Executive Summary: Human Health and Environmental Risk Assessment

Ecological and human health risk assessment work was completed for the Project. Risk assessments identify, analyze, and evaluate the effects of a project on human and ecological (i.e., the health of animals, birds, and fish) health. The risk assessments followed guidance provided by Health Canada and Environment Canada. Conservative assumptions were made throughout the risk assessments to ensure that the risks were not underestimated. The risk assessment work was completed in four parts as described below.

The baseline human health risk assessment (Section 5.3) and environmental risk assessment (Section 5.5) looked at the potential health risks to humans and animals, birds, and fish (ecological receptors) when exposed to existing levels of contaminants in water, sediment, food, air, and soil. These are known as exposure pathways, and are the ways that contaminants can reach humans or ecological receptors.

The Madrid-Boston Project-related human health risk assessment (Section 5.4) and the Madrid-Boston Project-related environmental risk assessment (Section 5.6) looked at the potential health risks to human and ecological receptors due to the Madrid-Boston Project developments using the same exposure pathways.

The risk assessments found that the Project would not affect human or environmental health as there was a minimal increase in risk above existing conditions due to the Madrid-Boston Project. The predicted changes in the environment and risks as a result of the Madrid-Boston Project are not measurable, so if the Madrid-Boston Project is developed the risk to human and ecological receptors would be the same as now.

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.

AANDC	Aboriginal Affairs and Northern Development Canada
ASIL	Acceptable source impact level
ASTDR	Agency for Toxic Substances and Disease Registry
AQMP	Air Quality Management Plan
AQO	Provincial Air Quality Objective
AWR	All weather road
BC	British Columbia
BCF	Bioconcentration factor
BC MOE	British Columbia Ministry of Environment
BIPR	Bathurst Inlet and Road Project
BTF	Biotransfer factor
BW	Body weight
CAAQSs	Canadian Ambient Air Quality Standards
CAC	Criteria air contaminant
CCME	Canadian Council of Ministers of the Environment
CFIA	Canadian Food Inspection Agency
CO	Carbon monoxide
COPC	Contaminant of potential concern
Cr(III)	Trivalent chromium
Cr(VI)	Hexavalent chromium
CSF	Cancer slope factor
CUR	Cancer unit risk
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
dBA	A-weighted decibels
dBC	C-weighted decibels
dw	Dry weight
DWQG	Drinking water quality guideline
EAA	Existing and Approved Authorizations
Eco-SSL	Ecological Soil Screening Level

EDI	Estimated daily intake
EGVM	Expert Group on Vitamins and Minerals
EIS	Environmental Impact Statement
ELDE	Estimated lifetime daily exposure
EMF	Electromagnetic field
ERA	Environmental risk assessment
ERM	ERM Consultants Canada Ltd.
ET	Exposure time
FAO	Food and Agriculture Organization
HHERA	Human health and environmental risk assessment
HHRA	Human health risk assessment
HQ	Hazard quotient
HTO	Hunter and Trappers Organization
ILCR	Incremental lifetime cancer risk
INAC	Indian and Northern Affairs Canada (currently known as AANDC)
IOL	Inuit-owned Lands
IQ [a]	Intelligence quotient
IR [a]	Ingestion rate
IRIS	Integrated Risk Information System
ISQG	Interim sediment quality guideline
JECFA	Joint FAO/WHO Expert Committee on Food Additives
kg	Kilogram
KIA	Kitikmeot Inuit Association
LOAEL	Lowest observed adverse effect level
L_{90}	Lowest 10th percentile noise level
L_d	Day equivalent level (noise metric for sleep disturbance)
L_{dn}	Day-night equivalent level (noise metric for complaints)
L_{eq}	Equivalent noise level
L_n	Night equivalent (noise metric for sleep disturbance)
L_{max}	Instantaneous noise level in dBA for assessing sleep disturbance
LSA	Local study area
M	Million or Mega
MAC	Maximum acceptable concentration
MDL	Method detection limit

MRL	Minimal risk level
n	Sample size
NIRB	Nunavut Impact Review Board
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxide
NOAEL	No observed adverse effect level
NTU	Nephelometric Turbidity Units
NU	Nunavut
NWB	Nunavut Water Board
NWHS	Nunavut Wildlife Harvest Study
NWMB	Nunavut Wildlife Management Board
NWT	North West Territories
O_3	Ozone
ORNL	Oak Ridge National Laboratory
PAH	Polycyclic aromatic hydrocarbon
PASS	Passive Air Sampling System
PD	Property boundary
PDA	Project development area
PEL	Probable effects level
PM_{10}	Particulate matter of 10 micrometers or less
$PM_{2.5}$	Particulate matter of 2.5 micrometers or less
POP	Persistent organic pollutant
Project, the	The Madrid-Boston Project
PTDI	Provisional tolerable daily intake
PTWI	Provisional tolerable weekly intake
QA/QC	Quality assurance and quality control
RAF	Relative absorption factor
RSA	Regional study area
SARA	*Species at Risk Act* (2002)
SO_2	Sulphur dioxide
SRK	SKR Consulting (Canada) Inc.
TD	Tumorigenic dose
TDI	Tolerable daily intake
TIA	Tailings impoundment area

TK	Traditional knowledge
TMAC	TMAC Resources Inc.
TRV	Toxicity reference value
TSP	Total suspended particulate
UCLM	Upper confidence limit of the mean
UCF	Unit conversion factor
UF	Uncertainty factor
US EPA	United States Environmental Protection Agency
USL	Upper safe level
UTM	Universal Transverse Mercator
VEC	Valued Ecosystem Component
VSEC	Valued Socio-economic Component
WHO	World Health Organization
WRR	Winter Road Route
WSCC	Worker's Safety and Compensation Commission
ww	Wet weight

Notes:
[a] *The use of this acronym is specific to this particular section.*

5. Human Health and Environmental Risk Assessment

5.1 INTRODUCTION

The proposed Madrid-Boston Project (the Project) is a development by TMAC Resources Inc. (TMAC) of an underground gold mine in the West Kitikmeot region of Nunavut. The Project is located in the Hope Bay Greenstone Belt and comprises an area of approximately 80 by 20 km with four areas of primary gold deposits: Doris, Madrid North, Madrid South, and Boston.

The centre of the Project lies approximately 143 km above the Arctic Circle. The Project is located 705 km northeast of Yellowknife, North West Territories (NWT) and 153 km southwest of Cambridge Bay in Nunavut Territory (NU), and is situation east of Bathurst Inlet. The nearest settlements are the unincorporated communities of Omingmaktok (62 km to the west) and Kingaok (Bathurst Inlet; 130 km southwest). The next nearest permanently populated settlement is Cambridge Bay (153 km northeast), on the southeast corner of Victoria Island. Kugluktuk is 600 km west of the Project area, and northeast of the Project is Gjoa Haven (447 km away) on King William Island. Further east on the mainland are Taloyoak (558 km away), and Kugaaruk (694 km away). Yellowknife and Edmonton are the largest nearby hubs for transportation of goods and services and non-Nunavut employees.

The primary access route to the Project for bulk commodities such as fuel, mining and mill equipment, and sundry supplies is via a marine link through the Arctic Ocean. The shipping season is typically from August to September when ice-free conditions allow for passage. Goods are transported by air during the rest of the year. Personnel are transported by air year-round. Currently, the gravel strip allows for aircraft such as the Dash 8 and Buffalo. In addition, a winter ice strip is constructed on Doris Lake each year, and is operational from February to April. The Project includes plans for construction of the Boston airstrip, which is intended to support Dash 8 and Boeing 737-200 aircraft for reliable year-round access. A potential 450 m extension to this primary airstrip will support larger aircraft such as the Hercules C-130. The nearest community and commercial airport is Cambridge Bay, approximately 160 km by air.

Section 8.3 of the *Guidelines for the Preparation of an Environmental Impact Statement for Hope Bay Mining Ltd.'s Phase 2 Hope Bay Belt Project* (the EIS Guidelines) requires that a Human Health (HHRA) and Environmental Risk Assessment (ERA) be completed as part of the EIS submission to the Nunavut Impact Review Board (NIRB 2012). In this context, HHRAs and ERAs involve comprehensive and systematic processes designed to identify, analyze, and evaluate the effects of a project on environmental and human health (Health Canada 1999; Stantec 2009). A risk assessment defines existing environmental conditions and uses this information to evaluate potential changes to environmental quality resulting from project-related effects that could impact environmental or human health. As part of this assessment, types and sources of contaminants or noise emissions were identified, and pathways of exposure were identified for the various human and ecological receptors. The assessment included consideration of Project-related changes to noise levels and the quality of environmental media (i.e., air, water, sediment, soil, vegetation, and country foods), and the subsequent potential change in risk of adverse health effects in human and ecological receptors.

All contaminants from anthropogenic or natural sources have the potential to cause toxicological effects in human and ecological receptors. However, three criteria must be present for a contaminant of potential concern (COPC) to pose a potential risk to the health of ecological or human receptors (Health Canada 2010f):

- There must be potential for emissions or release of COPCs at sufficiently high concentrations to cause toxicological effects.
- Receptor(s) must be present.
- There must be existing pathway(s) for COPC exposure by receptor(s), and the receptor must be able to take up the COPC.

Risk assessment of contaminants characterizes the nature and estimated magnitude of potential risks to health associated with the exposure of receptors (e.g., wildlife and humans) to contaminants that may be present at concentrations that exceed applicable guidelines/standards or site-specific background levels as a result of project activities. Consideration of existing conditions is important to ensure that only changes in contaminant concentrations relative to existing levels are identified and assessed as potential project-related effects. This is particularly true for contaminants where their concentrations exceed guideline limits under existing conditions, prior to project development.

For the Project, the primary COPCs are most likely to be metals, given that the Project includes the development of a metal mine and metals occur naturally in the surrounding environment (e.g., air, soil, and water). Following Health Canada's guidance on HHRAs (Health Canada 2010f, 2010b, 2016a, 2016b, 2017) and Environment Canada's guidance on ERAs (Environment Canada 2012), this report presents the methods and results of the HHRA and ERA conducted for existing conditions, and the Project-related HHRA and ERA, which capture the change in risk to the health of human and ecological receptors that potential emissions from the Project may produce.

Each of the risk assessment components includes consideration of assumptions and uncertainties that may affect the confidence of the risk assessment conclusions. The assumptions and uncertainties in the HHRAs and ERAs are described in detail in Sections 5.3.6, 5.4.5, 5.5.5, and 5.6.5.

5.2 APPROACH

The approach for the HHRAs and ERAs was based on Health Canada's guidelines for human health risk assessments (Health Canada 2010b, 2010e, 2010f, 2016a, 2016b, 2017) and Environment Canada's guidance for ecological risk assessments (Environment Canada 2012). As such, the HHRAs and ERAs are divided into the following six stages:

1. Problem Formulation:

   Conceptual models for the existing conditions and Project-related HHRAs and ERAs were developed in the problem formulation stage. This stage screened and identified the COPCs, identified potential human and ecological receptors, described human and ecological receptor characteristics, and identified the exposure routes considered in the assessment.

2. Exposure Assessment:

   Exposure equations, COPC-specific characteristics, receptor assumptions, and the measured or modeled COPC concentrations in environmental media (e.g., air, water, soil, sediment, vegetation, and wildlife) are presented in this section. For country foods and wildlife species where COPC concentrations in tissue were not measured, food chain modeling was conducted. Food chain modeling of COPC uptake into wildlife tissue is generally considered to be conservative relative to direct measurement and has the potential to overestimate COPC tissue concentrations by orders of magnitude (Health Canada 2010e). This maintains the conservative nature of the HHRAs and ERAs and ensures with a high degree of certainty that risks will not be under-estimated or overlooked (Health Canada 2010e).

3. Toxicity Assessment:

   Toxicity thresholds, toxicity reference values (TRVs), or tolerable daily intakes (TDIs; levels of daily exposure that can be taken into the body without appreciable health risk) were identified for human and ecological receptors. For simplicity in the language of this assessment, all toxicity thresholds, TRVs, or TDI are referred to as TRVs.

4. Risk Characterization:

   The exposure and toxicity assessments were integrated by comparing the estimated daily intakes (EDIs) with TRVs to produce quantitative risk estimates: hazard quotients (HQs) for threshold COPCs for human and ecological receptors, and incremental lifetime cancer risks (ILCRs) for non-threshold COPCs (i.e., carcinogens) for human receptors.

5. Uncertainty Analysis and Data Gaps:

   The assumptions made throughout the HHRAs and ERAs and their effects on the confidence in the conclusions were identified and evaluated.

6. Conclusions:

   The potential for risk to human and ecological receptor health was assessed based on the results of the risk characterization for existing conditions compared to the risk characterization for the Project, with qualitative consideration of uncertainties and data gaps that might influence the quantitative assessment.

The main stages of risk assessment are the same for HHRAs and ERAs and relevant guidance for each was followed (i.e., Health Canada and Environment Canada guidance). Since risk assessments for both existing conditions and the Project were conducted, it was possible to characterize the risk due to the incremental change from existing conditions through the life of the Project.

5.2.1 Spatial and Temporary Boundaries

The spatial boundaries selected to shape the HHRAs and ERAs are determined by the Project's potential impacts on the health of human and ecological receptors. This was informed by the spatial boundaries for the valued ecosystem components (VECs) and valued socio-economic components (VSECs) for the Project (e.g., air quality, freshwater fish, and wildlife).

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 the health of human and ecological receptors.

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.

For the purposes of the HHRA and ERA, only the phases with the greatest potential for effects to human or ecological health were assessed. This was done to represent the "worst-case" scenarios expected from Project-related changes and therefore represents the phases associated with the greatest levels of risk; risk during other phases would be expected to be lower.

5.2.2 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, comprising 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 projects are described below.

5.2.2.1 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.

Hope Bay Regional Exploration Project

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.

Madrid Advanced Exploration

In 2017, the NWB approved 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.

Boston Advanced Exploration

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.

5.2.2.2 The Madrid-Boston Project

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

Construction

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

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

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

- expansion of the Doris TIA (raising of the South Dam, construction of West Dam, development of a west road to facilitate access, and quarrying, crushing, and screening of aggregate for the construction);
- construction of a cargo dock at Roberts Bay (including a fuel pipeline, mooring points, beach landing and gravel pad, shore manifold);
- construction of an additional tank farm at Roberts Bay (consisting of two 10 ML tanks);

- expansion of Doris accommodation facility (from 280 to 400 person), mine dry and administrative building, water treatment at Doris site;
- expansion of the Doris mill to accommodate concentrate handling on the south end of the building facility and rearrangement of indoor crushing and processing within the mill building;
- complete development of the Madrid North and Madrid South mine workings;
- incremental expansion of infrastructure at Madrid North and Madrid South to accommodate production mining, including vent raise, access road, process plant buildings;
- construction of a 1,200 tpd concentrator, fuel storage, power plant, mill maintenance shop, warehouse/reagent storage at Madrid North;
- all weather access road and tailings line from Madrid North to the south end of the TIA;
- AWR linking Madrid to Boston (approximately 53 km long, nine quarries for permitting purposes, four of which will likely be used);
- all-weather airstrip, airstrip building, helipad and heliport building at Boston;
- construction of a 2,400 tpd process plant at Boston;
- all infrastructure necessary to support mining and processing activities at Boston including construction of a new 300-person accommodation facility, mine office and dry and administration buildings, additional fuel storage, laydown area, ore pad, waste rock pad, diesel power plant and dry-stack tailings management area (TMA);
- infrastructure necessary to support ongoing exploration activities at both Madrid and Boston; and
- wind turbines near the Doris (2), Madrid (2), and Boston (2) sites.

<u>Operation</u>

The Madrid-Boston Project Operation phase includes:

- mining of the Madrid North, Madrid South, and Boston deposits by way of underground portals and Crown Pillar Recovery;
- operation of a concentrator at Madrid North;
- transportation of ore from Madrid North, Madrid South, and Boston to the Doris process plant, and transporting the concentrate from the Madrid North concentrator to the Doris process plant;
- extending the operation at Roberts Bay and Doris;
- processing the ore and/or concentrate from Madrid North, Madrid South, and Boston at the Doris process plant with disposal of the detoxified tailings underground at Madrid North, flotation tailings from the Doris process plant pumped to the expanded Doris TIA, and discharge of the TIA effluent to the marine environment;
- operation of a concentrator at Madrid North and disposal of tailings at the Doris TIA;
- operation of a process plant and wastewater treatment plant at Boston with disposal of flotation tailings to the Boston TMA and a portion placed underground and the detoxified leached tailings 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).

<u>Reclamation and Closure</u>

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.

5.2.2.3 Spatial Boundaries

The Project is located in the Southern Arctic Ecozone, which is characterized by short, cool summers (mean temperature of 5°C), long cold winters (mean temperature of -28°C), and precipitation is limited to 200 mm per year (Appendix V4-8A; Rescan 2011f). The Project area is further defined as falling within the Queen Maud Ecoregion. The physiography of the area is represented by broad, sloping uplands that reach approximately 300 m elevation in the south, and subdued undulating plains near the coast.

Vegetation in this ecoregion and within the human health RSA consists of predominantly shrub tundra vegetation such as dwarf birch (*Betula nana*), willow (*Salix* spp.), Labrador tea (*Ledum decumbens*), avens (*Dryas* spp.), and blueberries (*Vaccinium* spp.). Warm sites consist of tall dwarf birch, willow, and alder (*Alnus* spp.), while wetter sites consist of sphagnum moss and sedge tussocks. There is a continuous permafrost layer under the landscape that prevents water from penetrating deep into the soils. This creates surface run-off from precipitation and waterlogged soils that freeze regularly. There are numerous depressions, kettle lakes, ponds, and deposits in the area that were left by retreating glaciers. A more detailed description of the Ecoregion's ecology is provided in Rescan (2011f).

The spatial boundaries for the HHRAs and ERAs are defined, in part, by the extent to which the Project might be expected to have effects on the environment (i.e., air quality, drinking water quality, country foods quality), which could in turn affect human and ecological health. The following criteria were used to determine the spatial boundaries:

- the location and distribution of receptors, including the spatial extent of ecosystems and protected areas potentially affected by the Project; and
- the spatial extent of the known current use of lands and resources for traditional purposes.

Three general spatial boundaries were used in the HHRAs and ERAs:

1. Project development area – includes all physical structures and activities that comprise the Project as specified in the Project Description (TMAC 2017).
2. Local study area – includes the Project footprint and is the area where there is a reasonable expectation of immediate direct and indirect effects on human and ecological health due to an interaction with Project components or activities.
3. Regional study area – a broader area where there is a potential for direct, indirect interaction and/or cumulative effects to occur, including lands, waters, and potentially affected communities.

<u>Project Development Area</u>

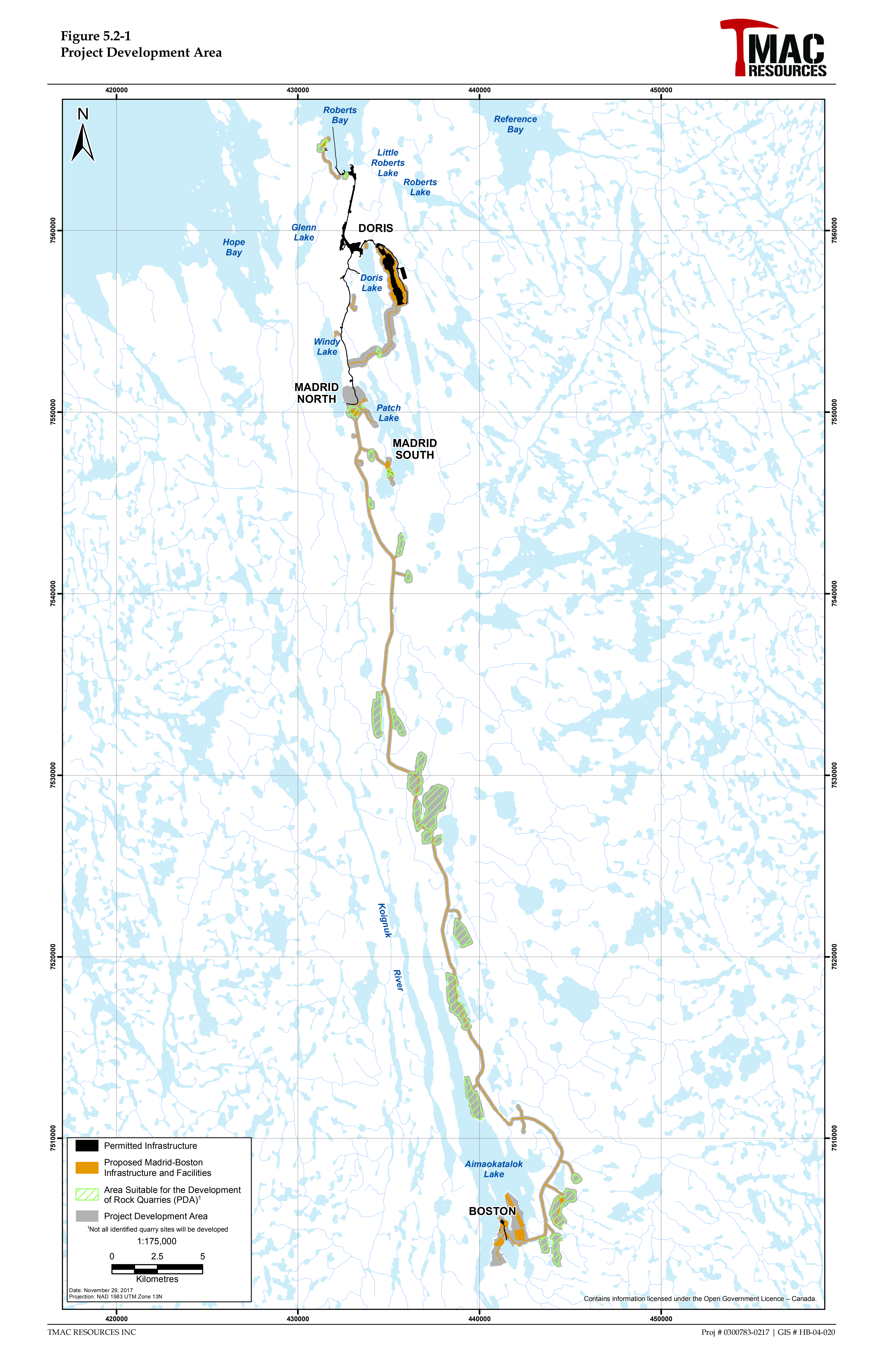
The Project Development Area (PDA) is shown in Figure 5.2-1. The exact locations of the facilities within the PDA are likely to change as the mining plan and engineering is finalized and detail design of the site proceeds. However, all facilities are expected to remain within the boundaries of the PDA. In order to capture conservative scenarios for the effects assessments, TMAC assumes that for terrestrial VECs the entire PDA is disturbed. The approach for water management, air quality, and noise remains unchanged, regardless of the final consideration of the site.

Since the infrastructure for the Doris Project is in place, the PDA exactly follows the footprints of these features. In all cases, the PDA does not include the Madrid–Boston Project design buffers applied to potentially environmentally sensitive features. These are detailed in Volume 3, Chapter 2 (Project Design Considerations).

<u>Local Study Area</u>

The Local Study Area (LSA) is defined as the PDA and the area surrounding the PDA within which there is a reasonable potential for effects on human and ecological health due to Project emissions to air or water. For example, the human health LSA includes watersheds that could be potentially indirectly or directly affected by mine development and operation.

Figure 5.2-1
Project Development Area



The selection of the human health LSA took into account the LSAs (or modeling domains) used by other VECs and VSECs with a pathway to human health. Thus the human health LSA (Figure 5.2-2) is the largest LSA boundary of the:

- atmospheric environment (Volume 4, Figure 2.5-2);
- noise and vibration environment (Volume 4, Figure 3.7-1);
- terrestrial environment (Volume 4, Figures 7.2-1 [Landforms and Soils], 8.2-1 [Vegetation and Special Landscape Features], 9.4-1 [Terrestrial Wildlife]);
- freshwater environment (Volume 5, Figures 4.2-2 [Freshwater Water Quality], 5.2-2 [Freshwater Sediment Quality], and 6.2-1 [Freshwater Fish]);
- marine environment (Volume 5, Figures 8.2-1 [Marine Water Quality], 9.2-1 [Marine Sediment Quality], 10.2-1 [Marine Fish], and 11.4-1 [Marine Wildlife]); and
- land use environment (Volume 6, Figure 4.2-1).

This LSA boundary for human health was chosen because of the strong link between these environmental components, human activities in the area, and wildlife use of the area. This approach recognizes the relationship between the environment, the people who use the land and rely on its resources, and the local wildlife species. The entire area of Roberts Bay was also included in the human health LSA as it is designed around the shipping route (Figure 5.2-2).

For the ERA, the LSA for each of the ecological receptors is based on the LSA for the specific VEC. For example, the LSA for caribou is equivalent to the LSA for the terrestrial environment described in Volume 4, Section 7.2.2 (Figure 7.2-1), while the LSA for freshwater fish is equivalent to the LSA for the freshwater environment described in Volume 5, Section 4.4.2 (Figure 4.2-2). The LSAs that apply to ecological receptors include:

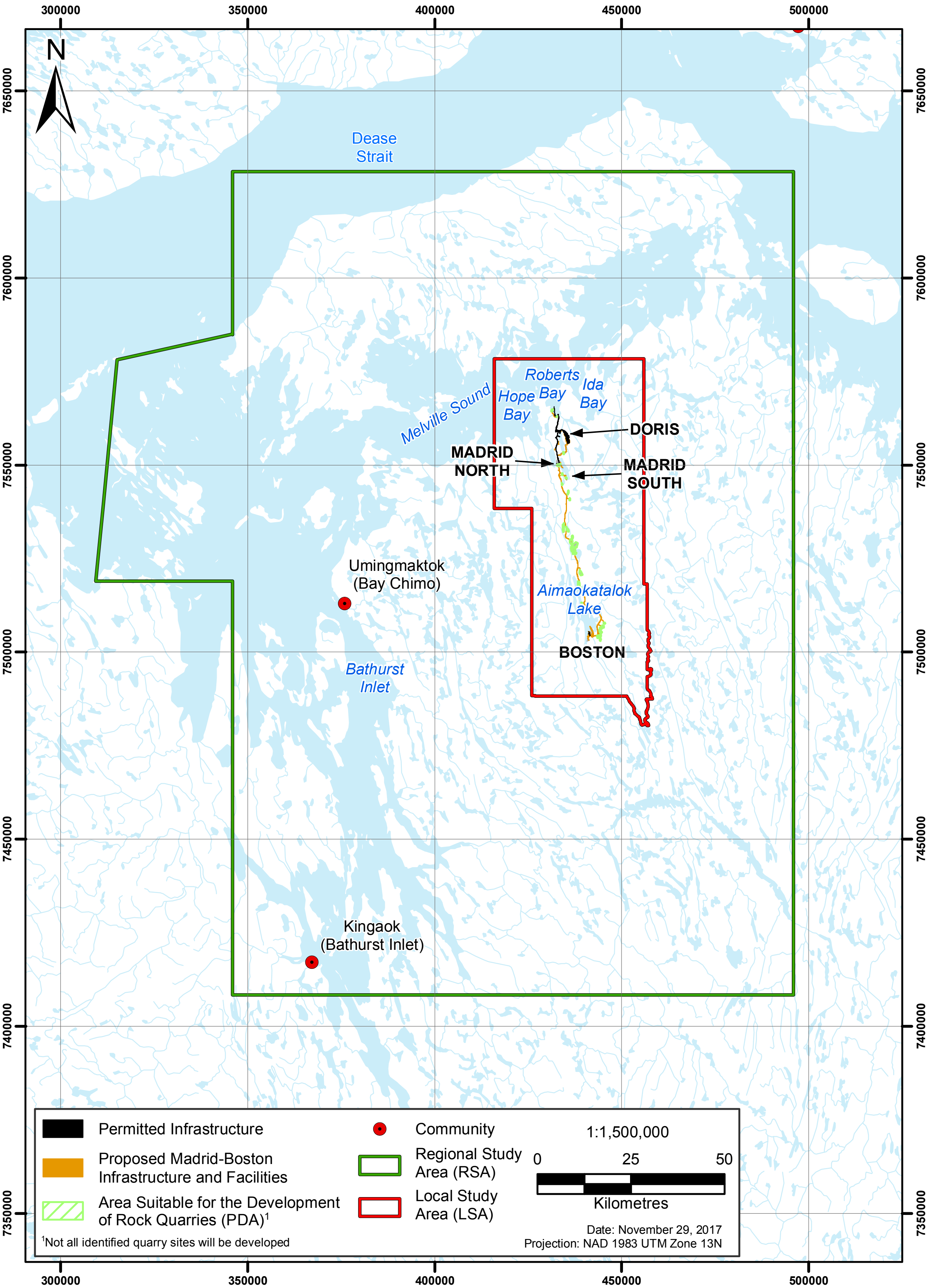
- terrestrial environment (Volume 4, Figure 9.4.1 [Terrestrial Wildlife]);
- freshwater environment (Volume 5, Figure 6.2-1 [Freshwater Fish]); and
- marine environment (Volume 5, Figures 10.2-1 [Marine Fish] and 11.4-1 [Marine Wildlife]).

<u>Regional Study Area</u>

The Regional Study Area (RSA) is defined as the broader spatial area representing the maximum limit where potential direct or indirect effects to human or ecological health may occur. The selection of the human health RSA took into account the RSAs used by other VECs and VSECs that have the potential to affect human health. The human health RSA (Figure 5.2-2) is the largest RSA boundary of the:

- atmospheric environment (Volume 4, Figure 2.4-2);
- noise and vibration environment (Volume 4, Figure 3.7-1);
- terrestrial environment (Volume 4, Figures 7.2-1 [Landforms and Soils], 8.2-1 [Vegetation and Special Landscape Features], 9.4-1 [Terrestrial Wildlife]);
- freshwater environment (Volume 5, Figures 4.4-2 [Freshwater Water Quality], 5.2-2 [Freshwater Sediment Quality], and 6.2-1 [Freshwater Fish]);
- marine environment (Volume 5, Figures 8.2-1 [Marine Water Quality], 9.2-1 [Marine Sediment Quality], 10.2-1 [Marine Fish], and 11.4-1 [Marine Wildlife]); and
- land use environment (Volume 6, Figure 4.2-1).

Figure 5.2-2
Human Health Local and Regional Study Areas, Madrid-Boston Project



This RSA boundary was chosen because of the strong link between these environmental components, human activities in the area, and wildlife use of the area. This approach recognizes the relationship between the environment and the local wildlife species. The human health RSA included marine waters from Roberts Bay through Melville Sound, to where the anticipated Project-related shipping would meet the main shipping lane in the Coronation Gulf.

For the ERA, the RSA for each of the ecological receptors is based on the RSA for those specific VECs. For example, the RSA for caribou is equivalent to the RSA for the terrestrial environment described in Volume 4, Section 7.2.2, while the RSA for freshwater fish is equivalent to the RSA for the freshwater environment described in Volume 5, Section 4.4.2 (Figure 4.2-2). The RSAs that apply to ecological receptors include:

- terrestrial environment (Volume 4, Figures 9.4.1 [Terrestrial Wildlife]);
- freshwater environment (Volume 5, Figures 6.2-1 [Freshwater Fish]); and
- marine environment (Volume 5, Figures 10.2-1 [Marine Fish] and 11.4-1 [Marine Wildlife]).

5.2.2.4 Temporal Boundaries

The Project represents a significant 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 (EAAs) for the Hope Bay Project and the extension of activities.

For the purposes of the EIS, distinct phases of the Project are defined (Table 5.2-1). It is understood that construction, operation and closure activities will, in fact, overlap among sites; this is outlined in Table 5.2-1 and further described in Volume 3, Chapter 2 (Project Description).

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 5.2-1. Temporal Boundaries for the Human Health and Environmental Risk Assessments

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

Phase	Project Year	Calendar Year	Length of Phase (Years)	Description of Activities
Operation	5 - 14	2023 - 2032	10	• **Roberts Bay**: shipping operations (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.

There are two main pathways for contaminants to enter the environment: airborne emissions (e.g., dust, particulates, and gases) and liquid emissions (e.g., effluent discharge). For the purpose of the HHRA and ERA and based on the information available at the time of writing, the phases in which the greatest potential for effects to human and ecological receptors were selected for assessment, with consideration of the potential for both air and water emissions during those phases. This was done to represent the upper bound of expected Project-related changes and therefore represents the periods associated with the greatest level of risk; risk during other phases would be expected to be lower. The Construction and Operational phases were considered to have the highest potential for Project-related air emissions and liquid emissions. Other phases of the Project would be expected to have lower emissions, and thus lower potential risk to human or ecological health due to changes in environmental quality. Therefore the Construction and Operational phases were the focus of the assessment.

5.3 EXISTING CONDITIONS HUMAN HEALTH RISK ASSESSMENT

5.3.1 Definition of Health

Canadian federal and provincial governments and health officials have accepted the World Health Organization's (WHO 1948) definition of holistic health:

> *A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.*

This was expanded to include (WHO 1984):

> *The extent to which an individual or group is able, on the one hand, to realize aspirations and to satisfy needs, and on the other, to change or cope with the environment. Health is therefore seen as a resource for everyday life, not the objective of living; it is seen as a positive concept emphasizing social and personal resources, as well as physical capacities.*

This definition indicates that all aspects of well-being should be considered when assessing human health, including physical, social, emotional, spiritual, and environmental impacts on health. There are many determinants of human health, such as: the physical environment (including environmental contaminants), heredity, lifestyle (e.g., smoking, drinking, diet, exercise, and coping skills), occupation, education, and the social and economic environment a person lives in (Health Canada 2000). However, not all of the health aspects are relevant for an HHRA since they would not be considered susceptible to effects from contaminants or noise, or would not be pathways for contaminant exposure in human receptors.

Humans, and consequently human health, have the potential to interact with Project components and health is of high importance to society and individuals. The physical component of human health was considered in the HHRAs because the physical health of humans living in or travelling through the Project area has the potential to be affected directly through either biochemical pathways (e.g., contaminants in water, air, or country foods) or biophysical pathways (i.e., noise). Volume 6, Chapters 3 (Socio-economics) and 4 (Land Use), of this EIS contain an assessment of other non-physical determinants of health that are not included in this HHRA, such as education, employment, health and community well-being, and land use.

Inuit perspectives on food and health are strongly integrated. The social, cultural, spiritual, nutritional, and economic benefits of country foods together play a role in how Aboriginal groups in general perceive country foods. The hunting, fishing, and gathering of country foods, and subsequent sharing of these foods with others throughout the community are social activities that bring individuals and families together (Chan et al. 2011).

5.3.2 Problem Formulation

The purpose of the problem formulation stage of the risk assessment is to create a conceptual model for the existing conditions HHRA. This stage identifies data requirements to accurately assess the potential for human health effects due to exposure to noise and COPCs from within the human health LSA and RSA. The objectives of the problem formulation stage are to:

- identify potential human receptors, characteristics, and the relevant life stages that may be in the area;

- identify the relevant human exposure pathways; and
- identify and select the relevant COPCs within the human health study areas.

5.3.2.1 Human Receptors and Traditional Knowledge

The quantitative existing conditions HHRA focused on human receptor locations within the human health LSA (Figure 5.3-1), where people may reside (as opposed to specific fishing locations or travel paths).

Two types of land users may access areas near to the Project: commercial land and resource users (e.g., sport hunters, licenced outfitters, tourism operators) and local Inuit land users participating in traditional land use activities (e.g., hunting, trapping, gathering).

Inuit land users will be allowed to travel over Project areas to access KIA IOL (Kitikmeot Inuit Association Inuit-owned Lands) outside of the land covered by the TMAC Advanced Exploration Agreement and Commercial Lease. This will facilitate the continued use of areas outside of the Project site for typical land use activities. In addition, traditional land users will be able to stay overnight at site while travelling on the land if they are in need of emergency shelter.

The Project is located within the traditional territory of the Kitikmiut Inuit, which is the Kitikmeot region of Nunavut (Banci and Spicker 2015). In 2011, the majority of the Kitikmeot population (91%) self-identified as Aboriginal, of which 99% were Inuit. In Cambridge Bay, 81% of the population self-identified as Aboriginal; however, 91% or more people identify as Aboriginal in other communities in the area (Statistics Canada 2015).

Primary information about current land use activities was obtained through interviews with representatives of the Hunter and Trappers Organization (HTO) in each Kitikmeot community, local hunters, and government land and resource managers as presented in the *2011 Socio-economic and Land Use Baseline Report* (Rescan 2012c). In November 2011, a land use focus group session was held with people from Omingmaktok (Bay Chimo), the community closest to the Project. Additionally, in September 2016, TMAC held a workshop with Elders and harvesters to discuss the potential effects of the Project on wildlife, with a focus on caribou and related traditional land use activities (ERM and EDI 2016).

No roads connect communities in Nunavut, making them remote and isolated from one another. The five communities within the Kitikmeot Region of Nunavut are: Cambridge Bay, Kugluktuk, Gjoa Haven, Taloyoak, and Kugaaruk. Cambridge Bay, a traditional hunting and fishing location, is the largest community that acts as a regional hub for government, business, and transportation. However, all five of these communities are well outside the human health RSA (Figure 5.3-1). The settlements of Kingaok and Omingmaktok on the shores of Bathurst Inlet are no longer occupied year-round and are now used primarily as seasonal camps. Residents of Kingaok relocated to Cambridge Bay in 2006, and residents of Omingmaktok relocated to Cambridge Bay in 2011. Both of these settlements are also located outside of the human health LSA but are within the RSA (Figure 5.3-1).These are the only known communities or settlements within the human health RSA.

Travelling on the land, hunting, and fishing remain important cultural activities throughout the Kitikmeot Region. Individuals interviewed did not identify specific locations that people visit for ceremonial and spiritual reasons; however, an Elders group has started going to old camp sites and places where relatives were born. Approximately 20 to 25 hunters (in some years more) are active within and near the land use LSA (Rescan 2012c). Figure 5.3-1 and Table 5.3-1 notes the location of camps (C), cabins (CB), important fishing locations (F), important hunting areas (H), and important travel routes (T) located within the human health LSA and RSA. While several known hunting and fishing camps and cabins are noted in Figure 5.3-1, local land users camp in many places as they travel through the area hunting and fishing and camping is not limited to the identified camps (Rescan 2012c).

Figure 5.3-1

Human Receptor Locations, Madrid-Boston Project

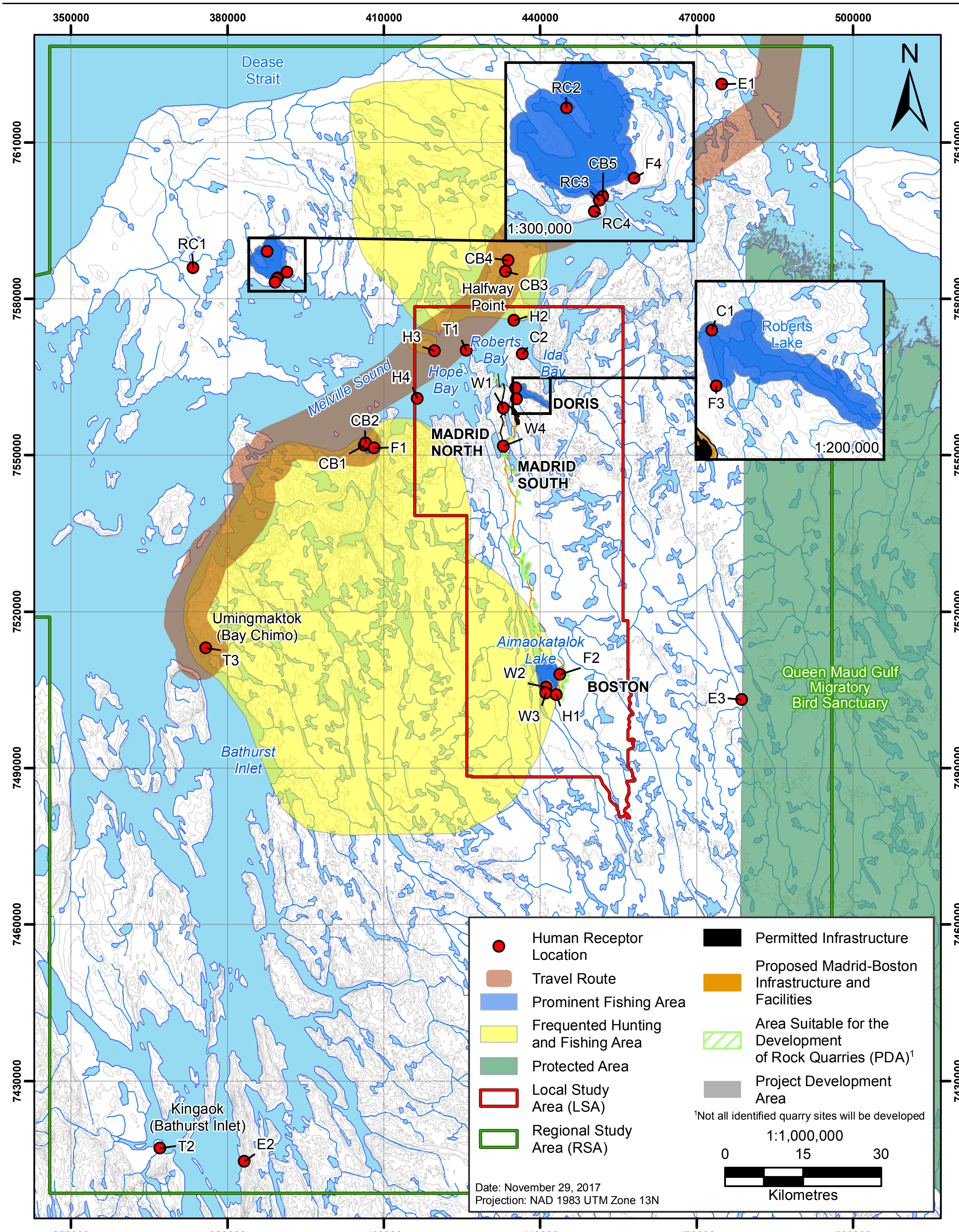


Table 5.3-1. Human Receptor Locations in the Human Health Risk Assessment Study Areas

		Within the Risk Assessment		UTM Zone 13			
Human Receptor Location	**Site ID**	**LSA**	**RSA**	**Easting**	**Northing**	**Easting**	**Northing**
Cabin	CB1	No	Yes	406275	7551932	-	-
Cabin	CB2	No	Yes	406503	7552314	-	-
Cabin	CB3	No	Yes	433389	7585228	-	-
Cabin	CB4	No	Yes	433848	7587353	-	-
Cabin	CB5	No	Yes	389681	7584010	-	-
Research Cabin	RC1	No	Yes	373407	7585963	-	-
Research Cabin	RC2	No	Yes	387595	7589105	-	-
Research Cabin	RC3	No	Yes	389480	7583781	-	-
Research Cabin	RC4	No	Yes	389183	7583152	-	-
Outpost Camp	C1	Yes	Yes	435299	7562924	-	-
Seasonal Camp (spring/summer)	C2	Yes	Yes	436579	7569440	-	-
Kingaok (Bathurst Inlet)	T2	No	Yes	367070	7417143	-	-
Umingmaktok (Bay Chimo)	T3	No	Yes	375882	7513041	-	-
Fishing Area [a]	F1	No	Yes	408133	7551357	407201	7551371
Fishing Area [a]	F2	Yes	Yes	443743	7507934	441365	7507453
Fishing Area [a]	F3	Yes	Yes	435464	7560803	437868	7561545
Fishing Area [a]	F4	No	Yes	391467	7585067	388224	7587813
Hunting and Fishing [a, b]	H1	Yes	Yes	443076	7504032	407779	7514800
Hunting and Fishing [a, b]	H2	Yes	Yes	435004	7575863	423352	7600111
Hunting and Fishing [a, c]	H3	Yes	Yes	419714	7570035	417448	7571578
Hunting and Fishing [d]	H4	Yes	Yes	416437	7560887	-	-
Travel Route [a]	T1	Yes	Yes	425864	7570078	429838	7578818
Elu Inlet Lodge	E1	No	Yes	474870	7621170	-	-
Bathurst Inlet Lodge	E2	No	Yes	383240	7414590	-	-
Queen Maude Gulf Migratory Bird Sanctuary	E3	No	Yes	478687	7503125	384996	7452750
Doris Camp (active)	W1	Yes	Yes	432965	7559019	-	-
Boston Exploration Camp	W2	Yes	Yes	441137	7505488	-	-
Boston Operations Camp	W3	Yes	Yes	441091	7504366	-	-
Quarry D Camp	W4	Yes	Yes	432902	7551719	-	-

Notes:
(-) = indicates a point location that has only one set of UTM coordinates (i.e., not an area).
[a] *The first easting and northing UTM is the location closest to Project infrastructure; the second easting and northing UTM is the location of the middle of the area.*
[b] *Subsistence hunting for wolves, caribou, wolverine, and muskox. Grizzly bear sport hunts in spring.*
[c] *Subsistence hunting for wolverine and seals.*
[d] *Subsistence hunting for migratory birds in spring and summer.*

Other areas frequented by people include the Walker Bay Research facility and a research cabin (RC1 and RC2 in Figure 5.3-1, respectively) near the west end of Kent Peninsula that belong to the Government of Nunavut Department of Environment. There are also two Fisheries and Oceans Canada cabins on the south side of Kent Peninsula (RC3 and RC4 in Figure 5.3-1). Areas visited by eco-tourists are the sites labeled E1 to E3 on Figure 5.3-1.

The largest protected area proximal to the Project is the Queen Maud Gulf Migratory Bird Sanctuary (site labeled E3 in Figure 5.3-1), which is a legislated conservation area. Designated conservation zones are also found near Hood River in the Wilberforce Falls area and the Hiukitiak River watershed, east of the Bathurst Inlet area. These zones are of cultural importance for local Inuit and serve as a destination for eco-tourists (NPC 2004). However, these locations fall outside of the human health RSA.

The Kitikmeot Region also includes numerous territorial parks, such as Ovayok (Mount Pelly) Territorial Park, the Northwest Passage Trail, and Kugluk/Bloody Falls; however, these locations fall outside of the human health RSA. The Bathurst Inlet Lodge and Elu Inlet Lodge (sites labeled E1 and E2 in Figure 5.3-1) offer eco-tourism services (see Volume 6, Section 4.2.4.4); however, recent economic downturns have limited their operations and the lodges are also located outside of the human health LSA.

In addition to land users, the existing conditions HHRA also includes the assessment of off-duty workers residing at the worker camps to allow comparison with off-duty workers assessed in the Project-related HHRA. Worker camps include: the Doris camp with capacity for up to 280 people, the Boston Exploration camp with capacity for up to 65 people, the Boston Operations camp with capacity for up to 100 people, and the Quarry D camp with capacity for up to 100 people (Figure 5.3-1).

For human receptors considered to be land users (e.g., guide outfitters and Inuit hunting and fishing), it was assumed they could be present in the human health LSA for three months of the year. As described in Volume 6, Section 4.2.4.4, the Bathurst Lodge is open during the summer months (June, July, and August). As described in Volume 6, Section 4.2.4.7, local land users report that most hunting occurs December through April, while fishing tends to occur primarily in winter, spring, and summer. At the nearby proposed Back River Project in NU, it was assumed in the HHRA that land users could be present for 11 days of the year (ERM 2015). At the nearby proposed Meliadine Gold Project in NU, it was assumed that land users could be present for one month of the year (Golder Associates Ltd. 2014). At the nearby proposed Jay Project at Ekati Diamond Mine in NWT, it was assumed that land users could be present for three months of the year (Golder Associates Ltd. 2015). Therefore, assuming a land user could be present in the human health LSA for three months of the year (12 weeks) is a conservative assumption, consistent with other HHRAs conducted in the area.

For human receptors considered to be off-duty workers, it was assumed they could be present for half the year (26 weeks) due to a two week on and two week off shift rotation. This assumption is also conservative as it does not account for any additional time off a worker could take due to vacation, illness, or other factors. The off-duty worker was assumed to be at the Project site throughout the duration of the Project for a total of 14 years (4 years Construction and 10 years Operational phase). The off-duty worker is not expected to hunt and consume country foods from within the human health study area as the camp kitchens provide commercially prepared foods.

Table 5.3-1 shows which human receptor locations fall within human health LSA and/or RSA (Figure 5.3-1).

<u>Human Receptor Characteristics</u>

Chemicals that cause health effects are generally divided into two categories: threshold (i.e., non-carcinogenic) and non-threshold (i.e., carcinogenic) responses. These two categories of chemicals are evaluated differently. Therefore, when selecting human receptors to evaluate, the types of chemicals that people may be exposed to must be considered.

The human receptors selected were toddlers (1 year to 3 years and 11 months) and adults (greater than 20 years of age; Richardson and Stantec Consulting Ltd. 2013). Toddlers are often most susceptible to chemicals with a threshold response due to their ratio of body size to ingestion rates (IRs) compared to other life stages (Health Canada 2010c, 2010d). Therefore, if an evaluation finds that COPC concentrations in media are unlikely to pose a health risk to toddlers, all other life-stages would be considered protected. An adult receptor was also selected for both threshold and non-threshold response chemicals based on guidance provided by Health Canada (2010a). For assessing exposure to mercury (in the form of methylmercury), women of child-bearing age were also assessed as a sensitive group.

The human receptor characteristics used to calculate the EDI of COPCs were body weight (kg), consumption amount/serving size (kg), and consumption frequency (number of servings per year or per week of highest exposure) of the selected country foods. The body weight for adults (76.5 kg) and toddlers (15.3 kg) were based on guidance provided by (Richardson and Stantec Consulting Ltd. 2013). It was assumed that a toddler would eat country foods at the same frequency as adults, since toddlers most likely consume the same meals together with adults. The assumed toddler serving sizes were calculated as 50% of the adult serving sizes (Health Canada 2007a). It is anticipated that this amount overestimates actual toddler serving sizes as Richardson (1997) suggests toddlers consume 43% of what adults do.

Country foods consumption characteristics (country food intake amounts and frequencies) used in the country foods assessment presented in Table 5.3-2 are based on information provided in the *Doris North EIS* (Miramar Hope Bay Ltd. 2005), the *Hope Bay Socio-economic and Land Use Baseline Report* (Rescan 2012c), Nancarrow (2007), Coad (1994), and Egeland (2010). The majority of data for country food daily intake estimates for this report was obtained from results of extensive and relatively recent surveys of portion sizes and consumption frequencies conducted for 25% of the adults from Repulse Bay and Kugaaruk communities between 2003 to 2005 (Nancarrow 2007). Portion size and annual consumption frequency for caribou, Arctic ground squirrel, willow ptarmigan, berries, Arctic Char, and Lake Trout were based on the results of these surveys and were amortized to obtain a daily consumption rate.

Table 5.3-2. Consumption Rates of Country Foods

Country Food	Toddler Consumption Rate [a] (kg/day)	Adult Consumption Rate (kg/day)
Large terrestrial mammal [b]	0.111	0.223
Large terrestrial mammal liver [c]	0.00168	0.00337
Large terrestrial mammal kidney [c]	0.000863	0.00173
Small terrestrial mammal [d]	0.0246	0.0492
Bird [e]	0.00571	0.0114
Berries [f]	0.00650	0.0130
Marine fish [g] (Arctic Char)	0.0240	0.0480
Freshwater fish (Lake Trout) [g]	0.00844	0.0169

Notes:
[a] *Toddler serving sizes are assumed to be 50% of adult serving sizes.*
[b] *From Nancarrow (2007). Consumption rate includes all types of caribou tissue (other than liver and kidney tissue), including polar bear tissue (as it is also a large terrestrial mammal).*
[c] *From Nancarrow (2007).*
[d] *From Coad (1994). For Dene/Metis of Colville Lake and Outpost Camps, NWT consuming beaver and rabbit.*
[e] *From Nancarrow (2007). Consumption rate includes all species of bird consumed (e.g., ptarmigan, swan, and king eider).*
[f] *From Egeland (2010).*
[g] *From Nancarrow (2007). Consumption rate includes all species of freshwater fish or marine fish and tissue types consumed (e.g., meat and eggs).*

Although Inuit are the primary harvesters of country foods in the study area, less than half (6 to 40%) of their total food consumed comes from country foods, depending on the degree of urbanization or remoteness of the community (INAC 2003). These estimates are based on 24-hour recall data of the Inuit that show the mean country food consumption for adult males between the ages of 20 and 40 years to be 245 g/day, and adult males over 40 years of age to be 440 g/day during the entire year (INAC 2003). Generally, older individuals had a higher consumption rate of traditional country foods (Kuhnlein and Receveur 2001). It is recognized that younger generations of Inuit are more urbanized and rely less on country foods; therefore, these consumption rates are likely to overestimate the true consumption for toddlers and younger adults (18 to 40 years old).

5.3.2.2 Human Exposure Pathways

Human exposure pathways are the routes by which people are exposed to chemicals. There are several potential exposure pathways between COPCs in environmental media to human receptors. The exposure pathways that may exist between COPCs and human receptors depend on many factors which may be direct, indirect, or both.

Exposure pathways were selected for the human health assessment based on the exposure from:

- inhalation of air;
- incidental ingestion of soil;
- dermal exposure to soil;
- ingestion of surface water; and
- ingestion of country foods.

In addition to the exposure pathways above, Health Canada (2010f) suggests that radiological effects and electromagnetic field (EMF) effects be included in HHRAs. However, more recent guidance on radiological impacts from Health Canada (2016c) states that the guidance only applies to environmental and human health assessments for nuclear facilities and uranium mines and mills. Therefore, radiological impacts were not included in the HHRAs for the Project because the proposed mine is a gold mine and radiation above background levels is not expected. Power lines and other electrical sources can cause weak electric currents to flow through the human body (EMF effects); however, the magnitude of the currents in power lines and other equipment is not associated with any known short- or long-term health risks. Therefore, radiological effects and EMF effects were excluded from the HHRAs because the Project activities (e.g., construction of the mine, underground mining, processing, and loading of ores) and infrastructure are not likely to generate radioactivity or EMFs with the potential to affect human health.

<u>Air</u>

Air quality was assessed in the EIS Volume 4, Chapter 2 (Air Quality) as part of the atmospheric environment assessment. Details of the baseline sampling program can be found in Volume 4, Section 2.2 and in Appendices V4-2A to V4-2H (Rescan 2009, 2010c, 2011c, 2011d, 2012a, 2012b; ERM Rescan 2014a, 2014b).

The Project is located in a remote area with few anthropogenic sources of air pollution and air quality in the West Kitikmeot region of Nunavut is considered pristine. Local emissions are limited to stationary (power generation and heating) and mobile sources (trucks, snowmobiles, all-terrain vehicles, etc.) operated by local residents in the few communities within the West Kitikmeot region. Mines operating in Nunavut represent the only major industrial emission source. Because of the limited local emission sources, long-range transport of air contaminants is the main influence on ambient air quality.

Baseline or background air quality data are the amounts of different air components represented as mass loadings per unit volume, concentrations, or deposition rates prior to Project commencement, and are due to emissions from both natural and anthropogenic sources. The existing TMAC Doris Project is in close proximity to the proposed Project and includes some overlapping infrastructure. The existing Doris Project conducts air quality monitoring as part of compliance reporting. These air quality monitoring data are used as baseline data for the proposed Project because these data represent the ambient existing air quality conditions prior to Project commencement.

Criteria Air Contaminants

An air quality baseline program was initiated for the Project in 2009 to 2014 and full details on the sampling methodology and data are presented in Volume 4, Section 2.2. Criteria air contaminants were sampled with one 24-hour Partisol particulate monitoring station and two Passive Air Sampling Systems (PASS) sampling stations (Doris and Boston). Criteria air contaminants include carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), coarse particulate matter (PM_{10}), and fine particulate matter ($PM_{2.5}$). Carbon monoxide was not included in the baseline monitoring program, thus annual average concentrations measured for the Bathurst Inlet and Road Project (BIPR; located northwest of the study area) were adopted as they are representative of background levels typical in Nunavut.

Metal Contaminants of Potential Concern

Baseline dustfall levels and metal concentrations in dustfall (in $mg/dm^2/day$) were monitored in the Project area from 2009 to 2012 in various areas throughout the Project area (see Figure 2.2-1 in Volume 4, Chapter 2: Air Quality). Raw dustfall metal data is presented in Appendix V6-5A. These data were considered when evaluating the inhalation exposure pathway in the existing conditions HHRA.

<u>Soil</u>

Soil quality was assessed in the EIS Volume 4, Chapter 7 (Landforms and Soils) as part of the terrestrial environment assessment. Details of the baseline sampling program can be found in Volume 4, Section 7.2 and in Appendix V4-7A (Rescan 2011k).

The terrain within the region is comprised largely of flat rolling bedrock covered with thin veneers of morainal, lacustrine, and fluvial deposits. Exposed bedrock is common, as repeated glacial advance and recession has removed much of the surficial material. Permafrost is found throughout the region and although annual precipitation is low, many low-lying areas remain permanently saturated. This is due to very low rates of evaporation and transpiration as well as a continual supply of moisture from within the soil profile due to seasonal melting of permafrost. The occurrence and development of Arctic wetlands, common throughout the region, is closely connected to the freezing and thawing of soil. Many Arctic wetlands are located in depressions, caused by glacial scour, that have filled with water from snowmelt.

Soil quality sampling was conducted for the Project in 2010 and 2014 and full details on the sampling methodology and results are presented in Volume 4, Section 7.2. Baseline soil quality from sites within the human health LSA that were sampled within the top 0 to 20 cm were included in the human health analysis. This resulted in the inclusion of 68 soil sampling sites (Figure 7.2-3 in Volume 4, Chapter 7: Landforms and Soils) and the raw data is provided in Appendix V6-5B. Metal concentrations that were below the method detection limit (MDL) were converted to half the MDL for calculation purposes.

<u>Water</u>

Freshwater aquatic resources and fish were assessed in the EIS Volume 5, Sections 4 (Freshwater Water Quality), 5 (Freshwater Sediment Quality), and 6 (Freshwater Fish) as part of the freshwater environment assessment. Details of the Project baseline sampling programs can be found in Volume 5, Sections 4.2, 5.2, and 6.2 and in Appendices V5-3J (Rescan 2010d), V5-3K (Rescan 2011g), V5-6D (Rescan 2010a), and V5-6E (Rescan 2011h).

Inuit using the land have indicated that drinking water is obtained from lakes, streams, and snow and that larger water bodies were better than smaller ones for obtaining drinking water (Rescan 2012c). In addition, areas near the coast do not have good quality drinking water due to underground seepage from the ocean, thus water inland is better for drinking (Banci and Spicker 2015). If clean water was unavailable, water could be treated by filtration or boiling. Water and ice were obtained from lakes; flowing rivers and creeks; pools under cliffs; pools among deep rock crevasses (from rain or melting snow); underground streams and cold water springs; wetlands; snow; inland in winter from lakes and rivers through an ice hole; on the ocean in winter from snow and icebergs; and on the ocean in spring from ice and pools of water on the ice surface. While at camp there were traditional places Inuit obtained water and while travelling they obtained water wherever they found it. Inuit felt they could obtain water everywhere and specific locations for obtaining drinking water were not mapped (Banci and Spicker 2015).

Water resources in Nunavut are managed by Aboriginal Affairs and Northern Development Canada (AANDC 2012). Nunavut does not have legislation for drinking water and utilizes Health Canada's Drinking Water Quality Guidelines (DWQGs; Health Canada 2015), which have been used in the existing conditions HHRA to screen for COPCs in drinking water. Health Canada recommends that surface water always be treated before using it for drinking water (Health Canada 2007b, 2016b). Groundwater will not be included as a drinking water source as permafrost below the soil prevents groundwater access to people using the land.

Water quality sampling of existing conditions of streams and lakes within the human health LSA was conducted for the Project from 2007 to 2017. Full details on the sampling methodology, raw data, and summary statistics of water quality parameters are presented in Volume 5, Chapter 4 (Freshwater Water Quality) and in Rescan (2010d, 2011g). Baseline surface water quality sampling locations are shown in Figures 4.2-3 (North Belt) and 4.2-4 (South Belt) in Volume 5, Chapter 4: Freshwater Water Quality.

Country Foods Quality

Country foods include a wide range of animal, plant, and fungi species that are harvested for medicinal or nutritional use. The primary objective when selecting country foods is to identify the most relevant foods to evaluate. Key considerations when selecting the country foods to evaluate include:

- which country foods may be currently collected in the human health RSA;
- how the country food is used *(*i.e., food, medicine, or both);
- what part(s) of the country food may be consumed *(*i.e., specific organs, plant leaves or roots);
- what quantities of each country food may be consumed; and
- what the consumption frequencies may be for each country food.

Traditional Knowledge on Country Foods Harvested

Subsistence hunting for caribou, muskox, wolverine, grey wolf, and fox takes place throughout the human health LSA; however, activity is most concentrated in areas west and south of the Project and on Kent Peninsula which is north of the Project (H1 and H2 on Figure 5.3-1; Rescan 2012c). The number of animals harvested by the average hunter depends on the size of their family (land use focus group participants; Rescan 2012c). Hunters will follow wildlife and change their hunting location based on animal populations and movements. For example, in past years Elders hunted more in areas extending from Hope Bay to Roberts Bay, as wildlife was plentiful there at the time. Now hunters have moved to other areas, following the wildlife pattern changes (Rescan 2012c).

Most hunting occurs from December through April. The season for muskox is set by regulation. The caribou hunt is open year round and caribou are hunted as they travel closer to communities during their migrations. Wolverines, wolves, and fox are hunted for their hides from October to April/May, as their hides are best in the winter (Rescan 2012c). Hunters from Omingmaktok noted that birds, including geese, swans, and eider ducks are also harvested everywhere they are found; however, an important area is site H4 on Figure 5.3-1. Island and lakes are some of the best areas for bird nesting (land use focus group participants; Rescan 2012c). Local land users noted that very few people are currently trapping, because of the low level of income that can currently be obtained from trapping relative to the cost of living.

Traditional hunting in the Roberts Bay area has included the harvest of ringed (*Phoca hispida*) and bearded (*Eringnathus barbatus*) seals in the past (Priest and Usher 2004). However, recent harvest activities have not targeted seals in the study area (Rescan 2012c). Focus group studies with hunters conducted in November 2011 indicated that they currently do not hunt seals or whales in the area or harvest other marine organisms (e.g., clams, seaweeds). Hence, only a marine fish species (i.e., Arctic Char) was included in the country foods assessment and marine mammals were not included.

Prominent fishing areas are noted within or near the human health RSA (F1 to F4 in Figure 5.3-1). Aimaokatalok Lake (F2) and a creek on the west side of Aimaokatalok Lake, which is open year round, are important fishing areas within the human health LSA (Rescan 2012c). During the land use focus group session, Roberts Lake was also highlighted as having abundant fish (F3 in Figure 5.3-1) and as being especially important to a family who lived at an outpost camp there for many years in the past (C1 in Figure 5.3-1).

Land users from Omingmaktok noted that there is abundant fish (e.g., Whitefish, Char, Cod, Sculpins, Flatfish) in Roberts Bay and Ida Bay (also known as Reference Bay), but that there is probably not a lot of activity in Roberts Bay because of its close proximity to the current Doris Project. Edible bivalves (e.g., *Mya truncata* and *Mytilus* spp.) are found in the marine area near Roberts Bay (Volume 5, Appendices V5-7A, V5-7C, V5-10D, and V5-10E) but people from Omingmaktok do not harvest them. Rather, they focus on Whitefish, Trout, and Cod (land use focus group participants; Rescan 2012c). Fish are harvested in winter, spring, and summer. Another outpost camp is located on the peninsula between Roberts and Ida bays and is used primarily in the spring and summer (site C2 on Figure 5.3-1).

In addition to traditional and subsistence activities, non-traditional land use activities, including commercial food harvesting, are of increasing importance throughout Nunavut. The main business venture in the region, Kitikmeot Food Ltd. currently conducts hunting for muskox and fishing for Arctic Char in the human health LSA (see Section 5.2.4.5 of Rescan 2012c).

The HTOs out of Bathurst Inlet (Burnside), Omingmaktok, and Cambridge Bay (Ekalututiak) each conduct sport hunts, mainly for grizzly bear, wolf, and muskox (Rescan 2012c). Although strict boundaries are not delineated, hunting areas may partially overlap the land use LSA and potentially the human health LSA. Muskox hunters commonly take the fur and head of the animal for trophies while the community receives the meat. Sport fishing is not currently reported to take place in the human health LSA.

The country foods selected for this study were largely based on information provided in the *Doris North EIS* (Miramar Hope Bay Ltd. 2005), the *Nunavut Wildlife Harvest Study* (NWHS; Priest and Usher 2004), the *2012 Socio-economic and Land Use Baseline Report* (Rescan 2012c), the *Inuit Traditional*

Knowledge for TMAC Resources Inc. Proposed Hope Bay Project, Naonaiyaotit Traditional Knowledge Project (NTKP; Banci and Spicker 2015), and the September 2016 caribou workshop (ERM and EDI 2016).

The NWHS conducted between 1996 and 2001, remains the most current comprehensive information source on subsistence harvests in the Kitikmeot Region. The survey collected data on non-commercial hunting, trapping, gathering, and fishing of mammals, birds (and their eggs and feathers), fish, and shellfish. At a 2003 Inuit workshop, Elders from Omingmaktok, Bathurst Inlet, Kugluktuk, and Cambridge Bay stated that most of their food comes from the land (NPC 2004). In Goa Haven and Cambridge Bay, most people reportedly still eat country foods every day, which are sometimes mixed with store bought foods (Rescan 2012c). Recent government statistics indicate at least half of the meat and fish consumed in the household by 66% of Inuit adults (aged 15 years and over) across Nunavut is country foods (Statistics Canada 2008). An additional 38% report that more than half of the meat and fish consumed is obtain through harvesting activities (i.e., as compared to the amount that is purchased in stores).

For Inuit populations whose main food source is from harvesting, it is not always feasible to assess all country foods. This is due to the large number of species that are harvested and also seasonal availability due to migration patterns of the harvested populations or accessibility to hunting grounds (e.g., lack of sea ice for seal hunting during the summer). For such populations, the foods selected for evaluation are those that result in the highest exposure to COPCs (i.e., foods that are consumed most frequently and in the largest amounts). For instance, foods that are consumed every day are generally selected. Country foods that are consumed seasonally or infrequently may not be selected as they may not be a major exposure source of COPCs. These factors are considered when selecting the most relevant country food to evaluate. Therefore, one country food species was selected as a proxy from each of the following groups of foods: large mammals, small mammals, birds, fish, and vegetation.

The following sections provide more detailed information about country foods that may be harvested from the human health RSA and the rationale for the selection of representative food items to be evaluated in the existing conditions HHRA.

Terrestrial Wildlife Species

Terrestrial wildlife was assessed in the EIS Volume 4, Chapter 9 (Terrestrial Wildlife and Wildlife Habitat) as part of the terrestrial environment assessment. Details of the baseline programs can be found in the various reports listed in Section 9.2.4 of Volume 4. The wildlife baseline sampling program characterized the avian and mammalian communities within the study area between 1996 and 2015.

Terrestrial wildlife species include large and small mammals as well as avian species. To identify the most common terrestrial species harvested by the Inuit, the NWHS results were reviewed (Priest and Usher 2004). This study was mandated by the Nunavut Lands Claim Agreement and carried out under the direction of the Nunavut Wildlife Management Board (NWMB). Harvest data were collected monthly from Inuit hunters for a total of five years covering the harvest months from June 1996 to May 2001. The purpose of the NWHS was to determine current harvesting levels and patterns of Inuit use of wildlife resources. Harvest data for the communities adjacent to the Project area were reviewed. This included Omingmaktok (75 km to the southwest of the property), Cambridge Bay, and Kingaok (Bathurst Inlet; 160 km to the southwest of the property).

Large Terrestrial Mammals

Caribou (*Rangifer tarandus*) are the most commonly harvested large terrestrial mammal by Inuit in the west Kitikmeot Region and from Omingmaktok, Cambridge Bay, and Bathurst Inlet (Rescan 2012c; Banci and Spicker 2015; ERM and EDI 2016). Caribou have overlapping herding grounds and migration corridors within the human health RSA (Rescan 2011e; ERM and EDI 2016). As such, caribou was selected for evaluation in this study, with the muscle tissue being the most commonly identified part consumed. Although caribou do migrate over large areas well outside of the human health RSA, their importance to the Inuit diet supports their inclusion in this study. However, any potential future increase in COPC concentrations in caribou tissue, while useful to know to inform and protect local human health, may or may not be related to the Project due to the vast size of their home range. This is because caribou could take in COPCs anywhere within their vast home range.

Estimation of occurrence of caribou in the Madrid-Boston Project area is based on baseline collar data (for details of this program see Volume 4, Section 9.8.3.2). The area used in this assessment is based on the air quality assessment area. The air quality assessment evaluated dust deposition within a 2 km Property Boundary (PD) zone. This modeling predicted that maximum TSP and $PM_{2.5}$ concentrations met applicable standards at the PD, 2 km from the Doris, Madrid North, Madrid South and Boston PDA's. PM_{10} was predicted to exceed the applicable 24-hour average guideline by 19% along the property boundary to the southeast of Madrid South. However, exceedances were predicted to be infrequent (no more than one day per year).

In order to match the assessment used in the air quality assessment, the HHRA evaluated the residency time of caribou within the 2 km PD. For the Island caribou, which spend the greatest time in the Project area, a total of 5% of collars interact with the PD across all years of collar data and the residency time was calculated as 0.38 days per year for spring migration, fall migration and winter combined and 0.4 days per year during the winter, when caribou are actively feedings in the Project area. An initial (i.e., preliminary) residency time of 0.49 days per year was estimated for caribou (Volume 4, Section 9.8.3.7). As a conservative approach, this initial value of 0.49 days per year was used in the food chain model instead of the newer (and lower) frequency of 0.4 days per year.

In addition to the muscle, different organs of country food species may be a part of the diet of Inuit (Nancarrow 2007). For example, muscle, fat, bone marrow, and organs such as tongue, kidneys, liver, stomach, and intestine of caribou are included in the Inuit diet and provide a valuable nutritional source (Nancarrow 2007). This assessment estimates the daily intake of COPCs from ingestion of caribou (whole body) and in caribou liver and kidney. Consumption frequencies and portion sizes related to caribou were selected to reflect the consumption of all large terrestrial mammal tissues which were considered as caribou, with caribou liver and kidney considered separately from whole body.

Small Terrestrial Mammals

The Arctic ground squirrel (*Spermophilus parryii*) is the most commonly harvested small terrestrial mammal by the harvesters from Omingmaktok Bay and Bathurst Inlet (Rescan 2012c; Banci and Spicker 2015). Arctic fox (*Alopex lagopus*) is the most common small mammal harvested from Cambridge Bay; however, it is likely harvested for its pelt (Rescan 2012c; Banci and Spicker 2015). Consequently, muscle tissue of the Arctic ground squirrel was the small terrestrial mammal selected for evaluation.

Although Arctic ground squirrels are resident species of the area, they hibernate over winter from early September to late April. Thus, residency time of Arctic ground squirrel in the human health RSA is assumed to be five months. As such, hunting of Arctic ground squirrels is assumed to take place five months of the year. It is likely that some of the meat is preserved for future use when this species is not accessible during the remaining months of the year.

Birds

Birds harvested in the area include various species of ducks, geese, and ptarmigans. Willow ptarmigan (*Lagopus lagopus*) were selected for evaluation as their consumption is considered reflective of all avian species harvested from the human health LSA. Although ptarmigan is primarily harvested in the winter and early spring, their small home range would result in greater COPC exposure than species that migrate and they could potentially be within the LSA for their entire life. Therefore, residency time of willow ptarmigan in the human health LSA and RSA is the entire year.

Freshwater and Marine Fish Species

A total of 10 freshwater fish species have been identified in the freshwater environment RSA, including Arctic Char (*Salvelinus alpinus*), Arctic Grayling (*Thymallus arcticus*), Broad Whitefish (*Coregonus nasus*), Burbot (*Lota lota*), Lake Trout (*Salvelinus namaycush*), Lake Whitefish (*Coregonus clupeaformis*), Cisco (*Coregonus artedi*), Least Cisco (*Coregonus sardinella*), Ninespine Stickleback (*Pungitius pungitius*), and Slimy Sculpin (*Cottus cognatus*; Rescan 2010a, 2011h). Lake Trout and Ninespine Stickleback were the most common fish species in lakes, rivers, ponds, and streams within the freshwater environment RSA and have been found in almost all lakes surveyed (Rescan 2010a, 2011h). Lake Trout are the largest freshwater piscivorous fish species in the human health RSA and could experience increased COPC bioaccumulation in tissues relative to non-piscivorous fish. This contributes to its importance in the assessment.

The most commonly harvested fish species from the Project area are Arctic Char, Lake Trout, and Whitefish (*Coregonus spp.*; Rescan 2010a). The most commonly harvested marine fish species are Arctic Char and Cod (species unspecified; Priest and Usher 2004). In all three communities, Arctic Char are the most commonly consumed fish and were used as a surrogate for other marine fish species. Consumption of Arctic Char in the Project area is primarily of sea-run adults harvested from the Roberts Bay area. Lake Trout and Whitefish are considered equal in value as a food resource by the Inuit and are preferred fish species after Arctic Char (Miramar Hope Bay Ltd. 2005). In the Arctic, Lake Trout can also be anadromous (Swanson et al. 2010) but analysis was not conducted during baseline studies to determine if the fish sampled for tissue metal analysis were anadromous. The Arctic Char returning to freshwater, depending on how much growth occurred at sea (which can be substantial), will reflect a marine contaminant signature (though it will be partially representative of the freshwater environment).

Table 6.2-12 and Figures 6.2-16 and 6.2-17 in Volume 5, Chapter 6 (Freshwater Fish) show where Lake Trout (n = 69) and Whitefish (n = 7) were sampled for tissue metal concentrations during studies conducted between 2009 and 2014.Since only one freshwater fish species is required to represent freshwater fish consumption, Lake Trout was included as a country food due to the larger sample size than Whitefish and due to potential for COPC bioaccumulation in Lake Trout.

Appendix V5-10F in Volume 5, Chapter 10 (Marine Fish) describes where Arctic Char (n = 17) were sampled for tissue metal concentrations during the baseline study conducted in 2017. Spawning, rearing, and overwintering all occur in the freshwater environment, but adult Arctic Char feed in the marine environment (e.g., Roberts Bay) during the open-water season. Thus metal concentrations in Arctic Char tissues result from living in freshwater as well as marine environments.

Baseline metal concentrations in Ninespine Stickleback were also collected; however, that species is not consumed by humans and that data will only be used in the ERA (Section 5.5.1.3).

For Arctic Char and Lake Trout it was assumed that muscle (fillet) is consumed as specific consumption of various fish organs was not listed by Nancarrow (2007). Raw fish tissue data is provided in Appendix V6-5C.

Vegetation Species

Vegetation was assessed in the EIS Volume 4, Chapter 8 (Vegetation and Special Landscape Features) as part of the terrestrial environment assessment. Details of the baseline sampling program can be found in Volume 4, Section 8.2 and in Rescan (2011f).

Stunted forms of common tree species, such as dwarf birch (*Betula nana*), green alder (*Alnus viridis* spp. *crispa*), willow species (*Salix* spp.), and less commonly, white and black spruce (*Picea glauca* and *mariana*) grow throughout the region. Sedge meadows, tussock tundra, and heath tundra dominate the ground layers. Sparsely vegetated areas, such as the wind-swept crests of eskers, are also common.

Typically in country foods studies, a vegetation species is selected as a country food for direct human consumption. In addition, where measured country food tissue COPC concentrations are not available, models require COPC concentrations in vegetation to estimate the COPC concentrations in country foods. Therefore, vegetation COPC concentration data can be part of the country foods assessment both as direct contributions (i.e., direct ingestion of vegetation or berries) or as indirect contributors through the consumption of country foods (i.e., intake of vegetation by wildlife and subsequent intake of wildlife by humans).

The Project ecoregion is classified as having a low Arctic ecoclimate, characterized by shrub tundra vegetation, consisting of dwarf birch (*Betula nana*), willow (*Salix* spp.), northern Labrador tea (*Ledum decumbens*), perennial avens (*Dryas* spp.), and blueberries (*Vaccinium* spp.; Rescan 2011f). Dwarf birch, willow, and alder (*Alnus* spp.) occur on dry sites, while wet sites are dominated by sphagnum moss and extensive sedge (*Carex* spp.) and cottongrass (*Eriophorium* spp.; Miramar Hope Bay Ltd. 2005).

Liquorice root (also called mahok) is an important springtime food source and leaves of the mountain sorrel and beach peas are also harvested and consumed (Banci and Spicker 2015). Other plants having medicinal or other cultural importance include white arctic heather, crowberries, and Labrador tea (Banci and Spicker 2015).

Berries, Arctic cotton, and “Eskimo potatoes” are occasionally eaten by the Inuit, but vegetation is considered important because of its value to wildlife rather than its value as food for people in the area (Miramar Hope Bay Ltd. 2005). Ecological knowledge from the Bathurst, Perry, and Ellis elders showed that some Inuit consume various berry species, such as blueberries (*Vaccinium* spp.), crowberries (*Empetrum nigrum*), cloudberries (*Rubus chamaemorus*), and salmonberries (*Rubus spectabilis*) during the short summers (Thorpe 2000). Although berries would be rarely harvested from the study area, baseline data are available for crowberries (*E. nigrum*), bog blueberry (*V. uliginosum*), and bearberry (*Arctostaphylos alpina*; Rescan 2011f) and were included in the country foods assessment. The berry samples were pooled and included in the assessment directly as a country food consumed by people in the region. Only above-ground parts of plants (leaves and berries) were collected.

Vegetation is not considered a staple of the Inuit diet. Consequently, most country food surveys of the Inuit in the Canadian Arctic do not address locally harvested vegetation as a food. A country foods 24-hour recall survey of 1,092 individuals in Nunavut showed that only five people (<0.5% of total participants) indicated that they consume blueberries (Kuhnlein et al. 2002). Although fruits and vegetables are increasingly consumed, many are imported and purchased from markets. Berry portion size was based on data from the *Inuit Health Survey 2007 to 2008* (Egeland 2010). Berries were assumed to be consumed as a whole.

To support food chain modeling for wildlife country food species, samples of lichen (*Flavocetraria nivalis* and *F. cucullata*) were also collected from 67 and 58 sites, respectively, within the human health LSA in 2010, 2011, and 2014, and analyzed for tissue metal concentrations. Figure 8.2-6 in Chapter 8 (Vegetation and Special Landscape Features) of Volume 4, shows the vegetation sampling locations within the terrestrial environment LSA that were used for inputs to the food chain model for estimation of the country food COPC concentrations. The raw baseline vegetation data is presented in Appendix V6-5D and the 95th percentile COPC concentration data for berries and lichen collected are presented in

Table V6-5E4 of Appendix V6-5E. The lichen samples were pooled and included in the assessment as a diet item for country food species (i.e., caribou, Arctic ground squirrel, and willow ptarmigan).

An online search was conducted to determine if there was baseline vegetation data available nearby existing or proposed projects that could be included with the baseline vegetation data for the Project to increase the variety of vegetation species in the assessment. However, the nearby projects (e.g., Kiggavik, Gahcho Kué, Meliadine, Back River, Mary River, and Meadowbank) are located outside the Human Health RSA and likely are not representative of site-specific metal concentrations of the Madrid-Boston Project due to inherent differences in heavily mineralized areas. Furthermore, future concentrations of metals in vegetation samples are calculated from dustfall results from the air quality model (see Section 5.4.2.5). Vegetation samples from other projects that are outside of the human health RSA would be well outside of the air quality modeling domain, thus would be unaffected by Project metals in dustfall. Therefore, the baseline metal concentrations in those vegetation samples would be identical to the future metal concentrations. Thus vegetation samples from those projects were not included in the assessment as they were not considered to be sufficiently site-specific and they would be outside the air quality model domain and would not be affected by Project dustfall.

Summary of Country Foods Selected for Evaluation

A summary of the country foods selected for evaluation is presented in Table 5.3-3.

