MADRID-BOSTON PROJECT
FINAL ENVIRONMENTAL IMPACT STATEMENT

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Glossary and Abbreviations

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

AEMP	Aquatic Effects Monitoring Program
ANFO	Ammonium nitrate and fuel oil
AWR	All-weather road
CCME	Canadian Council of Ministers of Environment
CEA	Cumulative effects assessment
CEAA	Canadian Environmental Assessment Agency
DFO	Fisheries and Oceans Canada
DO	Dissolved oxygen
DWT	Deadweight tonnage
ECCC	Environment and Climate Change Canada
EEM	Environmental effects monitoring
EIS	Environmental Impact Statement
GN-DOE	Government of Nunavut, Department of Environment
GW	Groundwater
INAC	Indigenous and Northern Affairs Canada
KIA	Kitikmeot Inuit Association
kW/m	Kilowatt per metre, used as a unit of wave power
LSA	Local Study Area
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
OHF	Oil handing facilities

OPEP	Oil Pollution Emergency Plan
OPPP	Oil Pollution Prevention Plan
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PDA	Project Development Area
ppt	parts per thousand
Project	Madrid-Boston Project
QA/QC	Quality assurance and quality control
RSA	Regional Study Area
TBT	Tributyltin
TIA	Tailings impoundment area
TK	Traditional knowledge
TMA	Tailings management area
TMAC	TMAC Resources Inc.
tpd	Tonnes per day
TSS	Total suspended solids
VEC	Valued ecosystem component
WRR	Winter road route

8. Marine Water Quality

Marine water quality describes the physical, chemical, biological, and aesthetic characteristics of water in the marine environment. These characteristics are determined by regional and local factors, including physical mixing, terrestrial runoff, riverine discharge, biological activity, and anthropogenic sources. Marine water quality is a critical component of the biological and physical environment and is protected by legislation. The assessment of the potential effects from the Madrid-Boston Project (the Project) on the marine environment is critical to support an environmental effects assessment as well as to contribute to engineering analysis and the design of water management features.

This chapter examines the potential effects of the proposed Madrid-Boston Project on marine water quality. Monitoring studies of baseline 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 marine water quality could potentially affect other VECs, and effects on these VECs are assessed in the following effects assessment chapters:

- Volume 5, Chapter 9, Marine Sediment Quality;
- Volume 5, Chapter 10, Marine Fish;
- Volume 5, Chapter 11, Marine Wildlife; and
- Volume 6, Chapter 5, Human Health and Environmental Risk.

This chapter follows the effects assessment methodology described in Volume 2, Chapter 4 of the Application.

8.1 INCORPORATION OF TRADITIONAL KNOWLEDGE

8.1.1 Incorporation of Traditional Knowledge for Existing Environment and Baseline Information

The *Inuit Traditional Knowledge for TMAC Resources Inc. Proposed Hope Bay Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* report (Banci and Spicker 2016) was reviewed for information related to marine water quality. There are no direct references relevant to the existing marine water quality in the NTKP report.

8.1.2 Incorporation of Traditional Knowledge for Valued Ecosystem Component Selection

No direct references made to marine water quality are noted in the NTKP report (Banci and Spicker 2016). Inuit value the integrity of the environment, and noted the general importance of water quality, benthic invertebrates, fish communities, and fish habitat. Marine water quality describes the suitability of the marine environment for all water users, including marine life and fish. Therefore, the importance of marine water quality as a facet of environmental quality is used in the selection of marine water quality as a Valued Ecosystem Component (VEC).

8.1.3 Incorporation of Traditional Knowledge for Spatial and Temporal Boundaries

The results of the NTKP report are considered when developing the spatial and temporal boundaries for the 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 Hope Bay Development area as well as Roberts Bay and Melville Sound are included within the spatial boundaries of the assessment of marine water quality.

8.1.4 Incorporation of Traditional Knowledge for Project Effects Assessment

The results of the NTKP report were considered when developing the effects assessment for marine water quality. No specific references relevant to the effects assessment for water quality were included in the NTKP report.

8.1.5 Incorporation of Traditional Knowledge for Mitigation and Adaptive Management

The NTKP report was considered when developing mitigation and adaptive management plans for marine water quality. No information specific to mitigation and adaptive management of Project-related effects to marine water quality were noted.

8.2 EXISTING ENVIRONMENT AND BASELINE INFORMATION

The Madrid-Boston Project is a part of the Hope Bay Greenstone Belt development, which comprises several existing and approved projects. The development is approximately 153 km southwest of Cambridge Bay, Nunavut, on the southern shore of Melville Sound in the West Kitikmeot region of Nunavut (Figure 8.2-1). Infrastructure and activities associated with the Project are primarily along the southern and western shorelines of Roberts Bay (68º 12' N, 106º 38' W; Figure 8.2-2), a small inlet that empties into Melville Sound and is bordered by Hope Bay (west) and Ida Bay (east; Figure 8.2-1).

Locally, Roberts Bay is a broad estuary with a maximum north-south length of 5 km, an east-west width of 4 km giving a total surface area of 14.3 km^2 (Figure 8.2-2). The total volume of the bay is approximately $5.1×10^8$ m^3 with a mean depth of 36 m and maximum depth of 88 m at its mouth. The southernmost section of the bay is shallow (less than 20 m), and deepens to between 40 m and 88 m towards Melville Sound. Regionally, Ida Bay is a true fjord that is long (10 km), narrow (1 km at entrance), deep (more than 65 m), with a shallow sill (20 m deep) at its mouth that impedes deep-water exchange with Melville Sound. Hope Bay is a broad inlet dotted with many small islands and islets with free connection to Melville Sound.

The physiography of the surrounding area is represented by broad, sloping uplands (primarily igneous outcrops) that reach approximately 300 m in elevation in the south, and subdued undulating plains near the coast. 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).

Water exchange in Roberts Bay has free access to Melville Sound as there is no sill present in the inlet. Water exchange between the two waterbodies occurs primarily during the summer months when winds drive the upper freshwater layer towards the shoreline of Roberts Bay, and deeper waters move into Melville Sound (Rescan 2012b). The bay is typically ice covered from October to June, most of that time with land-fast ice that is about 1.5 m thick. During ice cover, the waters of the bay are isolated from wind stress and the exchange of water between Roberts Bay and Melville Sound is reduced.

Figure 8.2-1
Project Location and Local and Regional Marine Study Area

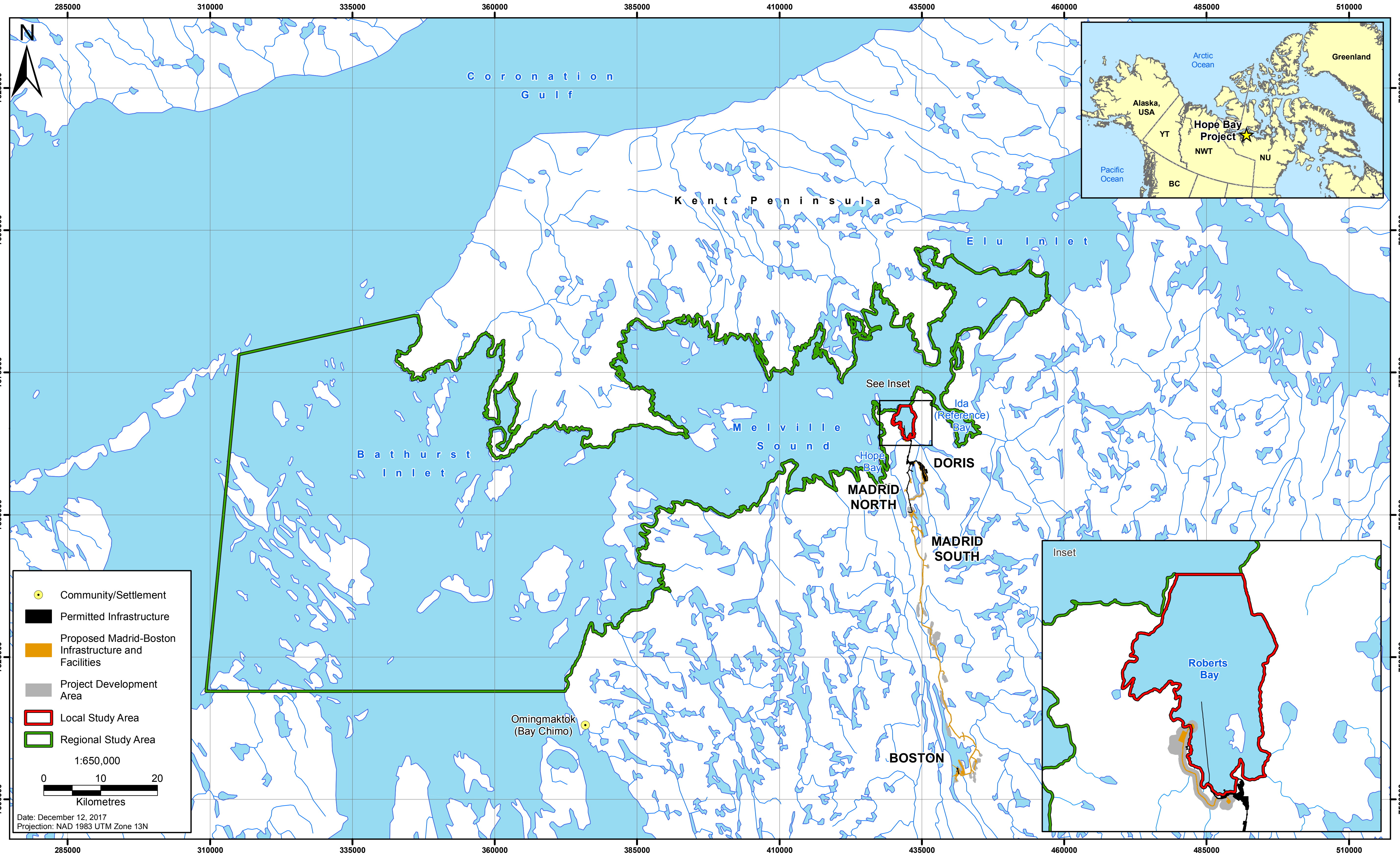
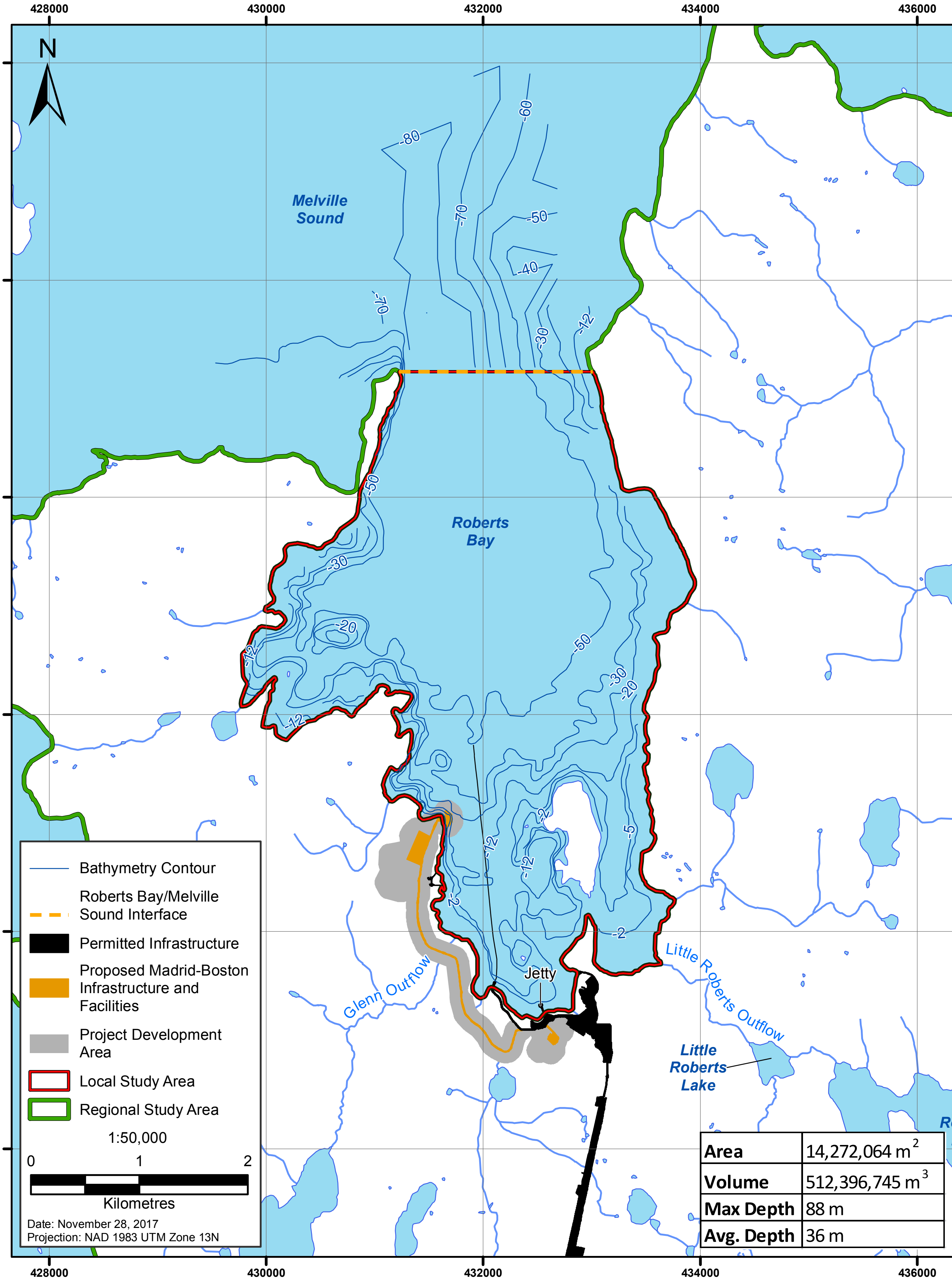


Figure 8.2-2
Roberts Bay

TMAC RESOURCES



Area	14,272,064 m^2
Volume	512,396,745 m^3
Max Depth	88 m
Avg. Depth	36 m

Freshwater enters Roberts Bay from Little Roberts Outflow, Glenn Outflow, and smaller tributaries (Figure 8.2-2), with Little Roberts Outflow being the dominant source. The Koignuk River and the Angimajuq River supply the vast majority of freshwater into Hope Bay and Ida Bay, respectively. These inputs contribute to the vertical stratification found in the inlets by forming a two-layer system with less dense water overlaying denser bottom water, which can reduce vertical mixing due to wind stress.

Roberts Bay and the surrounding embayments are generally well oxygenated, low in metals and nutrients, and have very low phytoplankton biomass levels. The marine fish community of Roberts Bay is representative of an Arctic marine ecosystem, and 25 species have been found in Roberts Bay to date (Volume 5, Chapter 10).

This section provides a summary of the methods and results from the marine water quality sampling carried out in Roberts Bay and the surrounding region for the Madrid-Boston Project.

8.2.1 Regulatory Framework

There are several acts, regulations, and guidelines relevant to the management and preservation of marine water quality. Table 8.2-1 lists and provides a brief description of the key acts and regulations pertaining to marine water quality.

Table 8.2-1. Federal and Territorial Acts and Regulations Relevant to Marine 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 (1985a)	1985 (2014)	Indigenous and Northern Affairs Canada (INAC)	Arctic Waters Pollution Prevention Regulations (C.R.C., c. 354) Arctic Shipping Pollution Prevention Regulations (C.R.C., c. 353)	• Prevents pollution of Arctic waters adjacent to the mainland and islands of the Canadian Arctic.
Canada Shipping Act	2001(2015)	Transport Canada	Ballast Water Control and Management Regulations (SOR/2011-237)	• Establishes ballast water exchange and treatment standards to prevent the introduction of pathogens. Prohibits the release of sediments that have settled in ballast tanks, and describes appropriate disposal method.
			Vessel Pollution and Dangerous Chemicals Regulations (SOR/2012-69)	• Prohibits the use of anti-fouling systems that contain any organotin compound that acts as a biocide. For organotin compounds applied to a vessel before January 1, 2008, requires that a coating be applied to act as a barrier to leaching.
			Response Organizations and Oil Handling Facilities Regulations (SOR/95-405)	• Regulations describing the procedures, equipment at the designated port, and resources to use in the event of an oil pollution incident.

Name of Act	Year (Year of Most Recent Amendment)	Administered by:	Relevant Regulations under the Act	Description/Purpose
Fisheries Act (1985b)	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)	1999 (2017)	ECCC	Disposal at Sea Regulations (SOR/2001-275)	• 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)	2002 (2016)	INAC		• Established the Nunavut Water Board, which can advise and make recommendations to any agency of the Government of Canada or Nunavut when making a decision that could affect a marine area.
Environmental Protection Act (1988a)	1988 (1999)	Government of Nunavut, Department of Environment (GN-DOE)		• Prohibits the discharge of contaminants into the environment without authorization.
Environmental Rights Act(1988b)	1988 (2011)	GN-DOE		• Grants all residents the ability to launch an investigation into the release of a contaminant into the environment.

In addition to these acts and regulations, the protection of marine 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 marine and estuarine organisms.

8.2.2 Data Sources

Marine water quality data were compiled from surveys carried out in marine waters near the Project between 1996 and 2016. Marine activities associated with the permitted Doris Project, including the construction of a jetty in Roberts Bay, began in 2007. Although the Doris Aquatic Effects Monitoring Program (AEMP) has shown that there have been no effects of the Doris Project on the marine 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.

The primary sources of water quality information used to describe the existing environment were the baseline studies conducted in Roberts Bay, Ida Bay (Reference Bay), Hope Bay, and Melville Sound in 2009, 2010, 2011, and 2016, and the Doris North Project Aquatic Effects Monitoring Program (AEMP) conducted in Roberts Bay and Ida Bay from 2010 to 2016.

Detailed sampling information can be found in the following reports:

- 2009 Marine Baseline Report, Hope Bay Belt Project (Rescan 2010; Appendix V5-7A);
- Hope Bay Belt Project: 2010 Marine Baseline Report (Rescan 2011c; Appendix V5-7B);
- Hope Bay Belt Project: 2010 Regional Marine Baseline Report (Rescan 2011d; Appendix V5-7C);
- Doris North Gold Mine Project: 2010 Aquatic Effects Monitoring Program Report (Rescan 2011a);
- Doris North Gold Mine Project: 2011 Aquatic Effects Monitoring Program (AEMP) Marine Expansion Baseline Report (Rescan 2011b, Appendix V5-7D);
- Doris North Gold Mine Project: 2011 Aquatic Effects Monitoring Program Report (Rescan 2012a);
- 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 2015b);
- Doris North Project: 2015 Aquatic Effects Monitoring Program Report (ERM 2016);
- Doris Project: 2016 Aquatic Effects Monitoring Program Report (ERM 2017b); and
- Doris Project: 2016 to 2018 Roberts Bay Marine Baseline Report (ERM In preparation).

Seven years of Doris Aquatic Effects Monitoring Program reports (2010 to 2016) are available on the Nunavut Water Board (NWB) FTP site (ftp://ftp.nwb-oen.ca).

8.2.3 Methods

8.2.3.1 Water Quality Sampling Overview

The most extensive marine water quality sampling programs in the coastal region near the Project were conducted in 2009, 2010, 2011, and 2016 (Rescan 2010, 2011c, 2011d, 2011b; ERM In preparation), with some preliminary sampling conducted in Roberts Bay in 2007 and 2008 (Golder Associates Ltd. 2008, 2009). Water quality samples were collected from numerous sites throughout Roberts Bay from the shallow nearshore area at the head to the deeper area near the entrance to Melville Sound (Table 8.2-2 and Figure 8.2-3). The nearshore sites, RBW and RBE, were sampled consistently from 2010 to 2016 as part of the Doris North AEMP sampling programs (Rescan 2011a, 2012a, 2013; ERM Rescan 2014; ERM 2015b, 2016, 2017b). Sampling in Roberts Bay was conducted during the under-ice and open-water seasons.

Baseline water quality samples were also collected in waterbodies adjacent to Roberts Bay, including Hope Bay, Ida Bay, and Melville Sound (Table 8.2-3 and Figure 8.2-3). Water quality samples were collected from one site in Hope Bay in 2007 and 2008 and six sites in Hope Bay in 2009 (Rescan 2010), five sites in Ida Bay from 2009 to 2011 (Rescan 2010, 2011c, 2011b), and five sites in Melville Sound in 2010 (Rescan 2011d). AEMP samples were also collected in Ida Bay from 2010 to 2016 (Rescan 2011a, 2012a, 2013; ERM Rescan 2014; ERM 2015b, 2016, 2017b). Sampling in Ida Bay and Hope Bay was conducted during the under-ice and open-water seasons, while Melville Sound was sampled under ice.

