0.000073	0.000057	0.000108	0.000135	0.000145	0%
Trout OF	Mercury	14	11	<0.0000006	0.0000022	0.0000015	0.0000037	0.0000050	0.0000024	0%
Trout OF	Molybdenum	14	11	0.00006	0.00007	0.00007	0.00009	0.00010	0.00011	0%
Trout OF	Nickel	14	11	0.00065	0.00098	0.00087	0.00111	0.00141	0.00145	0%
Trout OF	Selenium	14	11	<0.0001	0.00021	0.00017	0.00028	0.00042	0.00035	0%
Trout OF	Silver	14	11	0.0000008	0.0000043	0.0000050	0.0000051	0.0000094	0.0000120	0%
Trout OF	Thallium	14	11	0.0000011	0.0000162	0.0000038	0.0000285	0.0000500	0.0000070	0%
Trout OF	Uranium	14	11	0.000022	0.000036	0.000033	0.000043	0.000053	0.000058	0%
Trout OF	Zinc	14	11	<0.001	0.00211	0.00152	0.00194	0.00567	0.00806	0%
Windy OF	Hardness (as $CaCO_3$)	14	11	24.9	57.1	69.4	71.0	72.9	73.0	-
Windy OF	pH	13	10	6.94	7.38	7.49	7.85	7.99	7.99	0%
Windy OF	Total Alkalinity (as $CaCO_3$)	14	11	21.6	40.3	47.3	48.5	49.3	49.6	-
Windy OF	Total Suspended Solids	14	11	<1	1.1	0.5	1.5	2.8	4.0	-

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Windy OF	Total Dissolved Solids	14	11	43	170	204	213	220	224	-
Windy OF	Turbidity (NTU)	6	3	1.32	3.31	3.43	4.29	4.98	5.23	-
Windy OF	Ammonia (as N)	14	11	<0.005	0.006	0.005	0.007	0.014	0.020	0%
Windy OF	Nitrate (as N)	14	11	<0.005	0.0033	0.0025	0.0025	0.0068	0.0110	0%
Windy OF	Nitrite (as N)	14	11	<0.001	0.0007	0.0005	0.0005	0.0015	0.0020	0%
Windy OF	Total Phosphorus (as P)	14	11	0.004	0.007	0.007	0.008	0.014	0.016	-
Windy OF	Total Organic Carbon	14	11	1.58	2.50	2.10	2.35	4.59	6.57	-
Windy OF	Dissolved Organic Carbon	8	8	1.50	2.41	1.90	2.38	4.68	5.8	-
Windy OF	Chloride	14	11	8.9	74.5	89.6	95.4	95.9	96.1	0%
Windy OF	Fluoride	14	11	0.034	0.213	0.070	0.085	0.880	1.65	9%
Windy OF	Sulphate (SO_4)	14	11	3.00	5.94	5.00	8.19	9.00	9.00	-
Windy OF	Free Cyanide	0	0	-	-	-	-	-	-	-
Windy OF	Aluminum	14	11	0.027	0.082	0.058	0.129	0.172	0.192	40%
Windy OF	Arsenic	14	11	0.00016	0.00040	0.00042	0.00045	0.00071	0.00076	0%
Windy OF	Boron	14	11	0.0168	0.0384	0.0409	0.0482	0.0513	0.0526	0%
Windy OF	Cadmium	14	11	<0.000002	0.0000061	0.0000035	0.0000050	0.0000221	0.0000357	0%
Windy OF	Chromium	14	11	0.00014	0.00032	0.00031	0.00033	0.00048	0.00058	Cr(III) 0%; Cr(VI) 0%
Windy OF	Copper	14	11	0.00057	0.00097	0.00090	0.00094	0.00164	0.00223	9%
Windy OF	Iron	14	11	0.015	0.093	0.071	0.147	0.176	0.188	0%
Windy OF	Lead	14	11	0.000008	0.000066	0.000032	0.000077	0.000202	0.000247	0%
Windy OF	Mercury	14	11	<0.0000006	0.0000019	0.0000003	0.0000037	0.0000050	0.0000023	0%
Windy OF	Molybdenum	14	11	0.000258	0.000515	0.000585	0.000646	0.000674	0.000674	0%
Windy OF	Nickel	14	11	0.000005	0.000251	0.000219	0.000328	0.000578	0.000783	0%
Windy OF	Selenium	14	11	<0.0005	0.00085	0.00057	0.00113	0.00175	0.00216	27%
Windy OF	Silver	14	11	<0.0000005	0.0000023	0.0000012	0.0000043	0.0000050	0.0000036	0%
Windy OF	Thallium	14	11	<0.0000003	0.0000162	0.0000042	0.0000285	0.0000500	0.0000069	0%
Windy OF	Uranium	14	11	0.000045	0.000147	0.000138	0.000200	0.000214	0.000225	0%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Windy OF	Zinc	14	11	0.0002	0.0010	0.0008	0.0011	0.0029	0.0039	0%
Wolverine OF	Hardness (as $CaCO_3$)	2	1	13.4	13.5	13.5	13.5	13.5	13.5	-
Wolverine OF	pH	2	1	7.21	7.24	7.24	7.24	7.24	7.28	0%
Wolverine OF	Total Alkalinity (as $CaCO_3$)	2	1	10.2	10.6	10.6	10.6	10.6	10.9	-
Wolverine OF	Total Suspended Solids	2	1	<3	all concentrations below detection limits				<3	-
Wolverine OF	Total Dissolved Solids	2	1	35	39	39	39	39	43	-
Wolverine OF	Turbidity (NTU)	2	1	0.36	0.40	0.40	0.40	0.40	0.43	-
Wolverine OF	Ammonia (as N)	2	1	<0.005	all concentrations below detection limits				<0.005	0%
Wolverine OF	Nitrate (as N)	2	1	<0.005	all concentrations below detection limits				<0.005	0%
Wolverine OF	Nitrite (as N)	2	1	<0.001	all concentrations below detection limits				<0.001	0%
Wolverine OF	Total Phosphorus (as P)	2	1	<0.002	0.002	0.002	0.002	0.002	0.003	-
Wolverine OF	Total Organic Carbon	2	1	8.89	9.08	9.08	9.08	9.08	9.26	-
Wolverine OF	Dissolved Organic Carbon	0	0	-	-	-	-	-	-	-
Wolverine OF	Chloride	2	1	4.4	4.4	4.4	4.4	4.4	4.4	0%
Wolverine OF	Fluoride	2	1	0.028	0.029	0.029	0.029	0.029	0.029	0%
Wolverine OF	Sulphate (SO_4)	2	1	0.91	0.91	0.91	0.91	0.91	0.91	-
Wolverine OF	Free Cyanide	0	0	-	-	-	-	-	-	-
Wolverine OF	Aluminum	2	1	0.043	0.046	0.046	0.046	0.046	0.048	0%
Wolverine OF	Arsenic	2	1	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0%
Wolverine OF	Boron	2	1	0.0043	0.0044	0.0044	0.0044	0.0044	0.0045	0%
Wolverine OF	Cadmium	2	1	<0.00001	all concentrations below detection limits				<0.00001	0%
Wolverine OF	Chromium	2	1	0.00040	0.00042	0.00042	0.00042	0.00042	0.00043	Cr(III) 0%; Cr(VI) 0%
Wolverine OF	Copper	2	1	0.00111	0.00111	0.00111	0.00111	0.00111	0.00111	0%
Wolverine OF	Iron	2	1	0.116	0.128	0.128	0.128	0.128	0.139	0%
Wolverine OF	Lead	2	1	<0.00005	all concentrations below detection limits				<0.00005	0%
Wolverine OF	Mercury	2	1	<0.00001	all concentrations below detection limits				<0.00001	0%
Wolverine OF	Molybdenum	2	1	0.000107	0.000128	0.000128	0.000128	0.000128	0.000148	0%

Stream	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than CCME[d]
Wolverine OF	Nickel	2	1	0.00119	0.00130	0.00130	0.00130	0.00130	0.00140	0%
Wolverine OF	Selenium	2	1	<0.0001	all concentrations below detection limits				<0.0001	0%
Wolverine OF	Silver	2	1	<0.00001	all concentrations below detection limits				<0.00001	0%
Wolverine OF	Thallium	2	1	<0.0001	all concentrations below detection limits				<0.0001	0%
Wolverine OF	Uranium	2	1	0.0000130	0.0000135	0.0000135	0.0000135	0.0000135	0.0000140	0%
Wolverine OF	Zinc	2	1	0.00220	0.00225	0.00225	0.00225	0.00225	0.00230	0%

Notes:
'<' indicates that concentration was less than the analytical detection limit shown.
OF = Outflow, IF = Inflow, NE = Northeast
n = number of observations.
[a] Minimum represents the lowest concentration in any sample.
[b] One half of the value of the analytical detection limit was substituted for values that were below detection limits, and replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, the 75th and 95th percentiles, and CCME guidelines.
[c] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case maximum represents highest detection limit).
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed September 2017).
The CCME guideline for chromium is dependent on its speciation (Cr(VI) or Cr(III)). Routine metal analysis does not distinguish between chromium species, so total chromium results were used to compare with CCME guidelines to be conservative.

Mean and median total phosphorus concentrations were highest in the North Belt LSA, at approximately 0.02 mg/L (Table 4.2-13). Total phosphorus concentrations were highly variable among streams but also within streams over time. Table 4.2-14 provides a listing of all study streams and rivers by trophic status. Within the North Belt LSA, some streams and rivers such as P.O. Outflow, Patch Outflow, and the Koignuk River ranged widely in trophic status from oligotrophic to eutrophic based on total phosphorus concentrations (Table 4.2-14). Streams that were eutrophic during at least one sampling event also included AWRa, Doris Outflow, Glenn Outflow, Ogama Outflow, and Little Roberts Outflow. At the lower end the total phosphorus range, Wolverine Outflow was classified as ultra-oligotrophic, and Windy Outflow ranged from ultra-oligotrophic to mesotrophic (Table 4.2-14). In the South Belt LSA, stream S6 was classified as ultra-oligotrophic, while most streams and rivers in the area were oligotrophic to meso-eutrophic. Aimaokatalok NE Inflow ranged from meso-eutrophic to eutrophic, and Trout Outflow ranged from mesotrophic to eutrophic (Table 4.2-14). In the RSA, Reference B Outflow was at the low end of the total phosphorus range and was classified as ultra-oligotrophic to oligotrophic. Most streams and rivers in the RSA ranged from oligotrophic to meso-eutrophic. Only Pelvic Outflow fell into the eutrophic category during at least one sampling session (Table 4.2-14).

Metals

Table 4.2-15 presents the summary statistics for stream and river metal concentrations in each study area, and the percentage of sample metal concentrations that were above CCME guidelines. Table 4.2-17 presents stream- and river-specific metal concentrations and CCME guideline comparisons. Concentrations of many metals in stream and river samples were frequently near or less than analytical detection limits (e.g., silver, and thallium; Table 4.2-15).

As observed in lakes, some metals such as aluminum, chromium, copper, iron, and selenium were naturally elevated in LSA and RSA streams and rivers. With the exception of selenium, these metal concentrations were greater than CCME guideline levels in some stream and river samples collected from all study areas (North Belt LSA, South Belt LSA, and RSA; Table 4.2-15). The highest mean concentrations of these metals tended to occur in Glenn Outflow and stream AWRa (Table 4.2-17). Selenium concentrations were greater than the CCME guideline of 0.001 mg/L in 18% of samples collected from the North Belt LSA and 3.9% of samples collected from the RSA (Table 4.2-15); most of elevated concentrations occurred in 2007 and 2008. In the South Belt LSA, all concentrations of selenium in streams and rivers were below the CCME guideline (Table 4.2-15).

There were also some metal concentrations that were sporadically higher than CCME guidelines, including arsenic, cadmium, lead, and mercury. The arsenic concentration in one sample from Roberts Outflow in the RSA was slightly greater than the CCME guideline of 0.005 mg/L (Table 4.2-15). Cadmium concentrations were higher than the hardness-dependent, long-term CCME guideline in one sample collected from the Koignuk River (North Belt LSA; Table 4.2-17) and one sample collected from Reference B Outflow (RSA; Table 4.2-15). Lead concentrations were greater than the hardness-dependent CCME guideline in samples collected from Glenn Outflow and the Koignuk River in the North Belt LSA (Table 4.2-17) and in a sample collected from the Aimaokatalok River in the RSA (Table 4.2-15). The mercury concentration in one sample collected from Roberts Outflow in the RSA was higher than the CCME guideline for inorganic mercury of 0.000026 mg/L (Table 4.2-15).

Cyanide

Stream and river free cyanide concentrations were occasionally measured for comparison with the CCME guideline for the protection of aquatic life of 0.005 mg/L (CCME 2017). All free cyanide concentrations measured in North Belt LSA and RSA streams and rivers were below analytical detection limits (Table 4.2-16) and below the CCME guideline for free cyanide. Free cyanide concentrations were not measured in South Belt LSA streams and rivers.

4.3 VALUED ECOSYSTEM COMPONENTS

4.3.1 Potential Valued Components and Scoping

Valued Ecosystem Components (VECs) are those components of the biophysical environment considered to be of scientific, ecological, economic, social, cultural, or heritage importance (Volume 2, Chapter 4). The selection and scoping of VECs considers the biophysical conditions and trends that may interact with the proposed Project, the variability in biophysical conditions over time, and data availability as well as the ability to measure biophysical conditions that may interact with the Project. For an interaction to occur there must be spatial and temporal overlap between a VEC and a Project component and/or activity. The selection and scoping of a VEC also considers its importance to the communities potentially affected by the Project.

4.3.1.1 The Scoping Process and Identification of VECs

The scoping of VECs follows the process outlined in the Assessment Methodology (Volume 2, Chapter 4). The selection of VECs began with those proposed in the EIS guidelines and was further informed through consultation with communities, regulatory agencies, available TK, professional expertise, and the NIRB's final scoping report (Appendix B of the EIS Guidelines). The EIS guidelines (NIRB 2012a) propose that freshwater water quality be considered for inclusion in the effects assessment. The selection of freshwater water quality as a VEC was also informed by:

- the potential for Madrid-Boston activities and components to interact with the local and regional freshwater environment;
- review of recently completed Nunavut environmental assessments (e.g., Back River, Meliadine);
- consultation and engagement with local and regional Inuit groups (e.g., the Kitikmeot Inuit Association (KIA));
- the EIS guidelines and appendices (NIRB 2012a);
- the existence of federal or territorial acts, regulations, and guidelines that directly or indirectly identify water quality as an important freshwater component (e.g., CCME water quality guidelines, the Metal Mining Effluent Regulations (MMER) under the *Fisheries Act* (1985c); and
- The public, during several public consultation and open house meetings held in the Kitikmeot communities between August 2010 and May 2016 (see Volume 2, Chapter 3, Public Consultation and Engagement).

4.3.1.2 NIRB Scoping Sessions

Scoping sessions hosted by NIRB (2012b) with key stakeholders and local community members (i.e., the public) focused on identifying the components that are important to local residents, as related to the Project. Comments made during these sessions were compiled and analyzed as part of VEC scoping. Concerns regarding the effects of dust during spring runoff on freshwater water quality and post-closure effects to water quality (i.e., "water should be left as clean as when the mine first started"; Section 3.3.2, NIRB 2012b).

4.3.1.3 TMAC Consultation and Engagement Informing VEC Selection

Community meetings for the Madrid-Boston Project were conducted in each of the five Kitikmeot communities as described in Volume 2, Chapter 3. The meetings are a central component of engagement with the public and an opportunity to share information and seek public feedback.

Overall, the community meetings were well attended. Public feedback (questions, comments, and concerns) about the proposed Project was obtained through open dialogue during Project presentations, through discussions that arose during the presentation of Project materials and comments provided in feedback forms. No specific feedback was provided about freshwater water quality.

4.3.2 Valued Components Included in the Assessment

The scoping analysis identified the freshwater water quality VEC for inclusion in the assessment. The freshwater water quality VEC was selected as a component of the assessment of the potential effects of the Madrid-Boston Project on freshwater environment because of the following:

- the potential to interact with the activities and components of the Project;
- the importance of water quality in community consultations and TK;
- identification as important by government regulators and the NIRB;
- inclusion in recently completed Nunavut environmental assessments (e.g., Back River, Mary River); and
- informed by professional judgement.

Table 4.3-1 summarizes the rationale for including freshwater water quality as a VEC in this assessment.

Table 4.3-1. Valued Ecosystem Component(s) Included in the Assessment

VEC	Identified by			Rationale for Inclusion
	TK	NIRB Guidelines	Government	
Freshwater Water Quality	×	×	×	Moderate to significant comments expressed by regulatory agencies and potentially significant regulatory considerations.

4.4 SPATIAL AND TEMPORAL BOUNDARIES

The freshwater water quality spatial and temporal boundaries define the maximum spatial and temporal extent within which the potential effects assessment was conducted. The spatial boundaries selected to shape this assessment are determined by the Project's potential effects on the freshwater environment. The freshwater water quality VEC spatial and temporal boundaries are defined as the maximum limits within which the assessment is conducted. The boundaries are determined by the criteria specified in the EIS guidelines (NIRB 2012a), and outlined in the Effects Assessment Methodology (Volume 2, Chapter 4). Temporal boundaries consider the different phases of the Project and their durations. The Project's temporal boundaries reflect those periods during which planned activities will occur and have potential to affect the freshwater environment.

The determination of spatial and temporal boundaries also takes into account the development of the entire Hope Bay Greenstone Belt. The assessment considers both the incremental potential effects of the Madrid-Boston Project as well as the total potential effects of the additional Project activities in combination with the existing and approved projects including the Doris Project and advanced exploration activities at Madrid and Boston.

4.4.1 Project Overview

The Madrid-Boston Project consists of proposed mine operations at the Madrid North, Madrid South and Boston deposits. The Madrid-Boston Project is part of a staged approach to continuous development of the Hope Bay Project, comprised of existing operations at Doris and bulk samples followed by commercial mining at Madrid North, Madrid South, and Boston deposits. The Madrid-Boston Project would use and expand upon the existing Doris Project infrastructure.

The Madrid-Boston Project is the focus of this application. Because the infrastructure of existing and approved projects will be utilized by the Madrid-Boston Project, and because the existing and approved projects have the potential to interact cumulatively with the Madrid-Boston Project, existing and approved project are described below.

4.4.1.1 Existing and Approved Projects

Existing and approved projects include:

- the Doris Project (NIRB Project Certificate 003, NWB Type A Water Licence 2AM-DOH1323);
- the Hope Bay Regional Exploration Project (NWB Type B Water Licence 2BE-HOP1222);
- the Madrid Advanced Exploration Program (NWB Type B Water Licence 2BB-MAE1727); and
- the Boston Advanced Exploration Project (NWB Type B Water Licence 2BB-BOS1727).

<u>The Doris Project</u>

The Doris Project was approved by NIRB in 2006 (NIRB Project Certificate 003) and licenced by NWB in 2007 (Type A Water Licence 2AM-DOH0713). The Type A Water Licence was amended in 2010, 2011 and 2012 and received modifications in 2009, 2010, and 2011.

Construction of the Doris Project began in early 2010. In early 2012, the Doris Project was placed into care and maintenance, suspending further Project-related construction and exploration activity along the Hope Bay Greenstone Belt. Following TMAC's acquisition of the Hope Bay Project in March of 2013, NWB renewed the Doris Project Type A Water Licence (Type A Water Licence 2AM-DOH1323), and TMAC advanced planning, permitting, exploration, and construction activities. In 2016, NIRB approved an amendment to Project Certificate 003 and NWB granted Amendment No. 1 to Type A Water Licence 2AM-DOH1323, extending operations from two to six years through mining two additional mineralized zones (Doris Connector and Doris Central zones) to be accessed via the existing Doris North portal. Amendment No. 1 to Type A Water Licence 2AM-DOH1323 authorizes a mining rate of approximately 2,000 tonnes per day of ore and a milling throughput of approximately 2,000 tonnes per day of ore. The Doris Project began production early in 2017.