Table 5.3-3. Country Foods Selected for Evaluation

Category	Country Food	Species Name	Parts Consumed
Terrestrial Wildlife	Caribou	*Rangifer tarandus*	Muscle, Liver, Kidney
	Arctic ground squirrel	*Spermophilus parryii*	Muscle
	Willow ptarmigan	*Lagopus lagopus*	Muscle
Fish	Arctic Char	*Salvelinus alpinus*	Muscle
	Lake Trout	*S. namaycush*	Muscle
Plants	Crowberry	*Empetrum nigrum*	Fruit
	Bearberry	*Arctostaphylos alpina*	Fruit
	Bog blueberry	*Vaccinium uliginosum*	Fruit
	Lichen [a]	*Flavocetraria nivalis*	Thallus
	Lichen [a]	*F. cucullata*	Thallus

Notes:
[a] *Lichens were included as a food source for caribou, Arctic ground squirrel, and willow ptarmigan only.*

5.3.2.3 Selection of Contaminants of Potential Concern

The existing conditions HHRA focused on metals as the COPCs since they naturally occur in environmental media (e.g., air, soil, and water) due to local physical and geological processes and their concentrations could potentially change due to future Project activities. The present assessment did not consider other contaminants such as persistent organic pollutants (POPs) and radionuclides as these are not typically associated with metal mining and are unlikely to be affected by Project-related activities. Noise was also assessed as it is a biophysical change to the environment (not a chemical change) and it is included in the HHRA as per Health Canada (2010b, 2017) guidance.

Environmental media data collected from within the human health RSA that were considered in selection of COPCs for the existing conditions HHRA include:

- criteria air contaminants (CACs; nitrogen dioxide, sulphur dioxide, and particulate matter) concentrations collected from two stations during Project baseline studies between 2009 and 2014;
- metal concentrations bound to PM_{10}, which were calculated from metal concentrations in dustfall measured at five sites from 2009 to 2012;
- metal concentrations in soil samples collected from 68 sites in 2010 and 2014 (Figure 7.2-3 in Volume 4, Chapter 7: Landforms and Soils);
- contaminant concentrations in surface water samples collected from 21 stream sites and 13 lake sites during Project baseline studies between 2007 and 2017 (Figures 4.2-3 and 4.2-4 in Volume 5, Chapter 4: Freshwater Water Quality);
- contaminant concentrations in freshwater fish tissue samples were collected from 12 sites during Project baseline studies in 2009, and 2010 as part of the *Doris North Gold Mine Project 2010 Aquatic Effects Monitoring Program* (Table 6.2-12, and Figures 6.2-16, and 6.2-17 in Volume 5, Chapter 6: Freshwater Fish); and
- contaminant concentrations in marine fish (i.e., Arctic Char) tissue samples collected from Roberts Bay in 2017 (sampling locations described in Appendix V5-10F).

The MDL is the detectable concentration achievable by the analytical laboratory based on the chemistry of the sample. For the purpose of statistically summarizing the analytical data, when COPC concentrations were below the MDL, a value of half the MDL was substituted. Although this methodology for addressing what are essentially missing values does not capture the true frequency distribution of the concentrations (Nosal, Legge, and Krupa 2000), assigning values to undetected concentrations in this manner is conservative and a common practice where it can be assumed the values are not zero, but where the level of risk is low enough not to warrant additional statistical analyses (i.e., with regards to human health; US EPA 2000a).

Contaminant concentrations in vegetation were also measured within the human health RSA. However, there are no vegetation tissue residue guidelines for comparison so these data were not included in the COPC screening procedure.

Specific contaminants were selected as COPCs if they met at least one of the following screening criteria:

- The metal concentration bound to PM_{10} exceeded the Alberta Ambient Air Quality Objectives and Guidelines (Alberta Environment 2013), the Manitoba Ambient Air Quality Criteria Maximum Acceptable Level (Manitoba Government 2005), the Ontario Ministry of the Environment Ambient Air Quality Criteria (Ontario MOE 2012), the Texas Commission on Environmental Quality Effects Screening Levels (Texas CEQ 2016), and the Washington State Acceptable Source Impact Level (Washington State 2015).
- The maximum contaminant concentration in soil samples exceeded its Canadian Council of Ministers of the Environment (CCME) soil quality guideline value for the protection of environmental and human health for agricultural land use or residential parkland use (CCME 2017a).
- The maximum total contaminant concentration in surface water samples included in the assessment exceeded the Canadian DWQGs (Health Canada 2015).

- The maximum total mercury concentration in fish tissue exceeded the fish tissue standard for mercury (0.5 mg/kg wet weight) which is based on a consumption rate of 22 grams of fish per day (Health Canada 2007a) or the British Columbia Ministry of Environment (BC MOE) total mercury tissue residue guideline for fish/shellfish consumption by humans for high fish consumers (0.1 mg/kg wet weight) which is based on a consumption rate of 1,050 grams of fish per week or 150 grams per day (BC MOE 2001).
- The contaminant has a potential to bioaccumulate in organisms or biomagnify in food webs, such that there could be significant transfer of the contaminant from soil to plants and subsequently into higher trophic levels. Information on the bioaccumulation/biomagnification potential of each contaminant was obtained from a review of relevant documents from the Joint FAO/WHO Expert Committee on Food Additives (JECFA) and the United States Environmental Protection Agency (US EPA; JECFA 1972, 1982; US EPA 1997b; JECFA 2000; US EPA 2000b; JECFA 2005, 2007a, 2011).

Using the maximum contaminant concentrations from these environmental media for screening COPCs provides a conservative approach in the selection of COPCs within the human health LSA.

<u>Contaminants of Potential Concern in Air</u>

Air quality was assessed in the EIS Volume 4, Chapter 2 (Air Quality) as part of the atmospheric environment assessment. Details of the baseline sampling program can be found in Volume 4, Section 2.2 and in Appendices V4-2A to V4-2H (Rescan 2009, 2010c, 2011c, 2011d, 2012a, 2012b; ERM Rescan 2014a, 2014b).

Criteria Air Contaminants

Air quality standards and objectives are generally intended to protect all members of the general public, including sensitive individuals such as the elderly, infants, and persons with compromised health. Nunavut has developed and adopted Air Quality Standards for total suspended particulate (TSP), ground level ozone (O_3), $PM_{2.5}$, NO_2, and SO_2 (Government of Nunavut 2011), which will be used for screening of COPCs in air (Table 5.3-4). However, Nunavut has not developed Air Quality Standards for carbon monoxide (CO), PM_{10}, or annual averaged $PM_{2.5}$. Therefore, criteria from other jurisdictions for those CACs were adopted for screening COPCs in air.

The federal government established Canadian Ambient Air Quality Standards (CAAQSs) for $PM_{2.5}$ which came into effect in 2015, replacing the existing Canada Wide Standards (CCME 2017b). More stringent standards will come in effect in 2020 (Table 5.3-4). The annual averaged $PM_{2.5}$ CAAQS was adopted in the assessment for screening $PM_{2.5}$ as a COPC. The BC MOE (2017) has developed Air Quality Objectives (AQOs) for several CACs, including CO and PM_{10} (Table 5.3-4), which will be adopted for screening PM_{10} and CO as COPCs.

As shown in Table 5.3-4, none of the baseline CAC concentrations exceeded the Nunavut Air Quality Standards (Government of Nunavut 2011), the federal CAAQSs (CCME 2017b, 2017c), or BC MOE AQOs (BC MOE 2017). The only route of exposure to CACs is via inhalation. None of the CACs are considered COPCs and they were not carried forward for further consideration in the existing conditions HHRA.

Metal Contaminants of Potential Concern

BC MOE (2008) guidance states that if there is more than one representative dustfall monitoring site, an acceptable approach is to take the 98^{th} percentile concentration of total dustfall at each site and then take the average of these values to be used as a background total dustfall level. This calculation resulted in a baseline dustfall level of 1.81 $mg/dm^2/day$. To determine the EDI of metal COPCs from inhalation it is necessary to calculate the baseline COPC concentrations bound to PM_{10}, as that is the size fraction of particles that can be inhaled deep into the lungs.

Table 5.3-4. Ambient Air Quality Criteria and Baseline Concentrations of Criteria Air Contaminants

Criteria Air Contaminant	Averaging Period	Ambient Air Quality Criteria (µg/m³)			2009 - 2014 Baseline Air Quality Monitoring Data (µg/m³)		
		Canada [a, b]	Nunavut [c]	BC [d]	Minimum	Mean [e]	Maximum
SO_2	1-hour	183 (effective in 2020)	*450*	183 [f]	-	-	-
	24-hour	170 (effective in 2020)	*150*	-	-	-	-
	Annual	13 (effective in 2020)	*30*	13 [g]	0.1 [k]	0.4 [k]	5.0 [k]
NO_2	1-hour	-	*400*	188 [h]	-	-	-
	24-hour	-	*200*	-	-	-	-
	Annual	-	*60*	60	0.1 [k]	1.9 [k]	9.6 [k]
CO	1-hour	-	-	*14,300*	-	1,250 [l]	-
	8-hour	-	-	*5,500*	-	143 [l]	-
PM_{10}	24-hour	-	-	*50*	0.5	6.3	46.0
$PM_{2.5}$	24-hour	28 and 27 (effective in 2020)	*30*	25 [i]	0.1	-	20.0
	Annual	*10* and 8.8 (effective in 2020)	-	8 [j]	-	3.0	-

Notes:
SO_2 = sulphur dioxide
NO_2 = nitrogen dioxide
CO = carbon monoxide
$PM_{2.5}$ = particulate matter ≤2.5 µm in diameter
PM_{10} = particulate matter ≤10 µm in diameter
(-) = not available or applicable
Bold and italicized values indicate the air quality criteria used in the assessment.
[a] *CCME (2017b).*
[b] *CCME (2017c).*
[c] *Government of Nunavut (2011).*
[d] *BC MOE (2017).*
[e] *Mean value of all stations and measurements.*
[f] *Based on annual 99th percentile of daily 1-hour maximum, averaged over three consecutive years.*
[g] *Based on annual average of 1-hour concentrations over one year.*
[h] *Based on annual 98th percentile of daily 1-hour maximum, over one year.*
[i] *Based on annual 98th percentile of daily average over one year.*
[j] *Based on annual average over one year.*
[k] *Each sample was normally exposed for a period of 30 days. There are no 30-day guidelines for NO_2 or SO_2. These values can be conservatively compared with the annual Nunavut guideline values.*
[l] *CO baseline concentrations are the annual averages used for the Bathurst Inlet and Road Project (BIPR; located northwest of the study area), which is representative of background levels typical in Nunavut.*

Thus the average of the metal concentrations in dustfall (in mg/dm²/day) from all monitoring stations were divided by the 98th percentile dustfall level (1.81 mg/dm²/day) from all dustfall monitoring stations to determine the ratio of metals in dustfall (Table 5.3-5). The ratio of metals in dustfall was then multiplied by the 95th UCLM (upper confidence level of the mean) baseline 24-hour PM_{10} concentration (7.34 µg/m³) to obtain the concentration of metals bound to PM_{10} (Table 5.3-5).

Since there are no Canadian or Nunavut guidelines for metals in air, the baseline metal concentrations bound to PM_{10} (Table 5.3-5) were compared to available guidelines for 24-hour averaging periods, which included: the Manitoba Government (2005) Ambient Air Quality Criteria Maximum Acceptable Levels; the Ontario Ministry of the Environment Ambient Air Quality Criteria (Ontario MOE 2012); and the Washington State (2015) Acceptable Source Impact Levels. The lowest (most conservative) available guideline was used to screen the metal concentrations bound to PM_{10}.

Table 5.3-5. Baseline Metal Concentrations in Dustfall and Bound to PM_{10}

Metals	Air Quality Guidelines - 24-hour Averaging Period (µg/m³)			Average of the 98th Percentile Baseline Metal Concentration in Dustfall from all Monitoring Sites [d] (mg/dm²/day)	Ratio of Baseline Metal Concentration in Dustfall	Baseline Metal Concentration bound to PM_{10} (µg/m³)	COPC (Yes/No)
	Manitoba Ambient Air Quality Criteria, Maximum Acceptable Level [a]	Ontario MOE Ambient Air Quality Criteria [b]	Washington State ASIL [c]				
Antimony	-	25	-	0.00000137	0.000000753	0.00000552	No
Arsenic	0.3	0.3	-	0.00000929	0.00000512	0.0000376	No
Barium	-	10	-	0.0000417	0.0000230	0.000169	No
Beryllium	-	0.01	-	0.00000626	0.00000345	0.0000253	No
Boron	-	120	-	0.000138	0.0000762	0.000559	No
Cadmium	2	0.025	-	0.00000253	0.00000140	0.0000102	No
Chromium (hexavalent)	-	0.00035 (hexavalent); 0.5 (trivalent)	-	0.0000435	0.0000240	0.000176	No
Cobalt	-	0.1	0.1	0.00000635	0.00000350	0.0000257	No
Copper	50	50	-	0.000270	0.000149	0.00109	No
Iron	-	4	-	0.00932	0.00514	0.0377	No
Lead	2	0.5	-	0.0000256	0.0000141	0.000104	No
Lithium	-	20	-	0.0000626	0.0000345	0.000253	No
Manganese	-	0.2	0.04	0.000317	0.000175	0.00128	No
Mercury	-	2	0.09	0.00000133	0.000000732	0.00000537	No
Molybdenum	-	120	-	0.000000904	0.000000498	0.00000366	No
Nickel	2	0.1	-	0.0000856	0.0000472	0.000346	No
Selenium	-	10	20	0.0000124	0.00000684	0.0000502	No
Silver	-	1	-	0.000000332	0.000000183	0.00000134	No
Strontium	-	120	-	0.0000242	0.0000134	0.0000980	No
Tin	-	10	-	0.00000152	0.000000837	0.00000614	No
Titanium	-	120	-	0.000475	0.000262	0.00192	No
Uranium	-	0.15	-	0.000000130	0.0000000719	0.000000527	No
Vanadium	-	2	0.2	0.0000256	0.0000141	0.000104	No
Zinc	120	120	-	0.000184	0.000102	0.000745	No

Notes:
MOE = Ministry of the Environment
ASIL = acceptable source impact level
PM_{10} = particulate matter up to and including 10 µm in diameter
(-) = not available
[a] *Manitoba Government (2005).*
[b] *Ontario MOE (2012).*
[c] *Washington State (2015).*
[d] *Baseline metal concentrations in dustfall were obtained from five dustfall monitoring stations at the Project site from 2009 to 2012 (n = 68).*
The average of the 98^{th} percentile baseline metal concentrations in dustfall from each monitoring station were multiplied with the average of the 98^{th} percentile concentration of total dustfall from each monitoring station to determine the ratio of metals in dustfall.
The 95^{th} UCLM baseline 24-hour PM_{10} concentration at the Project site (7.34 µg/m^3) was multiplied by the ratio of metals in dustfall to determine the concentration of metals on PM_{10}.

None of the baseline 24-hour averaging period metal concentrations bound to PM_{10} (Table 5.3-5) exceeded screening criteria (Manitoba Government 2005; Ontario MOE 2012; Washington State 2015); therefore, no metal COPCs bound to PM_{10} were identified under baseline conditions.

Contaminants of Potential Concern in Soil

To determine the COPCs in soil, the maximum baseline metal concentrations in soil were compared to the most conservative of the CCME soil quality guidelines for the protection of agricultural or parkland/residential soil (Table 5.3-6; CCME 2017a).

Table 5.3-6. Screening Results for Selection of Contaminants of Potential Concern in Soil Samples Collected in 2010 and 2014

Parameter (mg/kg dry weight)	CCME Soil Quality Guideline for the Protection of Environmental and Human Health - Agricultural [a]	Detection Limit	N	Maximum	COPC (Yes/No)
Antimony	20	0.1 - 10	100	5.00	No
Arsenic	12	0.05 - 5	100	7.17	No
Barium [b]	750	0.5 - 1	100	164	No
Beryllium	4	0.2 - 0.5	100	0.790	No
Cadmium	1.4	0.05 - 0.5	100	0.250	No
Chromium	64	0.5 - 2	100	81.8	**Yes**
Cobalt	40	0.1 - 2	100	17.1	No
Copper	63	0.5 - 1	100	67.7	**Yes**
Lead	70	0.5 - 30	100	15.0	No
Mercury	6.6	0.005 - 0.005	100	0.158	No
Molybdenum	5	0.5 - 4	100	2.00	No
Nickel	45	0.5 - 5	100	53.5	**Yes**
Selenium	1	0.2 - 0.5	100	0.250	No
Silver	20	0.1 - 2	100	1.00	No
Thallium	1	0.05 - 1	100	0.500	No
Tin	5	2 - 5	100	2.50	No
Uranium	23	0.05	100	2.23	No
Vanadium	130	0.2 - 2	100	82.0	No
Zinc	200	1.00	100	80.5	No

Notes:
CCME = Canadian Council of Ministers of the Environment
COPC = contaminant of potential concern
[a] *CCME (2017a).The lowest of the human health and environmental health guideline/check value was chosen for COPC screening.*
[b] *The CCME soil quality guideline for barium is lower for residential parkland use (500 mg/kg) than it is for agricultural use (750 mg/kg); therefore, the residential parkland guideline was adopted for COPC screening.*
For calculation purposes, values that were below the method detection limit were replaced with values that were half of the method detection limit.
Shaded cells indicate that the soil metal concentration exceeds the CCME guideline.

As shown in Table 5.3-6, the maximum baseline concentrations of chromium, copper, and nickel in soil exceeded the CCME guidelines and are thus selected as COPCs.

Contaminants of Potential Concern in Water

To determine COPCs in surface water, the maximum measured baseline concentration of surface water quality parameters within the human health LSA were compared to Health Canada (2015) DWQGs. Health Canada also has guidelines for recreational water quality (Health Canada 2012); however, the recreational water quality guidelines are higher than the DWQGs and there are fewer parameters with guidelines. Therefore, screening surface water against the DWQGs will also protect people who use surface water for recreational purposes (e.g., swimming and fishing).

Non-metal Contaminants of Potential Concern

To determine the non-metal COPCs in surface water, the maximum measured baseline concentration of non-metal parameters (e.g., nutrients and anions) from the human health LSA were compared to Health Canada (2015) DWQGs (Table 5.3-7).

Table 5.3-7. Screening Results for Selection of Non-metal Contaminants of Potential Concern in Baseline Surface Water

Parameters	Units	Health Canada Drinking Water Quality Guidelines [a]	Maximum Surface Water Concentration [b] (n=259 - 788)	COPC (Yes/No)
Physical Parameters				
pH	pH units	6.5 to 8.5 [c]	8.51	No
Total Suspended Solids	mg/L	500 [d]	198	No
Turbidity	NTU	F	218	No
Nutrients				
Nitrate (as N)	mg/L	10	1.06	No
Nitrite (as N)	mg/L	1	0.0200	No
Ammonia	mg/L	0.1 [c]	0.260	Yes
Cyanide				
Total cyanide	mg/L	0.2	0.00840	No
Major Anions				
Chloride	mg/L	≤ 250 [d]	306	Yes
Fluoride	mg/L	1.5	1.65	Yes
Sulphate	mg/L	≤ 500 [d]	48.0	No

Notes:
NTU = nephelometric turbidity units
F = dependent on filtration type
[a] *Health Canada (2015).*
[b] *Maximum surface water concentration from all lake and stream water samples collected from within the human health LSA (North and South Belts) from 2007 to 2017.*
[c] *Operational guidance value.*
[d] *Aesthetic objective.*
Shaded cells indicate that the surface water metal concentration exceeds the Health Canada Drinking Water Quality Guideline.

As shown in Table 5.3-7, the non-metal COPCs identified in surface water were: ammonia, chloride, and fluoride. The federal DWQGs for pH, ammonia, and chloride (Health Canada 2015) are not based on direct toxic effects to human health. According to Health Canada (2015), the DWQG for ammonia is operationally based because it can affect drinking water quality in the water distribution system. Since ammonia is efficiently metabolized in healthy individuals, ingestion of levels found in drinking water typically do not result in adverse health effects (Health Canada 2015). The DWQG for chloride is an aesthetic objective as it is based on taste and the potential for it to corrode the water distribution system.

Because ammonia and chloride are considered innocuous substances in terms of direct risk to human health, they will not be considered further as COPCs for drinking water in the existing conditions HHRA. Only fluoride will be carried forward as a non-metal COPC in surface water in the existing conditions HHRA.

Metal Contaminants of Potential Concern

To determine the metal COPCs in surface water, the maximum measured baseline total metal concentrations from the human health LSA were compared to Health Canada (2015) DWQGs (Table 5.3-8).

Table 5.3-8. Screening Results for Selection of Metal Contaminants of Potential Concern in Baseline Surface Water

Parameters	Health Canada Drinking Water Quality Guidelines [a]	Maximum Surface Water Concentration [b] (n=788)	COPC (Yes/No)
Total Metal			
Aluminum	< 0.1 [c]	3.90	Yes
Antimony	0.006	0.000440	No
Arsenic	0.01	0.00493	No
Barium	1	0.0367	No
Boron	5	0.0980	No
Cadmium	0.005	0.000193	No
Chromium	0.05	0.00739	No
Copper	≤ 1 [d]	0.0156	No
Iron	0.3 [d]	3.97	Yes
Lead	0.01	0.00528	No
Manganese	0.05 [d]	0.957	Yes
Mercury	0.001	0.0000120	No
Selenium	0.05	0.00657	No
Sodium	≤ 200 [d]	158	No
Uranium	0.02	0.00112	No
Zinc	≤ 5 [d]	0.372	No

Notes:
LSA = human health local study area
All concentrations are mg/L.
[a] Health Canada (2015).
[b] Maximum surface water concentration from all lake and stream water samples collected from within the human health LSA (North and South Belts) from 2007 to 2017.
[c] Operational guidance value.
[d] Aesthetic objective.
Shaded cells indicate that the surface water metal concentration exceeds the Health Canada Drinking Water Quality Guideline.

As shown in Table 5.3-8, the metal COPCs identified in surface water were: aluminum, iron, and manganese.

The DWQG for aluminum is an operational guidance value, as Health Canada (2015) states there is no evidence to indicate that aluminum in drinking water causes adverse health effects in humans.

However, because there are other exposure pathways for aluminum and aluminum can cause adverse health effects at high enough concentrations, it was conservatively considered to be a COPC in water and was carried forward in the HHRA.

The DWQG for iron is an aesthetic objective based on taste and staining of laundry and plumbing fixtures (Health Canada 2015). Iron is an essential element as it is a required component in blood cells for the transportation of oxygen throughout the body (Adriano 2001). Iron toxicity in humans is very rare and most cases of acute poisoning have occurred when children accidentally consume large amounts of iron supplements (intended for adults) as they mistake the pills for candy (EGVM 2003; Tenenbein 2005). Even with increased oral iron intake there is generally no significant iron overload in adults unless the individual has increased iron absorption because the ingested iron is in a highly bioavailable form, the individuals has an accompanying genetic defect, or the individual has increased demand due to a disorder (EGVM 2003). Furthermore, adverse health effects from the ingestion of large amounts of iron have only been associated with iron supplements and not with iron in food or water (EGVM 2003). Because iron is an essential element for humans and since environmental exposure to iron from food consumption is not likely lead to adverse health effects, iron was not retained as a COPC in surface water.

The DWQG for manganese is an aesthetic objective based on taste and staining of laundry and plumbing fixtures (Health Canada 2015). However, because there are other exposure pathways for manganese and manganese can cause adverse health effects at high enough concentrations, it was conservatively considered to be a COPC in water and was carried forward in the HHRA.

After consideration of the type of DWQGs and potential for multiple routes of exposure, aluminum, fluoride, and manganese were selected as baseline COPCs in surface water, and were added to the overall list of COPCs considered in the existing conditions HHRA.

Contaminants of Potential Concern in Fish Tissue

Health Canada (2007a) and the Canadian Food Inspection Agency (CFIA) apply a standard of 0.5 mg/kg wet weight (ww) for total mercury to all commercially-sold fish. The fish tissue standard assumes an average consumption rate of fish of 22 grams/day (Health Canada 2007a). However, this consumption rate may not be protective of Aboriginal communities that consume large quantities of fish. The BC MOE (2001) aquatic life guidelines for fish/shellfish when the diet is primarily based on fish for different levels of fish consumption were also considered. The most conservative BC MOE (2001) guideline for total mercury for fish/shellfish consumption is 0.1 mg/kg wet weight for based on a consumption rate of 1,050 grams of fresh fish per week (equivalent to 150 grams per day). This high quantity of fish consumption is expected to be protective for Aboriginal communities with elevated fish consumption.

As shown in Table 5.3-9, none of the Arctic Char samples exceeded either the Health Canada or BC MOE tissue residue guidelines/standards for mercury in fish tissue. However, the baseline mean, median, 95^{th} percentile, and maximum mercury concentration in Lake Trout tissues exceeded the BC MOE (2001) total mercury tissue residue guideline for fish/shellfish consumption for high fish consumers (0.1 mg/kg ww). The 95^{th} percentile and maximum mercury concentrations in Lake Trout also exceeded the Health Canada/CFIA standard of 0.5 mg/kg (Table 5.3-9). Thus mercury was selected as a COPC due to elevated concentrations in fish tissue under baseline conditions.

Table 5.3-9. Screening Results for Selection of Contaminants of Potential Concern in Fish Tissue (Arctic Char 2017; Lake Trout 2009 and 2010)

Parameter	Realized Detection Limit	Arctic Char (*Salvelinus alpinus*)							Lake Trout (*Salvelinus namaycush*)						
		N	Standard Deviation	Minimum	Mean	Median	95th Percentile	Maximum	N	Standard Deviation	Minimum	Mean	Median	95th Percentile	Maximum
% Moisture	-	17	3.39	62.3	72.8	73.6	76.1	76.5	69	2.08	72.7	78.4	78.8	81.4	82.5
Metals (mg/kg ww)															
Mercury	0.001 - 0.003	17	0.0100	0.0144	0.0273	0.0259	0.0446	0.0492	69	0.400	0.00490	0.293	0.135	1.08	1.80

Notes:
ww = wet weight
(-) = not available
Grey highlighting indicates exceedance of the Health Canada (2007a) human consumption guideline for mercury (0.5 mg/kg ww) or the BC MOE (2001) total mercury tissue residue guideline for fish/shellfish consumption for high fish consumers (0.1 mg/kg ww based on 1.05 kg/week consumed).

Bioaccumulative Contaminants of Potential Concern

Certain metals are considered bioaccumulative due to their elevated bioconcentration factors (BCFs). Thus even if the concentrations of those metals in environmental media are lower than applicable guidelines, they were carried forward as COPCs as a conservative measure. These metals include:

- arsenic (ATSDR 2007a);
- cadmium (ATSDR 2012);
- lead (ATSDR 2007b);
- mercury (ATSDR 1999);
- nickel (ATSDR 2005a);
- selenium(ATSDR 2003);
- thallium (ATSDR 1992); and
- zinc (ATSDR 2005b).

Final List of Contaminants of Potential Concern Selected for Evaluation

No COPCs were identified in the baseline air quality screening for CACs or metals bound to PM_{10} (see Tables 5.3-4 and 5.3-5). The COPCs identified in the baseline soil quality screening (see Table 5.3-6) were: chromium, copper, and nickel. The COPCs identified in the baseline surface water quality screening (see Tables 5.3-7 and 5.3-8) were: aluminum, fluoride, and manganese. The only COPC identified in the baseline fish tissue screening (see Table 5.3-9) was mercury. Several COPCs, including arsenic, cadmium, lead, mercury, nickel, selenium, thallium, and zinc, were identified as being bioaccumulative.

Therefore, the final list of COPCs selected for the existing conditions HHRA include: aluminum, arsenic, cadmium, chromium, copper, fluoride, lead, manganese, mercury, nickel, selenium, thallium, and zinc.

5.3.2.4 Noise

Noise was assessed in the EIS Volume 4, Chapter 3 (Noise and Vibration) as part of the atmospheric assessment. Details of the noise baseline sampling program can be found in Volume 4, Section 3.2 and in Annex B (Golder Associates Ltd. 2008, 2009; Rescan 2011b) of Appendix V4-3A.

Noise monitoring programs conducted in 2007 (Golder Associates Ltd. 2008), 2008 (Golder Associates Ltd. 2009), and 2010 (Rescan 2011b) for the Doris Project have provided baseline data for the proposed Project. Details on the methodology used for noise monitoring and the subsequent calculation of baseline noise levels are provided in Volume 4, Section 3.2.2.

Aside from mine exploration activities, the noise environment of the Project area is pristine. There are no additional industrial sites or human settlements close enough to the Project to be audible; consequently, only natural sources such as wind, precipitation, and wildlife contribute to background noise levels.

Six monitoring stations were selected from the 2007 and 2010 monitoring programs to represent baseline conditions of the Project area. These stations were selected because they were negligibly influenced by anthropogenic noise. Sources of natural noise included animals, waves, and wind. In some cases, helicopter noise was filtered out of the baseline data in order to characterize natural ambient conditions. The mean baseline L_{eq} (logarithmic average) and the L_{90} (lowest 10th percentile) noise levels occurring at each station are presented in Table 5.3-10. Noise metrics used to assess potential effects to human health are described in A-weighted decibels (dBA), which match the frequency response of the human ear.

Table 5.3-10. Summary of Baseline Noise Levels with Wind Speed

Station	Monitoring Dates	Monitoring Period	Mean Leq (dBA)	L90 (dBA)	Mean Wind Speed (km/h)
NM-2/3	July 25 – 26 , 2007	27-hours	30.0	19.6	19.1
NM-4	July 26 – 27 , 2007	20-hours	47.2	34.9	28.2
S14	May 15 – 16, 2010	24-hours	46.8	18.0	20.3
S14	July 24 – 25, 2010	24-hours	50.2	28.6	30.3
S15	May 23 – 24, 2010	24-hours	22.9	16.9	11.3
S15	July 24 – 25, 2010	24-hours	41.5	18.6	32
S16	July 24 – 25, 2010	24-hours	53.3	21.5	27.4
S17	July 24 – 25, 2010	24-hours	48.6	23.0	29.2

Notes:
Leq = mean logarithmic average noise level
L90 = lowest 10th percentile noise level
dBA = A-weighted decibel corresponding to the frequency response of the human ear

Mean baseline noise levels ranged from 22.9 to 53.3 dBA (L_{eq}) and 16.9 to 34.9 dBA (L_{90}). In some cases, the mean L_{eq} values observed within the Project area exceed levels assumed to represent the baseline conditions of rural areas, which are approximately 35 dBA during the nighttime and 45 dBA during the daytime (Alberta ERCB 2007). However, the 2007 and 2010 monitoring programs reported that wind was a major source of noise in the Project area, and is likely the cause of relatively high baseline L_{eq} levels. In general, mean L_{eq} values increased proportionally with mean wind speed across stations (Pearson correlation coefficient: $r = 0.79$). These baseline noise levels are considered representative of natural conditions, reflective of a remote area with frequent wind and minimal anthropogenic activity.

Assessment of Existing Conditions Noise Effects to Human Receptors

In accordance with Health Canada (2017) guidance, the potential noise effects considered in this existing conditions assessment include sleep disturbance, speech comprehension, complaints, and annoyance. For consistency with the Project-related noise assessment (Section 5.4.1.4), the existing conditions noise assessment considers potential noise effects to both recreational land users and off-duty workers residing in a camp. Whereas the Project-related noise assessment utilizes modeled cumulative (existing + Project) noise levels, the existing-conditions assessment incorporates measured field data to assess potential noise effects prior to Project-related activity. Both predicted (Project-related noise) and measured (existing conditions) noise levels are expressed in terms of the metrics (e.g., L_d, L_n, L_{dn}) typically used to assess noise effects to human receptors. Noise assessment endpoints and their associated metrics are described below and summarized in Table 5.3-11. Further information pertaining to noise effects and metrics is available in Volume 4, Section 3.2.

Noise Assessment Endpoints and Associated Metrics

Sleep Disturbance

As per Health Canada (2017) guidance, the assessment of sleep disturbance is based on a night time continuous noise threshold (L_n) of 30 dBA (indoors). Because recreational land users may use open-windows at night, an outdoor-to-indoor noise attenuation of 15 dBA (US EPA 1974) was applied to provide an outdoor threshold of L_n = 45 dBA for recreational land use receptors. Because camp windows will be closed (i.e., the Project is located in the arctic), a noise attenuation of 27 dBA (US EPA 1974) was applied to provide an outdoor threshold of L_n = 57 dBA for off-duty staff (i.e., residential receptors).

Speech Comprehension

Speech comprehension (also referred to as speech intelligibility) is defined by Health Canada (2017) as "*the ability to recognize key words in a sentence using full concentration in a laboratory setting*". As per Health Canada (2017) guidance, the potential for Project noise to interfere with speech comprehension was assessed using a day time outdoor threshold of L_d = 55 dBA.

Noise Complaints

The potential for noise complaints from receptors within the Human Health RSA was assessed following Health Canada (2017) guidance, which supports a normalized day-night noise level (L_{dn}) of 62 dBA as a threshold for widespread complaints. Because shift workers are assumed to anticipate - and have a high tolerance for - potential Project noise during off-duty hours, they are not reasonably expected to lodge noise complaints. Thus, the potential for noise complaints was only assessed for recreational land use receptors.

Annoyance

As per Health Canada (2017), the potential for annoyance due to noise was assessed using a normalized threshold of L_{dn} = 75 dBA. Because the Boston-Madrid Project is located in a quiet rural area that could be considered to have a higher expectation of tranquillity, annoyance was conservatively assessed using an adjustment of +10 dBA as per Health Canada (2017) guidance. Health Canada (2017) states that the potential for annoyance should only be assessed for receptors exposed to long-term project noise (i.e., exposures greater than one year). For this reason, recreational (i.e., non-Project-related) land users were not assessed for annoyance. However, because off-duty workers are reasonably expected to anticipate and have a tolerance for Project-related noise, the assessment of annoyance using an adjustment of +10 dBA to account for the expectation of tranquillity in rural areas is considered a conservative approach for assessing annoyance to these receptors.

The L_d, L_n, and L_{dn} for each monitoring station were used to derive mean baseline noise levels for the overall Project area. These mean baseline noise levels are presented with applicable assessment endpoints and thresholds in Table 5.3-11. Further information about noise level thresholds and associated assessment criteria (e.g., sleep disturbance, habitat disturbance, likelihood of complaints, and speech interference) can be found in Volume 4, Section 3.2.

As shown in Table 5.3-11, all of the mean baseline noise levels for the Project LSA were below the noise thresholds applicable to human health. Furthermore, no baseline noise levels at any single monitoring station exceeded these thresholds (see Volume 4, Section 3.2.3). Therefore, none of the noise metrics used to assess potential adverse effects to humans from noise exposure were of concern and noise is not considered further in the existing conditions HHRA.

Table 5.3-11. Noise Parameters, Screening Criteria, and Mean Existing Conditions Noise Levels

Assessment Criteria	Noise Metric	Description	Applicable Period	Thresholds for Recreational/ Temporary Receptors [1]	Thresholds for Off-Duty Human Receptors Residing at Camp [2]	Mean Existing Conditions Levels
Sleep Disturbance [3]	L_n	Noise level threshold for assessing potential sleep disturbance associated with existing conditions	Night time (10 pm to 7 am)	45 dBA	57 dBA	40.2 dBA
	L_d		Daytime (7 am to 10 pm)		57 dBA	42.8 dBA
Speech Interference	L_d	Noise level threshold for assessing the potential for existing-conditions noise to interfere with speech comprehension	Daytime (7 am to 10 pm)	55 dBA	55 dBA	42.8 dBA
Likelihood of Complaints	L_{dn}	Day and night combined (24-hour equivalent) noise level for assessing the likelihood of complaints associated with existing conditions	24-hour Equivalent Period	62 dBA	N/A	49.6 dBA
Potential for Annoyance	L_{dn}	Day and night combined (24-hour equivalent) noise level for assessing the potential for annoyance due to existing conditions	24-hour Equivalent Period	N/A	75 dBA	59.6 dBA [4]

Notes:
[1] Noise thresholds for sleep disturbance pertaining to recreational land users assume open windows, corresponding to an attenuation factor of 15 dBA (US EPA 1974).
[2] Noise thresholds for sleep disturbance pertaining to off-duty workers assume closed windows, corresponding to an attenuation factor of 27 dBA (US EPA 1974). Off-duty workers are hypothetical receptors that are not actually present under existing conditions; these receptors are considered here for consistency with the Project-related noise assessment (Section 5.4.1.4).
[3] Sleep disturbance is assessed for both night time and daytime hours because 24-hour shift work is proposed.
[4] As per Health Canada (2017) guidance, annoyance is assessed by adding +10 dBA to measured existing conditions noise levels for receptors located in rural locations where a higher degree of tranquility is expected.

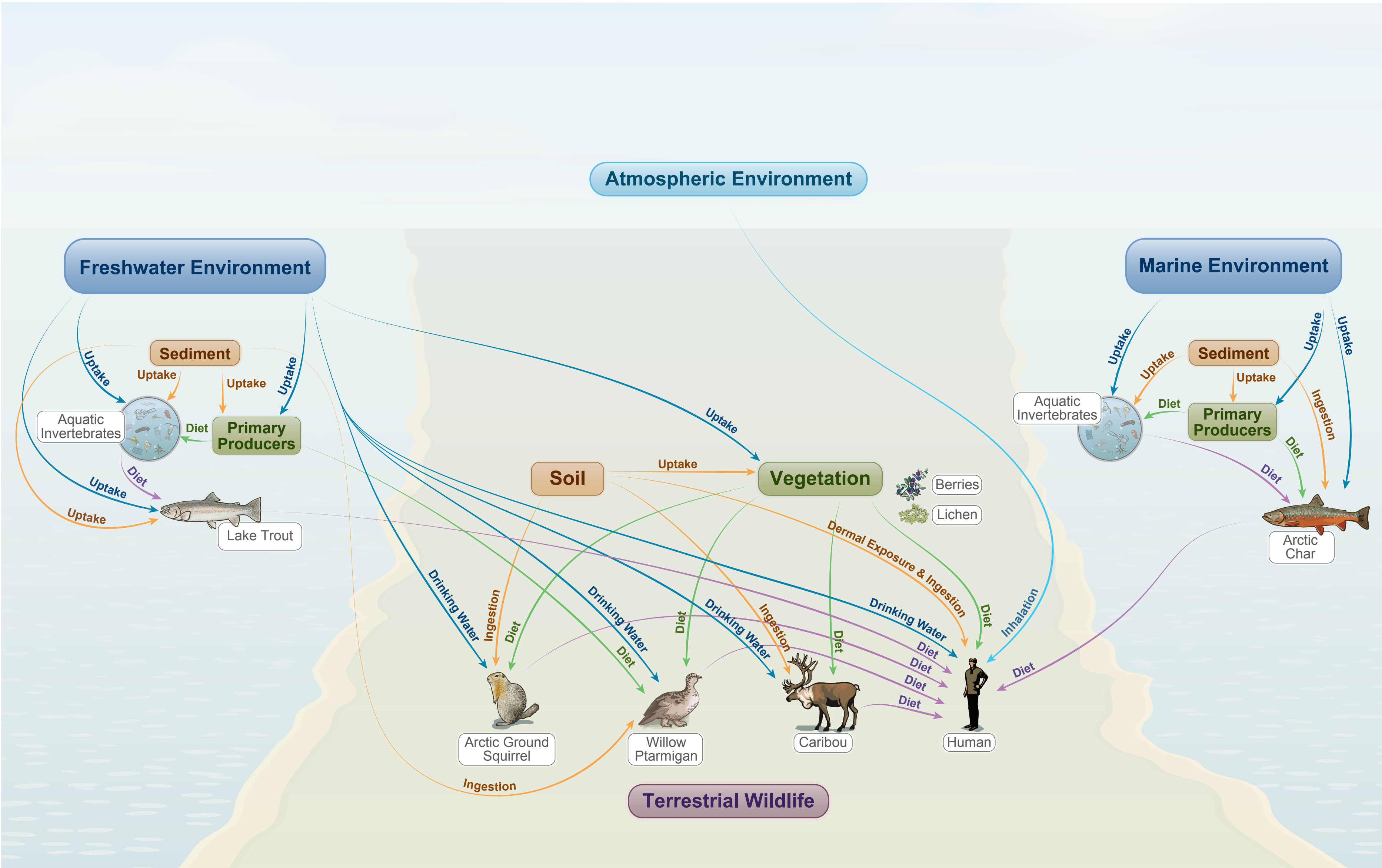
5.3.2.5 Conceptual Model

A conceptual model is a representation of the characteristics of the site in diagrammatic form, and is developed within a risk assessment to identify potential sources, fate, and transport of COPCs, potential exposure routes, and the possible interaction pathways between COPCs and receptors. Possible combinations of environmental components corresponding to significant exposure pathways were identified, while non-significant pathways were eliminated from further consideration.

A simplified schematic diagram of the pathways by which humans may be exposed to baseline levels of COPCs in the environment is depicted in Figure 5.3-2. This figure shows how COPCs in the environment (i.e., air, soil, sediment, surface water, vegetation, and country foods) move into humans via inhalation, ingestion, or dermal exposure. Off-duty workers are not exposed to COPCs via country foods as the camp kitchens provide commercially prepared foods.

Figure 5.3-2

Conceptual Model for Potential Human Exposure to Contaminants of Potential Concern under Existing Conditions



5.3.3 Exposure Assessment

5.3.3.1 Introduction

The amount of COPCs that people are exposed to depends on several factors including:

- the concentration of COPCs in air that are inhaled;
- the concentrations of COPCs in drinking water ingested from surface water sources;
- the concentration of COPCs in soil (via dermal exposure or incidental ingestion);
- the concentration of COPCs in country foods; and
- human receptor characteristics (*e.g.,* consumption amount, frequency, body weight; described in Section 5.3.2.1).

The parameters listed above are included in the exposure estimate equations to determine the EDI of each COPC through the various exposure pathways. The calculations of EDI are based on either measured COPC concentrations in media (e.g., water, soil, vegetation, fish) or modeled COPC concentration estimates based on a food chain model that incorporates measured COPC concentrations in environmental media (i.e., for country foods represented by caribou, Arctic ground squirrel, and willow ptarmigan).

As described in Section 5.3.2.4, none of the baseline noise levels exceeded the noise criteria (see Table 5.3-11); therefore, noise was not carried forward in the existing conditions HHRA.

5.3.3.2 Inhalation of Air

None of the baseline metal concentrations bound to PM_{10} exceeded the Ontario Ministry of Environment Ambient Air Quality Criteria (Ontario MOE 2012), Manitoba Ambient Air Quality Criteria (Manitoba Government 2005) or Washington State Acceptable Source Impact Levels (Washington State 2015; Table 5.3-5). However, metal COPCs were identified in other exposure media/routes (e.g., soil and water), thus an exposure assessment for the inhalation of those metal COPCs in air was conducted. The 98^{th} percentile of baseline metal concentrations (from dustfall metals) bound to the 95^{th} UCLM PM_{10} concentration (shown in Table 5.3-12) were used to determine the EDI of COPCs that humans receive via inhalation. The equation used to calculate human exposure to COPCs (mg/kg BW/day) from inhalation of PM_{10} was (Health Canada 2010b):

$$EDI = \frac{C_{Air} \times UCF \times IR_A \times RAF_{Inh} \times D_1 \times D_2 \times D_3}{BW} \quad \text{[Equation 1]}$$

where:

C_{Air} = concentration of COPC in air (µg/m^3)
UCF = unit conversion factor (1 mg/1,000 µg)
IR_A = receptor air intake (inhalation) rate (m^3/d)
RAF_{Inh} = relative absorption factor by inhalation (unitless)
D_1 = hours per day exposed/24 hours
D_2 = days per week exposed/7 days
D_3 = weeks per year exposed/52 weeks
BW = body weight (kg BW)

Table 5.3-12. Estimated Daily Intake of Contaminants of Potential Concern via the Inhalation Exposure Route

Exposure Characteristics		Land User Toddler	Land User Adult	Off-duty Worker
Hours/24 Hours		24	24	12
Days/7 Days		7	7	7
Weeks/52 Weeks		12	12	26
Inhalation Rate (m^3/day)		7.9	16.6	16.6
Relative Absorption Factor (unitless)		1	1	1
Body Weight (kg)		15.3	76.5	76.5
	Baseline Metal Concentration bound to PM_{10} (µg/m^3)	**Estimated Daily Intake (mg/kg BW/day)**		
COPC		**Land User Toddler**	**Land User Adult**	**Off-duty Worker**
Aluminum	0.0198	2.36E-06	9.92E-07	1.07E-06
Arsenic	0.0000376	4.48E-09	1.88E-09	2.04E-09
Cadmium	0.0000102	1.22E-09	5.13E-10	5.55E-10
Chromium	0.000176	2.10E-08	8.81E-09	9.54E-09
Copper	0.00109	1.30E-07	5.47E-08	5.92E-08
Lead	0.000104	1.23E-08	5.19E-09	5.62E-09
Manganese	0.00128	1.53E-07	6.42E-08	6.95E-08
Mercury	0.00000537	6.40E-10	2.69E-10	2.91E-10
Nickel	0.000346	4.12E-08	1.73E-08	1.88E-08
Selenium	0.0000502	5.98E-09	2.51E-09	2.72E-09
Thallium	0.00000502	5.98E-10	2.51E-10	2.72E-10
Zinc	0.000745	8.88E-08	3.73E-08	4.04E-08

Notes:
COPC = contaminant of potential concern
BW = body weight
PM_{10} = particulate matter up to and including 10 µm in size

The EDI of COPCs via the inhalation exposure route for toddlers and adults are presented in Table 5.3-12. The assumptions used in the calculation of the EDI of COPCs via inhalation were as follows:

- Since there were no annual PM_{10} concentrations available from the baseline monitoring, the exposure calculations using the 24-hour PM_{10} concentration are conservative as 24-hour concentrations are higher than if the concentrations were averaged over an entire year.
- The proportion of metals in dustfall under baseline conditions are the same as the proportion of metals associated with PM_{10}.
- Adults and toddler land users are exposed 24 hours per day, 7 days per week, and 12 weeks per year. This assumption is conservative since there are no permanent or full-time residents within the human health LSA. Workers were assumed to be off-duty 12-hours per day, 7 days per week, and 26 weeks per year (due to two week rotation shifts).
- Toddlers have an inhalation rate of 7.9 m^3/day and a body weight of 15.3 kg (Richardson and Stantec Consulting Ltd. 2013).
- Adults have an inhalation rate of 16.6 m^3/day and a body weight of 76.5 kg (Richardson and Stantec Consulting Ltd. 2013).

- o The exposure to COPCs in air was converted to an internal EDI based on the relative absorption factor; this was done to make exposure via the inhalation route comparable to TRVs derived for the ingestion route. It also allows the summation of EDIs from all ingestion exposure routes.
- o COPC concentrations below the MDL were replaced with concentrations half of the MDL. This may over- or under-estimate the actual COPC concentrations.

A sample calculation of the inhalation EDI of aluminum bound to PM_{10} using Equation 1 is provided below for toddlers:

$$EDI_{Aluminum} = \frac{0.0198\,\frac{\mu g}{m^3} \times \left(\frac{1\,mg}{1{,}000\,\mu g}\right) \times 7.9\,\frac{m^3}{day} \times 1 \times \frac{24\,hour}{24\,hour} \times \frac{7\,day}{7\,day} \times \frac{12\,week}{52\,week}}{15.3\,kg\,BW}$$

$$EDI_{Aluminum} = 2.36\ \times\ 10^{-6}\,mg/kg\,BW/day$$

5.3.3.3 Ingestion of Soil

The baseline 95th percentile concentrations of COPCs in soil from 68 sites within the human health LSA (Table 5.3-13) were used as an input in the equation to calculate the EDI of COPCs humans receive from incidental soil ingestion under baseline conditions. The equation used to calculate human exposure to COPCs (mg/kg BW/day) from soil ingestion was (Health Canada 2010b):

$$EDI = \frac{C_S \times IR_S \times RAF_{Oral} \times D_2 \times D_3}{BW} \qquad \text{[Equation 2]}$$

where:

C_S	= concentration of COPC in soil (mg/kg)
IR_S	= receptor soil ingestion rate (kg/d)
RAF_{Oral}	= relative absorption factor from the gastrointestinal tract (unitless)
D_2	= days per week exposed/7 days
D_3	= weeks per year exposed/52 weeks
BW	= body weight (kg BW)

The COPC EDI via the soil ingestion exposure route for toddlers and adults are presented in Table 5.3-13. The assumptions used in the calculation of the EDI of COPCs via soil ingestion were as follows:

- o Baseline soil quality at the 68 sampling sites is representative of baseline soil quality within the human health LSA.
- o Adults and toddlers are exposed 7 days per week and 12 weeks per year. This is a conservative assumption since there are no permanent or full-time residents within the human health LSA and because exposure to COPCs through ingestion of soil is unlikely during the portion of the year when snow is on the ground. Off-duty workers were assumed to be present 7 days per week and 26 weeks per year (due to a work rotation of two weeks on site and two weeks off site).
- o Toddlers have a soil ingestion rate of 0.00002 kg/day and a body weight of 15.3 kg (Richardson and Stantec Consulting Ltd. 2013).
- o Adults have a soil ingestion rate of 0.0000016 kg/day and a body weight of 76.5 kg (Richardson and Stantec Consulting Ltd. 2013).
- o COPC concentrations below the MDL were replaced with concentrations of half of the MDL. This may over- or under-estimate the actual COPC concentrations. However, given the conservative assumptions about exposure frequency, the assessment is considered to be conservative overall.

Table 5.3-13. Estimated Daily Intake of Contaminants of Potential Concern via the Soil Ingestion Exposure Route

Exposure Characteristics		Land User Toddler	Land User Adult	Off-duty Worker
Hours/24 Hours		24	24	12
Days/7 Days		7	7	7
Weeks/52 Weeks		12	12	26
Soil Ingestion Rate (kg/day)		0.00002	0.0000016	0.0000016
Relative Absorption Factor (unitless)		1	1	1
Body Weight (kg)		15.3	76.5	76.5
		Estimated Daily Intake (mg/kg BW/day)		
COPC	**Baseline 95th Percentile Concentration in Soil (mg/kg)**	**Land User Toddler**	**Land User Adult**	**Off-duty Worker**
Aluminum	21330	6.43E-03	1.03E-04	1.12E-04
Arsenic	3.78	1.14E-06	1.82E-08	1.98E-08
Cadmium	0.250	7.54E-08	1.21E-09	1.31E-09
Chromium	65.6	1.98E-05	3.17E-07	3.43E-07
Copper	38.3	1.16E-05	1.85E-07	2.00E-07
Lead	15.0	4.52E-06	7.24E-08	7.84E-08
Manganese	370	1.12E-04	1.79E-06	1.94E-06
Mercury	0.0506	1.53E-08	2.44E-10	2.65E-10
Nickel	34.7	1.05E-05	1.68E-07	1.82E-07
Selenium	0.250	7.54E-08	1.21E-09	1.31E-09
Thallium	0.500	1.51E-07	2.41E-09	2.61E-09
Zinc	59.1	1.78E-05	2.85E-07	3.09E-07

Notes:
COPC = contaminant of potential concern
BW = body weight

A sample calculation of the EDI of aluminum from soil ingestion using Equation 2 is provided below for toddlers:

$$EDI_{Aluminum} = \frac{21{,}330\ \frac{mg}{kg} \times 0.00002\ \frac{kg}{day} \times 1 \times \frac{7\ day}{7\ day} \times \frac{12\ week}{52\ week}}{15.3\ kg\ BW}$$

$$EDI_{Aluminum} = 6.43\ x\ 10^{-3}\ mg/kg\ BW/day$$

5.3.3.4 Dermal Exposure to Soil

The baseline 95th percentile COPC concentrations in soil from 68 sites within the human health LSA (Table 5.3-14) were used as an input in the equation to calculate the EDI of COPCs humans receive from dermal exposure to soil under baseline conditions. The equation used to calculate human exposure to COPCs (mg/kg BW/day) from dermal exposure to soil was (Health Canada 2010b):

$$EDI = \frac{C_S[(SA_H \times SL_H) + (SA_O \times SL_O)] \times RAF_{Derm} \times D_2 \times D_3}{BW} \quad \text{[Equation 3]}$$

where:

C_S = concentration of COPC in soil (mg/kg)
SA_H = surface area of hands exposed for soil loading (cm^2)
SL_H = soil loading rate to exposed skin of hands (kg/cm^2-event)
SA_O = surface area exposed other than hands (cm^2)
SL_O = soil loading rate to exposed skin other than hands (kg/cm^2-event)
RAF_{Derm} = relative dermal absorption factor (unitless)
D_2 = days per week exposed/7 days
D_3 = weeks per year exposed/52 weeks
BW = body weight (kg BW)

Table 5.3-14. Estimated Daily Intake of Contaminants of Potential Concern via Dermal Exposure to Soil

Exposure Characteristics	Land User Toddler	Land User Adult	Off-duty Worker
Days/7 Days	7	7	7
Weeks/52 Weeks	12	12	26
Surface Area of Hands Exposed for Soil Loading (cm^2)	4.56	9.53	9.53
Surface Area of Body, Other than Hands, Exposed for Soil Loading (cm^2) *	28.0	89.1	89.1
Soil loading rate to Exposed Skin of Hands (kg/cm^2-event)	1.00E-07	1.00E-07	1.00E-07
Soil loading rate to Exposed Skin of Body, other than Hands (kg/cm^2-event)	1.00E-08	1.00E-08	1.00E-08
Body Weight (kg)	15.3	76.5	76.5

COPC	Baseline 95th Percentile Concentration in Soil (mg/kg)	Relative Dermal Absorption Factor (unitless)	Estimated Daily Intake (mg/kg BW/day)		
			Land User Toddler	Land User Adult	Off-duty Worker
Aluminum	21330	1.00E+00	2.37E-04	1.19E-04	2.57E-04
Arsenic	3.78	3.00E-02	1.26E-09	6.30E-10	1.37E-09
Cadmium	0.250	1.00E-02	2.78E-11	1.39E-11	3.01E-11
Chromium	65.6	1.00E-01	7.28E-08	3.65E-08	7.91E-08
Copper	38.3	6.00E-02	2.55E-08	1.28E-08	2.77E-08
Lead	15.0	1.00E+00	1.67E-07	8.34E-08	1.81E-07
Manganese	370	1.00E+00	4.11E-06	2.06E-06	4.46E-06
Mercury	0.0506	1.00E+00	5.62E-10	2.81E-10	6.10E-10
Nickel	34.7	9.10E-02	3.51E-08	1.76E-08	3.81E-08
Selenium	0.250	1.00E-02	2.78E-11	1.39E-11	3.01E-11
Thallium	0.500	1.00E+00	5.55E-09	2.78E-09	6.03E-09
Zinc	59.1	1.00E-01	6.56E-08	3.29E-08	7.12E-08

Notes:
COPC = contaminant of potential concern
BW = body weight

The COPC EDI via the dermal exposure to soil route for toddlers and adults are presented in Table 5.3-14. The assumptions used in the calculation of the EDI of COPCs via dermal exposure to soil were as follows:

- Baseline soil quality at the 68 sampling sites is representative of baseline soil quality within the human health LSA.
- Adult and toddler land users are exposed 7 days per week and 12 weeks per year and off-duty workers are exposed 7 days per week 26 weeks per year (due to a work rotation of two weeks on site and two weeks off). These are conservative assumptions for exposure time since there are no permanent or full-time residents within the human health LSA and because exposure to soil through dermal contact is unlikely during the portion of the year when snow is on the ground.
- Toddlers have a surface area of hands exposed for soil loading of 4.56 cm^2, a soil loading rate to exposed skin of hands of 1.00 x 10^{-7} kg/cm^2, a soil loading rate to exposed skin of body (other than hands) of 1.00 x 10^{-8} kg/cm^2, and a body weight of 15.3 kg as recommended by Health Canada (2010b) and Richardson and Stantec Consulting Ltd. (2013).
- Adults have a surface area of hands exposed for soil loading of 9.53 cm^2, a soil loading rate to exposed skin of hands of 1.00 x 10^{-7} kg/cm^2, a soil loading rate to exposed skin of body (other than hands) of 1.00 x 10^{-8} kg/cm^2, and a body weight of 76.5 kg as recommended by Health Canada (2010b) and Richardson and Stantec Consulting Ltd. (2013).
- The surface area of the body (other than hands) exposed for soil loading for toddlers was 28.0 cm^2 (calculated as [9.70 cm^2 + 18.3 cm^2]) and for adults was 89.1 cm^2 (calculated as [27.0 cm^2 + 62.1 cm^2]). The values for surface area of the arms and legs were as recommended in Richardson and Stantec Consulting Ltd. (2013).
- The exposure to COPCs in soil through the dermal exposure route was adjusted with an internal dose absorption factor so that exposure via dermal contact with soil was comparable to TRVs derived for the ingestion route.
- The values for the RAF_{Derm} of COPCs from soil via the dermal exposure router were taken from Health Canada (2010c). When a RAF_{Derm} was not available for a specific COPC, it was assumed that the RAF_{Derm} was 1.0.
- COPC concentrations below the MDL were replaced with concentrations of half of the MDL. This may over- or under-estimate the actual COPC concentrations.

A sample calculation of the EDI of aluminum from dermal exposure to soil using Equation 3 is provided below for toddlers:

$$EDI_{Aluminum} = \frac{21{,}330\frac{mg}{kg} \times \left[\left(4.56\ cm^2 \times 1\ x\ 10^{-7}\frac{kg}{cm^2}\right) + \left(28.0\ cm^2 \times 1\ x\ 10^{-8}\frac{kg}{cm^2}\right)\right] \times 1 \times \frac{7day}{7day} \times \frac{12week}{52week}}{15.3\ kg\ BW}$$

$$EDI_{Aluminum} = 2.37\ \times 10^{-4}\ mg/kg\ BW/day$$

5.3.3.5 Drinking Water

The base case baseline surface water quality model results from 13 surface water quality modeling nodes were used in the risk calculations. In the Boston area there were six surface water quality model nodes, which included: Aimaokatalok Bay (AB node), Aimaokatalok Inflow (AI node), Aimakatalok Lake (AL node), Stickleback Lake (SL node), Trout Lake (TrL node), and Koignuk River 2 (K2 node). In the Doris area there were six surface water quality model nodes, which included: Doris Creek (DC node), Little Roberts Lake (LRL node), Ogama (OL node), Patch Lake (PL node), PO Lake (PoL node), and Wolverine Lake (WoL node). In the Madrid area there was one model node included: Windy Lake (WL node). The sewage, water treatment plant, and TIA nodes were excluded as those nodes do not exist under baseline conditions and it is not expected that water from those outfalls (once they are constructed for the Project) would be consumed by human receptors.

The reason for selecting the specific locations for inclusion in the existing conditions drinking water quality assessment is to enable direct comparison of the baseline water quality to predicted water quality at the exact same locations (i.e., model node assessment locations). The modeling nodes are considered the most likely to experience Project-related effects on surface water quality (e.g., because they are downstream of proposed Project infrastructure or influence). Other baseline water quality monitoring sites located further away or upstream of the Project are not expected to be affected by the Project and water concentrations of COPCs at these locations would be the same as baseline concentrations. By basing the assessment just on the sampling locations that match the modeling nodes where there is greatest potential for effects due to the Project, the assessment of Project-related effects is most conservative and comparison of baseline conditions to predicted conditions is most conservative.

A description of the data used in the base case baseline surface water quality model and the 13 surface water quality modeling nodes is provided in the Madrid-Boston Project Water and Load Balance (Package P5-4). For each surface water quality modeling node, the 95^{th} percentile concentration of each parameter was calculated from the base case baseline monthly model results for the years that matched the Construction (4 years) and Operational (10 years) phases. The median of the 95^{th} percentile concentrations from the 13 surface water quality modeling nodes was calculated and used to assess the risk from drinking water ingestion by land users.

The primary domestic water supplies for the Project will be trucked from a pump house with filtration at Windy Lake and Aimaokatalok Lake. The water quality at Windy Lake is superior to Doris Lake for domestic water needs as it requires less treatment. Thus, the higher of the base case baseline 95^{th} percentile concentrations at either Windy Lake or Aimaokatalok Lake were used in the existing conditions HHRA to assess the risk from drinking water ingestion by off-duty workers.

The equation used to calculate human exposure to COPCs (mg/kg BW/day) from drinking surface water was (Health Canada 2010b):

$$EDI = \frac{C_W \times IR_W \times RAF_{Oral} \times D_2 \times D_3}{BW} \qquad \text{[Equation 4]}$$

where:

- C_W = concentration of COPC in drinking water (mg/L)
- IR_W = receptor water intake rate (L/d)
- RAF_{Oral} = relative absorption factor from the gastrointestinal tract (unitless)
- D_2 = days per week exposed/7 days
- D_3 = weeks per year exposed/52 weeks
- BW = body weight (kg BW)

The COPC EDI via drinking surface water for toddlers and adults are presented in Table 5.3-15.

Table 5.3-15. Estimated Daily Intake of Contaminants of Potential Concern via the Drinking Water Exposure Route

Exposure Characteristics			Land User Toddler	Land User Adult	Off-duty Worker
Days/7 Days			7	7	7
Weeks/52 Weeks			12	12	26
Water Ingestion Rate (L/day)			0.6	1.5	1.5
Relative Absorption Factor (unitless)			1	1	1
Body Weight (kg)			15.3	76.5	76.5
COPC	**Baseline 95th Percentile Concentration in Water for Land Users (mg/L)**	**Baseline 95th Percentile Concentration in Water for Off-duty Workers (mg/L)**	**Estimated Daily Intake (mg/kg BW/day)**		
			Land User Toddler	**Land User Adult**	**Off-duty Worker**
Fluoride	0.0721	0.0674	6.53E-04	3.26E-04	6.61E-04
Aluminum	0.129	0.0740	1.17E-03	5.83E-04	7.25E-04
Arsenic	0.000444	0.000353	1.74E-05	2.01E-06	3.46E-06
Cadmium	0.0000143	0.00000785	5.60E-07	6.46E-08	7.70E-08
Chromium	0.000732	0.000635	2.87E-05	3.31E-06	6.23E-06
Copper	0.00243	0.00175	9.53E-05	1.10E-05	1.72E-05
Lead	0.000117	0.0000635	4.57E-06	5.28E-07	6.23E-07
Manganese	0.0314	0.0256	1.23E-03	1.42E-04	2.51E-04
Mercury	0.00000278	0.00000348	1.09E-07	1.26E-08	3.41E-08
Nickel	0.00107	0.000674	4.19E-05	4.84E-06	6.61E-06
Selenium	0.000536	0.000291	2.10E-05	2.42E-06	2.85E-06
Thallium	0.00000599	0.00000674	2.35E-07	2.71E-08	6.61E-08
Zinc	0.00470	0.00381	1.84E-04	2.13E-05	3.74E-05

Notes:
COPC = contaminant of potential concern
BW = body weight

The assumptions used in the calculation of the EDI of COPCs via ingestion of surface water were as follows:

- Base case baseline surface water quality at the 13 modeling nodes is representative of baseline surface water quality within the human health LSA.
- Adult and toddler land users are exposed 7 days per week and 12 weeks per year; all drinking water is assumed to come from the human health LSA during this period. This is a conservative assumption because there are no permanent or full-time residents within the human health LSA. Adult off-duty workers are exposed 7 days per week and 26 weeks per year and all drinking water comes from Windy Lake and Aimaokatalok Lake.
- Toddlers have a water ingestion rate of 0.6 L/day and a body weight of 15.3 kg as recommended by Health Canada (2010b) and Richardson and Stantec Consulting Ltd. (2013).
- Adults have a water ingestion rate of 1.5 L/day and a body weight of 76.5 kg as recommended by Health Canada (2010b) and Richardson and Stantec Consulting Ltd. (2013).

A sample calculation of the EDI of aluminum from ingestion of surface water using Equation 4 is provided below for toddlers:

$$EDI_{Alumium} = \frac{0.129\,\frac{mg}{L} \times 0.6\,\frac{L}{d} \times 1 \times \frac{7\,day}{7\,day} \times \frac{12\,week}{52\,week}}{15.3\,kg\,BW}$$

$$EDI_{Aluminum} = 1.17\ \times 10^{-3}\,mg/kg\,BW/day$$

5.3.3.6 Ingestion of Country Foods

Terrestrial Wildlife Tissue Concentrations

No terrestrial wildlife species from the human health LSA were harvested to obtain tissue samples. Rather, COPC concentrations in caribou, Arctic ground squirrel, and willow ptarmigan tissue were estimated using a food chain model described in Golder and Associates (2005) and recommended by Health Canada (2010a). Appendix V6-5E describes the food chain model used to predict the tissue concentrations. The model used baseline 95th percentile concentrations of COPCs in water, soil, and vegetation (lichen and berries) in addition to wildlife ingestion rates and COPC-specific biotransfer factors (BTFs; Table V6-5E2 in Appendix V6-5E). A scientific literature search on uptake or biotransfer factors was conducted for various terrestrial wildlife species included in this assessment (see Appendix V6-5E for further details) to ensure the most up to date and relevant BTFs were used within the food chain model. The model also takes into account residence time in the study area to enable evaluation of COPC uptake associated with exposures occurring within the study area.

For calculations of EDI, the arsenic concentration in country food items was adjusted to account for the amount of inorganic arsenic that is likely to be present, as that is the most toxic form. The inorganic arsenic fraction was used in the calculation of EDI from country foods. For caribou and Arctic ground squirrel it was assumed that 70% of the total arsenic was inorganic and for willow ptarmigan it was assumed that 50% of the total arsenic was inorganic (EFSA 2009, 2014). For berries it was assumed that 100% of the arsenic was inorganic (Nicholson 2002). For fish it was assumed that 10% of the arsenic was inorganic (Phillips 1990; Slejkovec, Bajc, and Doganoc 2004; Rosemond, Xie, and Liber 2008; Rahman, Haseqawa, and Lim 2012). For soil and water ingestion, it was assumed that 100% of the arsenic was inorganic.

Each terrestrial wildlife species was assumed to take up COPCs from the environmental medium (soil, water, and vegetation), based on information known about the species life histories. Table 5.3-16 presents the modeled caribou, Arctic ground squirrel, and willow ptarmigan COPC concentrations in tissue. As seen in Table 5.3-16, the food chain model predicts willow ptarmigan has a higher tissue concentration of aluminum than caribou and Arctic ground squirrel (see Appendix V6-5E).

Fish Tissue Concentrations

Lake Trout were sampled in 2009 and 2010 and Arctic Char were sampled in 2017 for the Project. In total, 38 Lake Trout and 17 Arctic Char collected from within the human health LSA (Table 6.2-12, and Figures 6.2-16, and 6.2-17 in Volume 5, Chapter 6: Freshwater Fish; and 2017 Arctic Char sampling locations are described in Appendix V5-10F) had tissue metals analysed, and were included in the assessment. Table 5.3-16 presents the 95th percentile concentrations of COPCs in tissue measured in the two fish species. Appendix V6-5C provides a summary of the results for all metals analyzed in the fish tissue samples. Metal concentrations with values below the MDL were replaced with half the value of the MDL for statistical calculations. The 95th percentile COPC concentrations in Lake Trout and Arctic Char were used to calculate the human EDI of COPCs from freshwater and marine fish consumption, respectively.

Table 5.3-16. Measured and Modeled Concentrations of Contaminants of Potential Concern in Country Foods

COPC	Modeled Concentrations (based on 95th Percentile Water, Soil, and Vegetation Concentrations)					Measured Concentrations (95th Percentiles)		
	Caribou	Caribou Liver [a]	Caribou Kidney [a]	Arctic Ground Squirrel	Willow Ptarmigan	95th Percentile Concentration in Berries	95th Percentile Concentration in Arctic Char	95th Percentile Concentration in Lake Trout
Aluminum	6.01E-02	-	-	6.49E-02	4.16E+01	5.48E+00	2.40E+00	4.24E+00
Arsenic	1.55E-05	2.10E-05	1.76E-05	1.91E-05	1.29E-02	3.62E-03	2.01E+00	1.44E-01
Cadmium	6.31E-07	8.80E-05	7.61E-04	1.35E-06	7.48E-04	3.80E-03	2.50E-03	2.50E-03
Chromium	1.03E-03	-	-	1.73E-03	1.52E-01	9.33E+00	1.92E-02	3.26E-01
Copper	8.75E-04	4.02E-02	6.39E-03	1.22E-03	1.20E-01	1.33E+00	1.72E+00	3.33E-01
Lead	9.21E-06	1.67E-03	2.00E-04	1.13E-05	4.83E-02	1.33E-02	8.28E-03	7.52E-02
Manganese	5.14E-04	-	-	9.74E-04	3.24E-01	2.35E+01	2.03E-01	2.63E-01
Mercury	1.24E-04	1.35E-02	6.45E-02	3.14E-04	1.19E-04	5.00E-04	-	-
Methylmercury [b]	-	-	-	-	-	-	4.46E-02	1.08E+00
Nickel	5.91E-04	-	-	9.95E-04	4.01E-04	5.25E+00	1.13E-01	1.96E-01
Selenium	2.16E-06	-	-	4.29E-06	5.82E-03	1.00E-02	5.66E-01	6.00E-01
Thallium	3.86E-05	-	-	4.34E-05	1.58E-02	2.00E-04	2.04E-03	1.10E-02
Zinc	2.20E-05	3.46E-05	4.16E-05	4.51E-05	1.23E-02	2.15E+00	7.91E+00	4.75E+00

Notes:
All values expressed in mg/kg wet weight.
COPC = contaminant of potential concern
(-) = not available
[a] *Tissue distribution ratios for caribou muscle tissue to caribou liver and kidney tissues only available for arsenic, cadmium, copper, lead, mercury, and zinc.*
[b] *Total mercury analyzed in fish tissue was conservatively assumed to be 100% methylmercury (Health Canada 2007a).*

Berry Tissue Concentrations

Crowberries, bog blueberries, and bearberries were collected in 2010 and 2014 baseline studies and were considered as a possible source of COPC intake through direct human consumption. In total, 59 berry samples were collected from 58 sites within the human health RSA (Figure 8.2-3 in Volume 4, Chapter 8: Vegetation and Special Landscape Features) and analyzed for metal concentrations. Table V6-5E4 in Appendix V6-5E provides a summary of the 95th percentile concentration of COPCs in berries used for the assessment. Appendix V6-5D summarizes the results for all metals analyzed in berry tissue.

Estimated Daily Intake

An EDI of each COPC for toddlers and adults was based on the predicted (caribou, Arctic ground squirrel, and willow ptarmigan) and measured (berries and fish) tissue concentrations and the human receptor characteristics. The following equation (Health Canada 2010b) was used to estimate the EDI of COPCs from the consumption of country foods:

$$EDI_{food} = \frac{C_{food} \times IR \times RAF \times ET}{BW} \quad \text{[Equation 5]}$$

where:

- EDI_{food} = estimated daily intake of COPCs from country food (mg COPC/kg BW/day)
- IR = ingestion rate (kg/day; from Table 5.3-2 of Section 5.3.2.1)
- C_{food} = mean concentration of COPCs in food (mg/kg)
- RAF = relative absorption factor from the gastrointestinal tract for the contaminant (unitless)
- ET = days per 365 days during which consumption of food will occur (days/365 days)
- BW = body weight (kg BW)

The EDI of each COPC for toddler and adult receptors is presented in Table 5.3-17. Assumptions used in the calculation of the EDI of COPCs via ingestion of country foods were as follows:

- Arctic Char were included in the assessment but they may migrate long distances and may be exposed to COPC concentrations outside of the human health LSA. Therefore these fish may not represent baseline COPC loads from the Project area.
- COPC concentrations below the MDL were replaced with concentrations of half of the MDL. This may over- or under-estimate the actual COPC concentrations.
- Since BTFs for wildlife species are not currently available, the BTFs for caribou and Arctic ground squirrel were assumed to be equivalent to published BTFs for cattle (Staven et al. 2003; RAIS 2017), and the BTFs for willow ptarmigan were assumed to be equivalent to published BTFs for poultry (Staven et al. 2003; US EPA 2005e).
- The published cattle and poultry BTFs used in the assessment are for food-to-tissue and it was assumed that the same BTFs would apply to water-to-tissue and soil-to-tissue. The BTFs also assume that animals are in a steady state and that their chemical intake rates are constant;
- The diets of caribou, Arctic ground squirrel, and willow ptarmigan include solely the vegetation species that were collected in baseline field studies and in the proportions used in the model (95th percentile concentrations from each species pooled).
- All country foods consumed by people came from within the human health LSA.
- Animals consume water, soil, and vegetation at the rates and frequencies used in the food chain model.

Table 5.3-17. Estimated Daily Intake of Contaminants of Potential Concern by Human Receptors

COPC	Estimated Daily Intake of COPC (mg/kg BW/day) by Adult Receptor								EDI_{Total} [a]
	Caribou	Caribou Liver	Caribou Kidney	Arctic Ground Squirrel	Ptarmigan	Berries	Arctic Char	Lake Trout	
Aluminum	1.75E-04	-	-	4.17E-05	6.20E-03	9.31E-04	1.50E-03	9.35E-04	9.79E-03
Arsenic [b]	3.17E-08	6.46E-10	2.77E-10	8.62E-09	9.61E-07	6.14E-07	1.26E-04	3.18E-06	1.31E-04
Cadmium	1.84E-09	3.88E-09	1.72E-08	8.65E-10	1.12E-07	6.46E-07	1.57E-06	5.52E-07	2.90E-06
Chromium	2.99E-06	-	-	1.11E-06	2.27E-05	1.59E-03	1.20E-05	7.19E-05	1.70E-03
Copper	2.55E-06	1.77E-06	1.44E-07	7.85E-07	1.79E-05	2.25E-04	1.08E-03	7.35E-05	1.40E-03
Lead	2.68E-08	7.34E-08	4.52E-09	7.25E-09	7.21E-06	2.25E-06	5.19E-06	1.66E-05	3.14E-05
Manganese	1.50E-06	-	-	6.27E-07	4.84E-05	3.98E-03	1.27E-04	5.80E-05	4.22E-03
Mercury	3.63E-07	5.96E-07	1.46E-06	2.02E-07	1.77E-08	8.50E-08	NA	NA	2.72E-06
Methylmercury	NA	NA	NA	NA	NA	NA	2.79E-05	2.39E-04	2.67E-04
Nickel	1.72E-06	-	-	6.40E-07	5.98E-08	8.92E-04	7.08E-05	4.32E-05	1.01E-03
Selenium	6.29E-09	-	-	2.76E-09	8.68E-07	1.70E-06	3.55E-04	1.32E-04	4.90E-04
Thallium	1.13E-07	-	-	2.79E-08	2.35E-06	3.40E-08	1.28E-06	2.43E-06	6.23E-06
Zinc	6.41E-08	1.52E-09	9.38E-10	2.90E-08	1.84E-06	3.66E-04	4.96E-03	1.05E-03	6.38E-03

COPC	Estimated Daily Intake of COPC (mg/kg BW/day) by Toddler Receptor								EDI Total [a]
	Caribou	Caribou Liver	Caribou Kidney	Arctic Ground Squirrel	Ptarmigan	Berries	Arctic Char	Lake Trout	
Aluminum	4.38E-04	-	-	1.04E-04	1.55E-02	2.33E-03	3.76E-03	2.34E-03	2.45E-02
Arsenic [b]	7.92E-08	1.62E-09	6.93E-10	2.15E-08	2.40E-06	1.54E-06	3.16E-04	7.94E-06	3.28E-04
Cadmium	4.59E-09	9.69E-09	4.29E-08	2.16E-09	2.79E-07	1.61E-06	3.92E-06	1.38E-06	7.25E-06
Chromium	7.47E-06	-	-	2.78E-06	5.67E-05	3.96E-03	3.01E-05	1.80E-04	4.24E-03
Copper	6.37E-06	4.43E-06	3.60E-07	1.96E-06	4.48E-05	5.63E-04	2.69E-03	1.84E-04	3.49E-03
Lead	6.71E-08	1.84E-07	1.13E-08	1.81E-08	1.80E-05	5.63E-06	1.30E-05	4.15E-05	7.84E-05
Manganese	3.74E-06	-	-	1.57E-06	1.21E-04	9.96E-03	3.18E-04	1.45E-04	1.06E-02
Mercury	9.07E-07	1.49E-06	3.64E-06	5.05E-07	4.42E-08	2.12E-07	NA	NA	6.80E-06
Methylmercury	NA	NA	NA	NA	NA	NA	6.98E-05	5.97E-04	6.67E-04
Nickel	4.31E-06	-	-	1.60E-06	1.50E-07	2.23E-03	1.77E-04	1.08E-04	2.52E-03
Selenium	1.57E-08	-	-	6.90E-09	2.17E-06	4.25E-06	8.88E-04	3.31E-04	1.23E-03
Thallium	2.81E-07	-	-	6.98E-08	5.87E-06	8.50E-08	3.20E-06	6.07E-06	1.56E-05
Zinc	1.60E-07	3.81E-09	2.35E-09	7.26E-08	4.60E-06	9.14E-04	1.24E-02	2.62E-03	1.59E-02

Notes:
(-) = not available
NA = not applicable
COPC = contaminant of potential concern
EDI = estimated daily intake
Shaded cells denote country foods with the highest estimated daily intake for a toddler or adult of a particular COPC.
[a] The total EDI sums the EDIs from all country food species.
[b] Arsenic EDIs are based on inorganic arsenic concentrations. See Section 5.3.3.6 for further explanation.

- The consumption rates of country foods described in Section 5.3.2.1 are representative of land users who may harvest country foods within the study area.
- Toddlers have a body weight of 15.3 kg as recommended by Richardson and Stantec Consulting Ltd. (2013).
- Adults have a body weight of 76.5 kg as recommended by Richardson and Stantec Consulting Ltd. (2013).

A sample calculation of the EDI of aluminum for toddlers from ingestion of Arctic ground squirrel using Equation 5 is provided below:

$$EDI_{squirrel} = \frac{C_{squirrel} \times IR \times RAF \times ET}{BW}$$

$$EDI_{squirrel} = \frac{0.0649\ mg/kg \times 0.0246\ kg/day \times 1 \times 1}{15.3\ kg}$$

$$EDI_{squirrel} = 0.000104\ mg\ aluminum/kg\ BW/day$$

An assessment of the EDIs in country foods (Table 5.3-17) shows that toddlers and adults had the highest EDI for: mercury from consuming caribou kidney; aluminum from consuming willow ptarmigan; chromium, manganese, and nickel from consuming berries; arsenic, cadmium, copper, selenium, and zinc from consuming Arctic Char; and lead, methylmercury, and thallium from consuming Lake Trout. The lowest EDIs of COPCs were associated with the consumption of caribou whole body, caribou liver, and Arctic ground squirrel.

A sample calculation of the total EDI of aluminum from ingestion of all country foods ($EDI_{Country\ Foods}$) is provided below for toddlers. The EDI of aluminum from each country food item was calculated first (see sample calculation using Equation 5 above) and then the EDI from all species was summed (Table 5.3-17).

$$EDI_{Aluminum-Country\ Foods} = EDI_{Aluminum-Caribou} + EDI_{Aluminum-Arctic\ ground\ squirrel} + EDI_{Aluminum-ptarmigan} + EDI_{Aluminum-Berries} + EDI_{Aluminum-Arctic\ Char} + EDI_{Aluminum-Lake\ Trout}$$

$$EDI_{Aluminum-Country\ Foods} = 0.000438\ mg/kg\ BW/day + 0.000104\ mg/kg\ BW/day + 0.0155\ mg/kg\ BW/day + 0.00233\ mg/kg\ BW/day + 0.00376\ mg/kg\ BW/day + 0.00234\ mg/kg\ BW/day$$

$$EDI_{Aluminum-Country\ Foods} = 0.0245\ mg/kg\ BW/day$$

5.3.4 Toxicity Assessment

5.3.4.1 Introduction

The toxicity assessment involves determining the amount of a COPC that can be taken into the human body without experiencing adverse health effects. Toxicity information is typically derived from laboratory studies, where dose-response information is extrapolated from animal test subjects to humans by applying uncertainty or safety factors. In most cases, uncertainty factors of 100 to 1,000 are applied to the laboratory-derived no observed adverse effect levels (NOAELs). The NOAELs are the highest concentration used in a toxicity test that results in no observed or measured chronic health effects. These uncertainty factors account for interspecies extrapolation and the protection of the most susceptible individuals in the population (i.e., children and the elderly). Therefore, TRVs based on animal studies generally have large margins of safety to ensure that the toxicity or risk of a substance to people is not underestimated. Lowest observed adverse effect levels (LOAEL) or NOAELs from human studies have smaller uncertainty factors because no extrapolation from animals to humans is required.

The TRVs in this assessment are presented as TDIs or Provisional Tolerable Daily Intakes (PTDIs). The TDI is defined as the amount of COPC per unit body weight that can be taken into the body each day (e.g., mg/kg BW/day) without risk of adverse health effects. The term tolerable is used because it signifies permissibility rather than acceptability for the intake of contaminants unavoidably associated with the consumption of otherwise wholesome and nutritious (country) foods (Herrman and Younes 1999). Use of the term “provisional” expresses the tentative nature of the evaluation, if adequate amounts of reliable data is not available the consequences of human exposure at levels approaching those indicated.

