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 Phase 2 Project human health risk assessment (Section 5.4) and the Phase 2 Project environmental risk assessment (Section 5.6) looked at the potential health risks to human and ecological receptors due to the Phase 2 Project developments using the same exposure pathways.

The risk assessments found that the Project would not affect human or environmental health as there was no increase in risk above existing conditions due to the Phase 2 Project. The predicted changes in the environment and risks as a result of the Phase 2 Project are not measurable, so if the Phase 2 Project is developed the risk to human and ecological receptors would be the same as now.

PHASE 2
DRAFT 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
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
CEA	*Cumulative effects assessment*
CEAA, 2012	*Canadian Environmental Assessment Act, 2012*
CEA Agency	Canadian Environmental Assessment Agency
CFIA	Canadian Food Inspection Agency
CO	Carbon monoxide
COPC	Contaminant of potential concern
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
EIS	Environmental Impact Statement
DWQG	Drinking water quality guideline
EA	Environmental Assessment
EAA	Existing and Approved Authorizations

EC	Environment Canada
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
EMP	Environmental Management Plan
ERA	Environmental risk assessment
ERM	ERM Consultants Canada Ltd.
ET	Exposure time
FAO	Food and Agriculture Organization
F_s	Fraction of year consuming country food
HHRA	Human health risk assessment
Hope Bay Project	The Phase 2 Greenstone Belt
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_d	Day equivalent level (noise metric for sleep disturbance)
L_{dn}	Day-night equivalent level (noise metric for complaints)
L_{eq}	Equivalent noise level
Ln	Night equivalent (noise metric for sleep disturbance)
L_{peak}	Peak sound level (metric for blasting overpressure)
LSA	Local study area

M	Million or Mega
MAC	Maximum acceptable concentration
MDL	Method detection limit
MRL	Minimal risk level
Mt	Million tonnes
MW	Mega Watts
NAAQOs	National Ambient Air Quality Objectives
NCP	Northern Contaminants Program
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
PAG	Potentially acid generating
PAH	Polycyclic aromatic hydrocarbon
PASS	Passive Air Sampling System
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
PPV	Peak particle velocity
PTDI	Provisional tolerable daily intake
PTWI	Provisional tolerable weekly intake
QA/QC	Quality assurance and quality control
RAF	Relative absorption factor
RDL	Realized detection limit

RfD	Reference Dose
RSA	Regional study area
SA	Standards Australia
SARA	*Species at Risk Act* (2002)
SEL	Sound exposure level
SO_2	Sulphur dioxide
SRK	SKR Consulting (Canada) Inc.
t/d	tonne per day
t/y	tonne per year
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
VOC	Volatile organic compound
VSEC	Valued Socio-economic Component
WHO	World Health Organization
WSCC	Worker’s Safety and Compensation Commission
WTP	Water treatment plant
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 Phase 2 Project is a development by TMAC Resources Inc. (TMAC) of an underground gold mine in the West Kitikmeot region of Nunavut. The Phase 2 Project has an area of 1,101 km^2 and comprises one contiguous property approximately 80 by 20 km. The Phase 2 Project comprises three distinct areas of known mineralization plus extensive exploration potential and targets. The three areas that host mineral resources are as follows: Doris, Madrid, and Boston. The Doris deposit area includes the Doris North, Doris Connector, Doris Central, and Doris Deep zone. The Madrid deposit area includes the Naartok East and West, Rand, Suluk, Wolverine, and Patch 14 zone deposits, and the Rand Spur, Suluk T3, South Suluk, and Patch 7. The Boston deposit area hosts the Boston deposit, including the Boston North, B2, B3, and B4 zones.

The centre of the Phase 2 Project lies approximately 143 km above the Arctic Circle. The Phase 2 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 Phase 2 Project site, and northeast of the Phase 2 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 is the largest nearby community and will likely serve as a hub for transportation and goods and services supply.

The primary access route to the Phase 2 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 late July through 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. This ice strip is operational from February to April, and is able to accommodate Boeing 737 and Hercules aircraft. 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 Phase 2 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; and
- 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 Phase 2 Project, the primary COPCs are most likely to be metals, given that the Phase 2 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) 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 Phase 2 Project-related HHRA and ERA, which capture the change in risk to the health of human and ecological receptors that potential emissions from the Phase 2 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 will be described in detail in Sections 5.3.6, 5.4.5, and 5.5.5.

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) 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 Phase 2 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 Phase 2 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 Phase 2 Project were conducted, it was possible to characterize the risk due to the incremental change from existing conditions through the life of the Phase 2 Project.

5.2.1 Spatial and Temporary Boundaries

The spatial boundaries selected to shape the HHRAs and ERAs are determined by the Phase 2 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 Phase 2 Project (e.g., air quality, freshwater fish, and wildlife).

Temporal boundaries are selected that consider the different phases of the Phase 2 Project and their durations. The Phase 2 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 Phase 2 Project as well as the total potential effects of the additional Phase 2 Project activities in combination with the existing and approved Phase 2 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 Phase 2 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.

5.2.1.1 Project Overview

Through a staged approach, the Hope Bay Project is scheduled to achieve mine operations in the Hope Bay Greenstone Belt through mining at Doris, a bulk sample followed by commercial mining at Madrid North and South, and mining of the Boston deposit. To structure the assessment, the Hope Bay Project is broadly divided into: 1) the Existing and Approved Projects, and 2) the Phase 2 Project (this application).

<u>Existing and Approved Projects</u>

The Approved Projects include:

1. the Doris Project (NIRB Project Certificate 003, NWB Type A Water Licence 2AM-DOH1323);
2. the Hope Bay Regional Exploration Project (NWB Type B Water Licence 2BE-HOP1222);
3. the Boston Advanced Exploration Project (NWB Type B Water Licence 2BB-BOS1217); and
4. the Madrid Advanced Exploration Program (NWB Type B Water Licence under Review).

The Doris Project

The Doris Project was permitted by the NIRB in 2006. The project was intended to be constructed over 2 years, to operate for 2 years and then be closed over the course of 2 years. The original Type A Water licence authorizes mining at 720 tonnes per day (tpd) and milling at 800 tpd during the operations phase. Construction of the Doris Project began in early 2010. In early 2012, the Doris Project was placed into care and maintenance, ending any further Project-related construction, as well as exploration activity along the Hope Bay Greenstone Belt.

Following acquisition of the Hope Bay Project by TMAC in March of 2013, planning and permitting, advanced exploration and construction activities have advanced focused on bringing Doris into production by 2017. In 2016, the Nunavut Impact Review Board and Nunavut Water Board (NWB) granted an amendment to the Doris Project Certificate and Doris Type A Water Licence respectively, to expand mine operations to six years and mine the full Doris deposit. Mining and milling rates were increased to a nominal 1,000 tpd to 2,000 tpd.

The Doris Project includes the following:

- the Roberts Bay offloading facility: marine jetty, barge landing area, beach laydown area, fuel tank farm/transfer station, and quarry;
- the Doris Site: 180 person camp, laydown area, service complex (e.g., workshop, wash bay), two quarries (mill site platform and solid waste landfill), fuel tank farm/transfer station, potable water treatment, waste water treatment, incinerator, explosives magazine, and diesel power plant;
- Doris Mine works and processing: underground portal, temporary waste rock pile, ore stockpile, and processing mill;
- Tailings Impoundment Area (TIA): Schedule 2 designation for Tail Lake with two dams (North and South dams), emergency tailings dump catch basins, pump house, and quarry;

- all-weather roads and airstrip, winter airstrip, and helicopter pads; and
- water discharge from the TIA will be directed to the outfall in Roberts Bay.

Hope Bay Regional Exploration Project

The Hope Bay Regional Exploration Project has been ongoing since the 1990s. Much of the previous work for the program was based out of the Windy Lake (closed in 2008) and Boston sites (put into care and maintenance in 2011). All exploration activities are currently based from the Doris Site with plans for some future exploration at the Boston Site. Components and activities for the Hope Bay Regional Exploration Project include:

- staging of drilling activities out of Doris or Boston sites; and
- operation of exploration drills in the Hope Bay Belt area, which are supported by helicopter.

Boston Advanced Exploration

The Boston Advanced Exploration Project Type B Water Licence was granted in July 2007 and is valid until July 2017 and includes:

- The Boston site (65 person), 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, temporary waste rock pile, and ore stockpile;
- potable water and industrial water taken from Aimaokatalok Lake; and
- treated sewage and greywater discharged to the tundra.

Since the construction of Boston will require the reconfiguration of the entire site, assessment of all phases for Boston will be considered as part of the Phase 2 Project for the purposes of the assessment.

Madrid Advanced Exploration

In 2014, TMAC applied for an advanced exploration permit to conduct a bulk sample at the Madrid North and Madrid South sites which are approximately 4 km south of the Doris Site. The program includes extraction of a 50,000 tonne bulk sample, which will be trucked to the mill at the Doris Site for processing and placement of tailings in the TIA. All personnel will be housed in the Doris Site.

The Water Licence application is currently before the NWB. Madrid advanced exploration includes constructing and operating of the following at each of the sites:

- Madrid North and Madrid South: workshop and office, laydown area, diesel generator, emergency shelter, fuel storage facility/transfer station, contact water pond, and quarry;
- Madrid North and Madrid South mine works: underground portal and works, waste rock pad, ore stockpile, compressor building, brine mixing facility, saline storage tank, air heating facility, and four vent raises;
- A road from the Doris site to Madrid (9.7 km) with branches to Madrid North, Madrid North vent raise, and the Madrid South portal.

The Phase 2 Project

The Phase 2 Project includes the construction and operation of commercial mining at the Madrid (North and 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 Phase 2 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

Phase 2 construction will use the infrastructure associated with Approved Projects. This may include:

Additional infrastructure to be constructed for the proposed Phase 2 Project includes:

- expansion of the Doris TIA (raising of the South Dam, construction of West Dam, and development of a west road to facilitate access);
- construction of an off-loading cargo dock at Roberts Bay (including a fuel pipeline, expansion of the fuel tank farm and laydown area);
- construction of infrastructure at Madrid North and Madrid South to accommodate mining;
- complete development of the Madrid North and Madrid South mine workings;
- construction of a process plant, fuel storage, power plant, and laydown at Madrid North;
- all weather access road (AWR) and tailings line from Madrid North to the south end of the TIA;
- AWR linking Madrid to Boston with associated quarries;
- all infrastructure necessary to support mining activities at Boston including construction of a new 200-person camp at Boston and associated support facilities, additional fuel storage, laydown area, ore pad, waste rock pad, process plant, airstrip, diesel power plant, and dry-stack tailings management area (TMA) at Boston; and
- infrastructure necessary to support ongoing exploration activities at both Madrid and Boston.

Operation

Phase 2 Project represents the staged development of the Hope Bay Belt beyond the Doris Project (Phase 1). Phase 2 operation includes:

- mining of the Madrid North, Madrid South, and Boston deposits;
- transportation of ore from Madrid North, Madrid South and Boston to Doris for processing, and transportation of concentrate from process plants at Madrid North and Boston to Doris for final gold refining once the process plants at Madrid North and Boston are constructed;
- use of Roberts Bay and Doris facilities, including processing at Doris and maintaining and operating the Roberts Bay outfall for discharge of water from the TIA;
- operation of a process plant at Madrid North to concentrate ore, and disposal of tailings at the Doris TIA;
- operation of a process plant at Boston to concentrate ore, and disposal of tailings to the Boston TMA; and
- ongoing use and maintenance of transportation infrastructure (cargo dock, jetty, roads, and quarries).

Reclamation and Closure

At Reclamation and Closure, all sites will be deactivated and reclaimed in the following manner (see Volume 3, Section 5.5):

- camps and associated infrastructure, laydown areas and quarries, buildings and physical structures will be decommissioned. All foundations will be re – graded to ensure physical and geotechnical stability and promote free-drainage, and any obstructed drainage patterns will be re – established.
- using non-hazardous landfill, facilities will receive a final quarry rock cover which will ensure physical and geotechnical stability.
- mine waste rock will be used as structural mine backfill.
- the Doris TIA surface will be covered 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 All-Weather Road 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. The balance of the berms will be left in place to prevent localised permafrost degradation.

5.2.1.2 Spatial Boundaries

The Phase 2 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 Phase 2 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 Phase 2 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 Phase 2 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 Phase 2 Project as specified in the Phase 2 Project Description (ERM 2015b).
2. Local study area – includes the Phase 2 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 Phase 2 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 and is defined as the area which has the potential for infrastructure to be developed as part of the Phase 2 Project. The PDA includes engineering buffers around the footprints of structures. These buffers allow for latitude in the final placement of a structure through later design and construction phases, reflecting the certainty of design and construction. Compounds with buildings and other infrastructure in close proximity are defined as pads with buffers whereas roads are defined as linear corridors with buffers. The buffers for pads varied depending on the local physiography and other buffered features such as sensitive environments or riparian areas. The average engineering buffer for roads is 100 m either side.

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

<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 Phase 2 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.

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 2.4-2);
- noise and vibration environment (Volume 4, Figure 3.4-1);
- 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).