The Doris Project includes the following components and facilities:

- The Roberts Bay offloading facility: marine jetty, barge landing area, beach laydown area, access roads, weather havens, fuel tank farm/transfer station, waste storage facilities and incinerator, and quarry;
- The Doris site: 280 person camp, laydown areas, service complex (e.g., workshop, wash bay, administration buildings, mine dry), two quarries (mill site platform and solid waste landfill), core storage areas, batch plant, brine mixing facilities, vent raise (3), air heating units, reagent storage, fuel tank farm/transfer station, potable water treatment, waste water

treatment, incinerator, landfarm and handling/temporary hazardous waste storage, explosives magazine, and diesel power plant;

- Doris Mine works and processing: underground portal, overburden stockpile, temporary waste rock pile, ore stockpile, and ore processing plant (mill);
- Tailings Impoundment Area (TIA): Schedule 2 designation for Tail Lake with two dams (North and South dams), sub-aerial deposition of flotation tailings, emergency tailings dump catch basins, pump house, and quarry;
- All-season main road with transport trucks: Roberts Bay to Doris site (4.8 km, 150 to 200 tractor and 300 fuel tanker trucks/year);
- Access roads from Doris site used predominantly by light-duty trucks to: the TIA, the explosives magazine, Doris Lake float plane dock (previously in use), solid waste disposal site, and to the tailings decant pipe, from the Roberts Bay offloading facility to the location where the discharge pipe enters the ocean; and
- All-weather airstrip (914 m), winter airstrip (1,524 m), helicopter landing site and building, and Doris Lake float plane and boat dock.

Water is managed at the Doris Project through:

- freshwater input from Doris Lake for mining, milling, and associated activities and domestic purposes;
- freshwater input from Windy Lake for domestic purposes;
- process water input primarily from the TIA reclaim pond;
- surface mine contact water discharged to the TIA;
- underground mine contact water directed to the TIA or to Roberts Bay via the marine outfall mixing box (MOMB);
- treated waste water discharged to the TIA; and
- water from the TIA treated and discharged to Roberts Bay via a discharge pipeline, with use of a MOMB.

<u>Hope Bay Regional Exploration Project</u>

The Hope Bay Regional Exploration Project has been renewed several times since 1995. The current extension expires in June 2022. Much of the previous work for the program was based out of Windy Lake and Boston camps. These camps were closed in October 2008 with infrastructure either decommissioned or moved to the Doris site. All exploration activities are now based from the Doris site. Components and activities for the Hope Bay Regional Exploration Project include:

- operation of helicopters from Doris; and
- the use of exploration drills, which are periodically moved by roads and by helicopter as required.

<u>Madrid Advanced Exploration</u>

In 2017, the NWB issued a Type B Water Licence (2BB-MAE1727) for the Madrid Advanced Exploration Program to support continued exploration and a bulk sample program at the Madrid North and Madrid South sites, located approximately 4 km south of the Doris site. The program includes extraction of a bulk sample totaling 50 tonnes from each of the Madrid North and South locations, which will be trucked to the mill at the Doris site for processing and placement of tailings in the tailings impoundment area (TIA). All personnel will be housed in the Doris camp.

The Madrid Advanced Exploration Program includes the following components and activities.

- Use of existing infrastructure associated with the Doris Project:
  - camp facilities to support up to 70 personnel as required to undertake the advanced exploration activities;
  - mill to process ore;
  - TIA;
  - landfill and hazardous waste areas, particularly if closure and remediation becomes required for the Madrid Advanced Exploration Program infrastructure;
  - fuel tank farms; and
  - Doris airstrip and Roberts Bay facility for transport of personnel and supplies.
- Use of existing infrastructure at the Madrid and Boston areas:
  - borrow and rock quarry facilities: existing Quarries A, B, and D along the Doris-Windy all-weather road (AWR);
  - AWR between Doris and Windy Lake for transportation of personnel, ore, waste, fuel, and supplies; and
  - future mobilization of existing exploration site infrastructure, should it become necessary.
- Construction of additional facilities at Madrid North and South:
  - access portals and ramps for underground operations at Madrid North and at Madrid South;
  - 4.7 km extension of the existing AWR originating from the Doris to the Windy exploration area (Madrid North) to the Madrid South deposit, with branches to Madrid North, Madrid North vent raise, and the Madrid South portal;
  - development of a winter road route (WRR) from Madrid North to access Madrid South until AWR has been constructed;
  - borrow and rock quarry facilities; two quarries referenced as Quarries G and H;
  - waste rock and ore stockpiles;
  - water and waste management structures; and
  - additional site infrastructure, including compressor building, brine mixing facility, saline storage tank, air heating facility, four vent raises, workshop and office, laydown area, diesel generator, emergency shelter, fuel storage facility/transfer station.
- Undertaking of advanced exploration access to aforementioned deposits through:
  - continue field mapping and sampling, as well as airborne/ground/downhole geophysics;
  - diamond drilling from the surface and underground; and
  - bulk sampling through underground mining methods and mine development.

<u>Boston Advanced Exploration</u>

The Boston Advanced Exploration Project Type B Water Licence No. 2BB-BOS1217 was renewed as Water Licence No. 2BB-BOS1727 in July 2017 and includes:

- the Boston camp (65 person), maintenance shops, workshops, laydown areas, water pumphouse, vent raise, warehouse, site service roads, sewage and greywater treatment plant, fuel storage and transfer station, landfarm, solid waste landfill and a heli-pad;
- mine works, consisting of underground development for exploration drilling and bulk sampling, waste rock and ore stockpiles;
- potable water and industrial water from Aimaokatalok Lake; and
- treated sewage and greywater discharged to the tundra.

4.4.1.2 The Madrid-Boston Project

The Madrid-Boston Project includes: the construction and operation of commercial mining at the Madrid North, Madrid South, and Boston sites; the continued operation of Roberts Bay and the Doris site to support mining at Madrid and Boston; and the Reclamation and Closure and Post-closure phases of all sites. Excluded from the Madrid-Boston Project for the purposes of the assessment are the reclamation and closure and post-closure components of the Doris Project as currently permitted and approved.

Construction

Madrid-Boston construction will use the infrastructure associated with Existing and Approved Projects. This may include:

- an all-weather airstrip at the Boston exploration area and helicopter pad;
- seasonal construction and/or operation of a winter ice strip on Aimaokatalok Lake;
- Boston camp with expected capacity for approximately 65 people during construction
- Quarry D Camp with capacity for up to 180 people;
- seasonal construction/operation of Doris to Boston WRR;
- three existing quarry sites along the Doris to Windy AWR;
- Doris camp with capacity for up to 280 people;
- Doris airstrip, winter ice strip, and helicopter pad;
- Roberts Bay offloading facility and road to Doris; and
- Madrid North and Madrid South sites and access roads.

Additional infrastructure to be constructed for the proposed Madrid-Boston Project includes:

- expansion of the Doris TIA (raising of the South Dam, construction of West Dam, development of a west road to facilitate access, and quarrying, crushing, and screening of aggregate for the construction);
- construction of a cargo dock at Roberts Bay (including a fuel pipeline, mooring points, beach landing and gravel pad, shore manifold);
- construction of an additional tank farm at Roberts Bay (consisting of two 10 ML tanks);
- expansion of Doris accommodation facility (from 280 to 400 person), mine dry and administrative building, water treatment at Doris site;
- expansion of the Doris mill to accommodate concentrate handling on the south end of the building facility and rearrangement of indoor crushing and processing within the mill building;

- complete development of the Madrid North and Madrid South mine workings;
- incremental expansion of infrastructure at Madrid North and Madrid South to accommodate production mining, including vent raise, access road, process plant buildings;
- construction of a 1,200 tpd concentrator, fuel storage, power plant, mill maintenance shop, warehouse/reagent storage at Madrid North;
- all weather access road and tailings line from Madrid North to the south end of the TIA;
- AWR linking Madrid to Boston (approximately 53 km long, nine quarries for permitting purposes, four of which will likely be used);
- all-weather airstrip, airstrip building, helipad and heliport building at Boston;
- construction of a 2,400 tpd process plant at Boston;
- all infrastructure necessary to support mining and processing activities at Boston including construction of a new 300-person accommodation facility, mine office and dry and administration buildings, additional fuel storage, laydown area, ore pad, waste rock pad, diesel power plant and dry-stack tailings management area (TMA);
- infrastructure necessary to support ongoing exploration activities at both Madrid and Boston; and
- wind turbines near the Doris (2), Madrid (2), and Boston (2) sites.

<u>Operation</u>

The Madrid-Boston Project Operation phase includes:

- mining of the Madrid North, Madrid South, and Boston deposits by way of underground portals and Crown Pillar Recovery;
- operation of a concentrator at Madrid North;
- transportation of ore from Madrid North, Madrid South, and Boston to the Doris process plant, and transporting the concentrate from the Madrid North concentrator to the Doris process plant;
- extending the operation at Roberts Bay and Doris;
- processing the ore and/or concentrate from Madrid North, Madrid South, and Boston at the Doris process plant with disposal of the detoxified tailings underground at Madrid North, flotation tailings from the Doris process plant pumped to the expanded Doris TIA, and discharge of the TIA effluent to the marine environment;
- operation of a concentrator at Madrid North and disposal of tailings at the Doris TIA;
- operation of a process plant and wastewater treatment plant at Boston with disposal of flotation tailings to the Boston TMA and a portion placed underground and the detoxified leached tailings placed in the underground mine at Boston;
- operation of two wind turbines for power generation; and
- on-going maintenance of transportation infrastructure at all sites (cargo dock, jetty, roads, and quarries).

Reclamation and Closure

Areas which are no longer needed to carry out Madrid-Boston Project activities may be reclaimed during Construction and Operation.

At Reclamation and Closure, all sites will be deactivated and reclaimed in the following manner (see Volume 3, Chapter 5):

- Camps and associated infrastructure will be disassembled and/or disposed of in approved non-hazardous site landfills.
- Non-hazardous landfills will be progressively covered with quarry rock, as cells are completed. At final closure, the facility will receive a final quarry rock cover which will ensure physical and geotechnical stability.
- Rockfill pads occupied by construction camps and associated infrastructure and laydown areas will be re-graded to ensure physical and geotechnical stability and promote free-drainage, and any obstructed drainage patterns will be re-established.
- Quarries no longer required will be made physically and geotechnically stable by scaling high walls and constructing barrier berms upstream of the high walls.
- Landfarms will be closed by removing and disposing of the liner, and re-grading the berms to ensure the area is physically and geotechnically stable.
- Mine waste rock will be used as structural mine backfill.
- The Doris TIA surface will be covered waste rock. Once the water quality in the reclaim pond has reached the required discharge criteria, the North Dam will be breached and the flow returned to Doris Creek.
- The Madrid to Boston AWR and Boston Airstrip will remain in place after Reclamation and Closure. Peripheral equipment will be removed. Where rock drains, culverts or bridges have been installed, the roadway or airstrip will be breached and the element removed. The breached opening will be sloped and armoured with rock to ensure that natural drainage can pass without the need for long-term maintenance.
- A low permeability cover, including a geomembrane, will be placed over the Boston TMA. The contact water containment berms will be breached and the liner will be cut to prevent collecting any water. The balance of the berms will be left in place to prevent localized permafrost degradation.

4.4.2 Spatial Boundaries

The spatial boundaries selected to shape this assessment are determined by the Project's potential effects on the freshwater environment. Spatial boundaries are determined based on the anticipated zone of influence between Project components/activities and freshwater water quality.

There are three zones of influence related to freshwater water quality: the Project Development Area (PDA), the Local Study Area (LSA), and the Regional Study Area (RSA).

4.4.2.1 Project Development Area

The PDA is shown in Figure 4.2-2 and is defined as the area that has the potential for infrastructure to be developed as part of the Madrid-Boston Project. The PDA includes engineering buffers around the footprints of structures. These buffers allow for refinement in the final placement of a structure through detailed design and necessary in-field modifications during the Construction phase. Areas with buildings and other infrastructure in close proximity are defined as pads with buffers, whereas roads are defined as linear corridors with buffers. The buffers for pads vary depending on the local physiography and other buffered features such as sensitive environments or riparian areas. The average engineering buffer for roads is 100 m on either side. Since the infrastructure for the Doris Project is in place, the PDA exactly follows the footprints of the Doris infrastructure.

4.4.2.2 Local Study Area

The LSA for the assessment of freshwater water quality is defined as the PDA and the area surrounding the PDA within which there is a reasonable potential for immediate effects on the freshwater environment due to an interaction with a Project component(s) or physical activity. The LSA includes the watersheds for key waterbodies, such as Aimaokatalok and Doris lakes, and is consistent with the LSA used for the surface hydrology, sediment quality, and fish and fish habitat VECs (Figure 4.2-2).

4.4.2.3 Regional Study Area

The RSA for the assessment of freshwater water quality is defined as the broader spatial area representing the maximum limit where potential direct or indirect effects may occur (Figure 4.2-2). The freshwater RSA includes the PDA, the LSA, and additional areas within which there is the potential for indirect or cumulative effects. The RSA for the freshwater water quality VEC includes portions of the Angimajuq watershed and the Koignuk River watershed to the west of the PDA, and is consistent with the RSA used for the surface hydrology, sediment quality, and fish and fish habitat VECs.

4.4.3 Temporal Boundaries

The Project represents an important development in the mining of the Hope Bay Greenstone Belt. Even though this Project spans the conventional Construction, Operation, Reclamation and Closure, and Post-closure phases of a mine project, the Madrid-Boston Project is a continuation of development currently underway. The Project has four separate operational sites: Roberts Bay, Doris, Madrid (North and South), and Boston. The development of these sites is planned to be sequential. As such, the temporal boundaries of this Project overlap with a number of existing and approved authorizations for the Hope Bay Project and the extension of activities.

For the purposes of the EIS, distinct phases of the Project are defined (Table 4.4-1). It is understood that Construction, Operation and Closure activities will, in fact, overlap among sites; this is outlined in Table 4.4-1 and further described in Volume 3, Chapter 2 (Project Description).

Table 4.4-1. Temporal Boundaries for the Effects Assessment for Freshwater Water Quality

Phase	Project Year	Calendar Year	Length of Phase (Years)	Description of Activities
Construction	1 - 4	2019 - 2022	4	• **Roberts Bay:** construction of access road (Year 1), marine dock and additional fuel facilities (Year 2 – Year 3); • **Doris**: expansion of the Doris TIA and accommodation facility (Year 1); • **Madrid North:** construction of concentrator and road to Doris TIA (Year 1 – Year 2); • **All-weather Road**: construction (Year 1 – Year 3); • **Boston**: site preparation and installation of all infrastructures including process plant (Year 2 – Year 5).

Phase	Project Year	Calendar Year	Length of Phase (Years)	Description of Activities
Operation	5 - 14	2023 - 2032	10	• **Roberts Bay**: sealift and fuel supply (Year 1 – Year 14) • **Doris**: processing and infrastructure use (Year 1 – Year 14); • **Madrid North:** mining (Year 1 – 13); ore transport to Doris process plant (Year 1 -13); ore processing and concentrate transport to Doris process plant (Year 2 – Year 13); • **Madrid South:** mining (Year 11 – Year 14); ore transport to Doris process plant (Year 11 – Year 14); • **All-weather Road**: operational (Year 4 – Year 14); • **Boston**: winter access road operating (Year 1 – Year 3); mining (Year 4 – Year 11); ore transport to Doris process plant (Year 4 – Year 6); and processing ore (Year 5 – Year 11).
Reclamation and Closure	15 - 17	2033 - 2035	3	• **Roberts Bay**: facilities will be operational during closure (Year 15 – Year 17); • **Doris**: camp and facilities will be operational during closure (Year 15 – Year 17); mine, process plant, and TIA decommissioning (Year 15 – Year 17); • **Madrid North:** all components decommissioned (Year 15 – Year 17); • **Madrid South:** all components decommissioned (Year 15 – Year 17); • **All-weather Road**: road will be operational (Year 15 – Year 16); decommissioning (Year 17); • **Boston**: all components decommissioned (Year 15 – Year 17).
Post-closure	18 - 22	2036 - 2040	5	• **All Sites:** Post-closure monitoring.
Temporary Closure	NA	NA	NA	• **All Sites:** Care and maintenance activities, generally consisting of closing down operations, securing infrastructure, removing surplus equipment and supplies, and implementing on-going monitoring and site maintenance activities.

The assessment also considers a Temporary Closure phase should there be a suspension of Project activities during periods when the Project becomes uneconomical due to market conditions. During this phase, the Project would be under care and maintenance. This could occur in any year of Construction or Operation with an indeterminate length (1 to 2 year duration would be typical).

4.5 PROJECT-RELATED EFFECTS ASSESSMENT

4.5.1 Methodology Overview

This assessment is informed by a methodology used to identify and assess the potential environmental effects of the Madrid-Boston Project and is consistent with the requirements of Section 12.5.2 of the Nunavut Agreement and the EIS guidelines (NIRB 2012a). The effects assessment evaluates the potential direct and indirect effects of the Project on the freshwater environment and follows the general methodology provided in Volume 2, Chapter 4 (Effects Assessment Methodology). It comprises a number of steps that collectively assess the manner in which the Madrid-Boston Project will interact with the freshwater water quality VEC defined for the assessment (Section 4.3).

To provide a comprehensive understanding of the potential effects of the Project, the components and activities of the Madrid-Boston Project are assessed on their own as well as in the context of the existing and approved projects (Doris and exploration) within the Hope Bay Greenstone Belt. The effects assessment process is summarized as follows:

1. Identify potential interactions between the Madrid-Boston Project and freshwater water quality;
2. Identify the resulting potential effects of those interactions;
3. Identify mitigation or management measures to eliminate or reduce the potential effects;
4. Identify residual effects (potential effects that would remain after mitigation and management measures have been applied) for the Madrid-Boston Project in isolation;
5. Identify residual effects of the Madrid-Boston Project in combination with the residual effects of existing and approved projects; and
6. Determine the significance of residual effects.

After the identification of potential interactions between the Madrid-Boston Project and freshwater water quality (Step 1, Section 4.5.2), the potential effects of these interactions are identified (Step 2, Section 4.5.2). Mitigation and management measures are then considered (Step 3, Section 4.5.3). If the application of these measures is expected to effectively mitigate the effects from the Madrid-Boston Project, the Madrid-Boston Project-related effects to freshwater water quality are characterized as *negligible* and not identified as residual effects (Step 4, Section 4.5.4). In parallel, the potential effects of the Madrid-Boston Project in combination with the existing and approved projects are assessed, and characterized as *negligible* if the mitigation and management measures are considered effective (Step 5, Section 4.5.4).

All remaining potential effects are then considered residual effects, and characterized (Step 6, Section 4.5.5) using the following attributes:

- direction;
- magnitude;
- duration;
- frequency;
- geographical (spatial) extent; and
- reversibility.

The rating criteria for the assessment of residual effects to freshwater water quality are described in the Effects Assessment Methodology section (Volume 2, Chapter 4). The observed and modeled baseline conditions are used, along with water quality guidelines (CCME 2017) and derived site-specific water quality objectives, as assessment thresholds for the determination of magnitude. The significance of each residual effects (Step 6, Section 4.5.5) is determined by considering the characterization of each residual effect, the probability of occurrence, and the confidence in the predictions of the effects.