Health Canada (2010c, 2011) TRVs were used preferentially (i.e., from Health Canada’s Bureau of Chemical Safety, Chemical Health Hazard Division) unless they were not available for certain COPCs, in which case alternative sources of TRVs were used. Other sources of TRVs included:

- US EPA’s Integrated Risk Information System (IRIS) TRVs;
- Food and Agriculture Organization of the United Nations (FAO)/ WHO Joint Expert Committee on Food Additives and Contaminants (JECFA) TRVs;
- Health Effects Assessment Summary Table (US EPA 1997a); and
- Agency for Toxic Substances and Disease Registry (ASTDR) toxicological profiles for metals.

The TRVs and cancer slope factors/unit risks used in the existing conditions HHRA are presented in Table 5.3-18. The toxicity studies on which the TRVs and cancer slope factors/unit risks were based and the rationale for their selection is briefly summarized in Section 5.3.4.2.

Table 5.3-18. Toxicity Reference Values for Contaminants of Potential Concern

	TRV (mg/kg BW/day)		
COPC	**Adult**	**Toddler**	**Reference**
Aluminum	0.3	0.3	Health Canada (2011)
Arsenic	0.0003	0.0003	US EPA (2017c)
Cadmium	0.001	0.001	Health Canada (2010c)
Chromium	0.001	0.001	Health Canada (2010c)
Copper	0.141	0.091	Health Canada (2010c)
Fluoride	0.105	0.105	Health Canada (2010c)
Lead	0.0013	0.0006	JECFA (2011)
Manganese	0.156	0.136	Health Canada (2010c)
Mercury [a]	0.0003	0.0003	Health Canada (2010c)
Methylmercury [b]	0.00047	0.00023	Health Canada (2011)
Nickel	0.011	0.011	Health Canada (2010c)
Selenium	0.00570	0.00620	Health Canada (2010c)
Thallium	0.00007	0.00007	Health Canada (2011)
Zinc	0.57	0.48	Health Canada (2010c)

Carcinogenic COPC	Inhalation Cancer Unit Risk (µg/m^3)$^{-1}$	Oral Cancer Slope Factor (mg/kg BW/day)$^{-1}$	Reference
Arsenic	0.0064	1.8	Health Canada (2010c)
Cadmium	0.0098	NA	
Chromium	0.011	NA	
Nickel	0.0013	NA	

Notes:
COPC = contaminant of potential concern
TRV = toxicity reference value
BW = body weight
NA = not applicable
[a] *Total mercury TRV for adults and toddlers eating biota other than fish.*
[b] *Methylmercury TRV for general public eating fish is 0.00047 mg/kg BW/day, while that for children, women of child-bearing age, and pregnant women eating fish is 0.00023 mg/kg BW/day.*

5.3.4.2 Toxicity Reference Values

Aluminum

Health Canada (2011) provides a PTDI of 0.3 mg/kg BW/day for aluminum. JECFA provides an estimate for a provisional tolerable weekly intake (PTWI) of 1 mg/kg BW/week which is equivalent to a PTDI of 0.14 mg/kg BW/day (JECFA 2007a). The Agency for Toxic Substances and Disease Registry (ATSDR 2008) has derived an intermediate-duration and a chronic-duration oral minimal risk level (MRL) of 1 mg aluminum/kg BW/day.

The chronic-duration MRL is based on a LOAEL of 100 mg aluminum/kg BW/day for neurological effects in mice exposed to aluminum lactate in the diet during gestation, lactation, and post-natally until two years of age (Golub et al. 2000). The MRL was derived by dividing the LOAEL by an uncertainty factor of 300 (3 for the use of a minimal LOAEL, 10 for animal to human extrapolation, and 10 for intra-human variability) and a modifying factor of 0.3 to account for the higher bioavailability of the aluminum lactate used in the principal study compared to the bioavailability of aluminum in the human diet and drinking water. However, the lower Health Canada PTDI (0.3 mg/kg BW/day) was used in this assessment to be conservative.

Arsenic

Health Canada does not provide a TRV for non-carcinogenic risks for arsenic. For assessment of non-cancer risks from arsenic, IRIS (US EPA 2017c) provides 0.0003 mg/kg BW/day for a chronic oral TDI, while JECFA recommends a TDI of 0.001 mg/kg BW/week for oral exposures (JECFA 2010). The more conservative US EPA value of 0.0003 mg/kg BW/day was used in the assessment.

Arsenic is the only metal in this report that is considered carcinogenic via the ingestion pathway. For carcinogens, slope factors are used as the TRVs (Health Canada 2010c). A slope factor is the upper bound estimate of the probability of a response-per-unit intake of a material of concern over an average human lifetime. It is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of arsenic. Upper-bound estimates conservatively exaggerate the risk to ensure that the risk is not underestimated if the underlying model is incorrect. The oral slope factor for arsenic cancer risk is 1.8 (mg/kg BW/day)$^{-1}$ (Health Canada 2010c), based on a tumourigenic dose (TD_{05}). Of the various species of arsenic that exist, inorganic arsenic has been identified as the primary carcinogenic form, while organic arsenic compounds have relatively low carcinogenic activity but a higher bioaccumulation potential (Roy and Saha 2002).

Arsenic is also carcinogenic via the inhalation route. Health Canada (2010c) provides a cancer unit risk for inhalation of arsenic of 0.0064 $(\mu g/m^3)^{-1}$, which is based on epidemiological studies in occupationally exposed people with lung cancer as the endpoint.

Cadmium

Health Canada (2010c) provides a PTDI of 0.001 mg/kg BW/day, which is similar to JECFA's provisional tolerable monthly intake of 0.025 mg/kg BW/month (equivalent to 0.00083 mg/kg BW/day; JECFA 2011), which accounts for the long half-life of cadmium in the body. The JECFA TDI of 0.0008 mg/kg BW/day will ensure cadmium concentrations in the renal cortex do not exceed 50 mg/kg; this level is thought to protect normal kidney function. IRIS (US EPA 2017c) provides a TDI of 0.001 mg/kg BW/day for oral exposures to cadmium based on recommendations by JECFA (1972, 2005). The PTDI provided by Health Canada was adopted as the TRV for cadmium in this assessment.

Cadmium is carcinogenic via the inhalation route. Health Canada (2010c) provides a cancer unit risk for inhalation of cadmium of 0.0098 $(\mu g/m^3)^{-1}$, which is based on chronic exposure studies in rats with lung cancer as the endpoint.

Chromium

Health Canada (2010c) provides a TDI of 0.001 mg/kg BW/day for total chromium. This value was based on water intake and was derived from multiplication of the maximum acceptable concentration (MAC) for total chromium of 0.05 mg/L by a water consumption rate of 1.5 L/day, and divided by the body weight of 70 kg. IRIS provides an TDI of 0.003 mg/kg BW/day (US EPA 2017c), which was derived from a NOAEL of 2.5 mg/kg BW/day based on a one year chronic toxicity study with rats (MacKenzie et al. 1958). An uncertainty factor of 900 was applied to the NOAEL: 10 for interspecies extrapolation, 10 for inter-human variability, 3 as modifying factor, and 3 to address concerns from other studies (Zhang and Li 1987). The more conservative Health Canada TDI of 0.001 mg/kg BW/day was used in this assessment.

Chromium is carcinogenic via the inhalation route. Health Canada (2010c) provides a cancer unit risk for inhalation of chromium of 0.011 $(\mu g/m^3)^{-1}$, which is based on epidemiological studies in occupationally exposed people with lung cancer as the endpoint.

Copper

Health Canada (2010c) reports a TDI of 0.091 to 0.141 mg/kg BW/day for copper based on specific age groups. Copper is an essential nutrient. JECFA recommends a PTDI of 0.5 mg/kg BW/day (WHO 1982). However, recommendations by JECFA were made for further collection of information on copper with emphasis on epidemiological surveys to study the evidence of copper-induced ill-health. TDIs of 0.091 mg/kg BW/day and 0.141 mg/kg BW/day were used for toddlers and adults, respectively, in this report.

Fluoride

Health Canada (2010c) reports an oral TDI of 0.105 mg/kg BW/day for fluoride. The TDI is based on a NOAEL from epidemiological studies on children where the critical health effect was moderate dental fluorosis (Health Canada 2010c). Dental fluorosis is a common disorder where hypomineralization of tooth enamel is caused by excessive ingestion of fluoride during enamel formation, resulting in white spots on the teeth. Some evidence suggests that inorganic fluoride is carcinogenic; however, the data are inconclusive (Health Canada 2010c). The ATSDR, IRIS, and JECFA do not provide a TDI for fluoride. However, the US EPA (1997a) Health Effects Summary Tables lists a TDI for fluoride of 0.06 mg/kg BW/day, which is also based on human studies where the critical endpoint was dental fluorosis.

The more recent fluoride TDI provided by Health Canada (2010c) of 0.105 mg/kg BW/day was used in this assessment.

Lead

Health Canada (2013b, 2013a) is currently reviewing the TDI for lead and has not established a definitive TDI for risk assessment purposes. JECFA (2000) established a PTWI for lead of 0.025 mg/kg BW/week; however, JECFA withdrew this PTWI in 2011 (JECFA 2011) because the intake value was associated with a decrease of at least three Intelligence Quotient (IQ) points in children and an increase in systolic blood pressure of approximately 3 mmHg (0.4 kPa) in adults.

JECFA (2011) undertook a comprehensive review of available data and determined that a lead exposure level of 0.0006 mg/kg BW/day is associated with a population decrease of 1 IQ point in children (Wilson and Richardson 2013), which was adopted as the lead TRV for toddlers in this assessment.

JECFA (2011) also determined that a lead exposure level of 0.0013 mg/kg BW/day was associated with a 1 mmHg increase in systolic blood pressure in adults, which was adopted as the lead TRV for adults in this assessment.

Manganese

Manganese is an essential element that is required for normal physiological function in all animal species; however, individual requirements and toxicity can be highly variable (US EPA 2017c). Excess intake of manganese can result in symptoms such as lethargy, increased muscle tonus, tremor, and metal disturbances (US EPA 2017c), thus Health Canada (2010c) provides a manganese TDI for toddlers of 0.136 mg/kg BW/day and for adults of 0.156 mg/kg BW/day. The IRIS (US EPA 2017c) TDI is 0.14 mg/kg/day which is the same as the NOAEL for chronic human consumption of manganese in the diet from a composite of data from several studies. IRIS states that the confidence in the dietary TDI for manganese is medium (US EPA 2017c). The Health Canada TDIs for toddlers and adults were adopted in this assessment.

Mercury

Health Canada (2010c) provides a TDI of 0.0003 mg/kg BW/day for inorganic mercury exposure for the general public, based on CCME soil quality guidelines and supporting documentation on health-based guidelines prepared by Health Canada. As data are not readily available on the mercury species present in the local vegetation and terrestrial animals, for caribou, willow ptarmigan, Arctic ground squirrel, and plant tissues, total mercury was compared to the Health Canada (2010c) inorganic mercury PTDI as a TRV.

For fish, mercury was assumed to be present 100% as methylmercury (Health Canada 2007a). For methylmercury, JECFA (2007b) recommends a PTDI of 0.00047 mg/kg BW/day for the general public and 0.00023 mg/kg BW/day for sensitive groups (i.e., children and women who are pregnant or who are of child-bearing age). This was also adopted by Health Canada (2010c) and is the TRV for methylmercury adopted in this assessment.

Nickel

Health Canada (2010c) provides a TDI of 0.011 mg/kg BW/day. The TDI for total nickel (as soluble salts) was based on a dietary study in rats that found a NOAEL of 5 mg/kg BW/day for altered organ to body weight ratios (Springborn Laboratories Inc. 2000). An uncertainty factor of 200 was applied to the NOAEL: 10 for interspecies variation and 10 to protect sensitive populations. A modifying factor of 2 was also applied to account for the inadequacies of the reproductive studies. The Health Canada TDI of 0.011 mg/kg BW/day was used as the TRV for nickel in this assessment.

Nickel is carcinogenic via the inhalation route. Health Canada (2010c) provides a cancer unit risk for inhalation of nickel (combined oxidic, sulphidic, and soluble nickel) of 0.0013 $(\mu g/m^3)^{-1}$, which is based on epidemiological studies in occupationally exposed people with lung and nasal cancer (also kidney, prostrate, and buccal cavity cancers) as the endpoints.

Selenium

Selenium is an essential element and is required for human nutrition. Health Canada (2010c) provides an age- and body weight-adjusted tolerable upper limit for selenium of 0.0057 to 0.0062 mg/kg BW/day (adults and toddlers, respectively). This was based on a NOAEL in adults of 0.8 mg/kg/day in a cohort study by Yang and Zhou (1994) and a NOAEL in children of 0.007 mg/kg/day (Shearer and Hadjimarkos 1975). Health effects due to an exposure to elevated levels of selenium are described as selenosis (gastrointestinal disorders, hair loss, sloughing of nails, fatigue, irritability, and neurological damage). The Health Canada TDI of 0.0057 and 0.0062 mg/kg BW/day for adults and toddlers, respectively was used as the TRVs for selenium in this assessment.

Thallium

Health Canada (2011) provides a PTDI of 0.00007 mg/kg BW/day for thallium. Health Canada does not provide a rationale for the derivation of this PTDI, but states that the PTDI is considered temporary as it was derived from an incomplete data set. The Health Canada PTDI of 0.00007 mg/kg BW/day for thallium was used as the TRV in this assessment.

Zinc

Zinc is an essential element and is required for human nutrition. Health Canada (2011) provides a TDI of 0.7 mg/kg BW/day. This value was based on the upper safe level (USL) established by the Expert Group on Vitamins and Minerals (EGVM 2003). A LOAEL of 50 mg/day was found for both men and women exposed to zinc supplements (i.e., additional zinc exposure besides that incurred through normal food and water intake). The LOAEL was converted to a NOAEL by dividing it by an uncertainty factor of 2 to give a NOAEL of 25 mg/day, which is 0.42 mg/kg BW/day in a 60 kg person. Thus, the USL for zinc supplements is 0.42 mg/kg BW/day. If the maximum zinc intake of 17 mg/day (0.28 mg/kg BW/day) from food is added to the USL, the maximum total intake for zinc is equivalent to 0.7 mg/kg BW/day.

However, Health Canada (2010c) provides more conservative TRVs for zinc for adults (using a body weight of 70.7 kg) and toddlers (average of the TRV for toddlers 7 months to 8 years old, using a body weight of 16.5 kg) of 0.57 and 0.48 mg/kg BW/day, respectively. The more conservative TRVs from Health Canada were used in this assessment.

5.3.5 Risk Characterization

5.3.5.1 Introduction

Using the results of the exposure assessment and TRV assessment, human health risks were quantified using HQs. The HQ is the ratio between the EDI and the TRV and provides a measure of exposure to a COPC through the various exposure pathways. In addition, the ILCR was determined for COPCs (e.g., arsenic) that may be associated with carcinogenic potential via ingestion or inhalation.

5.3.5.2 Estimation of Non-carcinogenic Risks from All Exposure Routes

Non-Metal Contaminants of Potential Concern

Non-metal COPCs (i.e., fluoride) only occurred in surface water; thus, surface water is the only route of exposure and the EDI is not summed with other exposure pathways in order to obtain the total EDI. Thus, the HQ is simply the drinking water EDI divided by the TRV. Table 5.3-19 (for toddlers) and 5.3-20 (for adults) show the fluoride EDIs and the HQs from the drinking water exposure route.

The toddler and adult (land user and off-duty worker) HQs for fluoride were all below the threshold of 0.2. Therefore, no risks from non-metal COPCs were identified in the existing conditions HHRA.

Metal Contaminants of Potential Concern

The formula used to calculate the total estimated daily intake (EDI_{Total}; in mg/kg BW/day) of COPCs from all exposure routes was:

$$\mathrm{EDI_{Total}} = \mathrm{EDI_{Inhalation}} + \mathrm{EDI_{Water}} + \mathrm{EDI_{Soil\ ingestion}} + \mathrm{EDI_{Soil\ contact}} + \mathrm{EDI_{Country\ foods}} \quad \text{[Equation 6]}$$

where:

- $EDI_{Inhalation}$ = estimated daily intake of COPCs from inhalation (mg/kg BW/day)
- EDI_{Water} = estimated daily intake of COPCs from drinking water ingestion (mg/kg BW day)
- $EDI_{Soil\ ingestion}$ = estimated daily intake of COPCs from incidental soil ingestion (mg/kg BW day)
- $EDI_{Soil\ contact}$ = estimated daily intake of COPCs from dermal soil contact (mg/kg BW day)
- $EDI_{Country\ foods}$ = estimated daily intake of COPCs from country food ingestion (mg/kg BW/day)

The total estimated daily intake (EDI_{Total}) of COPCs from all routes was then divided by the TRV (in mg/kg BW/day) to obtain the existing conditions HQ (unitless), as follows:

$$\mathrm{HQ_{existing}} = \mathrm{EDI_{Total}}/\mathrm{TRV} \quad \text{[Equation 7]}$$

Table 5.3-19 (for toddlers) and 5.3-20 (for adults) show the COPC EDIs from each exposure route, the sum of the COPC EDIs from all exposure routes (EDI_{Total}), the TRV, as well as the HQ for each COPC.

For non-carcinogenic COPCs, Health Canada (2010b) suggests that an HQ of less than 0.2 indicates that the exposure does not pose a significant health risk to human receptors. An HQ of 0.2 is used (instead of 1.0) because the assessment does not consider intake of contaminants from all potential exposure routes (e.g., from retail foods consumed by all receptors or exposures from outside of the study area for land users).

An HQ value greater than 0.2 does not necessarily indicate that adverse health effects will occur since the TRVs are conservative (i.e., protect human health by including additional uncertainty factors) and many of the assumptions made in the assessment are conservative. An HQ of greater than 0.2 does suggest that the potential risk to human health may require a more detailed evaluation. However, in an EIS, the purpose of conducting a HHRA is to quantitatively identify the incremental change in risk to human health, rather than the absolute risk. Therefore, in this context, the most important use of the results of the existing conditions HHRA is to provide the basis for determining the relevance and potential for change in human health due to the Project.

Table 5.3-19. Risk Characterization for Toddlers under Existing Conditions

COPC	Estimated Daily Intake for Land User Toddler (mg/kg BW/day)						Toxicity Reference Value (mg/kg BW/day)	Baseline Hazard Quotient for Land User Toddler
	Inhalation	Drinking Water	Soil Ingestion	Dermal Contact With Soil	Ingestion of Country Foods	Total (All Exposure Routes)		
Fluoride	NA	6.53E-04	NA	NA	NA	6.53E-04	0.105	0.0062
Aluminum	2.36E-06	1.17E-03	6.43E-03	2.37E-04	2.45E-02	3.23E-02	0.3	0.11
Arsenic	4.48E-09	1.74E-05	1.14E-06	1.26E-09	3.28E-04	3.46E-04	0.0003	1.2
Cadmium	1.22E-09	5.60E-07	7.54E-08	2.78E-11	7.25E-06	7.89E-06	0.001	0.0079
Chromium	2.10E-08	2.87E-05	1.98E-05	7.28E-08	4.24E-03	4.29E-03	0.001	4.3
Copper	1.30E-07	9.53E-05	1.16E-05	2.55E-08	3.49E-03	3.60E-03	0.091	0.040
Lead	1.23E-08	4.57E-06	4.52E-06	1.67E-07	7.84E-05	8.77E-05	0.0006	0.15
Manganese	1.53E-07	1.23E-03	1.12E-04	4.11E-06	1.06E-02	1.19E-02	0.136	0.087
Mercury	6.40E-10	1.09E-07	1.53E-08	5.62E-10	6.80E-06	6.92E-06	0.0003	0.023
Methylmercury	NA	NA	NA	NA	6.67E-04	6.67E-04	0.00023	2.9
Nickel	4.12E-08	4.19E-05	1.05E-05	3.51E-08	2.52E-03	2.57E-03	0.011	0.23
Selenium	5.98E-09	2.10E-05	7.54E-08	2.78E-11	1.23E-03	1.25E-03	0.0062	0.20
Thallium	5.98E-10	2.35E-07	1.51E-07	5.55E-09	1.56E-05	1.60E-05	0.00007	0.23
Zinc	8.88E-08	1.84E-04	1.78E-05	6.56E-08	1.59E-02	1.61E-02	0.48	0.034

Notes:
COPC = contaminant of potential concern
NA = not applicable
BW = body weight
Hazard quotients greater than 0.2 are shaded grey.

For toddlers, the HQs for arsenic, chromium, methylmercury, nickel, selenium, and thallium were greater than 0.2 (Table 5.3-19). For land user adults, the HQs for arsenic, chromium, and methylmercury (general public and sensitive populations) were greater than 0.2 (Table 5.3-20). For off-duty workers, all of the HQs were below the threshold of 0.2 and no potential risks to off-duty worker health due to COPCs were identified.

In a screening level risk assessment, such as this existing conditions HHRA, it is common to make a number of conservative assumptions during the assessment which will overestimate the actual risk to human health. If no unacceptable risks are identified using this conservative approach, then it is unlikely that human health will be affected by the exposure pathways considered and the rates used in the assessment. However, identification of potential risks due to existing conditions does not necessarily mean that human health will be adversely affected, since the risk has been overestimated intentionally in a screening level HHRA.

It is likely that the risk is significantly overestimated due to the conservative assumptions made throughout the existing conditions HHRA. Conservative, upper-bound estimates of existing environment media concentrations (i.e., 95^{th} percentile) were used in the calculations and risk levels would likely be substantially lower if other statistics of more central tendency were used (e.g., medians, means, upper confidence limits of the mean, etc.). There are no known full-time, year-round residents within the human health RSA; however, the estimated daily intake of COPCs were assumed to come from air, water, and soil contact within the human health LSA for significant portions of the year (3 months per year, 24 hours a day). In addition, not all of the country foods that an individual will eat will come from the human health LSA, as was assumed in the assessment.

Overall, it is concluded under existing conditions that several COPCs have the potential to affect human health (i.e., arsenic, chromium, methylmercury, nickel, selenium, and thallium for toddlers; and arsenic, chromium, and methylmercury for land user adults). However, there is uncertainty in the assessment for the reasons outlined in Section 5.3.6, and due to assumptions made in the assessment (Section 5.3.3).

The existing conditions HHRA also likely overestimated risk to off-duty workers, since it is based on the assessment of workers being on site for 26 weeks of the year. This is an overestimate as it does not account for vacation time, sick time, or other time off-site other than the two week on and two week off shift rotation.

5.3.5.3 Estimation of Cancer Risks

<u>Incremental Lifetime Cancer Risk via the Inhalation Exposure Route</u>

Arsenic, cadmium, chromium, and nickel are considered to be carcinogens via the inhalation exposure route, thus the incremental lifetime cancer risk (ILCR) was calculated using the equation (Health Canada 2010b):

$$\mathrm{ILCR} = \mathrm{C_A} \times \mathrm{T} \times \mathrm{CUR} \qquad \text{[Equation 8]}$$

where:

- C_A = concentration in air (μg/m^3)
- T = fraction of time exposed
- CUR = cancer unit risk (μg/m^3)$^{-1}$

Table 5.3-20. Risk Characterization for Adult Land User and Off-duty Worker under Existing Conditions

COPC	Estimated Daily Intake for Land User Adult (mg/kg BW/day)						Estimated Daily Intake for Off-duty Worker (mg/kg BW/day)							
	Inhalation	Drinking Water	Soil Ingestion	Dermal Contact With Soil	Ingestion of Country Foods	Total (All Exposure Routes)	Inhalation	Drinking Water	Soil Ingestion	Dermal Contact With Soil	Total (All Exposure Routes)	Toxicity Reference Value (mg/kg BW/day)	Baseline Hazard Quotient for Land User Adult	Baseline Hazard Quotient for Off-duty Worker
Fluoride	NA	3.26E-04	NA	NA	NA	3.26E-04	NA	6.61E-04	NA	NA	6.61E-04	0.105	0.0031	0.0063
Aluminum	9.92E-07	5.83E-04	1.03E-04	1.19E-04	9.79E-03	1.06E-02	1.07E-06	7.25E-04	1.12E-04	2.57E-04	1.09E-03	0.3	0.035	0.0036
Arsenic	1.88E-09	2.01E-06	1.82E-08	6.30E-10	1.31E-04	1.33E-04	2.04E-09	3.46E-06	1.98E-08	1.37E-09	3.48E-06	0.0003	0.44	0.012
Cadmium	5.13E-10	6.46E-08	1.21E-09	1.39E-11	2.90E-06	2.97E-06	5.55E-10	7.70E-08	1.31E-09	3.01E-11	7.89E-08	0.001	0.0030	0.000079
Chromium	8.81E-09	3.31E-06	3.17E-07	3.65E-08	1.70E-03	1.70E-03	9.54E-09	6.23E-06	3.43E-07	7.91E-08	6.66E-06	0.001	1.7	0.0067
Copper	5.47E-08	1.10E-05	1.85E-07	1.28E-08	1.40E-03	1.41E-03	5.92E-08	1.72E-05	2.00E-07	2.77E-08	1.75E-05	0.141	0.010	0.00012
Lead	5.19E-09	5.28E-07	7.24E-08	8.34E-08	3.14E-05	3.20E-05	5.62E-09	6.23E-07	7.84E-08	1.81E-07	8.88E-07	0.0013	0.025	0.00068
Manganese	6.42E-08	1.42E-04	1.79E-06	2.06E-06	4.22E-03	4.37E-03	6.95E-08	2.51E-04	1.94E-06	4.46E-06	2.57E-04	0.156	0.028	0.0017
Mercury	2.69E-10	1.26E-08	2.44E-10	2.81E-10	2.72E-06	2.73E-06	2.91E-10	3.41E-08	2.65E-10	6.10E-10	3.53E-08	0.0003	0.0091	0.00012
Methylmercury (general adult population)	NA	NA	NA	NA	2.67E-04	2.67E-04	NA	NA	NA	NA	NA	0.00047	0.57	NA
Methylmercury (sensitive populations)	NA	NA	NA	NA	2.67E-04	2.67E-04	NA	NA	NA	NA	NA	0.00023	1.2	NA
Nickel	1.73E-08	4.84E-06	1.68E-07	1.76E-08	1.01E-03	1.01E-03	1.88E-08	6.61E-06	1.82E-07	3.81E-08	6.85E-06	0.011	0.092	0.00062
Selenium	2.51E-09	2.42E-06	1.21E-09	1.39E-11	4.90E-04	4.92E-04	2.72E-09	2.85E-06	1.31E-09	3.01E-11	2.86E-06	0.0057	0.086	0.00050
Thallium	2.51E-10	2.71E-08	2.41E-09	2.78E-09	6.23E-06	6.26E-06	2.72E-10	6.61E-08	2.61E-09	6.03E-09	7.50E-08	0.00007	0.089	0.0011
Zinc	3.73E-08	2.13E-05	2.85E-07	3.29E-08	6.38E-03	6.40E-03	4.04E-08	3.74E-05	3.09E-07	7.12E-08	3.78E-05	0.57	0.011	0.000066

Notes:
COPC = contaminant of potential concern
NA = not applicable
BW = body weight
Hazard quotients greater than 0.2 are shaded grey.

The inhalation cancer unit risk for arsenic is 0.0064 $(\mu g/m^3)^{-1}$, for cadmium is 0.0098 $(\mu g/m^3)^{-1}$, for chromium is 0.011 $(mg/m^3)^{-1}$, and for nickel is 0.0013 $(\mu g/m^3)^{-1}$ (Health Canada 2010c). Since arsenic, cadmium, chromium, and nickel can cause lung cancer, the risks are assumed to be additive and are summed (Health Canada 2010b). The baseline concentrations of arsenic, cadmium, chromium, and nickel used in the ILCR calculations were 0.0000376, 0.0000102, 0.000176, and 0.000346 $\mu g/m^3$, respectively.

Based on being exposed for 14 years out of an 80 year lifetime (to allow for comparison to the Project-related HHRA that considers the Construction and Operational phases, which total 14 years in duration) for three months of the year for adult land users and half of the year for off-duty workers, the ILCRs for arsenic, cadmium, chromium, and nickel are shown in Table 5.3-21.

Table 5.3-21. Incremental Lifetime Cancer Risk (Inhalation Route) under Existing Conditions

	Incremental Lifetime Cancer Risk	
Parameter	**Adult Land User**	**Off-duty Worker**
Arsenic	9.7E-09	1.1E-08
Cadmium	4.1E-09	4.4E-09
Chromium	7.8E-08	8.5E-08
Nickel	1.8E-08	2.0E-08
Summed ILCR (inhalation)	1.1E-07	1.2E-07

Notes:
ILCR = incremental lifetime cancer risk

The summed arsenic, cadmium, chromium, and nickel lifetime ILCR for land users and off-duty workers (1.1×10^{-7} and 1.2×10^{-7}, respectively) are less than 1.0×10^{-5}, which according to Health Canada (2010b), is considered to be an acceptable risk benchmark. Thus there is negligible risk to human health from inhalation of carcinogenic metals bound to PM_{10} under existing conditions.

A sample calculation of the arsenic ILCR from inhalation for adult land users using Equation 8 is provided below:

$$\mathrm{ILCR_{Arsenic}} = \mathrm{C_A} \times \mathrm{T} \times \mathrm{CUR}$$

$$\mathrm{ILCR_{Arsenic}} = \left(3.76 \times 10^{-5}\,\frac{\mu g}{m^3}\right) \times \left(\frac{24\ hours}{24\ hours}\right) \times \left(\frac{7\ days}{7\ days}\right) \times \left(\frac{12\ weeks}{52\ weeks}\right) \times \left(\frac{14\ years}{80\ years}\right) \times \left(6.40 \times 10^{-3}\left(\frac{\mu g}{m^3}\right)^{-1}\right)$$

$$\mathrm{ILCR_{Arsenic}} = 9.7 \times 10^{-9}$$

Incremental Lifetime Cancer Risk via the Ingestion and Direct Contact Exposure Routes

Of the COPCs evaluated, only arsenic is considered carcinogenic through ingestion. Carcinogenic risks were calculated as ILCR estimates according to the following formula (Health Canada 2010b):

$$\mathrm{ILCR} = \mathrm{ELDE} \times \mathrm{Oral\ CSF} \qquad \text{[Equation 9]}$$

where:

ILCR = Incremental lifetime cancer risk (unitless)
ELDE = Estimated lifetime daily exposure (mg/kg BW/day)
Oral CSF = Oral cancer slope factor $(mg/kg\ BW/day)^{-1}$

The oral CSF for arsenic is 1.80 $(mg/kg\ BW/day)^{-1}$ (Health Canada 2010c).

The following equation was used to calculate the estimated lifetime daily exposure from ingestion (ELDE; Golder Associates Ltd. 2005):

$$\mathrm{ELDE} = \frac{\mathrm{C \times IR \times RAF \times ET \times D2}}{\mathrm{BW \times LE}} \quad \text{[Equation 10]}$$

where:

C = concentration of the COPC (mg/kg)
IR = ingestion rate (kg/day)
RAF = relative absorption factor (unitless)
ET = days per 365 days consuming food, water, or soil from area (days/365 days)
D2 = total years exposed to site (carcinogens only; years)
BW = body weight (kg)
LE = life expectancy (years)

The total years exposed to the site (D2) was assumed to be 14 years out of an 80 year life expectancy (Richardson and Stantec Consulting Ltd. 2013). A sample calculation of the estimated daily lifetime exposure to arsenic for an adult land user consuming Arctic Char tissue using Equation 10 is provided below. The concentration of arsenic in the country food items was adjusted to account for the amount of inorganic arsenic (see Section 5.3.3.6), which was used in the calculation of ELDE for the country foods.

$$\mathrm{ELDE_{arsenic}} = \frac{\mathrm{C \times IR \times RAF \times ET \times D2}}{\mathrm{BW \times LE}}$$

$$\mathrm{ELDE_{arsenic}} = \frac{\left(2.01\,\frac{\mathrm{mg}}{\mathrm{kg}} \times 0.1\right) \times 0.0480\,\frac{\mathrm{kg}}{\mathrm{day}} \times 1 \times 1 \times 14\ \mathrm{years}}{76.5\ \mathrm{kg} \times 80\ \mathrm{years}}$$

$$\mathrm{ELDE_{arsenic}} = 2.21 \text{ x } 10^{-5}$$

An ELDE was calculated for all ingestion and, conservatively, the soil contact pathways (i.e., drinking water, soil ingestion, soil contact, and country food species) and it was assumed that 100% of the soil and water concentration of arsenic was inorganic arsenic. The formula used to calculate the total estimated lifetime daily exposure ($ELDE_{Total}$ in mg/kg BW/day) from each pathway was:

$$\mathrm{ELDE_{Total}} = \mathrm{ELDE_{water}} + \mathrm{ELDE_{soil\ ingestion}} + \mathrm{ELDE_{soil\ contact}} + \mathrm{ELDE_{caribou}} + \mathrm{ELDE_{squirrel}} + \mathrm{ELDE_{ptarmigan}} + \mathrm{ELDE_{berries}} + \mathrm{ELDE_{Arctic\ Char}} + \mathrm{ELDE_{Lake\ Trout}} \quad \text{[Equation 11]}$$

where:

$ELDE_{water}$ = estimated lifetime daily exposure from drinking water ingestion (mg/kg BW/day)
$ELDE_{soil\ ingestion}$ = estimated lifetime daily exposure from incidental soil ingestion (mg/kg BW/day)
$ELDE_{soil\ contact}$ = estimated lifetime daily exposure from dermal soil contact (mg/kg BW/day)
$ELDE_{caribou}$ = estimated lifetime daily exposure from caribou ingestion (mg/kg BW/day)

$ELDE_{squirrel}$ = estimated lifetime daily exposure from Arctic ground squirrel ingestion (mg/kg BW/day)
$ELDE_{ptarmigan}$ = estimated lifetime daily exposure from willow ptarmigan ingestion (mg/kg BW/day)
$ELDE_{berries}$ = estimated lifetime daily exposure from berry ingestion (mg/kg BW/day)
$ELDE_{Arctic\ char}$ = estimated lifetime daily exposure from Arctic Char ingestion (mg/kg BW/day)
$ELDE_{Lake\ Trout}$ = estimated lifetime daily exposure from Lake Trout ingestion (mg/kg BW/day)

The ELDE was calculated for each ingestion and soil contact pathway and the summed total ELDE is provided in Table 5.3-22.

Table 5.3-22. Incremental Lifetime Cancer Risk from Arsenic Ingestion and Contact under Existing Conditions

Pathway	Adult Land User		Off-duty Worker	
	ELDE for Inorganic Arsenic (mg/kg BW/day)	ILCR for Inorganic Arsenic	ELDE for Inorganic Arsenic (mg/kg BW/day)	ILCR for Inorganic Arsenic
Drinking Water	3.51E-07	6.3E-07	6.06E-07	1.1E-06
Soil Ingestion	3.19E-09	5.7E-09	3.46E-09	6.2E-09
Soil Dermal Contact	1.10E-10	2.0E-10	2.39E-10	4.3E-10
Country Foods				
Caribou	5.55E-09	1.0E-08	NA	NA
Caribou Liver	1.13E-10	2.0E-10	NA	NA
Caribou Kidney	4.85E-11	8.7E-11	NA	NA
Arctic Ground Squirrel	1.51E-09	2.7E-09	NA	NA
Ptarmigan	1.68E-07	3.0E-07	NA	NA
Berries	1.08E-07	1.9E-07	NA	NA
Marine fish (Arctic Char)	2.21E-05	4.0E-05	NA	NA
Freshwater fish (Lake Trout)	5.56E-07	1.0E-06	NA	NA
Total ELDE / ILCR	2.27E-05	4.1E-05	6.09E-07	1.1E-06

Notes:
ILCR = incremental lifetime cancer risk
ELDE = estimated lifetime daily exposure
BW = body weight
NA = not applicable
Incremental lifetime cancer risks greater than 1.0 x 10^{-5} are shaded grey.

A sample calculation of the arsenic ILCR for soil ingestion for an adult land user using Equation 9 is provided below:

$$\mathrm{ILCR_{soil}} = \mathrm{ELDE} \times \mathrm{Oral\ CSF}$$

$$\mathrm{ILCR_{soil}} = 3.19 \text{ x } 10^{-9}\ \mathrm{mg/kg\ BW/day} \times 1.8\ (\mathrm{mg/kg\ BW/day})^{-1}$$

$$\mathrm{ILCR_{soil}} = 5.7 \text{ x } 10^{-9}$$

The concentration of arsenic in the country food items was adjusted to account for the amount of inorganic arsenic (Section 5.3.3.6), which was used in the calculation of ILCR for the country foods. A sample calculation of the arsenic ILCR from consumption of caribou, including the adjustment for proportion of inorganic arsenic (70% for caribou), using Equation 9 combined with Equation 10 is provided below:

$$\mathrm{ILCR}_{\mathrm{arsenic-caribou}} = \left[\frac{[\sum[\mathrm{IR}_{\mathrm{Foodi}} \times \mathrm{C}_{\mathrm{Foodi}} \times \mathrm{RAF}_{\mathrm{Orali}} \times \mathrm{DE_i}]] \times \mathrm{YE}}{\mathrm{BW} \times \mathrm{DE} \times \mathrm{LE}}\right] \times \mathrm{CSF}$$

$$\mathrm{ILCR}_{\mathrm{arsenic-caribou}} = \frac{\left(\left[0.223\,\frac{\mathrm{kg}}{\mathrm{day}} \times \left(0.0000155\,\frac{\mathrm{mg}}{\mathrm{kg}} \times 70\%\right) \times 1 \times 365\ \mathrm{days}\right] \times 14\ \mathrm{years}\right)}{76.5\ \mathrm{kg\ BW} \times 365\ \mathrm{days} \times 80\ \mathrm{years}} \times 1.80\ (\mathrm{mg/kg\ BW/day})^{-1}$$

$$\mathrm{ILCR}_{\mathrm{arsenic-caribou}} = 1.0 \times 10^{-8}$$

Table 5.3-22 provides the arsenic ILCR for each ingestion (drinking water, soil ingestion, country food items) and soil contact pathway and the summed arsenic ILCR for all exposure pathways for land users and off-duty workers.

The arsenic ILCR for an adult land user (4.1 x 10^{-5}) for all exposure pathways summed is larger than the threshold of 1.0 x 10^{-5}; thus, there is an elevated cancer risk from arsenic ingestion under existing conditions for adult land users. This is due primarily to the elevated ILCR from the consumption of Arctic Char (4.0x 10^{-5}).

The ILCR for an adult off-duty worker (1.1 x 10^{-6}) for all exposure pathways summed is below the threshold of 1.0 x 10^{-5}; thus, there is no elevated cancer risk from arsenic ingestion under existing conditions for off-duty workers.

5.3.6 Uncertainty Analysis

5.3.6.1 Introduction

The process of evaluating human health risks from exposure to environmental media involves multiple steps, each containing inherent uncertainties that ultimately affect the final risk estimates. These uncertainties exist in numerous areas, including the collection of samples, laboratory analysis, estimation of potential exposures, and derivation of TRVs, resulting in either an over- or under-estimation of risk. However, for the present assessment, where uncertainties existed, a conservative approach was taken to overestimate rather than underestimate potential risks.

Some of the uncertainties have been mentioned in the preceding report sections. The following uncertainty analysis is a qualitative discussion of the key sources of uncertainty in this study. There may be sources of uncertainty other than those evaluated here; however, their effect on the calculation of ERs and ILCRs, are considered to be less significant.

5.3.6.2 Contaminants of Potential Concern

The COPCs selected for this assessment were metals, since the proposed Project involves development of a metal mine. Metals naturally occur in environmental media (i.e., soil, sediment, water, and plant and animal tissue) and have been monitored during baseline studies to support Project planning and processes. By screening maximum measured baseline metal concentrations in the different media against environmental quality guidelines, it is likely that all relevant metal COPCs have been selected for inclusion in the existing conditions HHRA.

However, there exists a possibility that other COPCs (e.g., other metals, organic chemicals, etc.) could be associated with Project activities in the future, but do not occur or were not measured under existing conditions.

5.3.6.3 Tissue Concentrations

Terrestrial Species

Concentrations of COPCs in the tissue of caribou, Arctic ground squirrel, and willow ptarmigan were estimated with a food chain model. As with all modeled data, the results are highly dependent on the accuracy of input parameters and the quality of the model itself. Standard methodologies for application of models have been used and described throughout this report and in Appendix V6-5E.

The main uncertainty in the food chain model was in the selection of BTFs. For all animal exposure routes, BTFs from food-to-tissue were used. However, it is unlikely that the BTFs from soil-to-tissue and water-to-tissue are the same as food-to-tissue. In addition, the caribou and Arctic ground squirrel BTFs were based on values for beef, as BTFs are not available specifically for caribou or Arctic ground squirrel. Similarly, values for willow ptarmigan were based on available avian species information (chickens). This is the accepted method to model the uptake of COPCs into animals when empirical data are not available and uses the best available data to enable the assessment.

The caribou, Arctic ground squirrel, and willow ptarmigan ingestion rates used for food, soil, and water were based on guidance for estimating wildlife exposure characteristics provided by the Oakridge National Laboratory (Sample et al. 1997), the US EPA (1993), the Central Science Laboratory (CSL 2002), and other literature sources (see Appendix V6-5E). Wherever possible, conservative assumptions have been made to ensure that potential risks are not underestimated. For example, most soil ingestion by caribou occurs incidentally from foraging for vegetation on the ground. Caribou and other ungulates occasionally intentionally consume soils directly to obtain minerals and salts to supplement their nutrient-poor vegetative diet, but this amount is small relative to the amount of soils consumed with vegetation. The food chain model assumed that caribou would consume soil at the combined intentional and incidental ingestion rate (i.e., soil ingestion rate was assumed to be 20% of the food ingestion rate; MacDonald and Gunn 2004). The same approach was used for willow ptarmigan ingesting soil because they may consume small rocky material to aid in physically breaking down food in their gizzards. Overall, it is anticipated that the soil and plant ingestion rates by caribou, Arctic ground squirrel, and willow ptarmigan have been overestimated, which would result in conservatism in the risk estimates.

The migratory nature of caribou introduces another level of uncertainty. Contaminants of potential concern in the tissue of country food species were modeled; however, any measured increase in tissue concentrations would not necessarily be indicative of a Project effect. Caribou have ranges covering thousands of square kilometers, where they consume food and water outside the human health RSA. Therefore, increased COPC loads could result from effects unrelated to the Project. Regardless, caribou were included due to their importance in the Inuit diet. Therefore, any increased COPC concentrations would provide information to local people in order to reduce their consumption of this food source. This would serve as a public health service rather than a Project monitoring tool. Use of localized plant (lichen and berries), animal (Arctic ground squirrel), and fish species (Arctic Char and Lake Trout) provide better monitoring tools for potential ecological (and human health) effects from the Project.

The datasets available for Lake Trout (n = 38), Arctic Char (n = 17), lichen (n = 78), and berries (n = 59) are considered large enough to provide a good indication of the COPC concentrations in these tissues in the Project area.

Other uncertainties associated with the predicted animal tissue concentrations include the assumption that the diet of caribou, Arctic ground squirrel, and willow ptarmigan include solely the vegetation species (i.e., berries and lichen) that were collected in the field during baseline studies. Although selected for their prevalence, the lichens and berries may not be representative of the actual foods consumed by the evaluated terrestrial mammals and birds. For instance, ptarmigan feed on a wide variety of vegetation species. Arctic ground squirrels eat a wide variety of plants including seeds, berries, willow leaves, mushrooms, grasses, and flowers. Therefore, some uncertainty exists in applying the same model to animals with different feeding habits. However, the conservative nature of the food chain model is expected to compensate for these uncertainties and ensure that concentrations are being overestimated (Golder Associates Ltd. 2005).

Aquatic Species

Lake Trout were collected from creeks, rivers, and lakes within the human health LSA in 2009 and 2010 and were analyzed for tissue metal residues. Arctic Char were collected from Roberts Bay in 2017 and were analyzed for tissue metal residues. The dataset for the two fish species is considered sufficient and the use of conservative statistics (95^{th} percentile of fish tissue COPC concentrations) ensures that the overall assessment is considered to be conservative.

Many tissue concentrations were below the MDL in the food fish and values of half the MDL were used to calculate 95^{th} percentile concentrations of COPCs in tissue. This may over- or under-estimate the actual concentrations of COPCs in the tissues (depending on what the actual concentration is compared to the MDL) and result in uncertainties in the statistical summaries used as inputs for the modeling of tissue concentrations, ELDEs, and ILCR. However, the use of a 95^{th} percentile (which is a non-parametric statistic) will be influenced less by samples with concentrations below the MDL since the statistic is an estimate based on ranking of samples, not actual concentrations. Therefore, it is likely that the use of a 95^{th} percentile concentration adequately overestimates the concentrations across the LSA.

Vegetation Species

Within the human health RSA a total of 100 soil samples were collected for analysis of metal concentrations in 2010 and 2014. A total of 137 vegetation samples were collected within the human health RSA for analysis of tissue metal concentrations in 2010, 2011, and 2014. There can be a high degree of variation in metal concentrations between the plant species, likely due to species-specific physiological characteristics. While it is important to collect different plant species and not rely on surrogates, sometimes sampling programs are limited by the species available at the time of sampling. It is likely that, given the high number of samples collected and the use of a conservative statistic (95^{th} percentile), the concentrations are reasonably representative or overestimate the concentrations in vegetation across the LSA.

Overall, plants are unlikely to be harvested for direct consumption in substantial quantities from within the human health LSA by people because it is an unpopulated area. The contribution of vegetation, especially berries, on total consumed metals by people is likely to be insignificant compared to animal consumption due to the lower rates of berry consumption.

Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) procedures were followed during the sampling of the soil, surface water, marine water, vegetation, and fish for metal analysis. All persons collecting the water, soil, and tissue samples were trained on appropriate sampling techniques. This minimized the potential for cross contamination and ensured that the sample sizes were adequate for chemical analyses. Additional details on the QA/QC of the environmental media sampling are presented in the respective soil, vegetation, surface water quality, marine water quality, and fish baseline reports.

All chemistry samples were analyzed by ALS Environmental in Burnaby, BC. ALS is certified by the Canadian Association of Environmental Analytical Laboratories. Chain of custody forms were completed and transported with all water, soil, and tissue samples that were sent to ALS.

5.3.6.4 Locations of Country Foods Harvested

For all of the country foods evaluated, it was assumed that 100% of the country foods consumed by people each year came from the human health LSA. This is an overestimate, given the vast area available for harvesting and the distance from the communities to the Project area. This overestimation provides conservatism in the risk predictions.

5.3.6.5 Country Foods Consumption Quantity and Frequency

The consumption amount and frequency data used in this assessment were based on values provided by Nancarrow (2007), Egeland (2010), and Coad (1994). The frequency of consumption was amortized over an entire year and includes all types of country foods consumed in the different categories (e.g., large terrestrial mammals includes the consumption rate of caribou and polar bear, and birds includes the consumption rate of ptarmigan, swan, and king eider). Therefore the consumption rates are likely overestimates, rather than underestimates.

5.3.6.6 Toxicity Reference Values

There is uncertainty associated with estimating TRVs by extrapolating potential effects on humans from animal studies in the laboratory. For HHRAs, it is a standard practice to assume that people are more sensitive to the toxic effects of a substance than laboratory animals. Therefore, the toxicity benchmarks for human health are set at much lower levels than the animal benchmarks (typically 100 to 1,000 times lower due to the application of safety factors). This large margin ensures that doses less than the TRV are safe and that minor exceedances of these benchmarks are unlikely to cause adverse health effects.

Toxicity reference values are derived for individual contaminants. However, it is recognized that multiple chemicals may be present within a food item and interactions between compounds may result in additivity (overall effect is the sum of the individual effects), antagonism (overall effect less than the sum of the individual effects), synergism (overall effect is greater than the sum of the individual effects), or potentiation (presence of one chemical results in toxicity of another chemical that otherwise would have been safe). Many of these interactions are poorly understood or remain unknown by modern science. Furthermore, in natural systems numerous physical variables (e.g., media temperature, pH, salinity, hardness, etc.) can accelerate or impede these chemical interactions. Because of these environmental variables, as well as poorly understood interactions among different compounds, assessments were only conducted for the individuals COPC levels and not for overall health effects. However, given the conservatism in each individual TRV, consideration of mixtures is not likely to change the outcome or conclusions of the HHRA.

Cancer slope factors were used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of arsenic from ingestion and to a particular level of arsenic, cadmium, chromium, and nickel from inhalation. Upper-bound estimates conservatively exaggerate the risk to ensure that the risk is not underestimated if the underlying model is incorrect.

The arsenic ingestion slope factor is based on one affected population in Taiwan concerning non-fatal skin cancer incidence, age, and level of exposure to arsenic via drinking water (not food; US EPA 2017c). The confidence in the oral slope factor is considered to be low overall. Animal studies have not associated arsenic exposure via ingestion with cancer, the mechanism of action in causing human cancers is not known, and studies on arsenic mutagenicity are inconclusive (US EPA 2017c).

However, the cancer inhalation unit risks for arsenic, chromium, and nickel are based on human epidemiological studies on occupationally exposed cohorts with lung cancer endpoints (Health Canada 2010c), thus the confidence in the cancer unit risk is high. The cancer inhalation unit risk for cadmium is based on studies in rats with lung cancer as the endpoint and cadmium has been classified as probably carcinogenic to humans (Health Canada 2010c), thus the confidence in the cancer unit risk is medium. However, safety factors included in the cadmium cancer unit risk for humans provides a conservative estimate of risk.

5.3.7 Conclusions

This existing conditions HHRA integrated the results of the environmental media baseline studies, human receptor characteristics, traditional knowledge, and regulatory-recommended TRVs. This assessment evaluated potential human health risks associated with the summed exposure to COPCs from several exposure pathways (i.e., inhalation, ingestion of soil, dermal contact with soil, ingestion of drinking water, and ingestion of country foods).

For toddlers, HQs were greater than 0.2 for arsenic, chromium, methylmercury, nickel, selenium, and thallium (Table 5.3-19). For adult land users, HQs were greater than 0.2 for arsenic, chromium, and methylmercury (Table 5.3-20). For off-duty workers, all HQs were below 0.2 (Table 5.3-20). This suggests that there could be risk to the health of toddler and adult land users due to non-carcinogens; however, it is highly probable that risk is overestimated.

For carcinogenic COPCs via the inhalation route (arsenic, cadmium, chromium, and nickel), no risk to human health for land users or off-duty workers under existing conditions was noted (Section 5.3.5.3). For arsenic, which is considered carcinogenic through ingestion, there were no potential risks identified for off-duty workers as the ILCR (1.10×10^{-6}) was below the threshold of 1.0×10^{-5}. However, potential risks to the health of adult land users were identified because the ILCR was elevated (4.09×10^{-5}), due to the consumption of Arctic Char.

There are uncertainties in this assessment, as described in Section 5.3.6 and throughout Section 5.3.3. This assessment is considered to be conservative since it assumes that all of the inhaled air, ingested drinking water, and incidentally ingested soil were from within the LSA for three months of the year for land users and six months of the year for off-duty workers. It was also assumed that all of the country foods consumed by an individual land user were from within the boundaries of the human health LSA for the entire year. There are currently no known permanent, full-time residents within the human health LSA. Furthermore, the 95th percentile metal concentrations in environmental media were used in the exposure calculations as were summed ingestion rates of country food items. Therefore, the existing conditions HHRA is likely to substantially overestimate risk to people (including Inuit) who may periodically or transiently use the human health LSA for various purposes (e.g., hunting, gathering, fishing, etc.) and for off-duty workers on the Project site.

The risk from existing conditions is due to naturally-occurring or existing conditions within the human health LSA since the Project has not been developed or approved for development at this time. It is noted that there has been development of other projects in the area (e.g., Doris), so the existing conditions may not be fully representative of naturally-occurring conditions. Nevertheless, this existing conditions HHRA provides the foundation for assessing the potential for Project-related effects on human health. The data used in the existing conditions HHRA has also been used in the models for predicting environmental quality during the Project (so that all predictions include existing conditions plus Project), which enables direct comparison of existing conditions and predicted environmental quality to determine incremental changes due to the Project.

5.4 MADRID-BOSTON PROJECT-RELATED HUMAN HEALTH RISK ASSESSMENT

Many of the features of the Project-related HHRA are the same as the existing conditions HHRA (Section 5.3), thus much of the text applies to both assessments and will not be repeated here and instead the existing conditions HHRA is referred to. Features that are the same in both HHRAs include: the approach that contains the six stages of toxicological risk assessment (Section 5.2; Health Canada 2010b); the human health LSA and RSA boundaries (Section 5.2.1); the definition of health (Section 5.3.1); the human exposure pathways (Section 5.3.2.2); the country food species considered (Section 5.3.2.1); the human receptor characteristics (Section 5.3.2.1); and the toxicity reference values (Section 5.3.4.2). The methodology for the Project-related HHRA is the same as for the existing conditions HHRA (see Section 5.2); however, predictive modeling is used to determine Project-related noise levels and COPC concentrations in environmental media.

5.4.1 Problem Formulation

As stated in Section 5.3.2, the purpose of the problem formulation stage of a HHRA is to create a conceptual model for the HHRA and identify data requirements to accurately assess the potential for human health effects due to exposure to Project-related emissions. The purposes of the problem formulation stage are the same as those listed in Section 5.3.2; however, the assessment will establish whether there is a reasonable possibility that there is a linkage between a Project-related source of contaminants and human receptors.

5.4.1.1 Human Receptors and Receptor Characteristics

The same human receptors, human receptor characteristics, and exposure pathways that were used in the existing conditions HHRA (Sections 5.3.2.1 and 5.3.2.2) will be used in the Project-related HHRA.

On-duty worker health and safety was not considered because TMAC must adhere to occupational health and safety requirements to ensure provision of a safe working environment. Thus, mine workers are only assessed in this DEIS while off-duty at the workers camps.

For off-duty workers, it was assumed they could be present for half the year (26 weeks) due to a two week on and two week off shift rotation. This assumption is also conservative as it does not account for any additional time off a worker could take due to vacation, illness, or other factors. The off-duty worker was assumed to be at the Project site throughout the duration of the Project for a total of 14 years (4 years Construction and 10 years Operational phase). The off-duty worker is not expected to hunt and consume country foods.

5.4.1.2 Human Exposure Pathways

Since human health can be affected by changes in air quality, drinking water quality, soil quality, or country foods quality, potential Project-related sources of contaminants were identified that could lead to changes in these pathways. There are two main potential sources of Project-related contaminants: atmospheric emissions and liquid effluent.

Atmospheric emissions (e.g., CAC emissions, dust) have the potential to enter the atmosphere, travel some distance, and be inhaled by receptors (for CACs and PM_{10}-bound metals) or settle where they can reside in different media such as soil, vegetation, and country foods (for dust). Liquid effluent has the potential to enter the marine and freshwater environments (water and sediment) through runoff from the terrestrial environment.

Air quality can be affected by the generation of atmospheric emissions from Project components or activities. Drinking water could be affected by Project components or activities that affect freshwater. Soil and country foods quality could be affected by Project-related sources of contaminants released to the atmospheric, freshwater, marine, or terrestrial environments. The exposure pathways are described in more detail in the following sections.

Air

Off-duty workers and land users could be exposed to air contaminants released into the atmosphere by the Project via inhalation. A detailed inventory of Project-related emission sources, points of release and quantities of air contaminants released is provided in the *Madrid-Boston Project: Air Quality Modeling Study* (Volume 4, Appendix V4-2I; Nunami Stantec 2017b).

The Project components and activities that involve the combustion of a fuel source will result in air pollution emissions. This applies to a wide range of mobile and stationary equipment, such as: aircraft, blasting, generators and power plants, incinerators, mine air heating facilities, non-electric mobile surface and underground equipment, shipping vessels, and smelting. The primary air pollution emissions from these components and activities include SO_2, nitrogen oxides (NO_x), CO, and particulates that will cause ambient air quality to decrease.

Any Project components and activities that involve the disturbance of ground material (e.g., rock, dirt, soil, silt, etc.) or the exposure of ground material (e.g., stockpiles, TIA and TMA) have the potential to release fugitive dust emissions. This applies to a wide range of components and activities, such as: blasting, earthworks, general infrastructure construction, ground material handling and transfers, mobile equipment and vehicles travelling on unpaved roads and surfaces, rock crushing, unpaved road and pad maintenance, and use of quarries, stockpiles, the TIA and TMA. The primary pollution emissions from these components and activities include TSP and PM sub-fractions (e.g., PM_{10} and $PM_{2.5}$) that will cause ambient air quality to decrease. Fugitive dust (including TSP and PM) may be associated with COPCs such as metals.

The air quality model considered all of the Project-related sources of air pollutants.

Soil

Fugitive dust will arise from several Project activities such as rock blasting, vehicle movement, and handling of fine materials. Generally dust will occur sporadically and be suspended for a relatively short time prior to deposition. Dust particles can be a carrier of metals naturally occurring in rocks and can deposit onto soils. Off-duty workers and land users could be exposed to the COPCs in soil via incidental soil ingestion and dermal contact.

Water

Discharge of effluent from water management structures during the Operational phase could introduce contaminants to the freshwater environment. Off-duty workers and land users could be exposed to the COPCs in water via drinking water ingestion.

The potential effects to freshwater quality from the Project sources of effluent are described in Volume 5, Sections 4.5.2 and 4.5.4. The surface water quality model considered all of the Project-related sources of effluent to the freshwater environment. The potential effects to freshwater sediment quality from the Project sources of effluent are described in Volume 5, Sections 5.5.2 and 5.5.4.

Country Foods Quality

Fugitive dust will arise from several Project activities such as rock blasting, vehicle movement, and handling of fine materials. Generally dust will occur sporadically and be suspended for a relatively short time prior to deposition. Dust particles can be a carrier of metals naturally occurring in rocks and can deposit onto vegetation. The COPCs could then be taken up by terrestrial wildlife and could accumulate in country foods.

Discharge of effluent from water management structures during the Operational phase could introduce contaminants to the terrestrial environment where soil and vegetation could take up COPCs. The COPCs could then be taken up by terrestrial wildlife and country foods.

5.4.1.3 Selection of Project-related Contaminants of Potential Concern

A description and inventory of the types of materials and chemicals likely to be present at the Project is provided in the Project Description (see Table 4.4-11 in Volume 3, Section 4.4.11). Potential sources of Project-related COPCs could be from fuel, mining and milling process chemicals, explosives, inert chemical fire suppression systems, dust suppressant chemicals, and other chemicals that may be used around the Project site. However, these chemicals and materials are likely to reach the terrestrial or freshwater environments only in the event of unusual circumstances such as spills or malfunctions. Mitigation and management plans (e.g., Environmental Protection Plan, Risk Management and Emergency Response, Fuel Management, Spill Contingency, Tailings Management, Waste Management, and Hazardous Materials Management) are provided (see Volume 8, Chapter 1) to ensure the safe handling and storage of these materials to prevent their release to the environment where exposures to off-duty workers or land users could occur. Therefore, the contaminants that may come from these potential sources were not considered further in this assessment.

Consistent with the existing conditions HHRA (Section 5.3), the focus of this assessment is the metals and non-metals (e.g., CACs, ions, nutrients) that could be present in Project atmospheric emissions or discharges.

To select COPCs for evaluation in the Project-related HHRA, the same screening methodology described in Section 5.3.2.3 was used.

Contaminants of Potential Concern in Air

To assess effects to human health from changes in air quality due to Project-related emissions, future Project-related air quality was modeled for the Construction and Operational phases. The methodology and assumptions used in the air quality dispersion model and the results are described in Volume 4, Section 2.6.1 and Nunami Stantec (2017b). There are several hunting and fishing areas, camps, cabins, worker camps, and research camps located within the human health LSA (see Figure 5.3-1); which encompasses the air quality model domain. Thus predicted air quality is provided for these 17 human receptor locations that fall within the human health LSA.

Predicted air concentrations of COPCs due to Project emissions were modeled with the US EPA-approved version of CALPUFF (version 7.2.1 level 150618) and its related processors. CALPUFF is a multi-layer, multi-species non-steady-state puff dispersion model that is capable of simulating the effects of time- and space-varying meteorological conditions on contaminant transport, transformation, and removal. In order to perform dispersion modeling using CALPUFF, meteorological data was processed by CALMET, to provide meteorological input data in the modeling.

Two air quality LSAs were selected for the Project (Figure 2.5-2 of Volume 4, Chapter 2). The northern LSA includes the area around Roberts Bay, Doris, Madrid North, Madrid South and approximately 20 km of the AWR extending out to potential quarry M. This northern LSA is a square area extending 30 km north to south, by 30 km east to west, and is centred approximately half way between Doris and Madrid North. The southern LSA includes the area around Boston and approximately 20 km of the AWR extending from Boston to potential quarry T. This southern LSA is a square area extending 30 km north to south, by 30 km east to west, and is centred approximately on the proposed Boston mill.

The two air quality LSAs include the "zone of influence" beyond which the potential residual effects of the Project are expected to diminish to a negligible state.

The air quality model was run using the worst-case scenario, which was determined to occur for the Construction phase during the Project Year 1 (calendar year 2019) for the Northern Domain and Year 4 (calendar year 2022) for the Southern Domain. The worst-case year of the Operational phase was during the Project Year 12 (calendar year 2030) for both the Northern Domain, and year 10 (2028) for the Southern domain (Nunami Stantec 2017b). The air quality model results used in the HHRA were for the cumulative Construction phase (i.e., emissions from permitted activities plus Project construction activities) and cumulative Operational phase (i.e., emissions from permitted activities plus Project operation activities).

As described in the air quality modeling study (Nunami Stantec 2017b), cumulative air quality in the Northern Domain was modeled as two discrete scenarios. The first scenario adopts the reference location for the Madrid North facility, and the second scenario adopts an alternate location for the Madrid North facility 400 meters north of the reference location. For conservatism, the highest modeled concentrations of criteria air contaminants and dustfall across both scenarios were used in the HHRA. This approach considered maximum parameter values for each individual human receptor in the Northern Domain.

In addition to human receptors, air quality at soil and vegetation receptor locations (Figure 7.2-3 in Volume 4, Chapter 7 and Figure 8.2-6 in Volume 4, Chapter 8) was also considered as part of the HHRA. The influence of predicted air quality (e.g., levels of fugitive dust) on the concentration of metals at soil and vegetation receptors is incorporated into the food chain model to assess potential risk to human health from the ingestion of country foods. However, some soil and vegetation receptors in the human health LSA are located outside of both the Northern and Southern air quality domains. Because the Northern and Southern Domain modeling scenarios provided air quality predictions for all soil and vegetation receptors within the human health LSA (regardless of receptor location in relation to a domain), soil and vegetation receptors not located in either domain were assigned the highest modeled levels of dustfall from the Northern and Southern Domain scenarios.

Criteria Air Contaminants

Concentrations of CACs were modeled within the human health LSA and at the specific human health receptor locations during the Construction and Operational phases and compared to relevant guidelines (Table 5.4-1). The air quality model provided predictions for SO_2 (1-hour, 24-hour, and annual averaging period concentrations), NO_2 (1-hour, 24-hour, and annual averaging period concentrations), CO (1-hour and 8-hour averaging period concentrations), PM_{10} (24-hour averaging period concentration), and $PM_{2.5}$ (24-hour and annual averaging period concentrations).

Table 5.4-1. Predicted Concentrations of Criteria Air Contaminants at the Human Receptor Locations during Construction and Operational Phases

						Construction Phase																
		Ambient Air Quality Criteria ($\mu g/m^3$)				Off-duty Workers at:				Land Users at:												
Criteria Air Contaminant	Averaging Period	Canada [a, b]	Nunavut [c]	BC [d]	Mean of 2009-2014 Baseline Air Quality Monitoring Data [e]	Doris Camp	Boston Exploration Camp	Boston Operational Camp	Quarry D Camp	Cabin CB1	Cabin CB2	Outpost Camp C1	Seasonal Camp C2	Fishing Area F1	Fishing Area F2	Fishing Area F3	Hunting and Fishing Area H1	Hunting and Fishing Area H2	Hunting and Fishing Area H3	Hunting and Fishing Area H4	Travel Route T1	Queen Maude Gulf Migratory Bird Sanctuary E3
SO_2	1-hour	-	*450*	183 [f]	0.4	0.365	0.300	0.880	1.02	0.300	0.300	0.300	0.300	0.300	0.302	0.300	0.365	1.02	0.300	0.300	0.300	0.300
	24-hour	-	*150*	-	0.4	2.01	1.26	5.35	4.09	0.317	0.318	0.506	0.365	0.316	0.519	0.504	2.01	5.02	1.11	0.835	0.825	0.795
	Annual	-	*30*	13 [g]	0.4	0.583	0.382	1.57	1.31	0.301	0.301	0.321	0.304	0.301	0.324	0.324	0.583	1.46	0.363	0.362	0.358	0.353
NO_2	1-hour	-	*400*	188 [h]	1.9	338	220	464	668	26.9	27.1	175	140	28.6	174	174	338	684	187	179	179	176
	24-hour	-	*200*	-	1.9	194	163	337	237	6.11	5.93	69.0	18.9	7.15	69.3	69.7	194	268	129	113	105	105
	Annual	-	*60*	60	1.9	83.1	25.2	181	166	1.42	1.42	8.21	2.48	1.45	9.34	9.38	83.2	170	17.0	15.1	14.3	14.1
CO	1-hour	-	-	*14,300*	1,250	1680	792	1734	2830	274	275	415	307	277	465	465	1681	2985	558	613	626	605
	8-hour	-	-	*5,500*	143	1304	597	1322	1508	266	266	356	281	267	376	374	1305	1706	444	473	472	469
PM_{10}	24-hour	-	-	*50*	6.3	84.9	73.1	271	130	5.91	5.90	12.2	7.67	6.04	29.6	14.1	84.9	163	43.0	24.9	24.7	25.1
$PM_{2.5}$	24-hour	28 and 27 (effective in 2020)	*30*	25 [i]	3	38.4	22.0	132	72.3	3.28	3.28	5.80	3.82	3.29	8.28	6.57	38.4	75.0	11.4	9.21	9.63	9.00
	Annual	*10 and 8.8 (effective in 2020)*	-	8 [j]	3	12.6	6.23	42.8	31.4	3.13	3.13	3.68	3.21	3.13	4.00	3.79	12.6	33.8	4.66	4.41	4.33	4.27

Notes:

Each predicted concentration is in units of $\mu g/m^3$ and is the maximum value of two different air quality model cases: the "Madrid North Reference Location" case, and the "Madrid North Alternate location" case (where a worker camp is moved 400 m North).

SO_2 = sulphur dioxide; NO_2 = nitrogen dioxide ; CO = carbon monoxide; $PM_{2.5}$ = particulate matter ≤2.5 µm in diameter; PM_{10} = particulate matter ≤10 µm in diameter.

(-) = not available or applicable.

Modeled NO_2 concentrations are based on the ozone limiting method (OLM).

Grey shading indicates exceedance of the air quality guidelines.

Bold and italicized values indicate the air quality criteria used in the assessment.

[a] CCME (2017); [b] CCME (2017); [c] Government of Nunavut (2011); [d] BC MOE (2017).

[e] Mean value of all stations and measurements.

[f] Based on annual 99th percentile of daily 1-hour maximum, averaged over three consecutive years.

[g] Based on annual average of 1-hour concentrations over one year.

[h] Based on annual 98th percentile of daily 1-hour maximum, over one year.

[i] Based on annual 98th percentile of daily average over one year.

[j] Based on annual average over one year.

Table 5.4-1. Predicted Concentrations of Criteria Air Contaminants at the Human Receptor Locations during Construction and Operational Phases

		Ambient Air Quality Criteria (µg/m³)				Operational Phase																
						Off-duty Workers at:				Land Users at:												
Criteria Air Contaminant	Averaging Period	Canada [a, b]	Nunavut [c]	BC [d]	Mean of 2009-2014 Baseline Air Quality Monitoring Data [e]	Doris Camp	Boston Exploration Camp	Boston Operational Camp	Quarry D Camp	Cabin CB1	Cabin CB2	Outpost Camp C1	Seasonal Camp C2	Fishing Area F1	Fishing Area F2	Fishing Area F3	Hunting and Fishing Area H1	Hunting and Fishing Area H2	Hunting and Fishing Area H3	Hunting and Fishing Area H4	Travel Route T1	Queen Maude Gulf Migratory Bird Sanctuary E3
SO_2	1-hour	-	***450***	183 [f]	0.4	0.300	0.300	1.10	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.356	0.300	0.300	0.300	0.300	0.300
	24-hour	-	***150***	-	0.4	0.638	12.5	7.11	2.36	0.314	0.315	0.470	0.359	0.314	0.804	0.328	1.71	3.85	1.13	0.900	0.885	0.916
	Annual	-	***30***	13 [g]	0.4	0.346	1.63	2.08	0.321	0.301	0.301	0.314	0.303	0.301	0.343	0.303	0.423	0.744	0.357	0.376	0.375	0.373
NO_2	1-hour	-	***400***	188 [h]	1.9	253	397	553	249	22.2	22.3	170	123	23.3	170	160	254	342	172	177	177	175
	24-hour	-	***200***	-	1.9	174	228	396	176	4.79	4.66	39.5	14.7	5.58	83.7	48.1	175	223	132	105	99.0	107
	Annual	-	***60***	60	1.9	65.4	46.1	201	37.6	1.38	1.39	5.49	2.10	1.41	8.91	5.46	66.5	56.4	15.7	14.7	14.4	14.0
CO	1-hour	-	-	***14,300***	1,250	576	4091	2431	803	272	271	370	295	274	581	284	838	1649	513	624	632	593
	8-hour	-	-	***5,500***	143	401	2897	1600	498	265	265	332	276	265	421	273	663	992	429	478	476	454
PM_{10}	24-hour	-	-	***50***	6.3	59.5	171	299	84.9	5.77	5.75	9.60	7.29	5.86	26.5	6.62	64.9	133	47.5	26.1	25.4	26.4
$PM_{2.5}$	24-hour	28 and 27 (effective in 2020)	***30***	25 [i]	3	19.7	69.2	161	26.9	3.24	3.25	4.87	3.66	3.27	8.82	3.50	22.9	42.4	10.6	9.94	10.4	10.2
	Annual	***10 and 8.8 (effective in 2020)***	-	8 [j]	3	6.48	15.0	53.6	5.57	3.12	3.12	3.47	3.18	3.12	3.96	3.17	9.59	12.0	4.60	4.50	4.48	4.41

Notes:

Each predicted concentration is in units of µg/m³ and is the maximum value of two different air quality model cases: the "Madrid North Reference Location" case, and the "Madrid North Alternate location" case (where a worker camp is moved 400 m North).

SO_2 = sulphur dioxide; NO_2 = nitrogen dioxide ; CO = carbon monoxide; $PM_{2.5}$ = particulate matter ≤2.5 µm in diameter; PM_{10} = particulate matter ≤10 µm in diameter.

(-) = not available or applicable

Modeled NO_2 concentrations are based on the ozone limiting method (OLM).

Grey shading indicates exceedance of the air quality guidelines.

Bold and italicized values indicate the air quality criteria used in the assessment.

[a] *CCME (2017);* [b] *CCME (2017);* [c] *Government of Nunavut (2011);* [d] *BC MOE (2017).*

[e] *Mean value of all stations and measurements.*

[f] *Based on annual 99th percentile of daily 1-hour maximum, averaged over three consecutive years.*

[g] *Based on annual average of 1-hour concentrations over one year.*

[h] *Based on annual 98th percentile of daily 1-hour maximum, over one year.*

[i] *Based on annual 98th percentile of daily average over one year.*

[j] *Based on annual average over one year.*

The model predictions were compared to the Nunavut Air Quality Standards (Government of Nunavut 2011), the federal CAAQSs (CCME 2017b, 2017c), and the BC MOE (2017) AQOs. All presented results include baseline concentrations. Preference was given to the Nunavut Air Quality Standards, where available, and the federal standards or BC MOE objectives were only used in the absence of Nunavut-specific Standards.

If predicted CAC concentrations were lower than the applicable guidelines at a particular receptor location, no risk to human receptors at that location would be expected. If the concentration of a predicted CAC was greater than the guideline limit and greater than background conditions, it would be considered a COPC for human health due to air quality at that particular receptor location.

On-duty worker health and safety was not considered because TMAC must adhere to occupational health and safety requirements to ensure provision of a safe working environment. Thus, mine workers are only assessed in this EIS while off-duty at the workers camps, consistent with Health Canada (2010f) guidance.

As shown in Table 5.4-1, there were exceedances of the Nunavut Air Quality Standards (Government of Nunavut 2011), and the applicable federal CAAQSs (CCME 2017b, 2017c), and BC MOE (2017) AQOs. Predicted concentrations were also higher than background concentrations. Exceedances of the air quality standards or objectives during the Construction phase included:

- 1-hour NO_2 concentrations at the Boston Operational camp, Quarry D camp, and Hunting and Fishing Area H2;
- 24-hour NO_2 concentrations at the Boston Operational camp, Quarry D camp, and Hunting and Fishing Area H2;
- annual NO_2 concentrations at the Doris camp, Boston Operational camp, Quarry D camp, Hunting and Fishing Area H1, and Hunting and Fishing Area H2;
- 24-hour PM_{10} at the Doris camp, Boston Exploration camp, Boston Operational camp, the Quarry D camp, Hunting and Fishing Area H1, and Hunting and Fishing Area H2;
- 24-hour $PM_{2.5}$ at the Doris camp, Boston Operational camp, the Quarry D camp, Hunting and Fishing Area H1, and Hunting and Fishing Area H2; and
- annual $PM_{2.5}$ at the Doris camp, Boston Operational camp, the Quarry D camp, Hunting and Fishing Area H1, and Hunting and Fishing Area H2.

Exceedances of the air quality standards or objectives during the Operational phase included:

- 1-hour NO_2 concentrations at the Boston Operational camp;
- 24-hour NO_2 concentrations at the Boston Exploration camp, the Boston Operational camp, and Hunting and Fishing Area H2;
- annual NO_2 concentrations at the Doris camp, the Boston Operational camp, and Hunting and Fishing Area H1;
- 24-hour PM_{10} at the Doris camp, the Boston Exploration camp, the Boston Operational camp, the Quarry D camp, Hunting and Fishing Area H1, and Hunting and Fishing Area H2;
- 24-hour $PM_{2.5}$ at the Boston Exploration camp, the Boston Operational camp, and Hunting and Fishing Area H2; and

- annual $PM_{2.5}$ at the Boston Exploration camp, the Boston Operational camp, and Hunting and Fishing Area H2.

Since CAC contaminants are not present in environmental media other than air, there is no summing of pathways required. Furthermore, HQs for CACs are calculated as the predicted air contaminant concentration divided by the ambient air quality criteria, thus EDI calculations are not required. Therefore, the HQs for the CAC exceedances are provided in Section 5.4.4.2 (Table 5.4-18).

Metal Contaminants of Potential Concern

Project-related metal concentrations bound to PM_{10} were calculated for land users exposed to dust in the LSA (outside of the PDA), and for off-duty workers at the worker camps. The main source of dust in the human health LSA is from driving on unpaved roads (which will be made from quarry rock). The metal concentrations in quarry rock samples (n = 383) were obtained from SRK (2016a; P5-6). The median metal concentrations in quarry rock samples were multiplied with the highest predicted annual PM_{10} concentration at the land user human receptor location. The highest annual PM_{10} concentration during the Construction phase (49.3 µg/m^3) and Operational phase (28.2 µg/m^3) occurred at a hunting and fishing area (depicted as H2 on Figure 5.3-1).

Dust at the Doris camp, Boston Exploration camp, Boston Operational camp, and Quarry D camp is primarily from unpaved roads. Therefore, the median metal concentration from quarry rock samples was used as the metal concentration to apply to annual PM_{10} for off-duty workers at these camps. The highest annual PM_{10} concentrations during the Construction and Operational phases at the camps were:

- Doris camp: 20.6 and 11.9 µg/m^3, respectively;
- Boston Exploration camp: 13.2 and 24.8 µg/m^3, respectively;
- Boston Operational camp: 69.6 and 81.1 µg/m^3, respectively; and
- Quarry D camp: 46.0 and 18.7 µg/m^3, respectively.

The annual PM_{10} concentrations in µg/m^3 were converted to units of kg/m^3 prior to multiplication with the metal concentrations in quarry rock samples. The resulting Project-related metal concentrations bound to PM_{10} for inhalation exposure for land users and off-duty workers are shown in Table 5.4-2.

Since there are no Canadian or Nunavut guidelines for metals in air, the annual Project-related metal concentrations bound to PM_{10} (Table 5.4-2) were compared to lowest of the criteria for annual averaging periods obtained from the Alberta Ambient Air Quality Objectives and Guidelines (Alberta Environment 2013), Ontario Ministry of the Environment Ambient Air Quality Criteria (Ontario MOE 2012), the Texas Commission on Environmental Quality Effects Screening Levels (Texas CEQ 2016), and the Washington State Acceptable Source Impact Levels (Washington State 2015).

The only Project-related metal concentrations bound to PM_{10} (Table 5.4-2) that exceeded the relevant air quality guidelines was nickel during the Construction and Operational phases at the Boston Exploration camp. Predicted concentrations of metals bound to PM_{10} during the Construction and Operational phases were below guidelines for the land user human receptor.

Thus, the only metal COPC identified in air was nickel for off-duty workers. Nickel was carried forward as COPC bound to PM10 in the Project-related HHRA.