Figure 5.2-1
Project Development Area

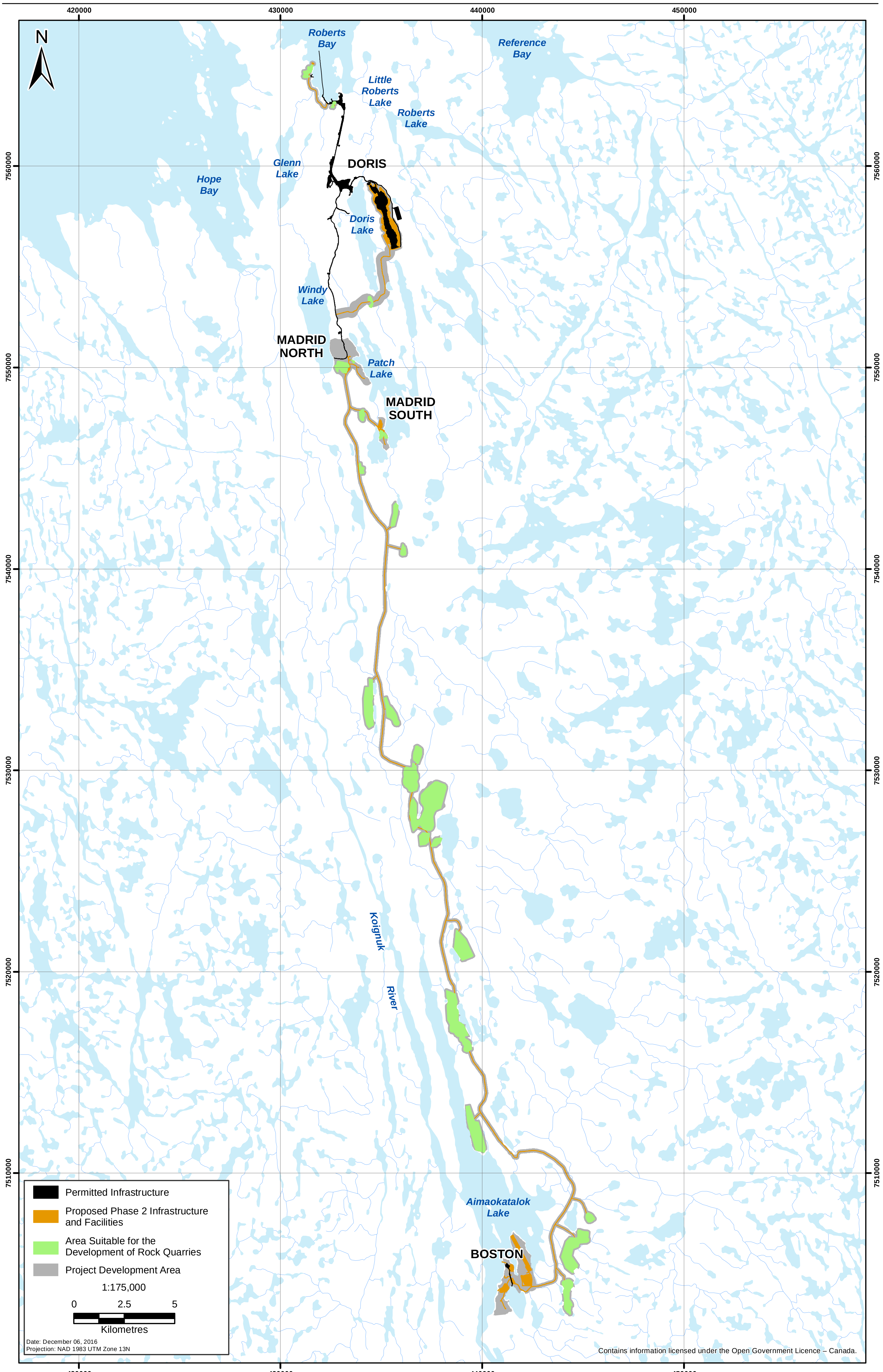
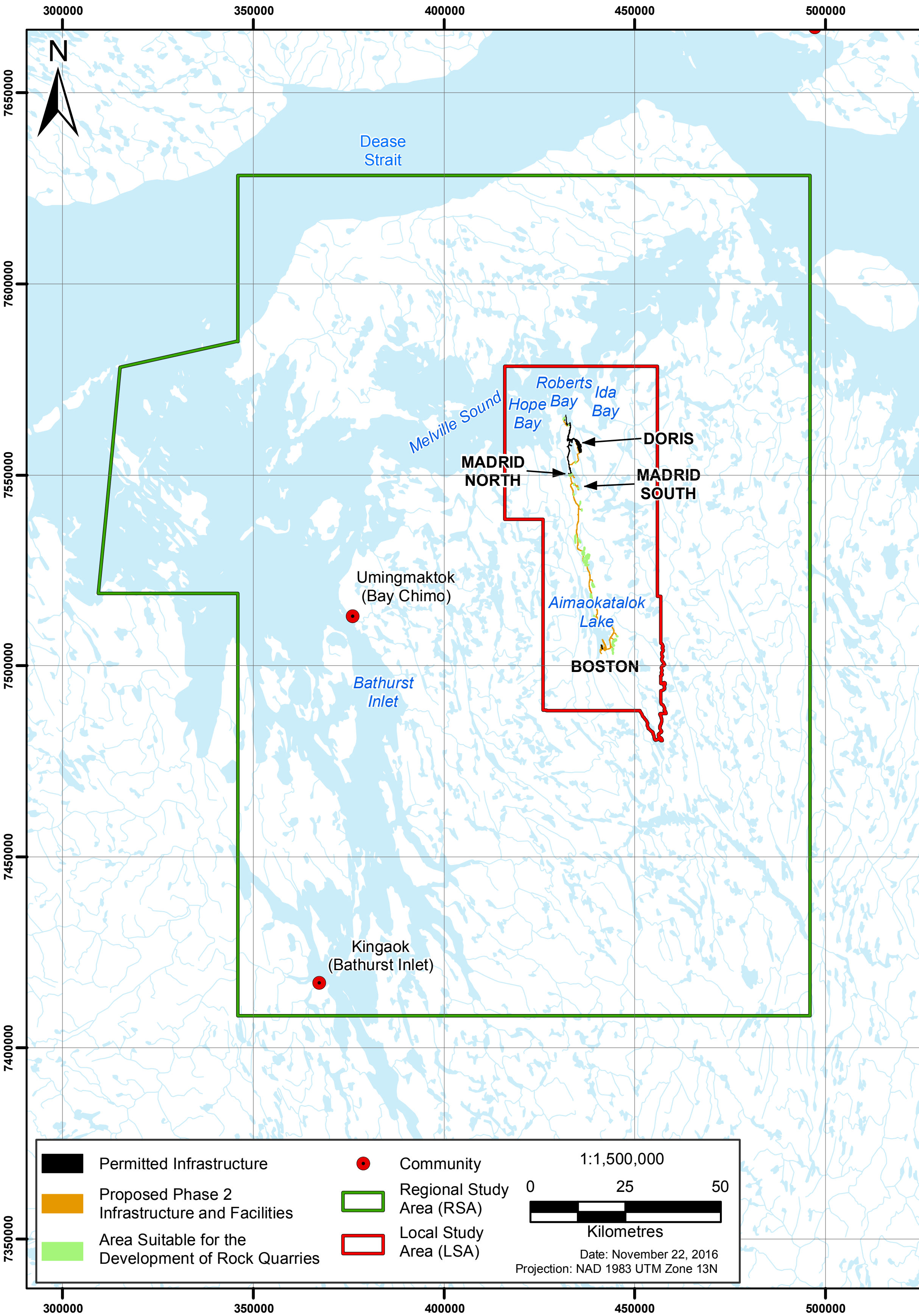


Figure 5.2-2
Human Health Local and Regional Study Areas, Phase 2 Project



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]).

Regional Study Area

The 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 3.4-1);
- 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).

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 Phase 2 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]).

5.2.1.3 Temporal Boundaries

The Phase 2 Project represents a significant development in the mining of the Hope Bay Greenstone Belt. Even though this Phase 2 Project spans the conventional Construction, Operation, Reclamation and Closure, and Post-closure phases of a mine project, Phase 2 is a continuation of development currently underway. Phase 2 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 the Phase 2 Project overlap with a number of Existing and Approved Authorizations (EAAs) for the Hope Bay Project and the extension of activities during Phase 2.

For the purposes of the EIS, distinct phases of the Phase 2 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, Section 2 (Project Description).

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	1. **Roberts Bay:** construction of marine dock and additional fuel facilities (Year 1 – Year 2); 2. **Doris**: expansion of the Doris TIA and camp (Year 1); 3. **Madrid North:** construction of process plant and road to Doris TIA (Year 1); 4. **All-weather Road**: construction (Year 1 – Year 3); 5. **Boston**: site preparation and installation of all infrastructures including process plant (Year 2 – Year 5).
Operation	5 - 14	2023 - 2032	10	6. **Roberts Bay**: shipping operations (Year 1 – Year 14) 7. **Doris**: mining (Year 1 - 4); milling and infrastructure use (Year 1 – Year 14); 8. **Madrid North:** mining (Year 1 – 13); ore transport to Doris mill (Year 1 -13); ore processing and concentrate transport to Doris mill (Year 2 – Year 13); **9. Madrid South:** mining (Year 11 – Year 14); ore transport to Doris mill (Year 11 – Year 14); 10. **All-weather Road**: operational (Year 4 – Year 14); 11. **Boston**: winter access road operating (Year 1 – Year 3); mining (Year 4 – Year 13); ore transport to Doris mill (Year 4 – Year 5); processing ore (Year 6 – Year 13); and concentrate transport to Doris mill (Year 6 – Year 13).
Reclamation and Closure	15 - 17	2033 - 2035	3	12. **Roberts Bay**: facilities will be operational during closure (Year 15 – Year 17); 13. **Doris**: camp and facilities will be operational during closure (Year 15 – Year 17); mining, milling, and TIA decommissioning (Year 15 – Year 17); 14. **Madrid North:** all components decommissioned (Year 15 – Year 17); **15. Madrid South:** all components decommissioned (Year 15 – Year 17); 16. **All-weather Road**: road will be operational (Year 15 – Year 16); decommissioning (Year 17); 17. **Boston**: all components decommissioned (Year 15 – Year 17).

Phase	Project Year	Calendar Year	Length of Phase (Years)	Description of Activities
Post-Closure	18 - 22	2036 - 2040	5	18. **All Sites:** Post-closure monitoring.
Temporary Closure	NA	NA	NA	**19. 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 Phase 2 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 Phase 2 Project-related air emissions and liquid emissions. Other phases of the Phase 2 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 Phase 2 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 Phase 2 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, Sections 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

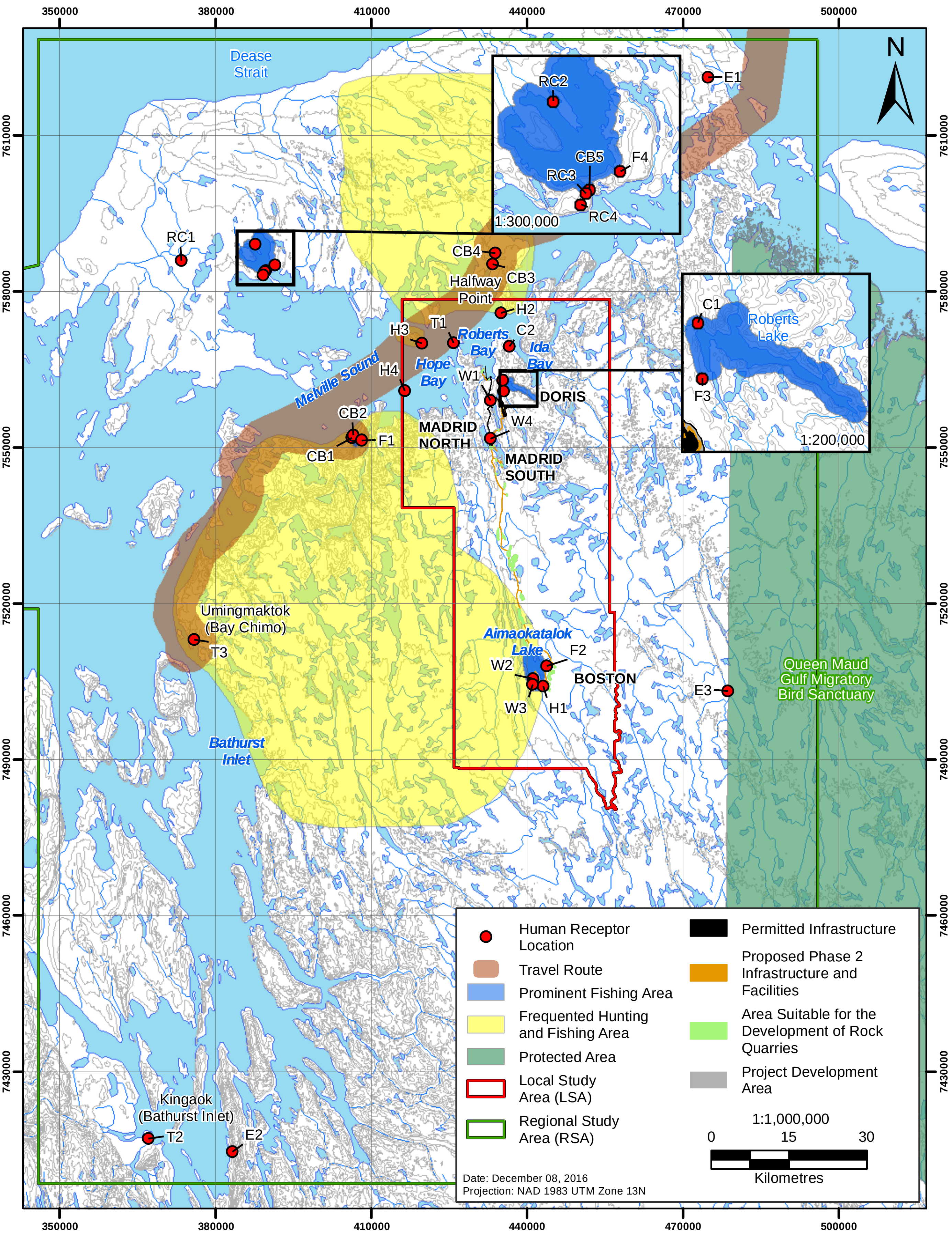
The quantitative existing conditions HHRA focused on human receptor locations within the human health LSA (Figure 5.3-1), where people may reside (as opposed to specific fishing locations or travel paths).