4.5.1.1 Water Quality Indicators

Water quality is an aggregate term that encompasses a complex suite of parameters and indicators that describe the aquatic environment and its ability to sustain ecological and biogeochemical functions. The assessment of the potential effects of the Madrid-Boston Project on freshwater water quality is based on several indicators that describe the most probable and significant interactions between the Project and the freshwater environment (Table 4.5-1). These indicators are chosen because they have the following characteristics:

- specific empirical definitions;
- established analytical measurement methodologies;
- existing baseline information;
- quantitative relationships or thresholds associated with supporting aquatic organisms and biogeochemical processes, including established guidelines for the protection of aquatic life and derived site-specific water quality objectives; and
- responsive to the potential effects of industrial and mining activities in the Arctic.

Table 4.5-1. Freshwater Water Quality Indicators for the Assessment of Effects

Indicator	Description	Interaction with Project
pH	Acid-base balance of water	Project activities may increase pH outside of natural range through runoff, deposition, and discharge.
TSS	Total suspended sediments in water	Project activities may disturb sediments, increase runoff of deposited sediment, or discharge suspended material.
Nutrients	Chemical compounds that may contribute to aquatic plant and algal growth, alter trophic interactions, and/or change primary producer community structure	Project activities may contribute nutrients to waterbodies.
Metals	Particulate or dissolved metals in water	Project activities may contribute metals to the aquatic environment in runoff, discharge, or deposition.
Hydrocarbons	Petroleum hydrocarbon compounds	Project activities may contribute hydrocarbon compounds in runoff, discharge, or aerial deposition.
Dissolved Oxygen	The concentration of dissolved oxygen in water	Project activities may contribute nutrients to the freshwater environment, which may affect dissolved oxygen concentrations in the water.
Other constituents	Chemical compounds from natural or human sources	Underground water may have high concentrations of cations and anions (i.e., chloride, sulphate, sodium), cyanide is a process chemical.

For the effects assessment, assessment thresholds are applied to the water quality indicators (Table 4.5-2). These assessment thresholds are based on observed baseline conditions, CCME water quality guidelines for the protection of aquatic life, and derived site-specific water quality objectives, when applicable. Greater emphasis is placed on thresholds when quantitative predictions of effects to water quality are available. Some residual effects may be assessed qualitatively, which do not necessarily permit the application of specific, quantitative thresholds.

Table 4.5-2. Assessment Thresholds for Freshwater Water Quality Indicators

Indicator	Parameter	Guideline
pH	pH	6.5 – 9.0 pH units
TSS	TSS	Narrative[a]
Nutrients	Ammonia N (total)	pH- and temperature-dependent[b]
	Nitrate N	124 mg/L (short term); 3 mg/L (long term)
	Nitrite N	0.06 mg/L
	Total P	Guidance framework[c]
Metals	Aluminum	0.005 mg/L (if pH < 6.5); 0.1 mg/L (if pH ≥ 6.5)
	Antimony	0.006 mg/L (HC)
	Arsenic	0.028 mg/L (SSWQO)[d]
	Barium	1 mg/L (HC)
	Beryllium	0.1 mg/L (Agriculture)
	Boron	29 mg/L (short term); 1.5 mg/L (long term)
	Cadmium	Hardness dependent[e]
	Calcium	1,000 mg/L (Agriculture)
	Chromium	0.001 mg/L (hexavalent); 0.0089 mg/L (trivalent)
	Cobalt	0.05 (Agriculture)
	Copper	0.009 mg/L (SSWQO)[f]
	Iron	0.3 mg/L
	Lead	0.001 mg/L[g]
	Lithium	2.5 mg/L (Agriculture)
	Mercury	0.000026 mg/L
	Molybdenum	0.073 mg/L
	Nickel	0.025 mg/L[h]
	Selenium	0.001 mg/L
	Silver	0.00025 mg/L
	Sodium	200 mg/L (HC)
	Thallium	0.0008 mg/L
	Uranium	0.033 mg/L (short term); 0.015 mg/L (long term)
	Vanadium	0.1 mg/L (Agriculture)
	Zinc	0.03 mg/L
Other indicators	Dissolved Oxygen	9.5 mg/L (early life stages); 6.5 mg/L (other life stages)
	Petroleum hydrocarbons	*range of guidelines for petroleum hydrocarbon compounds*
	Sulphate	128 mg/L (British Columbia long term)[i]
	Chloride	640 mg/L (short term) 120 mg/L (long term)
	Fluoride	0.12 mg/L

Indicator	Parameter	Guideline
	Cyanide	0.005 mg/L (as free cyanide); 0.2 mg/L (total cyanide; HC)

Notes:
The most conservative guideline available from the CCME and the Health Canada Drinking Water guidelines are used for the assessment. Guidelines are from the CCME Water Quality Guidelines for the Protection of Aquatic Life, unless otherwise indicated. Health Canada Drinking Water guidelines are noted with "HC", whereas CCME guidelines for the protection of agriculture (irrigation or livestock) are noted with "Agriculture".
[a] *Narrative described in CCME (2017)*
[b] *The CCME guideline for total ammonia depends on pH and temperature. For circumneutral freshwater (pH 6.5 - 7.5) at conservative temperatures (15°C), the guideline for total ammonia as N is 1.83 to 18.1 mg/L.*
[c] *Total phosphorus trigger ranges for Canadian lakes and rivers: ultra-oligotrophic : < 0.004 mg/L, oligotrophic: 0.004-0.01 mg/L, mesotrophic: 0.01-0.02 mg/L, meso-eutrophic: 0.02-0.035 mg/L, eutrophic: 0.035-0.1 mg/L, hyper-eutrophic: > 0.1 mg/L (CCME 2004b)*
[d] *A site specific water quality objective (SSWQO) was developed for arsenic (see Section 4.5.1.2).*
[e] *The CCME guideline for total cadmium is hardness-dependent.*
[f] *A SSWQO was developed for copper (see Section 4.5.1.3).*
[g] *The CCME guideline for lead is hardness-dependent. However, hardness in the Project area waterbodies was frequently less than 60 mg/L $CaCO_3$; therefore; the minimum guideline value of 0.001 mg/L would usually apply.*
[h] *The CCME guideline for nickel is hardness-dependent. However, in the Project area waterbodies was frequently less than 60 mg/L $CaCO_3$; therefore, the minimum guideline of 0.025 mg/L would usually apply.*
[i] *The BC freshwater guideline for sulphate is hardness dependent. However, some Project area waterbodies were less than 30 mg/L; therefore, the soft-water guideline of 128 mg/L was used.*

4.5.1.2 Site Specific Water Quality Objective for Arsenic

Arsenic in the Madrid-Boston Project is predicted to be elevated, particularly in Doris Creek, during Post-closure, when the natural Tail Lake catchment flow is restored (Section 4.5.4.2). Thus, a site specific water quality objective (SSWQO) developed for site with a similar Arctic habitat (Golder 2017) was proposed for use as a threshold for screening in the effects assessment. The SSWQO was developed using standard CCME guidance (CCME 2007) for the development of long-term guidelines for freshwater environments. Available chronic toxicity data for arsenic in freshwater meeting the minimum CCME requirements (CCME 2007) and surrogate or resident species characteristic of Arctic freshwater environments were included in the species sensitivity distribution (SSD; Golder 2017). The derived long-term arsenic SSWQO of 0.028 mg/L was subsequently used for the characterization of effects for all waterbodies in the Madrid-Boston Project.

4.5.1.3 Site Specific Water Quality Objective for Copper

Copper is naturally elevated in the Madrid-Boston Project waterbodies, and has been observed to be naturally greater than CCME water quality guidelines in many of lakes and streams (Section 4.2.4). The Water and Load Balance model developed for the evaluation of potential effects also predicted elevated copper concentrations relative to baseline concentrations in Doris Creek, Wolverine Lake, and Stickleback Lake (Section 4.5.4.2; Package P5-4). Thus, a SSWQO was developed for the Project. A Water Effects Ratio (WER) approach was used to develop the copper SSWQO using a Biotic Ligand Model (BLM) to assess the effect of concentrations of dissolved organic carbon (DOC) on copper toxicity (Appendix V5-4C). A BLM model was used because of the demonstrated effects of DOC and other constituents including pH and alkalinity on the toxicity of copper (Appendix V5-4C). The analysis indicated that the lowest copper SSWQO was 0.0091 mg/L in Stickleback Lake (Appendix V5-4C). Thus, a conservative copper SSWQO of 0.009 mg/L was used for characterization of effects for all waterbodies in the Madrid-Boston Project.

4.5.2 Identification of Potential Effects

The Madrid-Boston Project has the potential to interact with the freshwater environment through a number of activities, pathways, and mechanisms. Project activities are grouped into broad components as described in Section 4.3.4 of the Effects Assessment Methodology (Volume 2, Chapter 4). The interactions between the Madrid-Boston Project and freshwater water quality are further refined by an *interaction group*. Interaction groups are interaction pathways that share similar modes of interaction with the Project, specific mitigation and management measures, assessment thresholds, and key indicators. For example, 'fuel storage and handling' and 'TMA roads use and maintenance' in the Boston area during the Operation phase were both assigned to the *Fuels, Oils, and Polycyclic Aromatic Hydrocarbons* (PAH) interaction group because both Project components may interact with freshwater water quality through activities related to the storage and use of fuel. The defined interaction groups for the assessment of effects to freshwater water quality are the following:

- *Site Preparation, Construction, and Decommissioning* - activities that include the clearing of overburden, earthworks, and construction activities for pads and infrastructure.
- *Site and Mine Contact Water* - water that contacts site surface infrastructure, mine surfaces (e.g., waste rock piles, ore storage areas, crown pillar recovery trenches) and operations (e.g., water management, drilling water, underground mine water). The site and mine contact water interaction group also includes the operation of the water treatment plant (WTP) and sewage treatment plant (STP) at the Boston site, where the two water sources will be treated, combined, and then discharged into Aimaokatalok Lake through a single pipeline-diffuser system.
- *Quarries and Borrow Pits* - activities related to the operation of quarries and borrow pits.
- *Explosives* - Project activities related to the transport, manufacture, storage, and use of explosives.
- *Fuels, Oils, and PAH* - activities related to the storage of fuels, fueling and maintenance operations, and the combustion of waste.
- *Dust Deposition* - activities that generate dust, including vehicle traffic, airstrip activity, and quarry and borrow pit activities that can then be deposited in freshwater receiving environment.

The potential interactions between the Project and the freshwater environment are presented in Table 4.5-3. These components are expected to have probable or likely interactions with the freshwater environment. These potential interactions may be direct or indirect, and this screening step does not consider application of mitigation and management measures.

Activities and infrastructure interact with the environment through discrete pathways. These pathways describe specific mechanisms of interactions that are useful for specifying the physical relationship between a Project component and the freshwater environment, for identifying applicable mitigation measures, and for characterizing the residual effects. For the freshwater water quality effects assessment, the following pathways are defined:

- *runoff*, which describes the transport of material or compounds from the terrestrial environment into the freshwater environment by precipitation or snowmelt;
- *discharge*, which is the directed input of water into the freshwater environment;
- *water withdrawal,* which describes the influence that changes in volume and flow may have on freshwater waterbodies;

- *seepage*, which describes the flow of water through the active layer and taliks;
- *physical*, which is the direct physical interaction between Project activities and the freshwater environment; and
- *aerial deposition*, which is the direct input of material and chemical compounds from the air into the freshwater environment.

Table 4.5-3. Project Interaction with the Freshwater Water Quality VEC

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
Roberts Bay	**Construction – proposed Madrid-Boston infrastructure**						
	Dock access road	×	×				×
	Fuel pipeline and tank farm	×	×			×	
	Quarry	×	×	×	×		×
	Equipment and vehicle emissions					×	×
	Construction and Operation – use of existing approved and permitted infrastructure						
	Fuel tank farm	×	×			×	
	Laydown areas	×	×			×	×
	Equipment and vehicle emissions					×	×
	Roberts Bay-Doris road use and maintenance	×	×			×	×
	Site roads use and maintenance	×	×			×	×
	Water Management System	×	×				
	Operation – proposed Madrid-Boston infrastructure						
	Use of dock access road		×			×	×
	Fuel pipeline and tank farm		×			×	
	Quarry		×	×	×		×
	Equipment and vehicle emissions					×	×
	Reclamation and Closure – use of existing approved and permitted infrastructure						
	Site surface infrastructure	×	×			×	
	Equipment and vehicle emissions					×	×
	Roberts Bay-Doris road	×	×			×	×
	Reclamation and Closure – proposed Madrid-Boston infrastructure						
	Site surface infrastructure	×	×			×	
	Equipment and vehicle emissions					×	×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
	Dock access road	×	×			×	×
	Quarry	×	×				×
	Post Closure – proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	
Doris	**Construction – proposed Madrid-Boston infrastructure**						
	Expansion of the PDA	×	×				×
	Expansion of accommodations	×	×				×
	Equipment and vehicle emissions					×	×
	Quarries	×	×	×	×		×
	Raising the TIA South Dam	×	×				×
	TIA perimeter road extensions	×	×				×
	TIA West Dam	×	×				×
	Road to TIA South Dam	×	×				×
	Windy Lake north freshwater intake	×					
	Expansion to mine dry and administration building	×	×				×
	Expansion to water treatment plant	×	×				×
	Operation – use of existing approved and permitted infrastructure						
	Airstrip, winter ice strip and helicopter pad		×			×	×
	Accommodation facilities (sewage treatment facilities, domestic water treatment, fire suppression)		×				
	Chemical and hazardous material management facilities		×			×	
	Diesel power plant		×			×	×
	Fuel storage and handling		×			×	
	Incinerator		×			×	×
	Equipment and vehicle emissions					×	×
	Ore stockpile		×				×
	Site roads use and maintenance		×			×	×
	Storage and handling of explosives				×		
	Surface infrastructure (maintenance facilities, warehouses, laydown areas, waste management facilities)		×			×	×
	Water discharge to the receiving environment		×				

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
	Water management system		×				
	Operation – proposed Madrid-Boston infrastructure						
	Expanded PDA		×				
	Quarry		×	×	×		×
	TIA road use and maintenance		×			×	×
	TIA storage		×				
	Equipment and vehicle emissions					×	×
	Reclamation and Closure – use of existing approved and permitted infrastructure						
	Equipment and vehicle emissions					×	×
	Site surface and mining infrastructure	×	×				×
	Airstrip	×	×			×	×
	Reclamation and Closure – proposed Madrid-Boston infrastructure						
	Equipment and vehicle emissions					×	×
	Accommodations (expanded)	×					
	Quarry	×	×				×
	TIA roads (perimeter and South Dam)	×	×			×	×
	TIA	×	×				
	Windy Lake north freshwater intake	×					
	Post Closure – proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	
Madrid North	**Construction – use of existing approved and permitted infrastructure**						
	Air heating facility	×					×
	Brine mixing facility	×					×
	Diesel power plant	×				×	×
	Fuel storage and handling	×	×			×	
	Equipment and vehicle emissions					×	×
	Ore stockpile	×	×				×
	Quarry	×	×	×	×		×
	Site roads	×	×			×	×
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)	×	×				×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
	Underground mine (drilling, blasting, excavation, ventilation)	×	×		×		×
	Waste rock pile	×	×				×
	Water management system	×	×				
	Construction – proposed Madrid-Boston infrastructure						
	Expansion of the PDA	×	×				×
	Expansion of site pad (waste rock stockpile)	×	×				×
	Process plant (concentrator)	×					×
	Power plant	×				×	×
	Water discharge to the receiving environment		×				
	Water management system (including expanded CWP)	×	×				
	Expansion to fuel storage	×	×			×	×
	Expansion to power generation	×	×			×	×
	Expansion to ore and waste-rock stockpile	×	×				×
	Vent raise and access road	×	×				×
	Tailings pipeline and service road to Doris TIA	×	×				×
	Equipment and vehicle emissions					×	×
	Operation – use of existing approved and permitted infrastructure						
	Diesel power plant		×			×	×
	Doris - Madrid road use and maintenance		×			×	×
	Fuel storage and handling		×			×	
	Equipment and vehicle emissions		×			×	×
	Madrid North access road use and maintenance		×			×	×
	Ore stockpile		×				×
	Quarry		×	×	×		×
	Site roads use and maintenance		×			×	×
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)		×			×	×
	Underground mine (drilling, blasting, excavation, ventilation)		×		×		×
	Waste rock pile		×				×
	Water management system		×				
	Operation – proposed Madrid-Boston infrastructure						
	Expansion of PDA		×				
	Power plant					×	×
	Water discharge to the receiving environment		×				