Table 5.4-2. Predicted Metal Concentrations Bound to PM_{10} at the Human Receptor Locations during Construction and Operational Phases

	Air Quality Guidelines for Annual Averaging Period (μg/m³)				Metals due to Dust for Land Users		Metals due to Dust for Doris Camp		Metals due to Dust for Boston Exploration Camp		Metals due to Dust for Boston Operational Camp		Metals due to Dust for Quarry D Camp	
Metals	Alberta Ambient Air Quality Objectives and Guidelines [a]	Ontario MOE Ambient Air Quality Criteria [b]	Texas CEQ ESL [c]	Washington State ASIL [d]	Construction Phase Metal Concentration in Annual PM_{10} (μg/m³)	Operational Phase Metal Concentration in Annual PM_{10} (μg/m³)	Construction Phase Metal Concentration in Annual PM_{10} (μg/m³)	Operational Phase Metal Concentration in Annual PM_{10} (μg/m³)	Construction Phase Metal Concentration in Annual PM_{10} (μg/m³)	Operational Phase Metal Concentration in Annual PM_{10} (μg/m³)	Construction Phase Metal Concentration in Annual PM_{10} (μg/m³)	Operational Phase Metal Concentration in Annual PM_{10} (μg/m³)	Construction Phase Metal Concentration in Annual PM_{10} (μg/m³)	Operational Phase Metal Concentration in Annual PM_{10} (μg/m³)
Aluminum	-	-	5	-	1.43E+00	8.18E-01	5.98E-01	3.46E-01	3.84E-01	7.18E-01	2.02E+00	2.35E+00	1.33E+00	5.43E-01
Antimony	-	-	0.5	-	4.93E-06	2.82E-06	2.06E-06	1.19E-06	1.32E-06	2.48E-06	6.96E-06	8.11E-06	4.60E-06	1.87E-06
Arsenic	0.01	-	0.067	0.000303	2.46E-05	1.41E-05	1.03E-05	5.97E-06	6.61E-06	1.24E-05	3.48E-05	4.05E-05	2.30E-05	9.37E-06
Barium	-	-	0.5	-	1.48E-04	8.46E-05	6.19E-05	3.58E-05	3.97E-05	7.43E-05	2.09E-04	2.43E-04	1.38E-04	5.62E-05
Beryllium	-	-	0.002	0.000417	1.63E-05	9.31E-06	6.81E-06	3.94E-06	4.37E-06	8.18E-06	2.30E-05	2.68E-05	1.52E-05	6.18E-06
Bismuth	-	-	5	-	4.93E-06	2.82E-06	2.06E-06	1.19E-06	1.32E-06	2.48E-06	6.96E-06	8.11E-06	4.60E-06	1.87E-06
Boron	-	-	5	-	9.85E-04	5.64E-04	4.13E-04	2.39E-04	2.65E-04	4.95E-04	1.39E-03	1.62E-03	9.20E-04	3.75E-04
Cadmium	-	0.005	0.0033	0.000238	4.93E-06	2.82E-06	2.06E-06	1.19E-06	1.32E-06	2.48E-06	6.96E-06	8.11E-06	4.60E-06	1.87E-06
Calcium	-	-	-	-	1.58E+00	9.02E-01	6.60E-01	3.82E-01	4.23E-01	7.93E-01	2.23E+00	2.60E+00	1.47E+00	5.99E-01
Chromium	-	-	0.041	-	7.39E-03	4.23E-03	3.09E-03	1.79E-03	1.98E-03	3.72E-03	1.04E-02	1.22E-02	6.90E-03	2.81E-03
Cobalt	-	-	0.02	-	1.72E-03	9.87E-04	7.22E-04	4.18E-04	4.63E-04	8.67E-04	2.44E-03	2.84E-03	1.61E-03	6.56E-04
Copper	-	-	1	-	5.42E-03	3.10E-03	2.27E-03	1.31E-03	1.46E-03	2.73E-03	7.66E-03	8.92E-03	5.06E-03	2.06E-03
Iron	-	-	-	-	2.41E+00	1.38E+00	1.01E+00	5.85E-01	6.48E-01	1.21E+00	3.41E+00	3.97E+00	2.25E+00	9.18E-01
Lead	-	-	-	0.0833	2.96E-05	1.69E-05	1.24E-05	7.17E-06	7.94E-06	1.49E-05	4.18E-05	4.87E-05	2.76E-05	1.12E-05
Magnesium	-	-	-	-	1.13E+00	6.49E-01	4.74E-01	2.75E-01	3.04E-01	5.70E-01	1.60E+00	1.87E+00	1.06E+00	4.31E-01
Manganese	0.2	-	0.2	-	4.58E-02	2.62E-02	1.92E-02	1.11E-02	1.23E-02	2.30E-02	6.48E-02	7.54E-02	4.28E-02	1.74E-02
Mercury	-	-	0.025		4.93E-07	2.82E-07	2.06E-07	1.19E-07	1.32E-07	2.48E-07	6.96E-07	8.11E-07	4.60E-07	1.87E-07
Molybdenum	-	-	3	-	2.46E-05	1.41E-05	1.03E-05	5.97E-06	6.61E-06	1.24E-05	3.48E-05	4.05E-05	2.30E-05	9.37E-06
Nickel	0.05	0.02	0.059	0.0042	3.55E-03	2.03E-03	1.49E-03	8.60E-04	9.53E-04	1.78E-03	5.01E-03	5.84E-03	3.31E-03	1.35E-03
Phosphorus	-	-	-	20	1.08E-02	6.20E-03	4.54E-03	2.63E-03	2.91E-03	5.45E-03	1.53E-02	1.78E-02	1.01E-02	4.12E-03
Potassium	-	-	2	-	4.93E-03	2.82E-03	2.06E-03	1.19E-03	1.32E-03	2.48E-03	6.96E-03	8.11E-03	4.60E-03	1.87E-03
Selenium	-	-	0.2	-	2.46E-05	1.41E-05	1.03E-05	5.97E-06	6.61E-06	1.24E-05	3.48E-05	4.05E-05	2.30E-05	9.37E-06
Silver	-	-	0.01	-	4.93E-06	2.82E-06	2.06E-06	1.19E-06	1.32E-06	2.48E-06	6.96E-06	8.11E-06	4.60E-06	1.87E-06
Sodium	-	-	-	-	1.23E-02	7.05E-03	5.16E-03	2.99E-03	3.31E-03	6.19E-03	1.74E-02	2.03E-02	1.15E-02	4.68E-03
Strontium	-	-	2	-	6.90E-04	3.95E-04	2.89E-04	1.67E-04	1.85E-04	3.47E-04	9.75E-04	1.14E-03	6.44E-04	2.62E-04
Thallium	-	-	0.1	-	4.93E-06	2.82E-06	2.06E-06	1.19E-06	1.32E-06	2.48E-06	6.96E-06	8.11E-06	4.60E-06	1.87E-06
Titanium	-	-	5	-	1.08E-01	6.20E-02	4.54E-02	2.63E-02	2.91E-02	5.45E-02	1.53E-01	1.78E-01	1.01E-01	4.12E-02
Uranium	-	0.03	0.2	-	4.93E-06	2.82E-06	2.06E-06	1.19E-06	1.32E-06	2.48E-06	6.96E-06	8.11E-06	4.60E-06	1.87E-06
Vanadium	-	-	2	-	4.93E-03	2.82E-03	2.06E-03	1.19E-03	1.32E-03	2.48E-03	6.96E-03	8.11E-03	4.60E-03	1.87E-03
Zinc	-	-	2	-	2.91E-03	1.66E-03	1.22E-03	7.05E-04	7.81E-04	1.46E-03	4.11E-03	4.78E-03	2.71E-03	1.11E-03

Notes:
MOE = Ministry of the Environment
CEQ = Commission on Environmental Quality
ESL = effects screening levels
ASIL = acceptable source impact level
PM_{10} = particulate matter up to and including 10 μm in diameter
(-) = not available
[a] *Alberta Environment (2013).*
[b] *Ontario MOE (2012).*
[c] *Texas CEQ (2016).*
[d] *Washington State (2015).*
Dust in the human health LSA is primarily from unpaved roads; thus, the metal concentration from quarry rock samples (n=383) was used as the metal concentration to apply to annual PM_{10} for land users and off-duty workers.
Shaded cells indicated exceedance of an air quality guideline.
Beryllium concentrations in quarry rock samples were not analyzed; therefore, the beryllium concentration in Boston ore samples was adopted.
Mercury concentrations in quarry rock samples were not analyzed; therefore, the mercury concentration in Boston ore samples was adopted.
Tin concentrations in quarry rock samples were not analyzed; therefore, the tin concentration in Madrid North ore samples was adopted.

Contaminants of Potential Concern in Soil

The pathway through which COPCs may enter soil as a result of Project activities is from atmospheric deposition of COPCs in fugitive dust. The US EPA has published methods for use in HHRAs for calculating contaminant concentrations in soil due to atmospheric dust deposition (US EPA 2005e). Calculations of the incremental increase in soil COPC concentrations for both the Construction and Operational phases of the Project used predicted dustfall levels from the air quality dispersion model (Nunami Stantec 2017b) and metal concentrations in quarry rock samples (SRK 2016a; P5-6).

For the purpose of soil quality modeling, in addition to assumptions made in the air dispersion model (Nunami Stantec 2017b), the following assumptions were made:

- The worst-case annual amount of dustfall during the Construction phase is assumed to occur during each of the four years of the Construction phase.
- The worst-case annual amount of dustfall during the Operational phase is assumed to occur during each of the ten years of the Operational phase.
- All dust deposited onto soil is conservatively assumed to remain in place and not run-off during rain events and dust is incorporated into the top 2 cm of soil.
- The Project-related metal proportions in dust during the Construction and Operational phases are based on the metal composition of road dust (i.e., quarry rock).

The quarry rock metal concentrations (n = 383) were obtained from SRK (2016a; P5-6).

Beryllium concentrations in quarry rock samples were not analyzed; therefore, the median beryllium concentration in Boston ore samples (obtained from SRK 2016c; P5-25) was adopted. Mercury concentrations in quarry rock samples were not analyzed; therefore, the median mercury concentration in Boston ore samples (obtained from SRK 2016c; P5-25) was adopted. Tin concentrations in quarry rock samples were not analyzed; therefore, the median tin concentration in Madrid North ore samples (obtained from SRK 2016d; P5-20) was adopted.

The metal proportions for quarry rock were multiplied with the predicted annual dust deposition (in g/m^2/year) at the soil sampling sites to predict the metal concentrations in dust for the cumulative Construction (Appendix V6-5F) and Operational (Appendix V6-5G) phases of the Project. Predicted soil total metal concentrations were calculated by adding the baseline soil concentration to the incremental increase in soil metal concentration predicted using the US EPA methodology and formulas (US EPA 2005e). The incremental increase in soil metal concentrations was calculated for each metal using Equation 12, as suggested by the US EPA (2005e):

$$C_S = 100 \times \left(\frac{D}{Zs \times BD}\right) \times t_D \qquad \text{[Equation 12]}$$

where:

Cs = average soil concentration over exposure duration (mg COPC/kg soil)
100 = unit conversion factor (from $mg\text{-}m^2$ to $kg\text{-}cm^2$)
D = yearly dry deposition rate of contaminant (g $COPC/m^2$-year)
t_D = time period over which deposition occurs (years)
Z_s = soil mixing zone depth (cm)
BD = soil bulk density (g/cm^3)

The time period (t_D) over which dust deposition may occur was assumed to be the four years of the Construction phase and the 10 years of the Operational phase. Metals deposited with fugitive dust were assumed to mix with the top 2 cm of soil (Z_s), as recommended by US EPA (2005e) for untilled soils. The bulk density (BD) for soil was set at the default value of 1.5 g soil/cm^3 soil, as recommended by the US EPA (2005e). Weathering and degradation were considered to only be significant for organic contaminants and not metals (US EPA 2005e); thus, a soil loss constant was not necessary (i.e., it was assumed that none of the metals were lost to weathering or degradation).

A sample calculation of the incremental increase in the concentration of aluminum predicted in soil sample location "D06 (0-10)" during the Operational phase using Equation 12 is provided below:

$$C_{S-aluminum} = 100 \times \left(\frac{D}{Zs \times BD}\right) \times t_D$$

$$C_{S-aluminum} = 100 \times \left(\frac{0.128\ g/m^2/year}{2\ cm \times 1.5\ g\ soil/cm^3}\right) \times 10\ years$$

$$C_{S-aluminum} = 42.7\ mg/kg$$

The incremental increase in soil metal concentrations was summed with baseline metal concentrations to obtain predicted total soil metal concentrations during the Construction and Operation phases. Appendices V6-5H and V6-5I provide the baseline, predicted incremental change, and total soil metal concentrations at each soil sampling location for the Construction and Operational phases, respectively. Table 5.4-3 provides the results of the soil screening process for the Construction and Operational phases of the Project.

Table 5.4-3. Selection of Contaminants of Potential Concern based on Predicted Soil Quality during the Construction and Operational Phases

Metals	CCME Soil Quality Guidelines - Agricultural [a] (mg/kg)	Baseline (Measured) Maximum Soil Concentration [b] (mg/kg)	Construction Phase Predicted Maximum Soil Concentration (mg/kg)	Operational Phase Predicted Maximum Soil Concentration (mg/kg)
Antimony	20	5.00	5.00	5.00
Arsenic	12	7.17	7.17	7.17
Barium [c]	500	164	164	164
Beryllium	4	0.790	0.790	0.790
Cadmium	1.4	0.250	0.250	0.250
Chromium	64	81.8	81.9	82.0
Cobalt	40	17.1	17.1	17.1
Copper	63	67.7	67.7	67.8
Lead	70	15.0	15.0	15.0
Mercury	6.6	0.158	0.158	0.158
Molybdenum	5	2.00	2.00	2.00
Nickel	45	53.5	53.5	53.6
Selenium	1	0.250	0.251	0.251
Silver	20	1.00	1.00	1.00
Thallium	1	0.500	0.500	0.500
Tin	5	2.50	2.50	2.50
Uranium	23	2.23	2.23	2.23
Vanadium	130	82.0	82.0	82.0

Metals	CCME Soil Quality Guidelines - Agricultural [a] (mg/kg)	Baseline (Measured) Maximum Soil Concentration [b] (mg/kg)	Construction Phase Predicted Maximum Soil Concentration (mg/kg)	Operational Phase Predicted Maximum Soil Concentration (mg/kg)
Zinc	200	80.5	80.5	80.5

Notes:
CCME = Canadian Council of Ministers of the Environment
[a] CCME (2017a).The lowest of available human health and environmental health guidelines/check values were chosen for COPC screening.
[b] Soil baseline concentrations are from samples collected at 0-20 cm depth (n = 100), in 2010 and 2014.
[c] The CCME soil quality guideline for barium is lower for residential parkland use (500 mg/kg) than it is for agricultural use (750 mg/kg); therefore, the residential parkland guideline was adopted for COPC screening.
All soil concentrations are dry weight.
Grey shading indicates exceedance of the CCME soil quality guidelines – agricultural use or residential parkland use.

During the Construction and Operational phases, predicted maximum metal concentrations in soil were lower than CCME Guidelines for the Protection of Environmental and Human Health for agricultural land (residential parkland for barium), except for chromium, copper, and nickel (Table 5.4-3).

The baseline concentrations of these three metals also exceeded the soil quality guidelines. The predicted concentrations are almost identical to the baseline concentrations and the largest percent change relative to baseline concentrations for these parameters is only 0.33% (for selenium) in the Construction phase and 0.44% (for selenium) in the Operational phase (Table 5.4-3). A change in soil concentrations of less than 1% (and likely up to 10%) compared to existing background levels is not measurable and is not likely to translate into a measurable change in tissue quality in terrestrial organisms (i.e., vegetation and country foods) that may be consumed by humans. However, similar to the existing conditions HHRA, chromium, copper, and nickel are carried forward as COPCs in soil in the Project-related HHRA.

Contaminants of Potential Concern in Water

To assess the potential for human health effects from changes in drinking water quality due to Project-related activities, future surface water quality was modeled. The Madrid-Boston Project Water and Load Balance (P5-4) describes the methodology and assumptions used in the surface water quality model for the Project. Water quality modeling provided quantitative estimates of predicted surface water quality at 13 surface water quality modeling nodes located downstream of the Project (described in Section 5.3.3.5 of the existing conditions HHRA).

Consistent with the approach used in the characterization of existing conditions drinking water quality (Section 5.3.2.3), maximum predicted concentrations at the 13 surface water quality modeling nodes located within the human health LSA were compared to the Health Canada DWQGs (Health Canada (2015). Predicted surface water quality at the water quality modeling nodes is provided in the Madrid-Boston Project Water and Load Balance (P5-4). The 13 surface water quality modeling nodes were used to represent water quality that land users would potentially consume, while the surface water quality at the Windy Lake and Aimaokatalok Lake modeling nodes were used to represent water quality that off-duty workers would potentially consume.

Fugitive dust from the Project can also be deposited on surface waters as dustfall. For freshwater lakes and streams, water quality changes due to dustfall (i.e., air emissions) were evaluated in Volume 5, Section 4.5.4.8. Due to the low predicted total suspended solid loads from dustfall (0.0006 to 0.0066 mg/L/day), there are negligible effects to freshwater lakes and streams from dustfall (Volume 5, Section 4.5.4.7.1).

Non-metal Contaminants of Potential Concern

The maximum predicted concentrations of the non-metal parameters in surface water at the 13 surface water quality model nodes during the Construction and Operational phases were used to determine if the parameter was a COPC. The COPC screening of surface water quality is provided in Volume 5, Section 4.5.4.2. Non-metal COPCs were not identified in surface water during Construction and Operational phases for land users and off-duty workers.

Metal Contaminants of Potential Concern

The maximum predicted concentrations of the metal parameters in surface water at the 13 surface water quality model nodes during the Construction and Operational phases were used to determine if the parameter was a COPC or not. The COPC screening of surface water quality is provided in Volume 5, Section 4.5.4.2.

The predicted maximum concentrations of iron and manganese exceeded the DWQGs during the Construction and Operational phases (Volume 5, Section 4.5.4.2). The maximum concentrations of iron and manganese also exceeded the DWQGs under existing conditions (Table 5.3-8). The DWQGs for iron and manganese are aesthetic objectives (such as taste) that are also not health-based (see description in Section 5.3.2.3). However, because there are other exposure pathways for manganese and manganese can cause adverse health effects at high enough concentrations, it was conservatively considered to be a COPC in water and was carried forward in the Project-related HHRA.

Contaminants of Potential Concern in Fish Tissue

Lake trout tissue concentrations were predicted for Madrid-Boston Project-related HHRA based on site specific BCFs calculated using existing conditions fish and water data. To calculate predicted metal concentrations in fish tissue, BCFs for Lake Trout were calculated using Equation 13 (Arnot and Gobas 2006):

$$BCF_{fish} = C_{existing\ condition\ fish} / C_{existing\ condition\ water} \qquad \text{[Equation 13]}$$

where:

BCF_{fish}	= the fish bioconcentration factor for a metal (in kg/L)
$C_{existing\ condition\ fish}$	= the concentration of a metal in fish tissue under existing conditions (in mg/kg)
$C_{existing\ condition\ water}$	= the concentration of a metal in water under existing conditions (in mg/kg)

The BCF_{fish} was calculated as the 95th percentile of the measured metal concentrations in Lake Trout tissue (Appendix V6-5C) divided by the median of 95th percentile concentration of modeled baseline freshwater quality from 13 water quality model nodes within the LSA. The reason for using model baseline data from the 13 water quality nodes is to enable direct comparison to predicted water quality at the exact same locations (i.e., model node assessment locations). No measurable changes are expected to occur in marine water quality in Roberts Bay as a result of Project activities (see Volume 5, Section 8.5.4), thus metal concentrations are expected to remain the same as existing conditions. Therefore, marine fish BCFs were not calculated as the Arctic Char tissue concentrations are also expected to remain the same as the existing conditions concentrations. A sample calculation of the aluminum BCF for Lake Trout using Equation 13 is provided below:

$$BCF_{Lake\ Trout} = C_{existing\ condition\ Lake\ Trout}/C_{existing\ condition\ water}$$

$$BCF_{Lake\ Trout} = \frac{4.24\,\frac{mg}{kg}}{0.129\,\frac{mg}{L}}$$

$$BCF_{Lake\ Trout} = 32.9\ L/kg$$

The BCFs for Lake Trout are provided in Table 5.4-4. The BCFs were then multiplied by the predicted 95th percentile freshwater concentration from 13 water quality model nodes during the Construction and Operational phases to calculate the predicted metal concentrations in fish tissue during the Construction and Operational phases, using Equation 14:

$$C_{predicted\ fish} = C_{predicted\ water} \times BCF_{fish} \qquad \text{[Equation 14]}$$

where:

$C_{predicted\ fish}$	= the predicted metal concentration in fish tissue (in mg/kg)
$C_{predicted\ water}$	= the predicted metal concentration in surface water (in mg/L)
BCF_{fish}	= the bioconcentration factor for that fish species and metal (in L/kg)

A sample calculation of the predicted aluminum concentration in Lake Trout tissue during the Construction Phase using Equation 14 is provided below:

$$C_{predicted\ Lake\ Trout} = C_{predicted\ water} \times BCF_{Lake\ Trout}$$

$$C_{predicted\ Lake\ Trout} = 0.128\,\frac{mg}{L} \times 32.9\,\frac{L}{kg}$$

$$C_{predicted\ Lake\ Trout} = 4.23\,\frac{mg}{kg}$$

The predicted metal concentrations in Lake Trout during the Construction and Operational phases are provided in Table 5.4-4.

During Construction and Operational phases, the predicted mercury concentrations of 1.10 and 1.20 mg/kg, respectively in Lake Trout tissues exceeded the Health Canada human consumption guideline for mercury in fish of 0.5 mg/kg (Health Canada 2007a). Assuming that 100% of the mercury concentrations in fish are in the form of methylmercury, predicted methylmercury concentrations also exceeded the BC MOE methylmercury tissue residue guideline for the protection of wildlife consumers of aquatic biota of 0.033 mg/kg (BC MOE 2001).

<u>Final List of Contaminants of Potential Concern Selected for Evaluation</u>

The same screening criteria used in the existing conditions HHRA (i.e., screening against guidelines; Section 5.3.2.3) was used in the Project-related HHRA.

Table 5.4-4. Calculated Concentration of Metals in Lake Trout Tissue during the Construction and Operational Phases

Parameter	Construction Phase Predicted 95th Percentile Freshwater Concentration (mg/L)	Operational Phase Predicted 95th Percentile Freshwater Concentration (mg/L)	BCF Water-to-Lake Trout	Construction Phase Lake Trout Tissue Concentration (mg/kg ww)	Operational Phase Lake Trout Tissue Concentration (mg/kg ww)
Aluminum	1.28E-01	1.26E-01	32.9	4.23	4.16
Antimony	6.44E-05	6.73E-05	80.3	0.00517	0.00540
Arsenic	4.57E-04	6.00E-04	324	0.148	0.195
Barium	5.70E-03	5.79E-03	17.1	0.097	0.099
Beryllium	1.40E-05	1.47E-05	3503	0.0490	0.0515
Cadmium	1.39E-05	1.45E-05	175	0.00244	0.00253
Calcium	1.08E+01	1.09E+01	36.2	390	393
Chromium	7.33E-04	7.25E-04	445	0.326	0.323
Cobalt	1.37E-04	1.40E-04	72.7	0.00999	0.0102
Copper	2.62E-03	2.78E-03	137	0.358	0.381
Lead	1.22E-04	1.22E-04	645	0.0787	0.0787
Lithium	1.02E-02	1.03E-02	4.84	0.0496	0.0499
Magnesium	7.57E+00	7.53E+00	46.7	353	352
Manganese	3.22E-02	3.29E-02	8.38	0.270	0.275
Mercury	2.83E-06	3.08E-06	388859	1.10	1.20
Molybdenum	2.17E-04	2.20E-04	84.5	0.0183	0.0186
Nickel	1.09E-03	1.10E-03	183	0.199	0.202
Selenium	5.36E-04	5.30E-04	1120	0.600	0.594
Thallium	5.84E-06	6.11E-06	1836	0.0107	0.0112
Uranium	7.55E-05	8.02E-05	13.5	0.001022	0.00109
Vanadium	4.47E-04	4.63E-04	115	0.0515	0.0533
Zinc	4.79E-03	4.85E-03	1011	4.84	4.90

Notes:
BCF = bioconcentration factor
ww = wet weight
(-) = not available
Grey highlighting indicates exceedance of the Health Canada (2007a) human consumption guideline for mercury (0.5 mg/kg ww) or the BC MOE (2001) total mercury tissue residue guideline for fish/shellfish consumption for high fish consumers (0.1 mg/kg ww based on 1.05 kg/week consumed).
BCFs were calculated by dividing the existing conditions 95th percentile metal concentration in Lake Trout by the existing conditions 95th percentile metal concentration in freshwater.

Among CACs, NO_2, PM_{10}, and $PM_{2.5}$ were identified during the Construction and Operational phases for various Off-duty worker camp locations, and land user locations. The only metal COPCs identified in air during the Construction and Operational phases was nickel for off-duty workers (Table 5.4-2), thus nickel was carried forward as a COPC in the Project-related HHRA. The COPCs identified during the Construction and Operational phases in the soil quality screening (Table 5.4-3) were: chromium, copper, and nickel. The only COPC identified during the Construction and Operational phases in the surface water quality screening was manganese. The only COPC identified during the Construction and Operational phases in the fish tissue screening (Table 5.4-4) was mercury. Several metals are considered to be bioaccumulative (see Section 5.3.2.3), including arsenic, cadmium, lead, mercury, nickel, selenium, thallium, and zinc. Therefore, those metals were also carried forward in the Project-related HHRA.

Therefore, the final list of COPCs selected for the Project-related HHRA include: NO_2, PM_{10}, $PM_{2.5}$, arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, thallium, and zinc. These COPCs will be further evaluated in the Exposure Assessment (Section 5.4.2), Toxicity Assessment (Section 5.4.3), and Risk Characterization (Section 5.4.4).

5.4.1.4 Noise

Volume 4, Chapter 3 (Noise and Vibration), and the *Environmental Noise and Vibration Study Report* (Nunami Stantec 2017a) provide details of the modeling design and methodology to assess the environmental effects of noise associated with the Project during the Construction and Operational phases. Potential noise effects associated with Closure and Post-Closure phases are not assessed herein because it is reasonably assumed these phases will produce lower noise levels relative to the Construction and Operational phases.

The evaluation of Project-related noise effects includes the human receptor locations within the human health LSA (Figure 5.3-1). These receptor locations include recreational land use areas and Project-related sites such as the off-duty worker camps. Locations closest to the Project were chosen within the larger land use areas to provide a conservative assessment of potential noise effects on land users. The off-duty worker camps were selected for assessment because Project personnel are expected to reside at these sites during the Construction and Operational phases of the Project. Because workers will be on shift rotations, it is assumed that sleeping hours will include both day and night periods. For this reason, noise thresholds incorporated in the assessment of Project activity conservatively adopt the lower nighttime thresholds for both evening and daytime hours (Table 5.4-5). Exposure to Project noise for workers while on duty will be regulated by the Worker's Safety and Compensation Commission (WSCC), which administers the *Mine Health and Safety Act* (1994) and the *Workers Compensation Act* (2007) upheld by the Government of Nunavut.

The potential effects considered in this assessment include sleep disturbance, speech comprehension, complaints, and annoyance. The applicable assessment endpoints and thresholds used to assess potential noise effects to human receptors are described below and summarized in Table 5.4-5.

<u>Noise Assessment Endpoints</u>

Sleep Disturbance

As per Health Canada (2017) guidance, the assessment of sleep disturbance was based on a night time continuous noise threshold (L_n) of 30 dBA (indoors). Because recreational land users may use open-windows at night, an outdoor-to-indoor noise attenuation of 15 dBA (US EPA 1974) was applied to provide an outdoor threshold of L_n = 45 dBA for recreational land use receptors. Because camp windows will be closed, a noise attenuation of 27 dBA (US EPA 1974) was applied to provide an outdoor threshold of 57 dBA for off-duty staff (i.e., residential receptors).

Table 5.4-5. Noise Parameters, Screening Criteria, and Maximum Project-Related Noise Levels at Human Receptor Locations

Assessment Criteria	Noise Metric	Description	Applicable Period	Thresholds for Recreational/Temporary Receptors [1]	Thresholds for Off-Duty Human Receptors Residing at Camp [2]
Sleep Disturbance [3]	Ln	Noise level threshold for assessing potential sleep disturbance associated with existing conditions	Night time (10 pm to 7 am)	45 dBA	57 dBA
	Ld		Daytime (7 am to 10 pm)		57 dBA
Speech Interference	Ld	Noise level threshold for assessing the potential for existing-conditions noise to interfere with speech comprehension	Daytime (7 am to 10 pm)	55 dBA	55 dBA
Likelihood of Complaints	Ldn	Day and night combined (24-hour equivalent) noise level for assessing the likelihood of complaints associated with existing conditions	24-hour Equivalent Period	62 dBA	NA
Potential for Annoyance	Ldn	Day and night combined (24-hour equivalent) noise level for assessing the potential for annoyance due to existing conditions	24-hour Equivalent Period	NA	75 dBA [a]
Sleep Disturbance	Lmax	Instantaneous noise level in dBA for assessing sleep disturbance	Night time for recreational land users; Night time and daytime for off-duty workers	60 dBA	72 dBA

Notes:
NA = not applicable
[1] *Noise thresholds for sleep disturbance pertaining to recreational land users assume open windows, corresponding to an attenuation factor of 15 dBA (US EPA 1974).*
[2] *Noise thresholds for sleep disturbance pertaining to off-duty workers assume closed windows, corresponding to an attenuation factor of 27 dBA (US EPA 1974).*
[3] *Sleep disturbance is assessed for both night time and daytime hours because 24-hour shift work is proposed.*
[a] *As per Health Canada (2017) guidance, annoyance is assessed by adding +10 dBA to modeled noise levels for receptors located in rural locations where a higher degree of tranquility is expected.*

Sleep disturbance was also assessed using an outdoor night time instantaneous noise threshold of L_{max} = 60 dBA (windows open; recreational receptors) and 72 dBA (windows closed; off-duty receptors). The L_{max} threshold for sleep disturbance is based on a maximum noise level that should not be exceeded more than 10 to 15 times during sleeping hours Health Canada (2017). Thus, modeled L_{max} values do not explicitly predict whether the threshold to assess sleep disturbance will be exceeded, as the actual frequency of L_{max} levels surpassing 60 or 72 dBA during sleeping hours is impossible to accurately predict. Rather, predicted L_{max} exceedances indicate the *potential* for sleep disturbance from instantaneous noise events that may occur more than 10 to 15 times during sleeping hours.

Speech Comprehension

Speech comprehension is defined by Health Canada (2017) as "*the ability to recognize key words in a sentence using full concentration in a laboratory setting*". As per Health Canada (2017) guidance, the potential for Project noise to interfere with speech comprehension was assessed using a day time outdoor threshold of L_d = 55 dBA.

Noise Complaints

The potential for noise complaints from receptors within the Human Health RSA was assessed following Health Canada (2017) guidance, which supports a normalized day-night noise level (L_{dn}) of 62 dBA as a threshold for widespread complaints. Because shift workers are assumed to anticipate, and have a high tolerance for potential Project noise during off-duty hours, they are not reasonably expected to lodge noise complaints. Thus, the potential for noise complaints was only assessed for recreational land use receptors.

Annoyance

As per Health Canada (2017), the potential for annoyance due to noise was assessed using a normalized threshold of L_{dn} = 75 dBA. Because the Madrid-Boston Project is located in a quiet rural area that could be considered to have a higher expectation of tranquillity, annoyance was conservatively assessed using an adjustment of +10 dBA as per Health Canada (2017) guidance. Health Canada (2017) states that the potential for annoyance should only be assessed for receptors exposed to long-term project noise (i.e., exposures greater than one year). For this reason, non-Project-related human receptors were not assessed for annoyance due to the short-term and seasonal nature of recreational land use in the LSA. Because off-duty workers are reasonably expected to anticipate and have a high tolerance for Project-related noise, the assessment of annoyance using an adjustment of +10 dBA to account for the expectation of tranquillity in rural areas is considered a conservative approach for assessing annoyance to these human receptors.

Modeling Results

The modeling design and results to assess continuous noise levels (L_d, L_n, and L_{dn}) during the Construction and Operational phases are described in detail in Volume 4, Chapter 3 (Noise and Vibration) and the Environmental Noise and Vibration Study Report (Nunami Stantec 2017a). Project-related noise was modeled as two discrete scenarios. As described in the Environmental Noise and Vibration Study Report (Nunami Stantec 2017a), the first scenario adopts the reference location for the Madrid North facility, and the second scenario adopts an alternate location of the Madrid North facility 400 meters north of the reference location. For conservatism, the highest modeled noise levels across both scenarios were used in the HHRA.

Continuous Noise

Predicted continuous noise levels (in dBA) are not expected to exceed applicable thresholds for any non-Project related receptor (i.e., recreational land use locations) during the Construction and

Operational Phases. However, Project-related receptors (i.e., worker camps) are expected to experience noise levels which exceed thresholds for off-duty workers in the Construction and Operational phases. As shown in Table 5.4-6, predicted noise levels at the Doris Camp (Site W1), the Boston Operations Camp (Site W3), and the Quarry D Camp (Site W4) exceed applicable threshold values for off-duty workers. Overall, the exceeded thresholds include those for sleep disturbance (L_n or L_d = 57 dBA for off-duty workers), speech interference (L_d = 55 dBA), and the potential for annoyance (L_{dn} = 75 dBA). Table 5.4-5 summarizes the noise thresholds used to assess the potential for noise effects to human receptors. The assessment of continuous noise on human receptors is described in Volume 4, Chapter 3 (Noise and Vibration), and the Environmental Noise and Vibration Study Report (Nunami Stantec 2017a).

Table 5.4-6. Construction and Operational Phase Exceedances of Thresholds for Continuous Noise in A-Weighted Decibels (dBA)

Receptor Location	Receptor ID	Ld (dBA)	Ln (dBA)	Ldn (dBA)
Construction Phase				
Doris Camp (active)	W1	80.9	80.9	87.3
Boston Operations Camp	W3	56.9	56.9	63.3
Quarry D Camp	W4	81.7	81.7	88.1
Operational Phase				
Doris Camp (active)	W1	80.8	80.8	87.2
Boston Operations Camp	W3	75.3	75.3	81.7
Quarry D Camp	W4	56.9	56.9	57.3

Notes:
Shaded cells indicate exceedances of applicable continuous noise thresholds described in Table 5.4-5.
Ld = daytime equivalence level for noise occurring between the hours of 7:00 and 22:00
Ln = nighttime equivalence level occurring between the hours of 22:00 and 7:00
Ldn = 24-hour (day and night) equivalence level

Low-Frequency Noise

The indicative noise level threshold for low frequency noise is in C-weighted decibels (dBC), and was established for assessing potential noise effects associated with Construction and Operational phase emissions. This threshold is based on the addition of 15 dB to thresholds for continuous noise (L_d, L_n, and L_{dn}), which is commonly recognised as the typical noise level difference between dBA and dBC noise parameters (e.g., a threshold for sleep disturbance of 45 dBA corresponds to a threshold of 60 dBC).

As shown in Table 5.4-7, the modeling results for low-frequency Project-related noise levels reaching the Doris Camp (Site W1), the Boston Operations Camp (Site W3), and the Quarry D Camp (Site W4) during the Construction phase predict exceedances of applicable threshold values for off-duty workers. During the Operational phase, the Doris Camp (Site W1), the Boston Operations Camp (Site W3), and a single recreational land user location (Site C2 seasonal camp) are predicted to experience noise levels which exceed thresholds for low-frequency noise.

Overall, the exceeded thresholds include those for sleep disturbance (L_n = 60 dBC for non-Project-related receptors; L_n or L_d = 72 dBC for off-duty workers), speech interference (L_d = 70 dBC), and the potential for annoyance (L_{dn} = 90 dBC). Table 5.4-5 summarizes the noise thresholds (as dBA; add 15 dB for thresholds in dBC) used to assess the potential for noise effects to human receptors. The assessment of low-frequency noise on human receptors is described in Volume 4, Chapter 3 (Noise and Vibration), and the Environmental Noise and Vibration Study Report (Nunami Stantec 2017a).

Table 5.4-7. Construction and Operational Phase Exceedances of Thresholds for Continuous Low-Frequency Noise in C-Weighted Decibels (dBC)

Receptor Location	Receptor ID	Ld (dBC)	Ln (dBC)	Ldn (dBC)
Construction Phase				
Doris Camp (active)	W1	91.0	91.0	97.4
Boston Operations Camp	W3	75.0	75.0	81.4 [a]
Quarry D Camp	W4	92.3	92.3	98.7
Operational Phase				
Seasonal Camp (spring/summer)	C2	62.0	62.0	68.4
Doris Camp (active)	W1	90.5	90.5	96.9
Boston Operations Camp	W3	86.3	86.3	92.7

Notes:
Shaded cells indicate exceedances of applicable continuous noise thresholds described in Table 5.4-5.
Ld = daytime equivalence level for noise occurring between the hours of 7:00 and 22:00
Ln = nighttime equivalence level occurring between the hours of 22:00 and 7:00
Ldn = 24-hour (day and night) equivalence level
[a] The Ldn value is below the threshold for potential annoyance (90 dBC), but the addition of 10 dB to account for the expectation of tranquility in a rural setting triggers an exceedance at this receptor location.

Instantaneous Noise

The metric for instantaneous noise is L_{max} in A-weighted decibels (dBA). In contrast to continuous noise metrics (e.g., L_d, L_n, and L_{dn}), the L_{max} metric for noise effects considers the maximum level associated with single noise events.

As shown in Table 5.4-8, the modeling results for instantaneous Project-related noise levels reaching the Doris Camp (Site W1) and the Quarry D Camp (Site W4) indicate potential exceedances of the L_{max} threshold for sleep disturbance for off-duty workers (L_{max} = 72 dBA) during the Construction phase. During the Operational phase, the L_{max} threshold for sleep disturbance has the potential to be exceeded at the Doris Camp (Site W1) and the Boston Operations Camp (Site W3). The assessment of instantaneous noise on human receptors is described in Volume 4, Chapter 3 (Noise and Vibration), and the Environmental Noise and Vibration Study Report (Nunami Stantec 2017a).

Table 5.4-8. Construction and Operational Phase Exceedances of Thresholds for Instantaneous Noise in A-Weighted Decibels (dBA)

Receptor Location	Receptor ID	Lmax (dBA)
Construction Phase		
Doris Camp (active)	W1	81.4
Quarry D Camp	W4	81.7
Operational Phase		
Doris Camp (active)	W1	81.2
Boston Operations Camp	W3	77.7

Notes:
Shaded cells indicate potential exceedances of the Lmax threshold for sleep disturbance described in Table 5.4-5.
Lmax = maximum instantaneous noise level in A-weighted decibels (dBA)

Summary of Noise Effects to Human Receptors

An effects assessment, taking into consideration the potential risks to human health from Project noise and vibration, was provided in Volume 4, Chapter 3 (Noise and Vibration). Mitigation measures were described in Section 3.10.5 of Volume 4, Chapter 3 and included mitigation by project design and recommended best management practices. A Noise Abatement and Monitoring Plan has also been prepared for the Project (Annex V8-8 of Volume 8). Additional mitigation or control measures may be used to adaptively manage noise-related issues as they arise during the Project.

The residual effects due to noise and vibration were assessed as Not Significant (Volume 4, Section 3.10.6), and adverse effects to human health are not likely to occur. This is because the magnitude of the effects due to noise after mitigation were low or moderate at the identified human receptor locations Residual effects are confined to the PDA or LSA, and are intermittent, of medium duration, and reversible.

5.4.1.5 Mitigation Measures for Contaminants of Potential Concern

No additional mitigation measures were considered in the Project-related HHRA beyond what was outlined in the previous effects assessment chapters. Mitigation and management strategies will be in place for a number of VECs and VSECs that will serve to minimize the potential effects of the Project on country foods since the quality of country foods is dependent on the quality of the surrounding environmental media (i.e., air, water, soil, sediment, and vegetation). In addition, strategies to minimize the potential for Project-related effects to wildlife and people (land users and off-duty workers) have also been developed. Mitigation and adaptive management strategies for VECs and VSECs can be found in the following volumes and chapters:

- Air Quality: Volume 4, Chapter 2;
- Noise and Vibration: Volume 4, Chapter 3;
- Landforms and Soils: Volume 4, Chapter 7;
- Vegetation and Special Landscape Features: Volume 4, Chapter 8;
- Terrestrial Wildlife and Wildlife Habitat: Volume 4, Chapter 9;
- Freshwater Water Quality: Volume 5, Chapter 4;
- Freshwater Sediment Quality: Volume 5, Chapter 5;
- Freshwater Fish: Volume 5, Chapter 6;
- Marine Water Quality: Volume 5, Chapter 8;
- Marine Sediment Quality: Volume 5, Chapter 9;
- Marine Fish: Volume 5, Chapter 10;
- Marine Wildlife: Volume 5, Chapter 11;
- Socio-economics: Volume 6, Chapter 3; and
- Land Use: Volume 6, Chapter 4.

5.4.1.6 Conceptual Model

A simplified schematic diagram of the sources of COPCs and pathways by which humans may be exposed to Project-related emissions is depicted in Figure 5.4-1. There are two general sources of emissions from the Project: atmospheric emissions (e.g., CACs and fugitive dust with associated COPCs) and liquid effluent (e.g., effluent discharge and treated waste water). Fugitive dust and emission particulates have the potential to enter the atmosphere and be inhaled by humans as well as travel some distance, and settle, where they can reside in different media such as soil and vegetation. These media can be taken up by humans and country foods through the ingestion exposure route and humans can also be exposed via dermal contact.

Liquid effluent has the potential to enter the marine and freshwater environments. Humans, wildlife, aquatic habitat, and fish can then be exposed to the contaminants via ingestion of water. The conceptual model for the Project-related HHRA is presented in Figure 5.4-1, which shows how COPCs released from the Project could enter the environment (i.e., air, surface water, vegetation, wildlife/country foods, and soil) move into humans via inhalation, ingestion, or dermal exposure.

5.4.2 Exposure Assessment

The exposure assessment methodology follows that described in the existing conditions HHRA (Section 5.3.3.1).

5.4.2.1 Inhalation of Air

As described in Section 5.4.1.3, some CACs were considered COPCs and inhalation is the only exposure route. However, calculations of EDI are not required for CACs as HQs for the CAC exceedances are calculated as the predicted CAC concentration divided by the ambient air quality criteria; therefore, CACs are not included here and instead the risks are quantified in Section 5.5.4.2.

The COPCs identified in Section 5.4.1.3 were carried forward in the exposure assessment for the inhalation of those COPCs in air. The predicted concentrations of COPCs bound to PM_{10} (Table 5.4-2) were used to determine the EDI of COPCs that humans receive via inhalation. The equation used to calculate human exposure to metals (mg/kg BW/day) from inhalation of PM_{10} was Equation 1 (Health Canada 2010b) provided in Section 5.3.3.2 of the existing conditions HHRA.

The EDI of COPCs via the inhalation exposure route for adult and toddler land users and off-duty workers at the four camps during the Construction and Operational phases are presented in Table 5.4-9. The inhalation EDIs for land users were calculated from the location with the highest annual PM_{10} concentration, which occurred at the Hunting and Fishing Area H2 during the Construction and Operational phases. The assumptions used in the calculation of the EDI of COPCs via inhalation are the same as those provided in the existing conditions HHRA (Section 5.3.3.2) and a sample calculation was also provided in the existing conditions HHRA.

It was assumed that land users could be in the LSA for three months of the year, thus the exposure time for land users is 24 hours per day, 7 days per week, for 12 weeks of the year. This exposure duration is considered a conservative estimate (see Section 5.3.2.1).

It was assumed that Project workers occupy the Project camp areas during their off-duty time with worker shifts lasting 12-hours per day for six months per year (182 days) due to a work rotation of two weeks on and two weeks off. Thus the exposure duration for off-duty workers is 12-hours per day for six months of the year. This exposure duration is considered a conservative estimate since actual exposure times may be lower due to vacation or other leave from work.

Figure 5.4-1

Conceptual Model for Potential Human Exposure to Madrid-Boston Project-related Contaminants of Potential Concern

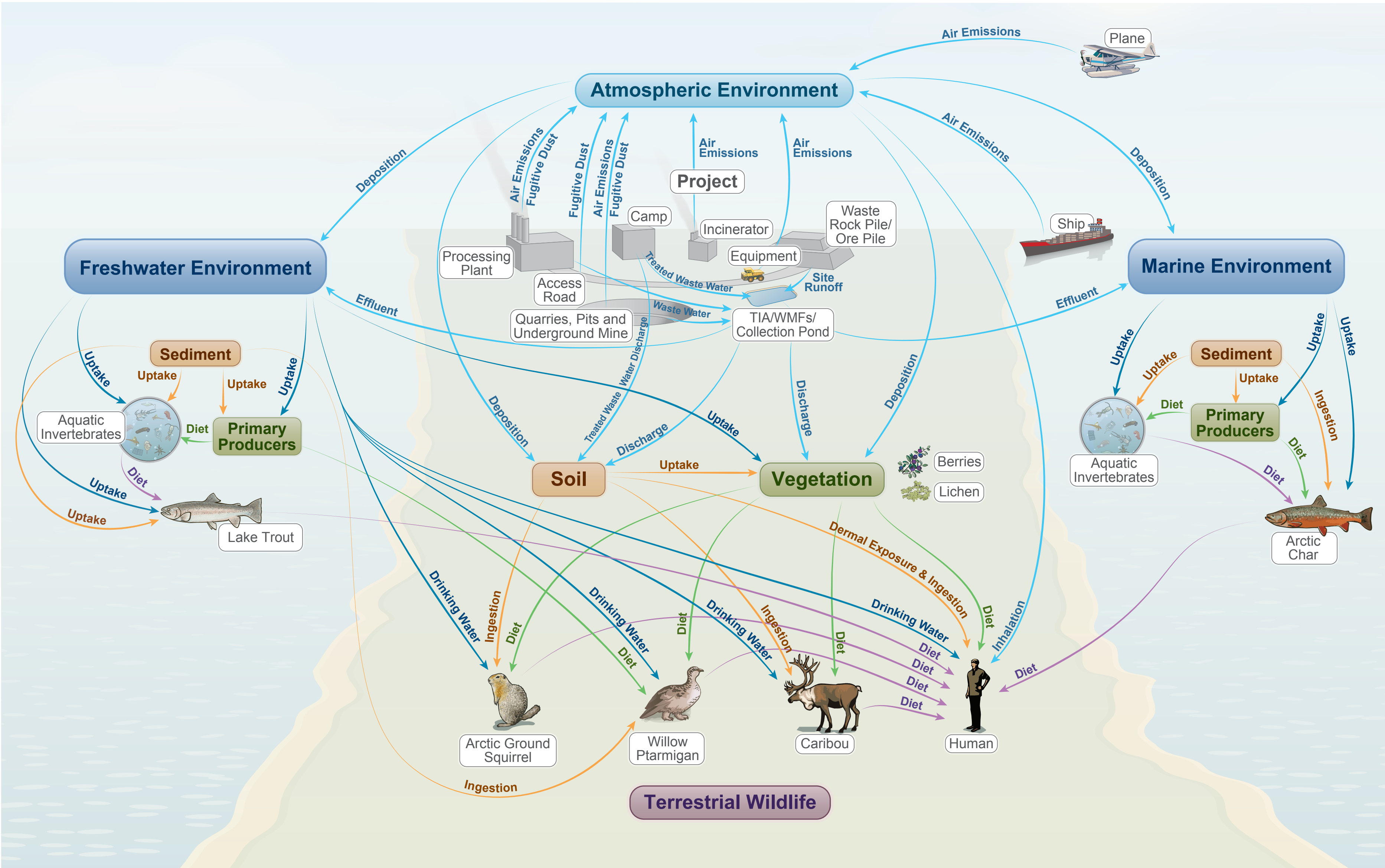


Table 5.4-9. Estimated Daily Intake of Contaminants of Potential Concern via the Inhalation Exposure Route

Exposure Characteristics	Land User Toddler	Land User Adult	Off-duty Worker
Hours/24 Hours	24	24	12
Days/7 Days	7	7	7
Weeks/52 Weeks	12	12	26
Inhalation Rate (m^3/day)	7.9	16.6	16.6
Relative Absorption Factor (unitless)	1	1	1
Body Weight (kg)	15.3	76.5	76.5

	Construction Phase Estimated Daily Intake (mg/kg BW/day)						Operational Phase Estimated Daily Intake (mg/kg BW/day)					
COPC	Land User Toddler	Land User Adult	Off-duty Worker at Doris Camp	Off-duty Worker at Boston Exploration Camp	Off-duty Worker at Boston Operational Camp	Off-duty Worker at Quarry D Camp	Land User Toddler	Land User Adult	Off-duty Worker at Doris Camp	Off-duty Worker at Boston Exploration Camp	Off-duty Worker at Boston Operational Camp	Off-duty Worker at Quarry D Camp
Arsenic	2.93E-09	1.23E-09	5.60E-10	3.59E-10	1.89E-09	1.25E-09	1.68E-09	7.06E-10	3.24E-10	6.72E-10	2.20E-09	5.08E-10
Cadmium	5.87E-10	2.47E-10	1.12E-10	7.18E-11	3.78E-10	2.50E-10	3.36E-10	1.41E-10	6.48E-11	1.34E-10	4.40E-10	1.02E-10
Chromium	8.80E-07	3.70E-07	1.68E-07	1.08E-07	5.67E-07	3.74E-07	5.04E-07	2.12E-07	9.72E-08	2.02E-07	6.60E-07	1.52E-07
Copper	6.46E-07	2.71E-07	1.23E-07	7.89E-08	4.16E-07	2.74E-07	3.70E-07	1.55E-07	7.13E-08	1.48E-07	4.84E-07	1.12E-07
Lead	3.52E-09	1.48E-09	6.71E-10	4.31E-10	2.27E-09	1.50E-09	2.02E-09	8.47E-10	3.89E-10	8.06E-10	2.64E-09	6.10E-10
Manganese	5.46E-06	2.29E-06	1.04E-06	6.67E-07	3.51E-06	2.32E-06	3.12E-06	1.31E-06	6.03E-07	1.25E-06	4.09E-06	9.45E-07
Mercury	5.87E-11	2.47E-11	1.12E-11	7.18E-12	3.78E-11	2.50E-11	3.36E-11	1.41E-11	6.48E-12	1.34E-11	4.40E-11	1.02E-11
Nickel	4.23E-07	1.78E-07	8.06E-08	5.17E-08	2.72E-07	1.80E-07	2.42E-07	1.02E-07	4.67E-08	9.68E-08	3.17E-07	7.32E-08
Selenium	2.93E-09	1.23E-09	5.60E-10	3.59E-10	1.89E-09	1.25E-09	1.68E-09	7.06E-10	3.24E-10	6.72E-10	2.20E-09	5.08E-10
Thallium	5.87E-10	2.47E-10	1.12E-10	7.18E-11	3.78E-10	2.50E-10	3.36E-10	1.41E-10	6.48E-11	1.34E-10	4.40E-10	1.02E-10
Zinc	3.46E-07	1.46E-07	6.60E-08	4.23E-08	2.23E-07	1.47E-07	1.98E-07	8.33E-08	3.82E-08	7.93E-08	2.60E-07	6.00E-08

Notes:

COPC = contaminant of potential concern

BW = body weight

PM_{10} = particulate matter up to and including 10 µm in size

5.4.2.2 Ingestion of Soil

The predicted 95th percentile metal concentrations in soil at 68 sites within the human health LSA (Appendices V6-5H and V6-5I) were used as an input into the equation to calculate the EDI of COPCs humans receive from ingestion of soil during the Construction and Operational phases. The equation used to calculate human exposure to COPCs (mg/kg BW/day) from soil ingestion was Equation 2 (Health Canada 2010b) provided in Section 5.3.3.3 of the existing conditions HHRA.

The COPC EDI via the soil ingestion exposure route for the Construction and Operational phases for adult and toddler land users and off-duty workers are presented in Table 5.4-10. The assumptions used in the calculation of the EDI of COPCs via ingestion of soil were the same as those described in the existing conditions HHRA (Section 5.3.2.3). A sample calculation was also provided in the existing conditions HHRA. The fraction of time exposed for land users and off-duty workers is described above for air inhalation (Section 5.4.2.1).

5.4.2.3 Dermal Exposure to Soil

The predicted 95th percentile metal concentrations in soil from 68 sites within the human health LSA (Appendix V6-5H and V6-5I) were used as an input in the equation to calculate the EDI of COPCs humans receive from dermal exposure to soil during the Construction and Operational phases. The equation used to calculate human exposure to COPCs (mg/kg BW/day) from dermal exposure to soil was Equation 3 (Health Canada 2010b), which was described in Section 5.3.3.4 of the existing conditions HHRA.

The COPC EDI via the dermal exposure to soil route for the Construction and Operational phases for adult and toddler land users and off-duty workers are presented in Table 5.4-11. The assumptions used in the calculation of the EDI of COPCs via dermal exposure to soil were the same as those described in the existing conditions HHRA (Section 5.3.3.4). A sample calculation was also provided in the existing conditions HHRA. The fraction of time exposed for land users and off-duty workers is described above for air inhalation (Section 5.4.2.1).

5.4.2.4 Drinking Water

The predicted 95th percentile concentration of COPCs at the Windy Lake and Aimaokatalok Lake surface water quality modeling nodes during the Construction and Operational phases were calculated and used as an input in the equation to calculate the EDI of COPCs that off-duty workers receive from drinking water. The highest concentration from either of the two lakes was used in the calculations to be conservative. For land users, the median of predicted 95th percentile surface water concentrations from the 13 model nodes during the Construction and Operational phases were calculated and used as an input in the equation to calculate the EDI of COPCs that adult and toddler land users receive from drinking water.

The equation used to calculate human exposure to COPCs (mg/kg BW/day) from drinking water was Equation 4 (Health Canada 2010b), which was described in Section 5.3.3.5 of the existing conditions HHRA.

The COPC EDI via the ingestion of drinking water route for the Construction and Operational phases for adult and toddler land users and off-duty workers are presented in Table 5.4-12. The assumptions used in the calculation of the EDI of COPCs via drinking water ingestion were the same as those described in the existing conditions HHRA (see Section 5.3.3.5). A sample calculation was also provided in the existing conditions HHRA.

Table 5.4-10. Estimated Daily Intake of Contaminants of Potential Concern via the Soil Ingestion Exposure Route

Exposure Characteristics	Land User Toddler	Land User Adult	Off-duty Worker
Hours/24 Hours	24	24	12
Days/7 Days	7	7	7
Weeks/52 Weeks	12	12	26
Soil Ingestion Rate (kg/day)	0.00002	0.0000016	0.0000016
Relative Absorption Factor (unitless)	1	1	1
Body Weight (kg)	15.3	76.5	76.5

COPC	Construction Phase 95th Percentile Concentration in Soil (mg/kg)	Operational Phase 95th Percentile Concentration in Soil (mg/kg)	Construction Phase Estimated Daily Intake (mg/kg BW/day)			Operational Phase Estimated Daily Intake (mg/kg BW/day)		
			Land User Toddler	Land User Adult	Off-duty Worker	Land User Toddler	Land User Adult	Off-duty Worker
Arsenic	3.70	3.70	1.12E-06	1.78E-08	1.93E-08	1.12E-06	1.78E-08	1.93E-08
Cadmium	0.250	0.250	7.55E-08	1.21E-09	1.31E-09	7.55E-08	1.21E-09	1.31E-09
Chromium	65.6	65.7	1.98E-05	3.17E-07	3.43E-07	1.98E-05	3.17E-07	3.44E-07
Copper	37.9	38.0	1.14E-05	1.83E-07	1.98E-07	1.15E-05	1.83E-07	1.99E-07
Lead	15.0	15.0	4.53E-06	7.24E-08	7.84E-08	4.53E-06	7.24E-08	7.84E-08
Manganese	369	369	1.11E-04	1.78E-06	1.93E-06	1.11E-04	1.78E-06	1.93E-06
Mercury	0.0498	0.0498	1.50E-08	2.40E-10	2.60E-10	1.50E-08	2.40E-10	2.60E-10
Nickel	34.7	34.7	1.05E-05	1.67E-07	1.81E-07	1.05E-05	1.68E-07	1.82E-07
Selenium	0.251	0.251	7.56E-08	1.21E-09	1.31E-09	7.57E-08	1.21E-09	1.31E-09
Thallium	0.500	0.500	1.51E-07	2.41E-09	2.62E-09	1.51E-07	2.41E-09	2.62E-09
Zinc	59.2	59.2	1.78E-05	2.86E-07	3.09E-07	1.79E-05	2.86E-07	3.09E-07

Notes:

COPC = contaminant of potential concern

BW = body weight

Table 5.4-11. Estimated Daily Intake of Contaminants of Potential Concern via Dermal Exposure to Soil

Exposure Characteristics	Land User Toddler	Land User Adult	Off-duty Worker
Days/7 Days	7	7	7
Weeks/52 Weeks	12	12	26
Surface Area of Hands Exposed for Soil Loading (cm^2)	4.56	9.53	9.53
Surface Area of Body, Other than Hands, Exposed for Soil Loading (cm^2) *	28.0	89.1	89.1
Soil loading rate to Exposed Skin of Hands (kg/cm^2-event)	1.00E-07	1.00E-07	1.00E-07
Soil loading rate to Exposed Skin of Body, other than Hands (kg/cm^2-event)	1.00E-08	1.00E-08	1.00E-08
Body Weight (kg)	15.3	76.5	76.5

COPC	Construction Phase 95th Percentile Concentration in Soil (mg/kg)	Operational Phase 95th Percentile Concentration in Soil (mg/kg)	Relative Dermal Absorption Factor (unitless)	Construction Phase Estimated Daily Intake (mg/kg BW/day)			Operational Phase Estimated Daily Intake (mg/kg BW/day)		
				Land User Toddler	Land User Adult	Off-duty Worker	Land User Toddler	Land User Adult	Off-duty Worker
Arsenic	3.70	3.70	3.00E-02	1.23E-09	6.17E-10	1.34E-09	1.23E-09	6.17E-10	1.34E-09
Cadmium	0.250	0.250	1.00E-02	2.78E-11	1.39E-11	3.01E-11	2.78E-11	1.39E-11	3.02E-11
Chromium	65.6	65.7	1.00E-01	7.29E-08	3.65E-08	7.91E-08	7.29E-08	3.65E-08	7.92E-08
Copper	37.9	38.0	6.00E-02	2.53E-08	1.27E-08	2.74E-08	2.53E-08	1.27E-08	2.75E-08
Lead	15.0	15.0	1.00E+00	1.67E-07	8.34E-08	1.81E-07	1.67E-07	8.34E-08	1.81E-07
Manganese	369	369	1.00E+00	4.10E-06	2.05E-06	4.45E-06	4.10E-06	2.05E-06	4.45E-06
Mercury	0.0498	0.0498	1.00E+00	5.53E-10	2.77E-10	6.00E-10	5.53E-10	2.77E-10	6.00E-10
Nickel	34.7	34.7	9.10E-02	3.51E-08	1.76E-08	3.81E-08	3.51E-08	1.76E-08	3.81E-08
Selenium	0.251	0.251	1.00E-02	2.78E-11	1.39E-11	3.02E-11	2.78E-11	1.40E-11	3.02E-11
Thallium	0.500	0.500	1.00E+00	5.55E-09	2.78E-09	6.03E-09	5.55E-09	2.78E-09	6.03E-09
Zinc	59.2	59.2	1.00E-01	6.57E-08	3.29E-08	7.13E-08	6.57E-08	3.29E-08	7.13E-08

Notes:

COPC = contaminant of potential concern

BW = body weight

** The value used for surface area of body, other than hands, exposed for soil loading for toddlers and adults is described in Section 5.3.3.4.*

Table 5.4-12. Estimated Daily Intake of Contaminants of Potential Concern via the Drinking Water Exposure Route

Exposure Characteristics	Land User Toddler	Land User Adult	Off-duty Worker
Days/7 Days	7	7	7
Weeks/52 Weeks	12	12	26
Water Ingestion Rate (L/day)	0.6	1.5	1.5
Relative Absorption Factor (unitless)	1	1	1
Body Weight (kg)	15.3	76.5	76.5

COPC	Construction Phase 95th Percentile Concentration in Water for Land Users (mg/L)	Construction Phase 95th Percentile Concentration in Water for Off-duty Workers (mg/L)	Construction Phase Estimated Daily Intake (mg/kg BW/day)			Operational Phase 95th Percentile Concentration in Water for Land Users (mg/L)	Operational Phase 95th Percentile Concentration in Water for Off-duty Workers (mg/L)	Operational Phase Estimated Daily Intake (mg/kg BW/day)		
			Land User Toddler	Land User Adult	Off-duty Worker			Land User Toddler	Land User Adult	Off-duty Worker
Arsenic	0.000457	0.000343	1.79E-05	2.07E-06	3.36E-06	0.000600	0.000347	2.35E-05	2.72E-06	3.40E-06
Cadmium	0.0000139	0.00000787	5.47E-07	6.31E-08	7.71E-08	0.0000145	0.00000789	5.67E-07	6.55E-08	7.74E-08
Chromium	0.000733	0.000618	2.87E-05	3.32E-06	6.06E-06	0.000725	0.000624	2.84E-05	3.28E-06	6.11E-06
Copper	0.00262	0.00171	1.03E-04	1.18E-05	1.67E-05	0.00278	0.00173	1.09E-04	1.26E-05	1.69E-05
Lead	0.000122	0.0000618	4.79E-06	5.53E-07	6.06E-07	0.000122	0.0000623	4.78E-06	5.52E-07	6.11E-07
Manganese	0.0322	0.0248	1.26E-03	1.46E-04	2.43E-04	0.0329	0.0251	1.29E-03	1.49E-04	2.46E-04
Mercury	0.00000283	0.00000345	1.11E-07	1.28E-08	3.38E-08	0.00000308	0.00000352	1.21E-07	1.39E-08	3.45E-08
Nickel	0.00109	0.000656	4.26E-05	4.91E-06	6.43E-06	0.00110	0.000662	4.31E-05	4.98E-06	6.49E-06
Selenium	0.000536	0.000291	2.10E-05	2.42E-06	2.85E-06	0.000530	0.000292	2.08E-05	2.40E-06	2.86E-06
Thallium	0.00000584	0.00000673	2.29E-07	2.64E-08	6.60E-08	0.00000611	0.00000675	2.40E-07	2.76E-08	6.62E-08
Zinc	0.00479	0.00371	1.88E-04	2.17E-05	3.64E-05	0.00485	0.00374	1.90E-04	2.19E-05	3.67E-05

Notes:

COPC = contaminant of potential concern

BW = body weight

5.4.2.5 *Ingestion of Country Foods*

Terrestrial Wildlife Tissue Concentrations

Madrid-Boston Project-related predicted COPC concentrations in caribou, Arctic ground squirrel, and ptarmigan were estimated using a food chain model described in Golder and Associates (2005) and recommended by Health Canada (2010a). The food chain model (Appendix V6-5N) uses predicted 95th percentile concentrations of COPCs in water, soil, sediment, and vegetation (lichen and berries), in addition to wildlife ingestion rates and COPC-specific BTFs (Table V6-5N2,) to predict country foods tissue metal concentrations. The model also takes into account residence time in the study area to enable evaluation of COPC uptake associated with exposures occurring within the study area.

The modeling methodology used for calculation of EDIs was the same methodology used for existing conditions (Section 5.3.3.6). For instance, the arsenic concentrations in country food items was adjusted to account for the amount of inorganic arsenic that is likely present, as that is the most toxic form. For additional details on the adjustments made to arsenic concentrations in country foods item, refer to Section 5.3.3.6 of this FEIS.

Each terrestrial wildlife species was assumed to take up COPCs from the environmental medium (e.g., soil, sediment, water, and vegetation), based on information known about the species life histories. Tables 5.4-13 and 5.4-14 present the modeled caribou, Arctic ground squirrel, and ptarmigan COPC concentrations in tissue during the Construction and Operational phases.

Table 5.4-13. Modeled Concentrations of Contaminants of Potential Concern in Country Foods during the Construction Phase

COPC	Caribou	Caribou Liver [a]	Caribou Kidney [a]	Arctic Ground Squirrel	Willow Ptarmigan	Berries	Arctic Char	Lake Trout
Arsenic	1.52E-05	2.05E-05	1.72E-05	1.88E-05	1.27E-02	3.87E-03	2.01E+00	1.48E-01
Cadmium	6.30E-07	8.79E-05	7.60E-04	1.34E-06	7.46E-04	3.69E-03	2.44E-03	2.44E-03
Chromium	1.04E-03	-	-	1.76E-03	1.56E-01	9.80E+00	1.92E-02	3.26E-01
Copper	8.75E-04	4.02E-02	6.39E-03	1.23E-03	1.23E-01	1.41E+00	1.72E+00	3.58E-01
Lead	9.20E-06	1.66E-03	2.00E-04	1.12E-05	4.80E-02	1.21E-02	8.28E-03	7.87E-02
Manganese	5.11E-04	-	-	9.67E-04	3.22E-01	2.24E+01	2.03E-01	2.70E-01
Mercury	1.23E-04	1.34E-02	6.39E-02	3.11E-04	1.18E-04	5.02E-04	-	-
Methylmercury [b]	-	-	-	-	-	-	4.46E-02	1.10E+00
Nickel	5.92E-04	-	-	9.98E-04	4.03E-04	5.31E+00	1.13E-01	1.99E-01
Selenium	2.16E-06	-	-	4.30E-06	5.82E-03	1.00E-02	5.66E-01	6.00E-01
Thallium	3.86E-05	-	-	4.34E-05	1.57E-02	2.01E-04	2.04E-03	1.07E-02
Zinc	2.20E-05	3.46E-05	4.16E-05	4.52E-05	1.23E-02	2.24E+00	7.91E+00	4.84E+00

Notes:
All values expressed in mg/kg wet weight.
COPC = contaminant of potential concern
(-) = not available
[a] *Tissue distribution ratios for caribou muscle tissue to caribou liver and kidney tissue only available for arsenic, cadmium, copper, lead, mercury, and zinc.*
[b] *Total mercury analyzed in fish tissue was assumed to be entirely methylmercury.*

Table 5.4-14. Modeled Concentrations of Contaminants of Potential Concern in Country Foods during the Operational Phase

COPC	Caribou	Caribou Liver [a]	Caribou Kidney [a]	Arctic Ground Squirrel	Willow Ptarmigan	Berries	Arctic Char	Lake Trout
Arsenic	1.52E-05	2.06E-05	1.72E-05	1.88E-05	1.27E-02	3.87E-03	2.01E+00	1.95E-01
Cadmium	6.31E-07	8.80E-05	7.61E-04	1.34E-06	7.48E-04	3.69E-03	2.53E-03	2.53E-03
Chromium	1.04E-03	-	-	1.76E-03	1.56E-01	9.80E+00	1.92E-02	3.23E-01
Copper	8.77E-04	4.03E-02	6.40E-03	1.24E-03	1.23E-01	1.41E+00	1.72E+00	3.81E-01
Lead	9.20E-06	1.66E-03	2.00E-04	1.12E-05	4.80E-02	1.21E-02	8.28E-03	7.87E-02
Manganese	5.11E-04	-	-	9.68E-04	3.22E-01	2.25E+01	2.03E-01	2.75E-01
Mercury	1.23E-04	1.34E-02	6.39E-02	3.12E-04	1.18E-04	5.02E-04	-	-
Methylmercury [b]	-	-	-	-	-	-	4.46E-02	1.20E+00
Nickel	5.92E-04	-	-	9.98E-04	4.03E-04	5.31E+00	1.13E-01	2.02E-01
Selenium	2.16E-06	-	-	4.30E-06	5.82E-03	1.00E-02	5.66E-01	5.94E-01
Thallium	3.86E-05	-	-	4.34E-05	1.57E-02	2.01E-04	2.04E-03	1.12E-02
Zinc	2.20E-05	3.46E-05	4.16E-05	4.52E-05	1.24E-02	2.24E+00	7.91E+00	4.90E+00

Notes:
All values expressed in mg/kg wet weight.
COPC = contaminant of potential concern
(-) = not available
[a] Tissue distribution ratios for caribou muscle tissue to caribou liver and kidney tissue only available for arsenic, cadmium, copper, lead, mercury, and zinc.
[b] Total mercury analyzed in fish tissue was assumed to be entirely methylmercury.

Fish Tissue concentrations

Predicted concentrations of COPCs in Lake Trout tissue during the Construction and Operational phases are described in Section 5.4.1.3. Since marine water quality in Roberts Bay will not be affected by the Project (see Volume 5, Section 8.5.4), the COPC concentrations in the tissue of Arctic Char will be unchanged.

Berry Tissue concentrations

Vegetation can take up COPCs via root uptake from soil and from direct deposition to their above ground surfaces (i.e., leaves). Berry tissue concentrations were calculated for both exposure routes using guidance from US EPA (2005e) and Golder Associated Ltd (2005e).

To predict Madrid-Boston Project-related COPC concentrations in vegetation from soil uptake, a BTF was used to account for metal uptake from soil. The BTF represents the relationship between metal concentrations in soil relative to metal concentrations in plant tissues (Equation 15; Sullivan and Krieger 2001):

$$BTF_{COPC} = \frac{C_{existing\ condition\ vegetation}}{C_{existing\ condition\ soil}} \quad \text{[Equation 15]}$$

where:

BTF_{COPC} = biotransfer factor for a COPC at a specific co-collected soil and vegetation site (unitless)

$C_{existing\ condition\ vegetation}$ = the concentration of a COPC in vegetation sample under existing conditions (in mg/kg dry weight)

$C_{existing\ condition\ soil}$ = the concentration of a COPC in soil sample under existing conditions (in mg/kg dry weight)

Since BTF values can be quite variable, site-specific BTF values were calculated whenever possible to predict COPC uptake in vegetation from soil. This was done by calculating a site- and species-specific BTF for locations where both soil and vegetation samples were collected at the same time. The site-specific BTFs are shown in Appendix V6-5L for the Construction Phase and in Appendix V6-5M for the Operational Phase. For sites that did not have co-collected soil and vegetation samples, it was assumed that the existing conditions soil quality did not change and that the predicted metals in dustfall were the only source of additional COPCs to the vegetation.

BTFs were calculated from dry weight soil and dry weight vegetation tissue concentrations. Dry weight concentrations in vegetation were obtained by using the measured percent moisture for the baseline vegetation samples. A sample calculation showing the BTF calculation of arsenic for co-collected crowberry and soil samples from sampling site LSA-02, using Equation 15 is provided below:

$$BTF_{arsenic} = \frac{C_{existing\ condition\ crowberry}}{C_{existing\ condition\ soil}}$$

$$BTF_{arsenic} = \frac{0.0100\,\frac{mg}{kg}}{3.77\,\frac{mg}{kg}}$$

$$BTF_{arsenic} = 0.00265$$

The site specific BTF was then multiplied by site-specific predicted soil concentration (in dry weight) to determine the predicted vegetation COPC concentration due to uptake from soil (Equation 16; Golder Associates Ltd. 2005; US EPA 2005e).

$$C_{COPC\ in\ veg\ due\ to\ soil\ uptake} = BTF_{COPC} \times C_{COPC\ predicted\ soil} \qquad \text{[Equation 16]}$$

where:

$C_{COPC\ in\ veg\ due\ to\ soil\ uptake}$	= the predicted COPC concentration in vegetation species due to uptake from the soil (in mg/kg dry weight)
BTF_{COPC}	= biotransfer factor for a COPC at a specific co-collected soil and vegetation site (unitless)
$C_{COPC\ predicted\ soil}$	= the predicted COPC concentration in the soil due to atmospheric deposition (in mg/kg dry weight)

Berry tissue concentrations are predicted for crowberries, bog blueberries, and bearberries. The sample calculation below using Equation 16 shows the predicted arsenic concentration (mg/kg in dry weight) due to soil uptake in crowberry collected from sampling site LSA-02 from the Operation Phase.

$$C_{arsenic\ in\ crowberry\ due\ to\ soil\ uptake} = 0.00265 \times 3.77\ mg/kg$$

$$C_{arsenic\ in\ crowberry\ due\ to\ soil\ uptake} = 0.0100\ mg/kg$$

Vegetation also uptakes COPCs into tissue from dustfall that deposits on above ground surfaces. Road dust is the primary source of dusfall at all soil and vegetation sampling sites. Plant uptake of COPCs due to direct deposition of dust to their above ground surfaces was calculated using Equation 17 provided by the US EPA (2005e):

$$P_d = \frac{1000 \times D \times R_p \times [1.0 - exp(-k_p \times T_p)]}{y_p \times k_p} \qquad \text{[Equation 17]}$$

where:

P_d = plant (above ground produce) concentration due to direct deposition (mg COPC/kg dry weight)

1000 = unit conversion factor (mg/g)

D = yearly average dry deposition (g/m^2-year)

R_p = Interception fraction of the edible portion of the plant (unitless)

k_p = Plant surface loss coefficient (year^{-1})

T_p = Length of plant exposure to deposition per harvest of the edible portion of the plant (year)

y_p = Yield or standing crop biomass of the edible portion of the plant (productivity; kg dry weight/m^2)

The dustfall results were provided in mg/dm^2-year (Nunami Stantec 2017b) and wer multiplied by 0.1 (unit conversion factor include conversion from dm^2 to m^2 (100 dm^2/m^2) and mg to g (1000 mg/g)) to convert into g/m^2-year. The site-specific dust deposition rate was then multiplied by the metal proportion in the quarry rock (as roads will be constructed from quarry rock) to obtain the COPC concentration in the dustfall (in g/m^2-year).

The interception fraction of the edible portion of the plant (Rp) was set 0.0324 for berries which is the value the US EPA (2005e) recommends for exposed produce and was set to 0.0846 for all vegetation species which is the value the US EPA (2005e) recommends for leafy vegetables. The plant surface loss coefficient (kp) was set to the default value of 18 year^{-1} recommended by US EPA (2005e). The length of plant exposure to deposition per harvest of the edible portion of the plant was conservatively set to 0.5 years since the vegetation experiences at most six months of snow free growing conditions annually. The yield or standing crop biomass of the edible portion of the plant (Yp) was set to 0.25 for berries, which the US EPA (2005e) recommends for exposure fruits, and was set to 5.66 for all other plants, which the US EPA (2005e) recommends for exposed vegetables.

A sample calculation of the dry weight concentration of arsenic predicted in crowberry due to direct deposition at sample location at LSA-02 during the Operational Phase using Equation 17 is provided below:

$$P_d = \frac{1000 \times D \times R_p \times \left[1.0 - exp\left(-k_p \times T_p\right)\right]}{y_p \times k_p}$$

$$P_d = \frac{1000 \times 0.000000443 \frac{g}{m^2}/year \times 0.0324 \times [1.0 - exp(-18\ year^{-1} \times 0.5\ year)]}{0.25\ DW/m^2 \times 18\ year^{-1}}$$

$$P_d = 0.00000319\ mg/kg$$

The total predicted metal concentration in vegetation species in dry weight was then calculated as the sum of the concentration predicted in the plant due to root uptake and the concentration in the plant due to dust deposition (Equation 18; US EPA 2005e):

$$C_{vegetation-COPC} = C_{COPC-soil\ uptake} + P_d \qquad \text{[Equation 18]}$$

where:

$C_{vegetation\text{-}COPC}$ = total COPC concentration in the vegetation species due to root uptake and dust deposition (mg/kg dry weight)

$C_{COPC\text{-}soil\ uptake}$ = the predicted COPC concentration in the vegetation species due to uptake from the soil (in mg/kg dry weight)

P_d = plant (above ground produce) concentration due to direct deposition (mg COPC/kg dry weight)

A sample calculation using Equation 18 to determine the total arsenic concentration in dry weight in crowberry at sample location LSA-02 during the Operational Phase is provided below:

$$C_{crowberry-arsenic} = C_{arsenic-soil\ uptake} + P_d$$

$$C_{crowberry-arsenic} = 0.0100\frac{mg}{kg} + 0.00000319\frac{mg}{kg}$$

$$C_{crowberry-arsenic} = 0.0100\frac{mg}{kg}$$

Results of the total predicted metal concentration in vegetation species in mg/kg dry weight was converted to mg/kg wet weight using the measured percent moisture and results are presented in Appendix V6-5L for the Construction Phase and Appendix V6-5M for the Operational Phase, along with the measured baseline vegetation concentration.

Table 5.4-15 provides a summary of the 95th percentile COPC concentrations in vegetation species used in the assessment during the Construction and Operational phases.

Table 5.4-15. Predicted Concentrations of Contaminants of Potential Concern in Vegetation Species during the Construction and Operational Phases

	Construction Phase		Operational Phase	
	95th Percentile Concentration in Berry Tissue	95th Percentile Concentration in Lichen Tissue	95th Percentile Concentration in Berry Tissue	95th Percentile Concentration in Lichen Tissue
Arsenic	0.00387	0.205	0.00387	0.205
Cadmium	0.00369	0.150	0.00369	0.150
Chromium	9.80	5.77	9.80	5.77
Copper	1.41	2.82	1.41	2.82
Lead	0.0121	0.787	0.0121	0.787
Manganese	22.4	113	22.5	113
Mercury	0.000502	0.0889	0.000502	0.0890
Nickel	5.31	2.70	5.31	2.70
Selenium	0.0100	0.100	0.0100	0.100
Thallium	0.000201	0.0138	0.000201	0.0138
Zinc	2.24	28.3	2.24	28.3

Notes:
All concentrations are in mg/kg wet weight.
COPC = contaminant of potential concern

<u>Estimated Daily Intake</u>

An EDI for each COPC was calculated for toddlers and adults and was based on the predicted country foods tissue concentrations and the human receptor characteristics for Construction and Operational phases using Equation 5, and methods and assumptions described in Section 5.3.3. A complete description of the food chain model is provided in Appendix V6-5N. The EDI for each country food item for toddler and adult receptors is presented in Tables 5.4-16 and 5.4-17 for the Construction and Operational phases, respectively.

Table 5.4-16. Estimated Daily Intake of Contaminants of Potential Concern from Country Foods by Human Receptors during the Construction Phase

COPC	Estimated Daily Intake of COPC (mg/kg BW/day) by Adult Receptor								EDI_{Total} [a]
	Caribou	Caribou Liver	Caribou Kidney	Arctic Ground Squirrel	Ptarmigan	Berries	Arctic Char	Lake Trout	
Arsenic [b]	3.11E-08	6.34E-10	2.72E-10	8.47E-09	9.48E-07	6.58E-07	1.26E-04	3.27E-06	1.31E-04
Cadmium	1.84E-09	3.87E-09	1.71E-08	8.63E-10	1.11E-07	6.26E-07	1.53E-06	5.38E-07	2.83E-06
Chromium	3.02E-06	-	-	1.13E-06	2.33E-05	1.66E-03	1.20E-05	7.20E-05	1.78E-03
Copper	2.55E-06	1.77E-06	1.44E-07	7.94E-07	1.84E-05	2.40E-04	1.08E-03	7.90E-05	1.42E-03
Lead	2.68E-08	7.33E-08	4.52E-09	7.23E-09	7.15E-06	2.05E-06	5.19E-06	1.74E-05	3.19E-05
Manganese	1.49E-06	-	-	6.22E-07	4.80E-05	3.81E-03	1.27E-04	5.96E-05	4.05E-03
Mercury	3.59E-07	5.91E-07	1.44E-06	2.00E-07	1.75E-08	8.52E-08	NA	NA	2.69E-06
Methylmercury	NA	NA	NA	NA	NA	NA	2.79E-05	2.43E-04	2.71E-04
Nickel	1.73E-06	-	-	6.42E-07	6.01E-08	9.02E-04	7.08E-05	4.39E-05	1.02E-03
Selenium	6.30E-09	-	-	2.76E-09	8.68E-07	1.70E-06	3.55E-04	1.32E-04	4.90E-04
Thallium	1.13E-07	-	-	2.79E-08	2.35E-06	3.42E-08	1.28E-06	2.37E-06	6.17E-06
Zinc	6.41E-08	1.53E-09	9.39E-10	2.91E-08	1.84E-06	3.81E-04	4.96E-03	1.07E-03	6.41E-03
COPC	Estimated Daily Intake of COPC (mg/kg BW/day) by Toddler Receptor								EDI_{Total} [a]
	Caribou	Caribou Liver	Caribou Kidney	Arctic Ground Squirrel	Ptarmigan	Berries	Arctic Char	Lake Trout	
Arsenic [b]	7.77E-08	1.58E-09	6.80E-10	2.12E-08	2.37E-06	1.65E-06	3.16E-04	8.17E-06	3.28E-04
Cadmium	4.59E-09	9.68E-09	4.29E-08	2.16E-09	2.78E-07	1.57E-06	3.83E-06	1.35E-06	7.08E-06
Chromium	7.56E-06	-	-	2.83E-06	5.81E-05	4.16E-03	3.01E-05	1.80E-04	4.44E-03
Copper	6.38E-06	4.43E-06	3.61E-07	1.98E-06	4.60E-05	6.00E-04	2.69E-03	1.98E-04	3.55E-03
Lead	6.70E-08	1.83E-07	1.13E-08	1.81E-08	1.79E-05	5.13E-06	1.30E-05	4.34E-05	7.97E-05
Manganese	3.72E-06	-	-	1.56E-06	1.20E-04	9.53E-03	3.18E-04	1.49E-04	1.01E-02
Mercury	8.98E-07	1.48E-06	3.60E-06	5.01E-07	4.38E-08	2.13E-07	NA	NA	6.74E-06
Methylmercury	NA	NA	NA	NA	NA	NA	6.98E-05	6.07E-04	6.77E-04
Nickel	4.31E-06	-	-	1.60E-06	1.50E-07	2.26E-03	1.77E-04	1.10E-04	2.55E-03
Selenium	1.58E-08	-	-	6.91E-09	2.17E-06	4.26E-06	8.88E-04	3.31E-04	1.23E-03

COPC	Estimated Daily Intake of COPC (mg/kg BW/day) by Toddler Receptor								EDI_{Total} [a]
	Caribou	Caribou Liver	Caribou Kidney	Arctic Ground Squirrel	Ptarmigan	Berries	Arctic Char	Lake Trout	
Thallium	2.81E-07	-	-	6.98E-08	5.87E-06	8.56E-08	3.20E-06	5.92E-06	1.54E-05
Zinc	1.60E-07	3.81E-09	2.35E-09	7.26E-08	4.60E-06	9.53E-04	1.24E-02	2.67E-03	1.60E-02

Notes:
(-) = not available
NA = not applicable
COPC = contaminant of potential concern
EDI = estimated daily intake
Grey shaded cells indicate country foods with the highest estimated daily intake for a toddler or adult of a particular COPC.
[a] The total EDI sums the EDIs from all country food species.
[b] Arsenic EDIs are based on inorganic arsenic concentrations. See Section 5.3.3.6 for further explanation.