Two types of land users may access areas near to the Phase 2 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 Phase 2 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 Phase 2 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 Phase 2 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).

Figure 5.3-1
Human Receptor Locations, Phase 2 Project



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 Phase 2 Project. Additionally, in September 2016, TMAC held a workshop with Elders and harvesters to discuss the potential effects of the Phase 2 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).

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	-	-

Human Receptor Location	Site ID	Within the Risk Assessment		UTM Zone 13			
		LSA	RSA	Easting	Northing	Easting	Northing
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 Phase 2 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 Phase 2 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 Phase 2

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 2015a). 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.

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 consumption frequency for caribou, Canada goose, Arctic Char, Lake Trout, and Whitefish 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
Fish [g]	0.0324	0.0648

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 fish and tissue types consumed (e.g., char and trout 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. Radiation was not included in the HHRAs for the Phase 2 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 Phase 2 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.

Air

Air quality was assessed in the EIS Volume 4, Section 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 Phase 2 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 Phase 2 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 Phase 2 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 Phase 2 Project because these data represent the ambient existing air quality conditions prior to Phase 2 Project commencement.

Criteria Air Contaminants

An air quality baseline program was initiated for the Phase 2 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 Phase 2 Project area from 2009 to 2012 in various areas throughout the Phase 2 Project area (see Figure 2.2-1 in Volume 4, Section 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.

Soil

Soil quality was assessed in the EIS Volume 4, Section 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 Phase 2 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, Section 7: Landforms and Soils) and the raw data is provided in Appendix V6-5B. Metal concentrations that were below the MDL were converted to half the MDL for calculation purposes.

Water

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 Phase 2 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 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). 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 Phase 2 Project from 2007 to 2015. Full details on the sampling methodology, raw data, and summary statistics of water quality parameters are presented in Volume 5, Section 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, Section 4: Freshwater Water Quality.

<u>Country Foods Quality</u>

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 Phase 2 Project and on Kent Peninsula which is north of the Phase 2 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 truncate* and *Mytilus trossulus*) are found in the marine area near Roberts Bay (Volume 5, Section 10: Marine Fish) 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, Section 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 Phase 2 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 Phase 2 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 Phase 2 Project area is based on baseline collar data (for details of this program see Volume 4, Section 9.2.6). From 1999 to 2004 there were 8 to 22 caribou per year collared from the Dolphin and Union herd and from 1996 to 2014 there were 3 to 57 caribou per year collared from the Ahiak herd. It was determined that the highest average number of days spent within the human health LSA was 1.3 days by the Dolphin and Union herd. Thus, for the purposes of this assessment it was assumed that caribou have an exposure period of 1.3 days per year in the human health LSA.

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. Canada geese (*Branta Canadensis*) were selected for evaluation as their consumption is considered reflective of all avian species harvested from the human health LSA, as they are thought to be more commonly harvested. Although ptarmigan (*Lagopus* spp.) provided an alternate subject, their harvest is primarily in the winter and early spring whereas Canada geese are typically harvested in the summer. As COPC exposure would be greatest to foraging birds in the summer, consumption of Canada geese would likely represent the worst case exposure to COPCs in birds. Like caribou, Canada geese undergo large migrations and can intake COPCs from outside the Arctic environment. Therefore, any potential increases in COPC concentrations may or may not be related to the Phase 2 Project.

Canada geese arrive on the central Canadian Arctic barrens in early to mid-May, and generally depart by mid-September. If a pair of geese were to nest and raise young in the human health RSA, it is conceivable that residency in the area would be for the entire time they are in the Arctic. Therefore, residency time and hunting of Canada geese in the human health RSA is at most, five months.

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 Phase 2 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 Phase 2 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).

Figures 6.2-8 and 6.2-9 in Volume 5, Section 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.

Heidi Swanson (University of Waterloo) kindly provided tissue metal data for five anadromous Arctic Char collected from Roberts Lake in 2006 and 2007. The five Arctic Char were verified as being anadromous, based on otolith microchemistry and stable isotope analysis. 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. It is noted that the total number of Arctic Char was relatively small, but included mature and immature female and male individuals and hence is a cross section of life stages and history.

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).

A statistical summary of the fish tissue metal concentrations are provided in Table 5.3-3. Detection limits were not provided for the Arctic Char samples. Raw data is provided in Appendix V6-5C.

For Arctic Char, Lake Trout, and Whitefish it was assumed that muscle (fillet) is consumed as specific consumption of various organs of fish was not listed by Nancarrow (2007).

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 5.3-3, 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, 95th percentile, and maximum mercury concentration in Lake Trout and Whitefish tissues exceeded the BC MOE (2001) tissue residue guideline for fish/shellfish consumption for high fish consumers (0.1 mg/kg ww). The 95th percentile and maximum mercury concentrations in Lake Trout also exceeded the Health Canada/CFIA standard of 0.5 mg/kg (Table 5.3-3). Thus mercury was selected as a COPC due to elevated concentrations in fish tissue under baseline conditions.

Vegetation Species

Vegetation was assessed in the EIS Volume 4, Section 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 Phase 2 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.

Table 5.3-3. Screening Results for Selection of Contaminants of Potential Concern in Fish Tissue (Arctic Char 2006 and 2007; Lake Trout 2009 and 2010; Whitefish 2009)

		Arctic Char (*Salvelinus alpinus*)							Lake Trout (*Salvelinus namaycush*)							Whitefish (*Coregonus* spp.)						
Parameter	Realized Detection Limit	N	Standard Deviation	Minimum	Mean	Median	95th Percentile	Maximum	N	Standard Deviation	Minimum	Mean	Median	95th Percentile	Maximum	N	Standard Deviation	Minimum	Mean	Median	95th Percentile	Maximum
% Moisture	-	5	0	80	80	80	80	80	69	2.08	72.7	78.4	78.8	81.4	82.5	7	2.22	74.7	78.7	78.7	81.4	82.0
Metals (mg/kg ww)																						
Aluminum	2 - 4	5	0.167	0.182	0.288	0.196	0.518	0.572	69	2.30	1.00	2.06	1.00	4.24	14.9	7	0.962	1.00	1.56	1.00	3.05	3.20
Antimony	0.01 - 0.02	-	-	-	-	-	-	-	69	0	0.00500	0.00500	0.00500	0.00500	0.00500	7	0	0.00500	0.00500	0.00500	0.00500	0.00500
Arsenic	0.01 - 0.02	5	1.27	0.765	2.00	1.53	3.71	4.10	69	0.113	0.0100	0.077	0.0500	0.144	0.928	7	0.0706	0.0200	0.0667	0.0510	0.175	0.222
Barium	0.01 - 0.02	5	0.00333	0.00320	0.00568	0.00400	0.0102	0.0112	69	0.0429	0.00500	0.0331	0.0240	0.0958	0.262	7	0.0159	0.00500	0.0279	0.0260	0.0497	0.0560
Beryllium	0.1 - 0.2	5	0.000607	0.000400	0.00124	0.00160	0.00176	0.00180	69	0	0.0500	0.0500	0.0500	0.0500	0.0500	7	0	0.0500	0.0500	0.0500	0.0500	0.0500
Bismuth	0.03 - 0.06	-	-	-	-	-	-	-	69	0	0.0150	0.0150	0.0150	0.0150	0.0150	7	0	0.0150	0.0150	0.0150	0.0150	0.0150
Cadmium	0.005 - 0.01	-	-	-	-	-	-	-	69	0	0.00250	0.00250	0.00250	0.00250	0.00250	7	0	0.00250	0.00250	0.00250	0.00250	0.00250
Calcium	2 - 4	5	20.7	44.0	74.2	83.4	93.2	94.8	69	151	40.3	159	115	373	1080	7	160	89.6	232	203	462	527
Cesium	-	5	0.0100	0.0196	0.0332	0.0322	0.0452	0.0474	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chromium	0.1 - 0.2	5	0.203	0.460	0.792	0.882	0.957	0.970	69	0.113	0.0500	0.116	0.0500	0.326	0.700	7	0.0293	0.0500	0.0671	0.0500	0.110	0.110
Cobalt	0.02 - 0.04	5	0.000474	0.00194	0.00259	0.00274	0.00304	0.00306	69	0	0.0100	0.0100	0.0100	0.0100	0.0100	7	0.00718	0.0100	0.0127	0.0100	0.0233	0.0290
Copper	0.01 - 0.02	5	0.0772	0.220	0.309	0.300	0.396	0.402	69	0.0538	0.148	0.260	0.261	0.333	0.417	7	0.0629	0.140	0.206	0.199	0.301	0.335
Gold	-	5	0.00455	0.00254	0.00726	0.00624	0.0132	0.0149	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lead	0.02 - 0.04	5	0.000672	0.00134	0.00183	0.00156	0.00276	0.00300	69	0.0234	0.0100	0.0198	0.0100	0.0752	0.115	7	0.0571	0.0100	0.0316	0.0100	0.116	0.161
Lithium	0.1 - 0.2	-	-	-	-	-	-	-	69	0	0.0500	0.0500	0.0500	0.0500	0.0500	7	0	0.0500	0.0500	0.0500	0.0500	0.0500
Magnesium	1 - 2	5	28.8	179	230	237	249	250	69	41	191	273	284	328	337	7	38.8	224	273	288	313	317
Manganese	0.01 - 0.02	5	0.0144	0.0362	0.0523	0.0572	0.0662	0.0670	69	0.0617	0.0720	0.162	0.145	0.263	0.407	7	0.274	0.149	0.351	0.257	0.769	0.953
Mercury	0.001 - 0.003	5	0.00205	0.00428	0.00663	0.00628	0.00903	0.00926	69	0.400	0.00490	0.293	0.135	1.08	1.80	7	0.104	0.0422	0.175	0.176	0.311	0.338
Molybdenum	0.01 - 0.02	-	-	-	-	-	-	-	69	0.00772	0.00500	0.00828	0.00500	0.0180	0.0440	7	0	0.00500	0.00500	0.00500	0.00500	0.00500
Nickel	0.1 - 0.2	5	0.00878	0.0190	0.0330	0.0330	0.0414	0.0422	69	0.0580	0.0500	0.0736	0.0500	0.196	0.380	7	0.121	0.0500	0.0957	0.0500	0.274	0.370
Potassium	-	5	708	2669	3406	3256	4340	4574	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubidium	-	5	0.204	0.980	1.18	1.10	1.45	1.52	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Selenium	0.2 - 0.4	5	0.0928	0.270	0.433	0.464	0.496	0.502	69	0.187	0.100	0.289	0.250	0.600	0.640	7	0.0632	0.100	0.230	0.250	0.277	0.280
Silver	-	5	0.000881	0.000300	0.000820	0.000420	0.00203	0.00238	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sodium	-	5	173	174	300	254	537	598	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strontium	0.01 - 0.02	5	0.0640	0.0618	0.139	0.128	0.211	0.215	69	0.249	0.0190	0.197	0.111	0.520	1.73	7	0.446	0.102	0.463	0.363	1.13	1.37
Thallium	0.01 - 0.02	5	0.00338	0.000640	0.00266	0.00132	0.00724	0.00868	69	0.00216	0.00500	0.00581	0.00500	0.0110	0.0140	7	0	0.00500	0.00500	0.00500	0.00500	0.00500
Tin	0.05 - 0.1	-	-	-	-	-	-	-	69	0.0459	0.0250	0.0411	0.0250	0.167	0.2440	7	0.0351	0.0250	0.0499	0.0250	0.103	0.110
Uranium	0.002 - 0.004	-	-	-	-	-	-	-	69	0	0.00100	0.00100	0.00100	0.00100	0.00100	7	0	0.00100	0.00100	0.00100	0.00100	0.00100
Vanadium	0.1 - 0.2	-	-	-	-	-	-	-	69	0	0.0500	0.0500	0.0500	0.0500	0.0500	7	0	0.0500	0.0500	0.0500	0.0500	0.0500
Zinc	0.1 - 0.2	5	0.457	1.76	2.17	2.10	2.77	2.90	69	0.646	2.52	3.68	3.59	4.75	5.52	7	0.448	2.77	3.32	3.24	3.90	3.97

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

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 of 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. Only above-ground parts of plants (leaves and berries) were collected. Figure 8.2-6 in Section 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 Canada goose).