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
	Water management system (including CWP)		×				
	Domestic water trucked from existing water intake location						×
	Equipment and vehicle emissions					×	×
	Reclamation and Closure – proposed Madrid-Boston infrastructure						
	Inter-site roads	×	×			×	×
	Machine and vehicle emissions					×	×
	Site surface and mining infrastructure	×	×			×	×
	Post Closure – proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	
Madrid South	**Construction – use of existing approved and permitted infrastructure**						
	Air heating facility	×					×
	Brine mixing facility	×					×
	Diesel power plant	×				×	×
	Fuel storage and handling	×	×			×	
	Equipment and vehicle emissions					×	×
	Ore stockpile	×	×				×
	Quarry	×	×	×	×		×
	Site roads	×	×			×	×
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)	×	×				×
	Underground mine (drilling, blasting, excavation, ventilation)	×	×		×		×
	Waste rock pile	×	×				×
	Water management system	×	×				
	Construction – proposed Madrid-Boston infrastructure						
	Expansion of PDA	×	×				×
	Expansion of site pad (waste rock stockpile)	×	×				×
	Water discharge to the receiving environment		×				
	Water management system (including expanded CWP)	×	×				
	Expansion of ore and waste-rock stockpile	×	×				×
	Vent raise and access road	×	×				×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
	Equipment and vehicle emissions					×	×
	Operation – use of existing approved and permitted infrastructure						
	Diesel power plant		×			×	×
	Doris - Madrid road use and maintenance		×			×	×
	Fuel storage and handling		×			×	
	Equipment and vehicle emissions					×	×
	Ore stockpile		×				×
	Quarry		×	×	×		×
	Site roads use and maintenance		×			×	×
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)		×			×	×
	Underground mine (drilling, blasting, excavation, ventilation)		×		×		×
	Waste rock pile		×				×
	Water management system – Type B licence		×				
	Operation – proposed Madrid-Boston infrastructure						
	Expansion of the PDA		×				
	Water discharge to the receiving environment		×				
	Water management system (including CWP)		×				
	Domestic water trucked from existing water intake location						×
	Equipment and vehicle emissions					×	×
	Reclamation and Closure – proposed Madrid-Boston infrastructure						
	Inter-site roads	×				×	×
	Equipment and vehicle emissions					×	×
	Site surface and mining infrastructure	×	×			×	×
	Post Closure – proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	
Madrid-Boston All-Weather Road	**Construction – use of existing approved and permitted infrastructure**						
	Quarries	×	×	×	×		×
	Construction – proposed Madrid-Boston infrastructure						
	All weather road (grading, backfill, excavation, drainage)	×	×			×	×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
	Animal crossings	×	×				
	Construction accommodations	×					×
	Equipment and vehicle emissions					×	×
	Quarries	×	×	×	×		×
	Water crossings	×	×				
	Operation – use of existing approved and permitted infrastructure						
	Equipment and vehicle emissions					×	×
	Operation – proposed Madrid-Boston infrastructure						
	All weather road use and maintenance		×			×	×
	Animal crossings		×				
	Equipment and vehicle emissions					×	×
	Quarries		×	×	×		×
	Water crossings		×				
	Reclamation and Closure – use of existing approved and permitted infrastructure						
	Madrid-Boston winter road	×	×			×	×
	Construction accommodation	×	×				×
	Equipment and vehicle emissions					×	×
	Reclamation and Closure – proposed Madrid-Boston infrastructure						
	All-weather road, quarries and associated infrastructure	×	×				×
	Equipment and vehicle emissions					×	×
	Post Closure – proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	
Boston	**Construction – use of existing approved and permitted infrastructure**						
	Airstrip and helicopter pad	×	×				×
	Winter ice strip on Aimaokatalok Lake	×	×				
	Accommodations	×	×				×
	Equipment and vehicle emissions					×	×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
	Construction – proposed Madrid-Boston infrastructure						
	Accommodations (sewage treatment facilities, potable water treatment, fire suppression)	×	×				×
	Diesel power plant	×	×			×	×
	Expansion of PDA	×	×				×
	Fuel storage and handling	×	×			×	
	Heliport and heliport shack	×	×				×
	Incinerator	×	×			×	×
	Landfarm	×	×				×
	Equipment and vehicle emissions					×	×
	Ore stockpile	×	×				×
	Overburden pile	×	×				×
	Quarries	×	×	×	×		×
	Second mine portal	×	×				×
	Site roads	×	×			×	×
	Surface infrastructure (exploration office, core storage facility, laydown area, emergency shelter, office, warehouse, reagent storage, workshop, waste management facility, brine mixing facility, vent raise)	×	×			×	×
	Underground mine (drilling, blasting, excavation, ventilation)	×	×		×		×
	Waste rock pad and pile	×	×				×
	Water discharge to the environment		×				
	Water management system	×	×				
	Process plant (concentrator)	×	×				×
	Dry-stack TMA	×	×				×
	TMA roads	×	×			×	×
	TMA water management system	×	×				
	Explosives facility	×	×		×		×
	Operation – proposed Madrid-Boston infrastructure						
	Camp (sewage treatment facilities, potable water treatment, fire suppression)		×				×
	Diesel power plant		×			×	×
	Expanded PDA		×				
	Fuel storage and handling		×			×	
	Heliport and heliport shack		×				×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
	Incinerator		×			×	×
	Landfarm		×				×
	Equipment and vehicle emissions					×	×
	Ore stockpile		×				×
	Overburden pile		×				×
	Quarries		×	×	×		×
	Site roads and maintenance		×			×	×
	Surface infrastructure (exploration office, core storage facility, laydown area, office, emergency shelter, warehouse, reagent storage, workshop, waste management facility)		×			×	×
	Underground mine (drilling, blasting, excavation, ventilation)		×		×		×
	Waste rock pile		×				×
	Water discharge to the environment		×				
	Water management system		×				
	Process plant (concentrator)		×				
	Dry-stack TMA		×				×
	TMA roads use and maintenance					×	×
	TMA water management system		×				
	Reclamation and Closure – proposed Madrid-Boston infrastructure						
	Site surface and mining infrastructure	×	×			×	×
	Equipment and vehicle emissions					×	×
	TMA and associated infrastructure	×	×				×
	Post Closure – proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	
Boston Airstrip	**Construction – proposed Madrid-Boston infrastructure**						
	Access road	×	×				×
	Airstrip and lighting	×	×				×
	PDA	×	×				×
	Equipment and vehicle emissions					×	×
	Quarry	×	×	×	×		×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
	Operation – proposed Madrid-Boston infrastructure						
	Access road use and maintenance		×			×	×
	Airstrip and lighting		×			×	×
	PDA		×				
	Equipment and vehicle emissions					×	×
	Quarry		×	×	×		×
	Reclamation and Closure – proposed Madrid-Boston infrastructure						
	Site surface infrastructure	×	×			×	×
	Equipment and vehicle emissions					×	×
	Post Closure – proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	

The pathways applicable to each Project interaction group are summarized in Table 4.5-4. These pathways are used throughout the effects assessment to describe the potential effects, identify mitigation and management measures, and characterize the residual effects from Project activities.

Table 4.5-4. Pathways of Interactions with the Freshwater Environment for the Freshwater Water Quality Effects Assessment

Project Activity	Pathway	Indicators	Project Phases
Site preparation, construction, and decommissioning activities	Runoff, physical, aerial deposition	pH, TSS, nutrients, dissolved oxygen, metals, hydrocarbons	Construction, Reclamation and Closure
Site and mine contact water	Runoff, discharge, seepage	pH, TSS, nutrients, dissolved oxygen, metals, hydrocarbons, other constituents (anions, cations, cyanide)	Construction, Operation, Reclamation and Closure, Post-closure, Temporary Closure
Quarries	Runoff and aerial deposition	pH, TSS, nutrients, metals, hydrocarbons	Construction and Operation
Explosives	Runoff and aerial deposition	Nutrients, dissolved oxygen, hydrocarbons	Construction and Operation
Fuels, oils, PAH	Runoff and aerial deposition	Hydrocarbons	Construction, Operation, Reclamation and Closure, Temporary Closure

Project Activity	Pathway	Indicators	Project Phases
Dust deposition	Aerial deposition	TSS, metals, hydrocarbons	Construction, Operation, and Reclamation and Closure

The potential effects of each of the Project activities identified in Table 4.5-3 are characterized in Sections 4.5.2.1 to 4.5.2.6. The potential effects analysis considered the proposed Project activities and the pathway(s) linking the Project activities to the freshwater environment. The potential effects are identified prior to the application of mitigation or management measures. The subsequent characterization of the potential effects (Section 4.5.4) considers mitigation and management measures, and may show that the potential effects are negligible.

4.5.2.1 Site Preparation, Construction, and Decommissioning Activities

During the Construction phase, ground preparation will be required throughout the PDA to construct necessary Madrid-Boston infrastructure, including buildings, roads, and mine works. As outlined in Table 4.5-3, the Madrid-Boston Project includes expansion of the TIA, which will require additional construction activities that were not authorized by the 2AM-DOH1323 Water Licence. Site preparation and construction activities will involve vegetation clearing, the removal and relocation of surficial materials, and the construction of pad areas from surficial material, borrow material, and quarried rock. The activities would also include the construction of water management structures, such as ditches, diversion structures and berms to mitigate runoff, and earthworks for the TIA (Doris area) and the TMA (Boston area). The decommissioning and reclamation of Madrid-Boston infrastructure will similarly require surface contact and the transportation and relocation of surficial materials.

Landscape disturbance (ground works) has the potential for effects on freshwater water quality. The primary pathway for these potential effects would be runoff (i.e., the transport of material in overland flow). This would occur primarily during snowmelt and freshet in the spring, during precipitation events in the summer and fall, and would be absent in the winter. Runoff from areas undergoing site preparation or decommissioning could affect freshwater water quality by contributing TSS (erosion), metals (TSS), nutrients (vegetation removal and blasting residue), and hydrocarbons (use of fuels and oils) into the freshwater environment.

In-water or near-water activities, including the installation or decommissioning of stream-crossing infrastructure for the AWRs, the discharge pipeline in Aimaokatalok Lake, and freshwater intake pipelines in Aimaokatalok and Windy lakes, also have the potential to affect water quality. Four AWRs are proposed that will cross streams including the Roberts Bay Cargo Dock Access Road, Madrid North-TIA AWR, the Madrid South AWR, and the Boston-Madrid AWR. Culverts or bridges will be installed in or over streams that will be crossed by roads to allow for the flow of water and passage of fish. Disturbance during in-water works could temporarily affect water quality through the direct physical interaction pathway. In-water works could disturb lakebeds and streambeds, which could lead to the temporary disturbance of sediments and increases in the concentrations of TSS and associated metals and nutrients in the overlying water.

The potential effects from site preparation, construction, and decommissioning activities may occur during the Construction and Reclamation and Closure phases.

Site Preparation, construction, and decommissioning can also interact with the freshwater environment through the generation of dust (which could ultimately be deposited in the freshwater environment); the potential effects of dust deposition are considered in Section 4.5.2.6.

4.5.2.2 Site and Mine Contact Water

Site contact water is defined as the runoff from snowmelt and precipitation events that interacts with constructed site surfaces including roads and laydown areas. A comprehensive geochemical characterization program was conducted to assess the metal leaching and acid rock drainage (ML/ARD) potential (see Volume 4, Chapter 5, Geochemistry); only rock from quarries defined as suitable for use based on a low risk of ARD and low risk of metal leaching under neutral pH conditions, will be used as construction material. Flowing surface water in runoff can contact these surfaces, and subsequently transport acid equivalents, suspended material, metals, nutrients, and petroleum hydrocarbon compounds into the freshwater environment if not managed or mitigated. The potential for effects from site contact water could occur during all phases of the Madrid-Boston Project.

Mine contact water is defined as the underground water removed from mine works; water that interacts with waste rock storage areas, ore stockpiles, crown pillar recovery trenches, and water management structures that will be directed to contact water ponds (CWPs); mill process water; drilling fluid from exploration activities; and water in the TIA. The pathways of interaction between mine contact water and the freshwater environment are runoff, discharge, and seepage. Operation of the STP at Boston is also included in this interaction group. Greywater and sewage will be treated and discharged in Aimaokatalok Lake in combination with discharge from the Boston Process Plant and WTP. The contact water discharge via the Roberts Bay Discharge System at the Doris site is not included in the freshwater water quality assessment because the effluent is directed to the marine environment (see Volume 5, Chapter 8).

Site and mine contact water (including water interacting with overburden, waste rock, and tailings) together with treated WTP and STP discharge could affect the freshwater water quality by changing pH, and contributing TSS, metals, nutrients (contact with blasting residues, treated sewage), and other water quality indicators such as hydrocarbons and chloride (e.g., saline groundwater) into the freshwater environment. Dissolved oxygen concentrations can also be indirectly affected by increases in nutrient concentrations, which could alter the productivity of freshwater environments.

The potential effects from site and mine contact water may occur during the Construction, Operation, Reclamation and Closure, Post-closure, and Temporary Closure phases of the Madrid-Boston Project.

4.5.2.3 Quarries and Borrow Pits

Quarries and borrow sources will be developed to meet the requirements for construction and maintenance. The pathway of interaction between quarries and the freshwater environment is through runoff. Contact water in quarries and borrow pits may transport acid equivalents, metals, nutrients (from contact with blasting residues – considered in Section 4.5.2.4), and suspended sediments into the freshwater environment. Runoff from quarries and borrow pits could affect freshwater water quality by changing pH (interaction with surficial material), and contributing TSS (erosion), metals, nutrients, and hydrocarbons (mechanical use of fuel, oil, and grease) into the freshwater environment.

The dust generated at quarries and borrow pits that could ultimately be deposited in the freshwater environment are considered in Section 4.5.2.6.

The potential effects from quarries and borrow pits may occur during the Construction and Operation phases.

4.5.2.4 Explosives

Ammonium nitrate-fuel oil (ANFO) explosives will be used as the explosive for quarries and mine development and production. Components of the explosives have the potential for effects on freshwater water quality because of the presence of ammonium nitrate and petroleum hydrocarbons. The pathways of interaction between explosives and the freshwater environment are runoff and aerial deposition. Runoff and deposition of explosives (or blasting residues) into the freshwater environment can affect water quality by increasing the concentrations of ammonia and nitrate. The petroleum hydrocarbons component, either as dissolved constituents or particle-attached compounds, is a minor fraction of the explosives by weight (e.g., hydrophobic hydrocarbon residues). The petroleum hydrocarbons components of the explosives are not considered further as a potential effect because of their small relative proportion in the ANFO explosives.

The airborne explosive nitrogen residues that could potentially be deposited in the freshwater environment are considered in Section 4.5.2.6.

The potential effects from explosives may occur during the Construction and Operation phases.

4.5.2.5 Fuels, Oils, and PAH

The *Fuels, Oils, and PAH* Project interaction group includes the storage and transport of fuels and petroleum hydrocarbons, fueling and maintenance operations, and the incineration of waste that may create PAH by incomplete combustion. The primary pathways of interaction between these sources of hydrocarbons and the freshwater environment are runoff and aerial deposition. Activities at facilities, laydown areas, fuel storage areas, and waste management areas can deposit hydrocarbon compounds such as oil or grease onto surfaces that can subsequently be transported into freshwater environments in runoff. Combustible waste, including the solids from sewage treatment, will be combusted using an incinerator. Incomplete combustion can create airborne hydrocarbons that can be deposited into freshwater environment via deposition or runoff. The potential effects from spills, including fuel spills, are not assessed as part of the normal operating conditions, and are considered in the Accidents and Malfunctions section of the EIS (Volume 7, Chapter 1).

The potential for the deposition of airborne PAH generated by incomplete combustion into the freshwater environment is considered in Section 4.5.2.6.

The potential effects from fuels and other hydrocarbons may occur during the Construction, Operation, Reclamation and Closure, and Temporary Closure phases.

4.5.2.6 Dust Deposition

Dust (i.e., airborne particulates) can be generated by a variety of Project activities, including construction activities, vehicle traffic, blasting, incinerator use, quarry operations, and rock processing. Areas cleared for infrastructure (i.e., laydown areas) can also be sources of dust. The aerial deposition of Project-generated dust is the primary pathway of interaction. Dust deposited into the freshwater environment can affect freshwater water quality by introducing suspended material and associated metals, nutrients, or other contaminants into waterbodies. The potential effects from dust deposition may occur during all phases of the Project.

The potential effects from dust deposition may occur during the Construction, Operation, and Reclamation and Closure phases.

4.5.3 Mitigation and Adaptive Management

4.5.3.1 Mitigation by Project Design

The following measures were included in the design of the Project to minimize or eliminate potential effects on the freshwater environment:

- Utilization of existing infrastructure associated with the Doris Project.
- Inclusion of climate change projections for key climatic and hydrological design details (Package P5-2).
- Construction of roads and pipelines as far as is practical from stream channel crossings and wet, boggy areas where fish habitat may be disturbed.
- Planned set-backs and buffer zones from waterways.
- Avoidance, as required and feasible, of sensitive features, including riparian ecosystems and floodplains, esker complexes, fragile or rare wetlands, shallow open water, ponds, marshes, beaches, intertidal areas, and marine backshores.
- Using geochemically suitable rock quarries and borrow sources will be used to construct roads, pads, and structures.
- Infrastructure will be located, whenever feasible, on competent bedrock or appropriate base material that will limit permeability and transport of potentially poor quality water into the active layer.
- Appropriate secondary containment systems will be used for petroleum product storage tanks to prevent spills and releases to water. Bulk fuel storage areas, hazardous materials storage areas, and explosives storage facilities will be bermed and lined with impermeable barriers to minimize leaks and spills.

The design of the Madrid-Boston Project also included adherence to regulatory requirements relevant to the mitigation of potential effects on the freshwater environment. These regulatory requirements included the following:

- The operation of incinerators will comply with Nunavut standards (Government of Nunavut Department of Environment 2012), Canada-Wide Standards for Dioxins and Furans (CCME 2001a) and Canada-Wide Standards for Mercury Emissions (CCME 2000), as well as TMAC's own Incinerator Management Plan (Package P4-16). Modern incineration equipment will be installed to minimize airborne contaminant loading of PAH.
- Treated effluent from Boston activities will be discharged to Aimaokatalok Lake in compliance with Type A Water Licence and Metal Mining Effluent Regulation (MMER; SOR/2002-222) requirements in a manner that will facilitate mixing and dispersion and consequently result in dilution to concentrations protective of aquatic life within 250 m of the discharge point.
- Blasting restrictions outlined in DFO's *Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters* (Wright and Hopky 1998) will be implemented for blasting occurring near water.
- Culvert maintenance will be conducted following the guidance provided in *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2016), which adheres to the *Fisheries Act* (1985c).
- In-water work will be conducted during approved timing windows presented in *Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat* (DFO 2013).

- Water withdrawal for exploration drilling will follow the conditions outlined in *Water Withdrawal under Ice Guidelines* (DFO 2010).
- Water withdrawal will follow Type A Water Licence conditions.

4.5.3.2 Best Management Practices

Reducing potential effects to the freshwater environment by avoidance is the most effective mitigation measure to reduce the potential for serious damage or harm. The design of the Project includes a number of features to avoid or minimize potential effects. Management and mitigation measures relevant to the avoidance or minimization of potential effects to the freshwater environment are described in the following plans and manuals:

- Oil Pollution Prevention Plan (OPPP) / Oil Pollution Emergency Plan (OPEP; Annex V8-1);
- Air Quality Management Plan (Annex V8-2);
- Hope Bay Project Spill Contingency Plan (Package P4-3);
- Doris Project Domestic Wastewater Treatment Management Plan (Package P4-4);
- Hope Bay Project: Boston Sewage Treatment Operations and Maintenance Management Plan (Package P4-5);
- Hope Bay Project Groundwater Management Plan (Package P4-6);
- Hope Bay Project Doris-Madrid Water Management Plan (Package P4-7);
- Hope Bay Project Boston Water Management Plan (Package P4-8);
- Hope Bay Project Doris-Madrid Tailings Impoundment Area - Operations, Maintenance, and Surveillance Manual (Package P4-9);
- Hope Bay Project Boston Tailings Management Area - Operations, Maintenance, and Surveillance Manual (Package P4-10);
- Hope Bay Project Waste Rock and Ore Management Plan (Package P4-11);
- Hope Bay Project Water and Ore/Waste Rock Management Plan (Package P4-12);
- Hope Bay Project Non-hazardous Waste Management Plan (Package P4-13);
- Hope Bay Project Hydrocarbon Contaminated Material Management Plan (Package P4-14);
- Hope Bay Project Hazardous Waste Management Plan (Package P4-15);
- Hope Bay Project Incinerator Management Plan (Package P4-16);
- Hope Bay Quarry Management and Monitoring Plan (Package P4-17);
- Hope Bay Project Aquatic Effects Monitoring Plan (Package P4-18);
- Hope Bay Project Boston Conceptual Closure and Reclamation Plan, November 2017 (Package P4-19); and
- Hope Bay Project Doris-Madrid Interim Closure and Reclamation Plan, November 2017 (Package P4-21).

Specific mitigation and management measures relevant to the assessment of effects on freshwater water quality include the following:

- Implementation of sediment control measures for works in or near waterbodies and watercourses, such as use of silt fences at drainage points and the minimization of vegetation clearing.
- Implementation of erosion control measures where necessary, such as capping of soils exposed during construction activities with rock.
- Regular inspections will be conducted to ensure erosion and sediment control measures are functioning properly; all necessary repairs and adjustments will be conducted in a timely manner. Efforts shall be made to minimize the duration of any in-water works and minimize disturbance of riparian vegetation.
- Activities will be planned and executed to minimize the release of sediment or sediment laden water into water frequented by fish.
- Facilities are designed with consideration of footprint minimization and will be located, where possible, in areas of reduced runoff.
- Pads are constructed of non-mineralized rock and are designed to direct contact water to CWPs.
- Seepage and runoff from waste rock and ore stockpiles and crown pillar recovery trenches will be directed to CWPs.
- Clean water and snow will be managed such that they do not contribute to potentially poor quality water and be diverted to maintain natural drainage networks as much as possible.
- Non-contact water will be diverted around infrastructure, as much as feasible, and directed to the existing drainage networks.
- Crown pillar recovery trenches will be covered following use to restore natural runoff to the existing drainage networks.
- CWP storage capacity, freshet flows and expected storm event volumes will be determined based on site specific conditions. The sizing and design of these facilities is such that they can hold water during unusual storm events and contain freshet flows for prescribed periods.
- Water collected in the CWPs at Madrid North and Madrid South will be routinely discharged to the TIA or tundra (where permitted and in compliance with discharge requirements) to retain maximum pond holding capacity and reduce the possibility of unintentional releases.
- The TIA has been designed with substantial additional capacity to store both natural and Project-related inputs in excess of routinely expected volumes. Water will routinely be discharged from the TIA to Roberts Bay, and compliant groundwater preferentially be sent directly to Roberts Bay.
- Waters intended for discharge directly from the CWPs and the TIA to the environment will be sampled for, and meet, applicable requirements under the MMER, water licences and/or surface leases administered pursuant to the *Territorial Lands Act*.
- Exploration drilling water will be recycled to minimize the quantity of freshwater used, and to reduce salt use. Excess brine remaining following drill completion will be disposed of with salt-containing drill cuttings. Drill cuttings will be moved to a cuttings management containment system that allows the cuttings to settle and separate from the drill water. The clarified water will be re-circulated through the system. If cuttings are brine free (where not generated while

added salt was used), cuttings sludge may be deposited into a natural depression near the drill hole, or transported by helicopter to a central cuttings management area where direct flow into a water body is not possible and no additional effects created. If the cuttings are contaminated with brine, they will be transported to a containment facility where runoff will be captured for treatment or transferred to an appropriate wastewater disposal facility (e.g., Doris TIA, or Boston TMA).