Table 5.4-17. Estimated Daily Intake of Contaminants of Potential Concern from Country Foods by Human Receptors during the Operational Phase

COPC	Estimated Daily Intake of COPC (mg/kg BW/day) by Adult Receptor								EDI_{Total} [a]
	Caribou	Caribou Liver	Caribou Kidney	Arctic Ground Squirrel	Ptarmigan	Berries	Arctic Char	Lake Trout	
Arsenic [b]	3.11E-08	6.34E-10	2.72E-10	8.47E-09	9.48E-07	6.58E-07	1.26E-04	4.30E-06	1.32E-04
Cadmium	1.84E-09	3.88E-09	1.72E-08	8.65E-10	1.12E-07	6.26E-07	1.59E-06	5.59E-07	2.91E-06
Chromium	3.02E-06	-	-	1.13E-06	2.33E-05	1.66E-03	1.20E-05	7.12E-05	1.78E-03
Copper	2.56E-06	1.78E-06	1.44E-07	7.95E-07	1.84E-05	2.40E-04	1.08E-03	8.41E-05	1.42E-03
Lead	2.68E-08	7.33E-08	4.52E-09	7.23E-09	7.15E-06	2.05E-06	5.19E-06	1.74E-05	3.19E-05
Manganese	1.49E-06	-	-	6.23E-07	4.80E-05	3.82E-03	1.27E-04	6.08E-05	4.06E-03
Mercury	3.59E-07	5.91E-07	1.44E-06	2.00E-07	1.75E-08	8.53E-08	NA	NA	2.70E-06
Methylmercury	NA	NA	NA	NA	NA	NA	2.79E-05	2.64E-04	2.92E-04
Nickel	1.73E-06	-	-	6.42E-07	6.01E-08	9.02E-04	7.08E-05	4.45E-05	1.02E-03
Selenium	6.30E-09	-	-	2.76E-09	8.68E-07	1.70E-06	3.55E-04	1.31E-04	4.89E-04
Thallium	1.13E-07	-	-	2.79E-08	2.35E-06	3.42E-08	1.28E-06	2.48E-06	6.28E-06
Zinc	6.42E-08	1.53E-09	9.40E-10	2.91E-08	1.84E-06	3.81E-04	4.96E-03	1.08E-03	6.43E-03

COPC	Estimated Daily Intake of COPC (mg/kg BW/day) by Toddler Receptor								EDI_{Total} [a]
	Caribou	Caribou Liver	Caribou Kidney	Arctic Ground Squirrel	Ptarmigan	Berries	Arctic Char	Lake Trout	
Arsenic [b]	7.77E-08	1.58E-09	6.80E-10	2.12E-08	2.37E-06	1.65E-06	3.16E-04	1.07E-05	3.31E-04
Cadmium	4.59E-09	9.69E-09	4.29E-08	2.16E-09	2.79E-07	1.57E-06	3.97E-06	1.40E-06	7.27E-06
Chromium	7.56E-06	-	-	2.83E-06	5.82E-05	4.16E-03	3.01E-05	1.78E-04	4.44E-03
Copper	6.39E-06	4.44E-06	3.61E-07	1.99E-06	4.60E-05	6.00E-04	2.69E-03	2.10E-04	3.56E-03
Lead	6.70E-08	1.83E-07	1.13E-08	1.81E-08	1.79E-05	5.13E-06	1.30E-05	4.34E-05	7.97E-05
Manganese	3.72E-06	-	-	1.56E-06	1.20E-04	9.55E-03	3.18E-04	1.52E-04	1.02E-02
Mercury	8.98E-07	1.48E-06	3.61E-06	5.01E-07	4.38E-08	2.13E-07	NA	NA	6.74E-06
Methylmercury	NA	NA	NA	NA	NA	NA	6.98E-05	6.60E-04	7.30E-04
Nickel	4.32E-06	-	-	1.60E-06	1.50E-07	2.26E-03	1.77E-04	1.11E-04	2.55E-03
Selenium	1.58E-08	-	-	6.91E-09	2.17E-06	4.26E-06	8.88E-04	3.27E-04	1.22E-03
Thallium	2.81E-07	-	-	6.98E-08	5.87E-06	8.55E-08	3.20E-06	6.19E-06	1.57E-05
Zinc	1.60E-07	3.82E-09	2.35E-09	7.27E-08	4.61E-06	9.53E-04	1.24E-02	2.70E-03	1.61E-02

Notes:
(-) = not available
NA = not applicable
COPC = contaminant of potential concern
EDI = estimated daily intake
Grey shaded cells indicate country foods with the highest estimated daily intake for a toddler or adult of a particular COPC.
[a] The total EDI sums the EDIs from all country food species.
[b] Arsenic EDIs are based on inorganic arsenic concentrations. See Section 5.3.3.6 for further explanation.

An assessment of the EDIs in country foods shows that during Construction (Table 5.4-16) and Operational (Table 5.4-17) phases, toddlers and adults had the highest EDI for: mercury from consuming caribou kidney; chromium, manganese, and nickel from consuming berries; arsenic, cadmium, copper, selenium, and zinc from consuming Arctic Char; and lead, methylmercury, and thallium from consuming Lake Trout. The lowest EDIs of COPCs were associated with the consumption of caribou whole body, caribou liver, Arctic ground squirrel, and willow ptarmigan.

5.4.3 Toxicity Assessment

5.4.3.1 Introduction

The TRV assessment is the same as that presented in Section 5.3.4 of the existing conditions HHRA. The same TRVs for COPCs used in the existing conditions HHRA (Section 5.3.4.2) were used in the Project-related HHRA.

5.4.4 Risk Characterization

5.4.4.1 Introduction

Using the results of the exposure assessment and TRV assessment, health risks to adult and toddler land users and off-duty workers were quantified by calculating HQs for both the Construction and Operational phases. The HQ is the ratio between the EDI and the TRV and provides a measure of risk due to exposure to a COPC through the various exposure pathways. In addition, the ILCR was determined for COPCs (i.e., arsenic) that may be associated with carcinogenic potential via ingestion or inhalation.

5.4.4.2 Estimation of Risks from Exposure to Criteria Air Contaminants

Hazard quotients for the CAC exceedances were calculated by dividing the predicted CAC concentration by the ambient air quality criteria (Table 5.4-18), obtained from either from Canada (CCME 2017b), Nunavut (Government of Nunavut 2011), or BC (BC MOE 2017).

Exceedances of the air quality guidelines for CACs occurred primarily at the worker camp locations. A HQ threshold of 1.0 applies to CACs as inhalation is the only route of exposure to these contaminants, and the majority of the HQs were below 2.

Off-duty workers will likely be indoors during their time off (i.e., majority of that time will be spent sleeping). It is also expected that off-duty workers will not spend much time outside, particularly in the winter, due to the cold Arctic temperatures. Since the air quality model predicted outdoor concentrations, the indoor CAC concentrations that off-duty workers inhale would likely be much lower due to central air conditioning systems in the camps.

During the Operational phase, there were also exceedances of air quality guidelines for NO_2, PM_{10}, and $PM_{2.5}$ at two land user hunting and fishing locations (H1 and F2). However, the majority of HQs for the land user locations were below 2. The H1 location is just outside of the PDA, as it is only 0.43 km from an unpaved Project road. The F2 location is also just outside of the PDA, as it is only 0.16 km from an unpaved Project road. The PDA buffer for roads is 100 m either side; thus, both of these land user locations are just outside of the PDA.

Although it is possible that a land user may pass through the area or use the road, it is unlikely that they would spend 24 hours (or more) adjacent to the road during the occasions when air quality guidelines are exceeded. Thus, the potential exposure time at the two hunting and fishing locations are likely to be less than 24 hours and human health is unlikely to be affected by short-term, transient exposure that may occur in the affected area; therefore, these exceedances are not considered further in this chapter. Contour maps for the predicted CACs during the Construction and Operational phases that show the human receptor locations are provided in Appendix V4-2I (Nunami Stantec 2017b). These contour maps show the geographic extent and magnitude of pollutants emitted from the Project with existing permitted activities.

Contour maps showing CACs and dustfall concentrations during the Construction and Operational phases are provided in Appendices E, F, G, H, I, and J of Appendix V4-2I in Volume 4, Chapter 2. Exceedances of the air quality guidelines for CACs are only predicted to occur during the Construction and Operational phases for a limited time and in a confined area within the atmospheric LSAs (Volume 4, Section 2.6.5). Furthermore, the effects assessment for air quality conducted in Volume 4, Chapter 2 concluded that the effects to air quality were Not Significant for all Project phases.

The air quality dispersion model has been run assuming limited anthropogenic dust and pollution control (Nunami Stantec 2017b). Proposed mitigation measures such as the use of baghouses on mill stacks would substantially reduce the predicted level of CACs, but are not accounted for in the model. The lack of pollution control considered in the model and placement of worker camps in the model domain produces predicted concentrations that are conservative and likely substantially overestimate the potential concentrations of CACs.

Air quality will be monitored and mitigated during the Project phases as described in the Air Quality Management Plan (AQMP; Annex V8-2). The AQMP outlines legislation and guidance relevant to the plan, and describes the potential sources of emissions to the air and the mitigation measures that TMAC will implement during mine construction, operations, and care and maintenance. The plan also describes the air quality monitoring and reporting that will be conducted and is intended primarily for use by TMAC and its contractors to ensure that best practices are employed at the Project, thus ensuring certificate conditions are met and minimal environmental impacts occur.

5.4.4.3 Estimation of Non-carcinogenic Risks from All Exposure Routes for Off-duty Workers

The formula used to calculate the total EDI (in mg/kg BW/day) from all exposure routes was Equation 6 from Section 5.3.5.2 of the existing conditions HHRA. The HQs for the Construction and Operational phases were calculated using Equation 7 from Section 5.3.5.2 of the existing conditions HHRA. Tables 5.4-19, 5.4-20, and 5.4-21 show the Construction and Operational phase COPC EDIs from each exposure route as well as the sum of the COPC EDIs from all exposure routes (EDI_{Total}) and the associated HQs for toddler land users, adult land users, and off-duty workers, respectively.

For non-carcinogenic COPCs, Health Canada (2010b) suggests that an HQ of less than 0.2 indicates that the exposure does not pose a significant health risk to human receptors. An HQ of 0.2 is used (instead of 1.0) because the assessment does not consider intake of contaminants from all potential exposure routes (i.e., from retail foods consumed or other background exposures outside of the study area).

For land user toddlers during the Construction and Operational phases, the HQs for arsenic, chromium, methylmercury, nickel, selenium, and thallium were greater than 0.2 (Table 5.4-19). These are the same COPCs that also had HQs greater than 0.2 in the Existing Conditions HHRA for toddlers (Table 5.3-19). Table 5.4-22 shows the HQs for toddlers during existing conditions, the Construction phase, and the Operational phase as well as the percent change in the HQ between existing conditions and the two Project phases. As shown in the percent change calculations (Table 5.4-22), the largest percent change in risk to toddler health from the Project phases is 9.1% for methylmercury. There was no change in risk from the existing conditions to the Construction and Operational phases for arsenic, selenium, and thallium.

Table 5.4-18. Hazard Quotients for Criteria Air Contaminant Ambient Air Quality Criteria Exceedances

			Construction Phase												Operational Phase											
			Off-duty Workers at:								Land Users at:				Off-duty Workers at:								Land Users at:			
Criteria Air Contaminant	Averaging Period	Ambient Air Quality Criteria Adopted as Toxicity Reference Value [a, b, c] ($\mu g/m^3$)	Doris Camp Air Quality Prediction	Doris Camp HQ	Boston Exploration Camp Air Quality Prediction	Boston Exploration Camp HQ	Boston Operational Camp Air Quality Prediction	Boston Operational Camp HQ	Quarry D Camp Air Quality Prediction	Quarry D Camp HQ	Hunting and Fishing Area H1 Air Quality Prediction	Hunting and Fishing Area H1 HQ	Hunting and Fishing Area H2 Air Quality Prediction	Hunting and Fishing Area H2 HQ	Doris Camp Air Quality Prediction	Doris Camp HQ	Boston Exploration Camp Air Quality Prediction	Boston Exploration Camp HQ	Boston Operational Camp Air Quality Prediction	Boston Operational Camp HQ	Quarry D Camp Air Quality Prediction	Quarry D Camp HQ	Hunting and Fishing Area H1 Air Quality Prediction	Hunting and Fishing Area H1 HQ	Hunting and Fishing Area H2 Air Quality Prediction	Hunting and Fishing Area H2 HQ
NO_2	1-hour	400	NA	NA	NA	NA	464	1.2	668	1.7	NA	NA	684	1.7	NA	NA	NA	NA	553	1.4	NA	NA	NA	NA	NA	NA
	24-hour	200	NA	NA	NA	NA	337	1.7	237	1.2	NA	NA	268	1.3	NA	NA	228	1.1	396	2.0	NA	NA	NA	NA	223	1.1
	Annual	60	83.1	1.4	NA	NA	181	3.0	166	2.8	83.2	1.4	170	2.8	65.4	1.1	NA	NA	201	3.4	NA	NA	66.5	1.1	NA	NA
PM_{10}	24-hour	50	84.9	1.7	73.1	1.5	271	5.4	130	2.6	84.9	1.7	163	3.3	59.5	1.2	171	3.4	299	6.0	84.9	1.7	64.9	1.3	133	2.7
$PM_{2.5}$	24-hour	30	38.4	1.3	NA	NA	132	4.4	72.3	2.4	38.4	1.3	75.0	2.5	NA	NA	69.2	2.3	161	5.4	NA	NA	NA	NA	42.4	1.4
	Annual	10	12.6	1.3	NA	NA	42.8	4.3	31.4	3.1	12.6	1.3	33.8	3.4	NA	NA	15.0	1.5	53.6	5.4	NA	NA	NA	NA	12.0	1.2

Notes:

Each predicted concentration is in units of $\mu g/m^3$ and is the maximum value of two different air quality model cases: the "Madrid North Reference Location" case and the "Madrid North Alternate location" case (where a worker camp is moved 400 m North).

NO_2 = nitrogen dioxide; $PM_{2.5}$ = particulate matter ≤2.5 µm in diameter; PM_{10} = particulate matter ≤10 µm in diameter.

HQ = hazard quotient; calculated as the predicted air contaminant concentration divided by the ambient air quality criteria .

NA = not applicable

[a] CCME (2017); [b] Government of Nunavut (2011); [c] BC MOE (2017).

Table 5.4-19. Risk Characterization for Land User Toddler during Construction and Operational Phases

COPC	Toxicity Reference Value (mg/kg BW/day)	Construction Phase - Land User Toddler							Operational Phase - Land User Toddler						
		Estimated Daily Intake (mg/kg BW/day)						Hazard Quotient	Estimated Daily Intake (mg/kg BW/day)						Hazard Quotient
		Inhalation	Drinking Water	Soil Ingestion	Dermal Contact With Soil	Ingestion of Country Foods	Total (All Exposure Routes)		Inhalation	Drinking Water	Soil Ingestion	Dermal Contact With Soil	Ingestion of Country Foods	Total (All Exposure Routes)	
Arsenic	0.0003	2.93E-09	1.79E-05	1.12E-06	1.23E-09	3.28E-04	3.47E-04	1.2	1.68E-09	2.35E-05	1.12E-06	1.23E-09	3.31E-04	3.55E-04	1.2
Cadmium	0.001	5.87E-10	5.47E-07	7.55E-08	2.78E-11	7.08E-06	7.70E-06	0.0077	3.36E-10	5.67E-07	7.55E-08	2.78E-11	7.27E-06	7.91E-06	0.0079
Chromium	0.001	8.80E-07	2.87E-05	1.98E-05	7.29E-08	4.44E-03	4.49E-03	4.5	5.04E-07	2.84E-05	1.98E-05	7.29E-08	4.44E-03	4.49E-03	4.5
Copper	0.091	6.46E-07	1.03E-04	1.14E-05	2.53E-08	3.55E-03	3.66E-03	0.040	3.70E-07	1.09E-04	1.15E-05	2.53E-08	3.56E-03	3.68E-03	0.040
Lead	0.0006	3.52E-09	4.79E-06	4.53E-06	1.67E-07	7.97E-05	8.92E-05	0.15	2.02E-09	4.78E-06	4.53E-06	1.67E-07	7.97E-05	8.91E-05	0.15
Manganese	0.136	5.46E-06	1.26E-03	1.11E-04	4.10E-06	1.01E-02	1.15E-02	0.085	3.12E-06	1.29E-03	1.11E-04	4.10E-06	1.02E-02	1.16E-02	0.085
Mercury	0.0003	5.87E-11	1.11E-07	1.50E-08	5.53E-10	6.74E-06	6.86E-06	0.023	3.36E-11	1.21E-07	1.50E-08	5.53E-10	6.74E-06	6.88E-06	0.023
Methylmercury	0.00023	NA	NA	NA	NA	6.77E-04	6.77E-04	2.9	NA	NA	NA	NA	7.30E-04	7.30E-04	3.2
Nickel	0.011	4.23E-07	4.26E-05	1.05E-05	3.51E-08	2.55E-03	2.60E-03	0.24	2.42E-07	4.31E-05	1.05E-05	3.51E-08	2.55E-03	2.60E-03	0.24
Selenium	0.0062	2.93E-09	2.10E-05	7.56E-08	2.78E-11	1.23E-03	1.25E-03	0.20	1.68E-09	2.08E-05	7.57E-08	2.78E-11	1.22E-03	1.24E-03	0.20
Thallium	0.00007	5.87E-10	2.29E-07	1.51E-07	5.55E-09	1.54E-05	1.58E-05	0.23	3.36E-10	2.40E-07	1.51E-07	5.55E-09	1.57E-05	1.61E-05	0.23
Zinc	0.48	3.46E-07	1.88E-04	1.78E-05	6.57E-08	1.60E-02	1.62E-02	0.034	1.98E-07	1.90E-04	1.79E-05	6.57E-08	1.61E-02	1.63E-02	0.034

Notes:

COPC = contaminant of potential concern

NA = not applicable

BW = body weight

Hazard quotients greater than 0.2 are shaded grey.

Table 5.4-20. Risk Characterization for Adult Land Users during Construction and Operational Phases

COPC	Toxicity Reference Value (mg/kg BW/day)	Construction Phase - Land User Adult							Operational Phase - Land User Adult						
		Estimated Daily Intake (mg/kg BW/day)						Hazard Quotient	Estimated Daily Intake (mg/kg BW/day)						Hazard Quotient
		Inhalation	Drinking Water	Soil Ingestion	Dermal Contact With Soil	Ingestion of Country Foods	Total (All Exposure Routes)		Inhalation	Drinking Water	Soil Ingestion	Dermal Contact With Soil	Ingestion of Country Foods	Total (All Exposure Routes)	
Arsenic	0.0003	1.23E-09	2.07E-06	1.78E-08	6.17E-10	1.31E-04	1.33E-04	0.44	7.06E-10	2.72E-06	1.78E-08	6.17E-10	1.32E-04	1.35E-04	0.45
Cadmium	0.001	2.47E-10	6.31E-08	1.21E-09	1.39E-11	2.83E-06	2.89E-06	0.0029	1.41E-10	6.55E-08	1.21E-09	1.39E-11	2.91E-06	2.98E-06	0.0030
Chromium	0.001	3.70E-07	3.32E-06	3.17E-07	3.65E-08	1.78E-03	1.78E-03	1.8	2.12E-07	3.28E-06	3.17E-07	3.65E-08	1.78E-03	1.78E-03	1.8
Copper	0.141	2.71E-07	1.18E-05	1.83E-07	1.27E-08	1.42E-03	1.43E-03	0.010	1.55E-07	1.26E-05	1.83E-07	1.27E-08	1.42E-03	1.44E-03	0.010
Lead	0.0013	1.48E-09	5.53E-07	7.24E-08	8.34E-08	3.19E-05	3.26E-05	0.025	8.47E-10	5.52E-07	7.24E-08	8.34E-08	3.19E-05	3.26E-05	0.025
Manganese	0.156	2.29E-06	1.46E-04	1.78E-06	2.05E-06	4.05E-03	4.20E-03	0.027	1.31E-06	1.49E-04	1.78E-06	2.05E-06	4.06E-03	4.21E-03	0.027
Mercury	0.0003	2.47E-11	1.28E-08	2.40E-10	2.77E-10	2.69E-06	2.71E-06	0.0090	1.41E-11	1.39E-08	2.40E-10	2.77E-10	2.70E-06	2.71E-06	0.0090
Methylmercury (general adult population)	0.00047	NA	NA	NA	NA	2.71E-04	2.71E-04	0.58	NA	NA	NA	NA	2.92E-04	2.92E-04	0.62
Methylmercury (sensitive populations)	0.00023	NA	NA	NA	NA	2.71E-04	2.71E-04	1.2	NA	NA	NA	NA	2.92E-04	2.92E-04	1.3
Nickel	0.011	1.78E-07	4.91E-06	1.67E-07	1.76E-08	1.02E-03	1.02E-03	0.093	1.02E-07	4.98E-06	1.68E-07	1.76E-08	1.02E-03	1.03E-03	0.093
Selenium	0.0057	1.23E-09	2.42E-06	1.21E-09	1.39E-11	4.90E-04	4.93E-04	0.086	7.06E-10	2.40E-06	1.21E-09	1.40E-11	4.89E-04	4.91E-04	0.086
Thallium	0.00007	2.47E-10	2.64E-08	2.41E-09	2.78E-09	6.17E-06	6.20E-06	0.089	1.41E-10	2.76E-08	2.41E-09	2.78E-09	6.28E-06	6.31E-06	0.090
Zinc	0.57	1.46E-07	2.17E-05	2.86E-07	3.29E-08	6.41E-03	6.44E-03	0.011	8.33E-08	2.19E-05	2.86E-07	3.29E-08	6.43E-03	6.45E-03	0.011

Notes:

COPC = contaminant of potential concern

NA = not applicable

BW = body weight

Hazard quotients greater than 0.2 are shaded grey.

Table 5.4-21. Risk Characterization for Off-Duty Workers during Construction and Operational Phases

		Construction Phase - Off-Duty Workers														
		Estimated Daily Intake (mg/kg BW/day)											Hazard Quotient for Off-Duty Workers			
COPC	Toxicity Reference Value (mg/kg BW/day)	Inhalation at Doris Camp	Inhalation at Boston Exploration Camp	Inhalation at Boston Operational Camp	Inhalation at Quarry D Camp	Drinking Water	Soil Ingestion	Dermal Contact With Soil	Total for Doris Camp (All Exposure Routes)	Total for Boston Exploration Camp (All Exposure Routes)	Total for Boston Operational Camp (All Exposure Routes)	Total for Quarry D Camp (All Exposure Routes)	Hazard Quotient for Doris Camp	Hazard Quotient for Boston Exploration Camp	Hazard Quotient for Boston Operational Camp	Hazard Quotient for Quarry D Camp
Arsenic	0.0003	5.60E-10	3.59E-10	1.89E-09	1.25E-09	3.36E-06	1.93E-08	1.34E-09	3.38E-06	3.38E-06	3.38E-06	3.38E-06	0.011	0.011	0.011	0.011
Cadmium	0.001	1.12E-10	7.18E-11	3.78E-10	2.50E-10	7.71E-08	1.31E-09	3.01E-11	7.86E-08	7.85E-08	7.88E-08	7.87E-08	0.000079	0.000079	0.000079	0.000079
Chromium	0.001	1.68E-07	1.08E-07	5.67E-07	3.74E-07	6.06E-06	3.43E-07	7.91E-08	6.65E-06	6.59E-06	7.05E-06	6.86E-06	0.0067	0.0066	0.0071	0.0069
Copper	0.141	1.23E-07	7.89E-08	4.16E-07	2.74E-07	1.67E-05	1.98E-07	2.74E-08	1.71E-05	1.70E-05	1.74E-05	1.72E-05	0.00012	0.00012	0.00012	0.00012
Lead	0.0013	6.71E-10	4.31E-10	2.27E-09	1.50E-09	6.06E-07	7.84E-08	1.81E-07	8.66E-07	8.65E-07	8.67E-07	8.66E-07	0.00067	0.00067	0.00067	0.00067
Manganese	0.156	1.04E-06	6.67E-07	3.51E-06	2.32E-06	2.43E-04	1.93E-06	4.45E-06	2.51E-04	2.50E-04	2.53E-04	2.52E-04	0.0016	0.0016	0.0016	0.0016
Mercury	0.0003	1.12E-11	7.18E-12	3.78E-11	2.50E-11	3.38E-08	2.60E-10	6.00E-10	3.47E-08	3.47E-08	3.47E-08	3.47E-08	0.00012	0.00012	0.00012	0.00012
Nickel	0.011	8.06E-08	5.17E-08	2.72E-07	1.80E-07	6.43E-06	1.81E-07	3.81E-08	6.73E-06	6.71E-06	6.93E-06	6.83E-06	0.00061	0.00061	0.00063	0.00062
Selenium	0.0057	5.60E-10	3.59E-10	1.89E-09	1.25E-09	2.85E-06	1.31E-09	3.02E-11	2.85E-06	2.85E-06	2.86E-06	2.86E-06	0.00050	0.00050	0.00050	0.00050
Thallium	0.00007	1.12E-10	7.18E-11	3.78E-10	2.50E-10	6.60E-08	2.62E-09	6.03E-09	7.47E-08	7.47E-08	7.50E-08	7.49E-08	0.0011	0.0011	0.0011	0.0011
Zinc	0.57	6.60E-08	4.23E-08	2.23E-07	1.47E-07	3.64E-05	3.09E-07	7.13E-08	3.68E-05	3.68E-05	3.70E-05	3.69E-05	0.000065	0.000065	0.000065	0.000065

Notes:

COPC = contaminant of potential concern

BW = body weight

Table 5.4-21. Risk Characterization for Off-Duty Workers during Construction and Operational Phases

COPC	Toxicity Reference Value (mg/kg BW/day)	Operational Phase - Off-Duty Workers														
		Estimated Daily Intake (mg/kg BW/day)											Hazard Quotient for Off-Duty Workers			
		Inhalation at Doris Camp	Inhalation at Boston Exploration Camp	Inhalation at Boston Operational Camp	Inhalation at Quarry D Camp	Drinking Water	Soil Ingestion	Dermal Contact With Soil	Total for Doris Camp (All Exposure Routes)	Total for Boston Exploration Camp (All Exposure Routes)	Total for Boston Operational Camp (All Exposure Routes)	Total for Quarry D Camp (All Exposure Routes)	Hazard Quotient for Doris Camp	Hazard Quotient for Boston Exploration Camp	Hazard Quotient for Boston Operational Camp	Hazard Quotient for Quarry D Camp
Arsenic	0.0003	3.24E-10	6.72E-10	2.20E-09	5.08E-10	3.40E-06	1.93E-08	1.34E-09	3.42E-06	3.42E-06	3.42E-06	3.42E-06	0.011	0.011	0.011	0.011
Cadmium	0.001	6.48E-11	1.34E-10	4.40E-10	1.02E-10	7.74E-08	1.31E-09	3.02E-11	7.88E-08	7.88E-08	7.91E-08	7.88E-08	0.000079	0.000079	0.000079	0.000079
Chromium	0.001	9.72E-08	2.02E-07	6.60E-07	1.52E-07	6.11E-06	3.44E-07	7.92E-08	6.63E-06	6.74E-06	7.20E-06	6.69E-06	0.0066	0.0067	0.0072	0.0067
Copper	0.141	7.13E-08	1.48E-07	4.84E-07	1.12E-07	1.69E-05	1.99E-07	2.75E-08	1.72E-05	1.73E-05	1.76E-05	1.72E-05	0.00012	0.00012	0.00012	0.00012
Lead	0.0013	3.89E-10	8.06E-10	2.64E-09	6.10E-10	6.11E-07	7.84E-08	1.81E-07	8.70E-07	8.71E-07	8.73E-07	8.71E-07	0.00067	0.00067	0.00067	0.00067
Manganese	0.156	6.03E-07	1.25E-06	4.09E-06	9.45E-07	2.46E-04	1.93E-06	4.45E-06	2.53E-04	2.53E-04	2.56E-04	2.53E-04	0.0016	0.0016	0.0016	0.0016
Mercury	0.0003	6.48E-12	1.34E-11	4.40E-11	1.02E-11	3.45E-08	2.60E-10	6.00E-10	3.54E-08	3.54E-08	3.54E-08	3.54E-08	0.00012	0.00012	0.00012	0.00012
Nickel	0.011	4.67E-08	9.68E-08	3.17E-07	7.32E-08	6.49E-06	1.82E-07	3.81E-08	6.76E-06	6.81E-06	7.03E-06	6.79E-06	0.00061	0.00062	0.00064	0.00062
Selenium	0.0057	3.24E-10	6.72E-10	2.20E-09	5.08E-10	2.86E-06	1.31E-09	3.02E-11	2.86E-06	2.86E-06	2.86E-06	2.86E-06	0.00050	0.00050	0.00050	0.00050
Thallium	0.00007	6.48E-11	1.34E-10	4.40E-10	1.02E-10	6.62E-08	2.62E-09	6.03E-09	7.49E-08	7.50E-08	7.53E-08	7.49E-08	0.0011	0.0011	0.0011	0.0011
Zinc	0.57	3.82E-08	7.93E-08	2.60E-07	6.00E-08	3.67E-05	3.09E-07	7.13E-08	3.71E-05	3.71E-05	3.73E-05	3.71E-05	0.000065	0.000065	0.000065	0.000065

Notes:

COPC = contaminant of potential concern

BW = body weight

Table 5.4-22. Risk Characterization for Land User Toddler during Existing Conditions, the Construction Phase, and the Operational Phase

COPC	Existing Conditions HQ	Construction Phase HQ	Operational Phase Hazard Quotient	% Change in HQ from Existing Conditions to Construction Phase	% Change in HQ from Existing Conditions to Operational Phase
Arsenic	1.2	1.2	1.2	0	0
Chromium	4.3	4.5	4.5	4.6	4.5
Methylmercury	2.9	2.9	3.2	0	9.1
Nickel	0.23	0.24	0.24	1.1	1.2
Selenium	0.20	0.20	0.20	0	0
Thallium	0.23	0.23	0.23	0	0

Notes:
COPC = contaminant of potential concern
HQ = hazard quotient

For land user adults during the Construction and Operational phases, the HQs for arsenic, chromium, and methylmercury (general public and sensitive populations) were greater than 0.2 (Table 5.4-20). These are the same COPCs that also had HQs greater than 0.2 in the Existing Conditions HHRA for adult land users (Table 5.3-20). Table 5.4-23 shows the HQs for land user adults during existing conditions, the Construction phase, and the Operational phase as well as the percent change in the HQ between existing conditions and the two Project phases. As shown in the percent change calculations (Table 5.4-23), the largest percent change in risk to adult land user health from the Project phases is 9.1% for methylmercury.

Table 5.4-23. Risk Characterization for Land User Adult during Existing Conditions, the Construction Phase, and the Operational Phase

COPC	Existing Conditions HQ	Construction Phase HQ	Operational Phase Hazard Quotient	% Change in HQ from Existing Conditions to Construction Phase	% Change in HQ from Existing Conditions to Operational Phase
Arsenic	0.44	0.44	0.45	0	1.4
Chromium	1.7	1.8	1.8	4.6	4.6
Methylmercury (general adult population)	0.57	0.58	0.62	1.6	9.1
Methylmercury (sensitive populations)	1.2	1.2	1.3	0	9.1

Notes:
COPC = contaminant of potential concern
HQ = hazard quotient

All HQs for off-duty workers at all camps are below the threshold of 0.2 during both the Construction and Operational phases (Tables 5.4-21). Thus no potential risks to off-duty worker health due to exposure to COPCs were identified.

5.4.4.4 Estimation of Cancer Risks

Incremental Lifetime Cancer Risk via the Inhalation Exposure Route

Arsenic, cadmium, chromium, and nickel are considered to be carcinogens via the inhalation route, thus the ILCR was calculated using Equation 8 (Health Canada 2010b) presented in Section 5.3.5.3 of the existing conditions HHRA.

The inhalation cancer unit risk for arsenic is 0.0064 $(\mu g/m^3)^{-1}$, for cadmium is 0.0098 $(\mu g/m^3)^{-1}$, for chromium is 0.011 $(mg/m^3)^{-1}$, and for nickel is 0.0013 $(\mu g/m^3)^{-1}$ (Health Canada 2010c). Since inhalation of arsenic, cadmium, chromium, and nickel can cause lung cancer, the risks are assumed to be additive and are summed (Health Canada 2010b). The predicted concentrations of arsenic, cadmium, chromium, and nickel bound to PM_{10} during the Construction and Operational phases were used in the ILCR calculations (Section 5.4.1.3 and Table 5.4-2). The Construction and Operational phase ILCRs were then summed to provide the total ILCR (Table 5.4-24). The exposure time in the calculations was 4 years for the Construction phase and 10 years for the Operational phase, for a total of 14 years exposed. Section 5.3.5.5 of the existing conditions HHRA provides a sample calculation of the inhalation ILCR.

The summed arsenic, cadmium, chromium, and nickel lifetime ILCRs for adult land users and off-duty workers during the Construction and Operational phases and for the summed Construction and Operational phases (Table 5.4-24) are all less than 1.0×10^{-5}, which according to Health Canada (2010b), is considered to be an acceptable risk benchmark. Thus, there is an acceptable level of risk to human health from inhalation of carcinogenic metals bound to PM_{10} during the Construction and Operational phases combined.

Incremental Lifetime Cancer Risk via the Ingestion and Direct Soil Contact Exposure Route

Of the COPCs evaluated, only arsenic is considered carcinogenic through ingestion. Carcinogenic risks were calculated as ILCR estimates using Equation 9 (Health Canada 2010b) provided in Section 5.3.5.3 of the existing conditions HHRA. Equation 10 (Health Canada 2010b) and Equation 11 provided in Section 5.3.5.3 of the existing conditions HHRA were used to calculate the ELDE from ingestion and $ELDE_{Total}$, respectively.

The oral CSF for arsenic is 1.80 $(mg/kg\ BW/day)^{-1}$ (Health Canada 2010c).

Table 5.4-25 provides the adult land user and off-duty worker arsenic ILCR for each ingestion (drinking water, soil ingestion, , and country foods for land user adults only) and, conservatively, soil contact pathway and the summed arsenic ILCR for all exposure pathways for both the Construction and Operational phases, and for the Construction and Operational phases summed. The exposure time in the calculations was 4 years for the Construction phase and 10 years for the Operational phase, for a total of 14 years exposed. A sample calculation of the arsenic ILCR is provided in Section 5.3.5.3 of the existing conditions HHRA.

The arsenic ILCR for off-duty workers for the Construction and Operational phases summed and for all exposure pathways summed (Table 5.4-25) is less than the threshold of 1.0×10^{-5}; thus, there is an acceptable level of risk to human health from arsenic ingestion and soil contact for off-duty workers during the Construction and Operational phases. However, the arsenic ILCR for adult land users for the Construction (1.2×10^{-5}) and Operational phases (3.0×10^{-5}), and the phases summed (4.2×10^{-5}), exceeds the threshold of 1.0×10^{-5}. The highest contribution to the ILCR is from the ingestion of Arctic Char (4.0×10^{-5} for phases summed).

Table 5.4-24. Incremental Lifetime Cancer Risk (Inhalation Route) during the Construction and Operational Phases

Parameter	Incremental Lifetime Cancer Risk for the Construction Phase					Incremental Lifetime Cancer Risk for the Operational Phase					Summed Incremental Lifetime Cancer Risk				
	Land User Adult	Off-duty Worker at Doris Camp	Off-duty Worker at Boston Exploration Camp	Off-duty Worker at Boston Operational Camp	Off-duty Worker at Quarry D Camp	Land User Adult	Off-duty Worker at Doris Camp	Off-duty Worker at Boston Exploration Camp	Off-duty Worker at Boston Operational Camp	Off-duty Worker at Quarry D Camp	Land User Adult	Off-duty Worker at Doris Camp	Off-duty Worker at Boston Exploration Camp	Off-duty Worker at Boston Operational Camp	Off-duty Worker at Quarry D Camp
Arsenic	1.8E-09	8.3E-10	5.3E-10	2.8E-09	1.8E-09	2.6E-09	1.2E-09	2.5E-09	8.1E-09	1.9E-09	4.4E-09	2.0E-09	3.0E-09	1.1E-08	3.7E-09
Cadmium	5.6E-10	2.5E-10	1.6E-10	8.5E-10	5.6E-10	8.0E-10	3.7E-10	7.6E-10	2.5E-09	5.7E-10	1.4E-09	6.2E-10	9.2E-10	3.3E-09	1.1E-09
Chromium	9.4E-07	4.3E-07	2.7E-07	1.4E-06	9.5E-07	1.3E-06	6.2E-07	1.3E-06	4.2E-06	9.7E-07	2.3E-06	1.0E-06	1.6E-06	5.6E-06	1.9E-06
Nickel	5.3E-08	2.4E-08	1.5E-08	8.1E-08	5.4E-08	7.6E-08	3.5E-08	7.2E-08	2.4E-07	5.5E-08	1.3E-07	5.9E-08	8.8E-08	3.2E-07	1.1E-07
Summed ILCR	**9.9E-07**	**4.5E-07**	**2.9E-07**	**1.5E-06**	**1.0E-06**	**1.4E-06**	**6.5E-07**	**1.4E-06**	**4.4E-06**	**1.0E-06**	**2.4E-06**	**1.1E-06**	**1.6E-06**	**6.0E-06**	**2.0E-06**

Notes:

ILCR = incremental lifetime cancer risk

Table 5.4-25. Incremental Lifetime Cancer Risk from Arsenic Ingestion and Soil Contact during the Construction and Operational Phases

Pathway	Construction Phase				Operational Phase				Summed Incremental Lifetime Cancer Risk for an Land User Adult	Summed Incremental Lifetime Cancer Risk for an Off-duty Worker
	Land User Adult		Off-duty Worker		Land User Adult		Off-duty Worker			
	ELDE for Inorganic Arsenic (mg/kg BW/day)	ILCR for Inorganic Arsenic	ELDE for Inorganic Arsenic (mg/kg BW/day)	ILCR for Inorganic Arsenic	ELDE for Inorganic Arsenic (mg/kg BW/day)	ILCR for Inorganic Arsenic	ELDE for Inorganic Arsenic (mg/kg BW/day)	ILCR for Inorganic Arsenic		
Drinking Water	1.0E-07	1.9E-07	1.7E-07	3.0E-07	3.4E-07	6.1E-07	4.2E-07	7.6E-07	8.0E-07	1.1E-06
Soil Ingestion	8.9E-10	1.6E-09	9.7E-10	1.7E-09	2.2E-09	4.0E-09	2.4E-09	4.3E-09	5.6E-09	6.1E-09
Soil Dermal Contact	3.1E-11	5.6E-11	6.7E-11	1.2E-10	7.7E-11	1.4E-10	1.7E-10	3.0E-10	1.9E-10	4.2E-10
Country Foods										
Caribou	1.6E-09	2.8E-09	NA	NA	3.9E-09	7.0E-09	NA	NA	9.8E-09	NA
Caribou Liver	3.2E-11	5.7E-11	NA	NA	7.9E-11	1.4E-10	NA	NA	2.0E-10	NA
Caribou Kidney	1.4E-11	2.4E-11	NA	NA	3.4E-11	6.1E-11	NA	NA	8.6E-11	NA
Arctic Ground Squirrel	4.2E-10	7.6E-10	NA	NA	1.1E-09	1.9E-09	NA	NA	2.7E-09	NA
Ptarmigan	4.7E-08	8.5E-08	NA	NA	1.2E-07	2.1E-07	NA	NA	3.0E-07	NA
Berries	3.3E-08	5.9E-08	NA	NA	8.2E-08	1.5E-07	NA	NA	2.1E-07	NA
Marine fish (Arctic Char)	6.3E-06	1.1E-05	NA	NA	1.6E-05	2.8E-05	NA	NA	4.0E-05	NA
Freshwater fish (Lake Trout)	1.6E-07	2.9E-07	NA	NA	5.4E-07	9.7E-07	NA	NA	1.3E-06	NA
Total ELDE / ILCR	**6.7E-06**	**1.2E-05**	**1.7E-07**	**3.0E-07**	**1.7E-05**	**3.0E-05**	**4.3E-07**	**7.7E-07**	**4.2E-05**	**1.1E-06**

Notes:

ILCR = incremental lifetime cancer risk

ELDE = estimated lifetime daily exposure

BW = body weight

NA = not applicable

Incremental lifetime cancer risks greater than 1.0 x 10^{-5} are shaded grey.

The percent change between the existing conditions arsenic ILCR (4.1×10^{-5}) and the summed Project phases arsenic ILCR (4.2×10^{-5}) for adult land users is 3.4%. It is unlikely that a change in the ILCR of less than 10% is measurable, and a change in cancer risk from arsenic exposure due to the Project is unlikely to occur.

5.4.5 Uncertainty Analysis

5.4.5.1 Introduction

The uncertainties in the Project-related HHRA (i.e., uncertainties in the selection of COPCs, modeling tissue concentrations, consumption amount and frequency data, and TRVs) are the same as those presented in Section 5.3.6 of the existing conditions HHRA; however, there is an additional level of uncertainty due to modeling of environmental media concentrations that are used in the HHRA calculations for the Project, which replace the measured media concentrations used in the HHRA for the existing condition. There is inherent uncertainty associated with the use of any model as real world processes are simplified and errors can be compounded throughout the modeling process resulting in less accurate model results. Because the HHRA conservatively used predicted 95^{th} percentile media COPC concentrations, the predicted HQs and ILCRs for the Madrid-Boston Project are likely overestimated.

5.4.5.2 Air Quality Modeling

Air dispersion models can predict atmospheric concentrations and deposition levels to a reasonable accuracy but the accuracy is highly dependent on the accuracy of the information being fed into the model (i.e., the model's inputs). The input data with the highest amount of uncertainty is commonly the air emissions inventory and this was the case for the modeling of the air quality for the Project's existing permitted activities.

The emissions inventory was built using a number of information sources, calculations, and assumptions. Some information sources and assumptions were informed by existing information about the Doris Project. At the time of preparing the emissions inventory (December, 2017), the most up-to-date information was used. Note that there may be changes to the Project design before construction as additional planning and detailed engineering design develops.

Where input data uncertainties existed, conservative assumptions were used following regulatory guidance, professional judgement, and experience. The use of conservative assumptions can lead to conservative model predictions and, therefore, the model results of the model study are interpreted with the understanding that the predicted effects are likely overestimated.

5.4.5.3 Surface Water Quality Modeling

The Madrid-Boston Project Water and Load Balance report (P5-4) describes in detail the surface water quality modeling effort and associated assumptions and uncertainties.

5.4.5.4 Soil Quality Modeling

The soil quality predictions adopted the worst-case annual amount of dustfall during each of the four years of the Construction phase and each of the ten years of the Operational phase, leading to a conservative estimate of predicted soil concentrations. It was assumed the metal proportion in dustfall was equivalent to the primary source of dust for each soil sampling location, which was determined from the air quality model results. However, this is a simplification as most sites were affected by several sources of dust, which leads to some uncertainty in the proportions of metals used in the model. It was also assumed that all dust deposited onto soil remains in place, and does not run-off during rain events, which leads to conservative (overestimated) soil metal predictions.

In addition, beryllium, mercury, and tin concentrations in quarry rock samples were not available; therefore, the median beryllium, mercury, and tin concentrations in Boston ore and/or Madrid North ore samples were adopted. This leads to uncertainty with predicted concentrations of these parameters in soil; however, it is likely that these metal concentrations in ore samples are higher than they would be in quarry rock samples.

However, where input data uncertainties existed, conservative assumptions were used which leads to conservative model predictions. Therefore, the predicted soil metal concentrations are interpreted with the understanding that the predicted concentrations are likely overestimated.

5.4.5.5 Vegetation Quality Modeling

The vegetation quality predictions adopted the worst-case annual amount of dustfall during each of the four years of the Construction phase and each of the ten years of the Operational phase, leading to a conservative overestimate of predicted vegetation concentrations.

It was assumed that the metal proportion in dustfall was equivalent to the primary source of dust for each soil sampling location, which was determined from the air quality model results. However, this is a simplification as most sites were affected by several sources of dust, which leads to some uncertainty in the proportions of metals used in the model.

The methodology for predicting vegetation concentrations assumes that there is no loss of metals from soil due to weathering, leaching, run-off, or burial. Thus all dust deposited onto soil and onto plant surfaces is entirely taken into the plant tissues, which leads to conservative overestimation of vegetation metal concentration predictions. It was also assumed that plants would be growing and taking in metals for six months of the year, which is a conservative estimate as they are likely covered by snow for up to eight months of the year.

Where input data uncertainties existed, conservative assumptions were used which leads to conservative model predictions. Therefore, the predicted vegetation metal concentrations are interpreted with the understanding that the predicted concentrations are likely overestimated.

5.4.6 Conclusions

This Project HHRA integrated the results of the environmental media predictive studies, human receptor characteristics, traditional knowledge, and regulatory-recommended TRVs. Existing environmental conditions (e.g., naturally-occurring environmental media concentrations of COPCs) were also considered to enable identification of Project-related sources of risk to human health. This assessment considered potential human health risks associated with the summed exposure to COPCs from several exposure pathways (i.e., inhalation, ingestion of soil, dermal contact with soil, ingestion of drinking water, and ingestion of country foods).

<u>Air Quality Risk Assessment Conclusions</u>

Predicted concentrations of certain CACs (i.e., NO_2, PM_{10}, and $PM_{2.5}$) during the Construction and Operational phases at four off-duty worker camps and two land user locations resulted in HQs that exceeded the threshold of 1.0 (Table 5.4-18). However, the risks to off-duty workers and land users due to inhalation of NO_2, PM_{10}, and $PM_{2.5}$ are likely overestimated because a) the air quality model used worst-case predictions during the Construction and Operational phases, b) off-duty workers will likely be spending time indoors during rest where concentrations of CACs in air will be much lower than those predicted outdoors, and c) land user locations (H1 and H2) represent “worst-case” locations closest to Project infrastructure for much larger hunting and fishing areas and thus, land users are not likely to spend much time at these two locations while traveling, hunting, and fishing in these areas.

Nickel bound to PM_{10} was predicted to exceed applicable guidelines for metals in air at the Boston Operational camp where off-duty workers would reside during the Construction and Operational phases. However, as mentioned above, off-duty workers will likely be spending time indoors during rest where concentrations of nickel in air will be much lower than those predicted outdoors.

COPC Screening Conclusions

Screening for COPCs based on predictive model results indicated that the concentrations of existing-conditions COPCs in soil (i.e., chromium, copper, and nickel) and surface water (i.e., manganese) were predicted to remain within the range of natural variability (i.e., similar to existing conditions), and were included in the assessment for Construction and Operational phases. No additional COPCs were identified. The only COPC identified during the Construction and Operational phases in the screening of fish tissue was mercury. Several metals were considered bioaccumulative, including arsenic, cadmium, lead, mercury, nickel, selenium, thallium, and zinc, and were therefore included in the assessment of risks for land users and off-duty workers.

Lake Trout tissue concentrations of mercury (assumed to be entirely methylmercury) were predicted to exceed consumption guidelines during the Construction and Operational phases, as they did under existing conditions.

Non-carcinogenic Risk Assessment Conclusions

No unacceptable risks were identified for off-duty workers for non-carcinogenic health effects from exposure to COPCs via inhalation of air, ingestion of soil, dermal contact with soil, and ingestion of water, as all HQs were below a HQ of 0.2 (Table 5.4-21). This is consistent with the findings for the existing conditions HHRA for off-duty workers (Section 5.3.5.2).

For toddlers, health risks from non-carcinogenic effects of COPCs, based on the summed HQs from all exposure pathways (inhalation of air, ingestion of soil, dermal contact with soil, and ingestion of water and country foods) exceeded the threshold of 0.2 during the Construction and Operational phases for arsenic, chromium, methylmercury, nickel, selenium, and thallium (Table 5.4-19). However, when the HQs calculated for the Construction and Operational phases were compared to those for the existing conditions, the percent change in the risk was less than 10% (Table 5.4-22). Given the uncertainties inherent in modeling exposure concentrations and risk, it is unlikely that a change in risk less than 10% is measurable, and a change in toddler health due to the Project is unlikely to occur.

For land user adults (for both the general adult population and sensitive populations), health risks from non-carcinogenic effects of COPCs, based on the summed HQs from all exposure pathways (inhalation of air, ingestion of soil, dermal contact with soil, and ingestion of water and country foods) exceeded the threshold of 0.2 during the Construction and Operational phases (Table 5.4-20) for arsenic, chromium, and methylmercury. However, when the HQs calculated for the Construction and Operational phases were compared to those for the existing conditions, the percent change in the risk was less than 10% (Table 5.4-23). Given the uncertainties inherent in modeling exposure concentrations and risk, it is unlikely that a change in risk less than 10% is measurable, and a change in health of a land user adult due to the Project is unlikely to occur.

Incremental Lifetime Cancer Risk Conclusions

For carcinogenic COPCs via the inhalation route (arsenic, cadmium, chromium, and nickel), risk to health of off-duty workers and adult land users was acceptable (Section 5.4.4.4). For arsenic, which is also considered carcinogenic through ingestion, the ILCR for off-duty workers was below the acceptable threshold of 1.0×10^{-5} (Table 5.4-25). However, for adult land users the ILCR for arsenic ingestion during the Construction and Operational phases was elevated above the acceptable threshold of 1.0×10^{-5} (Table 5.4-25). The exceedance was driven by the elevated ILCR from Arctic Char ingestion, which also occurred under existing conditions. The comparison between ILCR during Project phases and the ILCR during existing conditions showed that the percent change was less than 10%. It is unlikely that a change in cancer risk less than 10% is measurable, and a change in human health due to the Project is unlikely to occur.

Uncertainties

There are inherent compounded uncertainties in this assessment, as described in Section 5.4.5 and throughout Section 5.4.2. It is likely that the risk to human health is significantly overestimated due to the conservative assumptions made in the prediction of Project environmental media COPC concentrations and throughout the Project-related HHRA. Conservative, upper-bound estimates of predicted environment media concentrations (i.e., 95th percentile) were used in the calculations and risk levels would likely be substantially lower if other statistics of more central tendency were used (e.g., medians, means, upper confidence limits of the mean, etc.). However, using the 95th percentile ensures that the risk assessment is conservative and that any predicted risks are over-estimated. Further, the estimated daily intake of COPCs was assumed to come from air, water, soil, and country foods within the human health LSA for significant portions of the year (i.e., 6 months per year, 24 hours a day for off-duty workers and three months per year, 24 hours per day for land users). Thus, health risk to off-duty workers and land users due to the Project is likely overestimated.

5.5 EXISTING CONDITIONS ENVIRONMENTAL RISK ASSESSMENT

Many of the features of the existing conditions ERA are the same as the existing conditions HHRA (Section 5.3). Much of the text applies to both assessments and will not be repeated here; instead reference will be made to the existing conditions HHRA where appropriate. Features that are the same in both the HHRA and ERA include: the approach that contains six stages of toxicological risk assessment (Section 5.2; Health Canada 2010b; Environment Canada 2012), and the objectives (consistent with the standard Health Canada and Environment Canada framework; Section 5.3.2; Health Canada 2010b, 2010e; Environment Canada 2012).

A difference between the HHRA and ERA are the spatial boundaries. For the ERA, the LSA and RSA for each of the ecological receptors are based on the LSA and RSA for those specific VECs. For example, the LSA and RSA for terrestrial wildlife VECs such as caribou are equivalent to the terrestrial environment LSA and RSA described in Volume 4, Section 7.2.2, while the LSA and RSA for marine mammals such as seals are equivalent to the marine environment LSA and RSA described in Volume 5, Section 8.4.

The potential effects of noise on wildlife species is described in Volume 4, Chapter 9 (Terrestrial Wildlife and Wildlife Habitat) and Volume 5, Chapter 11 (Marine Wildlife).

5.5.1 Problem Formulation

The purpose of the problem formulation stage of the risk assessment is to create a conceptual model for the existing conditions ERA (see Section 5.5.1.4). This stage identifies data requirements to accurately assess the potential for health effects to ecological receptors due to exposure to COPCs from within their respective LSAs and RSAs. The objectives of the problem formulation stage are to:

- identify potential ecological receptors that may be in the area and their characteristics;
- identify the relevant exposure pathways for ecological receptors; and
- identify and screen the relevant COPCs within the respective LSAs and RSAs.

The existing conditions ERA was performed to assess the potential for adverse effects under existing conditions on key ecological species. The ERA does not consider all potentially affected ecological species, but instead focuses on selected wildlife and aquatic life species identified as VECs in the EIS Guidelines (NIRB 2012), as well as species that represent ecological guilds as described by Environment Canada (2012). These selected wildlife and aquatic species are described in Section 5.5.1.1 and Appendix V6-5E.

5.5.1.1 Wildlife and Aquatic Life Receptors

There are numerous aquatic and terrestrial wildlife species present in the sub-Arctic environment. As it is not practical to evaluate all species that may be present at or around the Project site, representative aquatic and terrestrial wildlife receptors were selected for consideration in the ERA.

Receptor types were identified in accordance with Environment Canada (2012) guidance for selection of ecological receptors for ERAs and considered the following factors:

- Receptor types were included in the assessment to ensure representation of various trophic levels, habitats, and feeding guilds within the environments appropriate for the Project site.
- Species were considered as a potential receptor if they were found at the Project site or in close proximity to the Project site.
- Some species may reside at the Project site year round while others may be expected to be present during particular times or seasons.

Representative ecological receptor types and the species selected to represent those types of receptors considered the wildlife VECs identified for the Project (NIRB 2012) as well as:

- the species is representative of the local ecosystem;
- the species has the greatest potential for exposure;
- the species is considered sensitive to the COPCs;
- the species is of relative social, economic, and/or cultural importance;
- the species plays a key role in the food chain or could be representative of a trophic level within the food chain;
- the species has sufficient characterization data to facilitate the calculation of exposure and risk; and
- the species is of intrinsic ecological significance (e.g., endangered species).

General site characteristics, regional and local habitat surveys, records of environmental conditions, species inventories, and a list of Species at Risk were considered in the selection of potential receptors, as recommended by the Environment Canada (2012) guidelines. A brief description of the potential ecological receptors, as well as the rational for their selection is provided in Table 5.5-1. Additional information on the wildlife receptors can be found in Appendix V6-5E and in the respective VEC chapters.

Table 5.5-1. Ecological Receptor Types and Representative Species

Receptor Group	Receptor Type	Representative Species	Rationale For Selection
Freshwater			
Primary producer	Phytoplankton Periphyton Plants and Algae	Phytoplankton community Periphyton community Plant/algae community	Aquatic primary producer communities are the building blocks of the aquatic food web. The primary exposure pathway for this group of receptors is direct contact with water. A large body of life history and toxicity data is available for these organisms.
Pelagic Invertebrate	Zooplankton Others	Zooplankton community Amphipods	The primary exposure pathway for the pelagic invertebrate community is direct contact with water. A large body of life history and toxicity data is available for pelagic invertebrates.
Benthic Invertebrate	Epifauna Infauna	No representative receptor Benthic invertebrate community	The primary exposure pathway for the benthic invertebrate community is direct contact with water and sediment. A large body of life history and toxicity data is available for benthic organisms.
Fish	Benthivorous	Ninespine Stickleback (*Pungitius pungitius*)	The primary exposure pathway for Ninespine Stickleback is direct contact with sediment and water. They could also be exposed indirectly through trophic effects if a bioaccumulative COPC (e.g., selenium, mercury, some hydrocarbons) were present. Some life history and water toxicity data is available for Stickleback species.
	Planktivorous	Lake Whitefish (*Coregonus clupeaformis*)	The primary exposure pathway for Lake Whitefish is direct contact with water. They could also be exposed indirectly through trophic effects if a bioaccumulative COPC (e.g., selenium, mercury, some hydrocarbons) were present. Limited life history and water toxicity data is available for Lake Whitefish.
	Piscivorous	Lake Trout (*Salvelinus namaycush*)	The primary exposure pathway for Lake Trout is direct contact with water. Lake Trout could also be exposed indirectly through trophic effects if a bioaccumulative COPC (e.g., selenium, mercury, some hydrocarbons) were present. A large amount of life history and water toxicity data is available for Lake Trout. Some food web toxicological studies may also be available for this species.
Mammal	Herbivorous	No representative receptor	No representative receptor
	Piscivorous	No representative receptor	No representative receptor
	Omnivorous	Grizzly bear (*Ursus arctos horribilis)*	Grizzly bear can be directly and indirectly exposed to COPCs via water, soil, and food. Grizzly bears feed on large and small mammals, aquatic and terrestrial plants, and fish. Grizzly bear could be exposed indirectly through trophic effects if a bioaccumulative COPC (e.g., selenium, mercury, some hydrocarbons) were present. A reasonable amount of grizzly bear life history data is available. Limited to no toxicological data is available for grizzly bear. Grizzly bears are not good indicators of localized anthropogenic effects because of their large home range. However, grizzly bears are listed as a Species of Special Concern by COSEWIC (2016).

Receptor Group	Receptor Type	Representative Species	Rationale For Selection
Bird	Herbivorous	Canada goose (*Branta canadensis*)	Canada goose may be present at the Project site during the breeding season and can be directly and indirectly exposed to COPCs via water, sediment, and food (i.e., vegetation). Some life history data is available and some toxicological data is available for geese.
	Insectivorous	Least sandpiper (*Calidris minutilla*)	Least sandpipers are present at the Project site during the breeding season and can be directly and indirectly exposed to COPCs via water, sediment, and food (i.e., aquatic invertebrates). Some life history data is available and some toxicological data is available for sandpipers.
	Piscivorous	Red-breasted merganser (*Mergus serrator*)	Red-breasted mergansers may be present at the Project site during the breeding season and can be directly and indirectly exposed to COPCs via water, sediment, and food (i.e., fish). Some life history data is available and little to no toxicological data is available for mergansers.
	Omnivorous	Long-tailed duck (*Clangula hyemalis*)	Long-tailed duck may be present at the Project site during the breeding season and can be directly and indirectly exposed to COPCs via water, sediment, and food (i.e., aquatic plants, invertebrates, bivalves, fish eggs, and fish). Some life history data is available for long-tailed duck, but limited to no toxicological data is available.
Amphibian Reptile	Carnivorous Omnivorous	No representative receptor	Species ranges of all known amphibians in Nunavut are located to the south and west of the Project site and there are no reptiles found in Nunavut (Canadian Herpetological Society 2012). Therefore, amphibians and reptiles are not expected to be present at the Project site.
Marine Water			
Primary producer	Phytoplankton Periphyton Plants and Algae	Phytoplankton community No representative receptor Plant/algae community	Aquatic primary producer communities are the building blocks of the aquatic food web. The primary exposure pathway for this group of receptors is direct contact with water. A large body of life history and toxicity data is available for these organisms.
Pelagic Invertebrate	Zooplankton Others	Zooplankton community Amphipods	The primary exposure pathway for the pelagic invertebrate community is direct contact with water. A large body of life history and toxicity data is available for pelagic invertebrates.
Benthic Invertebrate	Epifauna Infauna	Bay mussel (*Mytilus trossulus*) Benthic invertebrate community	The primary exposure pathway for the benthic invertebrate community is direct contact with water and sediment. A large body of life history and toxicity data is available for benthic organisms.

Receptor Group	Receptor Type	Representative Species	Rationale For Selection
Fish	Benthivorous	Fourhorn Sculpin (*Myoxocephalus quadricornis*)	The primary exposure pathway for Fourhorn Sculpin is direct contact with sediment and water. They could also be indirectly exposed through trophic effects if a bioaccumulative COPC (e.g., selenium, mercury, some hydrocarbons) were present. Some life history and water toxicity data is available for Sculpin species.
	Planktivorous	Capelin (*Mallotus villosus*)	The primary exposure pathway for Capelin is direct contact with water. They could also be indirectly exposed through trophic effects if a bioaccumulative COPC (e.g., selenium, mercury, some hydrocarbons) were present. Limited life history and water toxicity data is available for Capelin.
	Piscivorous	Arctic Char (*Salvelinus alpinus*)	The primary exposure pathway for Arctic Char is direct contact with water. They could also be indirectly exposed through trophic effects if a bioaccumulative COPC (e.g., selenium, mercury, some hydrocarbons) were present. A large amount of life history data is available for Arctic Char but limited and water toxicity data is available.
Mammal	Herbivorous	No representative receptor	No representative receptor
	Piscivorous	Ringed seal (*Phoca hispida*)	Ringed seal may be present at the Project site the entire year and can be directly and indirectly exposed to COPCs via water, sediment, and food (i.e., fish). Some life history data and toxicity data is available for this species. The ringed seal is listed by (COSEWIC 2016) as Not at Risk and they are more abundant than bearded seals in the area.
	Omnivorous	No representative receptor	No representative receptor
Bird	Herbivorous	Brant (*Branta bernicla*)	Brant may be present at the Project site during the breeding season and can be directly and indirectly exposed to COPCs via water, sediment, and food (i.e., plants). Some life history data is available but limited to no toxicological data is available for brant.
	Insectivorous	No representative receptor	No representative receptor
	Piscivorous	No representative receptor	No representative receptor
	Omnivorous	Herring gull (*Larus smithsonianus*)	Herring gull may be present at the Project site during the breeding season and can be directly and indirectly exposed to COPCs via water, sediment, and food (i.e., aquatic plants, invertebrates, bivalves, fish eggs, and fish). Some life history data is available for but limited to no toxicological data is available for herring gull.
Amphibian Reptile	Carnivorous Omnivorous	No representative receptor	Species ranges of all known amphibians in Nunavut are located to the south and west of the Project site and there are no reptiles found in Nunavut (Canadian Herpetological Society 2012). Therefore, amphibians and reptiles are not expected to be present at the Project site.

Receptor Group	Receptor Type	Representative Species	Rationale For Selection
Terrestrial			
Primary producer	Moss/grass/shrub/tree/forb	Plant community	The plant community consists of primary producers at the lowest trophic level of the terrestrial food chain. The primary exposure pathway for this group of receptors is direct contact with soil and water. Some data on life history and toxicity data are available for these organisms.
Invertebrate	Ground-dwelling Aerial	Invertebrate community Dipterans	The primary exposure pathway for the terrestrial invertebrate community is direct contact with soil and soil ingestion. Some data on life history and toxicity data are available for these communities.
Mammal	Herbivorous (large)	Caribou (*Rangifer tarandus*) and Muskox (*Ovibos moschatus*)	Caribou and muskox can be directly and indirectly exposed to COPCs via water, soil, and food (i.e., vegetation). However, similar to most terrestrial mammals, the greatest exposure is via soil ingestion. A reasonable amount of data is available on caribou and muskox life history. Some toxicological data is available for caribou. Caribou are an important cultural and socioeconomic species to people in Nunavut and the Dolphin-Union herd is listed as Special Concern by COSEWIC (2016) and federally on Schedule 1 SARA (2002). Caribou are not good indicators of localized anthropogenic effects because of their large home range; however, muskox has a smaller home range.
	Herbivorous (small)	Arctic ground squirrel (*Spermophilus parryii*)	Arctic ground squirrel can be directly and indirectly exposed to COPCs via water, soil, and food (i.e., vegetation). However, similar to most terrestrial mammals, the greatest exposure is via soil ingestion. A reasonable amount of data is available on their life history but little toxicological data is available. Arctic ground squirrels are good indicators of localized anthropogenic effects because of their small home range.
	Insectivorous	Arctic shrew (*Sorex arcticus*)	Arctic shrew can be directly and indirectly exposed to COPCs via water, soil, and food. Insects constitute the diet of the Arctic shrew. Some life history data is available but limited to no toxicological data is available for the Arctic shrew.
	Carnivorous (large)	Wolf (*Canis lupus arctos*)	Wolves can be directly and indirectly exposed to COPCs via water, soil, and food (i.e., mammals). However, similar to most terrestrial mammals, the greatest exposure is via soil ingestion. A reasonable amount of data is available on their life history but little toxicological data is available.
	Carnivorous (small)	Wolverine (*Gulo gulo*)	Wolverines can be directly and indirectly exposed to COPCs via water, soil, and food (i.e., mammals and birds). However, similar to most terrestrial mammals, the greatest exposure is via soil ingestion. A reasonable amount of data is available on their life history but little toxicological data is available. Wolverines are listed as Species of Special Concern by COSEWIC (2016).
	Omnivorous (large)	Grizzly bear (*Ursus arctos horribilis*)	See section above on grizzly bear (freshwater omnivore).

Receptor Group	Receptor Type	Representative Species	Rationale For Selection
	Omnivorous (small)	Northern red-backed vole (*Myodes rutilus*)	Northern red-backed vole can be directly and indirectly exposed to COPCs via water, soil, and food. They mostly feed on vegetation but also consume terrestrial invertebrates. Some life history data is available but limited to no toxicological data is available for northern red-backed vole.
Bird	Herbivorous	Willow ptarmigan (*Lagopus lagopus*)	Willow ptarmigan may be present at the Project site during the breeding season and can be directly and indirectly exposed to COPCs via water, soil, and food (i.e., plants). Some life history data is available for willow ptarmigan, but limited to no toxicological data is available.
	Insectivorous	Yellow warbler (*Setophaga petechia*)	Yellow warbler may be present at the Project site during the breeding season and can be directly and indirectly exposed to COPCs via water, soil, and food (i.e., insects). Some life history data is available but limited to no toxicological data is available for yellow warbler.
	Carnivorous	Peregrine falcon (*Falco peregrinus*)	Peregrine falcon may be present at the Project site during the breeding season and can be directly and indirectly exposed to COPCs via water, soil, and food (i.e., birds and small mammals), especially if a bioaccumulative COPC were to be identified. Some life history data is available for peregrine falcon, but limited to no toxicological data is available. Peregrine falcons are listed as Species of Special Concern by COSEWIC (2016) and federally on Schedule 1 under SARA (2002).
	Omnivorous	American tree sparrow (*Spizella arborea*)	American tree sparrow may be present at the Project site during the breeding season and can be directly and indirectly exposed to COPCs via water, soil, and food (i.e., vegetation and insects). Some life history data is available but limited to no toxicological data is available for American tree sparrow.
Amphibian Reptile	Carnivorous Omnivorous	NA	Species ranges of all known amphibians in Nunavut are located to the south and west of the Project site and there are no reptiles found in Nunavut (Canadian Herpetological Society 2012). Therefore, amphibians and reptiles are not expected to be present at the Project site.

Notes:
COPC = contaminant of potential concern
COSEWIC = Committee on the Status of Endangered Wildlife in Canada
NA = not applicable
The marine aquatic biota VEC is represented by the: marine phytoplankton community, marine plant/algae community, marine zooplankton community, marine amphipod, bay mussel, marine benthic invertebrate community, Fourhorn Sculpin, Capelin, and Arctic Char.
The freshwater aquatic biota VEC is represented by the: freshwater phytoplankton community, freshwater periphyton community, freshwater plant/algae community, freshwater zooplankton community, freshwater amphipod, freshwater benthic invertebrate community, Ninespine Stickleback, Lake Whitefish, and Lake Trout.
The seabird VEC is represented by: brant and herring gull.
The marine wildlife VEC is represented by: ringed seal.
The "less conspicuous species that may be maximally exposed to contaminants" VEC is represented by: Arctic ground squirrel, Arctic shrew, and northern red-backed vole.
The migratory bird VEC is represented by: Canada goose, least sandpiper, red-breasted merganser, long-tailed duck, yellow warbler, and American tree sparrow.
The raptor VEC is represented by: peregrine falcon.

Ecological Receptor Characteristics

The characteristics of ecological receptors included in the existing conditions ERA are provided in Tables V6-5E7 and V6-5E8 of Appendix V6-5E. Appendix V6-5E describes the characteristics of the species modeled, which includes parameters such as body weight, ingestion rates (i.e., food, water, soil), the diet of each species, the proportion of each food item in the diet, and exposure time in the area. For species considered to be prey of other species (e.g., Arctic ground squirrel and fish), only fish and bay mussels have measured baseline tissue metal concentrations. Therefore a food chain model was used to calculate COPC concentrations in the tissue of prey species (Appendix V6-5E).

5.5.1.2 Exposure Pathways for Ecological Receptors

There are several potential exposure pathways between baseline COPCs in environmental media to ecological receptors. The exposure routes that may exist between COPCs and ecological receptors depend on many factors which may be direct, indirect, or both. Ecological receptors could be exposed to COPCs in environmental media directly by ingesting water, soil, sediment, and vegetation. Uptake of COPCs can also occur indirectly through the food chain by ingesting prey items.

Exposure pathways were selected for the ERA based on the exposure from:

- ingestion of soil or sediment;
- dermal contact with sediment (aquatic species only);
- gill uptake (fish and benthic invertebrates);
- ingestion of water;
- ingestion of terrestrial prey that have taken up COPCs through the ingestion of soil, vegetation, and surface water;
- ingestion of aquatic prey that have taken up COPCs from their diet and surrounding water; and
- ingestion of plants that have taken up COPCs from the soil and water.

Ecological receptor exposure to contaminants via inhalation and dermal contact are not pathways usually considered in ERAs (Environment Canada 2012). Wildlife TRVs for inhalation and dermal contact are unavailable. In addition, fur and feathers are effective at blocking most materials from direct contact with the skin and the ingestion pathway is expected to be a much larger contributor to wildlife exposure, while inhalation and dermal exposures are expected to be very small contributors (Sample et al. 1997; BC MOE 2013). Even species such as marine mammals and seabirds that spend the majority of their life in direct contact with seawater absorb very little through the skin (Walker et al. 2001). Thus, terrestrial wildlife exposure to contaminants via the inhalation and dermal contact pathways were not considered in the existing conditions ERA.

However, it is possible that some ecological receptors could uptake COPCs via dermal contact. The dermal contact route was included for aquatic VECs, where benthic invertebrates have a large surface area to volume ratio and are embedded in sediments and water. Therefore, the dermal exposure route may be a significant portion of benthic invertebrates' COPC exposure and thus was include for aquatic VECs.

5.5.1.3 Contaminants of Potential Concern Selected for Evaluation

The existing conditions ERA focused on metals as the COPCs since they naturally occur in environmental media (e.g., air, soil or sediment, and water) due to local physical and geological processes and their concentrations could potentially change due to future Project activities. The present assessment did not consider other contaminants such as POPs and radionuclides as these are not typically associated with metal mining and are unlikely to be affected by Project-related activities.

Specific contaminants were selected as COPCs if they met at least one of the following screening criteria:

1. The maximum contaminant concentration in soil samples considered in the assessment exceeded its CCME soil quality guideline value for agricultural land use or residential parkland use (CCME 2017a).
2. The maximum total contaminant concentration in freshwater and marine water samples included in the assessment exceeded its CCME guideline for the protection of freshwater aquatic life, marine aquatic life, or the protection of livestock (CCME 2017a).
3. The maximum total contaminant concentration in freshwater and marine sediment samples included in the assessment exceeded the CCME freshwater and marine sediment quality guidelines for the protection of aquatic life (CCME 2017a).
4. The maximum total contaminant concentration in fish and shellfish tissue exceeded the CCME methylmercury tissue residue guideline for the protection of wildlife consumers of aquatic biota (CCME 2017a) or the BC MOE selenium tissue residue guideline for fish/shellfish consumption by wildlife (Beatty and Russo 2014).
5. The contaminant has a potential to bioaccumulate in organisms or biomagnify in food webs, such that there could be significant transfer of the COPC from soil to plants and subsequently into higher trophic levels. Information on the bioaccumulation/biomagnification potential of each COPC was obtained from a review of relevant documents from the Joint FAO/WHO Expert Committee on Food Additives (JECFA) and the United States Environmental Protection Agency (US EPA; JECFA 1972, 1982; US EPA 1997b; JECFA 2000; US EPA 2000b; JECFA 2005, 2007a, 2011).

Contaminant concentrations in vegetation were also measured within the terrestrial LSA. However, there are no vegetation tissue residue guidelines for comparison so the vegetation data were not included in the COPC screening procedure.

Using the maximum contaminant concentrations from these environmental media for COPC screening provides a conservative approach in the selection of the COPCs within the respective LSAs and RSAs.

Environmental media data collected from within the respective LSAs that were used to selection COPCs for the existing conditions ERA include:

- contaminant concentrations in soil samples collected from 68 sites in 2010 and 2014 (Figure 7.2-1 in Volume 4, Chapter 7: Landforms and Soils);
- contaminant concentrations in surface water samples collected from 21 stream sites and 13 lake sites during Project baseline studies between 2007 and 2017 (Figures 4.2-3 and 4.2-4 in Volume 5, Chapter 4: Freshwater Water Quality);
- contaminant concentrations in freshwater sediment samples collected from 16 stream sites and 13 lake sites during Project baseline studies between 2007 and 2017 (Figures 5.2-3 and 5.2-4 in Volume 5, Chapter 5: Freshwater Sediment Quality);

- contaminant concentrations in freshwater fish tissue samples collected from 12 sites during Project baseline studies in 2006, 2007, 2009, and 2010 as part of the *Doris North Gold Mine Project 2010 Aquatic Effects Monitoring Program* (Table 6.2-12, and Figures 6.2-16 and 6.2-17 in Volume 5, Chapter 6: Freshwater Fish);
- contaminant concentrations in bivalve tissue samples (i.e., bay mussel) collected from three sites (Figure 5.5-1) in 2010 as part of the *Doris North Gold Mine Project 2010 Aquatic Effects Monitoring Program Report* (Rescan 2011a);
- contaminant concentrations in marine water samples collected from several sites within Roberts Bay during Project baseline studies between 2007 and 2016 (see Figure 8.2-3 in Volume 5, Chapter 8: Marine Water Quality);
- contaminant concentrations in marine sediment samples collected from 18 sites in Roberts Bay during Project baseline studies between 2009 and 2016 (Figure 9.2-3 in Volume 5, Chapter 9: Marine Sediment Quality); and
- contaminant concentrations in marine fish (i.e., Arctic Char) tissue samples collected from Roberts Bay in 2017 (the 2017 Arctic Char sampling locations are described in Appendix V5-10F).

The MDL is the detectable concentration achievable by the analytical laboratory based on the chemistry of the sample. For the purpose of statistically summarizing the data, when COPC concentrations in environmental media were below the MDL, a value of half the MDL was used. Although this methodology for addressing what are essentially missing values does not capture the true frequency distribution of the concentrations (Nosal, Legge, and Krupa 2000), assigning values to undetected concentrations in this manner is conservative and a common practice where it can be assumed the values are not zero, but where the level of risk is low enough not to warrant additional statistical analyses (i.e., with regards to ecological receptor health; US EPA 2000a).

<u>Contaminants of Potential Concern in Soil</u>

The soil quality screening that was conducted for the existing conditions HHRA (Section 5.3.2.3 and Table 5.3-6) also applies to the existing conditions ERA as the lowest of the human health and environmental health guideline was selected for the screening process; thus the screening procedure is not repeated here. As shown in Table 5.3-6, the maximum baseline concentrations of chromium, copper, and nickel in soil exceeded the CCME guidelines and are thus COPCs.

<u>Contaminants of Potential Concern in Water</u>

Freshwater

To select COPCs, the existing conditions ERA used the CCME guidelines for the protection of freshwater aquatic life (CCME 2017a) for fish and aquatic life, and CCME guidelines for the protection of agriculture – livestock (CCME 2017a) for all other wildlife VECs. Parameters were selected as COPCs if the maximum concentration in the LSA exceeded the applicable guidelines (Table 5.5-2).

As shown in Table 5.5-2, none of the parameters exceeded the CCME water quality guidelines for livestock; therefore, there are no COPCs in surface water that are applicable to terrestrial wildlife.

As shown in Table 5.5-2, the COPCs identified (i.e., exceeded CCME freshwater aquatic life guidelines) in freshwater that are applicable to freshwater fish and aquatic life were: chloride, fluoride, aluminum, chromium, copper, iron, selenium, and zinc.

Table 5.5-2. Screening Results for Selection of Contaminants of Potential Concern in Surface Water

Parameters	Units	CCME Water Quality Guidelines [a]		Maximum Surface Water Concentration (n=259 - 788)	COPC (Yes/No)
		For the Protection of Aquatic Life - Long Term	For the Protection of Agriculture - Livestock		
Physical Parameters					
Hardness	mg/L	-	-	208	No
pH	pH units	6.5 to 9.0	-	8.51	No
Total Suspended Solids	mg/L	B [b]	3,000	198	No
Turbidity	NTU	B [c]	-	218	No
Nutrients					
Nitrate (as N)	mg/L	13	-	1.06	No
Nitrite (as N)	mg/L	0.06	10	0.0200	No
Ammonia	mg/L	P	-	0.260	No
Phosphorus (total)	mg/L	T [d]	-	<0.3	No
Cyanide					
Free cyanide	mg/L	0.005	-	0.00200	No
Major Anions					
Chloride	mg/L	120	-	306	**Yes**
Fluoride	mg/L	0.12 [e]	2	1.65	**Yes**
Sulphate	mg/L	-	1,000	48.0	No
Total Metal					
Aluminum	mg/L	0.1	5	3.90	**Yes**
Arsenic	mg/L	0.005	0.025	0.00493	No
Beryllium	mg/L	-	0.1	0.0000825	No
Boron	mg/L	1.5	5	0.0980	No
Cadmium	mg/L	0.000284	0.08	0.000193	No
Calcium	mg/L	-	1,000	53.5	No
Chromium	mg/L	0.001 (CrVI); 0.0089 (CrIII) [e]	0.05	0.00739	**Yes**
Cobalt	mg/L	-	1	0.00236	No
Copper	mg/L	0.00400	0.5	0.0156	**Yes**
Iron	mg/L	0.3	-	3.97	**Yes**
Lead	mg/L	0.00700	0.1	0.00528	No
Mercury	mg/L	0.000026	0.003	0.0000120	No
Molybdenum	mg/L	0.073 [e]	0.5	0.00115	No
Nickel	mg/L	0.150	1	0.00701	No
Selenium	mg/L	0.001	0.05	0.00657	**Yes**
Silver	mg/L	0.00025	-	0.000117	No
Thallium	mg/L	0.0008	-	0.0000180	No
Uranium	mg/L	0.015	0.2	0.00112	No
Vanadium	mg/L	-	0.1	0.00890	No

Parameters	Units	CCME Water Quality Guidelines [a]		Maximum Surface Water Concentration (n=259 - 788)	COPC (Yes/No)
		For the Protection of Aquatic Life - Long Term	For the Protection of Agriculture - Livestock		
Zinc	mg/L	0.03	50	0.372	**Yes**

Notes:
B = dependent on background levels
P = dependent on pH and temperature. For a pH of 8.5 and temperature ranging between 0 and 10 °C, the guideline ranges from 0.343 to 0.749 mg/L. The guideline increases as pH decreases, thus pH lower than the maximum shown would have a less conservative guideline.
For calculation purposes, values that were below the method detection limit were replaced with values that were half of the method detection limit.
[a] *CCME (2017a).*
[b] *In clear flow, maximum increase of 25 mg/L from background levels for short-term exposure (e.g., 24 h period). Maximum average increase of 5 mg/L from background levels for long-term exposure (e.g., 30 d period). In high flow, maximum increase of 25 mg/L from background levels between 25 to 250 mg/L. If background is ≥250 mg/L, TSS should not increase more than 10% of background levels.*
[c] *In clear flow maximum increase of 8 NTUs from background levels for short-term exposure (e.g., 24 h period). Maximum average increase of 2 NTUs from background levels for a long-term exposure (e.g., 30 d period). In high flow, maximum increase of 8 NTUs from background levels between 8 to 80 NTUs. If background is > 80 NTUs, turbidity should not increase more than 10%.*
[d] *Trigger ranges: <0.004 mg/L ultra-oligotrophic; 0.004-0.01 mg/L oligotrophic; 0.01-0.02 mg/L mesotrophic; 0.02-0.035 mg/L meso-eutrophic; 0.035-0.1 mg/L eutrophic; >0.1 mg/L hyper-eutrophic.*
[e] *Interim guideline.*
Grey shading indicates exceedance of the CCME guideline.

Marine Water

Marine primary producers, invertebrates, and fish were assessed in the EIS Volume 5, Chapter 8 (Marine Water Quality), Chapter 9 (Marine Sediment Quality), and Chapter 10 (Marine Fish) as part of the marine environment assessment. Details of the baseline sampling program can be found in Volume 5, Sections 8.2, 9.2, and 10.2 and in Appendices V5-7A (Rescan 2010b), V5-7B (Rescan 2011i), and V5-7C (Rescan 2011j). Marine water quality sampling sites are shown in Figure 8.2-3 in Volume 5, Chapter 8: Marine Water Quality.

Contaminants of Potential Concern

To determine the COPCs in marine water, the baseline parameter concentrations were compared to the short-term and long-term CCME marine water quality guidelines for the protection of aquatic life (CCME 2017a). The maximum concentrations of the parameters in marine water were used to determine if the parameter was a COPC (Table 5.5-3).