Figure 8.2-3
Historical Marine Water Quality Sampling Locations, 1996-2016

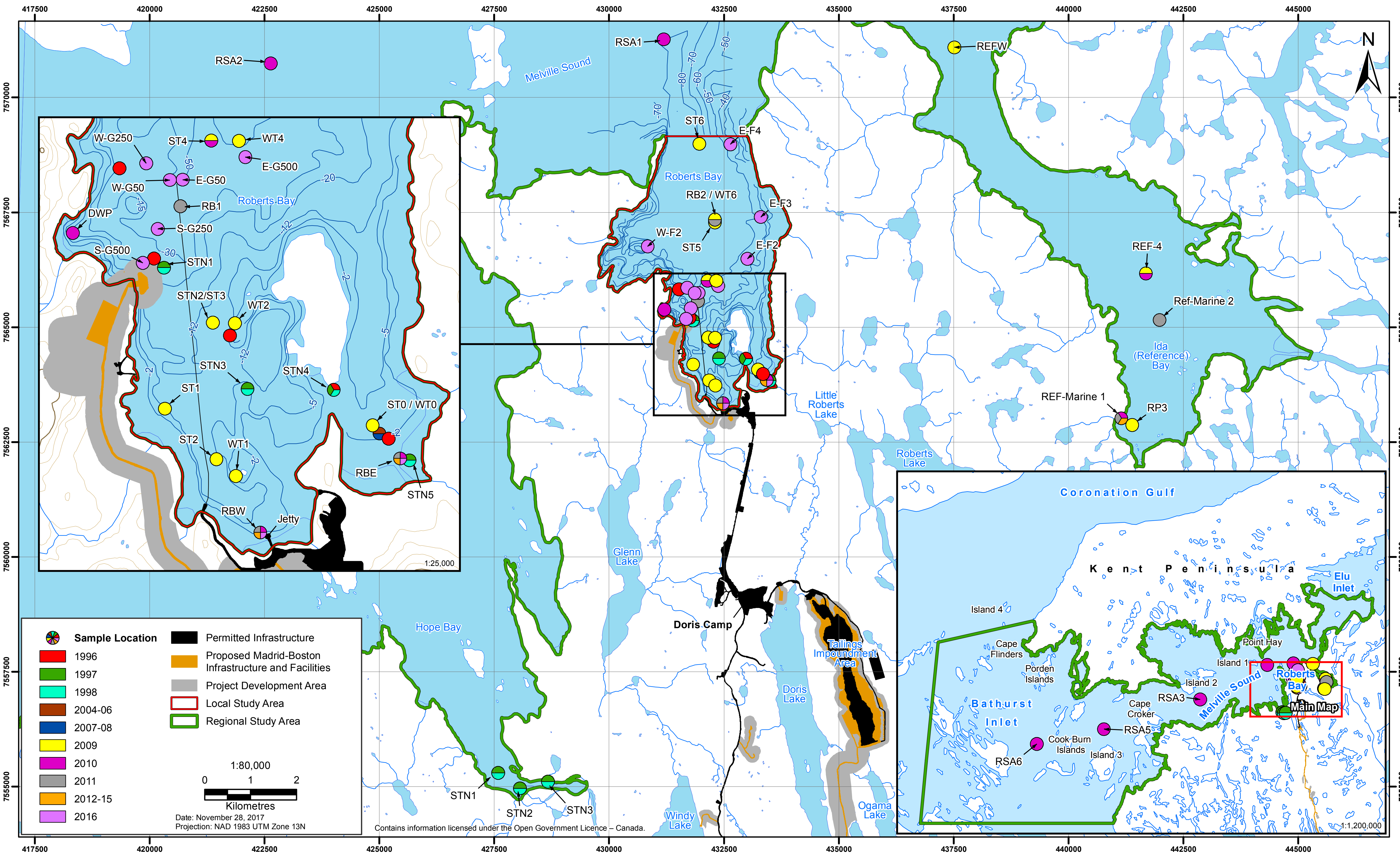


Table 8.2-2. Marine Water Quality Sampling Program in Roberts Bay (LSA), 2007 to 2016

Year	2007, 2008	2009		2010	2011	2012 to 2016	2016	
Month(s) Sampled	May*, July, August, September	April	August	April, July, August, September/October	April, July, August, September	April*, July, August, September	July, August, September	
Sites	Unnamed site in eastern basin	WT0 WT1 WT2 WT4 WT6	ST0 ST1 ST2 ST3 ST4 ST5 ST6	ST4 DWP RBW RBE	RB1 RB2 RBW RBE	RBW RBE	W-G50 W-G250 E-G50 E-G500 S-G250 S-G500	W-F2 E-F2 E-F3 E-F4
Site Replication	Single samples collected at surface and bottom depths	Surface samples at shallow sites (<5 m) and up to four depths at deep sites (> 5 m) with duplication for 20% of samples				Duplicate surface samples	3 depths per site with duplication for 5% of samples	

** May water quality sampling not conducted in 2008; April water quality sampling not conducted in 2013.*

Table 8.2-3. Marine Water Quality Sampling Program in the RSA, 2007 to 2016

Year	2007, 2008	2009			2010			2011		2012 to 2016
Marine Location	Hope Bay	Hope Bay	Ida Bay		Ida Bay		Melville Sound	Ida Bay		Ida Bay
Month(s) Sampled	May*, July, August, September	May	April	August	April	July, August, September	June	April	July, August, September	April*, July, August, September
Sites Sampled	Unnamed site	HB1 HB2 HB4 HB7 HB10 HB12	REFW	RP3 REF4	REF4	REF4 REF-Marine 1	RSA1 RSA2 RSA3 RSA5 RSA6	REF-Marine 1	REF-Marine 1 REF-Marine 2	REF-Marine 1
Site Replication	Single samples collected at surface and bottom depths	Surface samples at shallow sites (< 5 m) and from up to four depths at deep sites (> 5 m) with duplication for 20% of samples								Duplicate surface samples

** May water quality sampling not conducted in 2008; April water quality sampling not conducted in 2013.*

Water quality samples were collected using Kemmerer sampler in 2007 and 2008 at two depths: 1 m below surface and 1 m above the bottom. From 2009 to 2016, a 2.5 L Niskin (under ice) or 5 L GO-FLO (open water) sampler was used. For the more comprehensive surveys conducted in 2009, 2010, 2011, and 2016, depths of water quality sampling were determined based on the water column structure (as determined by temperature-salinity profiles), and whether the sites were deep (> 5 m; several depths sampled per site) or shallow (< 5 m; single sample at 1 m). At the deeper sites, samples were typically collected at the surface, near the pycnocline, and at 1 to 2 m above the seabed. The pycnocline is the depth zone where the density (i.e., salinity and temperature) changes most sharply. Surface samples from 0.5 or 1 m were collected at the shallow sites in Roberts and Ida bays monitored as part of the Doris AEMP.

Subsamples for the various water quality parameters (e.g., nutrients and metals) were drawn from the sampling bottles. After collection and preservation in the field, samples were transported on ice to ALS Environmental (Burnaby or Vancouver, BC), Maxxam Analytics Inc. (Burnaby, BC), or Alberta Research Council (Vegreville, AB) for analysis.

For the characterization of existing conditions, water quality data from shallower (under 20 m), nearshore sites with little vertical stratification were distinguished from deeper (over 30 m), offshore sites with more stratified water columns. Deep, offshore sites were further subdivided by depth class (above or below the pycnocline) since surface and deep waters often have distinct characteristics in vertically-stratified water columns. Water quality data were also grouped by season (under-ice or open-water) since water quality parameters can be affected by ice cover and other seasonal differences including temperature and photoperiod.

8.2.3.2 Quality Assurance and Quality Control

As part of all water quality surveys carried out between 2007 and 2016, equipment, field, and travel blanks were processed and submitted with the water samples as part of the quality assurance and quality control (QA/QC) program to identify potential sources of contamination. Field duplicate samples were collected for 5 to 100% of samples, depending on the water quality survey. All water quality samples were recorded on chain of custody forms before being sent to the analytical laboratory.

8.2.3.3 Calculation of Summary Statistics

Summary statistics were calculated for water quality parameters within the Local Study Area (LSA; see Section 8.4.2) of Roberts Bay and the Regional Study Area (RSA; see Section 8.4.2) of Hope Bay, Ida Bay, and Melville Sound (Figure 8.2-1).

For the calculation of minimum, maximum, mean, median, and the 75^{th} and 95^{th} 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., the sample concentration was 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) 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 75^{th} and 95^{th} percentiles, and for comparisons against water quality guidelines to give equal weighting to samples regardless of the degree of replication.

8.2.4 Characterization of Existing Conditions

Water quality is a set of parameters important for marine life and the CCME has established guidelines for specific parameters to protect marine life. These 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).

A summary of the water quality results for the marine sampling programs in Roberts Bay (LSA) and Hope Bay, Ida Bay, and Melville Sound (RSA) from 2007 to 2016 is presented below. These data are discussed within the framework of CCME water quality guidelines where applicable.

8.2.4.1 pH

The pH throughout the water column in Roberts Bay and the RSA from 2007 to 2016 ranged between 7.0 and 8.1 pH units (Table 8.2-4). pH levels were generally slightly higher during the open-water season than the ice-covered season, likely due to inorganic carbon uptake by phytoplankton. The pH of all samples in the marine surveys were within the CCME marine water quality guideline range of 7.0 to 8.7 pH units (CCME 2017).

Table 8.2-4. Marine pH at Roberts Bay (LSA) and RSA Sites, 2007 to 2016

	n (min, max)	n (mean, median percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[a]
Roberts Bay (LSA)								
pH								
Ice-covered season								
Nearshore, shallow	34	22	7.5	7.7	7.7	7.7	7.8	7.8
Offshore: AP	14	10	7.6	7.7	7.7	7.8	7.8	7.8
Offshore: BP	11	10	7.6	7.7	7.7	7.8	7.8	7.8
Open-water season								
Nearshore, shallow	111	67	7.0	7.7	7.8	7.9	8.0	8.1
Offshore: AP	67	54	7.7	7.8	7.8	7.9	7.9	7.9
Offshore: BP	86	83	7.7	7.8	7.8	7.8	7.9	7.9
RSA								
pH								
Ice-covered season								
Nearshore, shallow	21	14	7.6	7.7	7.7	7.8	7.8	7.8
Offshore: AP	24	17	7.6	7.7	7.8	7.8	7.8	7.9
Offshore: BP	19	18	7.3	7.7	7.7	7.8	7.9	7.9
Open-water season								
Nearshore, shallow	58	38	7.3	7.7	7.8	7.9	8.0	8.1
Offshore: AP	20	16	7.6	7.8	7.9	8.0	8.0	8.0
Offshore: BP	17	16	7.6	7.8	7.8	7.9	8.0	8.0

Notes: AP = above pycnocline, BP = below pycnocline, n = number of observations
pH was converted to the concentration of hydrogen ions for the calculation of summary statistics.
[a] Minimum and maximum represent the lowest and highest pH in any sample.
[b] Replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, and the 75th and 95th percentiles.

8.2.4.2 *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 column. Natural variation in TSS concentrations and turbidity can occur due to spatial differences in terrestrial runoff, bathymetry, currents and tides, and temporal changes from season and weather. Natural TSS and turbidity levels varied between seasons and depths in both Roberts Bay and the RSA (Table 8.2-5); however, TSS concentrations and turbidity were generally similar between the LSA and RSA. The highest turbidity and TSS levels typically occurred in shallow, nearshore areas where wind and wave action would result in the re-suspension of sediments or in bottom waters in close contact with the sediments.

Table 8.2-5. Marine TSS and Turbidity at Roberts Bay (LSA) and RSA Sites, 2007 to 2016

	n (min, max)	n (mean, median percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]
Roberts Bay (LSA)								
TSS (mg/L)								
Ice-covered season								
Nearshore, shallow	34	22	<2.0	4.8	2.0	6.0	15	25
Offshore: AP	14	10	<2.0	4.9	5.4	6.9	11	14
Offshore: BP	11	10	<2.0	3.8	2.0	5.5	10	10
Open-water season								
Nearshore, shallow	111	67	<2.0	6.0	4.1	6.9	19	27
Offshore: AP	67	54	<2.0	2.4	1.0	3.2	7.5	12
Offshore: BP	86	83	<2.0	4.2	1.0	3.0	15	79
Turbidity (NTU)								
Ice-covered season								
Nearshore, shallow	32	20	0.12	0.43	0.25	0.31	0.76	3.7
Offshore: AP	14	10	0.13	0.20	0.20	0.23	0.29	0.33
Offshore: BP	11	10	0.16	0.22	0.21	0.25	0.29	0.31
Open-water season								
Nearshore, shallow	99	55	0.22	2.1	0.73	2.0	6.5	16
Offshore: AP	67	54	0.18	0.45	0.42	0.52	0.76	0.90
Offshore: BP	86	83	0.18	1.2	0.40	0.52	0.93	46
RSA								
TSS (mg/L)								
Ice-covered season								
Nearshore, shallow	21	14	<2.0	4.9	2.4	7.2	15	17
Offshore: AP	24	17	<3.0	11	8.7	13	20	24
Offshore: BP	19	18	3.7	12	12	15	17	20
Open-water season								
Nearshore, shallow	58	38	<2.0	5.2	3.8	9.6	12	17
Offshore: AP	20	16	<2.0	6.2	5.9	9.9	13	13
Offshore: BP	17	16	<2.0	6.9	5.5	12	16	18

	n (min, max)	n (mean, median percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]
Turbidity (NTU)								
Ice-covered season								
Nearshore, shallow	19	12	0.16	0.31	0.26	0.34	0.59	0.74
Offshore: AP	24	17	0.12	0.53	0.28	0.40	2.1	2.3
Offshore: BP	19	18	0.11	0.21	0.21	0.23	0.33	0.38
Open-water season								
Nearshore, shallow	46	26	0.22	1.2	0.58	0.83	5.9	9.4
Offshore: AP	20	16	0.16	0.46	0.42	0.57	0.82	1.1
Offshore: BP	17	16	0.20	0.38	0.38	0.48	0.55	0.60

Notes: AP = above pycnocline, BP = below pycnocline, n = number of observations
'<' indicates that value was less than the analytical detection limit shown.
One half of the value of the analytical detection limit was substituted for values that were below detection limits for the calculation of summary statistics.
[a] *Minimum represents the lowest concentration in any sample.*
[b] *Replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, and the 75th and 95th percentiles.*
[c] *Maximum represents the highest detectable concentration in any sample (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).*

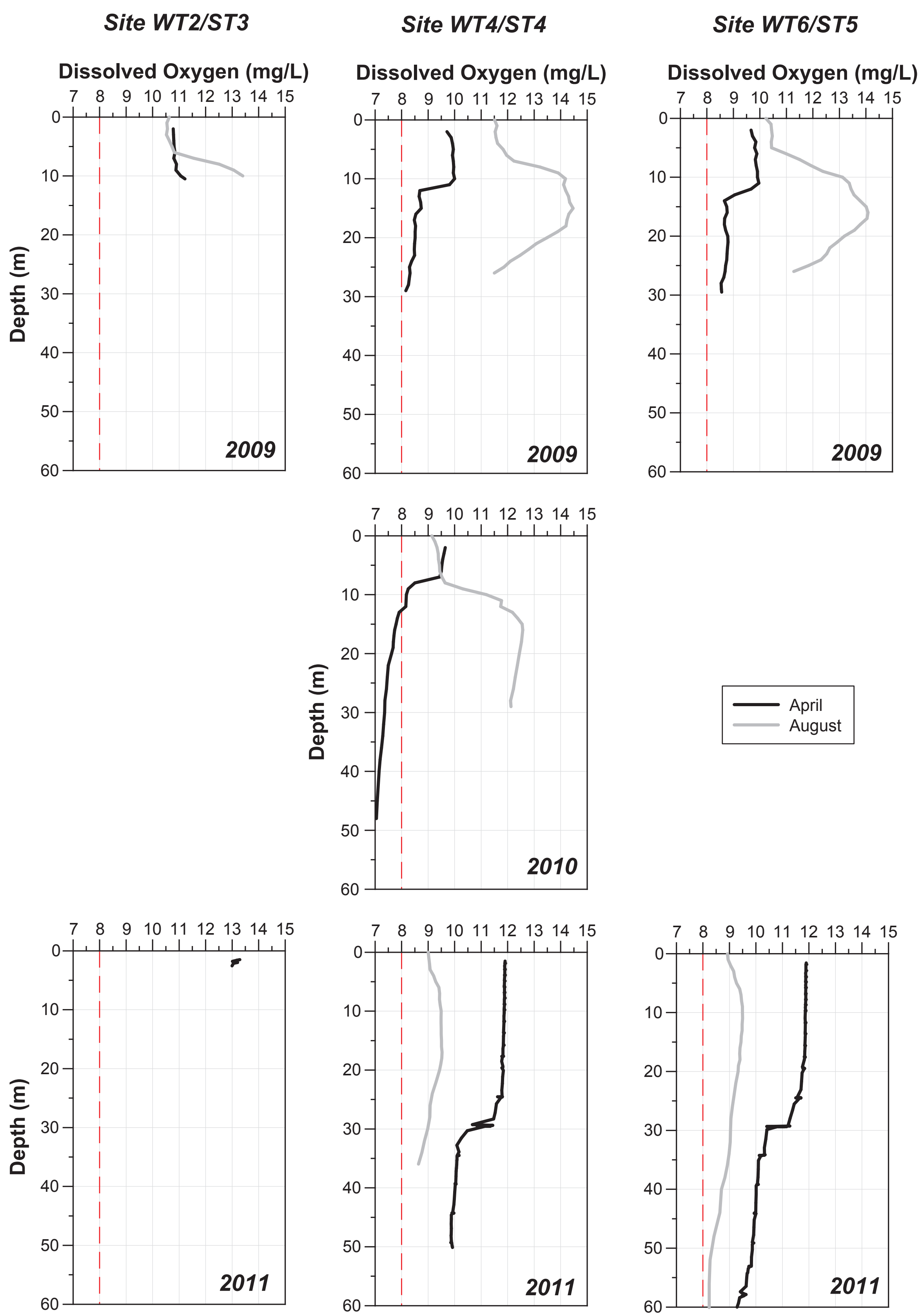
8.2.4.3 Dissolved Oxygen

Dissolved oxygen is an important environmental parameter affecting aquatic life and the chemistry of marine ecosystems. The atmosphere is the primary source of oxygen in marine environments with aquatic photosynthesis supplying oxygen when conditions favour the growth of primary producers. Respiration and the re-mineralization of organic matter consume oxygen. Therefore, the dissolved oxygen concentration, at any moment, is the balance between oxygen consumption (respiration), oxygen production (photosynthesis), and atmospheric influx. Water mixing processes are very important for oxygen concentrations, since the atmospheric influx is the largest source of oxygen for marine systems.

Dissolved oxygen concentrations in Roberts Bay varied between sampling sites, depths, seasons, and years. Between 2007 and 2016, the minimum recorded dissolved oxygen concentration in Roberts Bay was 7.1 mg/L (at 48 m depth at site ST4 in April 2010), and the maximum was 15.0 mg/L (at the surface in August 2008). The minimum dissolved oxygen concentration was lower than the CCME recommended minimum dissolved oxygen concentration for the protection of marine and estuarine aquatic life of 8.0 mg/L (CCME 2017). Figure 8.2-4 shows the April and August concentrations of dissolved oxygen at several sites in Roberts Bay from 2009 to 2011. In winter, dissolved oxygen concentrations generally decreased with depth, with the largest decline taking place below the pycnocline. As observed in April 2009 and 2010 at ST4, ice-covered dissolved oxygen concentrations at deep depths can naturally approach or drop below the CCME guideline of 8.0 mg/L (CCME 2017). This can occur when oxygen is consumed through the natural processes of respiration and re-mineralization at a faster rate than it is replenished through photosynthesis and water mixing (ultimately from the atmosphere). It is a common phenomenon that these natural processes can reduce the dissolved oxygen concentration to below the CCME guideline in coastal Arctic ecosystems. Open-water season dissolved oxygen concentrations in Roberts Bay were often greatest near the pycnocline (Figure 8.2-4).

Figure 8.2-4

Dissolved Oxygen Concentration Profiles in Roberts Bay, 2009 to 2011



Note: Dashed lines represent CCME water quality guideline for dissolved oxygen in marine and estuarine waters (8.0 mg/L).

Compared to winter dissolved oxygen concentrations, surface concentrations in summer were sometimes lower (for example in 2010 and 2011), likely because of the lower solubility of oxygen at higher water temperatures. The subsurface oxygen maxima observed in Roberts Bay during summer is also a common feature of vertically stratified water columns, as primary producers can often accumulate at the top of the pycnocline.