- Mill bleed from the Boston Process Plant will first be treated in a three-stage treatment plant for metals removal followed by a biological process for ammonia removal prior to discharge to Aimaokatalok Lake.
- Excess contact water from CWPs will be treated in a two-stage treatment plant prior to discharge to Aimaokatalok Lake.
- Appropriate secondary containment systems will be used for petroleum product storage tanks to prevent spills and releases to water.
- Spills will be contained according to the Spill Contingency Plan (Package P4-3) including the prioritization of the protection of sensitive areas.
- Soil, snow and water contaminated with diesel fuel, aviation gasoline, jet fuels and/or gasoline will report to the landfarm. Treated water from the snow or clean water pond will only be removed for discharge to the tundra only once sample analysis has confirmed the quality is suitable for release to the environment. If water does not meet discharge criteria following treatment, the water will be transferred to the TIA for disposal. Soil collected from the landfarm will either be disposed of underground or at the TIA.
- Hazardous waste will be minimized to the extent possible. Hazardous wastes will be shipped off site.
- Quarries will be developed to the extent possible to ensure that water entering the quarry from precipitation and snowmelt is retained within the quarry boundary. If required a quarry sump will be used to collect water, sump water will be sampled and discharged to the environment only if discharge requirements are met. Non-compliant water that needs to be discharged will be transported to CWPs for management and/or transported directly to the TIA for disposal.
- High quality ANFO explosives have been selected for blasting operations. The explosive product may be in the form of prills, emulsion, or be prepackaged. Different forms of the product may be used depending on the particular circumstances of use. Industry best practices will be employed to maximize source control and blast efficiency so as to minimize the potential for blasting product or blasting residues to occur in downstream waters.
- Dust suppression as appropriate will be applied to roadways to minimize dust from ore and waste rock haulage, site road traffic, and road maintenance (grading) when ambient air temperatures permit.
- Sewage and greywater will be treated and treated effluent may be discharged to the tundra only if water quality discharge criteria are met. Sewage sludge will be incinerated or disposed of in the TIA.
- Vehicular access across a watercourse or waterbody will be by road or bridge, or other acceptable method according to *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2016).
- The bulk fuel storage facilities and all transfer-related equipment will be routinely inspected repairs (if required) carried out promptly.

- During temporary closure the following will take place to protect freshwater water quality:
  - physical, chemical and biological monitoring and treatments will continue in accordance with the Project licences and permits.
  - Fuel, hazardous wastes and explosives will be properly stored or removed from site.
  - Waste rock and ore piles and tailings facilities as well as dams, roads and pipelines will be inspected and maintained.
  - Surface water management and sediment and erosion control will continue as needed.
- During closure, the TIA North Dam will be breached in a manner that minimizes harm to the freshwater receiving environment. To minimize environmental risk, the TIA North Dam will not be breached until the tailings have been covered as outlined in the approved closure plan and water quality in the TIA is confirmed suitable for discharge back into the Doris Lake system.
- During closure, a low infiltration cover will be placed over the tailings in the Boston TMA. Once the cover is in place, the contract water pond berm will be breached to restore natural drainage. The remainder of the berms will stay in place in order to preserve the permafrost. The closure plan for the Boston TMA will be refined through the operations period through monitoring of water quality in the CWPs and updating water quality predictions.

4.5.3.3 Proposed Monitoring Plans and Adaptive Management

An Aquatic Effects Monitoring Plan (Package P4-18) will be in place that outlines the Aquatic Effects Monitoring Program (AEMP) that will be carried out during all phases of the Project. The AEMP will include the following:

- monitoring the freshwater environment at locations potentially affected by the Project and at reference areas well away from Project activities;
- monitoring freshwater water quality, sediment quality, and aquatic biology.

Regular inspections of water management facilities will be conducted by on-site Environmental Personnel.

There will be a Surveillance Monitoring Program that will be outlined in the future Type A Water License. This monitoring program will cover all of the site compliance monitoring required for the management and release of water from all Project infrastructure.

Adaptive management and corrective actions will be determined on a case-by-case basis. The actions may include modifications to existing mitigation and management measures or installation of additional control measures. Indications of the need for corrective actions and additional control measures may include:

- non-compliant observations or trends from the Surveillance Monitoring Program; or
- the observations of negative effects to the freshwater environment in the AEMP.

4.5.4 Characterization of Potential Effects to Freshwater Water Quality

The potential for effects on freshwater water quality from the Project activities identified in Section 4.5.2 are characterized in this section. Specific mitigation and management measures are considered for each potential effect, and if the implementation of mitigation measures eliminates a potential effect, the effect is eliminated from further assessment. Project residual effects are the effects that remain after mitigation and management measures are taken into consideration. If the proposed mitigation measures are not sufficient to eliminate an effect, a residual effect is identified and carried forward for additional characterization and a significance determination (Section 4.5.5).

Residual effects of the Madrid-Boston Project can occur directly or indirectly. Direct effects result from direct interactions between Project activities and freshwater water quality. Indirect effects can occur when the primary effect is to another component of the environment (e.g., sediment disturbance), which can lead to secondary or indirect effects on freshwater water quality.

The potential for residual effects of the Project on freshwater water quality is assessed using both quantitative water quality modeling as well as qualitative methods. The characterization of potential effects considers both the incremental effects of Madrid-Boston developments and activities as well as the overall effects from all components of the Hope Bay Development.

4.5.4.1 Site Preparation, Construction, and Decommissioning Activities

The disturbance of the landscape through site preparation and the construction of infrastructure such as roads and pads creates the potential for runoff that can affect freshwater water quality. In-water or near-water works can also affect water quality through runoff or the disturbance of sediments. The primary indicator of change for the effects of site preparation, construction, and decommissioning activities is the concentration of suspended sediments in the water (i.e., TSS).

The primary goal of runoff and sedimentation control strategies is to prevent soil, sediments, and particulate matter from entering the receiving environment. The existing Doris Project has demonstrated that erosion and sedimentation control measures are effective (as evaluated in the Doris AEMP), including the implementation of additional control measures on a case-by-case basis. Although identified mitigation and best management strategies (Section 4.5.3) are effective in minimizing erosion, sedimentation, and potential siltation of the water column in the receiving environment, these strategies may not fully prevent all surface runoff and sediment entry or resuspension. Thus, a potential residual effect from construction and decommissioning activities on freshwater water quality may occur. Changes to water quality during construction and decommissioning activities will be monitored to ensure that erosion controls and sedimentation mitigation strategies are effective.

<u>Characterization of Madrid-Boston Project Potential Effects</u>

Infrastructure that will be constructed and potentially decommissioned as part of the Madrid-Boston Project includes additional pads, roads, laydown areas, ore stockpiles, waste rock storage areas, and site surface infrastructure (e.g., camps, offices, waste management facility). Site preparation, construction, and decommissioning activities will cause a disturbance to the landscape and could increase the potential for runoff into the freshwater environment.

Although the sediment and erosion control measures summarized in Section 4.5.3 (e.g., the use of silt fences as required, the minimization of vegetation clearing, the capping of soils exposed during construction activities with rock) are known to be effective, a potential residual effect from construction and decommissioning activities on freshwater water quality may occur. These residual effects to water quality are associated with the transport of suspended material (TSS), which may create localized increases in the concentrations of suspended sediments and sediment-associated metals or nutrients. These residual effects are anticipated to occur during or immediately after the construction or decommissioning activities when surface materials are more likely to be disturbed, and have the greatest potential to occur during periods of significant overland flow, such as freshet and rainfall events. Although sediment from runoff has the potential to increase TSS and turbidity in the receiving environment, the known effectiveness of the mitigation and management measures are predicted to mitigate the potential effects and the changes in suspended sediment concentrations are not expected to be greater than CCME guidelines for the protection of aquatic life.

The in-water works required for the installation and eventual decommissioning (the portion of pipe which is buried by rock fill will remain in place) of the discharge pipeline in Aimaokatalok Lake and the freshwater intake pipelines in Windy and Aimaokatalok lakes are also included in this interaction group, because the installation on the lakebed of infrastructure associated with the pipelines (e.g., cement pipeline anchors, rock berms, high-density polyethylene (HDPE) pipeline) could temporarily re-suspend sediments into the water column. The potential effects from the in-water construction and ultimate removal of the discharge and intake pipelines (the portions not covered in rock fill) are expected to be highly localized to the lakebed footprint of the infrastructure (i.e., 1,140 m^2 for the discharge pipeline, 1,603 m^2 for the Aimaokatalok Lake intake pipeline, and 88 m^2 for the Windy Lake intake pipeline, Packages P5-23 and P5-24), and will be short-lived as the re-suspended sediments will re-settle once the pipeline installation or removal is complete.

The installation of culverts or bridges where AWRs cross streams could also affect water quality by disturbing and re-suspending sediments, which would cause TSS concentrations in the overlying water to increase. Streams in which culverts or bridges could be installed include Glenn, Ogama, Wolverine, Trout, and Stickleback outflows, and Patch, Doris, and Aimaokatalok inflows, as well as Roberts Bay Inflow and Boulder Creek (see Table 6.5-4 in Volume 5, Chapter 6 for specific locations of these streams).

The potential effects of site preparation, construction, and decommissioning activities associated with the Madrid-Boston Project are considered to be potential residual effects and are further characterized in Section 4.5.5.

<u>Characterization of Hope Bay Development Potential Effects</u>

Construction of a substantial portion of the infrastructure at Roberts Bay and Doris has already been completed, and therefore does not contribute to the overall potential effect from construction activities across the Hope Bay Development. Similarly, construction at Madrid North under the Type “B” licence will be completed as authorized. These past residual effects were negligible, because no construction-related effects were observed in Doris as evaluated under the Doris AEMP. As a result, any localized, short-term changes in water quality from the construction of existing and permitted infrastructure will not coincide with the proposed Madrid-Boston Project activities, and there is minimal potential for a cumulative effects across the Hope Bay Development. Therefore, the residual effects from site preparation and construction activities for the Hope Bay Development are anticipated to be the same as the Madrid-Boston Project residual effects.

Decommissioning activities will occur throughout the Hope Bay Development, and will include the decommissioning of infrastructure at Roberts Bay and Doris. Effective mitigation and management measures will be applied, but the potential for residual effects from decommissioning activities remains. As discussed in the section for the Madrid-Boston potential effects, runoff or physical contact with sediments during decommissioning activities may transport or re-suspend sediments into the water column.

The potential residual effects of site preparation, construction, and decommissioning activities for the Hope Bay Development are further characterized in Section 4.5.5

4.5.4.2 Site and Mine Contact Water

The potential residual effects from site contact water and mine contact water are characterized together because of the quantitative predictions from the Water and Load Balance model (Package P5-4). The model considers the contributions of both site and mining activities for predicting the effects of the Project on the aquatic environment. For example, runoff from pad areas is combined in the model with runoff from ore stockpiles.

The potential for residual effects from site contact water are predicted to be reduced by the application of the mitigation and management measures outlined in Section 4.5.3. Once the water management systems are constructed, the majority of site contact water will be intercepted and prevented from contacting the freshwater receiving environment (Doris-Madrid Water Management Plan (Package P4-7) and Boston Water Management Plan (Package P4-8)). Intercepted site contact water will be stored in CWPs and discharged to the marine environment via the TIA (Doris, Madrid North, and Madrid South areas) or treated and discharged to Aimaokatalok Lake (Boston area). These water management and treatment measures are included in the Water and Load Balance model (Package P5-4), which improves the realism and accuracy of the model. During construction and decommissioning of Project infrastructure, some site contact water will report to the freshwater receiving environment when the water management system is not operational. Furthermore, runoff from some pads and laydown areas will not be diverted to the TIA or Boston WTP; site contact water from these locations will be collected in sumps and discharged if the contact water meets permit conditions for water quality. Site contact water will not be released to the receiving environment unless it meets the water quality criteria outlined in applicable water licences.

Throughout all areas of the Project, the release of site contact water has the potential to transport suspended sediments into the receiving environment. The application of the mitigation and management measures associated with suspended sediments (see Section 4.5.3) are predicted to be effective and reduce the quantities of transported suspended material. However, there is the potential for alteration of suspended sediment concentrations in the receiving environment prior to the completion of the water management infrastructure and during normal, permitted releases of contact water from sumps. Adherence to the water licence criteria and application of the proven mitigation and management measures are predicted to maintain suspended sediment concentrations below the CCME water quality guideline for the protection of aquatic life (i.e., increase of 25 mg/L short-term and 5 mg/L long-term for the TSS indicator), but there may be localized, temporary increases above baseline conditions.

The potential effects on freshwater water quality from exploration drilling fluids are considered fully mitigated by the measures outlined in Sections 4.8.2 and 4.8.3 of the Project Description (Volume 3). Drilling fluid is not expected to contact the freshwater environment, and therefore is not anticipated to have any effects to freshwater water quality.

Residual effects from mine contact water, which is defined as the runoff from waste rock, ore stockpiles, crown pillar recovery trenches, underground water, and water from ore processing mills, are also expected to be reduced by mitigation and management, including water treatment. The interception of mine contact water prior to contact with the freshwater environment is a fundamental measure in the design of the Madrid-Boston Project. In the Madrid area, mine contact water will be collected and transferred to the Doris TIA. In the Boston area, mine contact water during Operation will be treated at the Boston Contact WTP and then combined with treated water from the Boston Process Plant WTP and the Boston STP before being discharged to Aimaokatalok Lake. This infrastructure will be decommissioned during Closure, with the resulting runoff from the TIA (Doris area) and TMA (Boston area) being directed to the freshwater environment during Post-closure. Given that some water management structures will not be operational during the initial stages of the Madrid and Boston mine development, there is the potential for residual effects from site and mine contact water during all phases due to runoff and discharge to the freshwater environment.

Characterization of Madrid-Boston Project Potential Effects

The potential effects to the freshwater water quality VEC from site and mine contact water are assessed using the quantitative Water and Load Balance model (Package P5-4) as well as near-field (Appendix V5-4B) and far-field hydrodynamic mixing modeling (Appendix V5-4E). The Water and Load Balance model describes the flow of water and chemical constituents within and between the Hope Bay Development and the environment. The model includes terms for precipitation, evaporation, cryo-concentration, neutral load, runoff (from both disturbed and undisturbed areas), water withdrawal, discharge, groundwater flow, and climate change. The modeled chemical constituents include base cations and anions (e.g., sulphate, chloride, and calcium), inorganic nitrogen species (i.e., ammonia, nitrite, and nitrate), cyanide, and metals (e.g., arsenic, copper, mercury, and iron). The timing of specific infrastructure and activities (such as the commissioning of waste rock storage areas) is explicitly included in the model. The water balance model was constructed using Goldsim™ – a dynamic and probabilistic simulation software (Package P5-4). Goldsim™ models biogeochemical reactions that are expected to occur *in situ* to generate accurate predictions that reflect natural conditions.

For the characterization of the potential effects to freshwater water quality, the base case predictions of the Water and Load Balance model were screened against 1) the predicted baseline conditions, 2) the assessment thresholds (Table 4.5-2), and 3) the range of observed baseline conditions (Appendix V5-4D). The assessment against predicted baseline was included because of the inclusion of climate change and lake evaporation in the model, as well as to provide an efficient conceptual screen between the effects of Projects activities (predicted base case) and the environment without the Project (predicted baseline). For each Project phase (i.e., Construction, Operation, Reclamation and Closure, and Post-closure), the predicted value of the indicators was screened at each timestep of the model (one month), for each of the open-water (June to September) and under-ice periods (October to May). In the first screening step, predicted base case and predicted baseline concentrations of parameters were compared to assess whether predicted changes were attributable to the Project. Baseline concentration plus 10% was used in screening based on professional experience to allow for the variability that can occur due to analytical uncertainty. For the purposes of the assessment, the first screening step determines whether predicted base case concentrations are measurably different from predicted baseline concentrations (in the absence of the Project) and indicates the potential for a Project-related effect to freshwater water quality. This comparison provides a good indicator of the potential for incremental change due to Project-related activities and screens out parameters with background concentrations at or above guidelines, but which were not predicted to increase due to the Project (existing guideline exceedances are not a Project-related effect). If the predicted concentration of a parameter represented a greater than 10% increase over baseline concentrations, the parameter was retained for the second screening step. For the second screening step, the magnitude of the effect was compared to the water quality indicator thresholds described in Table 4.5-2. If the predicted increase in a parameter concentration was both greater than a 10% increase over baseline concentrations (screening step one) and greater than the indicator threshold (screening step 2), it was carried through to the third and final screening step. The third screening step assessed the predicted Project effect against natural variability by comparing the predicted base case concentration to the 95th percentile of the observed baseline concentrations.

The characterization of potential effects are assessed for each major watershed within the Project area because the specific interactions between Project activities and infrastructure are confined to these drainage networks, and therefore characterization of potential effects is most efficient at this scale.

Aimaokatalok Watershed

The screening of the water balance model predictions in the Aimaokatalok Watershed identified potential residual effects to freshwater water quality in Stickleback and Aimaokatalok lakes (Appendix V5-4D).

Stickleback Lake is close to infrastructure in the Boston area and receives runoff during the Construction, Operation, Closure, and Post-closure phases from some parts of the Boston infrastructure. This includes runoff from the reclaimed CWPs during the Post-closure phase. Screening of the water balance model predictions (Appendix V5-4D) identified the following parameters for which the base case predictions are more than 10% greater than the predicted baseline concentrations:

- antimony;
- arsenic;
- barium;
- beryllium;
- boron;
- calcium;
- cobalt;
- copper;
- lead;
- manganese;
- mercury;
- molybdenum;
- nickel;
- selenium;
- sodium
- silver;
- thallium;
- uranium;
- vanadium;
- zinc;
- ammonia;
- chloride;
- fluoride;
- ammonia; and
- sulphate.

With the exception of fluoride, the base case predictions for all parameters are below water quality indicator thresholds (Table 4.5-2). Predicted maximum concentrations of fluoride are slightly over the assessment threshold concentration of 0.12 mg/L during all Project phases (Table 4.5-5); however, these cases are infrequent and short-lived as they are restricted to the month of February when ice cover and the effects of cryo-concentration would be greatest. The predicted guideline exceedance for fluoride is likely the result of an over-estimated model cryo-concentration factor since the natural cryo-concentration factor for fluoride in Stickleback Lake (2.25) is nearly 20% lower than the factor applied in the model (2.67). Nonetheless, the maximum median predicted under-ice fluoride concentration (Post-closure; 0.093 mg/L) is lower than the assessment threshold (0.12 mg/L), and the maximum predicted fluoride concentration (0.133 mg/L) is well within the 95th percentile of baseline observations in Stickleback Lake (0.245 mg/L). Several other lakes along the Belt have also had fluoride concentrations that are naturally greater than the 0.12 mg/L CCME guideline (e.g., Wolverine, Trout, Aimaokatalok, Windy, Patch, P.O., Doris, Little Roberts; Table 4.2-10).