Table 5.5-3. Screening Results for Selection of Contaminants of Potential Concern in Marine Water

Parameters	Units	CCME Marine Water Quality Guidelines [a]		Maximum Detectable	COPC (Yes/No)
		Short-term	Long-term		
Physical Tests					
Hardness (as $CaCO_3$)	mg/L	-	-	5500	No
pH	pH	-	7.0 - 8.7	8.1	No
Salinity (EC)	g/L	-	B [c]	28.5	No
Total Suspended Solids	mg/L	-	B [d]	78.6	No
Turbidity	NTU	B [b]	B [b]	46.1	No

Parameters	Units	CCME Marine Water Quality Guidelines [a]		Maximum Detectable	COPC (Yes/No)
		Short-term	Long-term		
Anions and Nutrients					
Nitrate (as N)	mg/L	1500	200	0.409	No
Phosphorus (P) Total	mg/L	-	F	0.169	No
Total Metals					
Arsenic	mg/L	-	0.0125	0.0287	**Yes**
Cadmium	mg/L	-	0.00012	0.000102	No
Chromium	mg/L	-	0.0015 (CrVI); 0.056 (CrIII)	0.0317	**Yes**
Mercury	mg/L	-	0.000016	0.0000960	**Yes**
Silver	mg/L	0.0075	-	<0.001	No

Notes:
B = dependent on background levels
F = use guidance framework
For calculation purposes, values that were below the method detection limit were replaced with values that were half of the method detection limit.
[a] CCME (2017a).
[b] In clear flow maximum increase of 8 NTUs from background levels for short-term exposure (e.g., 24-h period). Maximum average increase of 2 NTUs from background levels for a long-term exposure (e.g., 30-d period). In high flow, maximum increase of 8 NTUs from background levels between 8 and 80 NTUs. If background is >80 NTUs, turbidity should not increase more than 10%.
[c] Interim guideline. Human activities should not cause the salinity (expressed as parts per thousand [%]) of marine and estuarine waters to fluctuate by more than 10% of the natural level expected at that time and depth.
[d] In clear flow, maximum increase of 25 mg/L from background levels for short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from background levels for long-term exposure (e.g., between 24-h and 30-d). In high flow, maximum increase of 25 mg/L from background levels between 25-250 mg/L. If background is ≥250 mg/L, total suspended solids should not increase more than 10% of background levels.
Grey shading indicates exceedance of the CCME guideline.

As shown in Table 5.5-3, the COPCs identified in marine water were: arsenic, chromium, and mercury. Furthermore, chromium was identified as a COPC because it exceeded the hexavalent chromium water quality guideline; however, the concentration is of total chromium. Therefore, inclusion of chromium as a COPC in marine water is a conservative measure.

Sediment Quality

Freshwater Sediment Samples

Freshwater sediment quality was assessed in the EIS Volume 5, Chapter 5 (Freshwater Sediment Quality) as part of the surface water environment assessment. Details of the baseline sampling program can be found in Volume 5, Section 5.2 and in Rescan (2010d, 2011g).

Lake and stream sediment quality sampling was conducted for the Project between 2007 and 2017. Full details on the sampling methodology and results are presented in Volume 5, Section 5.2.3 and sampling locations are shown in Figures 5.2-3 and 5.2-4 in Volume 5, Chapter 5: Freshwater Sediment Quality.

To determine COPCs in lake and stream sediments, the maximum baseline metal concentrations in lake and stream sediments were compared to the CCME freshwater sediment quality guidelines for the protection of aquatic life (Table 5.5-4; CCME 2017a). The CCME has provided freshwater interim sediment quality guidelines (ISQGs) and probable effects levels (PELs; CCME 2017a), both of which were used in the screening of COPCs in sediment. The ISQGs are conservative empirical thresholds below which no effects on freshwater benthic organisms are expected to occur, while the PELs are thresholds that describe the sediment concentration at which biological effects are likely to occur.

Table 5.5-4. Screening Results for Selection of Contaminants of Potential Concern in Lake and Stream Sediment Samples, 2007 to 2017

Parameter	CCME Sediment Quality Guidelines [a] ISQG	PEL	Maximum Concentration in Lakes	COPC (Yes/No)	Maximum Concentration in Streams	COPC (Yes/No)
Metals						
Arsenic	5.9	17	30.1	**Yes**	17.8	**Yes**
Cadmium	0.6	3.5	0.330	No	0.370	No
Chromium	37.3	90	91.0	**Yes**	193	**Yes**
Copper	35.7	197	60.8	**Yes**	58.4	**Yes**
Lead	35	91.3	15.1	No	9.50	No
Mercury	0.17	0.486	0.0807	No	0.134	No
Zinc	123	315	111	No	87.1	No

Notes:
All units in mg/kg dry weight
CCME = Canadian Council of Ministers of the Environment
ISQG = Interim Sediment Quality Guideline
PEL = Probable Effects Level
[a] CCME (2017a).
For calculation purposes, values that were below the method detection limit were replaced with values that were half of the method detection limit.
Grey shading indicates exceedance of the CCME guideline.

As shown in Table 5.5-4, the maximum baseline concentrations of arsenic, chromium, and copper in lake and stream sediments exceeded the CCME (2017a) ISQGs and/or PELs and are COPCs.

Marine Sediment Samples

Marine sediment quality was assessed in the EIS Volume 5, Chapter 9 (Marine Sediment Quality) as part of the marine environment assessment. Details of the baseline sampling program can be found in Volume 5, Section 9.2 and in Rescan (2010b, 2011i, 2011j), and in the *Doris North Project Aquatic Effects Monitoring Program* reports from 2010 to 2015, which are available on the Nunavut Water Board (NWB) FTP site (ftp://ftp.nwb-oen.ca/).

Marine sediment quality sampling was conducted for the Project in Roberts Bay from 2007 to 2016 (n = 103). The sampling locations are shown in Figure 9.2-3 in Volume 5, Chapter 9: Marine Sediment Quality. Full details on the sampling methodology, raw data, and results are presented in Volume 5, Section 9.2. Marine sediment samples were obtained from shallow (0 to 10 m) and deep sites (greater than 10 m) in Roberts Bay.

To determine the COPCs in marine sediments, the maximum baseline metal concentrations in marine sediments were compared to the CCME marine ISQGs and PELs for the protection of aquatic life (Table 5.5-5; CCME 2017a).

Polycyclic aromatic hydrocarbons (PAHs) were analyzed in sediment samples collected from Roberts Bay in 2009 and 2010. Data from those samples were screened against available marine CCME ISQGs and PELs (Table 5.5-5; CCME 2017a); however, PAH concentrations in all samples were below MDLs. Hydrocarbons were also analyzed but there are no marine CCME ISQGs or PELs for hydrocarbons.

Table 5.5-5. Screening Results for Selection of Contaminants of Potential Concern in Marine Sediments from Roberts Bay, 2007 to 2016

Parameters	CCME Guidelines for the Protection of Aquatic Life [a]		Maximum	COPC (Yes/No)
	ISQG	PEL		
Metals				
Arsenic	7.24	41.6	51.9	**Yes**
Cadmium	0.7	4.2	0.230	No
Chromium	52.3	160	72.4	**Yes**
Copper	18.7	108	29.3	**Yes**
Lead	30.2	112	9.70	No
Mercury	0.13	0.70	0.0189	No
Zinc	124	271	85.2	No
Polycyclic Aromatic Hydrocarbons				
Acenaphthene	0.00671	0.0889	<0.005	No
Acenaphthylene	0.00587	0.128	<0.005	No
Anthracene	0.0469	0.245	<0.004	No
Benz(a)anthracene	0.0748	0.693	<0.01	No
Benzo(a)pyrene	0.0888	0.763	<0.01	No
Chrysene	0.108	0.846	<0.01	No
Dibenz(a,h)anthracene	0.00622	0.135	<0.005	No
Fluoranthene	0.113	1.494	<0.01	No
Fluorene	0.0212	0.144	<0.01	No
2-Methylnaphthalene	0.0202	0.201	0.0150	No
Naphthalene	0.0346	0.391	<0.01	No
Phenanthrene	0.0867	0.544	<0.01	No
Pyrene	0.153	1.398	<0.01	No

Notes:
ISQG = Interim Sediment Quality Guideline
PEL = Probable Effects Level
Units are mg/kg dry weight.
For calculation purposes, values that were below the method detection limit were replaced with values that were half of the method detection limit.
[a] *Canadian marine sediment quality guidelines for the protection of aquatic life (CCME 2017a).*
Grey shading indicates exceedance of the CCME guideline.

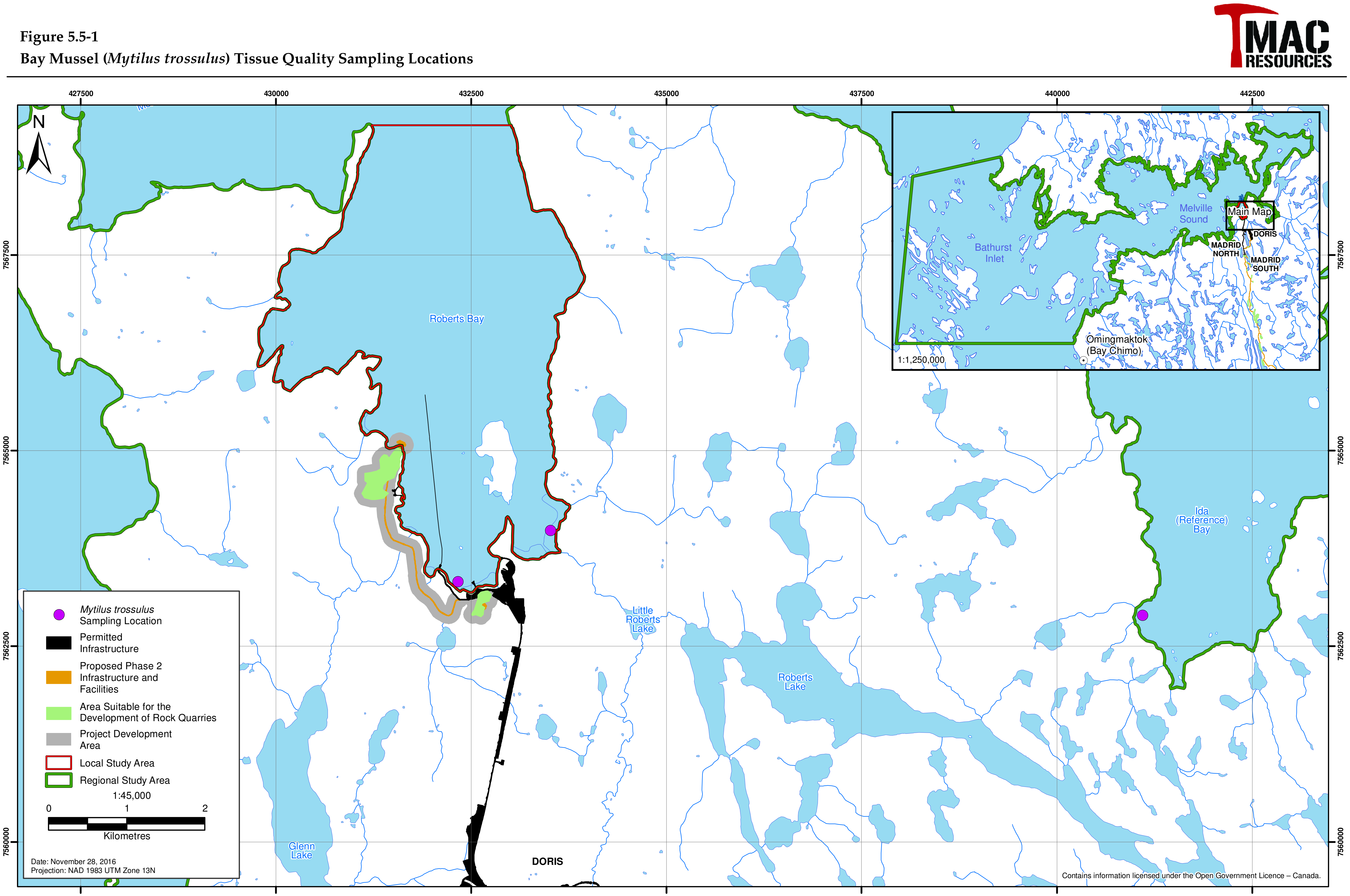
As shown in Table 5.5-5, the maximum baseline concentrations of arsenic, chromium, and copper in marine sediments exceeded the CCME ISQGs and are thus COPCs. Only the maximum arsenic concentration also exceeded the CCME PEL (Table 5.5-5).

<u>Contaminants of Potential Concern in Fish or Shellfish Tissue</u>

Marine Bivalves

Bay mussel (*Mytilus trossulus)*, were collected in August of 2010 for the *Doris North Gold Mine Project 2010 Aquatic Effects Monitoring Program Report* (Rescan 2011a). Samples were collected from two sites in Roberts Bay (RBW and RBE; n = 20) and one site in Reference Bay (REF; n = 24), as shown in Figure 5.5-1. Only eight mussels from each site had tissue metals analysis conducted. Three of the samples from Reference Bay (also known as Ida Bay) and two from each of RBE and RBW were also analyzed for PAHs. The raw data is presented in Appendix V6-5N.

Figure 5.5-1
Bay Mussel (*Mytilus trossulus*) Tissue Quality Sampling Locations



The maximum total contaminant concentration in mussel tissue was screened against the CCME methylmercury tissue residue guideline for the protection of wildlife consumers of aquatic biota (0.033 mg/kg ww; CCME 2017a). The maximum total contaminant concentration in mussel tissue was also screened against the BC MOE selenium tissue residue guideline for fish/shellfish consumption by wildlife (1 mg/kg ww; Beatty and Russo 2014). Screening results are presented in Table 5.5-6.

Table 5.5-6. Screening Results for Selection of Contaminants of Potential Concern in Mussel Tissue (*Mytilus trossulus*)

Parameter	Maximum	COPC (yes/no)
% Moisture	93.4	NA
Mercury (mg/kg ww)	0.0221	No
Selenium (mg/kg ww)	0.983	No

Notes:
NA = not applicable
The CCME methylmercury tissue residue guideline for the protection of wildlife consumers of aquatic biota (0.033 mg/kg ww; CCME 2017a) was not exceeded.
*The BC MOE (*Beatty and Russo 2014*) fish tissue consumption guideline for wildlife for selenium (1 mg/kg ww) was not exceeded.*

For fish and shellfish, it is typically assumed that 100% of the total mercury concentration is in the form of methylmercury, although the proportion of methylmercury might be slightly less than 100% (Health Canada 2007a). Since the actual concentrations of methylmercury are likely less than the total mercury concentration, this assumption ensures that the ERA is conservative.

As shown in Table 5.5-6, none of the baseline mercury or selenium concentrations in bay mussel tissue exceeded the CCME or the BC MOE tissue residue guidelines; thus, no COPCs were identified in bay mussel tissue.

Freshwater and Marine Fish Species

The same freshwater and marine fish species muscle tissue metal data included in the existing conditions HHRA (i.e., Arctic Char and Lake Trout; Section 5.3.2.2) were included in the existing conditions ERA. However, freshwater Ninespine Stickleback and Whitefish whole-body tissue metal data was also included for the ERA as they could potentially be consumed by wildlife species. There were 134 Ninespine Stickleback tissue samples collected from freshwater streams and lakes in the 2010 baseline study (Rescan 2011h) and the 2010 AEMP (Rescan 2011a). There were seven Whitefish tissue samples collected from freshwater streams and lakes in 2009.

For fish tissue COPC screening, the wildlife consumption guidelines were used in the existing conditions ERA (Table 5.5-7). The maximum total contaminant concentration in fish tissue was screened against the CCME methylmercury tissue residue guideline for the protection of wildlife consumers of aquatic biota (0.033 mg/kg ww; CCME 2017a) and the BC MOE fish tissue consumption guideline for wildlife for selenium (1 mg/kg ww; Beatty and Russo 2014).

Like shellfish, it is typically assumed that 100% of the total mercury concentration in fish is in the form of methylmercury, although the proportion of methylmercury might be slightly less than 100% (Bloom 1992; Health Canada 2007a). Again, this assumption ensures that the ERA is conservative.

Table 5.5-7. Screening Results for Selection of Contaminants of Potential Concern in Fish Tissue (Arctic Char 2017; Lake Trout 2009 and 2010; Whitefish 2009; Ninespine Stickleback 2010)

Parameter	Arctic Char	Lake Trout	Whitefish	Ninespine Stickleback	COPC (yes/no)
% Moisture	76.5	82.5	82.0	78.7	No
Maximum Concentration (mg/kg ww)					
Mercury	0.0492	1.80	0.338	0.178	**Yes**
Selenium	0.616	0.640	0.280	0.610	No

Notes:
ww = wet weight
Grey highlighting indicates exceedance of the CCME (2017a) methylmercury tissue residue guideline for the protection of wildlife consumers of aquatic biota (0.033 mg/kg ww).
*The BC MOE (*Beatty and Russo 2014*) selenium tissue residue guideline for fish/shellfish consumption by wildlife (1 mg/kg ww) was not exceeded.*

As shown in Table 5.5-7, the maximum baseline mercury concentrations in the tissue of Lake Trout, Whitefish, and Ninespine Stickleback exceeded the CCME methylmercury tissue residue guideline for the protection of wildlife consumers of aquatic biota (0.033 mg/kg ww; CCME 2017a). None of the selenium concentrations in fish tissue exceeded the BC MOE selenium tissue residue guideline for fish/shellfish consumption by wildlife (Beatty and Russo 2014). Therefore, mercury was the only COPC identified in fish tissue that is applicable to wildlife.

Final List of Contaminants of Potential Concern for Ecological Receptors

The COPCs identified in the baseline soil quality screening (see Section 5.5.1.3 and Table 5.3-6) were: chromium, copper, and nickel.

The COPCs identified in the baseline surface water quality screening (see Section 5.5.1.3 and Table 5.5-2) were: aluminum, chloride, chromium, copper, fluoride, iron, selenium, and zinc.

The COPCs identified in the baseline marine water quality screening (see Section 5.5.1.3 and Table 5.5-3) were: arsenic, chromium, and mercury.

The COPCs identified in the baseline lake and stream sediment quality screening (see Section 5.5.1.3 and Table 5.5-4) were: arsenic, chromium, and copper.

The COPCs identified in the baseline marine sediment quality screening (see Section 5.5.1.3 and Table 5.5-5) were: arsenic, chromium, and copper.

The only COPC identified in the baseline fish tissue screening (see Section 5.5.1.3 and Table 5.5-7) was mercury, which is assumed to be entirely methylmercury. No COPCs were identified in the baseline bay mussel tissue screening (see Section 5.5.1.3 and Table 5.5-6).

As mentioned in the existing conditions HHRA (Section 5.3.2.3), certain metals are considered bioaccumulative due to their elevated BCFs. Thus even if the concentrations of those metals in environmental media are lower than guidelines they were carried forward as COPCs. These metals include:

- arsenic (ATSDR 2007a);
- cadmium (ATSDR 2012);

- lead (ATSDR 2007b);
- mercury (ATSDR 1999);
- nickel (ATSDR 2005a);
- selenium (ATSDR 2003);
- thallium (ATSDR 1992); and
- zinc (ATSDR 2005b).

Based on the screening methodology outlined above, the COPCs selected for the existing conditions ERA include: aluminum, arsenic, cadmium, chloride, chromium, copper, fluoride, iron, lead, mercury, nickel, selenium, thallium, and zinc. However, chloride, fluoride, and iron only apply to freshwater aquatic life receptors (i.e., primary producers, pelagic and benthic invertebrates, and fish).

5.5.1.4 Conceptual Model

A simplified schematic diagram of the pathways by which ecological receptors may be exposed to baseline levels of COPCs in the environment is depicted in Figure 5.5-2. The COPCs in environmental media can be taken up by ecological receptors through the ingestion exposure route (i.e., ingestion of water, soil, sediment, and food), and gill uptake (aquatic organisms only).

5.5.2 Exposure Assessment

5.5.2.1 Introduction

The amount of COPCs that ecological receptors are exposed to depends on several factors including:

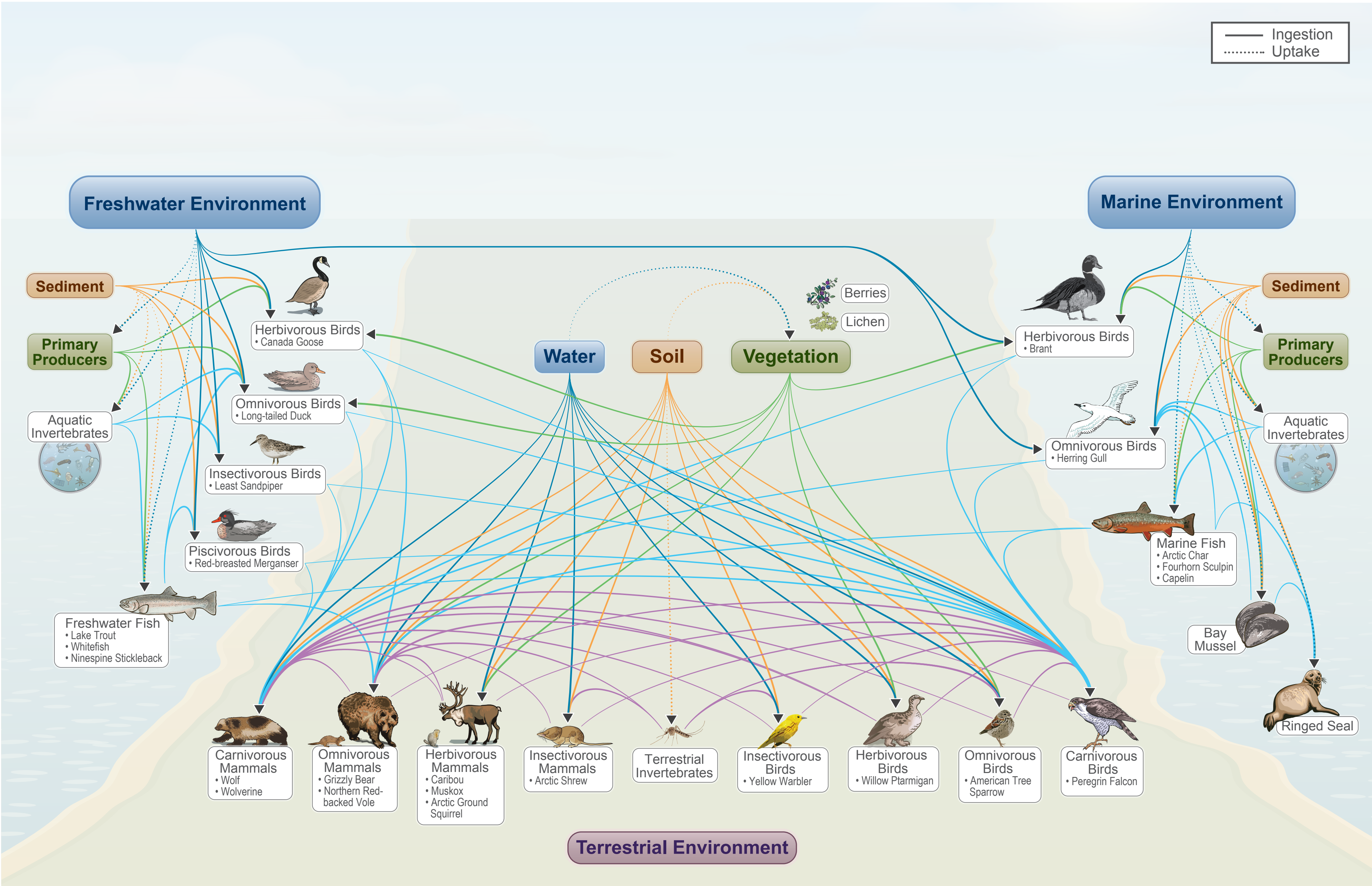
- the concentrations of COPCs in water ingested;
- the concentration of COPCs in soil (via incidental ingestion);
- the concentration of COPCs in sediment (via incidental ingestion or dermal exposure for aquatic organisms);
- the concentration of COPCs resulting from ingestion of vegetation and prey items and the proportion of those items in the diet;
- receptor characteristics (e.g., ingestion rates and body weights; as described in Appendix V6-5E).

The parameters listed above are included in the exposure estimate equations to determine the EDI of each COPC through the various exposure pathways. The calculations of EDI are based on either measured COPC concentrations in media (e.g., water, soil, sediment, vegetation, fish, mussels) or modeled COPC concentration estimates based on a food chain model (see Appendix V6-5E). The food chain model incorporates measured COPC concentrations in environmental media to estimate the EDI from food consumption for the ecological receptors: caribou, muskox, wolverine, grizzly bear, wolves, Arctic ground squirrel, Arctic shrew, northern red-backed vole, willow ptarmigan, American tree sparrow, peregrine falcon, Canada goose, red-breasted merganser, least sandpiper, long-tailed duck, herring gull, yellow warbler, brant, and ringed seals.

The sections below provide information how the EDI of each COPC was calculated for the different exposure routes for ecological receptors. The exposure routes are depicted in the conceptual model (Figure 5.5-2) and described in Section 5.5.1.2. For wildlife species, the COPC EDIs from each exposure route were then summed to determine the total EDI to a species, which was then used in the calculation of HQs by dividing the total EDI by the TRV.

Figure 5.5-2

Conceptual Model for Potential Exposure to Contaminants of Potential Concern for Ecological Receptors under Existing Conditions



Since TRVs for aquatic species (i.e., aquatic primary producers, pelagic and benthic invertebrates, fish, and bay mussels) are in mg/L, an EDI does not need to be calculated and the HQ was obtained by dividing the baseline 95th percentile COPC concentration in water and/or sediment by the TRV.

5.5.2.2 Ingestion of Soil and Sediment

The baseline 95th percentile concentrations of COPCs in soil from sites within the terrestrial LSA (Table V6-5E4 in Appendix V6-5E) were used as an input in the equation to calculate the EDI of COPCs terrestrial wildlife species receive from ingestion of soil under baseline conditions.

The baseline 95th percentile concentrations of COPCs in freshwater sediment (lakes and streams) from sites within the freshwater environment LSA (Table V6-5E4 in Appendix V6-5E) were used as an input in the equation to calculate the EDI of COPCs that freshwater species (i.e., Canada goose, least sandpiper, red-breasted merganser, and long-tailed duck) receive from ingestion of freshwater sediment under baseline conditions.

The baseline 95th percentile concentrations of COPCs in marine sediment from sites within the marine wildlife LSA (Table V6-5E4 in Appendix V6-5E) were used as an input in the equation to calculate the EDI of COPCs that marine species (i.e., brant, herring gull, and ringed seal) receive from ingestion of marine sediment under baseline conditions.

The equation used to calculate terrestrial wildlife exposure to COPCs (mg/kg BW/day) from soil/sediment ingestion was:

$$EDI = \frac{C \times IR \times ET \times RAF_{Oral}}{BW} \qquad \text{[Equation 19]}$$

where:

C	= concentration of COPC in soil or sediment (mg/kg)
IR	= receptor soil or sediment ingestion rate (kg/day)
ET	= exposure time (days exposed/365 days)
RAF_{Oral}	= relative absorption factor from the gastrointestinal tract (unitless)
BW	= body weight (kg)

The soil and sediment intake rates and exposure times are presented in Table V6-5E8 of Appendix V6-5E. The COPC EDI via the soil or sediment ingestion exposure route for wildlife species are presented in Table 5.5-8. The assumptions used in the calculation of the EDI of COPCs via ingestion of soil/sediment were as follows:

- baseline soil quality at the 68 sampling sites is representative of baseline soil quality within the terrestrial LSA;
- baseline freshwater sediment quality at the 16 stream sites and 13 lake sites is representative of baseline freshwater sediment quality within the freshwater environment LSA;
- baseline marine sediment quality at the 40 sites in Roberts Bay is representative of baseline marine sediment quality within the marine environment LSA;
- wildlife species are exposed to COPCs for the amount of time they spend in the wildlife LSA, which is the ratio called exposure time (ET; described in Appendix V6-5E);
- wildlife species have the soil or sediment ingestion rates and body weights as presented in Table V6-5E8 of Appendix V6-5E;

- the RAF_{oral} is 1, as it is conservatively assumed that all COPCs ingested are completely bioavailable; and
- COPC concentrations below the MDL were replaced with concentrations of half of the MDL. This may over- or under-estimate the actual COPC concentrations.

A sample calculation of the EDI of aluminum from soil ingestion using Equation 19 is provided below for caribou:

$$EDI = \frac{C \times IR \times ET \times RAF_{Oral}}{BW}$$

$$EDI_{soil} = \frac{21{,}330\frac{mg}{kg} \times 1.34\frac{kg}{day} \times 0.00134 \times 1}{150\ kg\ BW}$$

$$EDI_{soil} = 0.256\ mg/kg\ BW/day$$

5.5.2.3 Ingestion of Freshwater and Marine Water

The baseline 95th percentile concentrations of COPCs from the surface water quality model (13 nodes) were used as an input in the equation to calculate the EDI of COPCs terrestrial wildlife species receive from drinking surface water under baseline conditions. This was done to ensure direct comparisons of water quality in baseline and predicted water quality are possible.

Marine seabirds (i.e., brant and herring gull) have the ability to drink fresh or salt water. Therefore, to be conservative, the higher of the baseline 95th percentile concentrations of COPCs in freshwater or marine water were used as an input in the equation to calculate the EDI of COPCs that seabirds receive from ingestion of drinking water under baseline conditions.

The general equation used to calculate exposure to COPCs (mg/kg BW/day) from freshwater and marine water ingestion is:

$$EDI = \frac{C \times IR \times ET \times RAF_{Oral}}{BW} \qquad \text{[Equation 20]}$$

where:

C = concentration of COPC in water (mg/kg)
IR = receptor water ingestion rate (kg/day)
ET = exposure time (days exposed/365 days)
RAF_{Oral} = relative absorption factor from the gastrointestinal tract (unitless)
BW = body weight (kg)

The freshwater and marine water ingestion rates and exposure times are presented in Table V6-5E8 of Appendix V6-5E. The COPC EDI via the freshwater and marine water exposure route for wildlife species are presented in Table 5.5-8.

Table 5.5-8. Estimated Daily Intake of Contaminants of Potential Concern for Wildlife Species

COPC	Caribou				Muskox				Wolverine				Grizzly Bear					Wolf			
	$EDI_{[veg]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$
Aluminum	1.08E-02	2.56E-01	1.04E-05	2.67E-01	6.84E+00	5.52E+01	7.28E-03	6.20E+01	5.80E+00	6.27E+01	9.95E-03	6.86E+01	1.80E+00	1.28E+00	2.75E+01	3.17E-03	8.20E+00	4.88E-01	5.08E+01	8.63E-03	6.49E-01
Arsenic	6.33E-06	4.54E-05	3.57E-08	5.18E-05	4.01E-03	9.77E-03	2.51E-05	1.38E-02	3.80E-03	1.11E-02	3.43E-05	1.49E-02	1.05E-03	5.58E-04	4.87E-03	1.09E-05	1.74E-03	1.01E-04	9.00E-03	2.97E-05	1.56E-04
Cadmium	4.64E-06	3.01E-06	1.15E-09	7.64E-06	2.93E-03	6.47E-04	8.06E-07	3.58E-03	1.45E-04	7.35E-04	1.10E-06	8.82E-04	7.70E-04	6.43E-05	3.22E-04	3.52E-07	3.10E-04	1.03E-05	5.96E-04	9.57E-07	1.25E-05
Chromium	4.54E-04	7.89E-04	5.90E-08	1.24E-03	2.87E-01	1.70E-01	4.14E-05	4.57E-01	2.21E-02	1.93E-01	5.66E-05	2.15E-01	7.55E-02	5.25E-03	8.46E-02	1.80E-05	4.44E-02	1.31E-02	1.56E-01	4.91E-05	2.20E-03
Copper	1.23E-04	4.61E-04	1.96E-07	5.83E-04	7.75E-02	9.91E-02	1.37E-04	1.77E-01	2.17E-02	1.13E-01	1.88E-04	1.35E-01	2.04E-02	8.06E-03	4.94E-02	5.99E-05	2.09E-02	9.24E-03	9.13E-02	1.63E-04	1.53E-03
Lead	2.44E-05	1.80E-04	9.39E-09	2.05E-04	1.54E-02	3.88E-02	6.59E-06	5.42E-02	4.06E-03	4.41E-02	9.01E-06	4.82E-02	4.04E-03	1.20E-03	1.93E-02	2.87E-06	6.60E-03	8.51E-05	3.57E-02	7.82E-06	4.75E-04
Mercury	2.71E-06	6.08E-07	2.24E-10	3.32E-06	1.71E-03	1.31E-04	1.57E-07	1.85E-03	1.55E-03	1.49E-04	2.15E-07	1.70E-03	4.50E-04	1.89E-03	6.52E-05	6.85E-08	2.30E-04	2.41E-03	1.21E-04	1.86E-07	3.17E-05
Methylmercury	-	-	-	-	-	-	-	-	-	-	-	-	-	7.57E-05	-	-	4.15E-04	-	-	-	1.50E-04
Nickel	2.40E-04	4.17E-04	8.61E-08	6.57E-04	1.52E-01	8.98E-02	6.04E-05	2.41E-01	4.90E-03	1.02E-01	8.26E-05	1.07E-01	3.98E-02	1.92E-03	4.48E-02	2.63E-05	2.32E-02	7.57E-03	8.27E-02	7.16E-05	1.20E-03
Selenium	3.31E-06	3.01E-06	4.31E-08	6.36E-06	2.09E-03	6.47E-04	3.03E-05	2.77E-03	3.61E-03	7.35E-04	4.14E-05	4.39E-03	5.49E-04	2.00E-03	3.22E-04	1.32E-05	7.75E-04	3.28E-05	5.96E-04	3.59E-05	1.41E-04
Thallium	4.22E-07	6.01E-06	4.82E-10	6.43E-06	2.67E-04	1.29E-03	3.38E-07	1.56E-03	2.61E-03	1.47E-03	4.63E-07	4.08E-03	7.00E-05	3.69E-04	6.45E-04	1.48E-07	2.91E-04	3.27E-04	1.19E-03	4.01E-07	2.21E-05
Zinc	9.18E-04	7.11E-04	3.78E-07	1.63E-03	5.80E-01	1.53E-01	2.65E-04	7.34E-01	1.64E-03	1.74E-01	3.63E-04	1.76E-01	1.52E-01	9.33E-02	7.62E-02	1.16E-04	8.64E-02	3.45E-04	1.41E-01	3.15E-04	1.03E-02

Notes:

COPC = contaminant of potential concern

BW = body weight

EDI = estimated daily intake

All EDIs are in mg/kg BW/day.

$EDI_{[veg]}$ = estimated daily intake of COPC from vegetation consumption (mg/kg BW/day)

$EDI_{[soil]}$ = estimated daily intake of COPC from soil consumption (mg/kg BW/day)

$EDI_{[sediment]}$ = estimated daily intake of COPC from sediment consumption (mg/kg BW/day)

$EDI_{[water]}$ = estimated daily intake of COPC from water consumption (mg/kg BW/day)

$EDI_{[prey]}$ = estimated daily intake of COPC from prey consumption (mg/kg BW/day)

$EDI_{[total]}$ = total estimated daily intake of COPC an animal receives from soil, sediment, vegetation, prey, and water consumption (mg/kg BW/day)

(-) = not applicable

Table 5.5-8. Estimated Daily Intake of Contaminants of Potential Concern for Wildlife Species

COPC	Arctic Ground Squirrel				Arctic Shrew				Northern Red-backed Vole					Willow Ptarmigan				American Tree Sparrow				
	$EDI_{[veg]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$
Aluminum	4.60E+00	3.82E+01	5.31E-03	4.28E+01	1.33E+03	4.24E+02	2.21E-02	1.76E+03	2.07E+01	9.35E+02	4.69E+02	1.81E-02	1.42E+03	2.49E+01	5.90E+01	8.90E-03	8.38E+01	3.04E+01	1.37E+03	1.97E+02	1.02E-02	1.60E+03
Arsenic	2.69E-03	6.76E-03	1.83E-05	9.48E-03	1.18E-02	7.51E-02	7.61E-05	8.70E-02	1.21E-02	8.28E-03	8.30E-02	6.24E-05	1.03E-01	1.46E-02	1.04E-02	3.07E-05	2.50E-02	1.78E-02	1.22E-02	3.49E-02	3.53E-05	6.48E-02
Cadmium	1.97E-03	4.48E-04	5.88E-07	2.42E-03	6.82E-02	4.97E-03	2.45E-06	7.31E-02	8.86E-03	4.78E-02	5.50E-03	2.01E-06	6.22E-02	1.07E-02	6.91E-04	9.86E-07	1.14E-02	1.30E-02	7.03E-02	2.31E-03	1.14E-06	8.56E-02
Chromium	1.93E-01	1.17E-01	3.02E-05	3.11E-01	1.86E-01	1.30E+00	1.26E-04	1.49E+00	8.68E-01	1.31E-01	1.44E+00	1.03E-04	2.44E+00	1.04E+00	1.81E-01	5.06E-05	1.23E+00	1.28E+00	1.92E-01	6.06E-01	5.82E-05	2.07E+00
Copper	5.22E-02	6.86E-02	1.00E-04	1.21E-01	4.35E-01	7.61E-01	4.17E-04	1.20E+00	2.34E-01	3.05E-01	8.42E-01	3.42E-04	1.38E+00	2.82E-01	1.06E-01	1.68E-04	3.88E-01	3.44E-01	4.49E-01	3.54E-01	1.93E-04	1.15E+00
Lead	1.04E-02	2.69E-02	4.81E-06	3.72E-02	1.28E-01	2.98E-01	2.00E-05	4.26E-01	4.65E-02	8.97E-02	3.30E-01	1.64E-05	4.66E-01	5.60E-02	4.15E-02	8.06E-06	9.75E-02	6.83E-02	1.32E-01	1.38E-01	9.28E-06	3.39E-01
Mercury	1.15E-03	9.06E-05	1.15E-07	1.24E-03	5.75E-04	1.01E-03	4.77E-07	1.58E-03	5.18E-03	4.03E-04	1.11E-03	3.91E-07	6.69E-03	6.23E-03	1.40E-04	1.92E-07	6.37E-03	7.61E-03	5.93E-04	4.67E-04	2.21E-07	8.67E-03
Methylmercury	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nickel	1.02E-01	6.22E-02	4.41E-05	1.64E-01	1.97E-01	6.90E-01	1.83E-04	8.87E-01	4.57E-01	1.38E-01	7.63E-01	1.50E-04	1.36E+00	5.51E-01	9.60E-02	7.39E-05	6.47E-01	6.72E-01	2.03E-01	3.20E-01	8.50E-05	1.20E+00
Selenium	1.41E-03	4.48E-04	2.21E-05	1.88E-03	1.56E-02	4.97E-03	9.19E-05	2.07E-02	6.31E-03	1.10E-02	5.50E-03	7.53E-05	2.28E-02	7.60E-03	6.91E-04	3.70E-05	8.33E-03	9.28E-03	1.61E-02	2.31E-03	4.26E-05	2.77E-02
Thallium	1.79E-04	8.95E-04	2.47E-07	1.08E-03	3.12E-02	9.94E-03	1.03E-06	4.12E-02	8.05E-04	2.19E-02	1.10E-02	8.42E-07	3.37E-02	9.70E-04	1.38E-03	4.14E-07	2.35E-03	1.18E-03	3.22E-02	4.62E-03	4.76E-07	3.80E-02
Zinc	3.90E-01	1.06E-01	1.94E-04	4.97E-01	9.40E+00	1.18E+00	8.06E-04	1.06E+01	1.75E+00	6.60E+00	1.30E+00	6.61E-04	9.65E+00	2.11E+00	1.63E-01	3.25E-04	2.27E+00	2.58E+00	9.69E+00	5.46E-01	3.74E-04	1.28E+01

Notes:

COPC = contaminant of potential concern

BW = body weight

EDI = estimated daily intake

All EDIs are in mg/kg BW/day.

$EDI_{[veg]}$ = estimated daily intake of COPC from vegetation consumption (mg/kg BW/day)

$EDI_{[soil]}$ = estimated daily intake of COPC from soil consumption (mg/kg BW/day)

$EDI_{[sediment]}$ = estimated daily intake of COPC from sediment consumption (mg/kg BW/day)

$EDI_{[water]}$ = estimated daily intake of COPC from water consumption (mg/kg BW/day)

$EDI_{[prey]}$ = estimated daily intake of COPC from prey consumption (mg/kg BW/day)

$EDI_{[total]}$ = total estimated daily intake of COPC an animal receives from soil, sediment, vegetation, prey, and water consumption (mg/kg BW/day)

(-) = not applicable

Table 5.5-8. Estimated Daily Intake of Contaminants of Potential Concern for Wildlife Species

	Peregrine Falcon				Canada Goose				Red-breasted Merganser				Least Sandpiper				Long-tailed Duck				
COPC	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[sediment]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[sediment]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[sediment]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[prey]}$	$EDI_{[sediment]}$	$EDI_{[water]}$	$EDI_{[total]}$
Aluminum	4.40E+00	7.45E+01	3.39E-03	7.89E+01	5.87E+00	7.68E+01	2.17E-03	8.27E+01	2.05E+00	5.61E+01	3.09E-03	5.81E+01	1.22E+01	2.42E+02	1.08E-02	2.54E+02	4.74E-01	3.38E+00	6.92E+01	3.41E-03	7.31E+01
Arsenic	2.83E-03	1.32E-02	1.17E-05	1.60E-02	3.44E-03	4.99E-02	7.46E-06	5.34E-02	1.35E-03	3.65E-02	1.06E-05	3.78E-02	1.33E-03	1.58E-01	3.71E-05	1.59E-01	2.77E-04	4.30E-04	4.50E-02	1.17E-05	4.57E-02
Cadmium	1.35E-04	8.73E-04	3.75E-07	1.01E-03	2.52E-03	6.85E-04	2.40E-07	3.20E-03	1.58E-03	5.00E-04	3.42E-07	2.08E-03	2.03E-02	2.16E-03	1.19E-06	2.25E-02	2.03E-04	5.51E-03	6.17E-04	3.78E-07	6.33E-03
Chromium	1.03E-02	2.29E-01	1.93E-05	2.39E-01	2.47E-01	2.11E-01	1.23E-05	4.58E-01	2.44E-02	1.54E-01	1.76E-05	1.79E-01	9.04E-01	6.67E-01	6.12E-05	1.57E+00	1.99E-02	2.42E-01	1.91E-01	1.94E-05	4.53E-01
Copper	1.42E-02	1.34E-01	6.39E-05	1.48E-01	6.65E-02	1.37E-01	4.09E-05	2.04E-01	8.52E-02	1.00E-01	5.83E-05	1.85E-01	3.72E+00	4.32E-01	2.03E-04	4.15E+00	5.37E-03	9.97E-01	1.24E-01	6.43E-05	1.13E+00
Lead	3.11E-03	5.24E-02	3.07E-06	5.55E-02	1.32E-02	3.31E-02	1.96E-06	4.63E-02	8.41E-03	2.42E-02	2.80E-06	3.26E-02	2.43E-01	1.04E-01	9.75E-06	3.47E-01	1.07E-03	6.52E-02	2.99E-02	3.09E-06	9.61E-02
Mercury	4.20E-06	1.77E-04	7.32E-08	1.81E-04	1.47E-03	2.48E-04	4.68E-08	1.72E-03	-	1.81E-04	6.67E-08	1.81E-04	-	7.82E-04	2.33E-07	7.82E-04	1.19E-04	-	2.24E-04	7.36E-08	3.42E-04
Methylmercury	1.02E-03	-	-	1.02E-03	-	-	-	-	4.80E-02	-	-	4.80E-02	6.30E-01	-	-	6.30E-01	-	1.71E-01	-	-	1.71E-01
Nickel	5.85E-04	1.21E-01	2.81E-05	1.22E-01	1.30E-01	1.27E-01	1.80E-05	2.57E-01	2.33E-02	9.26E-02	2.56E-05	1.16E-01	1.23E-02	4.00E-01	8.94E-05	4.13E-01	1.05E-02	4.58E-03	1.14E-01	2.83E-05	1.29E-01
Selenium	3.80E-03	8.73E-04	1.41E-05	4.69E-03	1.79E-03	1.70E-03	9.01E-06	3.50E-03	4.25E-02	1.24E-03	1.28E-05	4.37E-02	2.78E-01	5.35E-03	4.48E-05	2.84E-01	1.45E-04	7.65E-02	1.53E-03	1.42E-05	7.82E-02
Thallium	1.87E-03	1.75E-03	1.58E-07	3.62E-03	2.29E-04	8.17E-04	1.01E-07	1.05E-03	9.85E-04	5.97E-04	1.44E-07	1.58E-03	3.70E-02	2.58E-03	5.01E-07	3.96E-02	1.85E-05	9.91E-03	7.37E-04	1.59E-07	1.07E-02
Zinc	6.24E-02	2.06E-01	1.24E-04	2.69E-01	4.98E-01	2.74E-01	7.90E-05	7.72E-01	2.72E+00	2.00E-01	1.13E-04	2.92E+00	8.85E+00	8.64E-01	3.93E-04	9.72E+00	4.02E-02	2.51E+00	2.47E-01	1.24E-04	2.80E+00

Notes:

COPC = contaminant of potential concern

BW = body weight

EDI = estimated daily intake

All EDIs are in mg/kg BW/day.

$EDI_{[veg]}$ = estimated daily intake of COPC from vegetation consumption (mg/kg BW/day)

$EDI_{[soil]}$ = estimated daily intake of COPC from soil consumption (mg/kg BW/day)

$EDI_{[sediment]}$ = estimated daily intake of COPC from sediment consumption (mg/kg BW/day)

$EDI_{[water]}$ = estimated daily intake of COPC from water consumption (mg/kg BW/day)

$EDI_{[prey]}$ = estimated daily intake of COPC from prey consumption (mg/kg BW/day)

$EDI_{[total]}$ = total estimated daily intake of COPC an animal receives from soil, sediment, vegetation, prey, and water consumption (mg/kg BW/day)

(-) = not applicable

Table 5.5-8. Estimated Daily Intake of Contaminants of Potential Concern for Wildlife Species

COPC	Herring Gull				Yellow Warbler				Brant				Ringed Seal		
	$EDI_{[prey]}$	$EDI_{[sediment]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[sediment]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[sediment]}$	$EDI_{[total]}$
Aluminum	1.13E+01	6.52E+01	3.14E-03	7.65E+01	1.98E+03	1.80E+02	1.45E-02	2.16E+03	7.61E+00	1.93E+01	2.77E-03	2.69E+01	6.61E+00	8.69E+01	9.35E+01
Arsenic	3.63E-02	4.81E-02	1.08E-05	8.44E-02	1.75E-02	3.19E-02	4.99E-05	4.95E-02	4.46E-03	1.42E-02	9.54E-06	1.87E-02	4.26E-02	6.41E-02	1.07E-01
Cadmium	7.34E-02	5.26E-04	3.48E-07	7.39E-02	1.01E-01	2.11E-03	1.60E-06	1.03E-01	3.26E-03	1.55E-04	3.07E-07	3.42E-03	4.15E-02	7.00E-04	4.22E-02
Chromium	1.93E+00	1.88E-01	1.78E-05	2.12E+00	2.77E-01	5.54E-01	8.23E-05	8.31E-01	3.20E-01	5.57E-02	1.57E-05	3.76E-01	1.09E+00	2.51E-01	1.34E+00
Copper	2.32E-01	7.75E-02	5.92E-05	3.10E-01	6.47E-01	3.23E-01	2.73E-04	9.70E-01	8.63E-02	2.29E-02	5.23E-05	1.09E-01	3.20E-01	1.03E-01	4.23E-01
Lead	1.93E-02	2.41E-02	2.84E-06	4.34E-02	1.90E-01	1.27E-01	1.31E-05	3.17E-01	1.71E-02	7.12E-03	2.51E-06	2.43E-02	1.18E-02	3.21E-02	4.39E-02
Mercury	-	5.12E-05	6.77E-08	5.13E-05	8.54E-04	4.27E-04	3.13E-07	1.28E-03	1.91E-03	1.51E-05	5.98E-08	1.92E-03	-	6.83E-05	6.83E-05
Methylmercury	4.01E-03	-	-	4.01E-03	-	-	-	-	-	-	-	-	7.16E-03	-	7.16E-03
Nickel	1.04E+00	9.28E-02	2.60E-05	1.13E+00	2.93E-01	2.93E-01	1.20E-04	5.86E-01	1.69E-01	2.74E-02	2.30E-05	1.96E-01	5.99E-01	1.24E-01	7.23E-01
Selenium	1.18E-01	1.54E-03	1.30E-05	1.19E-01	2.32E-02	2.11E-03	6.02E-05	2.54E-02	2.33E-03	4.56E-04	1.15E-05	2.79E-03	1.29E-01	2.05E-03	1.31E-01
Thallium	3.18E-04	7.59E-04	1.46E-07	1.08E-03	4.64E-02	4.22E-03	6.73E-07	5.06E-02	2.97E-04	2.24E-04	1.29E-07	5.21E-04	4.04E-04	1.01E-03	1.41E-03
Zinc	2.37E+00	2.22E-01	1.14E-04	2.59E+00	1.40E+01	4.99E-01	5.28E-04	1.45E+01	6.46E-01	6.57E-02	1.01E-04	7.12E-01	2.20E+00	2.96E-01	2.50E+00

Notes:

COPC = contaminant of potential concern

BW = body weight

EDI = estimated daily intake

All EDIs are in mg/kg BW/day.

$EDI_{[veg]}$ = estimated daily intake of COPC from vegetation consumption (mg/kg BW/day)

$EDI_{[soil]}$ = estimated daily intake of COPC from soil consumption (mg/kg BW/day)

$EDI_{[sediment]}$ = estimated daily intake of COPC from sediment consumption (mg/kg BW/day)

$EDI_{[water]}$ = estimated daily intake of COPC from water consumption (mg/kg BW/day)

$EDI_{[prey]}$ = estimated daily intake of COPC from prey consumption (mg/kg BW/day)

$EDI_{[total]}$ = total estimated daily intake of COPC an animal receives from soil, sediment, vegetation, prey, and water consumption (mg/kg BW/day)

(-) = not applicable

The assumptions used in the calculation of the EDI of COPC via ingestion of freshwater and marine water were as follows:

- Base case baseline surface water quality at the 13 modeling nodes in the surface water quality model is representative of baseline surface water quality within the freshwater environment LSA.
- Baseline marine water quality from Roberts Bay is representative of baseline marine water quality within the marine environment LSA.
- Wildlife species are exposed to COPCs for the amount of time they spend in the wildlife LSA, which is the ratio called exposure time (ET; described in Appendix V6-5E).
- Wildlife species have the freshwater and marine water ingestion rates and body weights as presented in Table V6-5E8 of Appendix V6-5E.
- The RAF_{oral} is 1, as it is conservatively assumed that all COPCs ingested are completely absorbed.

A sample calculation of the EDI of aluminum from freshwater ingestion using Equation 20 is provided below for caribou:

$$EDI = \frac{C \times IR \times ET \times RAF_{Oral}}{BW}$$

$$EDI_{water} = \frac{0.128\frac{mg}{L} \times \frac{9.00L}{day} \times 0.00134 \times 1}{150\ kg\ BW}$$

$$EDI_{water} = 1.04\ x\ 10^{-5}\ mg/kg\ BW/day$$

5.5.2.4 Ingestion of Vegetation

The baseline 95th percentile concentrations of COPCs in vegetation species from 119 sites within the terrestrial LSA (Table V6-5E4 of Appendix V6-5E) were used as an input in the EDI equation to calculate the EDI of COPCs terrestrial wildlife species receive from ingestion of vegetation under baseline conditions.

$$EDI = \frac{C \times IR \times ET \times RAF_{Oral}}{BW} \qquad \text{[Equation 21]}$$

where:

C = concentration of COPC in vegetation (mg/kg)
IR = receptor vegetation ingestion rate (kg/day)
ET = exposure time (days exposed/365 days)
RAF_{Oral} = relative absorption factor from the gastrointestinal tract (unitless)
BW = body weight (kg)

The vegetation ingestion rates and exposure times are presented in Table V6-5E8 of Appendix V6-5E. The COPC EDI via the vegetation ingestion exposure route for wildlife species are presented in Table 5.5-8.

The assumptions used in the calculation of the EDI of COPCs via ingestion of vegetation were as follows:

- Baseline vegetation quality at the 119 sampling sites is representative of baseline vegetation quality within the terrestrial LSA.

- The diets of wildlife species that consume vegetation include solely the vegetation species that were collected in baseline field studies and in the proportions used in the model (i.e., half berries and half lichen).
- Wildlife species are exposed to COPCs for the amount of time they spend in the wildlife LSA, (described in Appendix V6-5E).
- Wildlife species have the vegetation ingestion rates and body weights as presented in Table V6-5E8 of Appendix V6-5E.
- The RAF_{oral} is 1.0, as it is conservatively assumed that all COPCs ingested are completely absorbed.
- COPC concentrations below the MDL were replaced with concentrations of half of the MDL. This may over- or under-estimate the actual COPC concentrations.

A sample calculation of the EDI of aluminum from vegetation ingestion using Equation 21 is provided below for caribou:

$$EDI = \frac{C \times IR \times ET \times RAF_{Oral}}{BW}$$

$$EDI_{vegetation} = \frac{180\,\frac{mg}{kg} \times 6.72\,\frac{kg}{day} \times 0.00134 \times 1}{150\ kg\ BW}$$

$$EDI_{vegetation} = 0.0108\ mg/kg\ BW/day$$

5.5.2.5 Ingestion of Prey (Ingestion via the Food Chain)

<u>Terrestrial Wildlife Prey</u>

Tissue concentrations of COPCs for terrestrial prey species were estimated using a food chain model described in Golder and Associates (2005) and recommended by Health Canada (2010a). The food chain model is described and the prey tissue COPC concentrations are provided in Appendix V6-5E. The modeled baseline COPC concentrations in prey species were used as an input in the EDI equation to calculate the EDI of COPCs that carnivores and omnivores receive from ingestion of prey under baseline conditions. Some carnivores and omnivores consume several prey species, thus the EDI of COPCs from all the applicable prey species were summed for each carnivore and omnivore, depending on which prey items are consumed. The prey items consumed by each carnivore and omnivore species are listed in Table V6-5E7 and Table V6-5E8 of Appendix V6-5E.

For calculations of EDI, the arsenic concentration in diet items was adjusted to account for the amount of inorganic arsenic that is likely to be present, as that is the most toxic form. The inorganic arsenic fraction was used in the calculation of EDI from diet items. For mammalian diet items it was assumed that 70% of the total arsenic was inorganic and for bird diet items it was assumed that 50% of the total arsenic was inorganic (EFSA 2009, 2014). For vegetation it was assumed that 100% of the arsenic was inorganic (Nicholson 2002). For fish and aquatic invertebrates it was assumed that 10% of the arsenic was inorganic (Slejkovec, Bajc, and Doganoc 2004). For soil, water, and terrestrial invertebrate ingestion, it was assumed that 100% of the arsenic was inorganic.

$$EDI = \frac{C \times IR \times ET \times RAF_{Oral}}{BW} \qquad \text{[Equation 22]}$$

where:

C	= concentration of COPC in prey (mg/kg)
IR	= receptor prey or food item ingestion rate (kg/day)
ET	= exposure time (days exposed/365 days)
RAF_{Oral}	= relative absorption factor from the gastrointestinal tract (unitless)
BW	= body weight (kg)

The terrestrial prey intake rates and exposure times are presented in Table V6-5E8 of Appendix V6-5E. The COPC EDI via the terrestrial prey ingestion exposure route for carnivores and omnivores are presented in Table 5.5-8.

The assumptions used in the calculation of the EDI of COPCs via ingestion of terrestrial prey species were as follows:

- modeled baseline terrestrial prey quality is representative of baseline terrestrial prey quality within the wildlife LSA and that the carnivores and omnivores only consume those terrestrial prey species;
- carnivores and omnivores are exposed to COPCs for the amount of time they spend in the wildlife LSA (described in Appendix V6-5E);
- carnivores and omnivores have the vegetation ingestion rates and body weights as presented in Table V6-5E8 of Appendix V6-5E;
- the RAF_{oral} is 1.0, as it is conservatively assumed that all COPCs ingested are completely absorbed; and
- COPC concentrations below the MDL were replaced with concentrations of half of the MDL. This may over- or under-estimate the actual COPC concentrations.

A sample calculation of the EDI of aluminum from caribou ingestion using Equation 22 is provided below for wolverine:

$$EDI_{from\ caribou\ to\ wolverine} = \frac{C \times IR \times ET \times RAF_{Oral}}{BW}$$

$$EDI_{from\ caribou\ by\ wolverine} = \frac{0.0601\,\frac{mg}{kg} \times 0.147\,\frac{kg}{day} \times 1 \times 1}{12.0\ kg\ BW}$$

$$EDI_{from\ caribou\ by\ wolverine} = 0.000737\ mg/kg\ BW/day$$

<u>Aquatic Life Prey</u>

The baseline 95th percentile concentrations of COPCs in tissue of Lake Trout, Whitefish, Arctic Char, and Ninespine Stickleback sampled from within the freshwater fish LSA (Table V6-5E4 in Appendix V6-5E) were used as an input in the EDI equation to calculate the dose of COPCs piscivorous wildlife species (i.e., grizzly bear, wolf, peregrine falcon, red-breasted merganser, long-tailed duck, herring gull, and ringed seal) receive from ingestion of fish under baseline conditions. It was assumed that grizzly bear and peregrine falcon would consume both freshwater and marine fish species, while wolf, red-breasted merganser, and long-tailed duck would only consume freshwater fish species, and herring gull and ringed seal would only consume marine fish species.

The baseline 95th percentile concentrations of COPCs in bay mussels sampled from three sites within the marine environment RSA (Table V6-5E4 in Appendix V6-5E) were used as an input in the EDI equation to calculate the dose of COPCs wildlife species that consume bivalves (i.e., herring gull and ringed seal) receive from ingestion of bivalves under baseline conditions.

The general equation used to calculate exposure to COPCs (mg/kg BW/day) from fish or bivalve ingestion was the same as that presented in Section 5.5.2.2 (Equation 19).

The fish or bivalve ingestion rates and receptor exposure times are presented in Table V6-5E8 of Appendix V6-5E. The COPC EDI via the fish or bivalve ingestion exposure route for piscivorous wildlife species are presented in Table 5.5-8.

The assumptions used in the calculation of the EDI of COPCs via ingestion of fish or bivalves were as follows:

- Baseline freshwater fish quality at the 12 freshwater sampling sites is representative of baseline fish quality within the freshwater environment LSA.
- Baseline marine fish quality at the marine sampling sites in Roberts Bay is representative of baseline fish quality within the marine environment LSA.
- Baseline bivalve quality at the three sampling sites is representative of baseline bivalve quality within the marine environment LSA.
- Piscivorous wildlife species are exposed to COPCs for the amount of time they spend in the freshwater and marine environment LSA (described in Appendix V6-5E).
- Piscivorous wildlife species have the fish ingestion rates and body weights as presented in Table V6-5E8 of Appendix V6-5E.
- The RAF_{oral} is 1, as it is conservatively assumed that all COPCs ingested are completely absorbed.
- COPC concentrations below the MDL were replaced with concentrations of half of the MDL. This may over- or under-estimate the actual COPC concentrations.

A sample calculation of the EDI of aluminum from fish ingestion using Equation 22 is provided below for grizzly bear:

$$EDI_{from\,fish\,for\,grizzly\,bear} = \frac{C \times IR \times ET \times RAF_{Oral}}{BW}$$

$$EDI_{\,from\,fish\,for\,grizzly\,bear} = \frac{16.7\,\frac{mg}{kg} \times 3.91\,\frac{kg}{day} \times 0.458 \times 1}{450\;kg\;BW} 1$$

$$EDI_{fish} = 0.0667\;mg/kg\;BW/day$$

5.5.2.6 Total Estimated Daily Intake

The COPC EDI from each exposure route and the total summed EDI for each wildlife species is presented in Table 5.5-8.

5.5.3 Toxicity Assessment

5.5.3.1 Introduction

Protection goals for ecological receptors can be described and operationalized in the form of assessment and measurement endpoints used to guide the ERA process. With the exception of listed species (e.g., Threatened, Endangered, or of Special Concern), an ERA is concerned with estimating effects on populations, communities, and ecosystems. For the consideration of Species at Risk, effects on an individual level are considered relevant. Every effort was made to obtain low-effects threshold TRVs. Further information on receptor specific protection goals, measurement and assessment endpoints used to guide the ERA are provided in Table 5.5-9.

The TRVs used in this assessment are typically NOAELs, which are the highest concentration used in a toxicity test that results in no observed or measured chronic health effects. The TRVs for mammalian and avian wildlife species in this assessment are presented as the amount of COPC per unit body weight that can be taken into the body each day (e.g., mg/kg BW/day) without appreciable risk of adverse health effects. For aquatic life, TRVs are usually based on concentrations (e.g., mg/L in water, or mg/kg of sediment) in environmental media to which the receptors are directly exposed.

A database and literature search provided appropriate TRVs for each COPC identified in environmental media (i.e., soil, fresh and marine water, fresh and marine sediment, and fish tissue). The database and literature search for TRVs considered the following sources:

- technical appendices included in the CCME guidelines (CCME 2017a);
- US EPA Ecotox Database (US EPA 2017b);
- US EPA Integrated Risk Information System (US EPA 2017d);
- US EPA Ecological Soil Screening Level (Eco-SSL) documents (US EPA 2003b);
- Oak Ridge National Laboratory (ORNL) toxicological benchmarks for wildlife (Sample, Opresko, and Suter 1996); and
- primary literature.

The sections below provide a summary of the TRVs selected for ecological receptors and the applicable environmental media.

5.5.3.2 Toxicity Reference Values

<u>Aquatic Life</u>

For freshwater and marine life (i.e., primary producers, pelagic and benthic invertebrates, and fish), to initially evaluate risk, the 95^{th} percentile concentrations of the COPCs were compared to the freshwater and marine water long-term CCME (2017a) water quality guidelines for the protection of aquatic life (Table 5.5-10). In sediments, the 95^{th} percentile of the COPCs were compared to the CCME (2017a) PELs. Use of the PELs to define the potential for toxicity is justified because the protection goals and assessment endpoints for aquatic life (Table 5.5-9) are at the population or community level.

These comparisons differ from the COPC screening step described in Section 5.5.1.3 (where maximum concentrations were used) since it uses the 95^{th} percentile of COPC concentrations.

Table 5.5-9. Protection Goals for Ecological Receptors

Representative Species	Protection Goal	Assessment Endpoint	Measurement Endpoints - Lines of Evidence
Freshwater			
Phytoplankton community, periphyton community, plant/algal community	Maintain primary producer biomass at the community level as a food source for higher level organisms.	Primary producer community biomass	**Chemistry** - Evaluate receptor exposure via comparison of COPC concentrations in surface water to appropriate media assessment criteria (water quality guidelines or effects based toxicity thresholds).
Pelagic and benthic invertebrates	Maintain invertebrate community biomass at the community level as a food source for higher level organisms.	Invertebrate community biomass	**Chemistry** - Evaluate receptor exposure via comparison of COPC concentrations in surface water to appropriate media assessment criteria (water quality guidelines or effects based toxicity thresholds for mortality, growth, or reproduction).
Ninespine Stickleback (*Pungitius pungitius*) Lake Whitefish (*Coregonus clupeaformis*) Lake Trout (*Salvelinus namaycush*)	Maintain abundance of fish populations as a food source for humans and higher level organisms (e.g., piscivorous fish and wildlife).	Fish population abundance	**Chemistry** - Evaluate receptor exposure via comparison of COPC concentrations in surface water to appropriate media assessment criteria (water quality guidelines or effects based toxicity thresholds for mortality, growth, or reproduction).
Grizzly bear (*Ursus arctos horribilis*) [a]	Maintain abundance of individual organisms, since this is listed by COSEWIC as a species of Special Concern.	Organism level effects on listed species	**Food Chain Model** - Comparison of estimated exposure from all routes for COPC to dose-based TRVs relevant to effects on growth, survival, and reproduction.
Canada goose (*Branta canadensis*) Least sandpiper (*Calidris minutilla*) Red-breasted merganser (*Mergus serrator*) Long-tailed duck (*Clangula hyemalis*)	Maintain abundance of bird populations as a food source for humans and higher level organism (e.g., wildlife).	Avian population abundance	**Food Chain Model** - Comparison of estimated exposure from all routes for COPC to dose-based TRVs relevant to effects on growth, survival, and reproduction.
Marine Water			
Phytoplankton community, plant/algal community	Maintain primary producer biomass at the community level as a food source for higher level organisms.	Primary producer community biomass	**Chemistry** - Evaluate receptor exposure via comparison of COPC concentrations in marine water to appropriate media assessment criteria (water quality guidelines or effects based toxicity thresholds).
Pelagic and benthic invertebrates	Maintain invertebrate community biomass at the community level as a food source for higher level organisms.	Invertebrate community biomass	**Chemistry** - Evaluate receptor exposure via comparison of COPC concentrations in marine water to appropriate media assessment criteria (water quality guidelines or effects based toxicity thresholds for mortality, growth, or reproduction).

Representative Species	Protection Goal	Assessment Endpoint	Measurement Endpoints - Lines of Evidence
Fourhorn Sculpin (*Myoxocephalus quadricornis*) Capelin (*Mallotus villosus*) Arctic Char (*Salvelinus alpinus*)	Maintain abundance of fish populations as a food source for humans and higher level organisms (e.g., piscivorous fish and wildlife).	Fish population abundance	**Chemistry** - Evaluate receptor exposure via comparison of COPC concentrations in marine water to appropriate media assessment criteria (water quality guidelines or effects based toxicity thresholds for mortality, growth, or reproduction).
Ringed Seal (*Phoca hispida*)	Maintain abundance of marine mammal populations as a food source for higher level organism (e.g., wildlife).	Marine mammal population abundance	**Food Chain Model** - Comparison of estimated exposure from all routes for COPC to dose-based TRVs relevant to effects on growth, survival, and reproduction.
Brant (*Branta bernicla*) Herring gull (*Larus smithsonianus*)	Maintain abundance of bird populations as a food source for humans and higher level organism (e.g., wildlife).	Avian population abundance	**Food Chain Model** - Comparison of estimated exposure from all routes for COPC to dose-based TRVs relevant to effects on growth, survival, and reproduction.
Terrestrial			
Terrestrial Plant community	Maintain primary producer biomass at the community level as a food source for higher level organisms.	Primary producer community biomass	**Chemistry** - Evaluate receptor exposure via comparison of COPC concentrations in soil to appropriate media assessment criteria (soil quality guidelines or effects based toxicity thresholds).
Terrestrial invertebrate community	Maintain invertebrate community biomass at the community level as a food source for higher level organisms	Invertebrate community biomass	**Chemistry** - Evaluate receptor exposure via comparison of COPC concentrations in soil to appropriate media assessment criteria (soil quality guidelines or effects based toxicity thresholds for mortality, growth, or reproduction).
Grizzly bear (*Ursus arctos horribilis*) [a] Caribou (*Rangifer tarandus*) [b] Wolverine (*Gulo gulo*) [c]	Maintain survival, growth, and fecundity of individuals of federally listed species (caribou, grizzly bear, and wolverine).	Organism level effects on listed species	**Food Chain Model** - Comparison of estimated exposure from all routes for COPC to dose-based TRVs relevant to effects on growth, survival, and reproduction.
Muskox (*Ovibos moschatus*) Arctic ground squirrel (*Spermophilus parryii*) Wolf (*Canis lupus arctos*) Northern red-backed vole (*Myodes rutilus*) Arctic Shrew (*Sorex arcticus*)	Maintain abundance of mammal populations as a food source for humans and higher level organism (e.g., wildlife)	Mammal population abundance	

Representative Species	Protection Goal	Assessment Endpoint	Measurement Endpoints - Lines of Evidence
Willow ptarmigan (*Lagopus lagopus*) Yellow warbler (*Setophaga petechia*) American tree sparrow (*Spizella arborea*)	Maintain abundance of bird populations as a food source for humans and higher level organism (e.g., wildlife).	Avian population abundance	**Food Chain Model** - Comparison of estimated exposure from all routes for COPC to dose-based TRVs relevant to effects on growth, survival, and reproduction.
Peregrine falcon (*Falco peregrinus*) [d]	Maintain survival, growth, and fecundity of individuals of federally listed species. Maintain abundance of carnivorous bird populations as a regulator of lower level aquatic and/or terrestrial populations of ecological receptors.	Organism level effects on listed species	

Notes:

[a] *Grizzly bear are listed by* COSEWIC (2016) *as of Special Concern.*

[b] *The Dolphin-Union caribou herd is listed on SARA (*2002*) Schedule 1 and by* COSEWIC (2016) *as of Special Concern.*

[c] *Wolverine are listed by* COSEWIC (2016) *as of Special Concern.*

[d] *Peregrine falcon are listed on SARA (*2002*) Schedule 1 and by* COSEWIC (2016) *as of Special Concern.*

Table 5.5-10. CCME Water Quality Guidelines for Aquatic Life Receptors used for Initial Evaluation of Risk

COPCs in Water	CCME Water Quality Guideline for Freshwater [a] (mg/L)	CCME Water Quality Guideline for Marine Water [b] (mg/L)
Aluminum	0.1	NA
Arsenic	NA	0.0125
Chloride	120	NA
Chromium	0.001	0.0015
Copper	0.004	NA
Fluoride	0.12	NA
Iron	0.3	NA
Mercury	NA	0.000016
Selenium	0.001	NA
Zinc	0.03	NA
COPCs in Sediment	**CCME PEL for Freshwater Sediments [a] (mg/kg dw)**	**CCME PEL for Marine Sediments [b] (mg/kg dw)**
Arsenic	17	41.6
Chromium	90	160
Copper	197	108

Notes:
COPC = contaminant of potential concern
CCME = Canadian Council of Ministers of the Environment
PEL = probable effects level
NA = exposure route is not applicable and a toxicity reference value is not required
[a] Includes primary producers (phytoplankton, periphyton, and plant/algae communities), pelagic and benthic invertebrate communities, and fish (Ninespine Stickleback, Lake Whitefish, and Lake Trout).
[b] Includes primary producers (phytoplankton and plant/algae communities), pelagic and benthic invertebrate communities, and fish (Fourhorn Sculpin, Capelin, and Arctic Char).

Terrestrial Plants and Invertebrates

For terrestrial plants and invertebrates, to initially evaluate risk, the 95th percentile concentrations of the COPCs were compared to the CCME (2017a) soil quality guidelines for the protection of ecological and human health - agricultural (Table 5.5-11). This differs from the COPC screening step described in Section 5.5.1.3 (where maximum concentrations were used) since it uses the 95th percentile of COPC concentrations.

Table 5.5-11. CCME Soil Quality Guidelines for Terrestrial Plant and Invertebrate Receptors Used for Initial Evaluation of Risk

COPCs in Soil	CCME Soil Quality Guideline for Terrestrial Plant and Invertebrate Ecological Receptors (mg/kg dw)
Chromium	64
Copper	63
Nickel	45

Notes:
COPC = contaminant of potential concern
CCME = Canadian Council of Ministers of the Environment

Mammalian and Avian Wildlife

Of the mammalian and avian ecological receptors considered, grizzly bear, caribou, wolverine, and peregrine falcon are listed species under the SARA (2002) or by COSEWIC (2016). The effects thresholds chosen (including the listed species; Tables 5.5-12 and 5.5-13) are appropriate as they are based on the lowest NOAELs available in the published literature. The only exception was methylmercury for birds, as the TRV is based on the geometric mean of the LOAEL and NOAEL.

Wildlife TRVs for COPCs were preferentially obtained from the US EPA *Ecological Soil Screening Level* documents (Eco-SSLs; US EPA 2017a), which are a commonly used source of systematic and conservative wildlife toxicity information. The methodologies used to develop oral TRVs for avian and mammalian wildlife are described in detail in the US EPA's *Guidance for Developing Ecological Soil Screening Levels* document (US EPA 2003b). In all cases, the Eco-SSL TRV for a specific contaminant is lower than the lowest bound LOAEL reported across all studies within a taxonomic class (i.e., birds or mammals). The toxicological studies contributing to the development of a TRV are referenced in each contaminant-specific Eco-SSL document.

Eco-SSL documents were not available for all COPCs, thus wildlife TRVs were also obtained from the ORNL *Toxicological Benchmarks for Wildlife* (Sample, Opresko, and Suter 1996). If a chronic NOAEL was not provided for a specific COPC in the Sample, Opresko, and Suter (1996) document, a general literature search was conducted to find the most recent and robust toxicological data available. The mammalian and avian wildlife TRVs used in this existing conditions ERA are presented in Tables 5.5-12 and 5.5-13. The toxicity studies on which the mammalian and avian wildlife TRVs were based and the rationale for their selection is briefly summarized in this section.

Aluminum

The Eco-SSL document for aluminum (US EPA 2003a) lacks toxicity data for both mammalian and avian wildlife. However, the ORNL *Toxicological Benchmarks for Wildlife* (Sample, Opresko, and Suter 1996) document references studies that have investigated the chronic toxicity of aluminum exposure in laboratory test organisms. A chronic NOAEL of 109.7 mg/kg BW/day is provided for reproductive effects in birds, which is based on a 4-month exposure of orally-administered $Al_2(SO_4)_3$ in ringed dove (*Streptopelia risoria*) conducted by Carriere et al. (1986). In addition, a chronic NOAEL of 1.93 mg/kg BW/day is provided for reproductive effects in mammals, which is based on a 3-generation exposure of orally-administered $AlCl_3$ in mice (*Mus musculus*) by Ondreicka, Ginter, and Kortus (1966). Thus the avian and mammalian TRVs for aluminum adopted in this assessment were 109.7 and 1.93 mg/kg BW/day, respectively.

Arsenic

The Eco-SSL document for arsenic (US EPA 2005a) provides an avian TRV of 2.24 mg/kg BW/day, which is based on an orally-administered exposure of arsenic to chicken (*Gallus domesticus*) over 19 days. This avian TRV was the lowest NOAEL reported in the literature for reproduction, growth, and survival effects in either *G. domesticus* or Mallard duck (*Anas platyrynchos*). The Eco-SSL document for arsenic also provides an oral mammalian TRV of 1.04 mg/kg BW/day, which is the geometric mean of NOAELs reported for reproduction and growth effects in rodents (*M. musculus*, *Rattus norvegicus*, and *Sigmodon hispidus*), dog (*Canis familiaris*), and rabbit (*Oryctolagus cuniculus*) at various life stages. The mammalian TRV is based on toxicological data from orally-administered arsenic exposures ranging in duration from 9 days (*M. musculus*) to 2 years (*C. familiaris*). Thus the avian and mammalian TRVs for arsenic adopted in this assessment were 2.24 and 1.04 mg/kg BW/day, respectively. The majority of avian and mammalian studies reported in the Eco-SSL document for arsenic were conducted with inorganic arsenic (US EPA 2005a).

Table 5.5-12. Toxicity Reference Values for Mammalian Wildlife Receptors

COPC	Test Species	Effect	Endpoint	TRV (mg/kg BW/day)	Reference
Aluminum	Mouse	Reproduction	Chronic NOAEL	1.93	Ondreicka, Ginter, and Kortus (1966) in Sample, Opresko, and Suter (1996)
Arsenic	Various	Reproduction, Growth	Geometric mean of NOAELs [a]	1.04	Eco-SSL for arsenic (US EPA 2005a)
Cadmium	Rat	Reproduction, Growth, Survival	NOAEL [a]	0.77	Eco-SSL for cadmium (US EPA 2005c)
Chromium	Various	Reproduction, Growth	Geometric mean of NOAELs [b]	2.4	Eco-SSL for chromium (US EPA 2008)
Copper	Pig	Reproduction, Growth, Survival	NOAEL [a]	5.6	Eco-SSL for copper (US EPA 2007a)
Lead	Rat	Reproduction, Growth, Survival	NOAEL [a]	4.7	Eco-SSL for lead (US EPA 2005d)
Mercury	Mink	Reproduction	Chronic NOAEL	1.01	Aulerich, Ringer, and Iwamoto (1974) in Sample, Opresko, and Suter (1996)
Methylmercury	Mink	Survival	$TRV=((LOAEL*NOAEL)^{0.5})/UF$; (UF=5)	0.022	Chamberland et al. (1996) in CCME (2000)
Nickel	Mouse	Reproduction, Growth, Survival	NOAEL [a]	1.70	Eco-SSL for nickel (US EPA 2007b)
Selenium	Pig	Reproduction, Growth, Survival	NOAEL [a]	0.143	Eco-SSL for selenium (US EPA 2007c)
Thallium	Rat	Reproduction	Chronic NOAEL	0.074	Formigli et al. (1986) in Sample, Opresko, and Suter (1996)
Zinc	Various	Reproduction, Growth	Geometric mean of NOAELs [a]	75.4	Eco-SSL for zinc (US EPA 2007d)

Notes:
COPC = contaminant of potential concern
TRV = toxicity reference value
BW = body weight
NOAEL = no observed adverse effects level
LOAEL = lowest observed adverse effects level
UF = uncertainty factor
[a] *NOAEL to derive TRV based on highest NOAEL lower than lowest bound LOAEL reported in literature (as per US EPA's Eco-SSL methodology).*
[b] *This is the TRV for trivalent chromium, which is more conservative than the TRV for hexavalent chromium.*

Table 5.5-13. Toxicity Reference Values for Avian Wildlife Receptors

COPC	Test Species	Effect	Endpoint	TRV (mg/kg BW/day)	Reference
Aluminum	Ringed dove	Reproduction	Chronic NOAEL	109.7	Carriere et al. (1986) in Sample, Opresko, and Suter (1996)
Arsenic	Chicken	Reproduction, Growth, Survival	Lowest NOAEL	2.24	Eco-SSL for arsenic (US EPA 2005a)
Cadmium	Various	Reproduction, Growth	Geometric mean of NOAELs	1.47	Eco-SSL for cadmium (US EPA 2005c)
Chromium	Various	Reproduction, Growth	Geometric mean of NOAELs	2.66	Eco-SSL for chromium (US EPA 2008)
Copper	Chicken	Reproduction, Growth, Survival	Highest bounded NOAEL	4.05	Eco-SSL for copper (US EPA 2007a)
Lead	Chicken	Reproduction, Growth, Survival	Highest bounded NOAEL	1.63	Eco-SSL for lead (US EPA 2005d)
Mercury	Japanese quail	Reproduction	Chronic NOAEL	0.45	Hill and Schaffner (1976) in Sample, Opresko, and Suter (1996)
Methylmercury	Mallard	Growth, Survival	Geometric mean of LOAEL and NOAEL	0.031	Heinz (1976a, 1976b, 1979) in CCME (2000)
Nickel	Various	Reproduction, Growth	Geometric mean of NOAELs	6.71	Eco-SSL for nickel (US EPA 2007b)
Selenium	Chicken	Reproduction, Growth, Survival	Highest bounded NOAEL	0.290	Eco-SSL for selenium (US EPA 2007c)
Thallium	European Starling	Survival	NOAEL	0.35	Schafer (1972); US EPA (1999a)
Zinc	Various	Reproduction, Growth	Geometric mean of NOAELs	66.1	Eco-SSL for zinc (US EPA 2007d)

Notes:
COPC = contaminant of potential concern
TRV = toxicity reference value
BW = body weight
NOAEL = no observed adverse effects level
LOAEL = lowest observed adverse effects level

Cadmium

The Eco-SSL document for cadmium (US EPA 2005c) provides an oral mammalian TRV of 0.77 mg/kg BW/day, which is based on the numerous NOAELs reported in the literature for reproduction, growth, and survival in various life stages of rodents (*M. musculus, R. norvegicus, Microtus pennsylvanicus, Clethrionomys glareolos, Sorex araneus*), dog (*C. familiaris*), sheep (*Ovis aires*), pig (*Sus scrofa*), and cattle (*Bos Taurus*). The toxicological data from which the TRV was determined include orally-administered exposures ranging in duration from 4 days (*M. musculus* and *R. norvegicus*) to approximately 4.8 years (*C. familiaris*). Further details on the specific criteria used to select this mammalian TRV are provided in the Eco-SSL document for cadmium (US EPA 2005c).

The Eco-SSL document for cadmium also provides an avian oral TRV of 1.47 mg/kg BW/day, which is the geometric mean of NOAELs reported for reproduction and growth effects in juvenile or adult chicken (*G. domesticus*), mallard (*A. platyrynchos*), Japanese quail (*Coturnix japonica*), and woodduck (*Aix sponsa*). The avian TRV for cadmium is based on toxicological data from orally-administered exposures ranging in duration from 2 weeks (*G. domesticus*) to 1 year (*G. domesticus*). Thus the avian and mammalian TRVs for cadmium adopted in this assessment were 1.47 and 0.77 mg/kg BW/day, respectively.