Summary of Country Foods Selected for Evaluation

A summary of the country foods selected for evaluation is presented in Table 5.3-4.

Table 5.3-4. 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
	Canada goose	*Branta canadensis*	Muscle
Fish	Arctic Char	*Salvelinus alpinus*	Muscle
	Lake Trout	*S. namaycush*	Muscle
	Whitefish	*Coregonus* spp.	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 Canada goose 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 Phase 2 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 Phase 2 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) 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 Phase 2 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, Section 7: Landforms and Soils);
- contaminant concentrations in surface water samples collected from 20 stream sites and 12 lake sites during Phase 2 Project baseline studies between 2007 and 2015 (Figures 4.2-3 and 4.2-4 in Volume 5, Section 4: Freshwater Water Quality);
- contaminant concentrations in freshwater fish tissue samples were collected from 12 sites during Phase 2 Project baseline studies in 2006, 2007, 2009, and 2010 as part of the *Doris North Gold Mine Project 2010 Aquatic Effects Monitoring Program* (Figures 6.2-8 and 6.2-9 in Volume 5, Section 6: Freshwater Fish); and
- contaminant concentrations in marine fish (i.e., Arctic Char) tissue samples collected from Roberts Lake by Heidi Swanson (University of Waterloo) in 2006 and 2007. The five Arctic Char were verified as being anadromous.

The method detection limit (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 2016a).

- The maximum total contaminant concentration in surface water samples included in the assessment exceeded the Canadian drinking water quality guidelines (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) 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, Section 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 5.3-5). 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.

Table 5.3-5. 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

Criteria Air Contaminant	Averaging Period	Ambient Air Quality Criteria (µg/m^3)			2009 - 2014 Baseline Air Quality Monitoring Data (µg/m^3)		
		Canada [a, b]	Nunavut [c]	BC [d]	Minimum	Mean [e]	Maximum
$PM_{2.5}$	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 (2016b).
[b] CCME (2016c).
[c] Government of Nunavut (2011).
[d] BC MOE (2016).
[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.

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 2016b). More stringent standards will come in effect in 2020 (Table 5.3-5). The annual averaged $PM_{2.5}$ CAAQS was adopted in the assessment for screening $PM_{2.5}$ as a COPC. The BC MOE (2016) has developed Air Quality Objectives (AQOs) for several CACs, including CO and PM_{10} (Table 5.3-5), which will be adopted for screening PM_{10} and CO as COPCs.

As shown in Table 5.3-5, none of the baseline CAC concentrations exceeded the Nunavut Air Quality Standards (Government of Nunavut 2011), the federal CAAQSs (CCME 2016b, 2016c), or BC MOE AQOs (BC MOE 2016). 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 98th 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.

Thus the average of the metal concentrations in dustfall (in mg/dm^2/day) from all monitoring stations were divided by the 98th percentile dustfall level (1.81 mg/dm^2/day) from all dustfall monitoring stations to determine the ratio of metals in dustfall (Table 5.3-6). The ratio of metals in dustfall were then multiplied by the 95th UCLM baseline 24-hour PM_{10} concentration (7.34 µg/m^3; see Table 5.3-5) to obtain the concentration of metals bound to PM_{10} (Table 5.3-6).

Table 5.3-6. 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]				
Aluminum	-	-	-	0.00490	0.00270	0.0198	No
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
Bismuth	-	-	-	0.00000708	0.00000390	0.0000286	No
Boron	-	120	-	0.000138	0.0000762	0.000559	No
Cadmium	2	0.025	-	0.00000253	0.00000140	0.0000102	No
Calcium	-	-	-	0.0163	0.00899	0.0659	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
Magnesium	-	-	-	0.00583	0.00321	0.0236	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
Phosphorus	-	-	-	0.0119	0.00656	0.0481	No
Potassium	-	-	-	0.0432	0.0238	0.175	No
Selenium	-	10	20	0.0000124	0.00000684	0.0000502	No
Silicon	-	-	-	0.00741	0.00408	0.0300	No
Silver	-	1	-	0.000000332	0.000000183	0.00000134	No

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] ($mg/dm^2/day$)	Ratio of Baseline Metal Concentration in Dustfall	Baseline Metal Concentration bound to PM_{10} ($\mu g/m^3$)	COPC (Yes/No)
	Manitoba Ambient Air Quality Criteria, Maximum Acceptable Level [a]	Ontario MOE Ambient Air Quality Criteria [b]	Washington State ASIL [c]				
Sodium	-	-	-	0.0366	0.0202	0.148	No
Strontium	-	120	-	0.0000242	0.0000134	0.0000980	No
Thallium	-	-	-	0.00000124	0.000000684	0.00000502	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
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] 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 Phase 2 Project site from 2009 to 2012 (n = 68).
The average of the 98th percentile baseline metal concentrations in dustfall from each monitoring station were multiplied with the average of the 98th percentile concentration of total dustfall from each monitoring station to determine the ratio of metals in dustfall.
The 95th UCLM baseline 24-hour PM_{10} concentration at the Phase 2 Project site (7.34 $\mu g/m^3$) was multiplied by the ratio of metals in dustfall to determine the concentration of metals on PM_{10}.

Since there are no Canadian or Nunavut guidelines for metals in air, the baseline metal concentrations bound to PM_{10} (Table 5.3-6) were compared to the: Alberta Environment (2013) Ambient Air Quality Objectives and Guidelines; the Manitoba Government (2005) Ambient Air Quality Criteria Maximum Acceptable Levels; 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 (2015) Acceptable Source Impact Levels.

None of the baseline 24-hour averaging period metal concentrations bound to PM_{10} (Table 5.3-6) exceeded screening criteria (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 CCME soil quality guidelines for the protection of agricultural or parkland/residential soil (Table 5.3-7; CCME 2016a).

Table 5.3-7. 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 (2016a).*
[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 5.3-7, 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 5.3-8).

Table 5.3-8. 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=524)	COPC (Yes/No)
Physical Parameters				
pH	pH units	6.5 to 8.5 [c]	8.5	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	0.00640	No
Major Anions				
Chloride	mg/L	≤ 250 [d]	275	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 2015.
[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 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 and dissolved metal concentrations from the human health LSA were compared to Health Canada (2015) DWQGs (Table 5.3-9).

Table 5.3-9. 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=524)	COPC (Yes/No)
Total Metal			
Aluminum	< 0.1 [c]	3.90	Yes
Antimony	0.006	0.000440	No
Arsenic	0.01	0.00372	No
Barium	1	0.0346	No
Boron	5	0.0742	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	0.00440	No
Sodium	≤ 200 [d]	147	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 2015.
[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 5.3-9, 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.

<u>Bioaccumulative Contaminants of Potential Concern</u>

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 5.3-5 and 5.3-6). The COPCs identified in the baseline soil quality screening (see Table 5.3-7) were: chromium, copper, and nickel. The COPCs identified in the baseline surface water quality screening (see Tables 5.3-8 and 5.3-9) were: aluminum, fluoride, and manganese. The only COPC identified in the baseline fish tissue screening (see Table 5.3-3) 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, Section 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.

In Canada, there are currently no federally, provincially, or territorially regulated guidelines for the protection of public health from noise. Following the advice provided in Health Canada's *Useful Information for Environmental Assessments, Section 6: Noise Effects* (Health Canada 2010f), thresholds for multiple noise metrics have been adopted from international standards, including those endorsed by the WHO, the US EPA, and Standards Australia (SA). The guidance documents relevant to assessing potential impacts to human health from noise are summarized below:

- Guidelines for Community Noise (WHO 1999): the scope of the WHO's effort to derive guidelines for community noise is to consolidate scientific knowledge on the health impacts of community noise and to provide guidance to environmental health authorities and professionals trying to protect people from the harmful effects of noise in non-industrial environments.
- Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety (US EPA 1974): this US EPA guidance document is recognized by Health Canada as an international standard for noise in the context of public health protection, which can be used for the assessment of noise effects on human health in environmental assessments.
- Standards Australia AS2187.2-2006 Explosives—Storage and Use Part 2: Use of Explosives (Standards Australia 2006): this Standards Australia document provides requirements, information, and guidance for the use of explosives, and the management of a site where explosives are used, which ensure risks to human health are acceptable and minimized.

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 Phase 2 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 Phase 2 Project area is pristine. There are no additional industrial sites or human settlements close enough to the Phase 2 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 Phase 2 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 Phase 2 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 Phase 2 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.

In order to characterize the risk to human health associated with noise generated by the proposed Phase 2 Project, baseline noise levels have been calculated in terms of the metrics typically used for the assessment of noise effects on human health (US EPA 1974; WHO 1999; Standards Australia 2006). These metrics include the L_d, L_n, L_{dn}, and L_{max} and are described in Volume 4, Section 3.2. The L_d, L_n, L_{dn}, and L_{max} for each monitoring station were used to derive mean baseline noise levels for the overall Phase 2 Project area. These mean baseline noise levels are presented with applicable assessment criteria 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.

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

Assessment Criteria	Metric	Description	Applicable Period	Thresholds	Mean Baseline Levels (dBA)
Sleep Disturbance	L_n	Noise level threshold for assessing potential sleep disturbance associated with Phase 2 Project Construction and Operational phases.	Night time (10 pm to 7 am)	57 dB(A) [a]	40.3
	L_d		Daytime (7 am to 10 pm)		42.8
Likelihood of Complaints	L_{dn}	Day and night combined (24-hour equivalent) noise level for assessing the likelihood of complaints associated with Phase 2 Project Construction and Operational phases.	24-hour Equivalent Period	60 dB(A) [b]	49.6
Sleep Disturbance	L_{max}	The maximum level of noise not to be exceeded more than 10 times per night for assessing sleep disturbance associated with Phase 2 Project Construction and Operational phases.	Night time (10 pm to 7 am)	72 dB(A) [a]	62.8

As shown in Table 5.3-11, all of the mean baseline noise levels for the Phase 2 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.

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.

5.3.3 Exposure Assessment

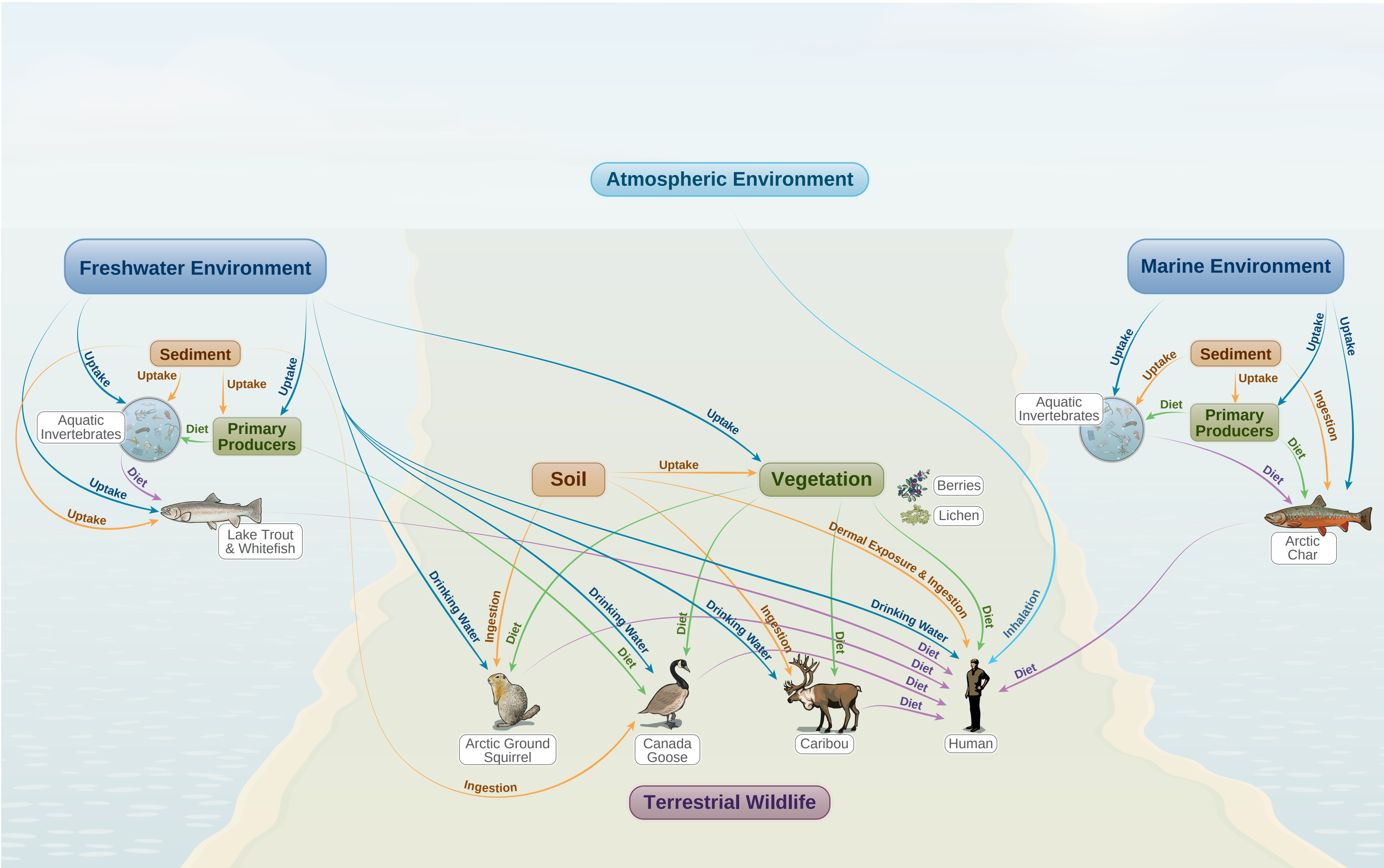
5.3.3.1 Introduction

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;
- 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).