Water quality predictions were generated for two separate parts of Aimaokatalok Lake (1) the small, eastern arm of Aimaokatalok Lake (indicated as Section 2b in Water and Load Balance report; Package P5-4) that is surrounded by infrastructure and connects the inflow of water from Stickleback and Trout lakes to the main lake; and (2) the main basin of Aimaokatalok Lake (Section 2a in modeling report). Both compartments were modeled as discrete units; thus, the smaller eastern arm of the lake was susceptible to the effects of cryo-concentration and the lack of exchange with the larger lake leading to overly-conservative water quality predictions. The main basin was conservatively modeled as a subsection of the whole lake. Both compartments integrated source inputs from runoff from disturbed and undisturbed areas, including runoff from the TMA in the Post-closure phase. The main basin of Aimaokatalok Lake also incorporated inputs from the Boston WTP-STP discharge and water withdrawal.

Table 4.5-5. Summary of Screening for Effects to Water Quality in Stickleback Lake

Variable	Threshold	Phase	Season	Observed Baseline			Predicted Baseline		Predicted Base Case		
				Median (mg/L)	95th Quantile (mg/L)	N	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months Exceeding Threshold[a]
Fluoride	0.12	C	Open	0.04	0.245	9	0.039	0.041	0.046	0.047	-
			Ice	0.09	0.095	3	0.076	0.107	0.089	0.124	Feb
		O	Open	0.04	0.245	9	0.041	0.042	0.046	0.047	-
			Ice	0.09	0.095	3	0.078	0.111	0.089	0.125	Feb
		CL	Open	0.04	0.245	9	0.042	0.043	0.047	0.048	-
			Ice	0.09	0.095	3	0.081	0.112	0.090	0.125	Feb
		PC	Open	0.04	0.245	9	0.046	0.049	0.048	0.051	-
			Ice	0.09	0.095	3	0.087	0.127	0.093	0.133	Feb

Notes:
C = Construction; O = Operation; CL = Closure; PC = Post-closure.
Open = Open-Water (June to September); Ice = Under-Ice (October to May)
[a] *Predicted base case concentration greater than predicted baseline + 10% and greater than a threshold in one or more Project phases (see Appendix V5-4D).*

The eastern arm of Aimaokatalok Lake was screened against baseline conditions and guidelines to predict potential Project effects due to mine and site contact water. The model results predict concentrations greater than 10% baseline concentrations in the eastern arm of Aimaokatalok Lake during at least one of the Project phases for:

- aluminum;
- antimony;
- arsenic;
- barium;
- beryllium;
- boron;
- cadmium;
- calcium;
- cobalt;
- copper;
- iron;
- lead;
- manganese;
- mercury;
- molybdenum;
- nickel;
- selenium;
- sodium;
- silver;
- thallium;
- uranium;
- vanadium;
- zinc;
- ammonia;
- nitrate; and
- sulphate.

For the main basin of Aimaokatalok Lake, which receives discharge from the Boston WTP-STP and other disturbed and undisturbed runoff inputs, base case predictions are elevated relative to baseline concentrations for the following indicators:

- antimony;
- beryllium;
- boron;
- cobalt;
- mercury;
- molybdenum;
- silver;
- ammonia;
- nitrate; and
- nitrite.

For all parameters, the predicted increases in concentrations are modest and lower than applicable thresholds (Appendix V5-4D). This was corroborated using near-field and far-field hydrodynamic mixing modeling, which examined the dispersion of effluent discharged from the Boston WTP-STP in Aimaokatalok Lake (Appendices V5-4B and V5-4E). Water quality predictions within the immediate near-field mixing zone showed all water quality parameters were below their assessment threshold within 3 m of the outfall diffuser (Table 4.5-6), and far-field hydrodynamic predictions indicated that water quality constituents would be effectively diluted within the inlet such that they would be near baseline levels at the lake outflow. Since the water leaving Aimaokatalok will be near baseline levels and there is no infrastructure on the western section of Aimaokatalok Lake or downstream to Hope Bay, no residual effects are predicted in the Koignuk River resulting from mine and site contact water.

A summary of constituents with predicted concentrations of more than 10% higher than predicted baseline concentrations within the Aimaokatalok Watershed is provided in Table 4.5-7. Constituents exceeding applicable thresholds but less than the observed 95^{th} percentile (within natural variability) are also included in Table 4.5-7 as part of the screening of effects. The results of the effects screening suggests that Project effects on water quality in the Aimaokatalok Watershed will generally be minor. The potential residual effects to water quality in the Aimaokatalok Watershed will be further characterized in Section 4.5.5.

Windy Watershed

Windy Lake is near the Madrid North site, and will interact with the Project through water withdrawals for industrial use at Madrid North, drinking water for the Doris site, runoff from the decommissioned CWP at the Madrid North, and the restoration of groundwater flow from the closure and flooding of the Madrid North mine. The water balance model predicts increases greater than predicted baseline concentrations for the following indicators (Appendix V5-4D):

- antimony;
- arsenic;
- beryllium;
- cadmium;
- cobalt;
- copper;
- lead;
- manganese;
- mercury;
- nickel;
- thallium;
- vanadium; and
- sulphate.

The maximum predicted increases are substantially lower than applicable water quality guidelines and thresholds. With the exception of mercury, all increases are predicted to occur during the Post-closure phase when natural flows are restored to Windy Lake from the closure of the Madrid North mine. This restored flow will be slow (0.3 m^3/d; Package P5-4), which is consistent with the predicted changes in concentrations. The predicted increases of mercury in Windy Lake during Operation and Closure phases are less than two times the baseline and far below the assessment threshold of 0.000026 mg/L (Appendix V5-4D).

A summary of water quality constituents with base case predictions of more than 10% greater than predicted baseline concentrations for the Windy Watershed (first step of screening process) is provided in Table 4.5-8. Predicted increases in parameter concentrations always remained below water quality thresholds; therefore no parameters were retained in the second step of the screening and advanced to the third step (Table 4.5-8). The results of the effects screening suggests that Project effects on water quality in the Windy Watershed will generally be minor. The potential residual effects to water quality in the Windy Watershed will be further characterized in Section 4.5.5.

Doris Watershed

The potential for residual effects to freshwater water quality in the Doris Watershed are identified in the screening of the predictions of the Water and Load Balance model. Wolverine and Patch lakes are proximate to the Madrid North and Madrid South mines, and P.O. Lake, Ogama Lake, Little Roberts Lake, and Doris Creek are downstream of Patch Lake. All these waterbodies were screened for potential water quality effects. Doris Lake was quantitatively considered within the water balance and not the load balance (Package P5-4).

Wolverine Lake is proximate to the Madrid South site, and could interact with the Project through groundwater flow and runoff from the Madrid South site, including runoff in Post-closure from decommissioned pad and stockpile areas. Wolverine Lake has a relatively small catchment area relative to the size of the lake, and is relatively shallow (i.e., the mean depth is less than 3 m). The water and load balance model predicts increases greater than predicted baseline for the following indicators (Appendix V5-4D):

- antimony;
- arsenic;
- beryllium;
- cobalt;
- copper;
- mercury;
- thallium;
- uranium;
- vanadium; and
- sulphate.

Table 4.5-6. Predicted Water Quality Concentrations in the immediate Aimaokatalok Lake receiving environment related to the Boston Combined WTP-STP Discharge.

Parameter	Predicted Effluent Concentions (75th; mg/L)			Predicted Baseline Concentrations (75th; mg/L)			Receiving Environment Concentrations (mg/L)				Assessment Threshold (mg/L)
	Under Ice	Freshet	Open Water	Under Ice	Freshet	Open Water	Under-Ice (low current scenario; 40.4:1 Dilution)	Under-Ice (high current scenario; 331:1 Dilution)	Under-Ice (freshet scenario; 171:1 Dilution)	Open-water (1,085:1 Dilution)	
Fluoride	0.125	0.272	0.162	0.0285	0.0287	0.0295	0.0308	0.0288	0.0301	0.0296	0.12
Chloride	651	335	598	9.23	9.05	9.16	24.7	11.2	10.9	9.71	120
Ammonia	10.0	6.38	9.54	0.0242	0.0240	0.0225	0.2652	0.0542	0.0609	0.0313	2.22
Nitrate	1.0	6.15	2.80	0.0180	0.0168	0.0179	0.0418	0.0210	0.0525	0.0205	3
Sulphate	230	293	247	3.49	3.38	3.45	8.97	4.17	5.07	3.67	128
Aluminum	0.224	0.244	0.223	0.0498	0.0482	0.0481	0.0540	0.0503	0.0493	0.0482	0.1
Antimony	0.0343	0.0333	0.0342	0.0000705	0.0000625	0.0000606	0.000897	0.000173	0.000256	0.0000920	0.006
Arsenic	0.0118	0.0134	0.0121	0.000186	0.000182	0.000183	0.000467	0.000221	0.000259	0.000194	0.005
Barium	0.0166	0.0915	0.0373	0.00226	0.00222	0.00227	0.00260	0.00230	0.00274	0.00230	1
Beryllium	0.0159	0.00977	0.0149	0.0000257	0.0000238	0.0000214	0.0004096	0.0000735	0.0000805	0.0000352	0.1
Boron	0.143	2.57	0.803	0.00704	0.00683	0.00700	0.01033	0.00745	0.02171	0.00773	1.5
Cadmium	0.0000812	0.0000924	0.00008291	0.00000558	0.00000627	0.00000639	0.00000741	0.00000581	0.00000677	0.00000646	0.00004
Calcium	410	465	418	3.28	3.23	3.22	13.1	4.5	5.9	3.6	1000
Chromium	0.0118	0.0130	0.0122	0.000289	0.000269	0.000272	0.000567	0.000324	0.000344	0.000283	0.001
Cobalt	0.00822	0.0154	0.00943	0.0000679	0.0000693	0.0000687	0.000265	0.0000924	0.000159	0.0000773	0.05
Copper	0.00165	0.00153	0.00162	0.000947	0.000940	0.000956	0.000963	0.000949	0.000944	0.000957	0.009
Iron	1.12	1.27	1.14	0.100	0.105	0.107	0.125	0.103	0.111	0.108	0.3
Lead	0.00164	0.00166	0.00165	0.0000381	0.0000367	0.0000372	0.0000768	0.0000429	0.0000461	0.0000387	0.001
Lithium	0.0114	0.0699	0.0274	0.00714	0.00717	0.00746	0.00724	0.00715	0.00753	0.00748	2.5
Mercury	0.000172	0.000191	0.000176	0.00000271	0.00000211	0.00000189	0.00000680	0.00000322	0.00000321	0.00000205	0.000026
Molybdenum	0.00798	0.00904	0.00814	0.0000610	0.0000598	0.0000590	0.000252	0.0000848	0.000112	0.0000664	0.073
Nickel	0.00754	0.00849	0.00769	0.000427	0.000425	0.000429	0.000598	0.000448	0.000472	0.000436	0.025
Selenium	0.00164	0.00183	0.00166	0.000204	0.000201	0.000202	0.000239	0.000209	0.000210	0.000204	0.001
Silver	0.000748	0.000477	0.000704	0.00000298	0.00000312	0.00000298	0.00002097	0.00000522	0.00000587	0.00000363	0.00025
Sodium	195	94.5	179	5.00	4.96	4.99	9.60	5.57	5.48	5.16	200
Thallium	0.000342	0.000451	0.000371	0.00000531	0.00000508	0.00000509	0.00001344	0.00000632	0.00000768	0.00000542	0.0008
Uranium	0.00163	0.00139	0.00159	0.0000238	0.0000233	0.0000234	0.0000627	0.0000287	0.0000312	0.0000248	0.015
Vanadium	0.0201	0.0190	0.0200	0.000199	0.000203	0.000198	0.000680	0.000259	0.000312	0.000216	0.1
Zinc	0.0168	0.0188	0.0171	0.00195	0.00206	0.00216	0.00231	0.00199	0.00216	0.00217	0.03

Note: Outfall dilution factors were obtained from Appendix V5-4B. 75th represents the 75th percentile of observations. Total cyanide and nitrite were not included because of their rapid transformations to other nitrogen constituents in oxygenated waters.

Table 4.5-7. Summary of Effects Screening Results for the Aimaokatalok Watershed

Lake	Parameter	Step 1: Greater than 10% of the Predicted Baseline[1]	Step 2: Greater than the Applicable Threshold[2]	Greater than all Three Screening Criteria[3]
Stickleback	Antimony	O, CL, PC	-	-
	Arsenic	C, O, CL, PC	-	-
	Barium	C, O, CL, PC	-	-
	Beryllium	O, CL, PC	-	-
	Boron	C, O, CL, PC	-	-
	Calcium	C, O, CL, PC	-	-
	Cobalt	C, O, CL, PC	-	-
	Copper	O, CL, PC	-	-
	Lead	C, O	-	-
	Manganese	C, O, CL, PC	-	-
	Mercury	C, O, CL, PC	-	-
	Molybdenum	C, CL, PC	-	-
	Nickel	PC	-	-
	Selenium	C, O, CL	-	-
	Sodium	C		
	Sliver	PC	-	-
	Thallium	PC	-	-
	Uranium	O, CL, PC	-	-
	Vanadium	PC	-	-
	Zinc	C	-	-
	Ammonia	C, O, CL,PC	-	-
	Chloride	C, O, CL, PC	-	-
	Fluoride	C, O, CL, PC	C, O, CL, PC	-
	Sulphate	PC	-	-
Eastern Arm of Aimaokatalok Lake	Aluminum	C	-	-
	Antimony	C, PC	-	-
	Arsenic	C, PC	-	-
	Barium	C	-	-
	Beryllium	C, O, CL, PC	-	-
	Boron	C, O, CL, PC	-	-
	Calcium	C, O, CL, PC	-	-
	Cadmium	C, PC	-	-
	Cobalt	PC	-	-
	Copper	C, O, CL, PC	-	-
	Iron	C	-	-
	Lead	C	-	-
	Manganese	C	-	-
	Mercury	C	-	-
	Molybdenum	C, O, CL, PC	-	-

Lake	Parameter	Step 1: Greater than 10% of the Predicted Baseline[1]	Step 2: Greater than the Applicable Threshold[2]	Greater than all Three Screening Criteria[3]
	Nickel	PC	-	-
	Selenium	C	-	-
	Sodium	C	-	-
	Silver	PC	-	-
	Thallium	C	-	-
	Uranium	PC	-	-
	Vanadium	CL, PC	-	-
	Zinc	C	-	-
	Ammonia	C	-	-
	Nitrate	C	-	-
	Fluoride	C	-	-
	Sulphate	C, PC	-	-
Aimaokatalok Lake	Antimony	C, O, CL, PC	-	-
	Beryllium	C, O, CL, PC	-	-
	Boron	C, O, CL, PC	-	-
	Calcium	O	-	-
	Cobalt	C, O, CL	-	-
	Mercury	C	-	-
	Molybdenum	O	-	-
	Silver	O	-	-
	Ammonia	C, O, CL, PC	-	-
	Nitrate	C, O	-	-
	Nitrite	C, O, CL, PC	-	-

C = Construction; O = Operation; CL = Closure; PC = Post-closure.
1: Predicted concentration is more than 10% greater than the predicted baseline during one or more of the Project phases (see Appendix V5-4D).
2: Predicted concentration is more than 10% greater than the predicted baseline and greater than applicable threshold for one or more of the time-step months (see Appendix V5-4D).
3: Predicted concentration is more than 10% greater than the predicted baseline and greater than applicable threshold for one or more of the time-step months, and is higher than the 95th percentile of observed baseline concentrations (see Appendix V5-4D).

Table 4.5-8. Summary of Effects Screening Results for the Windy Watershed

Lake	Parameter	Step 1: Greater than 10% of the Predicted Baseline[1]	Step 2: Greater than the Applicable Threshold[2]	Greater than all Three Screening Criteria[3]
Windy Lake	Antimony	PC	-	-
	Arsenic	PC	-	-
	Beryllium	PC	-	-
	Cadmium	PC	-	-
	Cobalt	PC	-	-
	Copper	PC	-	-
	Lead	PC	-	-

Lake	Parameter	Step 1: Greater than 10% of the Predicted Baseline[1]	Step 2: Greater than the Applicable Threshold[2]	Greater than all Three Screening Criteria[3]
	Manganese	PC	-	-
	Mercury	O, CL, PC	-	-
	Nickel	PC	-	-
	Thallium	PC	-	-
	Sulphate	PC	-	-

C = Construction; O = Operation; CL = Closure; PC = Post-closure.
1: Predicted concentration is more than 10% greater than the predicted baseline during one or more of the Project phases (see Appendix V5-4D).
2: Predicted concentration is more than 10% greater than the predicted baseline and greater than applicable threshold for one or more of the time-step months (see Appendix V5-4D).
3: Predicted concentration is more than 10% greater than the predicted baseline and greater than applicable threshold for one or more of the time-step months, and is higher than the 95th percentile of observed baseline concentrations (see Appendix V5-4D).

For these indicators, all predicted concentrations are less than applicable assessment thresholds. The largest increase relative to baseline concentrations is predicted for mercury in Post-closure (approximately four times higher than the predicted baseline; Appendix V5-4D); however, predicted concentrations are well below the CCME guideline of 0.000026 mg/L, and within the observed baseline 95th percentile (Appendix V5-4D).

Patch, P.O., and Ogama lakes are adjacent to and downstream of permitted and proposed Madrid-Boston activities at both the Madrid North and Madrid South sites. Potential Project effects on water quality are primarily upstream effects from runoff and groundwater seepage due to decommissioned underground mines. The potential for effects to water quality in Patch, P.O., and Ogama lakes during Post-closure is mainly due to decommissioning of water management infrastructure, such as CWPs at Madrid North and Madrid South, and the cessation of mine contact water management during Closure. In Patch Lake, the concentrations of antimony, arsenic, beryllium, cobalt, and mercury are predicted to be greater than baseline conditions in the Post-closure phase (Appendix V5-4D). In P.O. Lake, the concentrations of antimony, arsenic, beryllium, cobalt, and mercury are predicted to be greater than baseline conditions in the Post-closure phase (Appendix V5-4D). Mercury concentrations in both Patch and P.O. lakes are also predicted to be greater than baseline conditions during the Operation, Closure and Post-closure phases (Appendix V5-4D). However, predicted concentrations are within two times the baseline and less than the observed 95th percentile. Further downstream in Ogama Lake, arsenic and mercury concentrations are predicted to be greater than baseline conditions during Operation and Closure (mercury only) and Post-closure phases (Appendix V5-4D). All predicted increases in the concentrations of water quality indicators in Patch, P.O., and Ogama lakes are lower than applicable thresholds.

Water quality predictions were also made for Doris Creek and Little Roberts Lake downstream of Doris Lake. The Doris Creek node in the water balance model corresponds to the northern outflow from Doris Lake. As stated in the Water and Load Balance report, the model results are overly conservative as it assumes that the Tail Lake catchment bypasses Doris Lake entirely and flows directly to Doris Creek; however, in reality, the Tail Lake catchment flow will be diluted by Doris Lake before reaching Doris Creek (Package P5-4). The water balance model predicts increases relative to predicted baseline conditions for the majority of constituents in Doris Creek:

- aluminum;
- antimony;
- arsenic;
- barium;
- beryllium;
- boron;
- calcium;
- cadmium;
- chromium;
- cobalt;
- copper;
- iron;
- lead;
- lithium;
- manganese;
- mercury;
- molybdenum;
- nickel;
- selenium;
- sodium;
- silver;
- thallium;
- uranium;
- vanadium;
- zinc;
- TSS;
- fluoride;
- chloride;
- cyanide;
- ammonia;
- nitrate;
- nitrite;
- sulphate; and
- total phosphorus.