Dissolved oxygen (alongside temperature and salinity) was also logged continuously near the mouth of Roberts Bay (near ST6) at approximately 81.5 m depth between May 22 and October 4, 2011 to study the dynamics of the bottom water masses in conjunction with the current measurements (see Marine Physical Processes, Volume 5, Chapter 7 for further details). Water exchange in Roberts Bay has free access to Melville Sound as there is no sill present in the inlet. Water exchange between the two waterbodies occurs primarily during the summer months when winds drive the upper freshwater layer towards the shoreline of Roberts Bay, and deeper waters move into Melville Sound (Rescan 2012b). During the end of the ice-covered season in late May 2011, deep water dissolved oxygen concentrations decreased from 9.9 to 8.4 mg/L, and then increased to just above 10 mg/L in early June as oxygen-rich waters from Melville Sound were mixed into the Roberts Bay waters. During late June and early July, oxygen concentrations stabilized at 10.2 ± 0.2 mg/L, and then increased in late July to concentrations around 10.8 mg/L, before levelling off and then decreasing slightly through September. Roberts Bay is typically ice covered from October to June, during this period the waters of the bay are isolated from wind stress and the exchange of waters between Roberts Bay and Melville Sound is minimal (Rescan 2012b).

In neighbouring Ida Bay, seasonal and vertical trends in dissolved oxygen were generally similar to those observed in Roberts Bay, although oxygen minimums were lower in Ida Bay. This is because Ida Bay is a fjord system, with a sill at its mouth that restricts the exchange of water between Ida Bay and Melville Sound and increases the residence time of water in the fjord. Between 2009 and 2016, the minimum recorded dissolved oxygen concentration in Ida Bay was 5.6 mg/L (at 50 m depth at site REF4 in April 2010), and the maximum was 14.7 mg/L (at 4.9 m depth at site REF-Marine 2 in August 2011). This minimum dissolved oxygen concentration was lower than the CCME guideline of 8.0 mg/L (CCME 2017). Dissolved oxygen concentrations also dropped below the CCME guideline in deep waters during the open-water season, reaching a low of 6.6 mg/L at site REF-Marine 2 at 41 m depth in August 2011.

Dissolved oxygen concentrations in Hope Bay between 2007 and 2009 ranged from 7.2 mg/L (at 15 m depth in September 2007) to 15.5 mg/L (at the surface in August 2007). The range of dissolved oxygen concentrations in Hope Bay was similar to the range in Roberts Bay. The minimum dissolved oxygen concentration was lower than the CCME guideline of 8.0 mg/L (CCME 2017).

Under-ice dissolved oxygen concentrations in Melville Sound in June 2010 ranged from a deep water minimum of 9.8 mg/L to a surface maximum of 16.3 mg/L (Rescan 2011d). The near-surface depths (less than 6 m) were often supersaturated with dissolved oxygen, indicating that photosynthesis was active in the surface layer during this period. Dissolved oxygen concentrations closer to Roberts Bay (RSA1 and RSA2) were uniform below the sharp pycnocline (about 10 mg/L), while dissolved oxygen concentrations at the sites closer to Bathurst Inlet (RSA5 and RSA6) consistently declined with depth (Rescan 2011d).

8.2.4.4 Nutrients

Nutrients are required by photosynthetic organisms for growth and productivity and ultimately serve as building blocks for organic matter flowing through marine food webs. Variation in nutrient concentrations can be caused by periodic mixing, terrestrial and atmospheric inputs, and variations in nutrient uptake (primary producers) and re-mineralization (microbes). Nutrient uptake by phytoplankton is often greatest in the surface mixed layer, and re-mineralization occurs primarily in the sediments and in the deep waters. A classic “nutrient-type” profile has the lowest concentrations in the surface waters, increasing concentrations through the pycnocline, and the highest concentrations in the deep waters and near the sediments.

The concentration of nitrogen (ammonia, nitrate, and nitrite) and phosphorus (total phosphorus and orthophosphate) varied in the Roberts Bay and RSA waters, both vertically within the water column and seasonally between winter and summer (Tables 8.2-6 and 8.2-7 and Figures 8.2-5 and 8.2-6). In the Roberts Bay LSA, nutrient profiles generally showed higher concentrations in the surface waters during the ice-covered season than during the open-water season, likely the result of lower rates of phytoplankton growth and associated nutrient uptake during the light-limited winter months (Figure 8.2-5). This seasonal variability was less apparent in the RSA profiles (Figure 8.2-6).

Table 8.2-6. Marine Nitrate and Ammonia Concentrations at Roberts Bay (LSA) and RSA Sites, 2007 to 2016

	n (min, max)	n (mean, median percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]
Roberts Bay (LSA)								
Nitrate (mg N/L)								
Ice-covered season								
Nearshore, shallow	34	22	0.024	0.047	0.048	0.053	0.071	0.075
Offshore: AP	14	10	0.036	0.049	0.049	0.056	0.067	0.069
Offshore: BP	11	10	0.058	0.075	0.076	0.081	0.090	0.092
Open-water season								
Nearshore, shallow	100	58	<0.005	0.013	0.003	0.01	0.035	0.409
Offshore: AP	67	54	<0.006	0.0032	0.003	0.003	0.003	0.011
Offshore: BP	86	83	<0.006	0.014	0.003	0.008	0.068	0.080
Total Ammonia (mg N/L)								
Ice-covered season								
Nearshore, shallow	34	22	<0.005	0.0055	0.0025	0.0025	0.031	0.033
Offshore: AP	14	10	<0.005	0.0034	0.0025	0.0025	0.0073	0.0098
Offshore: BP	11	10	<0.005	0.018	0.0025	0.0025	0.086	0.16
Open-water season								
Nearshore, shallow	110	66	<0.005	0.013	0.0025	0.0045	0.026	0.26
Offshore: AP	67	54	<0.005	0.0026	0.0025	0.0025	0.0025	0.0055
Offshore: BP	86	83	<0.005	0.0032	0.0025	0.0025	0.0079	0.016
RSA								
Nitrate (mg N/L)								
Ice-covered season								
Nearshore, shallow	21	14	0.030	0.053	0.056	0.061	0.073	0.074
Offshore: AP	24	17	<0.006	0.028	0.0089	0.060	0.063	0.070
Offshore: BP	19	18	0.016	0.068	0.071	0.083	0.091	0.105
Open-water season								
Nearshore, shallow	44	27	<0.006	0.017	0.010	0.012	0.081	0.178
Offshore: AP	20	16	<0.006	0.011	0.003	0.003	0.066	0.066
Offshore: BP	17	16	<0.006	0.036	0.010	0.075	0.086	0.092

	n (min, max)	n (mean, median percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]
Total Ammonia (mg N/L)								
Ice-covered season								
Nearshore, shallow	21	14	<0.005	0.0076	0.0025	0.0037	0.032	0.034
Offshore: AP	24	17	<0.005	0.0089	0.0025	0.012	0.031	0.039
Offshore: BP	19	18	<0.005	0.0055	0.0025	0.0058	0.011	0.031
Open-water season								
Nearshore, shallow	55	35	<0.005	0.0087	0.0025	0.0090	0.030	0.051
Offshore: AP	20	16	<0.005	0.0066	0.0025	0.0069	0.026	0.026
Offshore: BP	17	16	<0.005	0.012	0.0039	0.017	0.035	0.050

Notes: AP = above pycnocline, BP = below pycnocline, n = number of observations.
'<' indicates that value was less than the analytical detection limit shown.
One half of the value of the analytical detection limit was substituted for values that were below detection limits for the calculation of summary statistics.
Nitrate-N concentrations reported as being below analytical detection limits of 0.25, 0.5, and 2.5 mg/L (much higher than the more typical detection limit of 0.006 mg/L achieved for most samples) and total ammonia-N concentrations reported as being below the analytical detection limit of 0.2 mg/L (much higher than the more typical detection limit of 0.005 mg/L achieved for most samples) were excluded from this data compilation so as not to bias the calculations of summary statistics.
[a] Minimum represents the lowest concentration in any sample.
[b] Replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detectable concentration in any sample (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).

Table 8.2-7. Marine Total Phosphorus and Orthophosphate Concentrations at Roberts Bay (LSA) and RSA Sites, 2007 to 2016

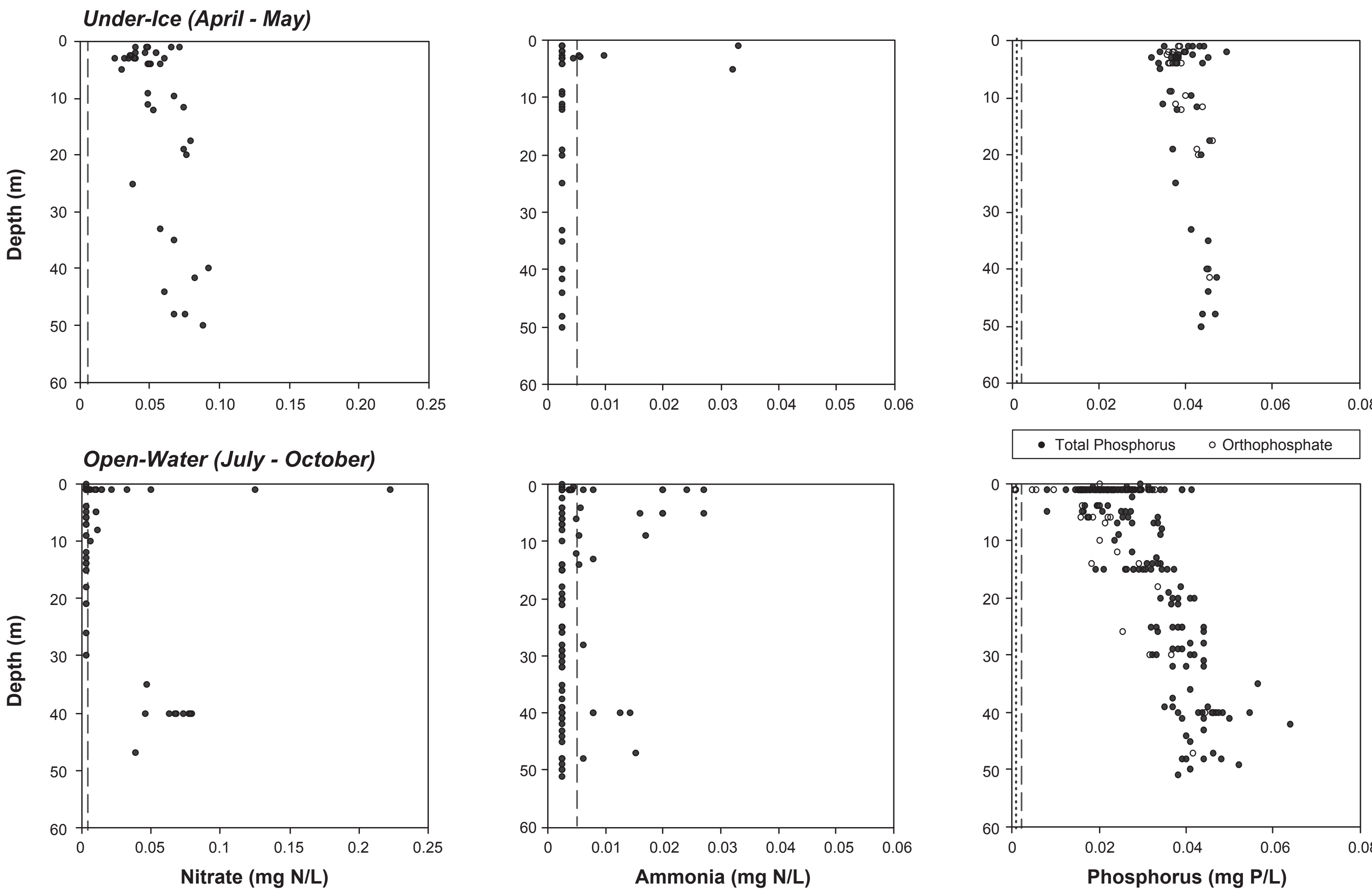
	n (min, max)	n (mean, median percentiles)	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]
Roberts Bay (LSA)								
Orthophosphate (mg P/L)								
Ice-covered season								
Nearshore, shallow	23	14	0.034	0.038	0.037	0.038	0.041	0.044
Offshore: AP	8	6	0.036	0.038	0.038	0.039	0.040	0.040
Offshore: BP	7	6	0.042	0.044	0.044	0.045	0.046	0.046
Open-water season								
Nearshore, shallow	63	36	<0.001	0.015	0.017	0.022	0.027	0.033
Offshore: AP	17	12	0.015	0.020	0.020	0.022	0.028	0.034
Offshore: BP	13	12	0.018	0.034	0.032	0.042	0.046	0.046
Total Phosphorus (mg P/L)								
Ice-covered season								
Nearshore, shallow	34	22	0.031	0.039	0.039	0.042	0.045	0.050
Offshore: AP	14	10	0.035	0.039	0.038	0.038	0.043	0.045
Offshore: BP	11	10	0.037	0.044	0.044	0.045	0.047	0.047

	n (min, max)	n (mean, median percentiles)	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]
Open-water season								
Nearshore, shallow	110	67	0.0080	0.024	0.025	0.028	0.035	0.044
Offshore: AP	67	54	0.013	0.023	0.021	0.027	0.034	0.039
Offshore: BP	86	83	0.019	0.040	0.039	0.044	0.052	0.169
RSA								
Orthophosphate (mg P/L)								
Ice-covered season								
Nearshore, shallow	15	10	0.036	0.038	0.038	0.038	0.039	0.040
Offshore: AP	24	17	0.014	0.031	0.036	0.037	0.038	0.044
Offshore: BP	19	18	0.031	0.041	0.039	0.044	0.050	0.055
Open-water season								
Nearshore, shallow	28	15	0.0026	0.018	0.016	0.021	0.034	0.047
Offshore: AP	14	10	0.0096	0.024	0.021	0.027	0.041	0.041
Offshore: BP	10	10	0.021	0.036	0.035	0.043	0.052	0.055
Total Phosphorus (mg P/L)								
Ice-covered season								
Nearshore, shallow	21	14	0.016	0.037	0.039	0.041	0.047	0.050
Offshore: AP	24	17	0.017	0.034	0.034	0.038	0.042	0.044
Offshore: BP	19	18	0.027	0.040	0.040	0.042	0.047	0.057
Open-water season								
Nearshore, shallow	59	38	0.0060	0.026	0.025	0.030	0.049	0.061
Offshore: AP	20	16	0.012	0.030	0.027	0.037	0.045	0.046
Offshore: BP	17	16	0.027	0.043	0.042	0.051	0.062	0.069

Notes: AP = above pycnocline, BP = below pycnocline, n = number of observations.
'<' indicates that value was less than the analytical detection limit shown.
One half of the value of the analytical detection limit was substituted for values that were below detection limits for the calculation of summary statistics.
[a] Minimum represents the lowest concentration in any sample.
[b] Replicate samples collected at the same site, date, and depth were averaged prior to the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detectable concentration in any sample (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).

In both the LSA and RSA, mean and median nitrate concentrations were always higher under-ice compared to open-water. As well, mean and median nitrate concentrations at the deeper, offshore sites were always lower above the pycnocline than in the bottom waters, indicative of biological uptake at the surface (Table 8.2-6). Mean nitrate concentrations in Roberts Bay during the ice-covered season were 0.048 mg N/L in nearshore, shallow waters, and ranged from 0.049 mg N/L above the pycnocline to 0.076 mg N/L below the pycnocline in deeper waters. During the open-water season, nitrate concentrations were frequently below the analytical detection limit (less than 0.006 mg/L) in Roberts Bay surface waters and showed a more classic nutrient-type profile with a lower mean concentration above the pycnocline (0.0032 mg N/L) than below the pycnocline (0.014 mg N/L; Table 8.2-6; Figure 8.2-5). The low nitrate concentrations observed in the surface waters of Roberts Bay, particularly in the summer, indicated that nitrogen was likely a limiting factor for the growth of phytoplankton, which is common in coastal Arctic ecosystems (e.g., Rysgaard, Nielsen, and Hansen 1999).

Seasonal Changes in Water Column Nutrient Concentrations in Roberts Bay (LSA), 2007 to 2016



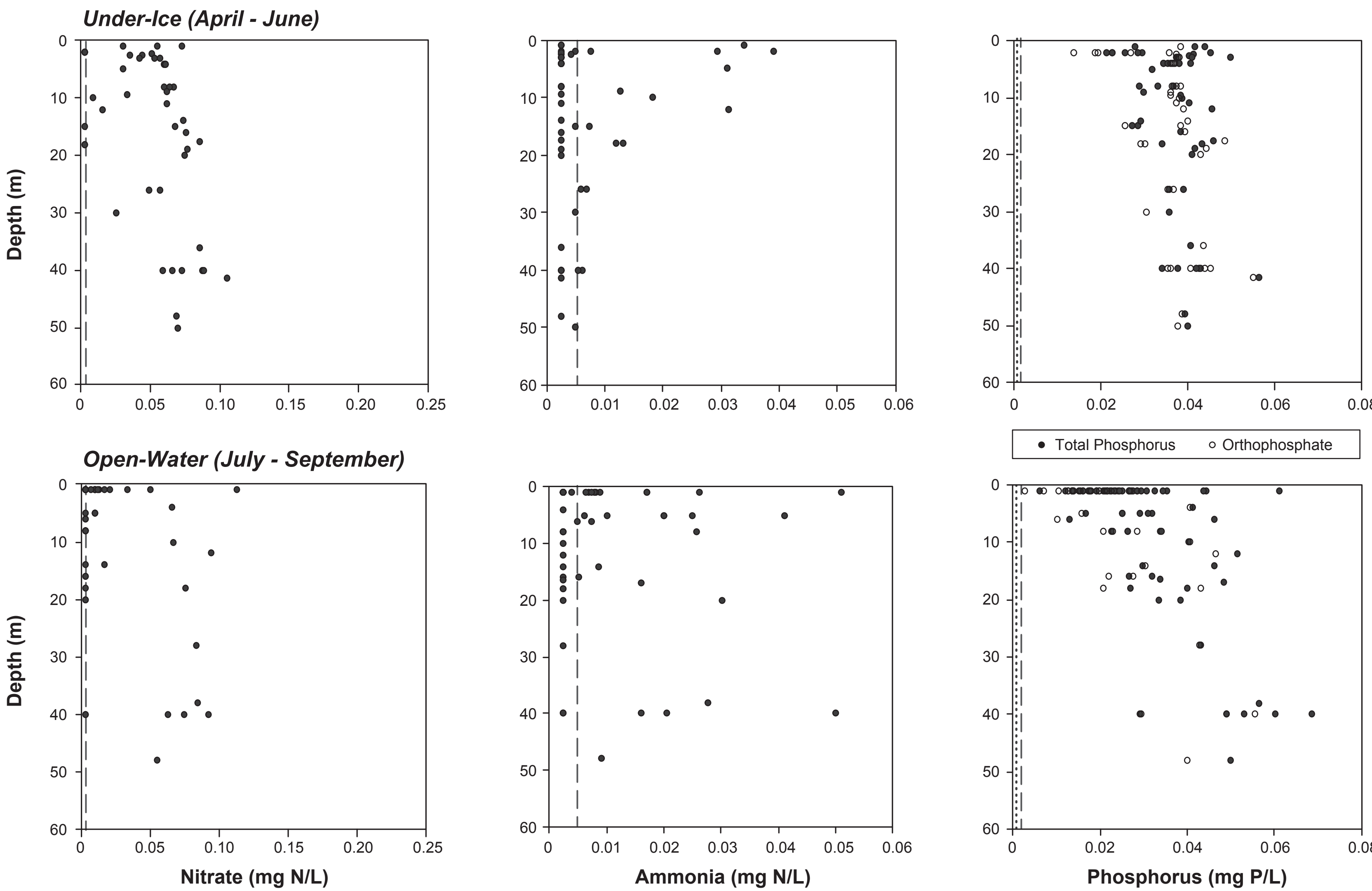
Notes:
Dashed lines indicate typical nitrate detection limit = 0.006 mg/L. Nitrate concentrations below detection limits of 0.25, 0.5, and 2.5 mg/L were excluded from the dataset.

Notes:
Dashed lines indicate typical ammonia detection limit = 0.005 mg/L. Several outliers exceeding 0.15 mg N/L were not plotted. Ammonia concentrations below the detection limit of 0.2 mg/L were excluded from the dataset.

Notes:
Dashed lines indicate typical total phosphorus detection limit = 0.002 mg/L. Dotted lines indicate typical orthophosphate detection limit = 0.001 mg/L.