Chromium

The Eco-SSL document for chromium (US EPA 2008) provides an avian TRV for trivalent chromium (Cr III) of 2.66 mg/kg BW/day, which is the geometric mean of NOAELs reported for reproduction and growth effects in juvenile or adult chicken (*G. domesticus*), turkey (*Meleagris gallopavo*), and black duck (*Anas rubripes*). The avian TRV for Cr(III) is based on toxicological data from orally-administered exposure periods ranging in duration from 14 days (*G. domesticus* and *M. gallopavo*) to 190 days (*A. rubripes*). Neither the chromium Eco-SSL nor the ORNL *Toxicological Benchmarks for Wildlife* (Sample, Opresko, and Suter 1996) documents provide an avian TRV for hexavalent chromium (Cr VI). Therefore the avian TRV for chromium adopted in this assessment is equivalent to the TRV for Cr(III).

The Eco-SSL document for chromium provides mammalian oral TRVs for Cr(III) and Cr(VI), which were calculated as 2.4 and 9.24 mg/kg BW/day, respectively. The TRV for Cr(III) is the geometric mean of NOAELs reported for reproduction and growth in juvenile and adult rodents (*M. musculus, R. norvegicus*), pig (*S. scrofa*), and cattle (*B. Taurus*). The toxicological data from which the mammalian TRV for Cr(III) is based involve orally-administered exposure periods ranging in duration from 4 days (*M. musculus* and *R. norvegicus*) to approximately 4.8 years (*C. familiaris*). The TRV for Cr(VI) is the geometric mean of NOAELs reported for reproduction and growth in juvenile and adult rodents (*M. musculus*, *R. norvegicus*). The toxicological data from which the mammalian TRV for Cr(VI) is based on involves orally-administered exposure periods ranging in duration from 6 days (*M. musculus*) to 1 year (*M. musculus* and *R. norvegicus*). Since the TRV for Cr(III) is lower, it was adopted as the mammalian TRV for chromium in this assessment.

Copper

The Eco-SSL document for copper (US EPA 2007a) provides an avian oral TRV of 4.05 mg/kg BW/day, which is based on numerous NOAELs reported in the literature for reproduction, growth, and survival in various life stages of chicken (*G. domesticus*), duck (*A. platyrynchos*), turkey (*M. gallopavo*), and Japanese Quail (*C. japonica*). Toxicological data from orally-administered copper exposures ranging in duration from 5 days (*G. domesticus*) to 336 days (*G. domesticus*) were used in the determination of the avian TRV.

The Eco-SSL document for copper also provides an oral mammalian TRV of 5.6 mg/kg BW/day, which is based on the numerous NOAELs reported in the literature for reproduction, growth, and survival in juvenile or gestating adult rodents (*M. musculus*, *R. norvegicus, S. araneus, Cavia porcellus*) sheep (*O. aires*), pig (*S. scrofa*), cattle (*B. Taurus*), rabbit (*O. cuniculus*), pony (*Equus caballus*), and mink (*Mustela vision*). The toxicological data from which the TRV is based involve orally-administered exposures ranging in duration from 1 week (*R. norvegicus*) to 783 days (*S. scrofa*). Further details on the specific criteria used to select the avian and mammalian TRVs are provided in the Eco-SSL document for copper (US EPA 2007a). Thus the avian and mammalian TRVs for copper adopted in this assessment were 4.05 and 5.6 mg/kg BW/day, respectively.

Lead

The Eco-SSL document for lead (US EPA 2005d) provides an avian oral TRV of 1.63 mg/kg BW/day, which is based on numerous NOAELs reported in the literature for reproduction, growth, or survival in various life stages of chicken (*G. domesticus*), duck (*A. platyrynchos*), turkey (*M. gallopavo*), Japanese quail (*C. japonica*), dove (*S. risoria*), American kestrel (*Falco sparverius*), pigeon (*Columba livia*), goose (*Anser cygnides*), and mallard (*A. platyrynchos*). Toxicological data from orally-administered lead exposures ranging in duration from 7 days (*C. japonica*) to 6 months (*F. sparverius*) were used in the determination of the avian TRV.

The Eco-SSL document for lead also provides an oral mammalian TRV of 4.7 mg/kg BW/day, which is based on the numerous NOAELs reported in the literature for reproduction, growth, or survival in various life stages of rodents (*M. musculus*, *R. norvegicus, S. hispidus, Mesocricetus auratus, C. porcellus*), dog (*C. familiaris*), sheep (*O. aires*), pig (*S. scrofa*), cattle (*B. Taurus*), rabbit (*O. cuniculus*), and horse (*E. caballus*). The toxicological data on which the TRV is based involve orally-administered exposures ranging in duration from 4 days (*R. norvegicus*) to 669 days (*M. musculus*). Further details on the specific criteria used to select the avian and mammalian TRVs are provided in the Eco-SSL document for lead (US EPA 2005d). Thus the avian and mammalian TRVs for lead adopted in this assessment were 1.63 and 4.7 mg/kg BW/day, respectively.

Mercury

There is currently no Eco-SSL document for mercury. However, the ORNL *Toxicological Benchmarks for Wildlife* (Sample, Opresko, and Suter 1996) document references studies that have investigated the chronic toxicity of mercury exposure in laboratory test organisms. A chronic NOAEL of 0.45 mg/kg BW/day is provided for reproductive effects in birds, which is based on a 1-year exposure of orally-administered mercuric chloride in Japanese quail (*C. japonica*) by Hill and Schaffner (1976). In addition, a chronic NOAEL of 1.01 mg/kg BW/day is provided for reproductive effects in mammals, which is based on a 6-month exposure of orally-administered mercuric chloride in mink (*Mustela vison*) by Aulerich, Ringer, and Iwamoto (1974). Thus the avian and mammalian TRVs used in this assessment for mercury are 0.45 and 1.0 mg/kg BW/day, respectively.

The CCME (2000) provides an avian TRV for methylmercury of 0.031 mg/kg BW/day, which is based on the geometric mean of LOAELs and NOAELs from studies conducted on mallard ducks with growth and survival as the endpoints (Heinz 1976a, 1976b, 1979). The CCME (2000) also provides a mammalian TRV for methylmercury of 0.022 mg/kg BW/day, from a study conducted on mink with survival as the endpoint (Chamberland et al. 1996). The avian and mammalian TRVs used in this assessment for methylmercury are 0.031 and 0.022 mg/kg BW/day, respectively, and will be used for wildlife receptors that consume fish and aquatic invertebrates (i.e., peregrine falcon, red-breasted merganser, least sandpiper, long-tailed duck, herring gull, and ringed seal).

Nickel

The Eco-SSL document for nickel (US EPA 2005a) provides an avian TRV of 6.71 mg/kg BW/day, which is the geometric mean of NOAELs reported in the literature for reproduction and growth effects in juvenile and egg-laying chicken (*G. domesticus*) and duck (*A. platyrhynchos*). The avian TRV is based on toxicological data from orally-administered nickel exposures ranging in duration from 3 weeks (*G. domesticus*) to 90 days (*A. platyrhynchos*).

The Eco-SSL document for nickel also provides an oral mammalian TRV of 1.70 mg/kg BW/day, which is based on the numerous NOAELs reported in the literature for reproduction, growth, and survival in juvenile or gestating adult rodents (*M. musculus*, *R. norvegicus, M. pennsylvanicus*), dog (*C. familiaris*), and cattle (*B. Taurus*). The toxicological data from which the TRV is based involve orally-administered exposures ranging in duration from 4 days (*M. musculus*) to 1,217 days (*R. norvegicus*). Further details on the specific criteria used to select the avian and mammalian TRVs are provided in the Eco-SSL document for nickel (US EPA 2007b). Thus the avian and mammalian TRVs used in this assessment for nickel are 6.71 and 1.70 mg/kg BW/day, respectively.

Selenium

The Eco-SSL document for selenium (US EPA 2007c) provides an avian oral TRV of 0.29 mg/kg BW/day, which is based on numerous NOAELs reported in the literature for reproduction, growth, or survival in various life stages of chicken (*G. domesticus*), Mallard (*A. platyrynchos*), Japanese quail (*C. japonica*), heron (*Nycticorax nycticorax*), and American kestrel (*F. sparverius*). Toxicological data from orally-administered selenium exposures ranging in duration from 7 days (*G. domesticus* and *A. platyrynchos*) to 105 weeks (*G. domesticus*) were used in the determination of the avian TRV.

The Eco-SSL document for selenium also provides an oral mammalian TRV of 0.143 mg/kg BW/day, which is based on the numerous NOAELs reported in the literature for reproduction, growth, or survival in various life stages of rodents (*M. musculus*, *R. norvegicus, S. hispidus, M. auratus*), sheep (*O. aires*), pig (*S. scrofa*), cattle (*B. Taurus*), rabbit (*O. cuniculus*), pronghorn (*Antilocarpa americana*), and goat (*Capra hircus*). The toxicological data on which the TRV is based involve orally-administered exposures ranging in duration from 4 days (*M. musculus*) to 360 days (*M. musculus*). Further details on the specific criteria used to select the avian and mammalian TRVs are provided in the Eco-SSL document for selenium (US EPA 2007c). The avian and mammalian TRVs used in this assessment for selenium are 0.29 and 0.143 mg/kg BW/day, respectively.

Thallium

There is currently no Eco-SSL document for thallium. Furthermore, no chronic toxicity studies for thallium are available in the literature. However, the ORNL *Toxicological Benchmarks for Wildlife* (Sample, Opresko, and Suter 1996) document references a mammalian study that provides a subchronic LOAEL of 0.74 mg/kg BW/day for reproductive effects. This LOAEL is based on the 60-day exposure of orally-administered thallium sulfate in rat (*R. norvegicus*) by Formigli et al. (1986). The chronic NOAEL provided in Sample, Opresko, and Suter (1996) is 0.0074 mg/kg BW/day following the application of a UF for LOAEL to NOAEL extrapolation. The mammalian TRV for thallium adopted in this assessment is 0.074 mg/kg BW/day.

The ORNL document (Sample, Opresko, and Suter 1996) does not provide thallium toxicity data for birds. However, the US EPA (1999a) provides an avian TRV for thallium of 0.35 mg/kg BW/day, which is based on a NOAEL in European starling (*Sturnus vulgaris*) with survival as the endpoint (Schafer 1972). Thus, the avian TRV for thallium adopted in this assessment is 0.35 mg/kg BW/day.

Zinc

The Eco-SSL document for zinc (US EPA 2007d) provides an avian TRV of 66.1 mg/kg BW/day, which is the geometric mean of NOAELs reported in the literature for reproduction and growth effects in juvenile and adult chicken (*G. domesticus*), turkey (*M. gallopavo*), and Japanese quail (*C. japonica*).

The avian TRV is based on toxicological data from orally-administered zinc exposures ranging in duration from 1 day (*G. domesticus*) to 44 weeks (*G. domesticus*).

The Eco-SSL document for zinc also provides an oral mammalian TRV of 75.4 mg/kg BW/day, which is the geometric mean of NOAELs reported for reproduction and growth effects in juvenile and gestating rodents (*M. musculus*, *R. norvegicus*, *M. auratus*), rabbit (*O. cuniculus*), mink (*M. vison*), water buffalo (*Bubalus bubalis*), pig (*S. scrofa*), and cattle (*B. Taurus*). The mammalian TRV is based on toxicological data from orally-administered zinc exposures ranging in duration from 4 days (*R. norvegicus*) to 1 year (*S. scrofa*). The avian and mammalian TRVs used in this assessment for zinc are 66.1 and 75.4 mg/kg BW/day, respectively.

5.5.4 Risk Characterization

5.5.4.1 Introduction

In a screening level risk assessment, such as this existing conditions ERA, it is common to make a number of conservative assumptions which will tend to overestimate the actual risk to ecological health. If no unacceptable risks are identified using this conservative approach, then it is unlikely that ecological health will be affected. However, identification of potential risks due to existing conditions does not necessarily mean that ecological receptor health will be adversely affected, since the risk has been overestimated intentionally.

Using the results of the exposure assessment and TRV assessment, ecological health risks were quantified using HQs. The HQ is the ratio between the total EDI and the TRV and provides a measure of exposure to a COPC through the various exposure pathways. Environment Canada (2012) states that an HQ of less than 1.0 indicates that the existence of adverse effects to ecological health is unlikely, while an HQ greater than 1.0 indicates a possibility of adverse effects to ecological health. It is likely that the risk is significantly overestimated due to the conservative assumptions made throughout the existing conditions ERA.

5.5.4.2 Estimation of Risk to Aquatic Life Ecological Receptors from Contaminants of Potential Concern

Hazard quotients for aquatic life ecological receptors were calculated for freshwater and marine water exposure, as well as freshwater and marine sediment exposure. The HQ was calculated by dividing the baseline 95th percentile concentration of the COPC in environmental media (i.e., water or sediment) by the CCME guideline for the protection of aquatic life. Hazard quotients for aquatic life ecological receptors are shown in Table 5.5-14.

As shown in Table 5.5-14, HQs for aquatic life ecological receptors were lower than 1.0 except for aluminum, where the HQ (HQ = 1.3) for aquatic life ecological receptors in freshwater was greater than 1.0, for chromium, where the HQ (HQ = 17) for aquatic life ecological receptors in marine water was greater than 1.0, and for arsenic, where the HQ (HQ = 1.1) for aquatic life ecological receptors in freshwater sediment was greater than 1.0. The calculated HQs are reflective of baseline conditions and naturally elevated concentrations. In the case of chromium in marine water, the derivation of the HQ for marine aquatic life is based on the CCME marine water quality guideline for hexavalent chromium (0.0015 mg/L). Hexavalent chromium is likely to be the most predominant form of chromium in marine environments and it is known to be more toxic than trivalent chromium.

Table 5.5-14. Hazard Quotients for Contaminants of Potential Concern in Fresh and Marine Waters

COPCs in Water	95th Percentile Baseline Freshwater Concentration (mg/L; n=13 modeling nodes)	95th Percentile Baseline Marine Water Concentration (mg/L; n=6 - 325)	CCME Water Quality Guideline (mg/L)		Hazard Quotient for Water	
			Freshwater [a]	Marine [b]	Freshwater Aquatic Life Receptors [a]	Marine Life Receptors [b]
Aluminum	0.129	NA	0.1	NA	1.3	NA
Arsenic	0.000444	0.00121	NA	0.0125	NA	0.10
Chloride	53.3	NA	120	NA	0.44	NA
Chromium	0.000732	0.025	0.001	0.0015	0.73	17 [c]
Copper	0.00243	NA	0.004	NA	0.61	NA
Fluoride	0.0721	NA	0.12	NA	0.60	NA
Iron	0.242	NA	0.3	NA	0.81	NA
Mercury	0.0000-278	0.00000500	NA	0.000016	NA	0.31
Selenium	0.000536	NA	0.001	NA	0.54	NA
Zinc	0.00470	NA	0.03	NA	0.16	NA
COPCs in Sediment	**95th Percentile Baseline Freshwater Sediment Concentration (mg/kg; n=271)**	**95th Percentile Baseline Marine Sediment Concentration (mg/kg; n=84)**	**CCME Probable Effects Level (mg/kg)**		**Hazard Quotient for Sediment**	
			Freshwater [a]	**Marine [b]**	**Freshwater Aquatic Life Receptors [a]**	**Marine Life Receptors [b]**
Arsenic	19.1	16.8	17	41.6	1.1	0.40
Chromium	81.0	65.8	90	160	0.90	0.41
Copper	52.5	27.1	197	108	0.27	0.25

Notes:
COPC = contaminant of potential concern
CCME = Canadian Council of Ministers of the Environment
NA = not applicable
Shaded cells indicate hazard quotients greater than 1.0.
[a] *Includes primary producers (phytoplankton, periphyton, and plant/algae communities), pelagic and benthic invertebrate communities, and fish (Ninespine Stickleback, Lake Whitefish, and Lake Trout).*
[b] *Includes primary producers (phytoplankton and plant/algae communities), pelagic and benthic invertebrate communities, and fish (Fourhorn Sculpin, Capelin, and Arctic Char).*
[c] *This HQ is based on the CCME guideline. However, if the HQ is calculated based on the lowest toxicity threshold for hexavalent chromium reported by CCME (1999), the HQ = 2.5 and the risk would be minimal for marine primary producers, invertebrates, or fish. See text for additional details.*

Based on data provided in CCME (1999), chronic toxicity of hexavalent chromium to marine fish could occur at concentrations between 0.5 and 44.0 mg/L. CCME (1999) also indicates that chronic toxicity to marine invertebrates and plants has been reported at concentrations of hexavalent chromium as low as 0.01 mg/L and 0.015 mg/L, respectively. If the safety factor of 10 is removed from the CCME guideline for hexavalent chromium, then the resulting HQ would be 1.7 However, as it is a highly conservative assumption that all chromium exists as hexavalent chromium in marine water, the actual risk to aquatic life from total chromium is overestimated and minor effects in marine life would not be expected, especially given that the total chromium concentration in marine water is not likely to be 100% hexavalent chromium under existing conditions.

5.5.4.3 Estimation of Risk to Terrestrial Plant and Invertebrate Terrestrial Receptors from Contaminants of Potential Concern

Hazard quotients for terrestrial plant and invertebrate ecological receptors were calculated for soil exposure. The HQ was calculated by dividing the baseline 95th percentile concentration of the COPC in soil by the CCME guideline for the protection of terrestrial plants and invertebrates. Hazard quotients for terrestrial plant and invertebrate ecological receptors are shown in Table 5.5-15.

Table 5.5-15. Terrestrial Plant and Invertebrate Toxicity Reference Values and Hazard Quotients for Contaminants of Potential Concern in Soil

COPCs in Soil	95th Percentile Baseline Soil Concentration (mg/kg dw; n=100)	Soil TRVs for Terrestrial Plant and Invertebrate Ecological Receptors (mg/kg)	Soil HQs for Terrestrial Plant and Invertebrate Ecological Receptors
Chromium	65.6	64	1.0
Copper	38.3	63	0.61
Nickel	34.7	45	0.77

Notes:
COPC = contaminant of potential concern
dw = dry weight
TRV = toxicity reference value
HQ = hazard quotient

As shown in Table 5.5-15, HQs for terrestrial plant and invertebrate ecological receptors were all equal to or below the threshold of 1.0; therefore, existing COPC concentrations in soil do not pose a risk to the health of terrestrial plant and invertebrate ecological receptors.

5.5.4.4 Estimation of Risk to Mammalian and Avian Receptors from Contaminants of Potential Concern

The total EDI of COPCs (in mg/kg BW/day) for each wildlife species was calculated by summing the EDI from all applicable exposure pathways (Table 5.5-8). The total EDI from all routes was then divided by the TRV (in mg/kg BW/day) to obtain the existing conditions HQ, as follows:

$$HQ_{existing} = \frac{EDI_{Total}}{TRV} \qquad \text{[Equation 23]}$$

Table 5.5-16 shows the HQ for each COPC for each wildlife species considered in the assessment.

Table 5.5-16. Wildlife Toxicity Reference Values and Hazard Quotients for Contaminants of Potential Concern

COPC	TRV (mg/kg BW/day)		Hazard Quotients																		
	Mammal	Bird	Caribou	Muskox	Wolverine	Grizzly Bear	Wolf	Arctic Ground Squirrel	Arctic Shrew	Northern Red-backed Vole	Willow Ptarmigan	American Tree Sparrow	Peregrine Falcon	Canada Goose	Red-breasted Merganser	Least Sandpiper	Long-tailed Duck	Herring Gull	Yellow Warbler	Brant	Ringed Seal
Aluminum	1.93	109.7	0.14	32	36	4.3	0.34	22	910	738	0.76	15	0.72	0.75	0.53	2.3	0.66	0.70	20	0.25	49
Arsenic	1.04	2.24	0.000050	0.013	0.014	0.0017	0.00015	0.0091	0.084	0.10	0.011	0.029	0.0072	0.024	0.017	0.071	0.020	0.038	0.022	0.0083	0.10
Cadmium	0.77	1.47	0.000010	0.0047	0.0011	0.00040	0.000016	0.0031	0.095	0.081	0.0077	0.058	0.00069	0.0022	0.0014	0.015	0.0043	0.050	0.070	0.0023	0.055
Chromium	2.4	2.66	0.00052	0.19	0.090	0.019	0.00092	0.13	0.62	1.0	0.46	0.78	0.090	0.17	0.067	0.59	0.17	0.80	0.31	0.14	0.56
Copper	5.6	4.05	0.00010	0.032	0.024	0.0038	0.00027	0.022	0.21	0.25	0.096	0.28	0.037	0.050	0.046	1.0	0.28	0.076	0.24	0.027	0.076
Lead	4.7	1.63	0.000044	0.012	0.010	0.0014	0.00010	0.0079	0.091	0.099	0.060	0.21	0.034	0.029	0.020	0.21	0.059	0.027	0.19	0.015	0.0093
Mercury	1.01	0.45	0.0000033	0.0018	0.0017	0.00023	0.000031	0.0012	0.0016	0.0066	0.014	0.019	0.00040	0.0038	0.00040	0.0017	0.00076	0.00011	0.0028	0.0043	0.000068
Methylmercury	0.022	0.031	-	-	-	0.019	0.0068	-	-	-	-	-	0.033	-	1.6	2.03	0.628	0.13	-	-	0.33
Nickel	1.7	6.71	0.00039	0.14	0.063	0.014	0.00071	0.097	0.52	0.72	0.096	0.18	0.018	0.038	0.017	0.061	0.019	0.17	0.087	0.029	0.43
Selenium	0.143	0.29	0.000044	0.019	0.031	0.0054	0.0010	0.013	0.15	0.16	0.029	0.096	0.016	0.012	0.15	0.98	0.27	0.41	0.088	0.0096	0.91
Thallium	0.0740	0.35	0.000087	0.021	0.055	0.0039	0.00030	0.015	0.56	0.46	0.0067	0.11	0.010	0.0030	0.0045	0.11	0.031	0.0031	0.14	0.0015	0.019
Zinc	75.4	66.1	0.000022	0.0097	0.0023	0.0012	0.00014	0.0066	0.14	0.13	0.034	0.19	0.0041	0.012	0.044	0.15	0.042	0.039	0.22	0.011	0.033

Notes:
COPC = contaminant of potential concern
TRV = toxicity reference value
BW = body weight
Shaded cells indicated hazard quotients greater than 1.0.

The HQs for aluminum and methylmercury were greater than 1.0 for several wildlife receptors (Table 5.5-16):

- aluminum for muskox, wolverine, grizzly bear, Arctic ground squirrel, Arctic shrew, northern red-backed vole, American tree sparrow, least sandpiper, yellow warbler, and ringed seal; and
- methylmercury for red-breasted merganser and least sandpiper.

The potential risk to terrestrial ecological receptors due to aluminum is associated with exposure via ingestion of soil, vegetation, or terrestrial invertebrates. The assumptions used in the food chain modeling and ingestion exposure calculations were very conservative and likely substantially overestimate the risk to ecological receptors. For aluminum, the assumption of 100% bioavailability in ingested food, water, and soil is likely contributing to the elevated HQs. Based on data provided in ATSDR (2008), the forms of aluminum found in drinking water and in food are much less bioavailable than the forms that are used in the laboratory studies for determining TRVs. Bioavailability of aluminum in food or water can be as less than 1% relative to the forms used in toxicity studies (e.g., aluminum lactate, aluminum citrate). Therefore, it is likely that the risk to ecological receptors due to aluminum is substantially overestimated by not accounting for the differences between laboratory- and field-based exposures.

Elevated HQs for fish-eating (red-breasted merganser) or aquatic invertebrate-eating (least sandpiper) birds due to methylmercury were identified, suggesting potential risks for adverse effects. This result is not unexpected since mercury is known to bioaccumulate through the aquatic food chain. It can accumulate to high concentrations in piscivorous animals and fish that are older, larger, or at the top of the food chain, and this can be seen by the concentrations of total mercury measured in fish such as Lake Trout (maximum concentration of 1.80 mg/kg wet weight; Table 5.5-7). Mercury also tends to bioaccumulate to a greater degree in foods chains in lakes, particularly when sediments are anoxic, have higher organic carbon content, and if sulphate concentrations are high. This is because inorganic mercury can be converted to methylmercury by bacteria present in sediments, which can then be taken up more readily by biota in the aquatic the food chain.

Since a conservative statistic (95^{th} percentile concentrations) was used in the risk calculations, there is potential that risk is overestimated for fish-eating birds. However, even if lower concentrations (e.g., a mean or median concentration) were used in the calculations the HQ for fish-eating birds would still be elevated, particularly if they were consuming Lake Trout. However, the Lake Trout samples used in the food chain model for the calculation of HQ in piscivorous animals were relatively larger (mean and maximum fork length of 479 mm and 765 mm, respectively) than what would be expected to be the size of food fish for piscivorous birds (approximate fish fork length of 10 to 15 cm; Lingle and Schupbach 1977). Because smaller fish tend to have lower methylmercury tissue concentrations than larger fish, it is likely that the food chain model for piscivorous birds overestimated the tissue concentration of methylmercury in birds, and thus overestimated the HQ for red-breasted merganser.

For invertebrate-eating birds, the concentration of methylmercury in prey items was modeled using a BCF from US EPA (1999b). It is possible that the BCF is too high, resulting in predictions of methylmercury in tissue that are not representative of invertebrates in Arctic lake environments. However, given that fish tissue mercury concentrations were measured to be elevated in baseline studies, it is likely that concentrations are also elevated in invertebrates.

All other HQs for all other wildlife species and COPCs were below 1.0.

5.5.4.5 Summary of Risk to Ecological Receptors

Overall, it is concluded that under existing conditions several COPCs may affect the health of ecological receptors, due to HQs greater than 1.0:

- aluminum for muskox, wolverine, grizzly bear, Arctic ground squirrel, Arctic shrew, northern red-backed vole, American tree sparrow, least sandpiper, yellow warbler, and ringed seal; and
- methylmercury for red-breasted merganser and least sandpiper.

However, there is uncertainty in the assessment for the reasons outlined in Section 5.5.5, and due to assumptions made in the assessment (Sections 5.5.2.2, 5.5.2.3, 5.5.2.4, and 5.5.2.5). The existing conditions ERA is conservative and is likely to substantially overestimate the potential for risk to the health of ecological receptors that may use the Project area. Also, the 95th percentile of COPC concentrations in environmental media were used in the assessment, leading to a conservative estimate of risk.

5.5.5 Uncertainty Analysis

5.5.5.1 Introduction

The process of evaluating the potential risk to the health of ecological receptors from exposure to COPCs in environmental media (e.g., water, sediment, soil) involves multiple steps, each containing inherent uncertainties that ultimately affect the final risk estimates. These uncertainties exist in numerous areas, including the collection of samples, laboratory analysis, estimation of potential exposures, assumptions used in food chain modeling, and derivation of TRVs. These uncertainties can result in either an over- or under-estimation of risk. However, for the existing conditions ERA, where uncertainties existed, a conservative approach was adopted to overestimate rather than underestimate potential exposure and related risks. Some of the uncertainties have been mentioned in the preceding sections; however, the following uncertainty analysis is a qualitative discussion of the key sources of uncertainty in the existing conditions ERA.

5.5.5.2 Contaminants of Potential Concern

The COPCs selected for this assessment were metals, since the proposed Project involves development of a metal mine. Metals naturally occur in environmental media (i.e., soil, sediment, water, and plant and animal tissue) and have been monitored during baseline studies to support Project planning and processes. By screening measured baseline metal concentrations against environmental quality guidelines it is likely that all relevant metal COPCs have been selected for inclusion in the existing conditions ERA.

However, there exists a possibility that other COPCs (e.g., other metals, organic chemicals, etc.) could be associated with Project activities in the future, but do not occur or were not measured under existing conditions.

The 95th percentile of baseline concentrations were used to represent the exposure concentrations in this assessment. This concentration represents the upper bound of concentrations that may be present in the LSA. It is an overly conservative statistic and would result in overestimation of risks, particularly for organisms with larger home ranges who may receive exposure across a larger area where concentrations of COPCs in environmental media would not be at the 95th percentile level. Further, it was assumed that total metal concentrations were represented by the most toxic metal species (for instance, total chromium was assumed to be 100% hexavalent chromium). Overall, it is highly probable that the risks to ecological receptors have been overestimated in this existing conditions ERA.

5.5.5.3 Tissue Concentrations

Aquatic and Terrestrial Invertebrates

The COPC concentrations in freshwater and terrestrial invertebrate prey were calculated using published BCFs (Appendix V6-5E, Section 2.2), since measured tissue concentrations for invertebrates were not available. There is uncertainty around the use of generic BCFs for determining site-specific invertebrate tissue concentrations; therefore, tissue concentrations may be under- or over-predicted.

Terrestrial Species

The same uncertainties presented in Section 5.3.6.3 for terrestrial country food species included in the existing conditions HHRA also apply to the existing conditions ERA. These include uncertainties around the use of domestic animal BTFs for wildlife species, derived ingestion rates, assumed exposure times in the study areas, and the composition of the diet. However, there were additional species that required modeling as the ERA was not limited to the three representative country food species (caribou, Arctic ground squirrel, and willow ptarmigan). The additional wildlife species that required modeling were those that are consumed as prey items by carnivores and omnivores. It was assumed that the beef BTFs would apply to mammalian prey species and that the chicken BTFs would apply to avian prey species.

Aquatic Species

The same uncertainties presented in the existing conditions HHRA Section 5.3.6.3 for aquatic species are applicable for the existing conditions ERA and thus will not be repeated here.

Vegetation Species

The same uncertainties presented in the existing conditions HHRA Section 5.3.6.3 for vegetation species are applicable for the existing conditions ERA and thus will not be repeated here.

Quality Assurance and Quality Control

The same uncertainties presented in the existing conditions HHRA Section 5.3.6.3 for quality assurance and quality control applies to the existing conditions ERA and thus will not be repeated here.

5.5.5.4 Wildlife Characteristics

Many of the characteristics required for modeling tissue COPC concentrations and total EDIs in wildlife species were based on values provided by scientific literature, allometric equations for ingestion rates, and best professional judgement. However, efforts were made to use conservative estimates, which would result in overestimates of risk rather than underestimates. For example, it was assumed that several species would spend all their time in the terrestrial wildlife LSA and consume all of their food and water from within the area.

5.5.5.5 Toxicity Reference Values

The TRVs for aquatic life ecological receptors were the CCME (2017a) freshwater and marine water quality guidelines and the freshwater and marine sediment PELs. These guidelines are based on toxicity thresholds in the most sensitive species and have UFs or safety factors applied, thus are conservative values to use in the calculation of HQs. When risk was identified (i.e., due to chromium), additional assessment indicated that adverse effects in marine aquatic life would not be expected. The assessment was conservative, using the lowest reported toxicity threshold and an upper statistic (95^{th} percentile) and conservative metal speciation to represent the marine water quality.

The TRVs for mammalian and avian ecological receptors were obtained from studies primary conducted on laboratory or domesticated species due to a lack of information on toxicity thresholds in wildlife. Therefore, the risk to the health of mammalian and avian receptors may be under- or over-predicted due to the uncertainties surrounding the applicability of these TRVs to wildlife species. However, because the TRVs for mammalian and avian receptors were based on NOAELs rather than effects based thresholds, the risks to these receptors are likely over-predicted.

5.5.6 Conclusions

This existing conditions ERA integrated the results of the environmental media baseline studies, ecological receptor characteristics, and regulatory-based TRVs. The quality of the different environmental media was conservatively representative of existing conditions at the Project site. This study evaluated potential risks to the health of ecological receptors associated with the summed exposure to COPCs from several exposure pathways (i.e., exposure to water and sediment for aquatic life receptors, ingestion of soil, ingestion of drinking water, and ingestion of diet items).

Based on the multi-media ERA described in Sections 5.2 and 5.5, risk from existing conditions to ecological health has been evaluated. The existing conditions ERA identified the following baseline COPCs that were considered to pose a risk (i.e., HQ > 1) to aquatic, mammalian, or avian ecological receptors using or foraging in the freshwater, marine, or terrestrial environments of the terrestrial or aquatic LSAs:

- aluminum for muskox, wolverine, grizzly bear, Arctic ground squirrel, Arctic shrew, northern red-backed vole, American tree sparrow, least sandpiper, yellow warbler, and ringed seal; and
- methylmercury for red-breasted merganser and least sandpiper.

This suggests that there could be risk to the health of ecological receptors due to the COPCs identified above, although it is likely that the risk has been overestimated and adverse effects may not occur. For all other ecological receptors (e.g., terrestrial plant and invertebrate ecological receptors), there is negligible potential risk to health from existing conditions.

There are uncertainties in this assessment, as described in Section 5.5.5 and throughout Section 5.5.2. However, this assessment was conducted in a manner that used multiple conservative assumptions, thus, the existing conditions ERA is likely to substantially overestimate risk to ecological receptors.

The risk from existing conditions is due to naturally-occurring or existing conditions within the respective LSAs since the Project has not been developed or approved for development at this time. It is noted that there has been development of other projects in the area (e.g., Doris), so the existing conditions may not be fully representative of naturally occurring conditions. Nevertheless, this existing conditions ERA provides the foundation for assessing the incremental changes on the health of ecological receptors due to Project-related effects. The same data, approaches, and assumptions used in the existing conditions ERA was also used in the models for predicting environmental quality during the Project (so that all predictions include existing conditions plus Project), which enables direct comparison of existing conditions and predicted environmental quality to determine incremental changes due to the Project.

5.6 MADRID-BOSTON PROJECT-RELATED ENVIRONMENTAL RISK ASSESSMENT

Many of the features of the Project-related ERA are the same as the existing conditions ERA (Section 5.5), thus much of the text applies to both assessments and will not be repeated here. Instead, the existing conditions ERA is referenced where applicable. Features that are the same in both

ERAs include: the approach that contains the six stages of toxicological risk assessment (Section 5.2; Environment Canada 2012); the LSA and RSA boundaries for the ecological receptors (Section 5.2.1); the exposure pathways (Section 5.5.1.2); the ecological receptors considered (Section 5.5.1.1); the ecological receptor characteristics (Section 5.5.1.1); and the toxicity reference values (Section 5.5.3.2). The methodology for the Project-related ERA is the same as for the existing conditions ERA (see Section 5.2); however, predictive modeling is used to determine Project-related noise levels and COPC concentrations in environmental media.

The potential Project-related effects of noise on wildlife species (i.e., ecological receptors) is described in Volume 4, Chapter 9 (Terrestrial Wildlife and Wildlife Habitat) and Volume 5, Chapter 11 (Marine Wildlife).

5.6.1 Problem Formulation

As stated in Section 5.5.1, the purpose of the problem formulation stage is to create a conceptual model for the ERA and identify data requirements to accurately assess the potential for health effects to ecological receptors due to exposure to Project-related emissions. The purpose of the problem formulation stage are the same as those listed in Section 5.5.1; however, the assessment will establish whether there is a reasonable possibility that there is a linkage between a Project-related source of contaminants and ecological receptors.

5.6.1.1 Ecological Receptors

The same ecological receptors and ecological receptor characteristics that were used in the existing conditions ERA (Section 5.5.1.1) will be used in the Project-related ERA.

5.6.1.2 Ecological Receptor Exposure Pathways

Since ecological health can be affected by changes in fresh and marine water quality, soil quality, sediment quality, vegetation quality, or prey quality, potential Project-related sources of contaminants were identified that could lead to changes in these pathways. There are two main potential sources of Project-related contaminants: atmospheric emissions and liquid effluent.

Atmospheric emissions (e.g., metals in dust) have the potential to enter the atmosphere, travel some distance, and settle where they can reside in different media such as soil, vegetation, and prey. Liquid effluent has the potential to enter the freshwater or marine environments due to direct discharges, or enter the marine and freshwater environments (water and sediment) through runoff.

Air quality can be affected by the generation of atmospheric emissions from Project components or activities. Freshwater could be affected by Project components or activities that affect freshwater. Marine water could be affected by Project components or activities that affect marine water. Soil, vegetation, and prey quality could be affected by Project-related sources of contaminants released to the atmospheric, freshwater, marine, or terrestrial environments. The exposure pathways are described in more detail in the following sections.

Soil

Fugitive dust will arise from several Project activities such as rock blasting, vehicle movement, and handling of fine materials. Generally dust will occur sporadically and be suspended for a relatively short time prior to deposition. Dust particles can be a carrier of metals naturally occurring in rocks and can deposit onto soils. Ecological receptors could be exposed to the COPCs in soil via incidental soil ingestion. Dermal contact to soil and inhalation of soil were not considered as significant exposure pathways in the ecological risk assessment for reasons outlined in Section 5.5.1.

Water

Freshwater

Discharge of effluent from water management structures during the Operational phase could introduce contaminants to the freshwater environment. Ecological receptors could be exposed to the COPCs in freshwater via water ingestion and contact with water (invertebrates).

The potential effects to freshwater quality from the Project sources of effluent are described in Volume 5, Sections 4.5.2 and 4.5.4. The surface water quality model considered all of the Project-related sources of effluent to the freshwater environment. The potential effects to freshwater sediment quality from the Project sources of effluent are described in Volume 5, Sections 5.5.2 and 5.5.4.

Marine Water

Discharge of effluent from water management structures during the Operational phase could introduce contaminants to the marine environment. Ecological receptors could be exposed to the COPCs in marine water via water ingestion and contact with water (invertebrates).

The potential effects to marine water quality from the Project sources of effluent are described in Volume 5, Sections 8.5.2 and 8.5.4. The marine water quality assessment considered all of the Project-related sources of effluent to the marine environment. The potential effects to marine sediment quality from the Project sources of effluent are described in Volume 5, Sections 9.5.2 and 9.5.4.

Vegetation and Prey Quality

Fugitive dust will arise from several Project activities such as rock blasting, vehicle movement, and handling of fine materials. Dust particles can be a carrier of metals naturally occurring in rocks and can deposit onto vegetation. The COPCs could then be taken up by terrestrial wildlife and could accumulate in prey items.

Discharge of effluent from water management structures during the Operational phase could introduce contaminants to the terrestrial environment where soil and vegetation could take up COPCs. The COPCs could then be taken up by terrestrial wildlife and prey items.

5.6.1.3 Selection of Project-related Contaminants of Potential Concern

A description and inventory of the types of materials and chemicals likely to be present at the Project is provided in the Project Description (see Table 4.4-11 in Volume 3 and Section 4.4.11). Potential sources of Project-related COPCs could be from fuel, mining and milling process chemicals, explosives, inert chemical fire suppression systems, and other chemicals that may be used around the Project site. However, these chemicals and materials are likely to reach the terrestrial or freshwater environments only in the event of unusual circumstances such as spills or malfunctions. Mitigation and management plans (e.g., Environmental Protection Plan, Risk Management and Emergency Response, Fuel Management, Spill Contingency, Tailings Management, Waste Management, and Hazardous Materials Management) are provided (see Volume 8, Chapter 1) to ensure the safe handling and storage of these materials to prevent their release to the environment where exposures to ecological receptors could occur. Therefore, the contaminants that may come from these potential sources were not considered further in this assessment.

Consistent with the existing conditions ERA (Section 5.5.1.3), the focus of this assessment is the metals and non-metals (e.g., ions, nutrients) that could be present in Project atmospheric emissions or discharges. To select COPCs for evaluation in the Project-related ERA, the same screening methodology described in Section 5.5.1.3 was used.

Contaminants of Potential Concern in Soil

The results of the soil quality screening that was conducted for the Project-related HHRA (Section 5.4.1.3 and Table 5.4-3) also apply to the Project-related ERA as the lowest of the CCME human health or environmental health guideline was selected for the screening process; thus the screening procedure is not repeated here.

During the Construction and Operational phases, predicted maximum metal concentrations in soil were lower than CCME guidelines for the protection of environmental and human health for agricultural land (residential parkland for barium), except for chromium, copper, and nickel (Table 5.4-3).

The baseline concentrations of these three metals also exceeded the soil quality guidelines. The predicted concentrations are almost identical to the baseline concentrations and the largest percent change relative to baseline concentrations for these parameters is only 0.33% (for selenium) in the Construction phase and 0.44% (for selenium) in the Operational phase (Table 5.4-3). A change in soil concentrations of less than 1% (and likely up to 10%) compared to existing background levels is not measurable and is not likely to translate into a measurable change in tissue quality in terrestrial organisms (i.e., vegetation and prey items) that may be consumed by ecological receptors. However, similar to the existing conditions ERA, chromium, copper, and nickel are carried forward as COPCs in soil in the Project-related ERA.

Tailings Contained within the Tailings Impoundment Area

Terrestrial wildlife could be exposed to tailings solids contained within the TIA during the Operational phase. Only floatation tailings will be deposited in the TIA, as detoxified tailings are expected to be backfilled underground as described in the Project Description (Volume 3, Chapter 2).

Tailings chemistry (metal concentrations) was obtained from analyses conducted on tailings samples (n = 14) generated from the various deposits (SRK 2015, 2016b). The maximum metal concentration reported for floatation tailings was used in the COPC screening. Tailings metal concentrations were compared to the CCME soil quality guidelines for the protection of environmental and human health for agricultural land (CCME 2017a). Results of the COPC screening for tailings are provided in Table 5.6-1.

Table 5.6-1. Screening Results for Selection of Contaminants of Potential Concern in Tailings for Caribou

Parameters	CCME Soil Quality Guidelines - Agricultural [a] (mg/kg)	Maximum Concentration in Tailings [b] (mg/kg)	COPC (Yes/No)
Arsenic	12	338	**Yes**
Antimony	20	5.00	No
Barium [b]	500	192	No
Beryllium	4	20.0	**Yes**
Cadmium	1.4	0.500	No
Chromium	64	274	**Yes**
Cobalt	40	34.9	No
Copper	63	86.8	**Yes**

Parameters	CCME Soil Quality Guidelines - Agricultural [a] (mg/kg)	Maximum Concentration in Tailings [b] (mg/kg)	COPC (Yes/No)
Lead	70	17.0	No
Mercury	6.6	3.00	No
Molybdenum	5	9.50	**Yes**
Nickel	45	323	**Yes**
Selenium	1	5.00	**Yes**
Silver	20	1.20	No
Thorium	1	0.400	No
Tin	5	1294	**Yes**
Uranium	23	0.100	No
Vanadium	130	75.0	No
Zinc	200	73.0	No

Notes:
All concentrations are dry weight.
CCME = Canadian Council of Ministers of the Environment
[a] CCME (2017a).
[b] Tailings metal data included five samples from the Doris Mine, three samples from the Madrid North deposit, five samples from the Madrid South deposit, and one sample from the Boston deposit.
[c] The CCME soil quality guideline for barium is lower for residential parkland use (500 mg/kg) than it is for agricultural use (750 mg/kg); therefore, the residential parkland guideline was adopted for COPC screening.
Grey shading indicates exceedance of the CCME soil quality guidelines - agricultural or residential/parkland.

Based on the screening results (Table 5.6-1), multiple COPCs were identified in floatation tailings for terrestrial wildlife including arsenic, beryllium, chromium, copper, molybdenum, nickel, selenium, and tin.

It is expected that most wildlife would be deterred from using the TIA due to mining activities that would be ongoing during the Operational phase. In addition, mitigation measures have been proposed to minimize the potential for terrestrial wildlife to be exposed to the tailings contained within the TIA during the Operational phase. These mitigation measures are described in Volume 4, Chapter 9. Monitoring and mitigation measures may include: monitoring of the TIA for wildlife (including caribou) usage, excluding caribou (or other wildlife) if water quality does not meet acceptable standards, or the use of water cannons or other types of deterrents to exclude wildlife from the TIA. Taking into consideration these monitoring and mitigation measures, it is considered unlikely that wildlife would spend appreciable amounts of time within the TIA and exposures to tailings is expected to be minimal; further consideration of this potential exposure route would not be warranted.

However, concerns regarding the potential for caribou to eat tailings from the TIA were raised in an information request from the KIA on the Doris North Type A Water License Amendment, during the hearings for the Water License, and during the Caribou Workshop held in Cambridge Bay in September 2016. Therefore, the potential risk to caribou health from this exposure route was evaluated in the Exposure Assessment (Section 5.6.2.7), Toxicity Assessment (Section 5.6.3.2), and Risk Characterization (Section 5.6.4.6).

Contaminants of Potential Concern in Water

Freshwater

Consistent with the approach used in the characterization of existing conditions freshwater quality (Section 5.5.1.3), maximum predicted concentrations at the 13 surface water quality modeling nodes located within the terrestrial environment LSA were compared to the CCME guidelines for the protection of freshwater aquatic life (CCME 2017a) for fish and aquatic life, and CCME guidelines for the protection of agriculture - livestock (CCME 2017a) for all other wildlife VECs.

Predicted surface water quality at the water quality modeling nodes is provided in the Madrid-Boston Project Water and Load Balance (P5-4). The 13 surface water quality modeling nodes were used to represent water quality that ecological receptors would potentially ingest and forage in. The Madrid-Boston Project Water and Load Balance (P5-4) describes the methodology and assumptions used in the surface water quality model for the Project. Water quality modeling provided quantitative estimates of predicted surface water quality at 13 surface water quality modeling nodes located downstream of the Project (described in Section 5.3.3.5 of the existing conditions HHRA).

Fugitive dust from the Project can also be deposited on surface waters as dustfall. For freshwater lakes and streams, water quality changes due to dustfall (i.e., air emissions) were evaluated in Volume 5, Section 4.5.4.8. Due to the low predicted total suspended solid loads from dustfall (0.0006 to 0.0066 mg/L/day), there are negligible effects to freshwater lakes and streams from dustfall (Volume 5, Section 4.5.4.7.1).

The maximum predicted concentrations of the non-metal parameters in surface water at the 13 surface water quality model nodes during the Construction and Operational phases were used to determine if the parameter was a COPC. The COPC screening of surface water quality is provided in Volume 5, Section 4.5.4.2.

Predicted maximum concentrations of some metals and nutrients exceeded the CCME freshwater quality guidelines during the Construction and Operational phases (Volume 5, Section 4.5.4.2). Therefore, the list of COPCs identified in freshwater during Construction and Operational phases were carried forward to the Madrid-Boston Project-Related ERA. The surface water COPCs for aquatic life ecological receptors include: chloride, fluoride, total aluminum, total cadmium, total chromium, total copper, total iron, total mercury, and total silver. There were no surface water COPCs identified for other ecological receptors (i.e., mammalian or avian wildlife species) during the Construction or Operational phases.

Water Contained within the Tailings Impoundment Area

Terrestrial wildlife could be exposed to water contained within the TIA during the Operational phase. No fish or aquatic life are expected to be present within the TIA so they are not considered further.

Water quality within the TIA was predicted in the surface water quality model (the Madrid-Boston Project Water and Load Balance, Package P5-4). Predictions were compared to the CCME water quality guidelines for the protection of agriculture - livestock (CCME 2017a). Results of the COPC screening are provided in Table 5.6-2.

Based on the screening results (Table 5.6-2), only arsenic was identified as a COPC in TIA water for caribou.

Table 5.6-2. Screening Results for Selection of Contaminants of Potential Concern in Tailings Impoundment Area (Tail Lake) Water for Caribou

Parameters	CCME Water Quality Guidelines For the Protection of Agriculture - Livestock [a] (mg/L)	Maximum Concentration Predicted in TIA during the Operational Phase [b] (mg/L)	COPC (Yes/No)
Physical Parameters			
Total Suspended Solids	3,000	2.97	No
Major Anions			
Fluoride	2	0.224	No
Sulphate	1,000	749	No
Nutrients			
Nitrite	10	1.79	No
Total Metal			
Aluminum	5	0.954	No
Arsenic	0.025	1.16	Yes
Beryllium	0.1	0.0161	No
Boron	5	0.286	No
Cadmium	0.08	0.000541	No
Calcium	1,000	173	No
Chromium	0.05	0.0195	No
Cobalt	1	0.0182	No
Copper	0.5	0.0409	No
Lead	0.1	0.00174	No
Mercury	0.003	0.000173	No
Molybdenum	0.5	0.199	No
Nickel	1	0.0887	No
Silver	0.05	0.00116	No
Uranium	0.2	0.00199	No
Vanadium	0.1	0.0227	No
Zinc	50	0.0534	No

Notes:
CCME = Canadian Council of Ministers of the Environment
TIA = tailings impoundment area
[a] *CCME (2017a).*
[b] *Equivalent to the Tail Lake node output results from the surface water quality model.*
Grey shading indicates exceedance of the CCME freshwater quality guidelines for the protection of agriculture/livestock.

It is expected that most wildlife would be deterred from using the TIA due to mining activities that would be ongoing during the Operational phase. In addition, mitigation measures have been proposed to minimize the potential for terrestrial wildlife (including birds) to be exposed to the water contained within the TIA during the Operational phase. These mitigation measures are described in Volume 4, Chapter 9. Monitoring and mitigation measures may include: monitoring of TIA water quality as part of the Aquatic Effects Monitoring Program; monitoring of the TIA for wildlife (including caribou) usage, excluding caribou (or other wildlife) if water quality does not meet acceptable standards, or the use of water cannons or other types of deterrents to exclude wildlife from the TIA. Taking into consideration these monitoring and mitigation measures, it is considered unlikely that wildlife would spend appreciable amounts of time within the TIA and exposures to TIA water is expected to be minimal; further consideration of this potential exposure route would not be warranted.

However, concerns regarding the potential for caribou to drink water from the TIA were raised in an information request from the KIA on the Doris North Type A Water License Amendment, during the hearings for the Water License, and during the Caribou Workshop held in Cambridge Bay in September 2016. Therefore, the potential risk to caribou health from this exposure was evaluated in the Exposure Assessment (Section 5.6.2.7), Toxicity Assessment (Section 5.6.3.2), and Risk Characterization (Section 5.6.4.6)

Marine Water

Potential Project-related effects on marine water quality during the Construction and Operational phases were assessed in Volume 5, Section 8.5.4. No measurable changes are expected to occur in marine water quality in Roberts Bay as a result of Project activities (see Volume 5, Section 8.5.4), thus metal concentrations are expected to remain the same as under existing conditions.

Fugitive dust from the Project can also be deposited on marine waters as dustfall. For marine waters, water quality changes due to dustfall (i.e., air emissions) were evaluated in Volume 5, Section 8.5.4.6. Due to the low predicted total suspended solid loads from dustfall (0.00007 to 0.00027 mg/L/day), there are negligible effects to marine water quality from dustfall (Volume 5, Section 8.5.4.6). However, the ecological risks associated with the Madrid-Boston Project related to potential effects on marine life were conducted in full. As there are no changes in marine water quality, the list of COPCs identified in the existing conditions ERA for marine water (i.e., arsenic, chromium, and mercury; Table 5.5-3) was carried forward to the Madrid-Boston Project-Related ERA.

Contaminants of Potential Concern in Sediment

Freshwater sediment quality was assessed in Volume 5, Chapter 5 as part of the freshwater environment assessment. Effects on freshwater sediment quality were informed by the analysis of effects to freshwater quality (Volume 5, Chapter 4), which was based on the quantitative water balance model (P5-4). Marine sediment quality was assessed in the EIS Volume 5, Chapter 9 as part of the marine environment assessment. Effects on marine sediment quality were informed by the analysis of effects to marine water quality (Volume 5, Chapter 8).

Metals, nutrients, and organic material are continuously exchanged between the water column and sediments depending on the specific environmental conditions and the properties of the constituents of water or sediments. It is conservative to assume that increases in metal and nutrient concentrations in the water would lead to increases in metal and nutrient concentrations in sediments.

Freshwater and marine sediment quality is not expected to change due to Project activities (see Volume 5, Sections 5.5.4 and 9.5.4). Therefore, the list COPCs identified under the existing conditions ERA for freshwater and marine sediments (i.e., arsenic, chromium, and copper) were carried forward to the Madrid-Boston Project-Related ERA.

Contaminants of Potential Concern in Vegetation and Prey

Contaminant concentrations in vegetation within the ecological RSA were predicted for the Construction and Operational phases (Appendices V6-5L and V6-5M). However, there are no vegetation tissue residue guidelines for comparison so these data were not included in the COPC screening procedure.

No measurable changes are expected to occur in marine water quality in Roberts Bay as a result of Project activities (see Volume 5, Section 8.5.4), thus metal concentrations in Arctic Char tissue and bay mussel tissue are expected to remain the same as under existing conditions.

Lake Trout, Whitefish, and Ninespine Stickleback tissue concentrations were predicted for the Madrid-Boston Project-related ERA based on site-specific BCFs calculated using baseline fish and water data, using the methodology described in Section 5.4.1.3. The predicted metal concentrations in Lake Trout, Whitefish, and Ninespine Stickleback tissue during the Construction and Operational phases are provided in Tables 5.6-3, 5.6-4, and 5.6-5.

During the Construction and Operational phases, the predicted mercury concentrations (assumed to be entirely methylmercury) in Lake Trout, Whitefish, and Ninespine Stickleback tissue (Tables 5.6-3, 5.6-4, and 5.6-5) exceeded the CCME methylmercury tissue residue guideline for the protection of wildlife consumers of aquatic biota (0.033 mg/kg ww; CCME 2017a). None of the predicted selenium concentrations in fish tissue exceeded the BC MOE selenium tissue residue guideline for fish/shellfish consumption by wildlife (Beatty and Russo 2014). Therefore, mercury was the only COPC identified in fish tissue that is applicable to wildlife.

Final List of Contaminants of Potential Concern Selected for Evaluation

The same screening criteria used in the existing conditions ERA (i.e., screening against guidelines; Section 5.5.1.3) was used in the Project-related ERA. This screening process identified the following COPCs during the Construction and Operational phases for inclusion in the Project-related ERA:

- chromium, copper, and nickel in soil for wildlife receptors;
- chloride, fluoride, total aluminum, total cadmium, total chromium, total copper, total iron, total mercury, and total silver in surface water for aquatic life receptors only;
- arsenic, chromium, and mercury in marine water for aquatic life and marine wildlife receptors;
- arsenic, chromium, and copper in freshwater and marine sediments for aquatic life and wildlife receptors; and
- mercury in fish tissue for wildlife consumers.

Several metals are considered to be bioaccumulative (see Section 5.3.2.3), including arsenic, cadmium, lead, mercury, nickel, selenium, thallium, and zinc. Therefore, those metals were also carried forward in the Project-related ERA.

Based on the screening methodology outlined above, the COPCs selected for the Project-related ERA include: aluminum, arsenic, cadmium, chloride, chromium, copper, fluoride, iron, lead, mercury, nickel, selenium, silver, thallium, and zinc. However, chloride, fluoride, aluminum, iron, and silver only apply to freshwater aquatic life receptors (i.e., primary producers, pelagic and benthic invertebrates, and fish).

For the assessment of caribou consumption of tailings and TIA water, several COPCs were identified. The COPCs identified in tailings included: arsenic, beryllium, chromium, copper, molybdenum, nickel, selenium, and tin. The only COPC identified in TIA water was arsenic. Consistent with the COPC selection process for all wildlife VECs above, metals (and metalloids) considered to be bioaccumulative were also included as COPCs for the caribou tailings assessment. Therefore, the final list of COPCs considered for caribou were: arsenic, beryllium, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, thallium, tin, and zinc.

Table 5.6-3. Calculated Concentration of Metals in Lake Trout Tissue during the Construction and Operational Phases

Parameter	Construction Phase Predicted 95th Percentile Freshwater Concentration (mg/L)	Operational Phase Predicted 95th Percentile Freshwater Concentration (mg/L)	BCF Water-to-Lake Trout	Construction Phase Lake Trout Tissue Concentration (mg/kg ww)	Operational Phase Lake Trout Tissue Concentration (mg/kg ww)
Aluminum	1.28E-01	1.26E-01	32.9	4.23	4.16
Antimony	6.44E-05	6.73E-05	80.3	0.00517	0.00540
Arsenic	4.57E-04	6.00E-04	324	0.148	0.195
Barium	5.70E-03	5.79E-03	17.1	0.097	0.099
Beryllium	1.40E-05	1.47E-05	3503	0.0490	0.0515
Cadmium	1.39E-05	1.45E-05	175	0.00244	0.00253
Calcium	1.08E+01	1.09E+01	36.2	390	393
Chromium	7.33E-04	7.25E-04	445	0.326	0.323
Cobalt	1.37E-04	1.40E-04	72.7	0.00999	0.0102
Copper	2.62E-03	2.78E-03	137	0.358	0.381
Lead	1.22E-04	1.22E-04	645	0.0787	0.0787
Lithium	1.02E-02	1.03E-02	4.84	0.0496	0.0499
Magnesium	7.57E+00	7.53E+00	46.7	353	352
Manganese	3.22E-02	3.29E-02	8.38	0.270	0.275
Mercury	2.83E-06	3.08E-06	388859	1.10	1.20
Molybdenum	2.17E-04	2.20E-04	84.5	0.0183	0.0186
Nickel	1.09E-03	1.10E-03	183	0.199	0.202
Selenium	5.36E-04	5.30E-04	1120	0.600	0.594
Thallium	5.84E-06	6.11E-06	1836	0.0107	0.0112
Uranium	7.55E-05	8.02E-05	13.5	0.001022	0.00109
Vanadium	4.47E-04	4.63E-04	115	0.0515	0.0533
Zinc	4.79E-03	4.85E-03	1011	4.84	4.90

Notes:
BCF = bioconcentration factor
ww = wet weight
(-) = not available
Grey highlighting indicates exceedance of the CCME (2000) methylmercury tissue residue guideline for the protection of wildlife consumers of aquatic biota (0.033 mg/kg ww).
The BC MOE (Beatty and Russo 2014) selenium tissue residue guideline for fish/shellfish consumption by wildlife (1 mg/kg ww) was not exceeded.
BCFs were calculated by dividing the existing conditions 95th percentile metal concentration in Lake Trout tissue by the existing conditions 95th percentile metal concentration in freshwater.

Table 5.6-4. Calculated Concentration of Metals in Whitefish Tissue during the Construction and Operational Phases

Parameter	Construction Phase Predicted 95th Percentile Freshwater Concentration (mg/L)	Operational Phase Predicted 95th Percentile Freshwater Concentration (mg/L)	BCF Water-to-Whitefish	Construction Phase Whitefish Tissue Concentration (mg/kg ww)	Operational Phase Whitefish Tissue Concentration (mg/kg ww)
Aluminum	1.28E-01	1.26E-01	23.7	3.04	3.00
Antimony	6.44E-05	6.73E-05	80.3	0.00517	0.00540
Arsenic	4.57E-04	6.00E-04	394	0.180	0.236
Barium	5.70E-03	5.79E-03	8.86	0.0505	0.0513
Beryllium	1.40E-05	1.47E-05	3503	0.0490	0.0515
Boron	3.09E-02	3.09E-02	-	-	-
Cadmium	1.39E-05	1.45E-05	175	0.00244	0.00253
Calcium	1.08E+01	1.09E+01	44.7	482	486
Chromium	7.33E-04	7.25E-04	150	0.110	0.109
Cobalt	1.37E-04	1.40E-04	169	0.0233	0.0237
Copper	2.62E-03	2.78E-03	124	0.324	0.344
Iron	2.43E-01	2.43E-01	-	-	-
Lead	1.22E-04	1.22E-04	992	0.121	0.121
Lithium	1.02E-02	1.03E-02	4.84	0.0496	0.0499
Magnesium	7.57E+00	7.53E+00	44.6	338	336
Manganese	3.22E-02	3.29E-02	24.5	0.790	0.806
Mercury	2.83E-06	3.08E-06	111662	0.316	0.344
Molybdenum	2.17E-04	2.20E-04	23.5	0.00510	0.00518
Nickel	1.09E-03	1.10E-03	256	0.278	0.282
Selenium	5.36E-04	5.30E-04	517	0.277	0.274
Silver	1.13E-05	1.16E-05	-	-	-
Sodium	3.01E+01	2.97E+01	-	-	-
Thallium	5.84E-06	6.11E-06	835	0.00488	0.00510
Uranium	7.55E-05	8.02E-05	13.5	0.001022	0.00109
Vanadium	4.47E-04	4.63E-04	115	0.0515	0.0533
Zinc	4.79E-03	4.85E-03	829	3.97	4.02

Notes:
BCF = bioconcentration factor
ww = wet weight
(-) = not available
Grey highlighting indicates exceedance of the CCME (2000) methylmercury tissue residue guideline for the protection of wildlife consumers of aquatic biota (0.033 mg/kg ww).
The BC MOE (Beatty and Russo 2014) selenium tissue residue guideline for fish/shellfish consumption by wildlife (1 mg/kg ww) was not exceeded.
BCFs were calculated by dividing the existing conditions 95th percentile metal concentration in Whitefish tissue by the existing conditions 95th percentile metal concentration in freshwater.

Table 5.6-5. Calculated Concentration of Metals in Ninespine Stickleback Tissue during the Construction and Operational Phases

Parameter	Construction Phase Predicted 95th Percentile Freshwater Concentration (mg/L)	Operational Phase Predicted 95th Percentile Freshwater Concentration (mg/L)	BCF Water-to-Ninespine Stickleback	Construction Phase Ninespine Stickleback Tissue Concentration (mg/kg ww)	Operational Phase Ninespine Stickleback Tissue Concentration (mg/kg ww)
Aluminum	1.28E-01	1.26E-01	445	57.1	56.2
Antimony	6.44E-05	6.73E-05	241	0.0155	0.0162
Arsenic	4.57E-04	6.00E-04	237	0.108	0.142
Barium	5.70E-03	5.79E-03	782	4.46	4.53
Beryllium	1.40E-05	1.47E-05	10508	0.147	0.154
Boron	3.09E-02	3.09E-02	3.49	0.108	0.108
Cadmium	1.39E-05	1.45E-05	3131	0.0436	0.0453
Calcium	1.08E+01	1.09E+01	1696	18282	18452
Chromium	7.33E-04	7.25E-04	455	0.333	0.330
Cobalt	1.37E-04	1.40E-04	447	0.0614	0.0627
Copper	2.62E-03	2.78E-03	842	2.20	2.34
Iron	2.43E-01	2.43E-01	381	92.6	92.5
Lead	1.22E-04	1.22E-04	633	0.0773	0.0773
Lithium	1.02E-02	1.03E-02	14.5	0.149	0.150
Magnesium	7.57E+00	7.53E+00	78.8	597	594
Manganese	3.22E-02	3.29E-02	645	20.8	21.2
Mercury	2.83E-06	3.08E-06	42318	0.120	0.130
Molybdenum	2.17E-04	2.20E-04	239	0.0520	0.0528
Nickel	1.09E-03	1.10E-03	247	0.269	0.272
Selenium	5.36E-04	5.30E-04	859	0.460	0.455

Parameter	Construction Phase Predicted 95th Percentile Freshwater Concentration (mg/L)	Operational Phase Predicted 95th Percentile Freshwater Concentration (mg/L)	BCF Water-to-Ninespine Stickleback	Construction Phase Ninespine Stickleback Tissue Concentration (mg/kg ww)	Operational Phase Ninespine Stickleback Tissue Concentration (mg/kg ww)
Silver	1.13E-05	1.16E-05	-	-	-
Sodium	3.01E+01	2.97E+01	51.3	1541	1520
Thallium	5.84E-06	6.11E-06	2504	0.0146	0.0153
Uranium	7.55E-05	8.02E-05	1513	0.114	0.121
Vanadium	4.47E-04	4.63E-04	538	0.240	0.249
Zinc	4.79E-03	4.85E-03	16364	78.4	79.3

Notes:
BCF = bioconcentration factor
ww = wet weight
(-) = not available
Grey highlighting indicates exceedance of the CCME (2000) methylmercury tissue residue guideline for the protection of wildlife consumers of aquatic biota (0.033 mg/kg ww).
The BC MOE (Beatty and Russo 2014) selenium tissue residue guideline for fish/shellfish consumption by wildlife (1 mg/kg ww) was not exceeded.
BCFs were calculated by dividing the existing conditions 95th percentile metal concentration in Ninespine Stickleback tissue by the existing conditions 95th percentile metal concentration in freshwater.

5.6.1.4 Mitigation Measures for Contaminants of Potential Concern

No additional mitigation measures were considered in the Project-related ERA beyond what was outlined in the previous effects assessment chapters. Mitigation and management strategies will be in place for a number of VECs that will serve to minimize the potential effects of the Project on ecological receptors since the health of ecological receptors is dependent on the quality of the surrounding environmental media (i.e., water, soil, sediment, and vegetation). In addition, strategies to minimize the potential for Project-related effects to wildlife have also been developed. Mitigation and adaptive management strategies for VECs can be found in the following volumes and chapters:

- Air Quality: Volume 4, Chapter 2;
- Landforms and Soils: Volume 4, Chapter 7;
- Vegetation and Special Landscape Features: Volume 4, Chapter 8;
- Terrestrial Wildlife and Wildlife Habitat: Volume 4, Chapter 9;
- Freshwater Water Quality: Volume 5, Chapter 4;
- Freshwater Sediment Quality: Volume 5, Chapter 5;
- Freshwater Fish: Volume 5, Chapter 6;
- Marine Water Quality: Volume 5, Chapter 8;
- Marine Sediment Quality: Volume 5, Chapter 9;
- Marine Fish: Volume 5, Chapter 10; and
- Marine wildlife: Volume 5, Chapter 11.

5.6.1.5 Conceptual Model

A simplified schematic diagram of the sources of COPCs and pathways by which ecological receptors may be exposed to Project-related emissions is depicted in Figure 5.6-1. There are two general sources of emissions from the Project: atmospheric emissions (e.g., fugitive dust with associated COPCs) and liquid effluent (e.g., effluent discharge and treated waste water). Fugitive dust and emission particulates have the potential to enter the atmosphere, travel some distance, and settle, where they can reside in different media such as soil and vegetation. These media can be taken up by wildlife through the ingestion exposure route.

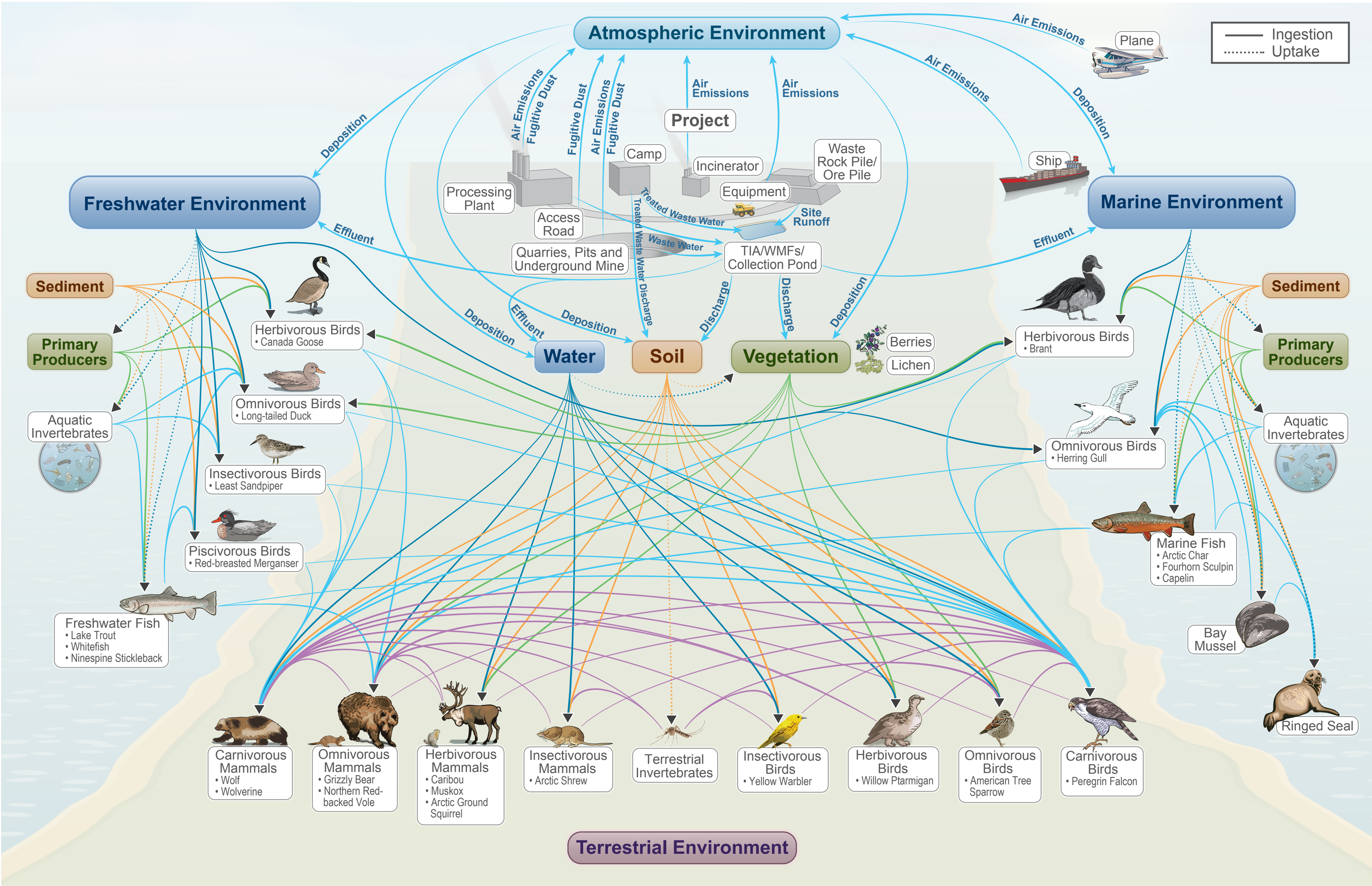
The conceptual model for the Project-related ERA is presented in Figure 5.6-1, which shows how COPCs released from the Project could enter the environment (i.e., air, surface water, vegetation, and soil) and move into ecological receptors via ingestion and gill uptake.

5.6.1.6 Identification of Disease Vectors

Certain infectious diseases have the ability to be transmitted between species (sometimes by a vector) from non-human animals to humans, or from humans to other animals, and are known as zoonotic diseases. Disease vectors are biological agents (e.g., person, animal, or microorganism) that can carry and transmit infectious diseases to other living hosts. Harmful diseases can be transmitted to humans via disease vectors such as arthropods (e.g., mites, ticks, lice, fleas, mosquitoes, and flies) and wildlife (e.g., bats, raccoons, and rodents).

Figure 5.6-1

Conceptual Model for Potential Human Exposure to Madrid-Boston Project-related Contaminants of Potential Concern for Ecological Receptors



It is possible to consider zoonotic diseases as contaminants if (Leighton 2003):

- they are introduced into an ecosystem for the first time by humans;
- human activity causes them to concentrate in specific areas;
- human activities alter the ecosystem in a way that changes the occurrence of diseases due to changes in relationships between pathogens and their hosts; or
- genetic engineering technology results in the creation of new man-made pathogen strains.

Arctic host species can transmit several zoonotic diseases, such as trichinella in walrus and polar bear and cryptosporidium in marine and terrestrial mammals (NRCan 2014). A lack of information exists on specific hosts and modes of transmission in the Arctic environment. Furthermore, climate change is rapidly changing the situation as a link exists between zoonotic diseases and temperature (NRCan 2014). Environmental temperature significantly affects vectors that have developmental stages that occur outside warm blooded hosts, for example cooler northern climates inhibit the developmental rate of insects and nematodes (Bradley et al. 2005). Two important zoonotic diseases that occur in Canada (i.e., Lyme disease spread by ticks and West Nile virus spread by mosquitoes and wild birds) have not been detected in the Arctic due to cold temperatures (Leighton 2011). However, as temperatures in the north increase the distribution of these zoonotic diseases may move north. Zoonotic disease transmission via wildlife is likely the predominant method of exposure for people residing in Nunavut.

Zoonotic diseases identified to occur in the Arctic include those caused by: *Trichinella*, *Anisakis*, *Diphyllobothrium*, *Echinococcus*, and *Toxoplasma*, and potentially *Cryptosporidium* and *Giardia* (Polley, Hoberg, and Kutz 2010). Furthermore, the Artic fox is a carrier for some strains of rabies, while Brucellosis is caused by the bacterial genus *Brucella* and can be transmitted from animals (e.g., bison, caribou, fox, bears, ringed seals, and beluga whales) to people upon contact or consumption (Leighton 2011). However, the identification of trends and prediction of future trends is not possible as the ecology of Brucella in caribou and marine mammals is currently too poorly understood (Leighton 2011). Zoonotic diseases can result in obvious clinical disease in humans; however, infected people do not necessarily display clinical symptoms. Potential zoonotic diseases in Nunavut and their wildlife vectors are presented in Table 5.6-6.

Table 5.6-6. Potential Zoonotic Diseases in Nunavut and Their Vectors

Disease	Disease Type	Vector
Anthrax (*Bacillus anthracis*)	Bacteria	Bison, cervids
Broad fish tapeworm (*Diphyllobothriasis*)	Parasite	Fish
Brucellosis (*Brucella* spp.)	Bacteria	Mammals
Cryptosporidosis (*Cryptosporidium* spp.)	Parasite	Mammals, mosquitos
Filarial worms (*Dirofilaria* spp.)	Parasite	Black flies
Giardia (*Giardia* spp.)	Parasite	Mammals, birds
Hantavirus (*Bunyaviridae*)	Virus	Rodents (e.g., mice)
Herring roundworm (*Anisakiasis simplex*)	Parasite	Fish
Hydatid Disease (*Echinococcus granulosus* and *Echinococcus multilocularis*)	Parasite	Canine (dog, wolf, coyote, fox)
Leptospirosis (*Leptospira* spp.)	Bacteria	Beaver, deer, rodents, raccoon
Plague (*Yersinia pestis*)	Bacteria	Rodents, squirrels, mink, marten, bobcat, lynx, flea

Disease	Disease Type	Vector
Rabies (*Rhabdoviridae*)	Virus	Bat, any mammal
Raccoon Roundworm (*Baylisascaris* spp.)	Parasite	Raccoon
Ringworm (*Microsporum canis* and *Trichophyton verrucosum*)	Parasite	Mammals
Sarcoptic mange (*Sarcoptes scabiei*)	Parasite	Canine (dog, wolf, coyote, fox)
Toxoplasmosis (*Toxoplasma gondii*)	Parasite	Mammals
Trichinellosis (*Trichinella spiralis*)	Parasite	Bear
Tuberculosis (*Mycobacterium bovis* and *Mycobacterium avium*)	Bacteria	Birds, bison, cervids
Tularemia (*Francisella tularensis*)	Bacteria	Beaver, hare, rabbit, muskrat

5.6.2 Exposure Assessment

5.6.2.1 Introduction

The exposure assessment methodology follows that described in the existing conditions ERA (Section 5.5.2).

As described in Section 5.6.1.3, concerns were identified regarding the potential for caribou to ingest tailings and water from the TIA. Therefore, the potential exposure to caribou from COPCs in tailings and TIA water is evaluated in this section. The exposure assessment methodology follows that described in the existing conditions ERA (Section 5.5.2).

5.6.2.2 Ingestion of Soil and Sediment

The predicted 95^{th} percentile COPC concentrations in soil at 68 sites within the terrestrial LSA (Appendices V6-5H and V6-5I) were used as an input into the equation to calculate the EDI of COPCs ecological receptors receive from ingestion of soil during the Construction and Operational phases.

The existing conditions 95^{th} percentile COPC concentrations in freshwater sediment (lakes and streams) from sites within the freshwater environment LSA (Table V6-5N4 in Appendix V6-5N) were used as an input in the equation to calculate the EDI of COPCs that freshwater species (i.e., Canada goose, least sandpiper, red-breasted merganser, and long-tailed duck) receive from ingestion of freshwater sediment during the Construction and Operational phases. This is because freshwater sediment quality is not changing from existing conditions (see Volume 5, Section 5.5.4).

The existing conditions 95^{th} percentile concentrations of COPCs in marine sediment from sites within the marine wildlife LSA (Table V6-5N4 in Appendix V6-5N) were used as an input in the equation to calculate the EDI of COPCs that marine species (i.e., brant, herring gull, and ringed seal) receive from ingestion of marine sediment during the Construction and Operational phases. This is because marine sediment quality is not changing from existing conditions (see Volume 5, Section 9.5.4).

The equation used to calculate ecological receptor exposure to COPCs (mg/kg BW/day) from soil ingestion was Equation 19 from Section 5.5.2.2 of the existing conditions ERA.

The COPC EDI via the soil or sediment ingestion exposure route for the Construction and Operational phases for ecological receptors are presented in Tables 5.6-7 and 5.6-8. The assumptions used in the calculation of the EDI of COPCs via ingestion of soil or sediment were the same as those described in the existing conditions ERA (Section 5.5.2.2). A sample calculation was also provided in the existing conditions ERA.

Table 5.6-7. Estimated Daily Intake of Contaminants of Potential Concern for Wildlife Species during the Construction Phase

	Caribou				Muskox				Wolverine				Grizzly Bear					Wolf			
COPC	$EDI_{[veg]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$
Aluminum	1.23E-02	2.56E-01	1.03E-05	2.68E-01	7.81E+00	5.50E+01	7.25E-03	6.29E+01	5.87E+00	6.26E+01	9.91E-03	6.85E+01	2.05E+00	1.30E+00	2.74E+01	3.16E-03	8.26E+00	4.94E-01	5.07E+01	8.60E-03	6.48E-01
Arsenic	6.28E-06	4.45E-05	3.68E-08	5.08E-05	3.97E-03	9.56E-03	2.58E-05	1.36E-02	3.80E-03	1.09E-02	3.53E-05	1.47E-02	1.04E-03	5.58E-04	4.77E-03	1.12E-05	1.71E-03	9.94E-05	8.81E-03	3.06E-05	1.55E-04
Cadmium	4.63E-06	3.01E-06	1.12E-09	7.63E-06	2.93E-03	6.47E-04	7.87E-07	3.57E-03	1.45E-04	7.36E-04	1.08E-06	8.82E-04	7.68E-04	6.31E-05	3.22E-04	3.43E-07	3.10E-04	1.03E-05	5.96E-04	9.34E-07	1.24E-05
Chromium	4.68E-04	7.89E-04	5.90E-08	1.26E-03	2.96E-01	1.70E-01	4.14E-05	4.66E-01	2.24E-02	1.93E-01	5.66E-05	2.15E-01	7.77E-02	5.35E-03	8.46E-02	1.80E-05	4.50E-02	1.34E-02	1.56E-01	4.91E-05	2.20E-03
Copper	1.27E-04	4.56E-04	2.11E-07	5.84E-04	8.05E-02	9.81E-02	1.48E-04	1.79E-01	2.23E-02	1.12E-01	2.02E-04	1.34E-01	2.11E-02	8.32E-03	4.89E-02	6.44E-05	2.10E-02	9.35E-03	9.04E-02	1.75E-04	1.54E-03
Lead	2.40E-05	1.80E-04	9.83E-09	2.04E-04	1.52E-02	3.88E-02	6.90E-06	5.40E-02	4.08E-03	4.41E-02	9.43E-06	4.82E-02	3.99E-03	1.21E-03	1.93E-02	3.01E-06	6.58E-03	8.48E-05	3.57E-02	8.18E-06	4.76E-04
Manganese	4.07E-03	4.44E-03	2.60E-06	8.51E-03	2.58E+00	9.55E-01	1.82E-03	3.53E+00	4.42E-02	1.09E+00	2.49E-03	1.13E+00	6.76E-01	3.11E-02	4.76E-01	7.94E-04	3.18E-01	7.38E-03	8.79E-01	2.16E-03	1.33E-02
Mercury	2.69E-06	5.99E-07	2.28E-10	3.29E-06	1.70E-03	1.29E-04	1.60E-07	1.83E-03	1.54E-03	1.46E-04	2.19E-07	1.69E-03	4.46E-04	1.91E-03	6.42E-05	6.98E-08	2.28E-04	2.39E-03	1.19E-04	1.90E-07	3.14E-05
Methylmercury	-	-	-	-	-	-	-	-	-	-	-	-	-	7.71E-05	-	-	4.23E-04	-	-	-	1.53E-04
Nickel	2.41E-04	4.17E-04	8.74E-08	6.58E-04	1.52E-01	8.97E-02	6.14E-05	2.42E-01	4.92E-03	1.02E-01	8.39E-05	1.07E-01	4.00E-02	1.93E-03	4.47E-02	2.68E-05	2.33E-02	7.59E-03	8.27E-02	7.28E-05	1.21E-03
Selenium	3.31E-06	3.01E-06	4.31E-08	6.37E-06	2.09E-03	6.48E-04	3.03E-05	2.77E-03	3.61E-03	7.38E-04	4.14E-05	4.39E-03	5.49E-04	2.01E-03	3.23E-04	1.32E-05	7.76E-04	3.29E-05	5.97E-04	3.59E-05	1.41E-04
Thallium	4.21E-07	6.01E-06	4.70E-10	6.44E-06	2.66E-04	1.29E-03	3.30E-07	1.56E-03	2.70E-03	1.47E-03	4.51E-07	4.17E-03	6.99E-05	3.68E-04	6.45E-04	1.44E-07	2.90E-04	5.07E-04	1.19E-03	3.92E-07	2.43E-05
Zinc	9.18E-04	7.11E-04	3.86E-07	1.63E-03	5.81E-01	1.53E-01	2.71E-04	7.34E-01	1.65E-03	1.74E-01	3.70E-04	1.76E-01	1.53E-01	9.50E-02	7.63E-02	1.18E-04	8.69E-02	3.45E-04	1.41E-01	3.21E-04	1.05E-02

Notes:

COPC = contaminant of potential concern

BW = body weight

EDI = estimated daily intake

All EDIs are in mg/kg BW/day.