Figure 5.3-2

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



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) 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 Canada goose).

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) or the Texas Commission on Environmental Quality Effects Screening Levels (Texas CEQ 2016; Table 5.3-6). 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 98th percentile of baseline metal concentrations (from dustfall metals) bound to the 95th 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):

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

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
		Estimated Daily Intake (mg/kg BW/day)		
COPC	**Baseline Metal Concentration bound to PM_{10} (µg/m^3)**	**Land User Toddler**	**Land User Adult**	**Off-duty Worker**
Aluminum	0.0198	2.36×10^{-6}	9.92×10^{-7}	1.07×10^{-6}
Arsenic	0.0000376	4.48×10^{-9}	1.88×10^{-9}	2.04×10^{-9}
Cadmium	0.0000102	1.22×10^{-9}	5.13×10^{-10}	5.55×10^{-10}
Chromium	0.000176	2.10×10^{-8}	8.81×10^{-9}	9.54×10^{-9}

COPC	Baseline Metal Concentration bound to PM_{10} (µg/m^3)	Estimated Daily Intake (mg/kg BW/day)		
		Land User Toddler	Land User Adult	Off-duty Worker
Copper	0.00109	1.30×10^{-7}	5.47×10^{-8}	5.92×10^{-8}
Lead	0.000104	1.23×10^{-8}	5.19×10^{-9}	5.62×10^{-9}
Manganese	0.00128	1.53×10^{-7}	6.42×10^{-8}	6.95×10^{-8}
Mercury	0.00000537	6.40×10^{-10}	2.69×10^{-10}	2.91×10^{-10}
Nickel	0.000346	4.12×10^{-8}	1.73×10^{-8}	1.88×10^{-8}
Selenium	0.0000502	5.98×10^{-9}	2.51×10^{-9}	2.72×10^{-9}
Thallium	0.00000502	5.98×10^{-10}	2.51×10^{-10}	2.72×10^{-10}
Zinc	0.000745	8.88×10^{-8}	3.73×10^{-8}	4.04×10^{-8}

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);
- 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; and
- 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)

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	6.43×10^{-3}	1.03×10^{-4}	1.12×10^{-4}
Arsenic	3.78	1.14×10^{-6}	1.82×10^{-8}	1.98×10^{-8}
Cadmium	0.250	7.54×10^{-8}	1.21×10^{-9}	1.31×10^{-9}
Chromium	65.6	1.98×10^{-5}	3.17×10^{-7}	3.43×10^{-7}
Copper	38.3	1.16×10^{-5}	1.85×10^{-7}	2.00×10^{-7}
Lead	15.0	4.52×10^{-6}	7.24×10^{-8}	7.84×10^{-8}
Manganese	370	1.12×10^{-4}	1.79×10^{-6}	1.94×10^{-6}
Mercury	0.0506	1.53×10^{-8}	2.44×10^{-10}	2.65×10^{-10}
Nickel	34.7	1.05×10^{-5}	1.68×10^{-7}	1.82×10^{-7}
Selenium	0.250	7.54×10^{-8}	1.21×10^{-9}	1.31×10^{-9}
Thallium	0.500	1.51×10^{-7}	2.41×10^{-9}	2.61×10^{-9}
Zinc	59.1	1.78×10^{-5}	2.85×10^{-7}	3.09×10^{-7}

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

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:

- baseline soil quality at the 68 sampling sites is representative of baseline soil quality within the human health LSA;
- 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);
- 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);
- 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); 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. However, given the conservative assumptions about exposure frequency, the assessment is considered to be conservative overall.

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):

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

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)			1.00×10^{-7}	1.00×10^{-7}	1.00×10^{-7}
Soil Loading Rate to Exposed Skin of Body, Other than Hands (kg/cm^2-event)			1.00×10^{-8}	1.00×10^{-8}	1.00×10^{-8}
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)**	**Relative Dermal Absorption Factor (unitless)**	**Land User Toddler**	**Land User Adult**	**Off-duty Worker**
Aluminum	21330	1.00	2.37×10^{-4}	1.19×10^{-4}	2.57×10^{-4}
Arsenic	3.78	0.0300	1.26×10^{-9}	6.30×10^{-10}	1.37×10^{-9}
Cadmium	0.250	0.0100	2.78×10^{-11}	1.39×10^{-11}	3.01×10^{-11}
Chromium	65.6	0.100	7.28×10^{-8}	3.65×10^{-8}	7.91×10^{-8}
Copper	38.3	0.0600	2.55×10^{-8}	1.28×10^{-8}	2.77×10^{-8}
Lead	15.0	1.00	1.67×10^{-7}	8.34×10^{-8}	1.81×10^{-7}
Manganese	370	1.00	4.11×10^{-6}	2.06×10^{-6}	4.46×10^{-6}
Mercury	0.0506	1.00	5.62×10^{-10}	2.81×10^{-10}	6.10×10^{-10}
Nickel	34.7	0.0910	3.51×10^{-8}	1.76×10^{-8}	3.81×10^{-8}
Selenium	0.250	0.0100	2.78×10^{-11}	1.39×10^{-11}	3.01×10^{-11}
Thallium	0.500	1.00	5.55×10^{-9}	2.78×10^{-9}	6.03×10^{-9}
Zinc	59.1	0.100	6.56×10^{-8}	3.29×10^{-8}	7.12×10^{-8}

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 1.00×10^{-7} kg/cm^2, a soil loading rate to exposed skin of body (other than hands) of 1.00×10^{-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; 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 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 14 surface water quality modeling nodes were used in the risk calculations. In the Boston area there were seven surface water quality model nodes, which included: Aimaokatalok Bay (AB node), Aimaokatalok Inflow (AI node), Aimakatalok Outflow (AL node), Stickleback Lake (SL node), Trout Lake (TrL node), Koignuk River 1 (K1 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 Phase 2 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 Phase 2 Project-related effects on surface water quality (e.g., because they are downstream of proposed Phase 2 Project infrastructure or influence). Other baseline water quality monitoring sites located further away or upstream of the Phase 2 Project are not expected to be affected by the Phase 2 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 Phase 2 Project, the assessment of Phase 2 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 14 surface water quality modeling nodes is provided in Appendix V3-2D. For each surface water quality modeling node, the 95th 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 95th percentile concentrations from the 14 surface water quality modeling nodes was calculated and used to assess the risk from drinking water ingestion by land users.

The primary domestic water supply for the Phase 2 Project will be trucked from a pump house with filtration at Windy Lake. The water quality at Windy Lake is superior to Doris Lake for domestic water needs as it requires less treatment. Thus, the base case baseline 95th percentile concentrations at Windy 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):

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

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.

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 14 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;
- 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); and
- 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).

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
			Estimated Daily Intake (mg/kg BW/day)		
Non-Metal COPC	**Baseline 95th Percentile Concentration in Water for Land Users (mg/L)**	**Baseline 95th Percentile Concentration in Water for Off-duty Workers (mg/L)**	**Land User Toddler**	**Land User Adult**	**Off-duty Worker**
Fluoride	0.0475	0.0550	4.30×10^{-4}	2.15×10^{-4}	5.39×10^{-4}
Aluminum	0.0605	0.0508	5.48×10^{-4}	2.74×10^{-4}	4.98×10^{-4}
Arsenic	0.000266	0.000298	1.04×10^{-5}	1.20×10^{-6}	2.92×10^{-6}
Cadmium	0.00000613	0.00000538	2.47×10^{-7}	2.85×10^{-8}	5.27×10^{-8}
Chromium	0.000437	0.000538	1.71×10^{-5}	1.98×10^{-6}	5.27×10^{-6}
Copper	0.00143	0.00143	5.61×10^{-5}	6.47×10^{-6}	1.40×10^{-5}
Lead	0.0000543	0.0000538	2.13×10^{-6}	2.46×10^{-7}	5.27×10^{-7}
Manganese	0.0220	0.0228	8.64×10^{-4}	9.97×10^{-5}	2.23×10^{-4}
Mercury	0.00000133	0.000000729	5.23×10^{-8}	6.04×10^{-9}	7.14×10^{-9}
Nickel	0.000576	0.000549	2.26×10^{-5}	2.61×10^{-6}	5.38×10^{-6}
Selenium	0.000250	0.000216	9.81×10^{-6}	1.13×10^{-6}	2.11×10^{-6}
Thallium	0.00000407	0.00000216	1.60×10^{-7}	1.84×10^{-8}	2.11×10^{-8}
Zinc	0.00320	0.00323	1.25×10^{-4}	1.45×10^{-5}	3.16×10^{-5}

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

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

$$EDI_{Alumium} = \frac{0.0605\,\frac{mg}{L} \times 0.6\,\frac{L}{d} \times 1 \times \frac{7\,day}{7\,day} \times \frac{12\,week}{52\,week}}{15.3\,kg\,BW}$$

$$EDI_{Aluminum} = 5.48\ \times 10^{-4}\,mg/kg\,BW/day$$

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 Canada goose 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, sediment, and vegetation (lichen and berries) in addition to wildlife ingestion rates and COPC-specific biotransfer factors (BTFs; Table V6-5E2 in Appendix V6-5E). 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 Canada goose 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, sediment, water, and vegetation), based on information known about the species life histories. Table 5.3-16 presents the modeled caribou, Arctic ground squirrel, and Canada goose COPC concentrations in tissue. As seen in Table 5.3-16, the food chain model predicts Canada goose has a higher tissue concentration of aluminum than caribou and Arctic ground squirrel, which is due to their elevated sediment ingestion rate (see Appendix V6-5E).

<u>Fish Tissue Concentrations</u>

Lake Trout and Whitefish were sampled in 2009 and 2010 for the Phase 2 Project and Arctic Char were sampled in 2006 and 2007 by an independent researcher from the University of Alberta. In total, 38 Lake Trout, four Whitefish, and five Arctic Char collected from within the human health LSA (Figures 6.2-8 and 6.2-9 in Volume 5, Section 6: Freshwater Fish) had tissue metals analysed, and were included in the assessment. Table 5.3-3 presents the 95th percentile concentrations of COPCs in tissue measured in the three 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 each fish species were used to calculate the human EDI of COPCs from fish consumption.

<u>Berry Tissue Concentrations</u>

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, Section 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.

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, Sediment, and Vegetation Concentrations)					Measured Concentrations (95th Percentiles)			
	Caribou	Caribou Liver [a]	Caribou Kidney [a]	Arctic Ground Squirrel	Canada Goose	Berries	Arctic Char	Lake Trout	Whitefish
Aluminum	0.0218	-	-	0.0648	209	5.48	0.518	4.24	3.05
Arsenic	0.00000867	0.0000117	0.00000980	0.0000191	0.124	0.00362	3.71	0.144	0.175
Cadmium	0.00000108	0.000151	0.00130	0.00000134	0.000995	0.00380	0.00250	0.00250	0.00250
Chromium	0.00117	-	-	0.00173	0.286	9.33	0.957	0.326	0.110
Copper	0.000672	0.0309	0.00490	0.001220	0.321	1.33	0.396	0.333	0.301
Lead	0.00000506	0.000916	0.000110	0.0000113	0.119	0.0133	0.00276	0.0752	0.116
Manganese	0.000725	-	-	0.000974	1.37	23.5	0.0662	0.263	0.769
Mercury	0.000276	0.0300	0.143	0.000314	0.000155	0.000500	-	-	-
Methylmercury [c]	-	-	-	-	-	-	0.00903	1.08	0.311
Nickel	0.000672	-	-	0.000994	0.000806	5.25	0.0414	0.196	0.274
Selenium	0.00000327	-	-	0.00000427	0.0124	0.0100	0.496	0.600	0.277
Thallium	0.0000163	-	-	0.0000434	0.0350	0.000200	0.00724	0.0110	0.00500
Zinc	0.0000354	0.0000557	0.0000670	0.0000451	0.0213	2.15	2.77	4.75	3.90

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] *Cadmium concentrations not available for Arctic Char, therefore the concentrations in Lake Trout were adopted for Arctic Char.*
[c] *Total mercury analyzed in fish tissue was assumed to be entirely methylmercury.*

Estimated Daily Intake

An EDI of each COPC for toddlers and adults was based on the predicted (caribou, Arctic ground squirrel, and Canada goose) 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:

$$EDI_{food} = \frac{C_{food} \times IR \times RAF \times ET}{BW}$$ [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 Phase 2 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 2010), and the BTFs for Canada goose 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 Canada goose include solely the vegetation species that were collected in baseline field studies and in the proportions used in the model (95^{th} percentile concentrations from each species pooled);
- all country foods consumed by people came from within the human health LSA;
- animals consume water, soil or freshwater sediment, and vegetation at the rates and frequencies used in the food chain model;
- 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); and
- adults have a body weight of 76.5 kg as recommended by Richardson and Stantec Consulting Ltd. (2013).