Figure 8.2-6

Seasonal Changes in Water Column Nutrient Concentrations in the RSA, 2007 to 2016



Notes:

Dashed lines indicate typical nitrate detection limit = 0.006 mg/L.
Nitrate concentrations below detection limits of 0.25, 0.5, and 2.5 mg/L were excluded from the dataset.

Notes:

Dashed lines indicate typical ammonia detection limit = 0.005 mg/L.
Ammonia concentrations below the detection limit of 0.2 mg/L were excluded from the dataset.

Notes:

Dashed lines indicate typical total phosphorus detection limit = 0.002 mg/L.
Dotted lines indicate typical orthophosphate detection limit = 0.001 mg/L.

Nitrate concentrations in the RSA waterbodies were similar to those in Roberts Bay, and displayed similar seasonal and vertical trends. The mean nitrate concentrations in the ice-covered season were 0.053 mg N/L in nearshore, shallow waters, and ranged from 0.028 mg N/L above the pycnocline to 0.068 mg N/L below the pycnocline in deeper waters. The mean concentrations in the open-water season were 0.017 mg N/L in shallow areas, and 0.011 and 0.036 mg N/L above and below the pycnocline in deeper waters (Table 8.2-6 and Figure 8.2-6). All nitrate concentrations throughout the marine sampling programs were lower than the conservative CCME long-term exposure guideline of 45 mg N/L (CCME 2017).

The other nitrogenous compounds, ammonia and nitrite, were generally present in low concentrations. Ammonia concentrations in Roberts Bay and the RSA were frequently below the analytical detection limit (< 0.005 mg/L), with no obvious seasonal or vertical trends (Table 8.2-6 and Figures 8.2-5 and 8.2-6). Nitrite concentrations were also frequently below the analytical detection limit (less than 0.002 mg N/L) in both winter and summer in Roberts Bay and the RSA waters.

Concentrations of both total phosphorus and orthophosphate were similar between Roberts Bay and the RSA across seasons and through the water column. There were slight vertical gradients during the ice-covered season (lower concentrations at surface), and more pronounced gradients during the open-water season when phytoplankton would be taking up phosphate from surface waters to meet their nutritional needs. Orthophosphate generally made up the major fraction of the total phosphorus pool, except in the surface waters during the open-water season when orthophosphate concentrations made up approximately half of the total phosphorus pool (Table 8.2-7 and Figures 8.2-5 to 8.2-6). As phytoplankton take up phosphate during the open-water season, the proportion of inorganic phosphate would likely decrease as more phosphorus becomes organically-bound in phytoplankton cells.

8.2.4.5 Metals

Table 8.2-8 presents a summary table of the metal concentrations at the marine sampling sites from 2007 to 2016, alongside applicable CCME guidelines (CCME 2017). Overall, total metal concentrations measured in Roberts Bay and the RSA waters were naturally low during both the ice-covered and open-water seasons. Many metals were near or below their analytical detection limits across seasons, depths, and years. During the open-water season in Roberts Bay, the total arsenic concentration in one sample and the total chromium concentration in three samples were greater than CCME guidelines (Table 8.2-8). During the ice-covered season, mercury concentrations in three samples from Roberts Bay were greater than the CCME guideline of 0.000016 mg/L.

In the RSA, cadmium and chromium concentrations were occasionally greater than CCME guidelines. The cadmium concentration in a single sample collected from Hope Bay in July 2008 was greater than the CCME guideline of 0.00012 mg/L (CCME 2017). Conspicuously, the total chromium concentration in every water sample collected from Hope Bay in the RSA during the ice-covered season of 2009 was either greater than the CCME guideline for hexavalent chromium (Cr(VI)) of 0.0015 mg/L, or was excluded from the data compilation for being below the anomalously high analytical detection limit of 0.05 mg/L. Most of these chromium concentrations were also higher than the CCME guideline for trivalent chromium (Cr(III)) of 0.056 mg/L. All other total chromium concentrations collected in the RSA (including samples collected from Hope Bay in 2008) were below CCME guidelines, except for total chromium in a single sample collected from Ida Bay that was slightly higher than the CCME guideline for Cr(VI) (Table 8.2-8).

All metal concentrations in the samples collected from Melville Sound in 2010 were below CCME guidelines.

Table 8.2-8. Marine Metal Concentrations at Roberts Bay (LSA) and RSA Sites, 2007 to 2016

	Metal Concentration									
	n (min, max)	n (mean, median percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	CCME Guideline[d] (mg/L)	% of Samples with Concentrations Greater than CCME Guidelines[b]
Roberts Bay (LSA)										
Arsenic (mg/L)									0.0125[e]	
Ice-covered season										
Nearshore, shallow	34	22	0.00010	0.0010	0.0010	0.0012	0.0013	0.0013		0
Offshore: AP	14	10	0.00084	0.00097	0.0010	0.0010	0.0010	0.0011		0
Offshore: BP	11	10	0.00093	0.00099	0.00098	0.0010	0.0011	0.0012		0
Open-water season										
Nearshore, shallow	111	67	<0.00040	0.0011	0.00092	0.0010	0.0014	0.0287		1.5
Offshore: AP	67	54	0.00050	0.00087	0.00093	0.0010	0.0011	0.0012		0
Offshore: BP	86	83	0.00074	0.0012	0.0012	0.0013	0.0014	0.0021		0
Cadmium (mg/L)									0.00012	
Ice-covered season										
Nearshore, shallow	34	22	0.000010	0.000057	0.000055	0.000060	0.000095	0.000102		0
Offshore: AP	14	10	0.000045	0.000053	0.000052	0.000054	0.000060	0.000054		0
Offshore: BP	11	10	0.000049	0.000055	0.000054	0.000058	0.000060	0.000058		0
Open-water season										
Nearshore, shallow	111	67	<0.000010	0.000034	0.000035	0.000050	0.000060	0.000060		0
Offshore: AP	67	54	0.000020	0.000037	0.000034	0.000041	0.000060	0.000065		0
Offshore: BP	86	83	0.000028	0.000045	0.000043	0.000050	0.000065	0.000071		0
Chromium[f] (mg/L)									Cr(VI): 0.0015 Cr(III): 0.056[e]	
Ice-covered season										
Nearshore, shallow	29	18	<0.0005	0.00035	0.00025	0.00044	0.00058	0.0010		0
Offshore: AP	9	6	<0.0005	all concentrations below detection limits				<0.0010		0
Offshore: BP	6	6	<0.0005	all concentrations below detection limits				<0.0010		0
Open-water season										
Nearshore, shallow	95	54	0.00018	0.00077	0.00035	<0.0010	0.0011	0.0317		Cr(VI): 3.7; Cr(III): 0
Offshore: AP	58	48	<0.0003	all concentrations below detection limits				<0.0010		0
Offshore: BP	80	77	<0.0003	0.00033	0.00025	0.00025	0.00050	0.0041		Cr(VI): 1.3; Cr(III): 0

	n (min, max)	n (mean, median percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	CCME Guideline[d] (mg/L)	% of Samples with Concentrations Greater than CCME Guidelines[b]
	Metal Concentration									
Mercury (mg/L)									0.000016[e]	
Ice-covered season										
Nearshore, shallow	34	22	<0.0000005	all concentrations below detection limits				<0.00001		0
Offshore: AP	14	10	<0.00001	0.000017	0.000005	0.000005	0.000066	0.000095		20
Offshore: BP	11	10	<0.00001	0.000014	0.000005	0.000005	0.000055	0.000096		10
Open-water season										
Nearshore, shallow	111	67	<0.0000005	0.0000021	0.0000008	0.0000050	0.0000050	0.0000057		0
Offshore: AP	67	54	<0.0000005	0.0000017	0.00000025	0.0000030	0.0000050	0.0000089		0
Offshore: BP	86	83	<0.0000005	0.0000012	0.00000025	0.0000012	0.0000050	0.0000030		0
Silver (mg/L)									Short term: 0.0075	
Ice-covered season										
Nearshore, shallow	34	22	<0.0001	all concentrations below detection limits				<0.0010		0
Offshore: AP	14	10	<0.0001	all concentrations below detection limits				<0.0010		0
Offshore: BP	11	10	<0.0001	all concentrations below detection limits				<0.0010		0
Open-water season										
Nearshore, shallow	111	67	<0.00002	all concentrations below detection limits				<0.0010		0
Offshore: AP	67	54	<0.0001	all concentrations below detection limits				<0.0010		0
Offshore: BP	86	83	<0.0001	all concentrations below detection limits				<0.0010		0
RSA										
Arsenic (mg/L)									0.0125[e]	
Ice-covered season										
Nearshore, shallow	21	14	0.00060	0.00096	0.00093	0.0011	0.0012	0.0014		0
Offshore: AP	24	17	0.00077	0.0010	0.0010	0.0010	0.0011	0.0012		0
Offshore: BP	19	18	0.00090	0.0010	0.0010	0.0011	0.0012	0.0012		0
Open-water season										
Nearshore, shallow	58	38	<0.00020	0.00090	0.00098	0.0011	0.0012	0.0026		0
Offshore: AP	20	16	0.00045	0.00094	0.0010	0.0010	0.0011	0.0012		0
Offshore: BP	17	16	0.00068	0.0010	0.0010	0.0010	0.0012	0.0013		0

	Metal Concentration								CCME Guideline[d] (mg/L)	% of Samples with Concentrations Greater than CCME Guidelines[b]
	n (min, max)	n (mean, median percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]		
Cadmium (mg/L)									0.00012	
Ice-covered season										
Nearshore, shallow	21	14	0.000049	0.000060	0.000054	0.000057	0.00010	0.00010		0
Offshore: AP	24	17	0.000049	0.000058	0.000060	0.000060	0.000060	0.000058		0
Offshore: BP	19	18	0.000048	0.000058	0.000060	0.000060	0.000060	0.000058		0
Open-water season										
Nearshore, shallow	58	38	<0.00002	0.000036	0.000033	0.000042	0.000060	0.00015		2.6
Offshore: AP	20	16	<0.00002	0.000046	0.000053	0.000060	0.000060	0.000056		0
Offshore: BP	17	16	0.000034	0.000054	0.000058	0.000060	0.000066	0.000076		0
Chromium[f] (mg/L)									Cr(VI): 0.0015	
Ice-covered season									Cr(III): 0.056[e]	
Nearshore, shallow	18	12	<0.0005	0.024	0.00025	0.060	0.077	0.078		Cr(VI): 33; Cr(III): 33
Offshore: AP	23	17	<0.0010	0.025	0.0005	0.058	0.079	0.081		Cr(VI): 35; Cr(III): 35
Offshore: BP	19	18	<0.0010	0.024	0.0005	0.061	0.080	0.082		Cr(VI): 33; Cr(III): 33
Open-water season										
Nearshore, shallow	49	29	<0.0001	0.00040	0.00025	0.00050	0.00077	0.00090		0
Offshore: AP	14	12	<0.0001	all concentrations below detection limits				<0.0010		0
Offshore: BP	13	12	<0.0001	0.00050	0.00038	0.00050	0.00131	0.0023		Cr(VI): 8.3; Cr(III): 0
Mercury (mg/L)									0.000016[e]	
Ice-covered season										
Nearshore, shallow	21	14	<0.0000005	all concentrations below detection limits				<0.000010		0
Offshore: AP	24	17	<0.000010	all concentrations below detection limits				<0.000010		0
Offshore: BP	19	18	<0.000010	all concentrations below detection limits				<0.000010		0
Open-water season										
Nearshore, shallow	58	38	<0.0000005	0.0000019	0.0000008	0.0000050	0.0000050	0.0000022		0
Offshore: AP	20	16	<0.0000005	0.0000038	0.0000050	0.0000050	0.0000068	0.000012		0
Offshore: BP	17	16	<0.0000005	0.0000034	0.0000050	0.0000050	0.0000050	0.0000008		0

	Metal Concentration								CCME Guideline[d] (mg/L)	% of Samples with Concentrations Greater than CCME Guidelines[b]
	n (min, max)	n (mean, median percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]		
Silver (mg/L)									Short term: 0.0075	
Ice-covered season										
Nearshore, shallow	21	14	<0.0001	all concentrations below detection limits				<0.0010		0
Offshore: AP	24	17	<0.0002	all concentrations below detection limits				<0.0010		0
Offshore: BP	19	18	<0.0002	all concentrations below detection limits				<0.0010		0
Open-water season										
Nearshore, shallow	58	38	<0.00002	0.00012	0.00005	0.00010	0.00050	0.00005		0
Offshore: AP	20	16	<0.0001	all concentrations below detection limits				<0.0010		0
Offshore: BP	17	16	<0.0001	all concentrations below detection limits				<0.0010		0

Notes: AP = above pycnocline, BP = below pycnocline, n = number of observations
'<' indicates that value was less than the analytical detection limit shown.
One half of the value of the analytical detection limit was substituted for values that were below detection limits for the calculation of summary statistics.
[a] Minimum represents the lowest concentration in any sample.
[b] Replicate samples collected at the same site, date, and depth were averaged prior to the calculation of mean, median, and the 75th and 95th percentiles, and for comparisons against CCME guidelines.
[c] Maximum represents the highest detectable concentration in any sample (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).
[d] CCME guidelines for the protection of marine aquatic life, accessed October 2016.
[e] Interim guideline
[f] Chromium concentrations reported as being below the analytical detection limits of 0.005, 0.025 and 0.05 mg/L (much higher than the more typical detection limits of 0.0001 to 0.001 mg/L) were excluded from this data compilation so as not to bias the calculation of the mean. 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.

8.3 VALUED ECOSYSTEM COMPONENTS

8.3.1 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 a VEC 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 Project components and/or activities. The selection and scoping of a VEC also considers its importance to the communities potentially affected by the Project.

8.3.1.1 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 marine water quality be considered for inclusion in the effects assessment. The selection of marine water quality as a VEC was also informed by:

- the potential for Madrid-Boston Project activities and components to interact with the local and regional marine environment;
- review of recently completed Nunavut environmental assessments (e.g., Back River, Mary River);
- 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 marine component (e.g., CCME water quality guidelines, the Metal Mining Effluent Regulations (MMER) under the Fisheries Act (1985b); 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).

8.3.1.2 NIRB Scoping Sessions

Scoping sessions hosted by NIRB (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 marine 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).

8.3.1.3 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 marine water quality.

8.3.2 Valued Components Included in the Assessment

The scoping analysis identified the marine water quality VEC for inclusion in the assessment. The marine water quality VEC was selected as a component of the assessment of the potential effects of the Madrid-Boston Project on marine 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 8.3-1 summarizes the marine water quality VEC included in this assessment.

Table 8.3-1. Valued Ecosystem Component(s) Included in the Assessment

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

8.4 SPATIAL AND TEMPORAL BOUNDARIES

The marine 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 marine environment. The spatial boundaries were defined by the coastal morphology, physical oceanography of Roberts Bay, and the proximity of Project infrastructure and activities to the marine environment.

Temporal boundaries are selected that 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 marine water quality.

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 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.

8.4.1 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.

8.4.1.1 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.

8.4.1.2 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.

<u>Construction</u>

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
- ongoing 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.

8.4.2 Spatial Boundaries

The spatial boundaries selected to shape this assessment are determined by the Project's potential effects on the marine environment. Spatial boundaries are determined based on the anticipated magnitude and spatial extent of the potential Madrid-Boston effects. Spatial boundaries are determined by the location and distribution of VECs and are here defined as the anticipated zone of influence between Project component/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).

8.4.2.1 Project Development Area

The PDA is shown in Figure 8.2-2 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-filed 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 varied 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 follows exactly the footprints of these features.

8.4.2.2 Local Study Area

The LSA is defined as the PDA and the area surrounding the PDA within which there is a reasonable potential for immediate effects on a VEC due to an interaction with a Project component(s) or physical activity. The LSA for marine water quality is set to encompass Roberts Bay and is bounded by the shoreline around the bay and where it exchanges water with Melville Sound (Figure 8.2-2). The marine LSA has a surface area of 14.3 km^2 and contains the PDA of the marine cargo dock and its near-shore marine waters, seabed, and shorelines. The marine LSA is designed to reflect the scale at which direct, immediate, and localized disturbances to the marine environment have the potential to occur.

8.4.2.3 Regional Study Area

The RSA is defined as the broader spatial area representing the maximum limit where potential direct or indirect effects may occur. The RSA encompasses the PDA and LSA, and is bounded by the shoreline of Melville Sound from the chain of islands just east of Ida Bay into the northern portion of Bathurst Inlet (Figure 8.2-1). The marine RSA includes the proposed shipping lane within Bathurst Inlet and Melville Sound that will bring sealifts and fuel into the Roberts Bay LSA, and represents the maximum extent where potential direct or indirect effects to the marine environment may occur.

8.4.3 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 Project and the extension of activities.

For the purposes of the EIS, distinct phases of the Project are defined (Table 8.4-1). It is understood that Construction, Operation and Closure activities will, in fact, overlap among sites; this is outlined in Table 8.4-1 and further described in Volume 3, Project Description and Alternatives.

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 (one to two year duration would be typical).

Table 8.4-1. Temporal Boundaries for the Effects Assessment for Marine 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).
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.

8.5 PROJECT-RELATED EFFECTS ASSESSMENT

8.5.1 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 Madrid-Boston on the 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 marine water quality VEC defined for the assessment (Section 8.3).

To provide a comprehensive understanding of the potential effects for the Project, the Madrid-Boston components and activities 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 the marine water quality VEC;
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 combined residual effects.

After the identification of potential interactions between the Madrid-Boston Project and marine water quality (Step 1, Section 8.5.2), the potential effects of these interactions are identified (Step 2, Section 8.5.2). Mitigation and management measures are then considered (Step 3, Section 8.5.3). 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 marine water quality are characterized as *negligible* and not identified as residual effects (Step 4, Section 8.5.4). 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 8.5.4).

All remaining potential effects are then considered residual effects (Steps 4 and 5), and characterized (Step 6, Section 8.5.5) using the following attributes:

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

The rating criteria for the assessment of residual effects to marine water quality are described in the Effects Assessment Methodology chapter (Volume 2, Chapter 4). The observed baseline conditions and CCME water quality guidelines for the protection of aquatic life (CCME 2017), when available, are used as assessment thresholds for the determination of magnitude. The significance of each residual effect (Step 6, Section 8.5.5) is determined by considering the characterization of each residual effect, the probability of occurrence, and the predictions of the effects.

8.5.1.1 Water Quality Indicators

Water quality is an aggregate term that encompasses a complex suite of parameters and indicators that describe the marine water environment and its ability to sustain ecological and biogeochemical functions. The assessment of the potential effects of the Madrid-Boston Project on marine water is based on eight indicators that describe the most probable and significant interactions between the Project and the marine water environment (Table 8.5-1). These indicators were 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
- responsive to the potential effects of industrial and mining activities in the Arctic.

Table 8.5-1. Marine 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	Solid material (i.e., not dissolved) material suspended in water	Project activities may disturb in-water sediments, increase runoff of deposited sediment, or discharge suspended material
Nutrients	Chemical compounds that may contribute to algal growth, alter trophic interactions, and/or change primary producer community structure	Project activities may contribute nutrients to the marine environment
Metals	Metals suspended or dissolved in water	Project activities may contribute metals to the marine 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 marine environment, which may affect dissolved oxygen concentrations in the water
Salinity	A parameter summarizing the total salt content of water	Underground water may have high concentrations of salts
Cyanide	Carbon-nitrogen compounds	Cyanide is a process chemical

For the effects assessment, assessment thresholds are applied to the water quality indicators when suitable for the analysis (Table 8.5-2). These assessment thresholds are based on observed baseline conditions and CCME water quality guidelines for the protection of aquatic life, 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 8.5-2. Water Quality Guidelines Used as Thresholds for Marine Water Quality Indicators

Indicator	Parameter	CCME Guideline for the Protection of Aquatic Life
pH		7 to 8.7 pH units[a]
TSS		CCME narrative[b]
Nutrients	Nitrate-N	339 mg/L (short term) 45 mg/L (long term)
	Total P	CCME Guidance framework
Metals	Arsenic	0.0125 mg/L
	Cadmium	0.00012 mg/L
	Chromium	0.0015 mg/L (hexavalent: Cr(VI)) 0.056 mg/L (trivalent: Cr(III))
	Mercury	0.000016 mg/L
	Silver	0.0075 mg/L
Other indicators	Petroleum hydrocarbons	*Range of guidelines for petroleum hydrocarbon compounds*
	Dissolved Oxygen	8.0 mg/L
	Salinity	CCME narrative[b]
	Cyanide	*no established CCME guideline*

[a] *Unless change in pH is demonstrated to be the result of natural processes.*
[b] *Narrative described in CCME (2017)*

8.5.2 Identification of Potential Effects

The Madrid-Boston Project has the potential to interact with the marine environment through a number of activities, pathways, and mechanisms. Project activities are grouped into broad components as described in Section 4.3.4.1 of the Effects Assessment Methodology (Volume 2, Chapter 4). The interactions between the Madrid-Boston Project and marine water quality are further refined by an *interaction group*. Interaction groups are interaction pathways that share similar modes of interaction with the Project through specific mitigation and management measures, assessment thresholds, and key indicators. For example, use of the Roberts Bay fuel tank farm and machinery use in the Roberts Bay laydown area during the Operation Phase are both assigned to the *Fuels, Oils, Polycyclic Aromatic Hydrocarbons (PAH)* interaction groups because both Project components may interact with marine water quality through activities related to the storage and use of fuel. The defined interaction groups for the assessment of effects to marine water quality are the following:

- *Sealift* – interactions related to sealifts include wake effects, propeller wash, ballast water, sewage from ships, antifouling agents, and airborne emissions.
- *Site Preparation, Construction, and Decommissioning* – activities that include the clearing of overburden, earthworks, and construction activities for pads and infrastructure.
- *Site Contact Water* – the runoff from infrastructure including pad areas, laydown areas, and roads.
- *Fuels, Oils, and PAH* – activities related to the storage of fuels, fueling and maintenance operations, and the combustion of waste.