Of the parameter concentrations that are predicted to increase relative to baseline conditions, only aluminium concentrations are predicted to be greater than a threshold value (within 10% of the threshold), and this occurs once (June 2029) during the freshet period of the Operation phase (Table 4.5-9). The June 2029 aluminum concentration (0.104 mg/L; Appendix V5-4D) in Doris Creek is barely over guideline (0.1 mg/L) and is far below observed baseline concentrations in the creek (0.37 mg/L).

Overall, the predicted concentrations in Doris Creek are highest in the Post-closure phase when the Tail Lake catchment flow to Doris Creek is restored. The predicted increases for all constituents in Doris Creek are likely related to the conservative modeling approach of not incorporating the diluting effect of Doris Lake into the model. It is likely that some of the TIA catchment flow during Post-closure will mix with Doris Lake, resulting in lower than predicted concentrations in Doris Creek. However, given that the concentrations of several parameters are predicted to be greater than baseline concentrations, there are residual effects predicted for Doris Creek. These are characterized in Section 4.5.5.

Downstream of the outflow from Doris Lake is Little Roberts Lake. The water balance model predicts increases relative to baseline in Little Roberts Lake for the following indicators:

- aluminum;
- antimony;
- arsenic;
- barium;
- beryllium;
- boron;
- calcium;
- cadmium;
- chromium;
- cobalt;
- copper;
- iron;
- lead;
- lithium;
- manganese;
- mercury;
- molybdenum;
- nickel;
- selenium;
- sodium;
- silver;
- thallium;
- uranium;
- vanadium;
- zinc;
- TSS;
- fluoride;

- chloride;
- cyanide;
- ammonia;
- nitrate;
- nitrite;
- sulphate; and
- total phosphorus.

Table 4.5-9. Summary of Effects Screening Results for the Doris Watershed

Lake	Parameter	Step 1: Greater than 10% of the Predicted Baseline[1]	Step 2: Greater than the Applicable Threshold[2]	Greater than all Three Screening Criteria[3]
Wolverine Lake	Antimony	PC	-	-
	Arsenic	PC	-	-
	Beryllium	PC	-	-
	Cobalt	PC	-	-
	Copper	PC	-	-
	Mercury	O, CL, PC	-	-
	Thallium	PC	-	-
	Uranium	PC	-	-
	Vanadium	PC	-	-
	Sulphate	PC	-	-
Patch Lake	Antimony	PC	-	-
	Arsenic	PC	-	-
	Beryllium	PC	-	-
	Cobalt	PC	-	-
	Mercury	O, CL, PC	-	-
P.O. Lake	Arsenic	PC	-	-
	Beryllium	PC	-	-
	Cobalt	PC	-	-
	Mercury	O, CL, PC	-	-
Ogama Lake	Arsenic	PC	-	-
	Mercury	O, CL, PC	-	-
Doris Creek	Aluminum	C, O, CL, PC	-	-
	Antimony	C, O, CL, PC	-	-
	Arsenic	C, O, CL, PC	-	-
	Barium	C, O, CL, PC	-	-
	Beryllium	C, O, CL, PC	-	-
	Boron	C, O, CL, PC	-	-
	Calcium	C, O, CL, PC	-	-
	Cadmium	C, O, CL, PC	-	-
	Chromium	C, O, CL, PC	-	-
	Cobalt	C, O, CL, PC	-	-
	Copper	C, O, CL, PC	-	-
	Iron	C, O, CL, PC	-	-
	Lead	C, O, CL, PC	-	-
	Lithium	C, O, CL, PC	-	-

Lake	Parameter	Step 1: Greater than 10% of the Predicted Baseline[1]	Step 2: Greater than the Applicable Threshold[2]	Greater than all Three Screening Criteria[3]
	Manganese	C, O, CL, PC	-	-
	Mercury	C, O, CL, PC	-	-
	Molybdenum	C, O, CL, PC	-	-
	Nickel	C, O, CL, PC	-	-
	Selenium	C, O, CL, PC	-	-
	Sodium	C, O, CL, PC	-	-
	Silver	C, O, CL, PC	-	-
	Thallium	C, O, CL, PC	-	-
	Uranium	C, O, CL, PC	-	-
	Vanadium	C, O, CL, PC	-	-
	Zinc	C, O, CL, PC	-	-
	Total Suspended Solids	C, O, CL, PC	-	-
	Fluoride	C, O, CL, PC	-	-
	Chloride	C, O, CL, PC	-	-
	Free Cyanide	C, O, CL, PC	-	-
	Total Cyanide	C, O, CL, PC	-	-
	Ammonia	C, O, CL, PC	-	-
	Nitrate	C, O, CL, PC	-	-
	Nitrite	C, O, CL, PC	-	-
	Sulphate	C, O, CL, PC	-	-
	Total Phosphorus	C, O, CL, PC	-	-
Little Roberts Lake	Aluminum	O	-	-
	Antimony	O, PC	-	-
	Arsenic	O, PC	-	-
	Barium	O	-	-
	Beryllium	C, O, Cl, PC	-	-
	Boron	O	-	-
	Calcium	O, PC	-	-
	Cadmium	O, PC	-	-
	Chromium	O	-	-
	Cobalt	O, PC	-	-
	Copper	O, PC	-	-
	Iron	O	-	-
	Lead	O	-	-
	Lithium	O	-	-
	Manganese	O, PC	-	-
	Mercury	C, O, Cl, PC	-	-
	Molybdenum	O, PC	-	-
	Nickel	O, PC	-	-
	Selenium	O, PC	-	-
	Sodium	O	-	-

Lake	Parameter	Step 1: Greater than 10% of the Predicted Baseline[1]	Step 2: Greater than the Applicable Threshold[2]	Greater than all Three Screening Criteria[3]
	Silver	O	-	-
	Thallium	O, PC	-	-
	Uranium	O, PC	-	-
	Vanadium	O, PC	-	-
	Zinc	O	-	-
	Total Suspended Solids	O	-	-
	Fluoride	O	-	-
	Chloride	O	-	-
	Free Cyanide	O	-	
	Total Cyanide	O	-	
	Ammonia	C, O	-	
	Nitrate	O	-	
	Nitrite	O	-	
	Sulphate	O, PC	-	
	Total Phosphorus	O	-	

C = Construction; O = Operation; CL = Closure; PC = Post-closure.
1: Predicted concentration is more than 10% greater than the predicted baseline during one or more of the Project phases (see Appendix V5-4D).
2: Predicted concentration is more than 10% greater than the predicted baseline and greater than applicable threshold for one or more of the time-step months (see Appendix V5-4D).
3: Predicted concentration is more than 10% greater than the predicted baseline and greater than applicable threshold for one or more of the time-step months, and is higher than the 95th percentile of observed baseline concentrations (see Appendix V5-4D).

The predicted increases in concentrations in Little Roberts Lake are the result of flow from Doris Creek and cryo-concentration within Little Roberts Lake during the ice-covered season. However, no concentrations are predicted to be greater than assessment thresholds (Appendix V5-4D).

A summary of constituents with concentrations predicted to increase by more than 10% relative to modeled baseline concentrations in the Doris Watershed for one or more of the Construction, Operation, Closure and Post-closure phases is provided in Table 4.5-9. Because concentrations of some water quality parameters are predicted to be greater than baseline concentrations, there is the potential for residual effects in the Doris Watershed due to site and mine contact water. This will be characterized in Section 4.5.5.

The water balance model also includes total suspended solids as a parameter. However, the model is not optimized to predict the transport of suspended material in runoff and relies on simple assumptions for the total suspended solid content of discharges. Site and mine contact water, including the discharge from the Boston site, has the potential to transport suspended material in the receiving environment, which may create localized increases in the concentrations of suspended sediments and sediment-associated metals. These residual effects are anticipated to have the greatest potential to occur during periods of significant overland flow, such as freshet and rainfall events. Although sediment from runoff has the potential to increase TSS and turbidity in the receiving environment, the known effectiveness of the mitigation and management measures are predicted to mitigate the potential effects and the changes in suspended sediment concentrations are not expected to be greater than CCME guidelines for the protection of aquatic life.

Characterization of Hope Bay Development Potential Effects

Potential effects from the Hope Bay Development as a whole are included in the site-wide water and load balance model. Mining operations at Doris will continue until 2021 under the current mine plan. These potential effects include components of the site and mine water contact interaction groups, including the following effects during the Operation, Closure, and Post-closure phases:

- runoff from pads and infrastructure at the Doris site;
- tailings from the Doris mine deposited in the TIA; and
- mine water from the Doris mine.

Therefore, the potential residual effects from the Doris development have already been assessed within the Madrid-Boston assessment for the Operation, Closure, and Post-closure phases. Site contact water during the construction of Doris infrastructure may have had the potential for residual effects to freshwater water quality. These potential residual effects would have included the runoff of metals, acid-equivalents, and hydrocarbons from disturbed areas of the landscape, pads areas, and laydown areas. However, the current Hope Bay water monitoring program, which includes surveillance monitoring of contact water and AEMP monitoring in the receiving environment, has not identified any Project-related effects in Doris Lake or downstream in Doris Creek and Little Roberts Lake. As a result, no incremental residual effects from the Hope Bay Development from site and mine contact water are identified, beyond the effects already described in the water balance model.

4.5.4.3 Quarries and Borrow Pits

Characterization of Madrid-Boston Project Potential Effects

Runoff is the primary pathway for interaction between quarries and the freshwater environment. As a result, minimizing the transport of material in runoff and reducing the quantity of runoff is the primary goal of mitigation and management measures (Section 4.5.3). The potential effects from quarries and borrow pits will be minimized by the following specific measures:

- only geochemically suitable material will be used for quarries and borrow pits;
- equipment will be maintained and repaired to avoid potential leaks of fuels and petroleum hydrocarbons;
- local drainage patterns will be maintained and the flow of water into the quarry minimized by the diversion of non-contact water around quarries; and
- quarry runoff water collected in quarry sumps will be monitored, and water that does meet discharge criteria will be transported to CWPs (Hope Bay Quarry Management and Monitoring Plan, Package P4-17).

If the runoff is turbid but chemically-unaltered, it will be allowed to infiltrate into the ground if it meets permit discharge criteria. By minimizing the volume of water within quarries and collecting water within the quarries, suspended sediments and sediment-associated metals can be settled in the sump and will not contact the freshwater environment. Due to the mitigation and management measures, including monitoring and adaptive management of quarry runoff, no residual effects from quarries and borrow pits are predicted for freshwater water quality for the Madrid-Boston development.

Characterization of Hope Bay Development Potential Effects

Existing quarries and borrow pits for the Doris site have been operating with no detected effects to water quality in the freshwater environment. The mitigation and management measures applied to quarries and borrow pits have been shown to be effective. Therefore, no residual effects from the overall Hope Bay Development are predicted.

4.5.4.4 Explosives

Characterization of Madrid-Boston Project Potential Effects

Potential residual effects from explosives may occur from the transport, storage, and use of ANFO explosives for mining and construction. The potential effects from transport and storage are considered fully mitigated by the following measures:

- storage and transport in accordance with the *Explosives Act* (1985b);
- the handling and manufacture of explosives by licensed operators;
- interception and collection of runoff from explosive storage and manufacture facilities prior to contact with the freshwater environment; and
- the application of best management practices for blasting and the handling of explosives to minimize residues and spillage.

Blasting residues on mine workings, waste rock, tailings, and run-of-quarry material could affect water quality through runoff and seepage. The Water and Load Balance model includes blasting residues, and provides quantitative predictions of nitrogenous residues (ammonia, nitrite, and nitrate) in the freshwater environment (Package P5-4). The model predicted that the concentrations of nitrogenous compounds may increase relative to baseline conditions in Stickleback and Aimaokatalok lakes and in Doris Creek and Little Roberts Lake (see Section 4.5.4.2). However, the predicted concentrations are always below both threshold concentrations (i.e., CCME water quality guidelines) and the 95th percentile of observed baseline concentrations, suggesting that the elevated concentrations are within the range of natural variability. The predicted increases are, at least partially, attributable to blasting residues in site and mine contact water.

The effects from blasting residues on water quality through the aerial deposition pathway is predicted to be negligible (see Section 4.5.4.6). The majority of explosives use will occur underground. Surface blasting for quarrying and construction will be designed to minimize the generation of dust.

The potential residual effects from the use of explosives from the Madrid-Boston Project are further characterized in Section 4.5.5

Characterization of Hope Bay Development Potential Effects

Construction and mining activities throughout the Hope Bay Development require the use of explosives. Mitigation and management measures have been effective for the existing Doris development, and no explosives-related changes in the concentration of nitrogen compounds have been observed in the current Doris AEMP (e.g., ERM 2017b). To be conservative, however, the potential for localized increased in nitrogen compounds from the development of the Madrid North infrastructure and on-going activities at the Doris site is considered to exist and may result in localized, small changes in nitrogen compound concentrations. These potential changes in nitrogen compound concentrations resulting from the use of explosives in the overall Hope Bay Development are predicted to be relatively small, based on the observed performance of the mitigation and management measures and the small magnitude of predicted effects in the water balance model.

The potential residual effects from the use of explosives in the Hope Bay Development are further characterized in Section 4.5.5

4.5.4.5 Fuels, Oils, and PAH

The fuels, oils, and PAH Project interaction group will interact with the freshwater environment through runoff and aerial deposition (for PAH, see Section 4.5.4.6). The potential effects to freshwater water quality from the use of fuels, including refueling and maintenance, are considered fully mitigated by the application of best management practices and the mitigation and management measures related to the use and potential spills of fuels and petroleum products, which are detailed in the Hope Bay Project Spill Contingency Plan (Package P4-3). These measures include secondary containment for fuel storage, the use of oil-water separators at maintenance facilities, and established spill response plans. The majority of runoff from site pads, laydown areas, and waste management areas will be directed to the water management infrastructure and not discharged to the freshwater environment. This intercepted water will be diverted to the TIA or the Boston Contact WTP. Otherwise, runoff will be collected in sumps and discharged only if it meets water quality standards under applicable water licences.

For the aerial deposition of PAH, the primary mitigation measure will be the efficient operation of the incinerator. The operation of the incinerator will comply with Nunavut guidelines (Government of Nunavut Department of Environment 2012), *Canada-Wide Standards for Dioxins and Furans* (CCME 2001a) and *Canada-Wide Standards for Mercury Emissions* (CCME 2000), as well as TMAC's own Incinerator Management Plan (Package P4-16). The operation of the incinerator includes the following management measures:

- waste segregation (i.e., materials that are unsuitable for incineration, e.g., chlorinated plastics, will be diverted to alternate waste disposal facilities);
- properly trained personnel for incinerator operations; and
- periodic stack testing and adaptive management to ensure compliance with standards.

Project activities related to fuels and other petroleum hydrocarbons are anticipated to have negligible effects on freshwater water quality. The mitigation and management measures are considered to be effective at minimizing the potential for effects on the freshwater environment during normal operations. No hydrocarbon compounds or sediments from Project activities at the sites, laydown areas, fuel areas, or waste storage areas are expected to reach the freshwater environment because of the adherence to best management practices for machinery operation, maintenance, and fueling, and the direction of runoff carrying potential compounds to the water management facilities. The incinerator will be operated according to guidelines and standards, which should result in negligible aerial deposition of PAH into the freshwater environment. Therefore, no residual effects from fuels, oils, and PAHs are anticipated on freshwater water quality. This prediction is applicable to both the incremental effects of the Madrid-Boston Project as well as the overall Hope Bay Development.

4.5.4.6 Dust Deposition

The Air Quality Management Plan (Annex V8-2) describes the specific mitigation measures that will be followed to ensure that the generation and transport of airborne particulates is minimized. Despite these mitigation measures, the results of air quality modeling work (Volume 4, Chapter 2) predicted that Madrid-Boston Project activities will generate dust that could potentially be deposited into the freshwater environment.

Characterization of Madrid-Boston Project Potential Effects

Quantitative air quality modeling predicted dust deposition rates across the Project area (Volume 4, Chapter 2). Potential dust sources such as construction activities, operation of the TIA, and vehicle traffic were incorporated into the model. The results of the quantitative dust deposition modeling are used to estimate average dust deposition rates in Project area lakes. The predicted average annual dust deposition rates for lakes in the LSA are presented in Table 4.5-10, and are based on interpolated deposition rates from the gridded air quality modeling field.

Table 4.5-10. Summary of Predicted Dust Deposition Rates in Project Area Lakes

Lake	Mean Depth (m)	Construction Mean Annual Deposition Rate (g/m^2/year)	Operation Mean Annual Deposition Rate (g/m^2/year)	Construction Daily Load (mg/L/d)	Operation Daily Load (mg/L/d)
North Belt LSA					
Doris	7.3	1.9	2.1	0.00070	0.00078
Imniagut	2.7	5.2	5.8	0.0053	0.0059
Little Roberts	2.3	0.98	0.97	0.0012	0.0012
Ogama	2.6	1.8	1.9	0.0019	0.0021
Patch	4.1	2.9	3.2	0.0019	0.0022
P.O.	2.1	1.4	1.5	0.0018	0.0019
Windy	9.9	2.8	3.0	0.00077	0.00083
Wolverine	2.3	2.5	2.3	0.0029	0.0027
South Belt LSA					
Aimaokatalok	6.4	1.4	1.5	0.00060	0.00063
Trout	2.3	1.9	2.1	0.0022	0.0025
Stickleback	2.5	5.2	6.0	0.0056	0.0066

Note: Daily loads calculated by integrating the annual load throughout the water column of the lake. Mean water depths are described in the Limnology and Bathymetry chapter (Volume 5, Chapter 3).
Annual and daily loads include background levels.

The predicted average daily load of dust deposited into each lake ranges from 0.0006 to 0.0066 mg/L/d for the South Belt LSA lakes, and from 0.0007 to 0.0059 mg/L/d for the North Belt LSA lakes (Table 4.5-10). For each lake, the predicted daily loads are similar between the Construction and Operation phases (Table 4.5-10). The predicted daily loads are approximately 170 to 5,000 times lower than the average TSS concentrations in the LSA lakes (mean TSS concentration of 3.5 mg/L in the North Belt LSA and 1.1 mg/L in the South Belt LSA; Table 4.2-5). Dust particles deposited into the freshwater environment will sink and aggregate, and therefore have a limited residence time in the water column. Even if dust particles reside in the water column for days to a week, the relative increase in total suspended sediment concentrations, and particle-associated metals, is negligible compared to observed water quality conditions. Therefore, the potential effects from dust deposition are not considered further.

Characterization of Hope Bay Development Potential Effects

The air quality model includes the contributions of the activities at the Doris site during the period of overlap between the existing and approved projects and the Madrid-Boston Project. No effects from dust deposition effects from the Doris Project have been observed in the Doris AEMP monitoring program (e.g., ERM 2017a). On the basis of the results of the quantitative air quality modeling and the absence of any evidence of dust-related effects, the potential effects from dust deposition for the Hope Bay Development on freshwater water quality is concluded to be negligible, and are not considered further.

4.5.5 Characterization of Residual Effects

4.5.5.1 Definitions for Characterization of Residual Effects

To determine the significance of a Project residual effect, each potential negative residual effect is characterized by a number of attributes consistent with those defined in the EIS guidelines (Section 7.14, Significance Determination for the Hope Bay Project; NIRB 2012a). A definition for each attribute and the contribution that it has on significance determination is provided in Table 4.5-11.