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

COPC	Caribou	Caribou Liver	Caribou Kidney	Arctic Ground Squirrel	Canada Goose	Berries	Arctic Char	Lake Trout	Whitefish	Maximum EDI from All Fish	EDI_{Total} [a]
	Estimated Daily Intake of COPC (mg/kg BW/day) by Adult Receptor										
Aluminum	6.34×10^{-5}	-	-	4.17×10^{-5}	3.12×10^{-2}	9.31×10^{-4}	4.39×10^{-4}	3.59×10^{-3}	2.59×10^{-3}	3.59×10^{-3}	3.58×10^{-2}
Arsenic [b]	1.77×10^{-8}	3.61×10^{-10}	1.55×10^{-10}	8.61×10^{-9}	9.23×10^{-6}	6.14×10^{-7}	3.14×10^{-4}	1.22×10^{-5}	1.48×10^{-5}	3.14×10^{-4}	3.24×10^{-4}
Cadmium	3.15×10^{-9}	6.64×10^{-9}	2.94×10^{-8}	8.65×10^{-10}	1.48×10^{-7}	6.46×10^{-7}	2.12×10^{-6}	2.12×10^{-6}	2.12×10^{-6}	2.12×10^{-6}	2.95×10^{-6}
Chromium	3.40×10^{-6}	-	-	1.11×10^{-6}	4.27×10^{-5}	1.59×10^{-3}	8.11×10^{-4}	2.76×10^{-4}	9.32×10^{-5}	8.11×10^{-4}	2.44×10^{-3}
Copper	1.96×10^{-6}	1.36×10^{-6}	1.11×10^{-7}	7.85×10^{-7}	4.78×10^{-5}	2.25×10^{-4}	3.36×10^{-4}	2.82×10^{-4}	2.55×10^{-4}	3.36×10^{-4}	6.13×10^{-4}
Lead	1.47×10^{-8}	4.03×10^{-8}	2.48×10^{-9}	7.25×10^{-9}	1.77×10^{-5}	2.25×10^{-6}	2.34×10^{-6}	6.37×10^{-5}	9.81×10^{-5}	9.81×10^{-5}	1.18×10^{-4}
Manganese	2.11×10^{-6}	-	-	6.27×10^{-7}	2.05×10^{-4}	3.98×10^{-3}	5.61×10^{-5}	2.23×10^{-4}	6.51×10^{-4}	6.51×10^{-4}	4.84×10^{-3}
Mercury	8.03×10^{-7}	1.32×10^{-6}	3.23×10^{-6}	2.02×10^{-7}	2.31×10^{-8}	8.50×10^{-8}	NA	NA	NA	NA	5.66×10^{-6}
Methylmercury	NA	NA	NA	NA	NA	NA	7.66×10^{-6}	9.17×10^{-4}	2.63×10^{-4}	9.17×10^{-4}	9.17×10^{-4}
Nickel	1.96×10^{-6}	-	-	6.40×10^{-7}	1.20×10^{-7}	8.92×10^{-4}	3.51×10^{-5}	1.66×10^{-4}	2.32×10^{-4}	2.32×10^{-4}	1.13×10^{-3}
Selenium	9.53×10^{-9}	-	-	2.74×10^{-9}	1.86×10^{-6}	1.70×10^{-6}	4.20×10^{-4}	5.09×10^{-4}	2.35×10^{-4}	5.09×10^{-4}	5.12×10^{-4}
Thallium	4.75×10^{-8}	-	-	2.79×10^{-8}	5.22×10^{-6}	3.40×10^{-8}	6.14×10^{-6}	9.32×10^{-6}	4.24×10^{-6}	9.32×10^{-6}	1.47×10^{-5}
Zinc	1.03×10^{-7}	2.46×10^{-9}	1.51×10^{-9}	2.90×10^{-8}	3.18×10^{-6}	3.66×10^{-4}	2.35×10^{-3}	4.02×10^{-3}	3.30×10^{-3}	4.02×10^{-3}	4.39×10^{-3}
	Estimated Daily Intake of COPC (mg/kg BW/day) by Toddler Receptor										
COPC	**Caribou**	**Caribou Liver**	**Caribou Kidney**	**Arctic Ground Squirrel**	**Canada Goose**	**Berries**	**Arctic Char**	**Lake Trout**	**Whitefish**	**Maximum EDI from All Fish**	**EDI_{Total} [a]**
Aluminum	1.59×10^{-4}	-	-	1.04×10^{-4}	7.79×10^{-2}	2.33×10^{-3}	1.10×10^{-3}	8.98×10^{-3}	6.46×10^{-3}	8.98×10^{-3}	8.95×10^{-2}
Arsenic [b]	4.42×10^{-8}	9.02×10^{-10}	3.87×10^{-10}	2.15×10^{-8}	2.31×10^{-5}	1.54×10^{-6}	7.86×10^{-4}	3.05×10^{-5}	3.71×10^{-5}	7.86×10^{-4}	8.10×10^{-4}
Cadmium	7.87×10^{-9}	1.66×10^{-8}	7.36×10^{-8}	2.16×10^{-9}	3.71×10^{-7}	1.61×10^{-6}	5.30×10^{-6}	5.30×10^{-6}	5.30×10^{-6}	5.30×10^{-6}	7.38×10^{-6}
Chromium	8.51×10^{-6}	-	-	2.78×10^{-6}	1.07×10^{-4}	3.96×10^{-3}	2.03×10^{-3}	6.91×10^{-4}	2.33×10^{-4}	2.03×10^{-3}	6.11×10^{-3}
Copper	4.89×10^{-6}	3.40×10^{-6}	2.77×10^{-7}	1.96×10^{-6}	1.20×10^{-4}	5.63×10^{-4}	8.39×10^{-4}	7.06×10^{-4}	6.37×10^{-4}	8.39×10^{-4}	1.53×10^{-3}
Lead	3.69×10^{-8}	1.01×10^{-7}	6.21×10^{-9}	1.81×10^{-8}	4.43×10^{-5}	5.63×10^{-6}	5.84×10^{-6}	1.59×10^{-4}	2.45×10^{-4}	2.45×10^{-4}	2.95×10^{-4}
Manganese	5.28×10^{-6}	-	-	1.57×10^{-6}	5.12×10^{-4}	9.96×10^{-3}	1.40×10^{-4}	5.57×10^{-4}	1.63×10^{-3}	1.63×10^{-3}	1.21×10^{-2}

COPC	Estimated Daily Intake of COPC (mg/kg BW/day) by Toddler Receptor									Maximum EDI from All Fish	EDI_{Total} [a]
	Caribou	Caribou Liver	Caribou Kidney	Arctic Ground Squirrel	Canada Goose	Berries	Arctic Char	Lake Trout	Whitefish		
Mercury	2.01×10^{-6}	3.30×10^{-6}	8.06×10^{-6}	5.05×10^{-7}	5.78×10^{-8}	2.12×10^{-7}	NA	NA	NA	NA	1.41×10^{-5}
Methylmercury	NA	NA	NA	NA	NA	NA	1.91×10^{-5}	2.29×10^{-3}	6.58×10^{-4}	2.29×10^{-3}	2.29×10^{-3}
Nickel	4.89×10^{-6}	-	-	1.60×10^{-6}	3.01×10^{-7}	2.23×10^{-3}	8.77×10^{-5}	4.15×10^{-4}	5.81×10^{-4}	5.81×10^{-4}	2.82×10^{-3}
Selenium	2.38×10^{-8}	-	-	6.86×10^{-9}	4.64×10^{-6}	4.25×10^{-6}	1.05×10^{-3}	1.27×10^{-3}	5.87×10^{-4}	1.27×10^{-3}	1.28×10^{-3}
Thallium	1.19×10^{-7}	-	-	6.98×10^{-8}	1.31×10^{-5}	8.50×10^{-8}	1.53×10^{-5}	2.33×10^{-5}	1.06×10^{-5}	2.33×10^{-5}	3.66×10^{-5}
Zinc	2.58×10^{-7}	6.14×10^{-9}	3.78×10^{-9}	7.26×10^{-8}	7.95×10^{-6}	9.14×10^{-4}	5.87×10^{-3}	1.01×10^{-2}	8.25×10^{-3}	1.01×10^{-2}	1.10×10^{-2}

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, except the maximum EDI from all fish is used.
[b] Arsenic EDIs are based on inorganic arsenic concentrations.

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

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

$$EDI_{squirrel} = \frac{0.0648\ mg/kg \times 0.0246\ kg/day \times 1 \times 1}{15.3\ kg}$$

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

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 Canada goose; chromium, manganese, and nickel from consuming berries; arsenic, cadmium, and copper from consuming Arctic Char; cadmium, methylmercury, selenium, thallium, and zinc from consuming Lake Trout; and cadmium and lead from consuming Whitefish. 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). In the calculations of $EDI_{Country\ Foods}$, the maximum EDI for each COPC from all three fish species was used as the fish EDI (see Table 5.3-17), which is a conservative assumption.

$$EDI_{Aluminum-Country\ Foods} = EDI_{Aluminum-Caribou} + EDI_{Aluminum-Arctic\ ground\ squirrel} + EDI_{Aluminum-Canada\ goose} + EDI_{Aluminum-Berries} + EDI_{Aluminum-Fish}$$

$$EDI_{Aluminum-Country\ Foods} = 0.000159\ mg/kg\ BW/day + 0.000104\ mg/kg\ BW/day + 0.0779\ mg/kg\ BW/day + 0.00233\ mg/kg\ BW/day + 0.00898\ mg/kg\ BW/day$$

$$EDI_{Aluminum-Country\ Foods} = 0.0895\ mg/kg\ BW/day$$

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 (2015)
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 ($\mu g/m^3$)$^{-1}$**	**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	

Carcinogenic COPC	Inhalation Cancer Unit Risk $(\mu g/m^3)^{-1}$	Oral Cancer Slope Factor (mg/kg BW/day)$^{-1}$	Reference
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 2015) 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 2015) 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 2015), 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 2015). Excess intake of manganese can result in symptoms such as lethargy, increased muscle tonus, tremor, and metal disturbances (US EPA 2015), 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 2015) 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 2015). 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, Canada goose, 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 Phase 2 Project.

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

Non-Metal 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	4.07×10^{-4}	NA	NA	NA	4.07×10^{-4}	0.105	0.0039
Metal COPC								
Aluminum	2.36×10^{-6}	5.48×10^{-4}	6.43×10^{-3}	2.37×10^{-4}	8.95×10^{-2}	9.66×10^{-2}	0.3	0.32
Arsenic	4.48×10^{-9}	1.04×10^{-5}	1.14×10^{-6}	1.26×10^{-9}	8.10×10^{-4}	8.22×10^{-4}	0.0003	2.7
Cadmium	1.22×10^{-9}	2.47×10^{-7}	7.54×10^{-8}	2.78×10^{-11}	7.38×10^{-6}	7.71×10^{-6}	0.001	0.0077
Chromium	2.10×10^{-8}	1.71×10^{-5}	1.98×10^{-5}	7.28×10^{-8}	6.11×10^{-3}	6.15×10^{-3}	0.001	6.1
Copper	1.30×10^{-7}	5.61×10^{-5}	1.16×10^{-5}	2.55×10^{-8}	1.53×10^{-3}	1.60×10^{-3}	0.091	0.018
Lead	1.23×10^{-8}	2.13×10^{-6}	4.52×10^{-6}	1.67×10^{-7}	2.95×10^{-4}	3.02×10^{-4}	0.0006	0.50
Manganese	1.53×10^{-7}	8.64×10^{-4}	1.12×10^{-4}	4.11×10^{-6}	1.21×10^{-2}	1.31×10^{-2}	0.136	0.096
Mercury	6.40×10^{-10}	5.23×10^{-8}	1.53×10^{-8}	5.62×10^{-10}	1.41×10^{-5}	1.39×10^{-5}	0.0003	0.047
Methylmercury	NA	NA	NA	NA	2.29×10^{-3}	2.29×10^{-3}	0.00023	10
Nickel	4.12×10^{-8}	2.26×10^{-5}	1.05×10^{-5}	3.51×10^{-8}	2.82×10^{-3}	2.85×10^{-3}	0.011	0.26
Selenium	5.98×10^{-9}	9.81×10^{-6}	7.54×10^{-8}	2.78×10^{-11}	1.28×10^{-3}	1.29×10^{-3}	0.00620	0.21
Thallium	5.98×10^{-10}	1.60×10^{-7}	1.51×10^{-7}	5.55×10^{-9}	3.66×10^{-5}	3.70×10^{-5}	0.00007	0.53
Zinc	8.88×10^{-8}	1.25×10^{-4}	1.78×10^{-5}	6.56×10^{-8}	1.10×10^{-2}	1.11×10^{-2}	0.48	0.023

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 aluminum, arsenic, chromium, lead, methylmercury, nickel, selenium, and thallium were greater than 0.2 (Table 5.3-19). For land user adults, the HQs for arsenic, chromium, methylmercury (general public and sensitive populations), and thallium 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., 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.). 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., aluminum, arsenic, chromium, lead, methylmercury, nickel, selenium, and thallium for toddlers; and arsenic, chromium, methylmercury, and thallium 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