- *Discharges* – discharge of TIA and saline groundwater via the Roberts Bay Discharge System.
- *Dust Deposition* – activities that generate dust, including vehicle traffic, airstrip activity, and quarry and borrow pit activities that can then be deposited in marine receiving environment.

The potential interactions between the Project and the marine environment are presented in Table 8.5-3. These Project components are considered to have probable or likely interactions with the marine environment. Potential interactions may be direct or indirect, and this screening step does not consider application of mitigation and management measures.

Table 8.5-3. Project Interaction with the Marine Water Quality in Roberts Bay

Project Component/Activity	Sealift	Site Preparation, Construction, and Decommissioning	Site Contact Water	Fuels, Oils, and PAH	Discharge	Dust Deposition
Construction – **proposed Madrid-Boston infrastructure**						
Cargo dock		×	×			×
Dock access road		×	×			×
Fuel pipeline and tank farm		×	×	×		
Marine transport of goods	×			×	×	×
Quarry		×	×			×
Equipment and vehicle emissions				×		×
Construction and Operations – **use of existing approved and permitted infrastructure**						
Fuel tank farm			×	×		
Laydown areas			×	×		×
Equipment and vehicle emissions				×		×
Marine discharge of TIA-groundwater					×	
Marine transport of goods	×			×	×	×
Site road use and maintenance			×	×		×
Operation – **proposed Madrid-Boston infrastructure**						
Cargo dock			×			
Use of dock access road			×	×		×
Fuel pipeline and tank farm			×	×		
Marine discharge of TIA-groundwater					×	
Marine transport of goods	×			×	×	×
Quarry			×			×
Equipment and vehicle emissions				×		×

Project Component/Activity	Sealift	Site Preparation, Construction, and Decommissioning	Site Contact Water	Fuels, Oils, and PAH	Discharge	Dust Deposition
Reclamation and Closure – use of existing approved and permitted infrastructure						
Site surface infrastructure		×	×	×		×
Equipment and vehicle emissions				×		×
Roberts Bay-Doris Road		×	×	×		×
Marine infrastructure		×	×	×		×
Marine transport of goods	×			×	×	×
Reclamation and Closure – proposed Madrid-Boston infrastructure						
Site surface infrastructure		×	×	×		×
Equipment and vehicle emissions				×		×
Dock access road		×	×	×		×
Marine infrastructure		×	×	×		×
Marine transport of goods	×			×	×	×
Quarry		×	×			×
Temporary Closure						
Care and maintenance			×	×		

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 the project component and the marine environment, for identifying applicable mitigation measures, and for characterizing the residual effects. For the effects assessment on the marine water quality VEC, the following pathways are defined:

- *runoff*, which describes the transport of material or compounds from the terrestrial environment into the marine environment by precipitation or snowmelt;
- *discharge*, which is the directed input of water into the marine environment;
- *contact*, which is the presence of Project-related infrastructure or vehicles (such as ships and barges) in the marine environment;
- *physical*, which is the direct physical effects of Project activities in the marine environment; and
- *aerial deposition*, which is the direct input of material and chemical compounds from the air into the marine environment.

The pathways applicable to each Project interaction group are summarized in Table 8.5-4. These pathways are used in the effects assessment to describe the potential effects, identify mitigation and management measures, and characterize the residual effects from Project activities.

Table 8.5-4. Pathways of Interactions with the Marine Environment for the Marine Water Quality Effects Assessment

Project Activity	Pathway	Indicators	Project Phases
Sealift activities (wakes, propeller wash, hydrocarbons, sewage, antifouling agents, ballast water)	Physical, discharge, contact, aerial deposition	TSS, nutrients, dissolved oxygen, metals, hydrocarbons	Construction, Operation, Reclamation and Closure
Site preparation, construction, and decommissioning activities	Runoff, physical	pH, TSS, nutrients, dissolved oxygen, metals, hydrocarbons	Construction, Reclamation and Closure
Site contact water	Runoff	TSS, nutrients, dissolved oxygen, metals, hydrocarbons	Construction, Operation, Reclamation and Closure, Temporary Closure
Fuels, oils, PAH	Runoff, aerial deposition	hydrocarbons	Construction, Operation, Reclamation and Closure, Temporary Closure
Discharge	Discharge	pH, TSS, nutrients, dissolved oxygen, metals, hydrocarbons	Construction, Operation, Reclamation and Closure
Dust deposition	Aerial deposition	TSS, nutrients, dissolved oxygen, metals, hydrocarbons	Construction, Operation, Reclamation and Closure

8.5.2.1 Sealift

Sealifts, fuel tankers, and ocean-going barges will deliver fuel, equipment, and supplies during the short shipping season from August through October. Ocean-going vessels will offload their cargo at either the Roberts Bay jetty (3 m depth) or the marine cargo dock (12 m water depth; Volume 1, Annex V1-7, Package P5-10). Larger fuel tankers with deeper drafts will moor offshore during fuel transfer activities.

The main pathways by which ocean-going vessels could interact with the marine environment include physical processes such as wake effects or propeller wash which could cause sediment resuspension and re-distribution, aerial deposition from ship exhaust, discharge such as the release of sewage and ballast water, and contact with ships and barges, which could result in exposure to toxic compounds if the ship's hull is treated with anti-fouling agents such as tributyltin (TBT).

Physical disturbances to sediments can result from wakes produced by ship movement and from propeller action. These processes can cause sediments to mobilize, which can increase water column concentrations of suspended sediments, and introduce sediment-associated indicators, such as metals, into the water. This suspended material can alter water quality.

The combustion of fuel by ships and tugs has the potential to alter water quality by depositing combustion by-products, such as PAH and acid-equivalents, in the marine environment. The deposition of these by-products therefore has the potential to alter water quality.

The discharge of sewage from vessels can alter the concentration of nutrients, metals, and suspended material, and alter oxygen conditions by increasing the rate of oxygen consumption. Vessels are permitted to discharge sewage into Arctic waters under the Arctic Shipping Pollution Prevention Regulations (C.R.C., c. 353) of the *Arctic Pollution Prevention Act* (1985a).

Ballast water is used to stabilize a ship and ensure that the propeller remains submerged by counterbalancing changes in weight as cargo is loaded or offloaded. Ballast water (including sediments suspended in the water) can be taken in at one port and discharged in another. The release of ballast water can alter water quality by introducing metals, sediments, and hydrocarbons in the marine environment. For the Hope Bay Development, ballast water will most often be taken on in Roberts Bay to counterbalance offloaded fuel and cargo. If the discharge of ballast water is required, ocean-going vessels will follow the Ballast Water Control and Management Regulations (SOR/2011-237) under the *Canada Shipping Act* (2001). This will ensure that ballast water is exchanged offshore outside of Roberts Bay. The effects of ballast water discharge on the water quality in Roberts Bay will be eliminated by avoidance and adherence to federal regulations, and are not considered further as potential effects.

Ocean-going vessels are also generally associated with the use of anti-fouling agents to prevent the accumulation of organisms such as barnacles or mussels that can interfere with the drag of a ship, increase fuel costs, and damage propulsion systems. Historically, TBT has been the most common biocide used in anti-fouling paints. Leaching from anti-fouling paints may cause increased concentrations of TBT in the water, which could affect the health of marine organisms. Ships will adhere to the Vessel Pollution and Dangerous Chemicals Regulations (SOR/2012-69) under the *Canada Shipping Act* (2001), which ban the use of anti-fouling systems that use organotin compounds (such as TBT) as biocides on all ships in Canadian waters or require that a coating be applied to anti-fouling paint to create a barrier to leaching of organotins into marine environments. The potential leaching of anti-fouling agents from ships will be eliminated by the adherence of vessels to federal regulations, and are not assessed further as potential effects.

The potential effects from sealifts may occur during the Construction, Operation, and Reclamation and Closure phases of the Project.

8.5.2.2 Site Preparation, Construction, and Decommissioning

The proposed Madrid-Boston infrastructure located in or near Roberts Bay that could interact with marine water quality because of site preparation, construction, and decommissioning activities includes a marine dock and access road, a fuel pipeline and tank farm, and two potential quarries (Table 8.5-3). The pathways of interaction between site preparation, construction, and decommissioning activities and the marine environment are through physical contact and runoff, and the Project phases during which this interaction could occur are Construction and Reclamation and Closure (Table 8.5-4).

The physical effect pathway linking the site preparation, construction, and decommissioning activities and the marine environment is the in-water work required to construct the cargo dock, such as the installation of sheet piles using a vibratory hammer. Physical vibration and in-water works may affect water quality by disturbing and mobilizing sediments, which can alter water column concentrations of suspended sediments and metals.

Site preparation, construction, and decommissioning activities will also interact with the marine environment through the runoff pathway. The clearing of overburden, construction of earthworks, and the construction and decommissioning of pads and infrastructure can affect the marine environment through the runoff of eroded terrestrial material from pad and working surfaces. Site preparation and construction of the quarry would also require blasting, which could introduce explosive residues into runoff water. The introduction of materials through runoff could affect the concentrations of metals, organic carbon, and hydrocarbons in the marine environment. Runoff would be expected to occur mainly during snowmelt and freshet in the spring, following rainfall events in the summer and fall, and would be absent in the winter.

8.5.2.3 Site Contact Water

Site contact water is defined as the runoff from snowmelt and precipitation events that interacts with geochemically neutral site infrastructure including roads, laydown areas, quarries, and buildings. Site contact water is considered separately from the potential effects of site preparation, construction, and decommissioning because the degree of disturbance is much lower, and because mitigation and management measures will be fully applied once construction is complete. The interaction between runoff and infrastructure could transport suspended material, metals, nutrients, organic matter, and petroleum hydrocarbon compounds into the marine environment if not managed or mitigated. The potential for effects from site contact water could occur during all phases of the Madrid-Boston Project (Table 8.5-3).

8.5.2.4 Fuels, Oils, and PAH

The transportation, transfer, storage, handling, and use of fuels and other petroleum products have the potential to introduce hydrocarbons into the marine environment and affect water quality. Unlikely events such as pipeline rupture or spills during transportation or transfer are addressed in Accidents and Malfunctions (Volume 7, Chapter 1) since these events will not occur under normal operating conditions. The combustion of fuels and the incineration of waste can generate PAH, which can then be deposited into the marine environment and alter water quality.

The pathways by which fuels, oils, and PAH could enter the marine environment include runoff from terrestrial sources and aerial deposition. Fuel will be shipped to site during the Construction and Operation phases by double-hulled fuel tankers. Fuel will be unloaded at either the Roberts Bay jetty or the cargo dock and transferred to the tank farm by hose or pipeline (Project Description, Volume 3). From the Roberts Bay main tank farm, tanker trucks will distribute fuel to designated storage areas and tank farms at Doris, Madrid, and Boston, as required. Activities at facilities, laydown areas, fuel storage areas, fueling stations, roads, and waste management areas can result in leaks or deposits of hydrocarbons such as fuel, oil, or grease onto surfaces that can subsequently be transported into the marine environment through runoff.

Waste management practices will include the incineration of food waste, sewage sludge, and limited portions of paper products and/or oily rags (Volume 3, Chapter 2). The incineration of wastes could produce PAH as a by-product of incomplete combustion of organic matter. These airborne PAH can then enter the marine environment directly by aerial deposition, or be deposited on land and enter the marine environment through runoff.

The potential effects from fuels and other hydrocarbons on marine water quality may occur during the Construction, Operation, Reclamation and Closure, and Temporary Closure phases (Table 8.5-3).

8.5.2.5 Discharge

The discharge of TIA and saline groundwater from the Roberts Bay Discharge System has the potential to affect marine water quality. The pathway of interaction between this discharge and marine water quality is the direct input of water into the marine environment. The discharge could alter the concentrations of nutrients, metals, and suspended solids into the marine environment. Discharge inputs could also affect other chemical properties of the water such as pH, dissolved oxygen, and salinity. The potential effects due to discharge into the marine environment could occur during all Project phases, except Temporary Closure (Table 8.5-3).

8.5.2.6 Dust Deposition

Dust can be generated by a variety of Madrid-Boston Project activities, including vehicle traffic, airstrip activities, blasting activities, and quarry operations. Areas cleared for infrastructure (e.g., laydown areas) could also be sources of dust. The aerial deposition of the Project-generated dust is the primary pathway of interaction. Deposited dust could affect marine water quality by altering the concentration of suspended material and associated metals and hydrocarbons in the marine environment. The potential effects from dust deposition may occur during the Construction, Operation, and Reclamation and Closure phases (Table 8.5-3).

8.5.3 Mitigation and Adaptive Management

Mitigation and management measures were identified through the construction and operation of the Doris Project; a review of best management practices from similar mining projects in the Arctic; comments from community members during scoping meetings; formal review by the KIA, ECCC, INAC, and DFO of the existing Doris Project management plan (the Aquatic Effects Monitoring Plan) and Roberts Bay Environmental Effects Monitoring (EEM) plan; scientific literature; and professional experience.

Many of the mitigations applied to the construction and operation of the Doris Project to date will be applied during Madrid-Boston development. The efficacy of these mitigation and management measures, as they apply to marine water quality, has been assessed through the Doris AEMP since 2010 (e.g., ERM 2017a). Two sites have been sampled in Roberts Bay since 2010 to address potential effects from activities associated with the Doris watershed (Site RBE) and the Roberts Bay Laydown Area and jetty (Site RBW). The annual evaluation of marine water quality has shown that there have been no effects in Roberts Bay related to Doris construction and operation activities. This indicates that the mitigation and management measures applied by TMAC during the Doris Project have been effective in managing potential effects to marine water quality in Roberts Bay.

8.5.3.1 Mitigation by Project Design

The following measures are included in the design of the Project to minimize or eliminate potential effects on marine water quality:

- Use of existing infrastructure associated with the Doris Project.
- Inclusion of climate change projections for key climatic and hydrologic design details (Package P5-2).
- Minimizing overall footprint and volume of contact water.
- Planned set-backs and buffer zones from waterways.
- Avoidance, as required and feasible, of sensitive features, including riparian ecosystems and floodplains, esker complexes, wetlands, shallow open ponds, marshes, bedrock cliffs, beaches, intertidal areas, and marine backshores.
- Applying speed limits to vehicles travelling on roads to reduce generation of dust.
- Only 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, and ultimately to the marine environment.
- 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.
- Ships will be conventional double-hulled, compartmentalized petroleum tankers, with Shipboard Oil Pollution Emergency Plans and appropriate response gear.
- Minimize groundwater inflows at the Madrid North and Madrid South mines through grouting as necessary.

The design of the Madrid-Boston Project will also adhere to regulatory requirements relevant to the mitigation of potential effects on the marine environment. These regulatory requirements include 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.
- Ships will carry out their operations in accordance with federal and territorial acts and regulations relating to vessel discharges, the transportation of dangerous goods, and anti-fouling surface treatments including the Arctic Waters Pollution Prevention Regulations (C.R.C., c. 354) and the Arctic Shipping Pollution Prevention Regulations (C.R.C., c. 353), under the *Arctic Waters Pollution Prevention Act* (1985a); the Vessel Pollution and Dangerous Chemicals Regulations (SOR/2012-69) and the Ballast Water Control and Management Regulations (SOR/2011-237) under the *Canada Shipping Act* (2001); and the *Transportation of Dangerous Goods Act* (1992).
- The Oil Pollution Prevention Plan (OPPP)/Oil Pollution Emergency Plan (OPEP; Volume 8, Annex V8-1) for Roberts Bay will be updated and submitted to Transport Canada for review on an annual basis.
- The bulk fuel storage facility and all transfer-related equipment will be inspected and maintained, with complete documentation.
- 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* (1985b).
- 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).

8.5.3.2 Best Management Practices

Reducing potential effects to marine water quality by avoidance is the most effective mitigation measure. As discussed in Section 8.5.3.1, the design of the Madrid-Boston Project includes a number of features to avoid potential effects. Marine-related management and mitigation measures are described in TMAC's management plans, including the following:

- OPPP/OPEP (Volume 8, Annex V8-1);

- Air Quality Management Plan (Volume 8, Annex V8-2);
- Hope Bay Project Spill Contingency Plan (Package P4-3);
- Hope Bay Quarry Management and Monitoring Plan (Package P4-17); and
- Hope Bay Project Aquatic Effects Monitoring Plan (Package P4-18).

The Roberts Bay Discharge System will discharge water from the TIA, as well as site contact water from the Doris, Madrid North, and Madrid South sites and groundwater. The quality of the effluent will be mitigated and management by the following plans, which therefore have indirect influences on marine water quality in Roberts Bay:

- Doris Project Domestic Wastewater Treatment Management Plan (Package P4-4);
- Hope Bay Project Groundwater Management Plan (Package P4-6);
- Hope Bay Project Doris-Madrid Water Management Plan (Package P4-7);
- Hope Bay Project Doris-Madrid Tailings Impoundment Area Operations, Maintenance, and Surveillance Manual (Package P4-9);
- 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); and
- Hope Bay Project Incinerator Management Plan (Package P4-16).

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

- Implementation of sediment control measures for works in or near the marine environment, 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.
- 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 ocean.

- Sewage will be treated and the effluent will be discharged to the TIA or onto the tundra. Sewage sludge will be incinerated or disposed with the backfill waste. No sewage from Hope Bay Development sites will be discharged directly to Roberts Bay.
- Mine water from Doris and water from the Doris TIA will be treated for arsenic prior to discharge in Roberts Bay.
- Sediment control measures for in-water works as required by DFO authorizations.
- 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 report 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 contact water ponds for management and/or transported directly to the TIA for disposal, and will therefore not contact the marine environment
- High quality ammonium nitrate and fuel oil (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 runoff.
- 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.
- 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 marine water quality:
  - Physical, chemical and biological monitoring and treatments will continue to follow Project licence and permit requirements.
  - Fuel, hazardous wastes and explosives will be properly stored or removed from site.
  - Surface water management and sediment and erosion control will continue as needed.
- Vessels will be prohibited from discharging untreated sewage in Roberts Bay and will only discharge sewage when transiting in open-waters away from shore.
- Vessels will exchange ballast water in the alternative exchange areas outlined in the Section 7(3) of the Ballast Control and Management Regulations (SOR/2011-237).

- Speed limits will be followed for vessel operations to minimize propeller wash and wake effects.
- The OPPP/OPEP detail the procedures and best practices to follow for fuel transfer to minimize leaks or spills, and describe the response and clean-up measures to follow in the event of a spill, which include:
  - measures to protect personnel and the environment;
  - spill response management, emergency response procedures, and reporting and notification protocols;
  - description of the spill containment and skimming equipment and deployment plans; and
  - training and auditing programs.
- 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).

8.5.3.3 Proposed Monitoring Plans and Adaptive Management

A Marine EEM Program established under the MMER will be in place that outlines the monitoring program in the marine environment that will be carried out during all phases of the Project. The Marine EEM Program will include the following:

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

In addition, the construction of the cargo dock is anticipated to require authorization under the *Fisheries Act* (1985b), which will likely include monitoring for potential construction-related effects on the marine environment. This construction monitoring will be tied to specific adaptive management responses designed to minimize the effects on the environment, such as the installation of silt curtains in the advent of elevated suspended sediment concentrations in the cargo dock construction area.

Regular inspections of water management facilities will be conducted by on-site Environmental Personnel, the KIA, and other federal agencies such as ECCC, INAC, and DFO.

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.