$EDI_{[veg]}$ = estimated daily intake of COPC from vegetation consumption (mg/kg BW/day)

$EDI_{[soil]}$ = estimated daily intake of COPC from soil consumption (mg/kg BW/day)

$EDI_{[sediment]}$ = estimated daily intake of COPC from sediment consumption (mg/kg BW/day)

$EDI_{[water]}$ = estimated daily intake of COPC from water consumption (mg/kg BW/day)

$EDI_{[prey]}$ = estimated daily intake of COPC from prey consumption (mg/kg BW/day)

$EDI_{[total]}$ = total estimated daily intake of COPC an animal receives from soil, sediment, vegetation, prey, and water consumption (mg/kg BW/day)

(-) = not applicable

Table 5.6-7. Estimated Daily Intake of Contaminants of Potential Concern for Wildlife Species during the Construction Phase

COPC	Arctic Ground Squirrel				Arctic Shrew				Northern Red-backed Vole					Willow Ptarmigan				American Tree Sparrow				
	$EDI_{[veg]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$
Aluminum	5.25E+00	3.81E+01	5.29E-03	4.34E+01	1.33E+03	4.23E+02	2.20E-02	1.75E+03	2.36E+01	9.33E+02	4.68E+02	1.80E-02	1.42E+03	2.84E+01	5.88E+01	8.87E-03	8.72E+01	3.46E+01	1.37E+03	1.96E+02	1.02E-02	1.60E+03
Arsenic	2.67E-03	6.62E-03	1.88E-05	9.31E-03	1.15E-02	7.35E-02	7.83E-05	8.51E-02	1.20E-02	8.10E-03	8.13E-02	6.42E-05	1.01E-01	1.44E-02	1.02E-02	3.16E-05	2.47E-02	1.76E-02	1.19E-02	3.41E-02	3.63E-05	6.37E-02
Cadmium	1.97E-03	4.48E-04	5.74E-07	2.42E-03	6.82E-02	4.97E-03	2.39E-06	7.32E-02	8.83E-03	4.78E-02	5.50E-03	1.96E-06	6.22E-02	1.06E-02	6.92E-04	9.63E-07	1.13E-02	1.30E-02	7.03E-02	2.31E-03	1.11E-06	8.56E-02
Chromium	1.99E-01	1.18E-01	3.02E-05	3.17E-01	1.86E-01	1.30E+00	1.26E-04	1.49E+00	8.94E-01	1.31E-01	1.44E+00	1.03E-04	2.47E+00	1.08E+00	1.81E-01	5.06E-05	1.26E+00	1.31E+00	1.92E-01	6.06E-01	5.83E-05	2.11E+00
Copper	5.41E-02	6.79E-02	1.08E-04	1.22E-01	4.31E-01	7.54E-01	4.49E-04	1.19E+00	2.43E-01	3.02E-01	8.34E-01	3.68E-04	1.38E+00	2.93E-01	1.05E-01	1.81E-04	3.98E-01	3.57E-01	4.44E-01	3.50E-01	2.08E-04	1.15E+00
Lead	1.02E-02	2.69E-02	5.03E-06	3.71E-02	1.28E-01	2.98E-01	2.09E-05	4.26E-01	4.59E-02	8.97E-02	3.30E-01	1.72E-05	4.65E-01	5.52E-02	4.15E-02	8.44E-06	9.67E-02	6.74E-02	1.32E-01	1.38E-01	9.71E-06	3.38E-01
Manganese	1.73E+00	6.61E-01	1.33E-03	2.39E+00	5.66E+00	7.34E+00	5.53E-03	1.30E+01	7.77E+00	3.97E+00	8.11E+00	4.53E-03	1.99E+01	9.36E+00	1.02E+00	2.23E-03	1.04E+01	1.14E+01	5.84E+00	3.41E+00	2.56E-03	2.07E+01
Mercury	1.14E-03	8.91E-05	1.17E-07	1.23E-03	5.65E-04	9.90E-04	4.86E-07	1.56E-03	5.13E-03	3.97E-04	1.09E-03	3.98E-07	6.63E-03	6.18E-03	1.38E-04	1.96E-07	6.32E-03	7.54E-03	5.83E-04	4.60E-04	2.25E-07	8.59E-03
Methylmercury	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nickel	1.02E-01	6.21E-02	4.48E-05	1.65E-01	1.97E-01	6.90E-01	1.86E-04	8.87E-01	4.60E-01	1.38E-01	7.63E-01	1.53E-04	1.36E+00	5.53E-01	9.59E-02	7.50E-05	6.49E-01	6.76E-01	2.03E-01	3.20E-01	8.64E-05	1.20E+00
Selenium	1.41E-03	4.49E-04	2.21E-05	1.88E-03	1.57E-02	4.98E-03	9.19E-05	2.07E-02	6.32E-03	1.10E-02	5.51E-03	7.53E-05	2.29E-02	7.60E-03	6.93E-04	3.70E-05	8.33E-03	9.28E-03	1.62E-02	2.31E-03	4.26E-05	2.78E-02
Thallium	1.79E-04	8.96E-04	2.41E-07	1.07E-03	3.12E-02	9.94E-03	1.00E-06	4.12E-02	8.04E-04	2.19E-02	1.10E-02	8.21E-07	3.37E-02	9.68E-04	1.38E-03	4.04E-07	2.35E-03	1.18E-03	3.22E-02	4.62E-03	4.65E-07	3.80E-02
Zinc	3.91E-01	1.06E-01	1.97E-04	4.97E-01	9.41E+00	1.18E+00	8.22E-04	1.06E+01	1.75E+00	6.60E+00	1.30E+00	6.74E-04	9.66E+00	2.11E+00	1.64E-01	3.31E-04	2.28E+00	2.58E+00	9.70E+00	5.46E-01	3.81E-04	1.28E+01

Notes:

COPC = contaminant of potential concern

BW = body weight

EDI = estimated daily intake

All EDIs are in mg/kg BW/day.

$EDI_{[veg]}$ = estimated daily intake of COPC from vegetation consumption (mg/kg BW/day)

$EDI_{[soil]}$ = estimated daily intake of COPC from soil consumption (mg/kg BW/day)

$EDI_{[sediment]}$ = estimated daily intake of COPC from sediment consumption (mg/kg BW/day)

$EDI_{[water]}$ = estimated daily intake of COPC from water consumption (mg/kg BW/day)

$EDI_{[prey]}$ = estimated daily intake of COPC from prey consumption (mg/kg BW/day)

$EDI_{[total]}$ = total estimated daily intake of COPC an animal receives from soil, sediment, vegetation, prey, and water consumption (mg/kg BW/day)

(-) = not applicable

Table 5.6-7. Estimated Daily Intake of Contaminants of Potential Concern for Wildlife Species during the Construction Phase

COPC	Peregrine Falcon				Canada Goose				Red-breasted Merganser				Least Sandpiper				Long-tailed Duck				
	EDI$_{[prey]}$	EDI$_{[soil]}$	EDI$_{[water]}$	EDI$_{[total]}$	EDI$_{[veg]}$	EDI$_{[sediment]}$	EDI$_{[water]}$	EDI$_{[total]}$	EDI$_{[prey]}$	EDI$_{[sediment]}$	EDI$_{[water]}$	EDI$_{[total]}$	EDI$_{[prey]}$	EDI$_{[sediment]}$	EDI$_{[water]}$	EDI$_{[total]}$	EDI$_{[veg]}$	EDI$_{[prey]}$	EDI$_{[sediment]}$	EDI$_{[water]}$	EDI$_{[total]}$
Aluminum	4.44E+00	7.43E+01	3.38E-03	7.88E+01	6.70E+00	7.68E+01	2.16E-03	8.35E+01	2.04E+00	5.61E+01	3.08E-03	5.81E+01	1.22E+01	2.42E+02	1.07E-02	2.54E+02	5.41E-01	3.37E+00	6.92E+01	3.40E-03	7.31E+01
Arsenic	2.83E-03	1.29E-02	1.20E-05	1.57E-02	3.41E-03	4.99E-02	7.68E-06	5.34E-02	1.39E-03	3.65E-02	1.09E-05	3.79E-02	1.37E-03	1.58E-01	3.82E-05	1.59E-01	2.75E-04	4.43E-04	4.50E-02	1.21E-05	4.58E-02
Cadmium	1.34E-04	8.73E-04	3.67E-07	1.01E-03	2.51E-03	6.85E-04	2.34E-07	3.19E-03	1.54E-03	5.00E-04	3.34E-07	2.04E-03	1.99E-02	2.16E-03	1.17E-06	2.20E-02	2.03E-04	5.38E-03	6.17E-04	3.69E-07	6.20E-03
Chromium	1.04E-02	2.29E-01	1.93E-05	2.40E-01	2.54E-01	2.11E-01	1.23E-05	4.65E-01	2.44E-02	1.54E-01	1.76E-05	1.79E-01	9.05E-01	6.67E-01	6.13E-05	1.57E+00	2.05E-02	2.43E-01	1.91E-01	1.94E-05	4.54E-01
Copper	1.48E-02	1.32E-01	6.88E-05	1.47E-01	6.90E-02	1.37E-01	4.40E-05	2.06E-01	9.16E-02	1.00E-01	6.27E-05	1.92E-01	4.00E+00	4.32E-01	2.19E-04	4.43E+00	5.58E-03	1.07E+00	1.24E-01	6.92E-05	1.20E+00
Lead	3.13E-03	5.24E-02	3.21E-06	5.55E-02	1.30E-02	3.31E-02	2.05E-06	4.62E-02	8.80E-03	2.42E-02	2.93E-06	3.30E-02	2.54E-01	1.04E-01	1.02E-05	3.59E-01	1.05E-03	6.83E-02	2.99E-02	3.23E-06	9.92E-02
Manganese	4.27E-02	1.29E+00	8.48E-04	1.33E+00	2.21E+00	6.50E+00	5.42E-04	8.71E+00	6.94E-01	4.74E+00	7.72E-04	5.44E+00	5.39E+01	2.05E+01	2.69E-03	7.44E+01	1.78E-01	1.44E+01	5.86E+00	8.53E-04	2.05E+01
Mercury	4.16E-06	1.74E-04	7.45E-08	1.78E-04	1.46E-03	2.48E-04	4.76E-08	1.71E-03	-	1.81E-04	6.79E-08	1.81E-04	-	7.82E-04	2.37E-07	7.82E-04	1.18E-04	-	2.24E-04	7.50E-08	3.41E-04
Methylmercury	1.04E-03	-	-	1.04E-03	-	-	-	-	4.88E-02	-	-	4.88E-02	6.41E-01	-	-	6.41E-01	-	1.74E-01	-	-	1.74E-01
Nickel	5.93E-04	1.21E-01	2.86E-05	1.22E-01	1.31E-01	1.27E-01	1.83E-05	2.57E-01	2.37E-02	9.26E-02	2.60E-05	1.16E-01	1.25E-02	4.00E-01	9.08E-05	4.13E-01	1.05E-02	4.65E-03	1.14E-01	2.87E-05	1.30E-01
Selenium	3.82E-03	8.75E-04	1.41E-05	4.71E-03	1.79E-03	1.70E-03	9.01E-06	3.50E-03	4.25E-02	1.24E-03	1.28E-05	4.37E-02	2.78E-01	5.35E-03	4.48E-05	2.84E-01	1.45E-04	7.65E-02	1.53E-03	1.42E-05	7.82E-02
Thallium	4.08E-02	1.75E-03	1.54E-07	4.25E-02	2.28E-04	8.17E-04	9.83E-08	1.05E-03	9.60E-04	5.97E-04	1.40E-07	1.56E-03	3.61E-02	2.58E-03	4.88E-07	3.86E-02	1.84E-05	9.67E-03	7.37E-04	1.55E-07	1.04E-02
Zinc	6.35E-02	2.07E-01	1.26E-04	2.70E-01	4.98E-01	2.74E-01	8.06E-05	7.72E-01	2.77E+00	2.00E-01	1.15E-04	2.97E+00	9.03E+00	8.64E-01	4.01E-04	9.89E+00	4.02E-02	2.56E+00	2.47E-01	1.27E-04	2.85E+00

Notes:

COPC = contaminant of potential concern

BW = body weight

EDI = estimated daily intake

All EDIs are in mg/kg BW/day.

EDI $_{[veg]}$ = estimated daily intake of COPC from vegetation consumption (mg/kg BW/day)

EDI $_{[soil]}$ = estimated daily intake of COPC from soil consumption (mg/kg BW/day)

EDI $_{[sediment]}$ = estimated daily intake of COPC from sediment consumption (mg/kg BW/day)

EDI $_{[water]}$ = estimated daily intake of COPC from water consumption (mg/kg BW/day)

EDI $_{[prey]}$ = estimated daily intake of COPC from prey consumption (mg/kg BW/day)

EDI $_{[total]}$ = total estimated daily intake of COPC an animal receives from soil, sediment, vegetation, prey, and water consumption (mg/kg BW/day)

(-) = not applicable

Table 5.6-7. Estimated Daily Intake of Contaminants of Potential Concern for Wildlife Species during the Construction Phase

	Herring Gull				Yellow Warbler				Brant				Ringed Seal		
COPC	$EDI_{[prey]}$	$EDI_{[sediment]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[sediment]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[sediment]}$	$EDI_{[total]}$
Aluminum	1.13E+01	6.52E+01	3.12E-03	7.65E+01	1.98E+03	1.80E+02	1.44E-02	2.16E+03	8.69E+00	1.93E+01	2.76E-03	2.80E+01	6.61E+00	8.69E+01	9.35E+01
Arsenic	3.63E-02	4.81E-02	1.11E-05	8.44E-02	1.72E-02	3.12E-02	5.13E-05	4.84E-02	4.42E-03	1.42E-02	9.82E-06	1.86E-02	4.26E-02	6.41E-02	1.07E-01
Cadmium	7.34E-02	5.26E-04	3.39E-07	7.39E-02	1.01E-01	2.11E-03	1.57E-06	1.03E-01	3.26E-03	1.55E-04	3.00E-07	3.41E-03	4.15E-02	7.00E-04	4.22E-02
Chromium	1.93E+00	1.88E-01	1.78E-05	2.12E+00	2.77E-01	5.54E-01	8.23E-05	8.31E-01	3.29E-01	5.57E-02	1.58E-05	3.85E-01	1.09E+00	2.51E-01	1.34E+00
Copper	2.32E-01	7.75E-02	6.37E-05	3.10E-01	6.40E-01	3.20E-01	2.94E-04	9.61E-01	8.96E-02	2.29E-02	5.62E-05	1.13E-01	3.20E-01	1.03E-01	4.23E-01
Lead	1.93E-02	2.41E-02	2.97E-06	4.34E-02	1.90E-01	1.27E-01	1.37E-05	3.17E-01	1.69E-02	7.12E-03	2.63E-06	2.40E-02	1.18E-02	3.21E-02	4.39E-02
Manganese	3.48E-01	1.14E+00	7.85E-04	1.49E+00	8.41E+00	3.12E+00	3.62E-03	1.15E+01	2.86E+00	3.38E-01	6.93E-04	3.20E+00	2.18E-01	1.52E+00	1.74E+00
Mercury	-	5.12E-05	6.90E-08	5.13E-05	8.40E-04	4.20E-04	3.18E-07	1.26E-03	1.89E-03	1.51E-05	6.09E-08	1.91E-03	-	6.83E-05	6.83E-05
Methylmercury	4.01E-03	-	-	4.01E-03	-	-	-	-	-	-	-	-	7.16E-03	-	7.16E-03
Nickel	1.04E+00	9.28E-02	2.64E-05	1.13E+00	2.93E-01	2.93E-01	1.22E-04	5.86E-01	1.69E-01	2.74E-02	2.34E-05	1.97E-01	5.99E-01	1.24E-01	7.23E-01
Selenium	1.18E-01	1.54E-03	1.30E-05	1.19E-01	2.33E-02	2.12E-03	6.02E-05	2.55E-02	2.33E-03	4.56E-04	1.15E-05	2.79E-03	1.29E-01	2.05E-03	1.31E-01
Thallium	3.18E-04	7.59E-04	1.42E-07	1.08E-03	4.64E-02	4.22E-03	6.57E-07	5.07E-02	2.96E-04	2.24E-04	1.26E-07	5.21E-04	4.04E-04	1.01E-03	1.41E-03
Zinc	2.37E+00	2.22E-01	1.17E-04	2.59E+00	1.40E+01	4.99E-01	5.38E-04	1.45E+01	6.46E-01	6.57E-02	1.03E-04	7.12E-01	2.20E+00	2.96E-01	2.50E+00

Notes:

COPC = contaminant of potential concern

BW = body weight

EDI = estimated daily intake

All EDIs are in mg/kg BW/day.

$EDI_{[veg]}$ = estimated daily intake of COPC from vegetation consumption (mg/kg BW/day)

$EDI_{[soil]}$ = estimated daily intake of COPC from soil consumption (mg/kg BW/day)

$EDI_{[sediment]}$ = estimated daily intake of COPC from sediment consumption (mg/kg BW/day)

$EDI_{[water]}$ = estimated daily intake of COPC from water consumption (mg/kg BW/day)

$EDI_{[prey]}$ = estimated daily intake of COPC from prey consumption (mg/kg BW/day)

$EDI_{[total]}$ = total estimated daily intake of COPC an animal receives from soil, sediment, vegetation, prey, and water consumption (mg/kg BW/day)

(-) = not applicable

Table 5.6-8. Estimated Daily Intake of Contaminants of Potential Concern for Wildlife Species during the Operational Phase

	Caribou				Muskox				Wolverine				Grizzly Bear					Wolf			
COPC	EDI$_{[veg]}$	EDI$_{[soil]}$	EDI$_{[water]}$	EDI$_{[total]}$	EDI$_{[veg]}$	EDI$_{[soil]}$	EDI$_{[water]}$	EDI$_{[total]}$	EDI$_{[prey]}$	EDI$_{[soil]}$	EDI$_{[water]}$	EDI$_{[total]}$	EDI$_{[veg]}$	EDI$_{[prey]}$	EDI$_{[soil]}$	EDI$_{[water]}$	EDI$_{[total]}$	EDI$_{[prey]}$	EDI$_{[soil]}$	EDI$_{[water]}$	EDI$_{[total]}$
Aluminum	1.23E-02	2.56E-01	1.02E-05	2.68E-01	7.81E+00	5.51E+01	7.15E-03	6.29E+01	5.87E+00	6.26E+01	9.77E-03	6.85E+01	2.05E+00	1.30E+00	2.75E+01	3.12E-03	8.27E+00	4.95E-01	5.07E+01	8.48E-03	6.48E-01
Arsenic	6.28E-06	4.45E-05	4.83E-08	5.08E-05	3.97E-03	9.56E-03	3.39E-05	1.36E-02	3.83E-03	1.09E-02	4.63E-05	1.48E-02	1.04E-03	5.71E-04	4.77E-03	1.48E-05	1.72E-03	9.94E-05	8.81E-03	4.02E-05	1.69E-04
Cadmium	4.63E-06	3.01E-06	1.16E-09	7.64E-06	2.93E-03	6.47E-04	8.17E-07	3.58E-03	1.45E-04	7.36E-04	1.12E-06	8.82E-04	7.70E-04	6.50E-05	3.22E-04	3.56E-07	3.11E-04	1.03E-05	5.96E-04	9.69E-07	1.26E-05
Chromium	4.68E-04	7.90E-04	5.84E-08	1.26E-03	2.96E-01	1.70E-01	4.10E-05	4.66E-01	2.24E-02	1.93E-01	5.60E-05	2.16E-01	7.77E-02	5.34E-03	8.47E-02	1.79E-05	4.50E-02	1.34E-02	1.57E-01	4.86E-05	2.20E-03
Copper	1.27E-04	4.57E-04	2.24E-07	5.85E-04	8.06E-02	9.83E-02	1.57E-04	1.79E-01	2.28E-02	1.12E-01	2.15E-04	1.35E-01	2.12E-02	8.51E-03	4.90E-02	6.85E-05	2.11E-02	9.36E-03	9.05E-02	1.87E-04	1.56E-03
Lead	2.40E-05	1.80E-04	9.82E-09	2.04E-04	1.52E-02	3.88E-02	6.89E-06	5.40E-02	4.08E-03	4.41E-02	9.42E-06	4.82E-02	3.99E-03	1.20E-03	1.93E-02	3.01E-06	6.58E-03	8.48E-05	3.57E-02	8.18E-06	4.76E-04
Manganese	4.07E-03	4.44E-03	2.65E-06	8.52E-03	2.58E+00	9.55E-01	1.86E-03	3.53E+00	4.44E-02	1.09E+00	2.54E-03	1.13E+00	6.76E-01	3.15E-02	4.76E-01	8.10E-04	3.18E-01	7.39E-03	8.80E-01	2.20E-03	1.34E-02
Mercury	2.69E-06	5.99E-07	2.48E-10	3.29E-06	1.70E-03	1.29E-04	1.74E-07	1.83E-03	1.54E-03	1.46E-04	2.38E-07	1.69E-03	4.47E-04	2.05E-03	6.42E-05	7.59E-08	2.28E-04	2.39E-03	1.19E-04	2.06E-07	3.14E-05
Methylmercury	-	-	-	-	-	-	-	-	-	-	-	-	-	7.83E-05	-	-	4.59E-04	-	-	-	1.66E-04
Nickel	2.41E-04	4.17E-04	8.85E-08	6.58E-04	1.52E-01	8.98E-02	6.21E-05	2.42E-01	4.92E-03	1.02E-01	8.49E-05	1.07E-01	4.00E-02	1.94E-03	4.47E-02	2.71E-05	2.33E-02	7.59E-03	8.27E-02	7.37E-05	1.21E-03
Selenium	3.31E-06	3.02E-06	4.27E-08	6.37E-06	2.09E-03	6.49E-04	2.99E-05	2.77E-03	3.59E-03	7.38E-04	4.09E-05	4.37E-03	5.49E-04	1.99E-03	3.23E-04	1.31E-05	7.72E-04	3.28E-05	5.98E-04	3.55E-05	1.40E-04
Thallium	4.21E-07	6.01E-06	4.92E-10	6.44E-06	2.66E-04	1.29E-03	3.45E-07	1.56E-03	2.64E-03	1.47E-03	4.72E-07	4.11E-03	6.99E-05	3.69E-04	6.45E-04	1.50E-07	2.91E-04	3.27E-04	1.19E-03	4.09E-07	2.22E-05
Zinc	9.19E-04	7.12E-04	3.90E-07	1.63E-03	5.81E-01	1.53E-01	2.74E-04	7.35E-01	1.66E-03	1.74E-01	3.74E-04	1.76E-01	1.53E-01	9.60E-02	7.63E-02	1.19E-04	8.72E-02	3.46E-04	1.41E-01	3.25E-04	1.06E-02

Notes:

COPC = contaminant of potential concern

BW = body weight

EDI = estimated daily intake

All EDIs are in mg/kg BW/day.

EDI $_{[veg]}$ *= estimated daily intake of COPC from vegetation consumption (mg/kg BW/day)*

EDI $_{[soil]}$ *= estimated daily intake of COPC from soil consumption (mg/kg BW/day)*

EDI $_{[sediment]}$ *= estimated daily intake of COPC from sediment consumption (mg/kg BW/day)*

EDI $_{[water]}$ *= estimated daily intake of COPC from water consumption (mg/kg BW/day)*

EDI $_{[prey]}$ *= estimated daily intake of COPC from prey consumption (mg/kg BW/day)*

EDI $_{[total]}$ *= total estimated daily intake of COPC an animal receives from soil, sediment, vegetation, prey, and water consumption (mg/kg BW/day)*

(-) = not applicable

Table 5.6-8. Estimated Daily Intake of Contaminants of Potential Concern for Wildlife Species during the Operational Phase

	Arctic Ground Squirrel				Arctic Shrew				Northern Red-backed Vole					Willow Ptarmigan				American Tree Sparrow				
COPC	$EDI_{[veg]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$
Aluminum	5.25E+00	3.81E+01	5.21E-03	4.34E+01	1.33E+03	4.23E+02	2.17E-02	1.75E+03	2.36E+01	9.34E+02	4.68E+02	1.78E-02	1.43E+03	2.84E+01	5.89E+01	8.74E-03	8.73E+01	3.47E+01	1.37E+03	1.97E+02	1.01E-02	1.60E+03
Arsenic	2.67E-03	6.62E-03	2.47E-05	9.32E-03	1.15E-02	7.35E-02	1.03E-04	8.51E-02	1.20E-02	8.10E-03	8.13E-02	8.44E-05	1.01E-01	1.44E-02	1.02E-02	4.15E-05	2.47E-02	1.76E-02	1.19E-02	3.41E-02	4.77E-05	6.37E-02
Cadmium	1.97E-03	4.48E-04	5.96E-07	2.42E-03	6.82E-02	4.97E-03	2.48E-06	7.32E-02	8.85E-03	4.79E-02	5.50E-03	2.03E-06	6.22E-02	1.07E-02	6.92E-04	9.99E-07	1.13E-02	1.30E-02	7.03E-02	2.31E-03	1.15E-06	8.56E-02
Chromium	1.99E-01	1.18E-01	2.99E-05	3.17E-01	1.87E-01	1.31E+00	1.24E-04	1.49E+00	8.94E-01	1.31E-01	1.44E+00	1.02E-04	2.47E+00	1.08E+00	1.82E-01	5.01E-05	1.26E+00	1.31E+00	1.92E-01	6.06E-01	5.77E-05	2.11E+00
Copper	5.42E-02	6.81E-02	1.15E-04	1.22E-01	4.32E-01	7.55E-01	4.77E-04	1.19E+00	2.43E-01	3.03E-01	8.36E-01	3.91E-04	1.38E+00	2.93E-01	1.05E-01	1.92E-04	3.98E-01	3.57E-01	4.45E-01	3.51E-01	2.21E-04	1.15E+00
Lead	1.02E-02	2.69E-02	5.03E-06	3.71E-02	1.28E-01	2.98E-01	2.09E-05	4.26E-01	4.59E-02	8.97E-02	3.30E-01	1.72E-05	4.65E-01	5.52E-02	4.15E-02	8.43E-06	9.67E-02	6.74E-02	1.32E-01	1.38E-01	9.70E-06	3.38E-01
Manganese	1.73E+00	6.62E-01	1.35E-03	2.40E+00	5.66E+00	7.34E+00	5.64E-03	1.30E+01	7.78E+00	3.98E+00	8.12E+00	4.62E-03	1.99E+01	9.36E+00	1.02E+00	2.27E-03	1.04E+01	1.14E+01	5.84E+00	3.41E+00	2.61E-03	2.07E+01
Mercury	1.14E-03	8.92E-05	1.27E-07	1.23E-03	5.65E-04	9.90E-04	5.28E-07	1.56E-03	5.14E-03	3.97E-04	1.09E-03	4.33E-07	6.63E-03	6.18E-03	1.38E-04	2.13E-07	6.32E-03	7.55E-03	5.83E-04	4.60E-04	2.45E-07	8.59E-03
Methylmercury	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nickel	1.02E-01	6.22E-02	4.53E-05	1.65E-01	1.97E-01	6.90E-01	1.89E-04	8.87E-01	4.60E-01	1.38E-01	7.63E-01	1.55E-04	1.36E+00	5.53E-01	9.60E-02	7.60E-05	6.50E-01	6.76E-01	2.03E-01	3.20E-01	8.74E-05	1.20E+00
Selenium	1.41E-03	4.49E-04	2.18E-05	1.88E-03	1.57E-02	4.99E-03	9.09E-05	2.07E-02	6.32E-03	1.10E-02	5.51E-03	7.45E-05	2.29E-02	7.60E-03	6.93E-04	3.66E-05	8.33E-03	9.28E-03	1.62E-02	2.32E-03	4.21E-05	2.78E-02
Thallium	1.79E-04	8.96E-04	2.52E-07	1.08E-03	3.12E-02	9.94E-03	1.05E-06	4.12E-02	8.04E-04	2.19E-02	1.10E-02	8.59E-07	3.37E-02	9.68E-04	1.38E-03	4.22E-07	2.35E-03	1.18E-03	3.22E-02	4.62E-03	4.86E-07	3.80E-02
Zinc	3.91E-01	1.06E-01	2.00E-04	4.97E-01	9.41E+00	1.18E+00	8.32E-04	1.06E+01	1.75E+00	6.60E+00	1.30E+00	6.82E-04	9.66E+00	2.11E+00	1.64E-01	3.35E-04	2.28E+00	2.58E+00	9.70E+00	5.46E-01	3.86E-04	1.28E+01

Notes:

COPC = contaminant of potential concern

BW = body weight

EDI = estimated daily intake

All EDIs are in mg/kg BW/day.

$EDI_{[veg]}$ = estimated daily intake of COPC from vegetation consumption (mg/kg BW/day)

$EDI_{[soil]}$ = estimated daily intake of COPC from soil consumption (mg/kg BW/day)

$EDI_{[sediment]}$ = estimated daily intake of COPC from sediment consumption (mg/kg BW/day)

$EDI_{[water]}$ = estimated daily intake of COPC from water consumption (mg/kg BW/day)

$EDI_{[prey]}$ = estimated daily intake of COPC from prey consumption (mg/kg BW/day)

$EDI_{[total]}$ = total estimated daily intake of COPC an animal receives from soil, sediment, vegetation, prey, and water consumption (mg/kg BW/day)

(-) = not applicable

Table 5.6-8. Estimated Daily Intake of Contaminants of Potential Concern for Wildlife Species during the Operational Phase

	Peregrine Falcon				Canada Goose				Red-breasted Merganser				Least Sandpiper				Long-tailed Duck				
COPC	**EDI$_{[prey]}$**	**EDI$_{[soil]}$**	**EDI$_{[water]}$**	**EDI$_{[total]}$**	**EDI$_{[veg]}$**	**EDI$_{[sediment]}$**	**EDI$_{[water]}$**	**EDI$_{[total]}$**	**EDI$_{[prey]}$**	**EDI$_{[sediment]}$**	**EDI$_{[water]}$**	**EDI$_{[total]}$**	**EDI$_{[prey]}$**	**EDI$_{[sediment]}$**	**EDI$_{[water]}$**	**EDI$_{[total]}$**	**EDI$_{[veg]}$**	**EDI$_{[prey]}$**	**EDI$_{[sediment]}$**	**EDI$_{[water]}$**	**EDI$_{[total]}$**
Aluminum	4.44E+00	7.43E+01	3.33E-03	7.88E+01	6.70E+00	7.68E+01	2.13E-03	8.35E+01	2.01E+00	5.61E+01	3.03E-03	5.81E+01	1.20E+01	2.42E+02	1.06E-02	2.54E+02	5.41E-01	3.32E+00	6.92E+01	3.35E-03	7.31E+01
Arsenic	2.86E-03	1.29E-02	1.58E-05	1.58E-02	3.41E-03	4.99E-02	1.01E-05	5.34E-02	1.82E-03	3.65E-02	1.44E-05	3.83E-02	1.80E-03	1.58E-01	5.02E-05	1.59E-01	2.75E-04	5.82E-04	4.50E-02	1.59E-05	4.59E-02
Cadmium	1.36E-04	8.73E-04	3.80E-07	1.01E-03	2.51E-03	6.85E-04	2.43E-07	3.20E-03	1.60E-03	5.00E-04	3.47E-07	2.10E-03	2.06E-02	2.16E-03	1.21E-06	2.28E-02	2.03E-04	5.58E-03	6.17E-04	3.83E-07	6.40E-03
Chromium	1.04E-02	2.29E-01	1.91E-05	2.40E-01	2.54E-01	2.11E-01	1.22E-05	4.65E-01	2.42E-02	1.54E-01	1.74E-05	1.79E-01	8.96E-01	6.67E-01	6.06E-05	1.56E+00	2.05E-02	2.40E-01	1.91E-01	1.92E-05	4.51E-01
Copper	1.52E-02	1.33E-01	7.32E-05	1.48E-01	6.91E-02	1.37E-01	4.68E-05	2.06E-01	9.75E-02	1.00E-01	6.67E-05	1.98E-01	4.26E+00	4.32E-01	2.33E-04	4.69E+00	5.58E-03	1.14E+00	1.24E-01	7.36E-05	1.27E+00
Lead	3.13E-03	5.24E-02	3.21E-06	5.55E-02	1.30E-02	3.31E-02	2.05E-06	4.62E-02	8.80E-03	2.42E-02	2.92E-06	3.30E-02	2.54E-01	1.04E-01	1.02E-05	3.58E-01	1.05E-03	6.82E-02	2.99E-02	3.23E-06	9.91E-02
Manganese	4.31E-02	1.29E+00	8.65E-04	1.33E+00	2.21E+00	6.50E+00	5.53E-04	8.71E+00	7.08E-01	4.74E+00	7.88E-04	5.45E+00	5.50E+01	2.05E+01	2.75E-03	7.55E+01	1.78E-01	1.47E+01	5.86E+00	8.70E-04	2.07E+01
Mercury	4.17E-06	1.74E-04	8.10E-08	1.78E-04	1.46E-03	2.48E-04	5.18E-08	1.71E-03	-	1.81E-04	7.38E-08	1.81E-04	-	7.82E-04	2.57E-07	7.82E-04	1.18E-04	-	2.24E-04	8.15E-08	3.42E-04
Methylmercury	1.13E-03	-	-	1.13E-03	-	-	-	-	5.31E-02	-	-	5.31E-02	6.97E-01	-	-	6.97E-01	-	1.89E-01	-	-	1.89E-01
Nickel	5.99E-04	1.21E-01	2.89E-05	1.22E-01	1.31E-01	1.27E-01	1.85E-05	2.57E-01	2.40E-02	9.26E-02	2.64E-05	1.17E-01	1.27E-02	4.00E-01	9.19E-05	4.13E-01	1.05E-02	4.71E-03	1.14E-01	2.91E-05	1.30E-01
Selenium	3.78E-03	8.76E-04	1.39E-05	4.67E-03	1.79E-03	1.70E-03	8.91E-06	3.50E-03	4.20E-02	1.24E-03	1.27E-05	4.33E-02	2.75E-01	5.35E-03	4.43E-05	2.81E-01	1.45E-04	7.57E-02	1.53E-03	1.40E-05	7.74E-02
Thallium	1.89E-03	1.75E-03	1.61E-07	3.64E-03	2.28E-04	8.17E-04	1.03E-07	1.05E-03	1.00E-03	5.97E-04	1.46E-07	1.60E-03	3.77E-02	2.58E-03	5.11E-07	4.03E-02	1.84E-05	1.01E-02	7.37E-04	1.62E-07	1.09E-02
Zinc	6.42E-02	2.07E-01	1.28E-04	2.71E-01	4.99E-01	2.74E-01	8.15E-05	7.73E-01	2.80E+00	2.00E-01	1.16E-04	3.00E+00	9.14E+00	8.64E-01	4.05E-04	1.00E+01	4.03E-02	2.59E+00	2.47E-01	1.28E-04	2.88E+00

Notes:

COPC = contaminant of potential concern

BW = body weight

EDI = estimated daily intake

All EDIs are in mg/kg BW/day.

EDI$_{[veg]}$ = estimated daily intake of COPC from vegetation consumption (mg/kg BW/day)

EDI$_{[soil]}$ = estimated daily intake of COPC from soil consumption (mg/kg BW/day)

EDI$_{[sediment]}$ = estimated daily intake of COPC from sediment consumption (mg/kg BW/day)

EDI$_{[water]}$ = estimated daily intake of COPC from water consumption (mg/kg BW/day)

EDI$_{[prey]}$ = estimated daily intake of COPC from prey consumption (mg/kg BW/day)

EDI$_{[total]}$ = total estimated daily intake of COPC an animal receives from soil, sediment, vegetation, prey, and water consumption (mg/kg BW/day)

(-) = not applicable

Table 5.6-8. Estimated Daily Intake of Contaminants of Potential Concern for Wildlife Species during the Operational Phase

	Herring Gull				Yellow Warbler				Brant				Ringed Seal		
COPC	$EDI_{[prey]}$	$EDI_{[sediment]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[soil]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[veg]}$	$EDI_{[sediment]}$	$EDI_{[water]}$	$EDI_{[total]}$	$EDI_{[prey]}$	$EDI_{[sediment]}$	$EDI_{[total]}$
Aluminum	1.13E+01	6.52E+01	3.08E-03	7.65E+01	1.98E+03	1.80E+02	1.42E-02	2.16E+03	8.69E+00	1.93E+01	2.72E-03	2.80E+01	6.61E+00	8.69E+01	9.35E+01
Arsenic	3.63E-02	4.81E-02	1.46E-05	8.44E-02	1.72E-02	3.12E-02	6.74E-05	4.84E-02	4.42E-03	1.42E-02	1.29E-05	1.86E-02	4.26E-02	6.41E-02	1.07E-01
Cadmium	7.34E-02	5.26E-04	3.52E-07	7.39E-02	1.01E-01	2.11E-03	1.63E-06	1.03E-01	3.26E-03	1.55E-04	3.11E-07	3.42E-03	4.15E-02	7.00E-04	4.22E-02
Chromium	1.93E+00	1.88E-01	1.77E-05	2.12E+00	2.77E-01	5.55E-01	8.15E-05	8.32E-01	3.29E-01	5.57E-02	1.56E-05	3.85E-01	1.09E+00	2.51E-01	1.34E+00
Copper	2.32E-01	7.75E-02	6.78E-05	3.10E-01	6.42E-01	3.21E-01	3.13E-04	9.63E-01	8.96E-02	2.29E-02	5.98E-05	1.13E-01	3.20E-01	1.03E-01	4.23E-01
Lead	1.93E-02	2.41E-02	2.97E-06	4.34E-02	1.90E-01	1.27E-01	1.37E-05	3.17E-01	1.69E-02	7.12E-03	2.62E-06	2.40E-02	1.18E-02	3.21E-02	4.39E-02
Manganese	3.48E-01	1.14E+00	8.00E-04	1.49E+00	8.42E+00	3.12E+00	3.69E-03	1.15E+01	2.87E+00	3.38E-01	7.07E-04	3.21E+00	2.18E-01	1.52E+00	1.74E+00
Mercury	-	5.12E-05	7.50E-08	5.13E-05	8.40E-04	4.20E-04	3.46E-07	1.26E-03	1.89E-03	1.51E-05	6.62E-08	1.91E-03	-	6.83E-05	6.83E-05
Methylmercury	4.01E-03	-	-	4.01E-03	-	-	-	-	-	-	-	-	7.16E-03	-	7.16E-03
Nickel	1.04E+00	9.28E-02	2.68E-05	1.13E+00	2.93E-01	2.93E-01	1.24E-04	5.86E-01	1.69E-01	2.74E-02	2.36E-05	1.97E-01	5.99E-01	1.24E-01	7.23E-01
Selenium	1.18E-01	1.54E-03	1.29E-05	1.19E-01	2.33E-02	2.12E-03	5.95E-05	2.55E-02	2.33E-03	4.56E-04	1.14E-05	2.79E-03	1.29E-01	2.05E-03	1.31E-01
Thallium	3.18E-04	7.59E-04	1.49E-07	1.08E-03	4.64E-02	4.22E-03	6.86E-07	5.07E-02	2.96E-04	2.24E-04	1.31E-07	5.21E-04	4.04E-04	1.01E-03	1.41E-03
Zinc	2.37E+00	2.22E-01	1.18E-04	2.59E+00	1.40E+01	4.99E-01	5.45E-04	1.45E+01	6.47E-01	6.57E-02	1.04E-04	7.12E-01	2.20E+00	2.96E-01	2.50E+00

Notes:
COPC = contaminant of potential concern
BW = body weight
EDI = estimated daily intake
All EDIs are in mg/kg BW/day.
$EDI_{[veg]}$ = estimated daily intake of COPC from vegetation consumption (mg/kg BW/day)
$EDI_{[soil]}$ = estimated daily intake of COPC from soil consumption (mg/kg BW/day)
$EDI_{[sediment]}$ = estimated daily intake of COPC from sediment consumption (mg/kg BW/day)
$EDI_{[water]}$ = estimated daily intake of COPC from water consumption (mg/kg BW/day)
$EDI_{[prey]}$ = estimated daily intake of COPC from prey consumption (mg/kg BW/day)
$EDI_{[total]}$ = total estimated daily intake of COPC an animal receives from soil, sediment, vegetation, prey, and water consumption (mg/kg BW/day)
(-) = not applicable

5.6.2.3 Ingestion of Freshwater and Marine Water

The predicted 95th percentile concentrations of COPCs from the 13 surface water quality model nodes were used as an input in the equation to calculate the EDI of COPCs terrestrial wildlife species receive from drinking surface water during the Construction and Operational phases.

Marine seabirds (i.e., brant and herring gull) have the ability to drink fresh or salt water. Therefore, to be conservative, the higher of the predicted 95th percentile concentrations of COPCs in freshwater or the baseline 95th percentile concentrations of COPCs in marine water were used as an input in the equation to calculate the EDI of COPCs that seabirds receive from ingestion of drinking water during the Construction and Operational phases. Marine water quality is unchanged from existing conditions (see Volume 5, Section 8.5.4).

The equation used to calculate exposure to COPCs (mg/kg BW/day) from freshwater and marine water ingestion was Equation 20, which was described in Section 5.5.2.3 of the existing conditions ERA.

The COPC EDI via the ingestion of drinking water route for the Construction and Operational phases for wildlife species are presented in Tables 5.6-7 and 5.6-8. The assumptions used in the calculation of the EDI of COPCs via drinking water ingestion were the same as those described in the existing conditions ERA (see Section 5.5.2.3). A sample calculation was also provided in the existing conditions ERA.

5.6.2.4 Ingestion of Vegetation

The predicted 95th percentile concentrations of COPCs in vegetation species from sites within the terrestrial LSA (Appendices V6-5L and V6-5M) were used as an input in the EDI equation to calculate the EDI of COPCs terrestrial wildlife species receive from ingestion of vegetation during the Construction and Operational phases. The equation used to calculate exposure to COPCs (mg/kg BW/day) from vegetation ingestion was Equation 21, which was described in Section 5.5.2.4 of the existing conditions ERA.

The COPC EDI via the ingestion of vegetation route for the Construction and Operational phases for wildlife species are presented in Tables 5.6-7 and 5.6-8. The assumptions used in the calculation of the EDI of COPCs via vegetation ingestion were the same as those described in the existing conditions ERA (see Section 5.5.2.4). A sample calculation was also provided in the existing conditions ERA.

5.6.2.5 Ingestion of Prey (Ingestion via the Food Chain)

<u>Terrestrial Wildlife Prey</u>

As with the existing conditions ERA (Section 5.5.2.5), tissue concentrations of COPCs for terrestrial prey species were estimated using a food chain model described in Golder and Associates (2005) and recommended by Health Canada (2010a). The food chain model is described and the prey tissue COPC concentrations are provided in Appendix V6-5N. The modeled COPC concentrations in prey species were used as an input in the EDI equation to calculate the EDI of COPCs that carnivores and omnivores receive from ingestion of prey during the Construction and Operational phases. Some carnivores and omnivores consume several prey species, thus the EDI of COPCs from all the applicable prey species were summed for each carnivore and omnivore, depending on which prey items are consumed. The prey items consumed by each carnivore and omnivore species are listed in Table V6-N8 of Appendix V6-5N.

As with the existing conditions ERA (Section 5.5.2.5), the arsenic concentration in diet items was adjusted to account for the amount of inorganic arsenic that is likely to be present, as that is the most toxic form.

The COPC EDI via the ingestion of prey route for the Construction and Operational phases for wildlife species are presented in Tables 5.6-7 and 5.6-8. The assumptions used in the calculation of the EDI of COPCs via vegetation ingestion were the same as those described in the existing conditions ERA (see Section 5.5.2.5). A sample calculation was also provided in the existing conditions ERA.

Aquatic Life Prey

The predicted 95th percentile concentrations of COPCs in tissue of Lake Trout, Whitefish, Arctic Char, and Ninespine Stickleback from within the freshwater fish LSA (Tables 5.6.3, 5.6.4, and 5.6.5) were used as an input in the EDI equation to calculate the dose of COPCs that piscivorous wildlife species (i.e., grizzly bear, wolf, peregrine falcon, red-breasted merganser, long-tailed duck, herring gull, and ringed seal) receive from ingestion of fish during the Construction and Operational phases. It was assumed that grizzly bear and peregrine falcon would consume both freshwater and marine fish species, while wolf, red-breasted merganser, and long-tailed duck would only consume freshwater fish species, and herring gull and ringed seal would only consume marine fish species.

The baseline 95th percentile concentrations of COPCs in bay mussels sampled from three sites within the marine environment RSA (Table V6-5E4 in Appendix V6-5E) were used as an input in the EDI equation to calculate the dose of COPCs wildlife species that consume bivalves (i.e., herring gull and ringed seal) receive from ingestion of bivalves during the Construction and Operational phases.

The general equation used to calculate exposure to COPCs (mg/kg BW/day) from fish or bivalve ingestion was the same as that presented in Section 5.5.2.2 (Equation 22).

The fish or bivalve ingestion rates and receptor exposure times are presented in Table V6-5N9 of Appendix V6-5N. The COPC EDI via the fish or bivalve ingestion exposure route for piscivorous wildlife species are presented in Tables 5.6-7 and 5.6-8. The assumptions used in the calculation of the EDI of COPCs via ingestion of fish or bivalves were the same as those described in the existing conditions ERA (see Section 5.5.2.5). A sample calculation was also provided in the existing conditions ERA.

5.6.2.6 Total Estimated Daily Intake for All VECs

The total EDI of COPCs (in mg/kg BW/day) for each wildlife species was calculated by summing the EDI from all applicable exposure pathways for the Construction and Operational phases (Tables 5.6-7 and 5.6-8). The COPC EDI from each exposure route and the total summed EDI for each wildlife species for the Construction and Operational phases are presented in Tables 5.6-7 and 5.6-8 (for all wildlife VECs).

5.6.2.7 Exposure Assessment for Caribou Exposure to the Tailings Impoundment Area

Ingestion of COPCs from Tailings from the TIA by Caribou

The 95th percentile metal concentrations from 14 tailings samples obtained from SRK (2016c; P5-7) and SRK (2015) were used as an input into the equation to calculate the EDI of COPCs caribou receive from ingestion of tailings. The equation used to calculate caribou exposure to COPCs (mg/kg BW/day) from tailings ingestion was Equation 19 provided in Section 5.5.2.2 of the existing conditions ERA.

Ingestion of COPCs from Water from the TIA by Caribou

The predicted 95th percentile concentration of COPCs from the Operational phase of the base case surface water quality model from the Tail Lake node (in the TIA) was used as an input in the equation to calculate the EDI of COPCs for caribou ingesting water from the TIA. The equation used to calculate caribou exposure to COPCs (mg/kg BW/day) from ingestion of water in the TIA was Equation 20 provided in Section 5.5.2.3 of the existing conditions ERA.

The surface water quality model did not provide predicted concentrations of tin at the Tail Lake node. Therefore, to be conservative, the maximum baseline concentration of tin measured in surface waters in the freshwater environment LSA (0.000967 mg/L; Rescan 2010d, 2011g) was used in the EDI calculations instead.

Total Estimated Daily Intake of COPCs from the TIA by Caribou

The COPC EDI via the soil ingestion exposure route for caribou are presented in Table 5.6-9. The assumptions used in the calculation of the EDI of COPCs via ingestion of tailings were the same as those described in the existing conditions ERA (Section 5.5.2.2). A sample calculation was also provided in the existing conditions ERA.

Table 5.6-9. Estimated Daily Intake of Contaminants of Potential Concern for Caribou from the Tailings Impoundment Area

COPC	$EDI_{[tailings]}$	$EDI_{[TIA\ water]}$	$EDI_{[total]}$
Arsenic	4.01E-03	7.98E-05	4.09E-03
Beryllium	2.40E-04	7.69E-07	2.41E-04
Cadmium	3.67E-06	3.55E-08	3.70E-06
Chromium	2.86E-03	1.35E-06	2.87E-03
Copper	6.65E-04	2.82E-06	6.68E-04
Lead	1.74E-04	8.22E-08	1.74E-04
Mercury	1.46E-05	1.21E-08	1.46E-05
Molybdenum	9.00E-05	1.41E-05	1.04E-04
Nickel	3.60E-03	6.10E-06	3.60E-03
Selenium	2.50E-05	1.23E-06	2.62E-05
Thallium	9.20E-06	3.11E-08	9.23E-06
Tin	1.11E-02	7.79E-08	1.29E-02
Zinc	8.47E-04	2.80E-06	8.49E-04

Notes:
All EDIs are in mg/kg BW/day.
COPC = contaminant of potential concern
BW = body weight
EDI = estimated daily intake
$EDI_{[tailings]}$ = *estimated daily intake of COPC from tailings consumption (mg/kg BW/day)*
$EDI_{[TIA\ water]}$ = *estimated daily intake of COPC from TIA water consumption (mg/kg BW/day)*
$EDI_{[total]}$ = *total estimated daily intake of COPC caribou receives from tailings and TIA water consumption (mg/kg BW/day)*

The COPC EDIs via the TIA water ingestion exposure route for caribou are presented in Table 5.6-9. The assumptions used in the calculation of the EDI of COPCs via ingestion of water in the TIA were the same as those described in the existing conditions ERA (Section 5.5.2.3). A sample calculation was also provided in the existing conditions ERA.

5.6.3 Toxicity Assessment

5.6.3.1 Introduction

The TRV assessment is the same as that presented in Section 5.5.3 of the existing conditions ERA. The same TRVs for COPCs used in the existing conditions ERA (Section 5.5.3.2) were used in the Project-related ERA.

5.6.3.2 Toxicity Assessment for Caribou Exposure to the Tailings Impoundment Area

The toxicity assessment is the same as that presented in Section 5.5.3 of the existing conditions ERA. The same TRVs for caribou for the COPCs in tailings were used in the existing conditions ERA (Section 5.5.3.2, Mammalian and Avian Wildlife) were used in the assessment of risk to caribou from the TIA. However, additional COPCs were identified based on the COPC selection process from floatation tailings and TIA water chemistry. The TRVs for these new COPCs are described in the following sections.

Beryllium

The Eco-SSL document for beryllium (US EPA 2005b) provides an oral mammalian TRV of 0.532 mg/kg BW/day (Schroeder and Mitchener 1975), which is based on a NOAEL for survival in juvenile mice (*M. musculus*). A study by Freundt and Ibrahim (1990) provides the only other NOAEL reported for mammalian species in the beryllium Eco-SSL document, which is 0.953 mg/kg BW/day for growth effects in sexually mature rats (*R. norvegicus*) exposed to oral doses of beryllium in drinking water. Because the lowest chronic NOAEL reported for reproduction, growth, or survival effects in mammals is 0.532 mg/kg BW/day, this value was adopted as the TRV for caribou.

Tin

The Oak Ridge National Laboratory (ORNL) document "*Toxicological Benchmarks for Wildlife: 1996 Revision*" (Sample, Opresko, and Suter 1996) provides a mammalian LOAEL for tin of 35 mg/kg BW/day, which is based on observed reproductive effects following a chronic oral exposure of tin to a critical lifestage (gestation) in mice (Davis et al 1987). Observed reproductive effects included decreased fetal survival and increased frequency of litter resorption. The corresponding NOAEL from this study was reported as 23.4 mg/kg BW/day, and was adopted as the TRV for caribou in this assessment.

5.6.4 Risk Characterization

5.6.4.1 Introduction

Using the results of the exposure assessment and TRV assessment, ecological health risks were quantified using HQs for both the Construction and Operational phases. The HQ is the ratio between the COPC concentration in an environmental media (for aquatic life receptors and terrestrial plant invertebrate receptors), or the total EDI (for wildlife) and the TRV identified for a COPC and provides a measure of risk due to exposure to a COPC through the various exposure pathways. Environment Canada (2012) states that an HQ of less than 1.0 indicates that the existence of adverse effects to ecological health is unlikely, while an HQ greater than 1.0 indicates a possibility of adverse effects to ecological health. It is likely that the risk is significantly overestimated due to the conservative assumptions made throughout the existing conditions ERA.

5.6.4.2 *Estimation of Risk to Aquatic Life Ecological Receptors from Contaminants of Potential Concern*

The HQ was calculated by dividing the predicted 95th percentile concentration of the COPC in environmental media (i.e., water or sediment) by the CCME guideline for the protection of aquatic life. Hazard quotients for aquatic life ecological receptors were calculated for freshwater exposure. Since freshwater sediment, marine water, and marine sediment concentrations are not changing from existing conditions (see Volume 5, Sections 5.5.4, 5.8.4, and 5.9.4), the HQs would be the same as in the existing conditions ERA (Table 5.5-14). Hazard quotients for aquatic life ecological receptors (i.e., primary producers, pelagic and benthic invertebrate communities, and fish (Ninespine Stickleback, Lake Whitefish, and Lake Trout)) are shown in Table 5.6-10 for the Construction and Operational phases.

Table 5.6-10. Aquatic Life Hazard Quotients for Contaminants of Potential Concern in Freshwater during the Construction and Operational Phases

COPCs in Surface Water	95th Percentile Predicted Freshwater Concentration (mg/L; n=13 modeling nodes)		CCME Water Quality Guideline (mg/L)	Hazard Quotient for Freshwater Aquatic Life Ecological Receptors [a]	
	Construction Phase	Operational Phase	Freshwater Aquatic Life Ecological Receptors [a]	Construction Phase	Operational Phase
Aluminum	1.28E-01	1.26E-01	0.1	1.3	1.3
Cadmium	1.39E-05	1.45E-05	0.1	0.00014	0.00014
Chloride	7.66E+01	7.08E+01	120	0.64	0.59
Chromium	7.33E-04	7.25E-04	0.001	0.73	0.73
Copper	2.62E-03	2.78E-03	0.004	0.65	0.70
Fluoride	7.48E-02	7.50E-02	0.12	0.62	0.63
Iron	2.43E-01	2.43E-01	0.3	0.81	0.81
Mercury	2.83E-06	3.08E-06	0.000026	0.11	0.12
Silver	1.13E-05	1.16E-05	120	0.000000094	0.000000097

Notes:
COPC = contaminant of potential concern
CCME = Canadian Council of Ministers of the Environment
Shaded cells indicate hazard quotients greater than 1.0.
[a] Includes primary producers (phytoplankton, periphyton, and plant/algae communities), pelagic and benthic invertebrate communities, and fish (Ninespine Stickleback, Lake Whitefish, and Lake Trout).

As shown in Table 5.6-10, HQs for aquatic life ecological receptors were lower than 1.0 except for aluminum, where the HQ was 1.3 for both the Construction and Operational phases. Under existing conditions, the HQ for aquatic life for aluminum was also 1.3, thus there is no change in the aluminum risk to aquatic life due to the Project.

5.6.4.3 *Estimation of Risk to Terrestrial Plant and Invertebrate Terrestrial Receptors from Contaminants of Potential Concern*

Hazard quotients for terrestrial plant and invertebrate receptors were calculated for exposure to soil COPCs. The HQ was calculated by dividing the predicted 95th percentile concentration of the COPC in soil (Appendices V6-5H and V6-5I) by the CCME guideline for the protection of terrestrial plants and invertebrates. Hazard quotients for terrestrial plant and invertebrate ecological receptors are shown in Table 5.6-11.

Table 5.6-11. Terrestrial Plant and Invertebrate Hazard Quotients for Contaminants of Potential Concern in Soil during the Construction and Operational Phases

COPCs in Soil	95th Percentile Predicted Soil Concentration (mg/kg dw)		CCME Soil Quality Guideline for Terrestrial Plant and Invertebrate Ecological Receptors (mg/kg dw)	Soil Hazard Quotients for Terrestrial Plant and Invertebrate Ecological Receptors	
	Construction Phase	Operational Phase		Construction Phase	Operational Phase
Chromium	65.6	65.7	64	1.0	1.0
Copper	37.9	38.0	63	0.60	0.60
Nickel	34.7	34.7	45	0.77	0.77

Notes:
COPC = contaminant of potential concern
CCME = Canada Council of Ministers of the Environment
dw = dry weight
TRV = toxicity reference value
HQ = hazard quotient

As shown in Table 5.6-11, HQs for terrestrial plant and invertebrate ecological receptors were all equal to or below the threshold of 1.0; therefore, predicted COPC concentrations in soil during the Construction and Operational phases do not pose a risk to the health of terrestrial plant and invertebrate ecological receptors.

5.6.4.4 Estimation of Risk to Mammalian and Avian Receptors from Contaminants of Potential Concern

The total EDI from all routes was divided by the TRV (in mg/kg BW/day) to obtain the HQs for the Construction and Operational phases. Tables 5.6-12 and 5.6-13 show the HQ for each COPC for each wildlife species considered in the assessment during the Construction and Operational phases.

The HQs for copper for least sandpiper during the Construction (1.1; Table 5.6-12) and Operational phases (1.2; Table 5.6-13) were greater than 1.0. The HQs for methylmercury for red-breasted merganser and least sandpiper during the Construction and Operational phases (Tables 5.6-12 and 5.6-13) were greater than 1.0. All other COPC HQs for all other wildlife receptors were below the threshold of 1.0, thus there is no risk to those receptors from exposure to COPCs during the Construction and Operational phases.

Table 5.6-14 shows the HQs for copper for least sandpiper during existing conditions, the Construction phase, and the Operational phase as well as the percent change in the HQ between existing conditions and the two Project phases. As shown in the percent change calculations (Table 5.6-14), the change in risk to least sandpiper from exposure to copper during the Construction and Operational phases are 6.5% and 12%, respectively.

Table 5.6-14 shows the HQs for methylmercury for red-breasted merganser and least sandpiper during existing conditions, the Construction phase, and the Operational phase as well as the percent change in the HQ between existing conditions and the two Project phases. As shown in the percent change calculations (Table 5.6-14), the change in risk to red-breasted merganser from exposure to methylmercury during the Construction and Operational phases are 1.8% and 10%, respectively. The changes in risk to least sandpiper from exposure to methylmercury during the Construction and Operational phases are 4.9% and 10%, respectively.

Table 5.6-12. Wildlife Toxicity Reference Values and Hazard Quotients for Contaminants of Potential Concern during the Construction Phase

COPC	TRV (mg/kg BW/day) Mammal	TRV (mg/kg BW/day) Bird	Caribou	Muskox	Wolverine	Grizzly Bear	Wolf	Arctic Ground Squirrel	Arctic Shrew	Northern Red-backed Vole	Willow Ptarmigan	American Tree Sparrow	Peregrine Falcon	Canada Goose	Red-breasted Merganser	Least Sandpiper	Long-tailed Duck	Herring Gull	Yellow Warbler	Brant	Ringed Seal
Aluminum	1.93	109.7	1.39E-01	3.26E+01	3.55E+01	4.28E+00	3.36E-01	2.25E+01	9.08E+02	7.38E+02	7.95E-01	1.46E+01	7.18E-01	7.61E-01	5.30E-01	2.32E+00	6.67E-01	6.98E-01	1.97E+01	2.55E-01	4.85E+01
Arsenic	1.04	2.24	4.9E-05	1.3E-02	1.4E-02	1.6E-03	1.5E-04	9.0E-03	8.2E-02	9.8E-02	1.1E-02	2.8E-02	7.0E-03	2.4E-02	1.7E-02	7.1E-02	2.0E-02	3.8E-02	2.2E-02	8.3E-03	1.0E-01
Cadmium	0.77	1.47	9.9E-06	4.6E-03	1.1E-03	4.0E-04	1.6E-05	3.1E-03	9.5E-02	8.1E-02	7.7E-03	5.8E-02	6.9E-04	2.2E-03	1.4E-03	1.5E-02	4.2E-03	5.0E-02	7.0E-02	2.3E-03	5.5E-02
Chromium	2.4	2.66	5.2E-04	1.9E-01	9.0E-02	1.9E-02	9.2E-04	1.3E-01	6.2E-01	1.0E+00	4.7E-01	7.9E-01	9.0E-02	1.7E-01	6.7E-02	5.9E-01	1.7E-01	8.0E-01	3.1E-01	1.4E-01	5.6E-01
Copper	5.6	4.05	1.0E-04	3.2E-02	2.4E-02	3.8E-03	2.7E-04	2.2E-02	2.1E-01	2.5E-01	9.8E-02	2.8E-01	3.6E-02	5.1E-02	4.7E-02	1.1E+00	3.0E-01	7.6E-02	2.4E-01	2.8E-02	7.5E-02
Lead	4.7	1.63	4.3E-05	1.1E-02	1.0E-02	1.4E-03	1.0E-04	7.9E-03	9.1E-02	9.9E-02	5.9E-02	2.1E-01	3.4E-02	2.8E-02	2.0E-02	2.2E-01	6.1E-02	2.7E-02	1.9E-01	1.5E-02	9.3E-03
Manganese	51.5	179	1.7E-04	6.9E-02	2.2E-02	6.2E-03	2.6E-04	4.6E-02	2.5E-01	3.9E-01	5.8E-02	1.2E-01	7.4E-03	4.9E-02	3.0E-02	4.2E-01	1.1E-01	8.3E-03	6.4E-02	1.8E-02	3.4E-02
Mercury	1.01	0.45	3.3E-06	1.8E-03	1.7E-03	2.3E-04	3.1E-05	1.2E-03	1.5E-03	6.6E-03	1.4E-02	1.9E-02	4.0E-04	3.8E-03	4.0E-04	1.7E-03	7.6E-04	1.1E-04	2.8E-03	4.2E-03	6.8E-05
Methylmercury	0.022	0.031	-	-	-	1.9E-02	7.0E-03	-	-	-	-	-	3.4E-02	-	1.6E+00	2.1E+01	5.6E+00	1.3E-01	-	-	3.3E-01
Nickel	1.7	6.71	3.9E-04	1.4E-01	6.3E-02	1.4E-02	7.1E-04	9.7E-02	5.2E-01	8.0E-01	9.7E-02	1.8E-01	1.8E-02	3.8E-02	1.7E-02	6.2E-02	1.9E-02	1.7E-01	8.7E-02	2.9E-02	4.3E-01
Selenium	0.143	0.29	4.5E-05	1.9E-02	3.1E-02	5.4E-03	9.9E-04	1.3E-02	1.5E-01	1.6E-01	2.9E-02	9.6E-02	1.6E-02	1.2E-02	1.5E-01	9.8E-01	2.7E-01	4.1E-01	8.8E-02	9.6E-03	9.1E-01
Thallium	0.0740	0.35	8.7E-05	2.1E-02	5.6E-02	3.9E-03	3.3E-04	1.5E-02	5.6E-01	4.6E-01	6.7E-03	1.1E-01	1.2E-01	3.0E-03	4.4E-03	1.1E-01	3.0E-02	3.1E-03	1.4E-01	1.5E-03	1.9E-02
Zinc	75.4	66.1	2.2E-05	9.7E-03	2.3E-03	1.2E-03	1.4E-04	6.6E-03	1.4E-01	1.3E-01	3.4E-02	1.9E-01	4.1E-03	1.2E-02	4.5E-02	1.5E-01	4.3E-02	3.9E-02	2.2E-01	1.1E-02	3.3E-02

Notes:

COPC = contaminant of potential concern

TRV = toxicity reference value

BW = body weight

Shaded cells indicated hazard quotients greater than 1.0.

Table 5.6-13. Wildlife Toxicity Reference Values and Hazard Quotients for Contaminants of Potential Concern during the Operational Phase

COPC	TRV (mg/kg BW/day)		Hazard Quotients																		
	Mammal	Bird	Caribou	Muskox	Wolverine	Grizzly Bear	Wolf	Arctic Ground Squirrel	Arctic Shrew	Northern Red-backed Vole	Willow Ptarmigan	American Tree Sparrow	Peregrine Falcon	Canada Goose	Red-breasted Merganser	Least Sandpiper	Long-tailed Duck	Herring Gull	Yellow Warbler	Brant	Ringed Seal
Aluminum	1.93	109.7	1.39E-01	3.26E+01	3.55E+01	4.28E+00	3.36E-01	2.25E+01	9.09E+02	7.39E+02	7.96E-01	1.46E+01	7.18E-01	7.61E-01	5.29E-01	2.32E+00	6.66E-01	6.98E-01	1.97E+01	2.55E-01	4.85E+01
Arsenic	1.04	2.24	4.9E-05	1.3E-02	1.4E-02	1.6E-03	1.6E-04	9.0E-03	8.2E-02	9.8E-02	1.1E-02	2.8E-02	7.0E-03	2.4E-02	1.7E-02	7.1E-02	2.0E-02	3.8E-02	2.2E-02	8.3E-03	1.0E-01
Cadmium	0.77	1.47	9.9E-06	4.6E-03	1.1E-03	4.0E-04	1.6E-05	3.1E-03	9.5E-02	8.1E-02	7.7E-03	5.8E-02	6.9E-04	2.2E-03	1.4E-03	1.5E-02	4.4E-03	5.0E-02	7.0E-02	2.3E-03	5.5E-02
Chromium	2.4	2.66	5.2E-04	1.9E-01	9.0E-02	1.9E-02	9.2E-04	1.3E-01	6.2E-01	1.0E+00	4.7E-01	7.9E-01	9.0E-02	1.7E-01	6.7E-02	5.9E-01	1.7E-01	8.0E-01	3.1E-01	1.4E-01	5.6E-01
Copper	5.6	4.05	1.0E-04	3.2E-02	2.4E-02	3.8E-03	2.8E-04	2.2E-02	2.1E-01	2.5E-01	9.8E-02	2.8E-01	3.7E-02	5.1E-02	4.9E-02	1.2E+00	3.1E-01	7.6E-02	2.4E-01	2.8E-02	7.5E-02
Lead	4.7	1.63	4.3E-05	1.1E-02	1.0E-02	1.4E-03	1.0E-04	7.9E-03	9.1E-02	9.9E-02	5.9E-02	2.1E-01	3.4E-02	2.8E-02	2.0E-02	2.2E-01	6.1E-02	2.7E-02	1.9E-01	1.5E-02	9.3E-03
Manganese	51.5	179	1.7E-04	6.9E-02	2.2E-02	6.2E-03	2.6E-04	4.7E-02	2.5E-01	3.9E-01	5.8E-02	1.2E-01	7.5E-03	4.9E-02	3.0E-02	4.2E-01	1.2E-01	8.3E-03	6.4E-02	1.8E-02	3.4E-02
Mercury	1.01	0.45	3.3E-06	1.8E-03	1.7E-03	2.3E-04	3.1E-05	1.2E-03	1.5E-03	6.6E-03	1.4E-02	1.9E-02	4.0E-04	3.8E-03	4.0E-04	1.7E-03	7.6E-04	1.1E-04	2.8E-03	4.2E-03	6.8E-05
Methylmercury	0.022	0.031	-	-	-	2.1E-02	7.6E-03	-	-	-	-	-	3.6E-02	-	1.7E+00	2.2E+01	6.1E+00	1.3E-01	-	-	3.3E-01
Nickel	1.7	6.71	3.9E-04	1.4E-01	6.3E-02	1.4E-02	7.1E-04	9.7E-02	5.2E-01	8.0E-01	9.7E-02	1.8E-01	1.8E-02	3.8E-02	1.7E-02	6.2E-02	1.9E-02	1.7E-01	8.7E-02	2.9E-02	4.3E-01
Selenium	0.143	0.29	4.5E-05	1.9E-02	3.1E-02	5.4E-03	9.8E-04	1.3E-02	1.5E-01	1.6E-01	2.9E-02	9.6E-02	1.6E-02	1.2E-02	1.5E-01	9.7E-01	2.7E-01	4.1E-01	8.8E-02	9.6E-03	9.1E-01
Thallium	0.0740	0.35	8.7E-05	2.1E-02	5.6E-02	3.9E-03	3.0E-04	1.5E-02	5.6E-01	4.6E-01	6.7E-03	1.1E-01	1.0E-02	3.0E-03	4.6E-03	1.2E-01	3.1E-02	3.1E-03	1.4E-01	1.5E-03	1.9E-02
Zinc	75.4	66.1	2.2E-05	9.7E-03	2.3E-03	1.2E-03	1.4E-04	6.6E-03	1.4E-01	1.3E-01	3.4E-02	1.9E-01	4.1E-03	1.2E-02	4.5E-02	1.5E-01	4.4E-02	3.9E-02	2.2E-01	1.1E-02	3.3E-02

Notes:

COPC = contaminant of potential concern

TRV = toxicity reference value

BW = body weight

Shaded cells indicated hazard quotients greater than 1.0.

Table 5.6-14. Risk Characterization for Wildlife during Existing Conditions, the Construction Phase, and the Operational Phase

Wildlife Species	COPC	Existing Conditions HQ	Construction Phase HQ	Operational Phase HQ	% Change in HQ from Existing Conditions to Construction Phase	% Change in HQ from Existing Conditions to Operational Phase
Least sandpiper	Copper	1.0	1.1	1.2	6.5	12
Red-breasted merganser	Methylmercury	1.5	1.6	1.7	1.8	10
Least sandpiper	Methylmercury	2.0	2.1	2.2	4.9	10

Notes:
COPC = contaminant of potential concern
HQ = hazard quotient

The potential risk to least sandpiper due to copper is associated with exposure via ingestion of freshwater, freshwater sediment, and freshwater invertebrates. Freshwater sediment copper concentrations during the Construction and Operational phases remained unchanged from the existing conditions concentration. Thus it was only the freshwater copper concentration and the freshwater invertebrate tissue concentration of copper (which is dependent on and positively correlated with the predicted freshwater concentrations) that caused the increase in risk to least sandpiper during Construction and Operational phases. The 95^{th} percentile copper concentrations in freshwater used in the calculations under existing conditions, the Construction phase, and the Operational phase were: 0.00243, 0.00262, and 0.00278 mg/L, respectively. The minor increases in copper concentrations resulted in a corresponding small increase in the HQs for least sandpiper. It is unlikely that a change in the magnitude of the HQ less than 10% (or 12%) is measurable, and a change in health of least sandpiper due to Project activities is unlikely to occur. A change in the magnitude of the HQ of 12% during the Operational phase is still considered small (an increase from HQ=1.0 to HQ=1.2), only slightly higher than the benchmark of 1.0, and unlikely to be measurable.

Elevated HQs for fish-eating (red-breasted merganser) or aquatic invertebrate-eating (least sandpiper) birds due to methylmercury were identified, suggesting potential risks for adverse effects. This result is not unexpected since mercury is known to bioaccumulate through the aquatic food chain. It can accumulate to high concentrations in piscivorous animals and fish that are older, larger, or at the top of the food chain., This can be seen by the concentrations of total mercury measured in fish such as Lake Trout under existing conditions (maximum concentration of 1.80 mg/kg ww, exceeding the methylmercury tissue residue guideline for the protection of wildlife consumers of aquatic biota of 0.033 mg/kg ww; Table 5.5-7). Mercury also tends to bioaccumulate to a greater degree in food chains in lakes, particularly when sediments are anoxic, have higher organic carbon content, and if sulphate concentrations are high. This is because inorganic mercury can be converted to methylmercury by bacteria present in sediments, which can then be taken up more readily by biota in the aquatic food chain. The HQs for methylmercury for fish- and aquatic invertebrate-eating birds are already elevated under existing conditions (HQ of 1.5 to 2.0, depending on bird species), and the HQ for existing condition, Construction phase, and Operational phase are similar in magnitude. It is unlikely that a change in the magnitude of the HQ less than or equal to 10% is measurable, and a change in health due to the Project is unlikely to occur for these avian receptors.

Since a conservative statistic (predicted 95^{th} percentile concentrations) was used in the risk calculations, there is potential for risk to be overestimated for fish-eating and invertebrate-eating birds. However, even if lower concentrations (e.g., a mean or median concentration) were used in the calculations, the HQ for fish-eating birds would still be elevated under existing conditions, particularly if they were consuming Lake Trout. However, the Lake Trout samples used in the food chain model for the calculation of HQ in piscivorous animals under existing conditions were relatively larger (mean and maximum fork length of 479 mm and 765 mm, respectively) than what would be expected to be the size of food fish for piscivorous birds (approximate fish length of 10 to 15 cm; Lingle and Schupbach 1977). Because smaller fish tend to have lower methylmercury tissue concentrations than larger fish, it is likely that the food chain model for piscivorous birds overestimated the tissue concentration of methylmercury in birds. Since these fish data were used to derive site-specific methylmercury BCFs from fish to piscivorous birds for prediction of HQ during Construction and Operational phases, it is likely that the HQ for methylmercury for red-breasted merganser was similarly overestimated for the Project phases.

For invertebrate-eating birds, the concentration of methylmercury in prey items was modeled (Appendix V6-5E) using a BCF from US EPA (1999b) of 55,000. This BCF was based on one laboratory exposure study, where clams were exposed for 74 days and the BCF was calculated by dividing the dry tissue concentration by the medium concentration. It is possible that the BCF is too high, resulting in predictions of methylmercury concentrations in invertebrate tissue that are higher and not representative of invertebrates in Arctic lake environments. This would result in an overestimation of methylmercury tissue concentrations in aquatic invertebrate-eating birds and hence an overestimation of the HQ in least sandpiper. However, given that fish tissue mercury concentrations were measured to be elevated in baseline studies, it is likely that concentrations are also elevated in invertebrates. For fish and shellfish, it is typically assumed that 100% of the total mercury concentration is in the form of methylmercury, although the proportion of methylmercury might be slightly less than 100% (Health Canada 2007a). Since the actual concentrations of methylmercury are likely less than the total mercury concentration, this assumption ensures that the ERA is conservative, but also contributes to an over-estimation of methylmercury associated risks for wildlife.

5.6.4.5 Summary of Risk to Ecological Receptors

Overall, it is concluded that during the Construction and Operational phase, copper and methylmercury may affect the health of fish-eating and aquatic invertebrate-eating birds, due to HQs greater than 1.0. However, HQs were already elevated under existing conditions and increases in HQs during Construction and Operational phases compared to existing conditions are small and unlikely to be measurable. The media concentration (predicted 95th percentile of COPC concentrations) and assumptions used in the food chain modeling and ingestion exposure calculations are conservative and likely substantially overestimate the risk to ecological receptors. For instance, assuming 100% bioavailability of COPCs in ingested food, water, and sediment is likely contributing to the elevated HQs. Similarly, the assumption that 100% of the total mercury concentration is in the form of methylmercury in fish and shellfish ensures that the ERA is conservative.

There is uncertainty in the assessment for the reasons outlined in Section 5.6.5, and due to assumptions made in the assessment (Sections 5.6.2.2, 5.6.2.3, 5.6.2.4, and 5.6.2.5). The Project-related ERA is conservative and is likely to substantially overestimate the potential for risk to the health of ecological receptors that may use the Project area.

5.6.4.6 Risk Characterization for Caribou Exposure to the Tailings Impoundment Area

Using the results of the exposure assessment and TRV assessment, caribou health risks due to the TIA were quantified using HQs. The HQ is the ratio between the total EDI and the TRV and provides a measure of exposure to a COPC through the various exposure pathways. Environment Canada (2012) states that an HQ of less than 1.0 indicates that the existence of adverse effects to ecological health is unlikely, while an HQ greater than 1.0 indicates a possibility of adverse effects to ecological health.

However, the magnitude of the HQ does not infer a proportional magnitude of health risk or a probability that an adverse effect will occur.

The total EDI of the COPCs (in mg/kg BW/day) for caribou was calculated by summing the EDI from the two exposure pathways from the TIA (Table 5.6-9; ingestion of floatation tailings and water within the TIA). The total EDI was then divided by the TRV (in mg/kg BW/day) to obtain the HQ for caribou, using Equation 23 provided in Section 5.5.4.4 of the existing conditions ERA. Table 5.6-15 shows the HQ for caribou exposure to COPCs in the TIA.

Table 5.6-15. Caribou Toxicity Reference Values and Hazard Quotients for Contaminants of Potential Concern from the Tailings Impoundment Area

COPC	$EDI_{[total]}$	Mammal TRV (mg/kg BW/day)	Hazard Quotient for Caribou
Arsenic	4.09E-03	1.04	0.0039
Beryllium	2.41E-04	0.532	0.00045
Cadmium	3.70E-06	0.77	0.0000048
Chromium	2.87E-03	2.4	0.0012
Copper	6.68E-04	5.6	0.00012
Lead	1.74E-04	4.7	0.000037
Mercury	1.46E-05	1.01	0.000014
Molybdenum	1.04E-04	0.26	0.00040
Nickel	3.60E-03	1.7	0.0021
Selenium	2.62E-05	0.143	0.00018
Thallium	9.23E-06	0.074	0.00012
Tin	1.29E-02	23.4	0.00055
Zinc	8.49E-04	75.4	0.000011

Notes:
COPC = contaminant of potential concern
$EDI_{[total]}$ = total estimated daily intake of COPC a caribou receives from ingestion of tailings and water from the TIA (mg/kg BW/day)
TRV = toxicity reference value
BW = body weight

All hazard quotients for caribou exposure to COPCs from the TIA were well below 1.0. Even if more conservative assumptions are made (e.g., exposure occurs for up to 4 months per year, and background uptake of COPCs from vegetation in the diet are added to the EDI), the HQs are still below 1.0. Based on this assessment, the risks and potential for effects to caribou from exposure to TIA water and tailings are expected to be negligible.

5.6.5 Uncertainty Analysis

The uncertainties in the Project-related ERA are the same as those presented in Section 5.5.5 of the existing conditions ERA; however, there are additional uncertainties due to modeling environmental media. There is inherent uncertainty associated with the use of any model as real world processes are simplified and errors can be compounded throughout the modeling process resulting in inaccurate model results. The uncertainties associated with air quality modeling, surface water quality modeling, soil quality modeling, and vegetation quality modeling are the same as those presented in Sections 5.4.5.2, 5.4.5.3, 5.4.5.4, and 5.4.5.5 of the Project-related HHRA.

5.6.6 Conclusions

This Project-related ERA integrated the results of the environmental media predictive studies, ecological receptor characteristics, and regulatory-recommended TRVs. This assessment considered potential ecological receptor health risks associated with the summed exposure to COPCs from several exposure pathways (i.e., ingestion of soil or sediment, ingestion of fresh or marine water, and ingestion of vegetation or prey items).

The Project-related ERA identified the following COPCs that were considered to potentially pose a risk (i.e., HQ > 1) to aquatic, mammalian, or avian ecological receptors using or foraging in the freshwater, marine, or terrestrial environments of the aquatic or terrestrial LSAs during the Construction and Operational phases:

- aluminum for aquatic life receptors (i.e., primary producers such as phytoplankton, periphyton, and plant/algae communities; pelagic and benthic invertebrate communities; and fish such as Ninespine Stickleback, Lake Whitefish, and Lake Trout);
- copper for least sandpiper;
- methylmercury for red-breasted merganser and least sandpiper.

This suggests that there could be risk to the health of ecological receptors due to the COPCs identified above, although it is likely that the risk has been overestimated and adverse effects may not occur. The same data, approaches, and assumptions used in the existing conditions ERA (Section 5.5) was also used in the models for predicting environmental quality during the Project phases (so that all predictions include existing conditions plus Project), which enables direct comparison of existing conditions and predicted environmental quality to determine incremental changes due to the Project. The risks identified during the Construction and Operational phases are very similar to those during existing conditions (Table 5.6-14). For all other ecological receptors (e.g., terrestrial plant and invertebrate ecological receptors, and other avian and mammalian wildlife species), there is negligible potential risk to health from the Project.

There are uncertainties in this assessment, as described in Section 5.6.5 and throughout Section 5.6.2. However, this assessment was conducted in a manner that used multiple conservative assumptions, thus, the Project-related ERA is likely to substantially overestimate risk to ecological receptors.

Concerns were raised about the potential for exposure of caribou to COPCs in tailings or water contained within the TIA. Therefore, a special assessment of risk for this exposure scenario was provided. A number of COPCs were identified in both floatation tailings and in water within the TIA based on comparing maximum predicted concentrations to CCME soil and freshwater quality guidelines (Section 5.6.1.3). The EDI for these COPCs was calculated (Section 5.6.2.7) and compared to TRVs for mammals (Section 5.6.3.2). The calculated HQs for caribou through ingestions of floatation tailings and water from the TIA were well below 0.2 for all COPCs. Therefore, the risks and potential for effects to caribou from exposure to TIA tailings and water are expected to be negligible.

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