	Estimated Daily Intake for Land User Adult (mg/kg BW/day)						Estimated Daily Intake for Off-duty Worker (mg/kg BW/day)							
Non-Metal COPC	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	2.03×10^{-4}	NA	NA	NA	2.03×10^{-4}	NA	5.39×10^{-4}	NA	NA	5.39×10^{-4}	0.105	0.0019	0.0051
Metal COPC														
Aluminum	9.92×10^{-7}	2.74×10^{-4}	1.03×10^{-4}	1.19×10^{-4}	3.58×10^{-2}	3.63×10^{-2}	1.07×10^{-6}	4.98×10^{-4}	1.12×10^{-4}	2.57×10^{-4}	8.67×10^{-4}	0.3	0.12	0.0028
Arsenic	1.88×10^{-9}	1.20×10^{-6}	1.82×10^{-8}	6.30×10^{-10}	3.24×10^{-4}	3.25×10^{-4}	2.04×10^{-9}	2.92×10^{-6}	1.98×10^{-8}	1.37×10^{-9}	2.94×10^{-6}	0.0003	1.1	0.0098
Cadmium	5.13×10^{-10}	2.85×10^{-8}	1.21×10^{-9}	1.39×10^{-11}	2.95×10^{-6}	2.98×10^{-6}	5.55×10^{-10}	5.27×10^{-8}	1.31×10^{-9}	3.01×10^{-11}	5.46×10^{-8}	0.001	0.0030	0.000055
Chromium	8.81×10^{-9}	1.98×10^{-6}	3.17×10^{-7}	3.65×10^{-8}	2.44×10^{-3}	2.45×10^{-3}	9.54×10^{-9}	5.27×10^{-6}	3.43×10^{-7}	7.91×10^{-8}	5.71×10^{-6}	0.001	2.4	0.0057
Copper	5.47×10^{-8}	6.47×10^{-6}	1.85×10^{-7}	1.28×10^{-8}	6.13×10^{-4}	6.20×10^{-4}	5.92×10^{-8}	1.40×10^{-5}	2.00×10^{-7}	2.77×10^{-8}	1.43×10^{-5}	0.141	0.0044	0.00010
Lead	5.19×10^{-9}	2.46×10^{-7}	7.24×10^{-8}	8.34×10^{-8}	1.18×10^{-4}	1.19×10^{-4}	5.62×10^{-9}	5.27×10^{-7}	7.84×10^{-8}	1.81×10^{-7}	7.92×10^{-7}	0.0013	0.091	0.00061
Manganese	6.42×10^{-8}	9.97×10^{-5}	1.79×10^{-6}	2.06×10^{-6}	4.84×10^{-3}	4.95×10^{-3}	6.95×10^{-8}	2.23×10^{-4}	1.94×10^{-6}	4.46×10^{-6}	2.30×10^{-4}	0.156	0.032	0.0015
Mercury	2.69×10^{-10}	6.04×10^{-9}	2.44×10^{-10}	2.81×10^{-10}	5.66×10^{-6}	5.67×10^{-6}	2.91×10^{-10}	7.14×10^{-9}	2.65×10^{-10}	6.10×10^{-10}	8.31×10^{-9}	0.0003	0.019	0.000028
Methylmercury (general adult population)	NA	NA	NA	NA	9.17×10^{-4}	9.17×10^{-4}	NA	NA	NA	NA	NA	0.00047	2.0	NA
Methylmercury (sensitive populations)	NA	NA	NA	NA	9.17×10^{-4}	9.17×10^{-4}	NA	NA	NA	NA	NA	0.00023	4.0	NA
Nickel	1.73×10^{-8}	2.61×10^{-6}	1.68×10^{-7}	1.76×10^{-8}	1.13×10^{-3}	1.13×10^{-3}	1.88×10^{-8}	5.38×10^{-6}	1.82×10^{-7}	3.81×10^{-8}	5.62×10^{-6}	0.011	0.10	0.00051
Selenium	2.51×10^{-9}	1.13×10^{-6}	1.21×10^{-9}	1.39×10^{-11}	5.12×10^{-4}	5.13×10^{-4}	2.72×10^{-9}	2.11×10^{-6}	1.31×10^{-9}	3.01×10^{-11}	2.12×10^{-6}	0.0057	0.090	0.00037
Thallium	2.51×10^{-10}	1.84×10^{-8}	2.41×10^{-9}	2.78×10^{-9}	1.47×10^{-5}	1.47×10^{-5}	2.72×10^{-10}	2.11×10^{-8}	2.61×10^{-9}	6.03×10^{-9}	3.00×10^{-8}	0.00007	0.21	0.00043
Zinc	3.73×10^{-8}	1.45×10^{-5}	2.85×10^{-7}	3.29×10^{-8}	4.39×10^{-3}	4.41×10^{-3}	4.04×10^{-8}	3.16×10^{-5}	3.09×10^{-7}	7.12×10^{-8}	3.20×10^{-5}	0.57	0.0077	0.000056

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	9.71×10^{-9}	1.05×10^{-8}
Cadmium	4.05×10^{-9}	4.39×10^{-9}
Chromium	7.81×10^{-8}	8.46×10^{-8}
Nickel	1.82×10^{-8}	1.97×10^{-8}
Summed ILCR (inhalation)	1.10×10^{-7}	1.19×10^{-7}

Notes:
ILCR = incremental lifetime cancer risk

The summed arsenic, cadmium, chromium, and nickel lifetime ILCR for land users and off-duty workers (1.10×10^{-7} and 1.19×10^{-7}, respectively) are less than 1×10^{-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:

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

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

$$\mathrm{ILCR_{Arsenic}} = 9.71 \times 10^{-9}$$

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

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 (ELDE; Golder Associates Ltd. 2005):

$$\mathrm{ELDE} = \frac{\mathrm{C \times IR \times RAF \times ET \times D2}}{\mathrm{BW \times LE}}$$ [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.

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

$$\mathrm{ELDE_{arsenic}} = \frac{\left(3.71\,\frac{\mathrm{mg}}{\mathrm{kg}} \times 0.1\right) \times 0.0648\,\frac{\mathrm{kg}}{\mathrm{day}} \times 1 \times 1 \times 14\ \mathrm{years}}{76.5\ \mathrm{kg} \times 80\ \mathrm{years}}$$

$$\mathrm{ELDE_{arsenic}} = 5.50\ \mathrm{x}\ 10^{-5}$$

An ELDE was calculated for all ingestion 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:

$$\mathrm{ELDE_{Total}} = \mathrm{ELDE_{water}} + \mathrm{ELDE_{soil\ ingestion}} + \mathrm{ELDE_{soil\ contact}} + \mathrm{ELDE_{caribou}} + \mathrm{ELDE_{squirrel}} + \mathrm{ELDE_{goose}} + \mathrm{ELDE_{berries}} + \mathrm{ELDE_{fish}}$$ [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)
$ELDE_{goose}$ = estimated lifetime daily exposure from Canada goose ingestion (mg/kg BW/day)

$ELDE_{berries}$ = estimated lifetime daily exposure from berry ingestion (mg/kg BW/day)
$ELDE_{fish}$ = estimated lifetime daily exposure from fish ingestion (mg/kg BW/day)

The ELDE was calculated for each ingestion pathway and the summed total ELDE is provided in Table 5.3-22. The highest $ELDE_{fish}$ from the three fish species (i.e., Arctic Char, Lake Trout, or Whitefish) was used in the calculation of $ELDE_{Total}$.

Table 5.3-22. Incremental Lifetime Cancer Risk from Arsenic Ingestion Under Existing Conditions

	Adult Land User		Off-duty Worker	
Pathway	**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	9.54×10^{-7}	1.72×10^{-6}	5.10×10^{-7}	9.19×10^{-7}
Soil Ingestion	3.19×10^{-9}	5.74×10^{-9}	3.46×10^{-9}	6.22×10^{-9}
Soil Dermal Contact	1.10×10^{-10}	1.99×10^{-10}	2.39×10^{-10}	4.30×10^{-10}
Country Foods				
Caribou	3.10×10^{-9}	5.57×10^{-9}	NA	NA
Caribou Liver	6.31×10^{-11}	1.14×10^{-10}	NA	NA
Caribou Kidney	2.71×10^{-11}	4.88×10^{-11}	NA	NA
Arctic Ground Squirrel	1.51×10^{-9}	2.71×10^{-9}	NA	NA
Canada Goose	1.62×10^{-6}	2.91×10^{-6}	NA	NA
Berries	1.08×10^{-7}	1.94×10^{-7}	NA	NA
Fish *	5.50×10^{-5}	9.90×10^{-5}	NA	NA
Total ILCR	5.77×10^{-5}	1.04×10^{-4}	5.14×10^{-7}	9.25×10^{-7}

Notes:
ILCR = incremental lifetime cancer risk
ELDE = estimated lifetime daily exposure
BW = body weight
NA = not applicable
** The fish species with the highest ELDE and ILCR (Arctic Char) was used in the calculations.*
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:

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

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

$$\mathrm{ILCR_{soil}} = 5.74 \text{ x } 10^{-9}$$

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:

$$ILCR_{arsenic-caribou} = \left[\frac{[\sum[IR_{Foodi} \times C_{Foodi} \times RAF_{Orali} \times DE_i]] \times YE}{BW \times DE \times LE}\right] \times CSF$$

$$ILCR_{arsenic-caribou} = \frac{\left(\left[0.223\,\frac{kg}{day} \times \left(0.00000867\,\frac{mg}{kg} \times 70\%\right) \times 1 \times 365\ days\right] \times 14\ years\right)}{76.5\ kg\ BW \times 365\ days \times 80\ years} \times 1.80\ (mg/kg\ BW/day)^{-1}$$

$$ILCR_{arsenic-caribou} = 3.10 \times 10^{-9}$$

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

The arsenic ILCR for an adult land user (1.04×10^{-4}) for all exposure pathways summed is larger than the threshold of 1.0×10^{-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 (9.90×10^{-5}), of which there were only five tissue samples that were provided by an independent researcher. In addition, laboratory procedures and analytical techniques for these fish were not provided so there is some uncertainty regarding the data.

However, if the arsenic ILCR for Lake Trout (3.84×10^{-6}) or Whitefish (4.67×10^{-6}) were used in the summed arsenic ingestion ILCR for land users instead of Arctic Char, then the ILCR is acceptable (8.74×10^{-6} and 9.56×10^{-6}, respectively). Therefore, the elevated ILCR for land users is likely an artifact of the small sample size of Arctic Char.

The ILCR for an adult off-duty worker (8.95×10^{-7}) for all exposure pathways summed is below the threshold of 1.0×10^{-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 Phase 2 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 Phase

2 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 Phase 2 Project activities in the future, but do not occur or were not measured under existing conditions.

5.3.6.3 Tissue Concentrations

<u>Terrestrial Species</u>

Concentrations of COPCs in the tissue of caribou, Arctic ground squirrel, and Canada goose 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 Canada goose 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 Canada goose ingestion rates used for food, soil/sediment, 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. The same approach was used for Canada goose ingesting sediment because they may consume small rocky material to aid in physically breaking down food in their gizzards. Overall, it is anticipated that the soil/sediment and plant ingestion rates by caribou, Arctic ground squirrel, and Canada goose have been overestimated, which would result in conservatism in the risk estimates.

The migratory nature of caribou and Canada goose 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 Phase 2 Project effect. As both species utilize a wide area (caribou have ranges covering thousands of square kilometers and Canada geese extend as far as Mexico to winter feeding grounds), where they consume food and water outside the human health RSA. Therefore, increased COPC loads could result from effects unrelated to the Phase 2 Project. Regardless, both species 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 these food sources. This would serve as a public health service rather than a Phase 2 Project monitoring tool. Use of localized plant (lichen and berries), animal (Arctic ground squirrel), and fish species (Arctic Char, Lake Trout, and Whitefish) provide better monitoring tools for potential ecological (and human health) effects from the Phase 2 Project.

The datasets available for Lake Trout (n = 38), 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 Phase 2 Project area.

Other uncertainties associated with the predicted animal tissue concentrations include the assumption that the diet of caribou, Arctic ground squirrel, and Canada goose 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, geese feed on grass seeds and sprouts, and some aquatic vegetation. 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

Arctic Char, Lake Trout, and Whitefish were collected from creeks, rivers, and lakes within the human health LSA in 2006, 2007, 2009, and 2010 and were analyzed for tissue metal residues. The dataset for Arctic Char and Whitefish tissue metal concentrations is comparatively small (n = 5 and 4, respectively). The dataset may not provide a good estimate of metal concentrations in Arctic Char tissues in the marine portion of the human health LSA. However, because of the use of conservative statistics (95th percentile of fish tissue COPC concentrations) and summed ingestion rates of fish 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 95th 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 95th 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 95th 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 (95th 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, sediment, 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, sediment, 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 Phase 2 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 2015). 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 2015).

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 aluminum, arsenic, chromium, lead, methylmercury, nickel, selenium, and thallium (Table 5.3-19). For adult land users, HQs were greater than 0.2 for arsenic, chromium, methylmercury, and thallium (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 (8.95×10^{-7}) 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 (1.04×10^{-4}), 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 Phase 2 Project site.

The risk from existing conditions is due to naturally-occurring or existing conditions within the human health LSA since the Phase 2 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 Phase 2 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 Phase 2 Project (so that all predictions include existing conditions plus Phase 2 Project), which enables direct comparison of existing conditions and predicted environmental quality to determine incremental changes due to the Phase 2 Project.