8.5.4 Characterization of Potential Effects on Marine Water Quality

The potential for effects on marine water quality from the Project activities identified in Section 8.5.2 are assessed in this section using both quantitative water quality modelling as well as qualitative methods, including a combination of best available data and professional judgment/experience. 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 or persist 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 8.5.5). Residual effects of the Project can occur directly or indirectly. Direct effects result from direct interactions between Project activities and marine water quality (e.g., discharge to Roberts Bay). Indirect effects can occur when the primary effect is to another component of the environment (e.g., air quality), which can lead to secondary or indirect effects on marine water quality. The characterization of potential effects considers both the incremental effects of Madrid-Boston activities as well as the overall effects from all components of the Hope Bay Development.

8.5.4.1 Sealift

Characterization of Madrid-Boston Project Potential Effects

Sealifts could potentially affect marine water quality through physical disturbance (propeller wash and ship-generated wakes), sewage discharge, and airborne emissions. Approximately five to seven vessels are expected to report to Roberts Bay each year during the Construction and Operation phases of the Madrid-Boston Project, and potentially for a short period during Reclamation and Closure. The Madrid-Boston Project will extend the vessel traffic 13 years beyond the 6-year lifespan of the existing and approved projects.

The potential effects of vessels moving within the LSA and RSA were analyzed using an empirical equation developed by Kriebel, Seelig, and Judge (2003) to predict maximum ship-generated wake heights using a "modified Froude number". This approach successfully unified a high degree of variation in 1,200+ data points from a wide range of vessel types. This equation is as follows:

$$gH/V^2 = \beta(F_*-0.1)^2(y/L)^{-0.33}$$

where the "modified Froude number" $F_*=F_L\exp(\alpha\times T/d)$
- H = wake height (m)
- V = ship speed (m)
- y = distance from sailing line (m)
- L = length of ship (m)
- d = water depth (m)
- T = draft of ship (m)
- g = gravitational acceleration (m/s^2)
- F_L = length based Froude number = $V/(gL)^{0.5}$

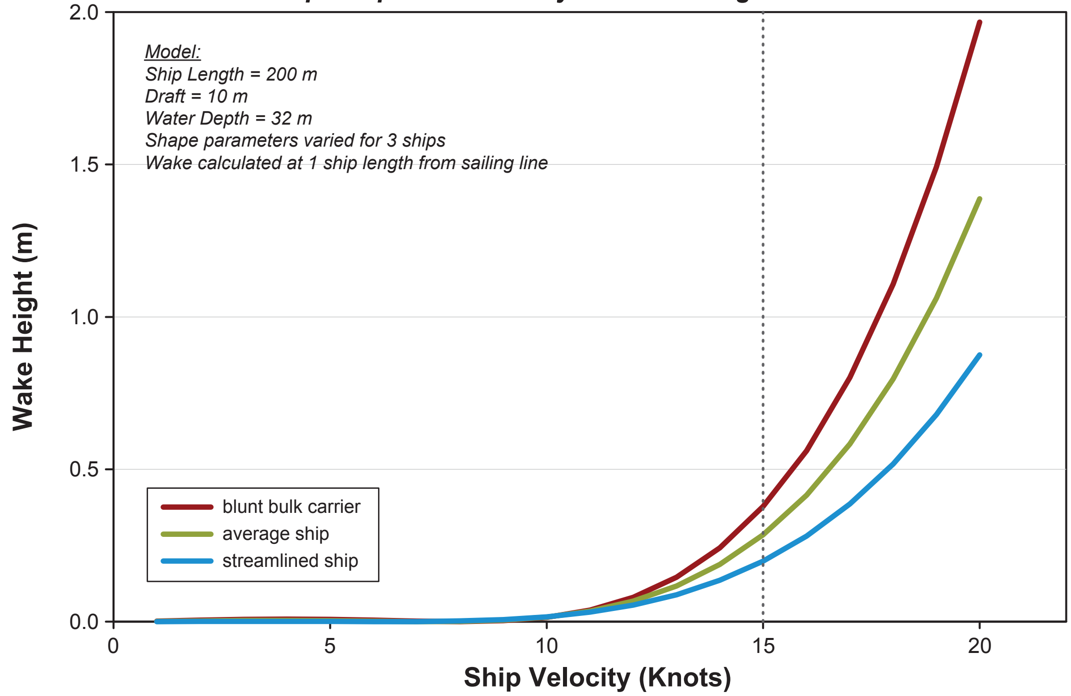
where α and β are coefficients related to variation in shape of ships.

Using the above equations, maximum predicted wake heights are calculated for varying ship speeds assuming a ship of 200 m length and 10 m draft. For Roberts Bay and Melville Sound, a water depth of 32 m is used (average water depth in Melville Sound, slightly less than the 36 m average water depth in Roberts Bay) and for Bathurst Inlet, a water depth of 61 m (average water depth in northern Bathurst Inlet). Ship shape parameters are set to a medium range tanker (25,000 to 45,000 DWT; deadweight tonnage) with a blunt bow, and are varied to simulate "average" or "streamlined vessels" of the same dimensions (Figures 8.5-1 and 8.5-2). Wake height is influenced by vessel speed and the shape of the ship. The blunt bow vessel generated an estimated wake height of about 0.38 m in Roberts Bay and Melville Sound, and 0.32 m in northern Bathurst Inlet at a "maximum" speed of 15 knots. This decreased to less than 0.2 m at 2 km from the sailing line at both water depths (Figures 8.5-1 and 8.5-2). Wakes are predicted to be mitigated substantially by a relatively modest reduction in ship speed; the bulk carrier operating at the more typical 10 knots would theoretically generate a wake of only 0.014 m in Roberts Bay and Melville Sound or 0.009 m in Bathurst Inlet at one ship length from the sailing line.

Figure 8.5-1

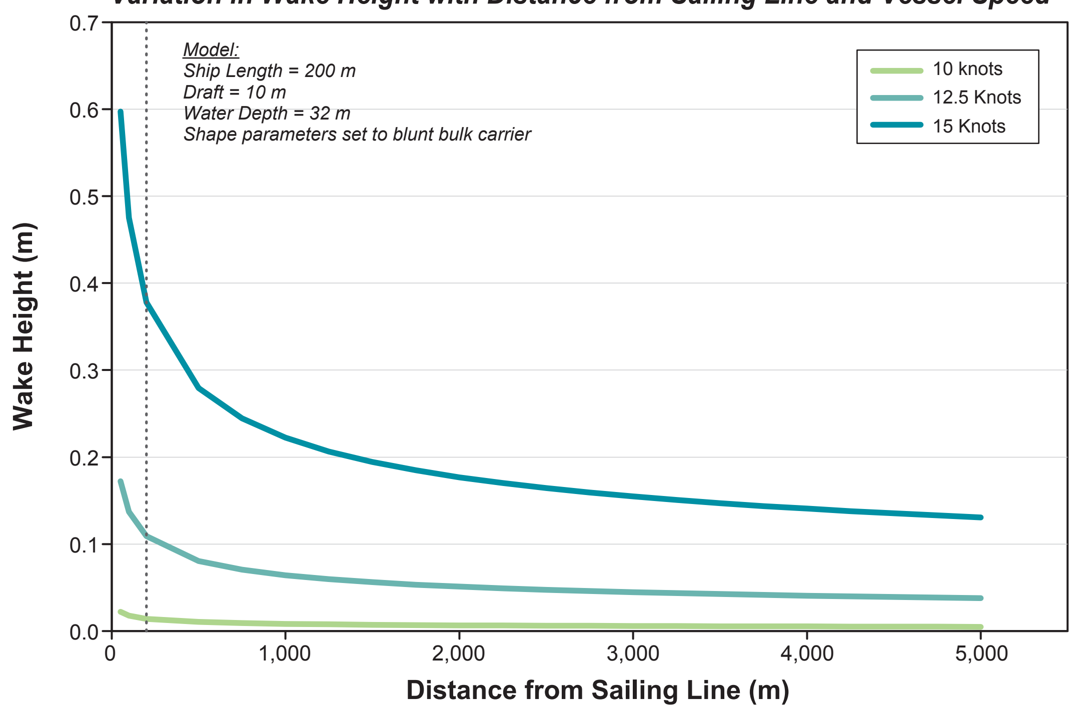
Modelled Wake Heights
Generated by Ships in Roberts Bay and Melville Sound

Influence of Ship Shape and Velocity on Wake Height



Note: Dotted line shows maximum speed of 15 knots for bulk carrier

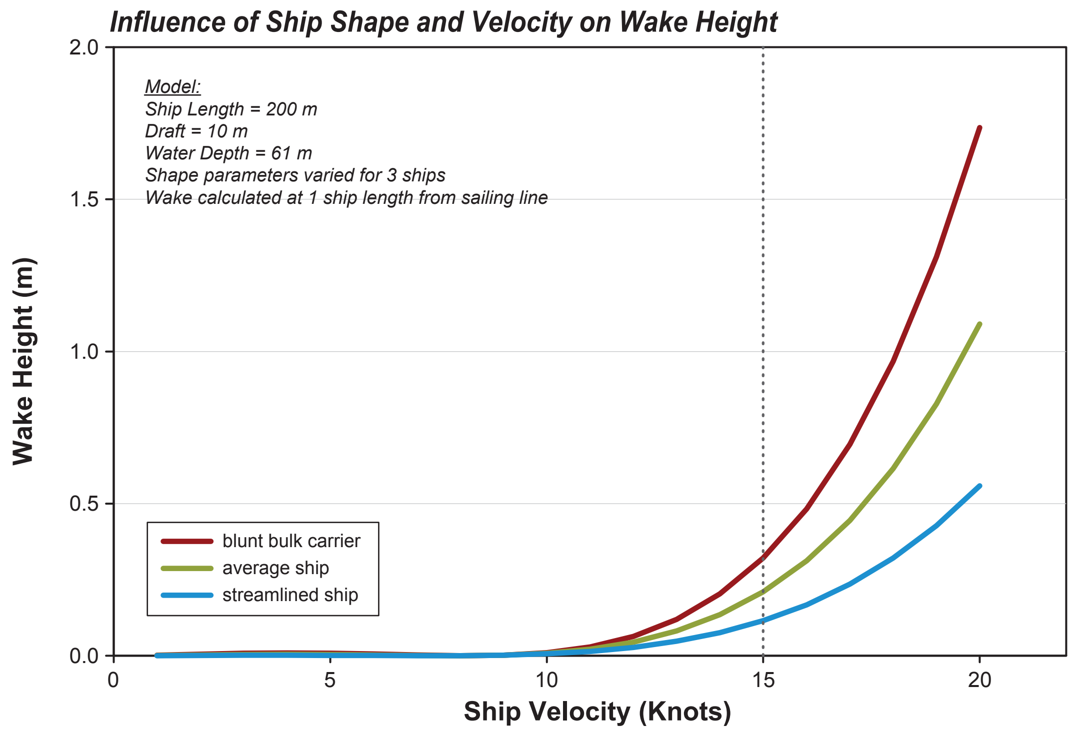
Variation in Wake Height with Distance from Sailing Line and Vessel Speed



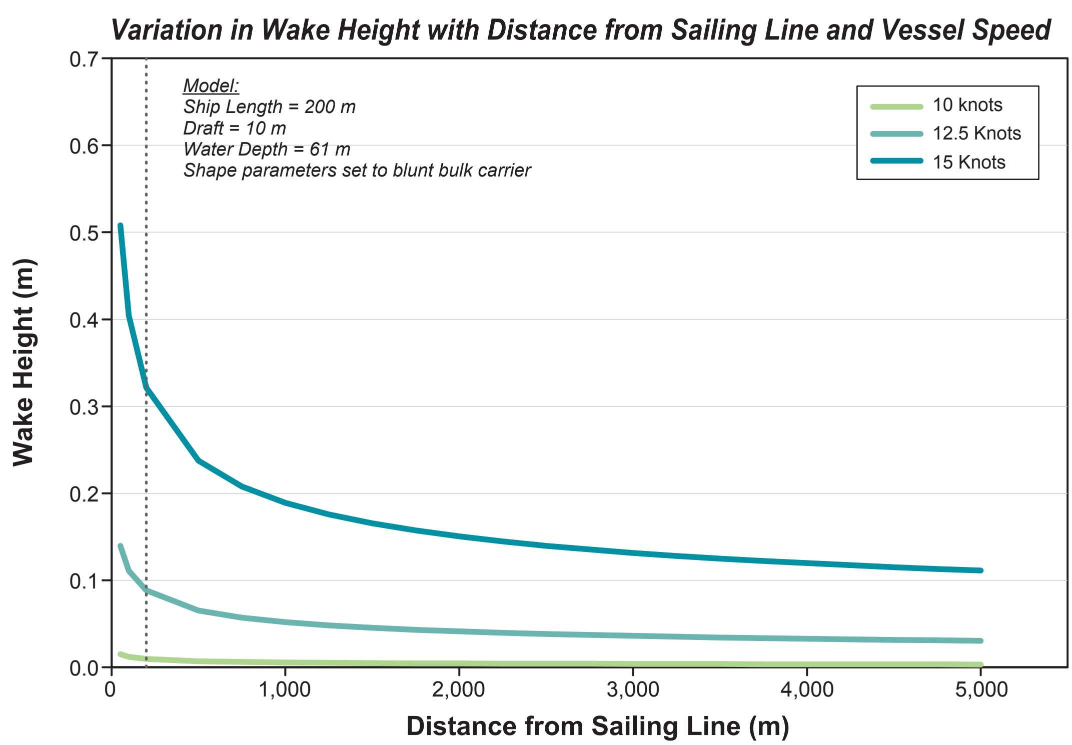
Note: Dotted line shows distance of one ship length (200 m) from sailing line.

Figure 8.5-2

Modelled Wake Heights
Generated by Ships in Bathurst Inlet



Note: Dotted line shows maximum speed of 15 knots for bulk carrier



Note: Dotted line shows distance of one ship length (200 m) from sailing line.

Maximum wave heights of ~0.5 m were estimated in Roberts Bay in 2011 (Rescan 2012b). Direct measurements in Bathurst Inlet in 2012 showed a persistent pattern of winds dominated by north and northwesterlies, and speeds typically in the range of 2 to 7 m/s, sometimes exceeding 11 m/s (Rescan 2012b). Maximum wave heights of ~1.2 m were observed in Bathurst Inlet in 2013 (ERM 2015a). The observations in Roberts Bay and Bathurst Inlet suggest that wind in the LSA and RSA could generate wind waves of approximately 0.5 to 3 m in height during sustained wind speeds in excess of 20 m/s and in areas with fetches of over 10 km (Bornhold 2008). Wind generated waves for Roberts Bay and Bathurst Inlet can be hind-cast from Cambridge Bay climate statistics, with average wind speeds of 5.5 to 6.4 m/s mainly from the north and north-west. Wind speeds in excess of 17.5 m/s occurred on average between 0.5 and 1.7 days per month between July and October. Direct measurements in Roberts Bay in 2011 showed a fairly persistent pattern alternating between general eastern and western directions, with strong inputs from the north in early summer. Wind velocities were typically in the range of 2 to 7 m/s but were recorded regularly above 10 m/s. In August, westerly and northerly winds weakened slightly, and easterlies increased in frequency and intensity with about 50% above 10 m/s and maximum velocities as great as 21 m/s.

For the purpose of comparing wakes with wind-generated waves, the approach of Bornhold (2008) is adopted. In Roberts Bay and Melville Sound, bulk carriers will operate at a typical speed of 10 knots or less. At this speed, the power of the calculated wake of 0.014 m in height with a wave period of 8 s is 0.0015 kW/m. This is considerably lower than the estimated power of between 0.24 and 0.85 kW/m for wind-generated waves in Roberts Bay with heights of 0.5 m and periods of 1 to 3.5 s (Rescan 2012b). In Bathurst Inlet, bulk carriers could operate at a maximum speed of 15 knots. The power of the calculated maximum wake of 0.32 m in height with a period of 8 s is 0.8 kW/m, which is lower than the estimated power of between 2.81 and 7.02 kW/m for the observed wind-generated waves in Bathurst Inlet of 1.2 m in height with wave periods of 2 to 5 s (ERM 2015a).

The effect of ships wakes on shorelines was also examined using the concept of “closure depth”, which is a measure of the depth (assuming a given grain size) to which wave reworking of the sediments is significant (Bornhold 2008). Using the maximum calculated ship generated wake of 0.32 m in height with a wave period of 8 s in Bathurst Inlet, a closure depth of 0.72 m was calculated. This is at the lower end of the range of closure depths of 0.2 to 2.3 m for wind-generated waves of 1.2 m in height with 2 to 5 s periods. The measure of closure depth assumes that wave conditions that result in changes in seafloor morphology occur over a minimum time period of 12 hours per year (Hallermeier 1981). However, Project-related vessel traffic is projected to be low, (seven vessels per year or fewer; Volume 3, Chapter 2), and the resulting wakes will persist only for seconds or minutes each year. In contrast, wind-generated waves of at least 1 m in height are likely to occur at least 1 day per month or more during the open-water season.

The primary environmental effects of ship wakes have been associated with narrow channels such as rivers and estuaries, where wake effects become relatively amplified by proximity to the shore and potentially exacerbated by reduced wind-induced waves in confined waters. In a river channel in Sweden of 8 m average depth (Althage 2010), wakes of 0.2 to 0.4 m generated short-term increases (1 to 2 h) in turbidity averaging 3.3 NTU (range between 0 and 16.9 NTU). This is of the same order of magnitude of turbidity in the LSA, which averaged 2.1 NTU (range between 0.22 and 16 NTU) in the nearshore shallow area, and turbidity for the RSA, which averaged 1.2 NTU (range between 0.22 and 9.4 NTU) in the nearshore shallow area (Table 8.2-5). The turbidity levels in the offshore areas of the LSA and RSA are lower than in the nearshore areas.

In short, episodic storm events are likely to generate waves of the order of 1 m or greater, on a time scale of hours or days per month, whilst maximum wakes of 0.32 m in height generated by a 200 m length vessel operating at a maximum speed of 15 knots in waters of Bathurst Inlet would be generated on a timescale of minutes per month. Wake heights depend strongly on the speed of ship, and proximity to shore, and will be fully mitigated by reductions in vessel speed. Therefore, there are no predicted residual effects to the marine water quality VEC from vessel wakes.

The wash from propellers of large vessels can be large enough to disturb marine sediments, with the potential effects of suspended sediments (and associated nutrients and metals) entering the water column. To estimate the potential significance to Roberts Bay and Melville Sound, maximum bottom velocities in the propeller wash of a maneuvering vessel are calculated using the equations of Maynord (1998):

Jet velocity (U_0) of water exiting a propeller:

$$U_0 = C \times [P_d / D_p^2]^{0.33}$$

and the maximum velocity ($V_b$max) of the propeller wash on the sea bottom:

$$V_b(max) = CU_0D_p / H_p$$

Where U_0 = jet velocity of water exiting the propeller (feet/sec)
V_b(max) = maximum bottom velocity (feet/sec)
D_p = propeller diameter in feet
H_p = distance from propeller shaft to channel bottom (feet)
P_d = applied engine power/propeller in (hp)
C_1 = 0.30, and C_2 =7.68 for ducted propellers (Maynord 1998)

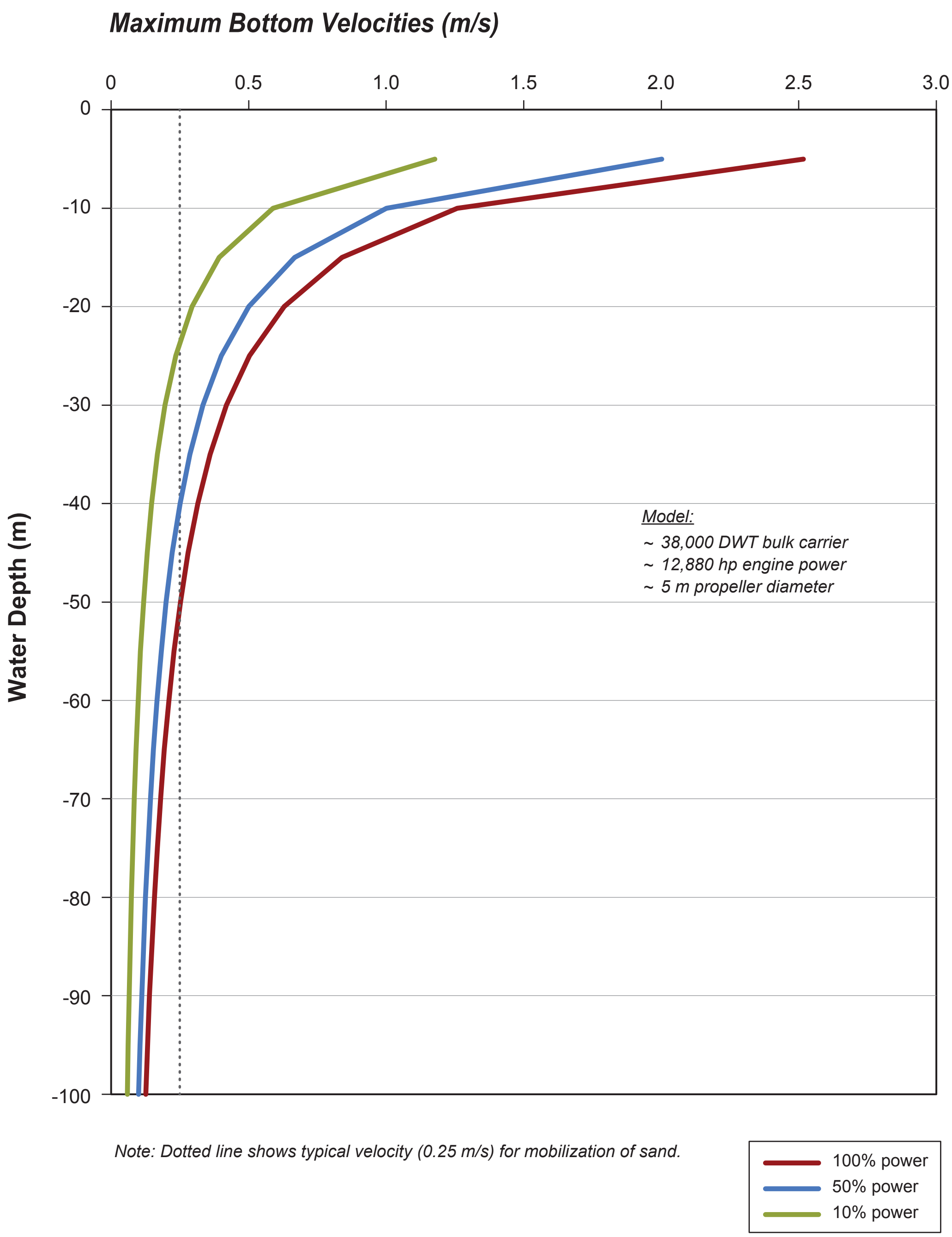
A vessel displacement of 38,000 DWT was assumed (Handysize tanker), with a 12,880 hp engine power and a 5 m diameter propeller. The outputs of the calculations are then converted into metric units. The applied engine power to the propeller is one of the more difficult parameters to estimate (Maynord 1998), and so bottom velocities are calculated at 10, 50, and 100% available engine power.