Table 4.5-11. Attributes to Evaluate Significance of Potential Residual Effects

Attribute	Definition and Rationale	Impact on Significance Determination
Direction (positive, neutral, or negative)	The ultimate long-term trend of a potential residual effect - positive, neutral, or negative.	Positive, neutral, and negative potential effects on VECs are assessed, but only negative residual effects are characterized and assessed for significance.
Magnitude (negligible, low, moderate, or high)	The degree of change in a measurable parameter or variable relative to existing conditions. This attribute may also consider complexity - the number of interactions (Project phases and activities) contributing to a specific effect.	The higher the magnitude, the higher the potential significance.
Duration (short, medium, long)	The length of time over which the residual effect occurs.	The longer the length of time of an interaction, the higher the potential significance.
Frequency (once, infrequent, frequent, continuous)	The number of times during the Project or a Project phase that an interaction or environmental effect can be expected to occur.	Greater the number times of occurrence (higher the frequency), the higher the potential significance.
Geographical Extent (PDA, LSA, RSA, beyond regional)	The geographical area over which the interaction will occur.	The larger the geographical area, the higher the potential significance.
Reversibility (reversible, reversible with effort, irreversible)	The likelihood an effect will be reversed once the Project activity or component is ceased or has been removed. This includes active management for recovery or restoration.	The lower the likelihood a residual effect will be reversed, the higher the potential significance.

For the determination of significance, each attribute is characterized. The characterizations and criteria for the characterizations are provided in Table 4.5-12. Each of the criteria contributes to the determination of significance.

Table 4.5-12. Criteria for Residual Effects for Environmental Attributes

Attribute	Characterization	Criteria
Direction	Positive	Beneficial
	Variable	Beneficial or undesirable
	Negative	Undesirable
Magnitude	Negligible	No change on the indicator or overall freshwater water quality
	Low	Differing from the modeled or observed baseline values to a small degree (more than 10%), but within the range of natural variation (defined as 95th quantile of observed baseline) and below a guideline or threshold value
	Moderate	Differing from the modeled or observed baseline values (more than 10%) and within the range of natural variation (defined as 95th quantile of observed baseline) but greater than or equal to a guideline or threshold value
	High	Differing from the modeled or observed baseline values (more than 10%), outside the range of natural variation (defined as 95th quantile of observed baseline), and exceeding guideline or threshold values
Duration	Short	Up to 4 years (Construction phase)
	Medium	Greater than 4 years and up to 17 years (combined Construction, Operation, and Reclamation and Closure phases)
	Long	Beyond the life of the Project
Frequency	Once	Occurring only once
	Infrequent	Occurring more than once but less than 50% of the time over the life of the Project
	Frequent	Occurring more than 50% but less than 100% of the time over the life of the Project
	Continuous	Continuously occurring over the life of the Project
Geographical Extent	Project Development Area (PDA)	Confined to the PDA
	Local Study Area (LSA)	Beyond the PDA and within the LSA
	Regional Study Area (RSA)	Beyond the LSA and within the RSA
	Beyond Regional	Beyond the RSA
Reversibility	Reversible	Effect reverses within an acceptable time frame with no intervention
	Reversible with effort	Active intervention (effort) is required to bring the effect to an acceptable level
	Irreversible	Effect will not be reversed

4.5.5.2 Determining the Significance of Residual Effects

Section 7.4 of the EIS guidelines provided guidance, attributes, and criteria for the determination of significance for residual effects (NIRB 2012a). The Canadian Environmental Assessment Agency's *Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects* (CEAA 1992) also guided the evaluation of significance for identified residual effects. The significance of residual effects is based on comparing the predicted state of the environment with and without the Project, including a judgment as to the importance of the changes identified.

Probability of Occurrence or Certainty

Prior to the determination of the significance for negative residual effects, the probability of the occurrence or certainty of the effect is evaluated. For each negative residual effect, the probability of occurrence is categorized as *unlikely*, *moderate*, or *likely*. Table 4.5-13 presents the definitions applied to these categories.

Table 4.5-13. Definition of Probability of Occurrence and Confidence for Assessment of Residual Effects

Attribute	Characterization	Criteria
Probability of occurrence or certainty	Unlikely	Some potential exists for the effect to occur; however, current conditions and knowledge of environmental trends indicate the effect is unlikely to occur.
	Moderate	Current conditions and environmental trends indicate there is a moderate probability for the effect to occur.
	Likely	Current conditions and environmental trends indicate the effect is likely to occur.
Confidence	High	Baseline data are comprehensive; predictions are based on quantitative predictive model; effect relationship is well understood.
	Medium	Baseline data are comprehensive; predictions are based on qualitative logic models; effect relationship is generally understood, however, there are assumptions based on other similar systems to fill knowledge gaps.
	Low	Baseline data are limited; predictions are based on qualitative data; effect relationship is poorly understood.

Determination of Significance

Significance of a residual effect depends on the magnitude of the effect and conditions under which the residual effect interacts with the freshwater environment. The magnitude of a **significant** residual effect must be *high*, because *moderate* or *low* magnitude residual effects are necessarily less than environmental quality criteria (e.g., CCME guidelines for the protection of aquatic life) or within the range of natural variation. Furthermore, a **significant** residual effect will also have a greater spatial and temporal extent, such as a *regional*-scale effect and *long*-term duration. **Significant** residual effects will also be *irreversible* or *reversible-with-effort* because the reversibility of the residual effect describes, in part, the resilience of the ecosystem component to change.

Confidence

The knowledge or analysis that supports the prediction of a potential residual effect—in particular with respect to limitations in overall understanding of the environment and/or the ability to foresee future events or conditions—determines the confidence in the determination of significance. In general, the lower the confidence, the more conservative the approach to prediction of significance must be. The level of confidence in the prediction of a significant or non-significant potential residual effect is based on the quality of the data and analysis and their extrapolation to the predicted residual effects. *Low* is assigned where there is a low degree of confidence in the inputs, *medium* when there is moderate confidence and *high* when there is a high degree of confidence in the inputs. Where rigorous baseline data were collected and scientific analysis performed, the degree of confidence will generally be *high*. Predictive water quality modeling is employed using industry standard modeling software to support the assessment process, including the investigation of multiple sensitivities. The goals are to remove as much subjectivity from the assessment process as possible, and to increase certainty in the predictions of changes to freshwater water quality indicators, residual effects, and significance determination to produce a robust, transparent, and defensible approach to the assessment of freshwater water quality effects. Therefore, there is *high* confidence in the results of this residual effects assessment for predicted water quality effects on the freshwater environment in the Madrid-Boston area. Water quality monitoring will be ongoing in Construction, Operation, and Reclamation and Closure phases and will serve to validate water quality predictions. Table 4.5-13 provides descriptions of the confidence criteria.

4.5.5.3 Characterization of Residual Effect for Freshwater Water Quality VEC

The potential residual effects carried forward from Section 4.5.4 are assessed in this section, according to the attributes and criteria described in Sections 4.5.5.1 and 4.5.5.2.

Site Preparation, Construction and Decommissioning Activities

Madrid-Boston Project Potential Effect

Residual effects from construction and decommissioning activities are anticipated during the Construction phase when water management features are in the process of being constructed and commissioned. Only small amounts of runoff are expected to reach the surrounding waterbodies while the water management features are being constructed. The extensive mitigation and management measures, which incorporate design, best management practices, and adaptive management, are predicted to minimize the transport of sediments through runoff into the freshwater environment. However, the potential for changes in water quality beyond the range of baseline conditions remain. The effectiveness of mitigation and management measures are expected to limit any changes in water quality to less than applicable water quality guidelines. Therefore, the predicted magnitude of the residual effect from all construction and decommissioning activities is *low* (Table 4.5-14).

The effects are expected to be footprint (within the PDA) or *local* (restricted to the LSA), *short-term* in duration, and *infrequent* as runoff would only occur during snowmelt and large precipitation events. The freshwater environment has the capacity to recover and the effects are expected to be fully *reversible*. The probability of occurrence is estimated to be *moderate* due to the uncertainties related to precipitation, and confidence was *high* because of the quantitative input from the baseline environmental data, the predictable nature of this potential effect, and the confidence in the mitigation and management strategies (Table 4.5-14).

The residual effect on freshwater water quality of Madrid-Boston Project construction and decommissioning activities (through the disturbance of the landscape due to the construction and reclamation of Project infrastructure) is concluded to be **not significant** (Table 4.5-14).

Hope Bay Development Potential Effect

The effects from the Hope Bay Development from construction and decommissioning activities are expected to be similar to the residual effects from the Madrid-Boston development. Closure and reclamation of infrastructure at the Doris site have the potential for *local*, *short*-term changes in water quality after the application of mitigation and management measures. However, these effects are expected to be less than applicable water quality guidelines, and therefore *low* in magnitude. Similarly, the probability of occurrence is concluded to be *moderate* due to uncertainties related to precipitation and runoff, and the confidence was *high* (Table 4.5-15).

The residual effect of construction and decommissioning activities for the Hope Bay Development are concluded to be **not significant**.

Table 4.5-14. Summary of Residual Effects and Overall Significance Rating for Freshwater Water Quality - Madrid-Boston Project

	Attribute Characteristic						Overall Significance Rating		
Residual Effect	**Direction** (*positive, variable, negative*)	**Magnitude** (negligible, *low, moderate, high*)	**Duration** (*short, medium, long*)	**Frequency** (once, *infrequent, frequent, continuous*)	**Geographic Extent** (PDA, *LSA, RSA, beyond regional*)	**Reversibility** (*reversible, reversible with effort, irreversible*)	**Probability** (*unlikely, moderate, likely*)	**Significance** *(not significant, significant)*	**Confidence** (*low, medium, high*)
Construction and Decommissioning Activities	Negative	Low	Short	Infrequent	LSA	Reversible	Moderate	Not significant	High
Site and Mine Contact Water	Negative	Moderate	Medium to Long	Intermittent to Continuous	LSA	Irreversible	Likely	Not significant	High
Explosives	Negative	Low	Medium	Frequent	LSA	Reversible	Moderate	Not significant	High

Table 4.5-15. Summary of Residual Effects and Overall Significance Rating for Freshwater Water Quality - Hope Bay Development

	Attribute Characteristic						Overall Significance Rating		
Residual Effect	**Direction** (*positive, variable, negative*)	**Magnitude** (negligible, *low, moderate, high*)	**Duration** (*short, medium, long*)	**Frequency** (once, *infrequent, frequent, continuous*)	**Geographic Extent** (PDA, *LSA, RSA, beyond regional*)	**Reversibility** (*reversible, reversible with effort, irreversible*)	**Probability** (*unlikely, moderate, likely*)	**Significance** *(not significant, significant)*	**Confidence** (*low, medium, high*)
Construction and Decommissioning Activities	Negative	Low	Short	Infrequent	LSA	Reversible	Moderate	Not significant	High
Site and Mine Contact Water	Negative	Moderate	Medium to Long	Intermittent to Continuous	LSA	Irreversible	Likely	Not significant	High
Explosives	Negative	Low	Medium	Frequent	LSA	Reversible	Moderate	Not significant	High

Site and Mine Contact Water

Madrid-Boston Project Potential Effect

Residual effects from site and mine contact water are predicted based on the quantitative water balance modeling, near-field and far-field mixing modeling, and extensive baseline data. The analysis, outlined in Section 4.5.4.2, predicts increases in metal, anion, cation, and nitrogen species resulting from the discharge, runoff, and seepage of site and mine contact water. Nearly all predicted changes are within baseline levels or below guideline thresholds. However, the magnitude of the residual effect is concluded to be *moderate* since there are predicted infrequent and short-lived exceedances of fluoride in Stickleback Lake from Construction through early Post-closure, and a single exceedance of aluminum in Doris Creek during Operations. These predicted concentrations (maximum = 0.133 mg F/L, 0.104 mg Al/L) are barely above the CCME guideline (0.12 mg F/L; 0.1 mg Al/L), and are within the range of observed natural variability (0.245 mg F/L; 0.37 mg Al/L).

Because increases in water quality concentrations extend into the Post-closure phase for fluoride, it was concluded to be *long-term* in duration. However, the geographical extent of the residual effects from site and mine contact water were concluded to be restricted to the *LSA* (Table 4.5-15). The residual effects from site and contact water are concluded to be *irreversible*. The long-term effects associated with runoff from the TIA, TMA, and reclaimed Project infrastructure are predicted to continue through-out the Post-closure phase. As discussed in the Water and Load Balance Model report (Package P5-4), interactions between decommissioned Project infrastructure may continue for hundreds of years as equilibria are reached in groundwater interactions between closed mine works and nearby lakes (Table 4.5-14).

The residual effects were concluded to be *likely* with a *high* degree of confidence. The quantitative water balance model included a range of source water and mass loadings, and included algorithms for modeling *in situ* biogeochemical reactions. Furthermore, sensitivities analyses carried out on the water balance model (Package P5-4) supported the overall conclusions and predictions of the model (Table 4.5-14).

The residual effect to freshwater water quality from site and mine contact water is concluded to be **Not Significant** because the predicted effects were *moderate* in magnitude and localized to the *LSA* (Table 4.5-14).

Hope Bay Development Potential Effect

No additional incremental effects from site and mine contact water beyond the effects assessment under the Madrid-Boston development are identified (Section 4.5.4.2). The water balance model includes the majority of potential residual effects, and these effects are analyzed as part of the Madrid-Boston development.

Therefore, the residual effect to freshwater water quality from site and mine contact water for the Hope Bay Development is concluded to be **Not Significant**, following the same criteria as for the Madrid-Boston analysis (Table 4.5-15).

Explosives

Madrid-Boston Project Potential Effect

The residual effects from explosives for the Madrid-Boston development are expected to be *low* in magnitude because of the known effectiveness of mitigation and management measures, and because of the results of the Water and Load Balance model, which predicted that concentrations of nitrogen species in Aimaokatalok and Stickleback lakes and in Doris Creek and Little Roberts Lake would increase above baseline concentrations but not above threshold concentrations. The effects are predicted to be *medium*-term in duration and restricted to the LSA. The frequency of the residual effect was concluded to be *frequent* because explosives residues could interact with freshwater during runoff events and during the discharge of contact water from the TMA. The effects from explosives are concluded to be *reversible* because the primary components are readily degraded in the freshwater environment as part of the nitrogen and carbon cycles (Table 4.5-14).

Therefore, the residual effect to freshwater water quality from explosives for the Madrid-Boston development is concluded to be **not significant** (Table 4.5-14).

Hope Bay Development Potential Effect

Additional, incremental residual effects from explosives are identified for the Hope Bay Development. The magnitude of this residual effect is concluded to be *low* because the Water and Load Balance (which incorporates the effects from the entire Hope Bay Development) predicted that concentrations of nitrogen species in some waterbodies would increase above baseline concentrations but not above threshold concentrations. Like the residual effect for the Madrid-Boston development, the residual effect for the Hope Bay Development is predicted to the *local* in scale and *medium*-term in duration. Similarly, the effect was predicted to be fully *reversible* (Table 4.5-15).

The residual effect to freshwater water quality from explosives for the Hope Bay Development is concluded to be **not significant** (Table 4.5-15).

4.6 CUMULATIVE EFFECTS ASSESSMENT

The potential for cumulative effects arises when the potential residual effects of the Madrid-Boston Project add to or otherwise interact with the residual effects of other past, existing or reasonably foreseeable projects or activities. As defined by the EIS guidelines (NIRB 2012a) and the *NIRB Technical Guide Series: Terminology and Definitions* (NIRB 2013), cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

4.6.1 Methodology Overview

4.6.1.1 Approach to Cumulative Effects Assessment

The general methodology for cumulative effects assessment (CEA) is described in Volume 2, Chapter 4, and follows these steps:

1. Identify the potential for Madrid-Boston Project-related residual effects to interact with residual effects from the Doris Project, the Hope Bay Regional Exploration Project, the Madrid Advanced Exploration Program, the Boston Advanced Exploration Project and other human activities and projects within specified assessment boundaries. Key potential residual effects associated with past, existing, and reasonably foreseeable future projects were identified using publicly available information or, where data was unavailable, professional judgment was used (based on previous experience in similar geographical locations) to approximate expected environmental conditions.
2. Identify and predict potential cumulative effects that may occur and implement additional mitigation measures to minimize the potential for cumulative effects.
3. Identify cumulative residual effects after the implementation of mitigation measures.

4. Determine the significance of any cumulative residual effects. A key task in the CEA is to understand the contribution of Madrid-Boston Project to the overall cumulative effect on freshwater water quality (i.e., the amount of the cumulative effect can be apportioned to Madrid-Boston Project as compared to the Doris Project, the Hope Bay Regional Exploration Project, the Madrid Advanced Exploration Program, the Boston Advanced Exploration Project and other projects and activities).

4.6.1.2 Assessment Boundaries

The CEA considers the spatial and temporal extent of Project-related residual effects on freshwater water quality combined with the anticipated residual effects from other projects and activities to assist with analyzing the potential for a cumulative effect to occur.

Spatial Boundaries

The CEA considers past, existing, and reasonably foreseeable projects with potential residual effects that occur within the outer geographical limit of possible interaction with Madrid-Boston Project and the Hope Bay Project. The spatial boundary for the CEA for freshwater water quality was the assessment Regional Study Area (RSA; Figure 4.2-2). This study area contains the LSA and was determined to cover the extent of direct and indirect effects of the Project on the freshwater environment.

Temporal Boundaries

The temporal boundaries of the CEA were defined by the timelines for past, existing, and reasonably foreseeable projects as described in the CEA methodology (Volume 2, Chapter 4). These timelines were compared to the Project timeline (Section 4.4.3).

4.6.2 Potential Interactions of Residual Effects with Other Projects

The mining industry is the main source of industrial activity in Nunavut, which is being explored for uranium, diamonds, gold and precious metals, base metals, iron, coal, and gemstones. In addition to major mining development projects, other land use activities were also considered for potential interactions with the Project, as required under Section 7.11 of the Project EIS guidelines (see Volume 2, Chapter 4 for more detail).

The potential residual effects identified for the Madrid Boston Project and the Hope Bay Development as a whole were confined to the LSA. Given that no past, present, or foreseeable projects that could potentially interact with the residual effects of the Hope Bay Project lie within the freshwater LSA, no cumulative effects to freshwater water quality are predicted.

4.7 TRANSBOUNDARY EFFECTS

The Project EIS guidelines define transboundary effects as those effects linked directly to the activities of the Project inside the NSA, which occur across provincial, territorial, international boundaries or may occur outside of the NSA (NIRB 2012a). Transboundary effects of the Project have the potential to act cumulatively with other projects and activities outside the NSA.

The non-significant Project effects to freshwater water quality are predicted to be restricted to the LSA. The LSA lies entirely within Nunavut; therefore, there is no potential for transboundary effects.

4.8 IMPACT STATEMENT

The assessment of effects of the Project on freshwater water quality considers potential effects based on specified interaction groups. These interaction groups incorporate Madrid-Boston Project effects that are related by timing, infrastructure, and mitigation and management measures. The following interaction groups are considered as potential effects:

- site preparation, construction and decommissioning activities;
- site and mine contact water;
- quarries and borrow pits;
- explosives;
- fuels, oils, and PAH;
- treated sewage discharge; and
- dust deposition.

Potential effects are characterized using key indicators and quantitative thresholds as well as experience from the Hope Bay Development. The assessment considers mitigation and management measures already applied in the Hope Bay Development, drawn from guidance documents, and applied in other mining projects in Nunavut and the Northwest Territories.

A quantitative water balance model is used to predict the effects of the Madrid-Boston Project on freshwater water quality. Residual effects are identified based on the predictions of the water balance model and the application of mitigation and management measures. Three residual effects are identified: site preparation, construction and decommissioning activities; site and mine contact water; and explosives.

Using the thresholds identified for the key indicators, each of these residual effects is concluded to be moderate in magnitude. All residual effects to freshwater water quality are predicted to be restricted to the LSA. As a result, the residual effects are rated as **not significant**. No cumulative effects are predicted to occur because the Project freshwater water quality residual effects are not predicted to overlap spatially with any other past, existing, or reasonably foreseeable project. Similarly, no transboundary effects are identified because the Project residual effects are predicted to extend only within the LSA, which is entirely within Nunavut.

4.9 REFERENCES

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