Sand may be mobilized in bottom sediments at a water velocity of approximately 0.25 m/s. Therefore, sediment re-suspension could occur in Roberts Bay (average depth of 36 m) and Melville Sound (average depth 32 m) if a vessel operated at full power. At full power, a vessel could generate bottom water velocities of the order of 0.25 m/s at depths of 50 m or less. A vessel operating between 10 and 50% of full power could mobilize sediments to some extent above approximately 24 m to 40 m depth (Figure 8.5-3). The currents are relatively weak in Roberts Bay, including the wind-driven currents between 0.03 and 0.1 m/s (Rescan 2012b). The estimated velocities of propeller wash deeper than 50 m are therefore of the same order as those observed for wind-driven currents during the open-water season. In the shallower waters of Roberts Bay and Melville Sound (average depth 32 m), the maneuvering of vessels are more likely to produce bottom velocities greater than naturally observed currents, even when mitigated by reduced engine power (Figure 8.5-3). Here, some sediment mobilization and exchange with the water column may be observed.

The mobilization of metals into the water column with sediments is a naturally occurring process. Naturally elevated concentrations of arsenic, cadmium, and chromium greater than CCME guidelines were observed in a small number of water quality samples in the LSA and RSA. These water column concentrations were likely the result of sediment-water interactions—natural concentrations of arsenic, chromium, and copper are greater than the CCME sediment quality guidelines in some nearshore and offshore sediments in the LSA and RSA (Table 9.2-5, Marine Sediment Quality, Volume 5, Chapter 9). Therefore, the concentrations of these metals in the water column can be naturally elevated and are not expected to be increased by propeller wash beyond the range of natural variation. The localized increases in concentrations would be near the sediments, and therefore unlikely to reach into surface waters. However, a residual effect to water quality is identified because of the potential for small, near-bottom changes in the water column concentrations of suspended sediments and associated metals. This residual effect from propeller wash is characterized in Section 8.5.5.3.

Figure 8.5-3

Depth Variation in Modelled Water Velocity Generated by Propeller Wash



Note: Dotted line shows typical velocity (0.25 m/s) for mobilization of sand.

Airborne emissions from vessels will be mitigated under the Vessel Pollution and Dangerous Chemicals Regulations (SOR/2012-69). The regulations put controls on ozone-depleting substances, a reduction of sulphur content in fuels in Arctic waters by January 1, 2020 (from 3.5% to 0.5% by mass), and prohibits the incineration of oil residues, polychlorinated biphenyls (PCB), garbage containing more than traces of heavy metals, as well as the burning of sewage sludge and sludge oil inside ports, harbours, or estuaries (Vessel Pollution and Dangerous Chemicals Regulations (SOR/2012-69); Division 6). The potential effects resulting from ship-borne emissions are rated as *not significant* for the air quality VEC (Volume 4, Chapter 2). Accordingly, no potential residual effects to the marine water quality are identified from ship-borne emissions and this is not assessed further.

The discharge of sewage from vessels can alter the concentration of nutrients, metals, and suspended material, and alter oxygen conditions by increasing the rate of oxygen consumption. Vessels are permitted to discharge sewage into Arctic waters under the Arctic Shipping Pollution Prevention Regulations (C.R.C., c. 353) of the *Arctic Pollution Prevention Act* (1985a). However, vessels will be prohibited from discharging untreated sewage in Roberts Bay and will only discharge sewage when transiting in open-waters away from shore. The discharge of vessel waste is eliminated as a potential effect through avoidance and management measures, and vessel sewage discharge is not assessed further.

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

The Madrid-Boston Project will add to the overall vessel traffic and to the expected duration of sealift activities associated with the Hope Bay Development. Although the total number of ships reporting to Roberts Bay and the duration of sealift activities associated with the Hope Bay Development are increased by the Madrid-Boston Project, the characterization of effects and mitigation measures for the Madrid-Boston Project sealift activities apply equally to the sealift activities supporting the Hope Bay Development as a whole. As is the case for the Madrid-Boston Project characterization of effects, propeller wash from sea-going vessels is identified as a potential residual effect to marine water quality for the Hope Bay Development. This will be further assessed in Section 8.5.5.3.

8.5.4.2 Site Preparation, Construction, and Decommissioning

The disturbance of the landscape through the construction of infrastructure such as roads and pads creates the potential for runoff that can influence the marine environment. The primary indicator of change would be the concentration of suspended sediments in the water (TSS; Table 8.5-4). The primary goal of erosion control and sedimentation mitigation 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. Although identified mitigation and best management strategies (Section 8.5.3) are effective in minimizing erosion, sedimentation, and potential siltation of the water column in the receiving environment, these strategies may not fully prevent all mobilization of sediments and transport into the marine environment. Thus, a potential residual effect from construction and decommissioning activities on marine water quality may occur. Changes to water quality during construction and decommissioning activities will be monitored to ensure drainage and erosion controls are effective.

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

The Madrid-Boston construction and decommissioning activities include the development of the cargo dock, the cargo dock access road, and the expansion of laydown areas and the fuel tank farm. Although the mitigation and management measures are known to be effective, a potential residual effect from construction and decommissioning activities on marine water quality may occur. These residual effects to water quality are anticipated to be related to the transport of suspended material (TSS) that may create localized increases in the concentrations of suspended sediments and sediment-associated metals. These residual effects are anticipated to occur during or immediately after the construction or decommissioning activities, when surface materials will likely be disturbed, and have the greatest potential to occur during periods of significant overland flow, such as freshet and rainfall events.

Construction of the cargo dock includes the installation of sheet-pile bulkheads and armour rock (Package P5-10). These physical disturbances in the marine environment have the potential to re-suspend sediments and locally increase the concentrations of suspended sediments and metals in the water column. Some disturbances to sediments are likely to occur, but are expected to be limited to the dock footprint and marine buffer zone around the dock within the PDA. Potential effects of the dock construction will be contained within the PDA as much as feasible during all phases of cargo dock construction. The monitoring and adaptive management of in-water construction through the Fisheries Authorization will limit turbidity levels surrounding the cargo dock and will ensure that suspended sediments are within the acceptable range of CCME water quality guidelines in the LSA. At closure, the cargo dock will remain, so the potential for direct physical effects of the marine dock on water quality are limited to the Construction phase.

Suspended sediment concentrations are variable in the shallow, near-shore marine environment in Roberts Bay (range: < 2 to 27 mg/L; Table 8.2-5). Elevated TSS concentrations occur naturally as a result of the re-suspension of sediments from wind and wave action. The localized addition of material in runoff may result in a short-term change in TSS or turbidity; however, the known effectiveness of the mitigation and management measures were 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. Furthermore, the duration of any changes in water quality from runoff during construction and decommissioning activities would be limited to periods with overland flow, as well as limited by the duration of activities.

The potential for residual effects for the Madrid-Boston development from site preparation, construction, and decommissioning is anticipated for the Construction and Reclamation and Closure phases. These residual effects are characterized in Section 8.5.5.3.

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

Existing and planned infrastructure in Roberts Bay as part of the Doris Project includes the marine jetty, and the future installation of the Roberts Bay Discharge System that is comprised of a marine outfall berm, subsea pipeline, and diffuser system. The construction of the jetty was completed in 2007, so any construction-related disturbances occurred in the past. These past residual effects were negligible, because no construction-related effects have been observed in Roberts Bay through the Doris AEMP. The construction of the Roberts Bay Discharge System has the potential for localized increases in suspended sediment and metals resulting from the re-suspension of sediments during the installation of cement anchors. The installation of the marine outfall pipeline is expected to be completed before construction associated with the Madrid-Boston Project begins in 2019, so there will be no temporal overlap in the in-water construction activities. The potential residual effects from all of the Hope Bay Development works near Roberts Bay do not temporally overlap. As a result, any localized, short-term changes in marine water quality will not coincide, and there is minimal potential for a cumulative effect 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 residual effects.

However, decommissioning activities will occur throughout the Project areas, and include the decommissioning of infrastructure at Roberts Bay. The effective mitigation and management measures will be applied, but a potential for residual effects from decommissioning activities remain. As discussed in the section for the Madrid-Boston potential effects, runoff during periods of decommissioning activities may transport suspended material into the marine environment. The application of mitigation and management measures are predicted to maintain receiving environment concentrations within applicable guidelines, but the potential for increased concentrations relative to baseline conditions on a local scale remains possible. However, the localized and short-term anticipated effects from decommissioning activities remain similar to the residual effects expected for Madrid-Boston. The Madrid-Boston Project will physically interact with marine sediments in Roberts Bay during the construction of the marine dock, which will cause local disturbance of sediments that could alter the concentrations of suspended sediments in Roberts Bay.

The potential for residual effects from site preparation, construction, and decommissioning is anticipated for the Construction and Reclamation and Closure phases. These residual effects are characterized in Section 8.5.5.3.

8.5.4.3 Site Contact Water

Characterization of Madrid-Boston Project Potential Effects

Site contact water has the potential to affect marine water quality through the runoff pathway. Potential effects are expected to be minimized by the proposed management and mitigation measures described in Section 8.5.3. Infrastructure around Roberts Bay will be set back from or avoid sensitive beaches, shorelines, and intertidal areas and will be located, wherever feasible, on bedrock or other suitable base material. Only geochemically suitable rock quarries and borrow sources (non-acid-generating rock) will be used to construct roads, pads, and structures, minimizing the potential for site contact water to transport acid equivalents or metals into the marine environment. As described in the Water Management Plan (Package P4-7), locating infrastructure pads within diversion berms and grading surfaces towards pollution control or sedimentation ponds ensures that runoff and seepage will flow to the select ponds for management. Diversion berms may be constructed to temporarily route water away from infrastructure as needed, to prevent contact.

Some site water (e.g., runoff from roads, laydown areas, and quarries) could enter the marine environment. However, mitigation and management measures such as the use of geochemically suitable material for construction, erosion controls, and sediment barriers, are anticipated to be effective. No effects to marine water quality have been observed in Roberts Bay that are attributable to current infrastructure, which includes roads, laydown areas, and a tank farm. Any potential effects to marine water quality from runoff are predicted to be localized. Suspended sediment concentrations are variable, with periodic elevated levels in the near-shore marine environment in Roberts Bay (Table 8.2-5); however, the localized addition of material in runoff may result in a short-term change in TSS or turbidity. However, 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. Furthermore, the duration of any changes in water quality from site contact water would be limited to periods with overland flow.

The potential for residual effects from site contact water from the Madrid-Boston development is anticipated for the Construction, Operation, Temporary Closure, and Reclamation and Closure phases. These residual effects are characterized in Section 8.5.5.3.

Characterization of Hope Bay Development Potential Effects

The characterization of effects associated with site contact water for the Hope Bay Development is identical to the characterization provided for the Madrid-Boston Project. The potential effects of runoff associated with site contact water on marine water quality are expected to be minimized or eliminated by the proposed management and mitigation measures described in Section 8.5.3, which apply to the entire Hope Bay Development. However, site contact water from the Roberts Bay facilities has the potential to cause short-term alterations of suspended sediment and metal concentrations during periods of overland flow (e.g., freshet). These potential alterations in water quality are not expected to be greater than CCME guidelines for the protection of aquatic life because of the application of effective mitigation and management measures.

The potential for residual effects from site contact water is anticipated for the Construction, Operation, Temporary Closure, and Reclamation and Closure phases. These residual effects are characterized in Section 8.5.5.3.

8.5.4.4 Fuels, Oils, and PAH

Characterization of Madrid-Boston Project Potential Effects

Activities related to the transportation, transfer, storage, and handling of fuels at the Roberts Bay facilities will be managed and mitigated as described in the OPPP/OPEP (Volume 8, Annex V8-1). The plan establishes comprehensive measures to ensure all shore preparations, emergency preparedness, equipment and personnel are in place to coordinate between TMAC and the other Project participants to transfer fuel between an anchored tanker and a barge, and from a barge moored at the jetty in Roberts Bay to the on-shore bulk fuel storage facility at Roberts Bay. The OPPP/OPEP is substantially focussed on the shipping, transfer, handling and storage of fuel at the Roberts Bay Oil Handing Facilities (OHF). The bulk fuel storage facility and all transfer-related equipment will be inspected and maintained, with complete documentation.

The potential effects to marine 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 that are detailed in OPPP/OPEP (Volume 8, Annex V8-1) and 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. As a result, the potential effects to marine water quality from the use of fuels and oils are not considered further.

The potential for airborne PAH to be introduced to the marine environment will be managed as outlined in the Incinerator Management Plan (Package P4-16). The objective of the incinerator management plan is to ensure that waste incineration is undertaken in a safe, efficient, and environmentally compliant manner and in a way that minimizes harmful emissions. Modern incineration equipment will be installed to minimize airborne contaminant loading of PAH, and hazardous material that can contribute to airborne PAH will be removed from the incineration waste stream.

The potential effects of fuels, oils, and PAH on marine water quality are expected to be effectively mitigated. No residual effects of fuels, oils, and PAH on the marine water quality in Roberts Bay are predicted to result from the Madrid-Boston Project.

Characterization of Hope Bay Development Potential Effects

The characterization of effects associated with the transportation, transfer, storage, handling, and use of fuels and other petroleum products for the Hope Bay Development is identical to the characterization provided for the Madrid-Boston Project. All management plans and mitigation measures that will serve to minimize or eliminate potential effects of fuels, oils, and PAH to marine water quality are adhered to across the entire Hope Bay Development. Therefore, no residual effects of fuels, oils, and PAH on marine water quality in Roberts Bay are predicted to result from the Hope Bay Development.

8.5.4.5 Discharge

Characterization of Madrid-Boston Project Potential Effects

The potential effects of discharge on marine water quality in Roberts Bay result from the discharge of TIA and saline groundwater from the Roberts Bay Discharge System. Near-field mixing (Appendices V5-8A and V5-8B) and far-field hydrodynamic modelling (Appendix V5-8C) have shown that the discharge of TIA and saline groundwater into Roberts Bay will be buoyant and will be trapped in the deep-waters of Roberts Bay where it will be diluted by several orders of magnitude and advected into Melville Sound.

The predictions from the quantitative water balance model (Madrid-Boston Project Water and Load Balance, Package P5-4) are used to characterize the effluent to be discharged via the Roberts Bay Discharge System (Table 8.5-5). The near-field mixing model is then used to predict the degree of mixing achieved within the plume from the outfall (Appendix V5-8A), and used to calculate water quality concentrations expected within the plume in the marine environment. The effluent discharged to Roberts Bay is expected to change over time, depending on the quantity of TIA and saline groundwater to be discharged. As a result, a number of different scenarios are considered to account for different seasons (ice covered and open water), discharge rates, temperatures, and salinities (shown as ppt in Table 8.5-5). To be conservative, the predictions assume background concentrations equivalent to the 75th percentile of observed baseline conditions.

The predicted maximum concentrations in the plume from the Roberts Bay Discharge System are identical to, or within 10% of background conditions for a wide range of parameters, including arsenic, cadmium, chromium, silver, copper, selenium, and zinc. The analysis predicts increases of greater than 10% over background concentrations at the extent of the near-field mixing zone (within 15 m of diffuser; Appendix V5-8A) under at least one scenario for nitrate, mercury, ammonia, nitrite, total cyanide, iron, lead, and manganese (Table 8.5-5). However, these predicted maximum concentrations are lower than applicable CCME water quality guidelines for the protection of aquatic life (e.g., arsenic) and are generally modestly greater than background concentrations at the extent of the predicted 15-m mixing zone. There is the potential for residual effects to marine water quality from the discharge of TIA water and saline groundwater into Roberts Bay; these residual effects are further characterized in Section 8.5.5.3.

Characterization of Hope Bay Development Potential Effects

The characterization of effects associated with discharging TIA and saline groundwater into Roberts Bay will be the same for the Hope Bay Development as they will be for the Madrid-Boston Project. Discharge related to the Doris Project will occur independently for approximately 1.5 years, with a 1.5 year period where discharge from Doris and Madrid North mining activities will be combined and discharged to Roberts Bay (Madrid-Boston Project Water and Load Balance, Package P5-4). The period of overlap is included in the effluent predictions from the water balance model. Therefore, the assessment for the

Madrid-Boston Project potential effects includes the potential influences of the Doris mining activities. The potential residual effects of groundwater and TIA water discharge to Roberts Bay from the Hope Bay Development as a whole are further characterized in Section 8.5.5.3.

8.5.4.6 Dust Deposition

Characterization of Madrid-Boston Project Potential Effect

Quantitative air quality modelling predicted dust deposition rates across the Project area (Volume 4, Chapter 2). This dust deposition modelling included the construction of the cargo dock and vehicle traffic as potential dust sources. The results of the quantitative dust deposition modelling are used to estimate average annual dust deposition rates over Roberts Bay. Table 8.5-6 presents the predicted dust deposition rates for the immediate vicinity of the cargo dock and for the Roberts Bay LSA based on interpolated dust deposition rates from the gridded air quality modelling field

Average daily dust deposition rates calculated from the air quality modelling results are predicted to range from 0.00007 to 0.00027 mg/L/d in the marine environment. These daily loads are more than 20,000 times lower than the average TSS concentration in the near-shore marine environment (6.0 mg/L, Table 8.2-5). Dust particles deposited into the marine 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 Effect

The air quality model includes the contributions of the existing and approved activities at Roberts Bay during the period of overlap between the Doris and Madrid-Boston projects. The Construction phase therefore represents the period of maximal potential dust influences of the marine environment from existing activities. No effects from dust deposition effects from the construction of the Doris site have been observed in the Doris AEMP monitoring program (e.g., ERM 2017a). On the basis of the results of the quantitative air quality modelling and the absence of any evidence of dust-related effects, the potential effects from dust deposition for the Hope Bay development on marine water quality is concluded to be negligible, and not considered further.

8.5.5 Characterization of Residual Effects

8.5.5.1 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 of 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 8.5-7. These attributes consider the baseline information presented in Section 8.3 and are focused on the indicators and thresholds described in Tables 8.5-1 and 8.5-2.

For the determination of significance, each attribute is characterized. The characterizations and criteria for the characterizations are provided in Table 8.5-8. Each of the criteria contributes to the determination of significance.

Table 8.5-5. Predicted Trapping Depth Concentrations of Selected Parameters Discharged from the Roberts Bay Discharge System.

				Effluent Water Quality Concentration (mg/L)								Plume Water Quality Concentration (mg/L)					
				Under Ice				Open Water				Under Ice			Open Water		
	CCME Guideline	Baseline (mg/L)		GW		GW+TIA		GW+TIA		TIA only		GW		GW+TIA	GW+TIA		TIA
Parameter	(mg/L)	Median	75th Percentile	Median	75th Percentile	Median	75th Percentile	Median	75th Percentile	Median	75th Percentile	25.3 ppt, 2°C	10.0 ppt, 2°C	4.8 ppt, 2°C	7.1 ppt, 8.2°C	1.5 ppt, 8.2°C	0.2 ppt 10°C
Nitrate (as N)	45	0.046	0.075	18.0	23.6	14.7	19.2	10.3	12.5	0.859	1.61	0.190	0.136	0.123	0.101	0.0994	0.0762
Arsenic	0.0125	0.0010	0.0014	0.0148	0.0148	0.0148	0.0148	0.0148	0.0148	0.0100	0.0100	0.00146	0.00142	0.00141	0.00140	0.00140	0.00139
Cadmium	0.00012	0.000056	0.000068	0.0000243	0.0000378	0.000187	0.000233	0.000146	0.000172	0.0000432	0.0000757	0.0000677	0.0000681	0.0000684	0.0000682	0.0000682	0.0000679
Chromium	0.0015	0.0010	0.0500	0.00414	0.00442	0.00968	0.0111	0.00744	0.00917	0.00158	0.00244	0.000523	0.000512	0.000531	0.000518	0.000517	0.000502
Mercury	0.000016	0.0000013	0.0000018	0.000274	0.000283	0.000244	0.000267	0.000231	0.000238	0.0000175	0.0000246	0.00000356	0.00000273	0.00000261	0.00000239	0.00000236	0.00000184
Silver	0.00750	0.00020	0.00100	0.0000238	0.0000412	0.000402	0.000495	0.000375	0.000517	0.0000723	0.000134	0.000994	0.000997	0.000998	0.000998	0.000998	0.000998
Ammonia (as N)	NA	0.005	0.005	8.69	10.8	10.6	12.4	7.65	9.40	0.00172	1.78	0.0610	0.0346	0.0402	0.0246	0.0236	0.00499
Nitrite (as N)	NA	0.002	0.002	0.0516	0.110	0.467	0.566	0.415	0.510	0.148	0.277	0.00232	0.00217	0.00355	0.00306	0.00300	0.00231
Total Cyanide	NA	0.0012	0.0013	0.000978	0.000978	0.119	0.167	0.00600	0.00770	0.000452	0.000615	0.00130	0.00130	0.00169	0.00131	0.00131	0.00130
Copper	NA	0.00041	0.00046	0.00373	0.00499	0.0157	0.0191	0.0113	0.0149	0.00537	0.00659	0.000485	0.000475	0.000515	0.000492	0.000490	0.000474
Iron	NA	0.011	0.031	1.40	1.40	1.40	1.40	1.40	1.40	0.500	0.500	0.0398	0.0357	0.0356	0.0345	0.0343	0.0320
Lead	NA	0.00005	0.00022	0.000200	0.000287	0.000484	0.000589	0.000389	0.000533	0.000215	0.000358	0.000224	0.000224	0.00100	0.00100	0.00100	0.00100
Manganese	NA	0.0015	0.0019	0.194	0.252	0.178	0.192	0.126	0.157	0.0430	0.0546	0.00309	0.00251	0.00244	0.00217	0.00216	0.00194
Selenium	NA	0.00050	0.00078	0.00179	0.00281	0.00682	0.00848	0.00465	0.00585	0.00107	0.00182	0.000787	0.000783	0.000800	0.000790	0.000789	0.000781
Zinc	NA	0.0008	0.0018	0.00661	0.0103	0.0189	0.0226	0.0146	0.0156	0.00790	0.0124	0.00186	0.00185	0.00189	0.00186	0.00186	0.00184

Notes:
The modelling considered multiple scenarios, including mixtures of groundwater (GW) and TIA water being discharged under-ice and during the open-water season (Appendix V5-8A). The plume water quality concentrations report the predicted concentrations of these parameters at the trapping depth (within metres of the outfall). The multiple mixing scenarios (e.g., 25.3 ppt and 2°C) correspond to different periods in the Mine plan (see Appendix V5-8A for details).

Table 8.5-6. Summary of Predicted Dust Deposition Rates in Roberts Bay

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)
Cargo Dock (PDA)	12	1.2	1.0	0.00027	0.00024
Roberts Bay (LSA)	36	0.9	0.9	0.00007	0.00007

Notes:
Daily loads calculated by integrating the average maximum annual load throughout the water column. Depth at the cargo dock is given as the minimum depth from the design of the cargo dock (Package P5-10), and the mean depth of Roberts Bay is described in the Marine Physical Processes chapter (Volume 5, Chapter 7).
Annual and daily loads include background levels.

Table 8.5-7. 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 the marine water quality VEC 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/ socio-economic 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.

Table 8.5-8. 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 marine water quality VEC
	Low	Differing from the average value for the existing environment to a small degree, but within the range of natural variation and well below a guideline or threshold value
	Moderate	Differing from the average value for the existing environment and approaching the limits of natural variation, but below or equal to a guideline or threshold value
	High	Differing from the existing environment and exceeding guideline or threshold values so that there will be a detectable change beyond the range of natural variation (i.e., change of state from the existing conditions)
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

Attribute	Characterization	Criteria
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

8.5.5.2 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.

<u>Probability of Occurrence or Certainty</u>

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 8.5-9 presents the definitions applied to these categories.

Table 8.5-9. 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 marine 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 qualifies the determination, 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 modelling is employed using industry standard modelling 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 surface water quality indicators, residual effects, and significance determination to produce a robust, transparent, and defensible approach to the assessment of surface water quality effects. Therefore, there is *high* confidence in the results of this residual effects assessment for predicted water quality effects on the marine environment in Roberts Bay. Water quality monitoring will be ongoing in Construction, Operations, and Reclamation and Closure phases and will serve to validate water quality predictions. Table 8.5-9 provides descriptions of the confidence criteria.

Residual effects identified in the Project-related effects assessment are carried forward to assess the potential for cumulative interactions with the residual effects of other projects or human activities and to assess the potential for transboundary impacts should the effects linked directly to the activities of the Project inside the Nunavut Settlement Area (NSA), which occurs across provincial, territorial, international boundaries or may occur outside of the NSA.

8.5.5.3 Characterization of Residual Effects to Marine Water Quality VEC

Sealift – Physical Disturbances from Propeller Wash

Madrid-Boston Project Residual Effect

The predicted magnitude of the residual effect of propeller wash is l*ow* because concentrations of all water quality indicators will be within baseline ranges and less than CCME guidelines. Propeller wash disturbances would occur within the *local* (restricted to the LSA) area, and would be *infrequent*, with five to seven vessels per shipping season. The *infrequent* incidences of propeller wash disturbance in the LSA would potentially occur throughout the Construction, Operations, and Reclamation and Closure phases, and therefore the duration is *medium-term*. The potential residual effects from propeller wash are predicted to be fully *reversible* because sediment is naturally re-suspended by waves and currents in the shallow, near-shore area, and any additional re-suspension caused by propeller wash would be reversed by the same natural processes.

The probability of occurrence is estimated to be *moderate*, and the confidence is *high* because of the quantitative input from the baseline environmental data and the confidence in the mitigation and management strategies.

The residual effect of propeller wash on the marine water quality VEC is predicted to be **not significant** (Table 8.5-10).

Hope Bay Development Residual Effect

The five to seven vessels that are expected to report to Roberts Bay each year includes vessel traffic for the entire Hope Bay Development, and not just the Madrid-Boston component. However, the Madrid-Boston Project will extend the duration of vessel traffic beyond the 6-year lifespan of the existing and approved projects for an additional 13 years. While the duration of vessel traffic will be extended by the Madrid Boston Project, the characterization of the duration of the residual effect is still considered *medium-term* since it will not occur beyond the life of the Madrid-Boston and existing approved projects. All attributes and characterizations of the residual effect of sealift disturbances are common to both the Madrid-Boston Project and the Hope Bay Development. Therefore, the overall significance of the effects of physical disturbances associated with sealifting in the Hope Bay Development is considered **not significant** (Table 8.5-11).

<u>Site Preparation, Construction, and Decommissioning</u>

Madrid-Boston Project Residual Effect

Potential residual effects to marine water quality may result from the construction of infrastructure, including the construction of the cargo dock. The disturbance of surfaces and the associated runoff from on-land construction and decommissioning can mobilize sediments, which can be transported in the marine environment. A summary of the characterization and assessment of the residual effects of physical disturbances associated with site preparation, construction, and decommissioning is provided in Table 8.5-10. Any *negative* residual effects are expected to be *moderate* in magnitude because of the use of geochemically suitable materials for construction and the installation of erosion and sedimentation control measures such as the use of a silt curtain during construction. The duration of the potential residual effects is expected be *short*, because the potential physical disturbance will only occur during the Construction and Reclamation and Closure phases and the marine dock is not expected to require decommissioning. The frequency of the potential effect is predicted to be *infrequent*, because potential sediment mobilization could occur periodically during the vibratory sheet pile installation required for the construction of the dock. The potential residual effects are expected be confined to the marine *PDA* in the waters immediately surrounding the dock, as the use of a silt curtain will prevent the transportation of sediments into the LSA. Any residual effects are predicted to be *reversible* once in-water construction activities are completed, because of natural dispersal and recovery processes driven by waves, currents, tides, and ice scour (Table 8.5-10).

The probability of occurrence of residual effects from in-water construction works is considered to be *moderate*. The overall significance of the effects of physical disturbances associated in-water work is considered not significant because of the magnitude, the confinement of the effect within the marine PDA, and the reversibility of the residual effect. The confidence of the overall rating is considered to be *medium* because of the use of widely used and effective best practices for erosion and sediment control and the well understood baseline conditions and physical processes in Roberts Bay (marine water quality, sediment quality, and the physical currents and circulation; Table 8.5-10).

Table 8.5-10. Summary of Residual Effects and Overall Significance Rating for Marine Water Quality - Madrid-Boston Project

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

Table 8.5-11. Summary of Residual Effects and Overall Significance Rating for Marine Water Quality - Hope Bay Development

Residual Effect	Attribute Characteristic						Overall Significance Rating		
	Direction (*positive, variable, negative*)	**Magnitude** (negligible, *low, moderate, high*)	**Duration** (*short, medium, long*)	**Frequency** (*once, infrequent, frequent, continuous*)	**Geographical Extent** (PDA, *LSA, RSA, beyond regional*)	**Reversibility** (*reversible, reversible with effort, irreversible*)	**Probability** (*unlikely, moderate, likely*)	**Significance** *(not significant, significant)*	**Confidence** (*low, medium, high*)
Sealift - Propeller Wash	Negative	Low	Medium	Infrequent	LSA	Reversible	Moderate	Not significant	High
Site, Preparation, Construction, and Decommissioning Activities	Negative	Moderate	Medium	Infrequent	LSA	Reversible	Moderate	Not significant	Medium
Site Contact Water	Negative	Low	Medium	Infrequent	PDA	Reversible	Moderate	Not significant	Medium
Discharges	Negative	Moderate	Medium	Frequent	LSA	Reversible	Likely	Not significant	High

Hope Bay Development Residual Effect

The Hope Bay Development residual effects from Site Preparation, Construction, and Decommissioning are similar to the effects assessment for the Madrid-Boston Project residual effects. The disturbance of surfaces and the associated runoff from on-land construction and decommissioning can mobilize sediments, which can be transported in the marine environment by runoff. A summary of the characterization and assessment of the residual effects of physical disturbances associated with site preparation, construction, and decommissioning is provided in Table 8.5-11. Site preparation, construction, and decommissioning activities associated with the Hope Bay Development are expected to interact with marine water quality as a result of on-land and in-water works. The Madrid-Boston Project includes the construction of a marine dock in Roberts Bay, and the Doris Project includes the installation of the Roberts Bay Discharge System (marine outfall pipeline and diffuser). The in-water works associated with the Doris Project are expected to be completed before construction associated with the Madrid-Boston Project begins in 2019, so there will be no temporal overlap in the in-water construction activities. There will also be no spatial overlap since the pipeline and diffuser are several hundred metres away from the marine dock location, and the geographical extent of any residual effects associated with each structure are expected to be highly localized. Furthermore, for both the marine dock and the Roberts Bay Discharge System, any localized changes in water quality are expected to return to baseline conditions shortly after construction and decommissioning activities are completed, as suspended sediments settle and the sediments are re-worked by natural physical processes such as waves, currents, and tides. Given that the in-water construction work associated with the Doris Project will not overlap temporally or spatially with the in-water work associated with the Madrid-Boston Project and all residual effects are expected to be reversible over the short-term, there are not expected to be any additive or cumulative effects of in-water construction on marine water quality in Roberts Bay.

However, decommissioning activities will occur throughout the Roberts Bay area, and will include both Madrid-Boston and existing and approved infrastructure. The residual effects to marine water quality from the Hope Bay Development decommissioning are expected to be similar in magnitude to the Madrid-Boston Project effects, but the spatial extent would extend to the *LSA*.

Compared to the Madrid-Boston Project in isolation, the characterization of the residual effects of in-water works during site preparation, construction, and decommissioning associated with the complete Hope Bay Development differ in two ways:

1. The potential residual effects associated with the installation of the Roberts Bay Discharge System will occur before the four-year Construction phase of the Madrid-Boston Project, which extends the duration of the potential residual effects from *short* to *medium*.
2. The potential residual effects associated with existing and approved activities, such as the construction of the Roberts Bay Discharge System and decommissioning of the Roberts Bay infrastructure, will occur within the LSA. Therefore, the geographical extent of the potential residual effects is changed from the *PDA* to the *LSA*.

Overall, the potential effects of the in-water works of the Hope Bay Development on marine water quality are rated as **not significant** (Table 8.5-11).

<u>Site Contact Water</u>

Madrid-Boston Project Residual Effect

Residual effects to marine water quality may result from site contact water. Runoff from roads, pads, and laydown areas can mobilize sediments and sediment-associated metals, which can be transported into the marine environment. A summary of the characterization and assessment of the residual effects of physical disturbances associated with site contact water is provided in Table 8.5-10. Any *negative* residual effects are expected to be *low* in magnitude because of the use of geochemically suitable materials for construction and the installation of erosion and sedimentation control measures. The Doris Project has demonstrated through the Doris AEMP that the mitigation and management measures are effective at mitigating potential construction effects to the marine environment, and these mitigation and management measures will be supported by monitoring and adaptive management. The duration of the potential residual effects is expected be *medium*, because the runoff of site contact water will continue throughout the Operation phase. The frequency of the potential effect is predicted to be *infrequent*, because potential sediment mobilization could occur during runoff events. The residual effects are expected be confined to the marine *PDA* in the waters immediately surrounding the Madrid-Boston Roberts Bay infrastructure (i.e., the cargo dock and expanded laydown areas). Any residual effects are predicted to be *reversible* once infrastructure is decommissioned are completed, because of natural dispersal and recovery processes driven by waves, currents, tides, and ice scour (Table 8.5-10).

The probability of occurrence of residual effects from site contact water is considered to be *moderate*. The overall significance of the effects of physical disturbances associated work is considered **not significant** because of the low magnitude, the confinement of the effect within the marine PDA, and the reversibility of the residual effect. The confidence of the overall rating is considered to be *medium* because of the use of widely used and effective best practices for erosion and sediment control and the well understood baseline conditions and physical processes in Roberts Bay (marine water quality, sediment quality, and the physical currents and circulation; Table 8.5-10).

Hope Bay Development Residual Effect

The Hope Bay Development residual effects from site contact water are similar to the effects assessment for the Madrid-Boston residual effects. The runoff from roads, pads, and infrastructure can mobilize sediments and associated material, which can be transported into the marine environment. A summary of the characterization and assessment of the residual effects of physical disturbances associated with site contact water is provided in Table 8.5-11.

The residual effects of site contact water for the Hope Bay Development are characterized in a similar manner to the Madrid-Boston residual effect. The effective mitigation and management measures, which are supported by adaptive management and monitoring, are expected to result in *low* magnitude residual effects. These residual effects are expected to be *infrequent*, *reversible*, and restricted to the *PDA*. Overall, the residual effects from site contact water of the Hope Bay Development on marine water quality are rated as **not significant** (Table 8.5-11).

<u>Discharges</u>

Madrid-Boston Project Residual Effect

The discharge of groundwater and TIA water by the Roberts Bay Discharge System is identified as a residual effect to marine water quality. The water balance model and the near-field mixing model predict increases in the concentrations of some metals and nutrients relative to background conditions at the extent of the 15-m mixing zone. The predicted increases are only modestly greater than baseline conditions, substantially less than applicable CCME water quality guidelines, and are predicted to occur within 15 m of the diffuser (Appendix V5-8A). Far-field hydrodynamic modelling has shown that the small, near-field plume is further diluted by 1,000 to 10,000:1 at 250 m from the outfall and orders of magnitude more beyond this distance (Appendix V5-8C). Therefore, the magnitude of the residual effects to water quality is classified as *moderate*. The geographical extent of the effect will be within the LSA because elevated water quality concentrations would occur only metres from the diffuser in Roberts Bay, and the duration is *medium* because the discharges will continue throughout the Operations phase and into the Reclamation and Closure phase. The frequency of the residual effect is considered to be *frequent*, depending on the requirements of groundwater and TIA water management. Any residual effects are expected to be fully *reversible*, because of the rapid dispersion of discharged effluent in Roberts Bay, the flushing of Roberts Bay water into Melville Sound, and natural biogeochemical processes (Table 8.5-10).

The probability of occurrence of residual effects from discharge is considered to be *likely*. The overall significance of the effects of discharges is considered **not significant** because of the magnitude, the confinement of the effect within the marine *LSA*, and the reversibility of the residual effect. The confidence of the overall rating is considered to be *high* because of the quantitative modelling used in the determination of effluent quality and near-field and far-field mixing (Table 8.5-10).

Hope Bay Development Residual Effect

The Hope Bay Development residual effect from discharge is anticipated to be the same as the residual effect from the Madrid-Boston Project. The quantitative water balance model includes a period of overlap between the Doris and Madrid-Boston mining activities, which is used as one of the scenarios in the near-field mixing model (Appendix V5-8A). The residual effects to water quality from the discharge of groundwater and TIA water for the Hope Bay Development are considered *moderate* in magnitude, because of the predicted near-field increases in the concentrations of selected metals and nutrients. However, the predicted increases are modest, and less than applicable CCME water quality guidelines. The residual effects are assessed to be restricted to the *LSA*, *reversible*, *medium* in duration, and *frequent* in frequency (Table 8.5-11).

The probability of occurrence of residual effects from discharge is considered to be *likely*. The overall significance of the effects of discharges is considered **not significant** because of the magnitude, the confinement of the effect within the marine LSA, and the reversibility of the residual effect. The confidence of the overall rating is considered to be *high* because of the quantitative modelling used in the determination of effluent quality and near-field and far-field mixing (Table 8.5-11).

8.6 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.

8.6.1 Methodology Overview

8.6.1.1 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 the marine water quality VEC (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).

8.6.1.2 Assessment Boundaries

The CEA considers the spatial and temporal extent of Project-related residual effects on the marine water quality VEC 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 the marine water quality VEC was the assessment Regional Study Area (RSA; Figure 8.2-1). This study area contains the LSA and was determined to cover the extent of direct and indirect effects of the Project on the marine 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 8.4.3).

8.6.2 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 Project lie within the marine LSA, no cumulative effects to the marine water quality VEC are predicted.

8.7 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 the marine water quality VEC are predicted to be restricted to the LSA. The LSA lies entirely within Nunavut; therefore, there is no potential for transboundary effects.

8.8 IMPACT STATEMENT

The assessment of effects from the Project to the marine water quality VEC 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:

- sealift;
- construction and decommissioning activities;
- site contact water;
- fuels, oils, and PAH;
- discharges; 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.

The assessment is supported by baseline studies throughout the Roberts Bay LSA and the wider Melville Sound area. Quantitative modelling is used to support the assessment of potential effects from sealifts and the discharge of groundwater and TIA water. Residual effects are identified based on the predictions of the quantitative modelling and the application of mitigation and management measures. Four residual effects are identified: sealift; site preparation, construction and decommissioning activities; site contact water; and discharges.

Using the thresholds identified for the key indicators, each of these residual effects is concluded to be low to moderate in magnitude. All residual effects to marine water quality are predicted to be restricted to the PDA or LSA. As a result, the residual effects are rated as **not significant**. No cumulative effects are predicted to occur because the Project marine 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.

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