5.4 PHASE 2 PROJECT HUMAN HEALTH RISK ASSESSMENT

Many of the features of the Phase 2 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 (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 Phase 2 Project-related HHRA is the same as for the existing conditions HHRA (see Section 5.2); however, predictive modeling is used to determine Phase 2 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 Phase 2 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 Phase 2 Project-related source of contaminants and human receptors.

5.4.1.1 Human Receptors

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 Phase 2 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.

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 Phase 2 Project-related sources of contaminants were identified that could lead to changes in these pathways. There are two main potential sources of Phase 2 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 terrestrial environment due to direct discharges, or 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 Phase 2 Project components or activities. Drinking water could be affected by Phase 2 Project components or activities that affect freshwater. Soil and country foods quality could be affected by Phase 2 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 Phase 2 Project via inhalation. A detailed inventory of Phase 2 Project-related emission sources, points of release and quantities of air contaminants released is provided in the *Phase 2 of the Hope Bay Project: Air Quality Modeling Study* (Volume 4, Appendix V4-2I; ERM 2016b).

Phase 2 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 Phase 2 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 Phase 2 Project-related sources of air pollutants.

Soil

Fugitive dust will arise from several Phase 2 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 Phase 2 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 Phase 2 Project-related sources of effluent to the freshwater environment. The potential effects to freshwater sediment quality from the Phase 2 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 Phase 2 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 Phase 2 Project-related Contaminants of Potential Concern

A description and inventory of the types of materials and chemicals likely to be present at the Phase 2 Project is provided in the Project Description (see Table 4.4-11 in Volume 3, Section 4.4.11). Potential sources of Phase 2 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 Phase 2 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, Section 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 Phase 2 Project atmospheric emissions or discharges.

To select COPCs for evaluation in the Phase 2 Project-related HHRA, the same screening methodology described in Section 5.3.2.3 was used, with one important additional criterion. In order to identify COPCs that occur as a result of Phase 2 Project components or activities, the predicted concentrations were compared to both environmental quality guidelines (as described in Section 5.3.2.3) and baseline concentrations. Only COPCs that had concentrations higher than applicable environmental quality guidelines and higher than baseline concentrations were retained for further evaluation as Phase 2 Project-related COPCs.

The reason for comparing predicted concentrations to baseline concentrations was to exclude COPCs that had concentrations that naturally exceeded environmental quality guidelines, where the concentrations were not notably changed by Phase 2 Project components and activities. For these parameters, although environmental quality guidelines were exceeded, the potential for risk is not associated with Phase 2 Project components or activities and the risks to human health would be equivalent to those described in the existing conditions HHRA in Section 5.3.5.

Contaminants of Potential Concern in Air

To assess effects to human health from changes in air quality due to Phase 2 Project-related emissions, future Phase 2 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 2.5.1 and 2.5.5.3 and ERM (2016b). 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 Phase 2 Project emissions were modeled with the US EPA-approved version of CALPUFF (version 7) 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 Phase 2 Project (Figure 2.4-2 of Volume 4). 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 Phase 2 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 Phase 2 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 Phase 2 Project Year 12 (calendar year 2030) for both the Northern and Southern domain (ERM 2016b). The air quality model results used in the HHRA were for the cumulative Construction phase (i.e., emissions from permitted activities plus Phase 2 construction activities) and cumulative Operational phase (i.e., emissions from permitted activities plus Phase 2 operation activities).

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 (µg/m³)				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	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	19.2	1.79	1.75	145	1.53	1.61	11.7	4.74	1.77	2.09	10.1	1.78	3.74	3.21	2.01	5.21	1.62
	24-hour	-	***150***	-	0.4	5.59	1.05	1.03	24.3	0.872	0.888	2.86	1.60	0.904	1.17	2.53	1.07	1.21	1.35	1.03	1.77	0.96
	Annual	-	***30***	13 [g]	0.4	1.87	0.712	0.712	6.32	0.711	0.712	0.886	0.758	0.713	0.716	0.914	0.713	0.732	0.749	0.733	0.768	0.711
NO_2	1-hour	-	***400***	188 [h]	1.9	251	62.7	60.1	1274	30.9	32.8	201	178	31.0	69.9	197	60.9	147	109	68.0	175	45.2
	24-hour	-	***200***	-	1.9	192	19.1	18.2	333	13.2	14.2	133	63.7	15.0	26.5	124	20.8	28.5	47.2	24.5	78.4	15.4
	Annual	-	***60***	60'	1.9	69.8	3.68	3.65	173	3.67	3.72	15.4	6.89	3.78	3.94	17.5	3.74	5.12	6.33	5.15	7.72	3.66
CO	1-hour	-	-	***14,300***	1,250	2,540	1,575	1,572	29,275	1,564	1,566	1,983	1,748	1,569	1,599	1,980	1,576	1,697	1,635	1,599	1,702	1,567
	8-hour	-	-	***5,500***	143	1,068	445	443	12,401	427	429	633	532	430	452	701	445	480	476	457	520	431
PM_{10}	24-hour	-	-	***50***	6.3	164	13.9	13.8	249	12.7	12.8	27.2	18.7	12.9	14.9	27.0	14.1	16.0	16.3	14.0	19.0	13.4
$PM_{2.5}$	24-hour	28 and 27 (effective in 2020)	***30***	25 [i]	3	31.3	6.75	6.72	96.6	6.51	6.54	11.0	8.13	6.60	6.88	13.3	6.86	7.18	7.66	7.08	8.54	6.56
	Annual	***10*** and 8.8 (effective in 2020)	-	8 [j]	3	13.6	6.16	6.16	32.7	6.16	6.16	6.98	6.39	6.17	6.18	7.16	6.17	6.26	6.36	6.28	6.44	6.16

						Operational Phase																
		Ambient Air Quality Criteria (µg/m³)				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	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	17.5	28.3	115	29.8	1.37	1.44	8.42	3.43	1.55	22.2	7.74	28.9	3.07	2.53	1.69	3.96	1.55
	24-hour	-	***150***	-	0.4	4.50	13.4	62.6	12.7	0.819	0.833	1.61	1.22	0.8	4.33	1.74	10.9	0.979	1.03	0.907	1.19	0.915
	Annual	-	***30***	13 [g]	0.4	1.57	2.27	11.3	1.83	0.709	0.709	0.783	0.731	0.710	0.961	0.804	1.36	0.718	0.730	0.722	0.733	0.718
NO_2	1-hour	-	***400***	188 [h]	1.9	246	348	960	353	20.8	21.9	180	117	24.0	280	179	346	70.5	67.1	44.6	88.9	35.0
	24-hour	-	***200***	-	1.9	170	239	592	238	9.5	10.0	58.5	34.5	10.9	178	67.7	211	16.9	23.1	15.4	34.0	13.4
	Annual	-	***60***	60'	1.9	55.4	53.7	216	44.5	3.50	3.53	7.88	4.85	3.58	17.5	9.40	29.9	4.08	4.90	4.32	5.04	4.13
CO	1-hour	-	-	***14,300***	1,250	2,287	2,869	5,692	2,646	1,534	1,535	1,608	1,572	1,537	2,330	1,629	2,697	1,549	1,556	1,540	1,562	1,535
	8-hour	-	-	***5,500***	143	926	1,464	3,461	1,107	414	414	463	441	414	657	475	1,124	423	426	419	438	419
PM_{10}	24-hour	-	-	***50***	6.3	185	162	428	231	12.6	12.7	23.2	17.9	12.8	71.1	25.0	149	15.4	15.5	13.7	17.8	16.1
$PM_{2.5}$	24-hour	28 and 27 (effective in 2020)	***30***	25 [i]	3	26.7	54.7	256	50.3	6.43	6.47	9.17	7.47	6.50	21.4	10.2	41.5	6.93	7.28	6.81	7.62	6.89
	Annual	***10*** and 8.8 (effective in 2020)	-	8 [j]	3	12.4	15.8	63.6	14.7	6.16	6.16	6.58	6.29	6.17	8.25	6.75	11.6	6.22	6.30	6.24	6.31	6.23

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 (2016b).

[b] CCME (2016c).

[c] Government of Nunavut (2011).

[d] BC MOE (2016).

[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.

Grey shading indicates exceedance of the air quality guidelines.

The model predictions were compared to the Nunavut Air Quality Standards (Government of Nunavut 2011), the federal CAAQSs (CCME 2016b, 2016c), and the BC MOE (2016) 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 2016b, 2016c), and BC MOE (2016) 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 Quarry D camp;
- 24-hour NO_2 concentrations at the Quarry D camp;
- annual NO_2 concentrations at the Doris camp and Quarry D camp;
- 1-hour CO at the Quarry D camp;
- 8-hour CO at the Quarry D camp;
- 24-hour PM_{10} at the Doris camp and the Quarry D camp;
- 24-hour $PM_{2.5}$ at the Doris camp and the Quarry D camp; and
- 24-hour $PM_{2.5}$ at the Doris camp and the Quarry D camp.

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, the Quarry D camp, and a land user hunting and fishing area (depicted as H1 in Figure 5.3-1);
- annual NO_2 concentrations at the Boston Operational camp;
- 24-hour PM_{10} at the Doris camp, the Boston Exploration camp, the Boston Operational camp, the Quarry D camp, a land user fishing area (depicted as F2 in Figure 5.3-1); and a land user hunting and fishing area (depicted as H1 in Figure 5.3-1);
- 24-hour $PM_{2.5}$ at the Boston Exploration camp, the Boston Operational camp, the Quarry D camp, and a land user hunting and fishing area (depicted as H1 in Figure 5.3-1); and
- annual $PM_{2.5}$ at the Doris camp, the Boston Exploration camp, the Boston Operational camp, the Quarry D camp, and a land user hunting and fishing area (depicted as H1 in Figure 5.3-1).

Exceedances of the air quality guidelines for CACs occurred primarily at the worker camp locations, which is a result of the placement of the camps directly on top of emission sources in the air quality model (ERM 2016b). Also, the predicted $PM_{2.5}$ concentrations are elevated because emission factors were not available for $PM_{2.5}$ (such as for mill primary and secondary crushing activities), thus it was conservatively assumed that emission rates of $PM_{2.5}$ were equivalent to PM_{10} (ERM 2016b).

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). The H1 location is just outside of the PDA, as it is only 0.43 km from an unpaved Phase 2 Project road. The F2 location is also just outside of the PDA, as it is only 0.16 km from an unpaved Phase 2 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 location are provided in ERM (2016b). These contour maps show the geographic extent and magnitude of pollutants emitted from Phase 2 with existing permitted activities.

The predicted CAC concentrations did not exceed the air quality guidelines within 3 km of the PDA, with the exception of PM_{10} which was within 13 km of the PDA (Volume 4, Section 2.5.5.3). 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 2.5.5.3). Furthermore, the effects assessment for air quality conducted in Volume 4, Section 2 concluded that the effects to air quality were Not Significant for all Phase 2 Project phases.

The air quality dispersion model has been run assuming limited anthropogenic dust and pollution control (ERM 2016b). 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.

Due to the reasoning outlined above, HQs were not calculated for human receptor locations with exceedances of the air quality guidelines. Rather, air quality will be monitored and mitigated during the Phase 2 Project phases as described in the Air Quality Management Plan (AQMP; Volume 8, Annex 19). 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 Phase 2 Project, thus ensuring certificate conditions are met and minimal environmental impacts occur.

Metal Contaminants of Potential Concern

Phase 2 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 Appendix V3-3A (SRK 2016a). 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 (7.11 µg/m^3) occurred at a fishing area (depicted as F3 on Figure 5.3-1), while the highest annual PM_{10} concentration during the Operational phase (17.6 µg/m^3) occurred at a hunting and fishing area (depicted as H1 on Figure 5.3-1).

Dust at the Doris 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: 22.3 µg/m^3 for both phases;
- Boston Operational camp: 5.48 and 82.3 µg/m^3, respectively; and
- Quarry D camp 55.0 and 40.6 µg/m^3, respectively.

Dust at the Boston Exploration camp is primarily from ore piles and metal concentrations from Boston area ore samples were obtained from Appendix V3-4E (SRK 2016c). The metal concentrations from Boston ore samples (n = 27) were used as the metal concentration to apply to annual PM_{10} for off-duty workers at Boston Exploration camp. At this camp, the highest annual PM_{10} concentration during the Construction phase was 5.48 µg/m^3, while the highest annual PM_{10} concentration during the Operational phase was 22.8 µg/m^3.

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 Phase 2 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 BC guidelines for metals in air, the Phase 2 Project-related metal concentrations bound to PM_{10} (Table 5.4-2) were compared to 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 Phase 2 Project-related metal concentrations bound to PM_{10} (Table 5.4-2) that exceeded the relevant air quality guidelines was arsenic during the Construction and Operational phases at Boston Exploration camp and nickel during the Operational phase at Boston Exploration camp and Boston Operational 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 COPCs identified in air were arsenic and nickel for off-duty workers. Arsenic and nickel will be carried forward as COPCs bound to PM_{10} in the Phase 2 Project-related HHRA for off-duty workers.

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

The pathway through which COPCs may enter soil as a result of Phase 2 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 Phase 2 Project used predicted dustfall levels from the air quality dispersion model (ERM 2016b) and metal concentrations in quarry rock samples, ore, and waste rock samples.

For the purpose of soil quality modeling, in addition to assumptions made in the air dispersion model (ERM 2016b), 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
- the Phase 2 Project-related metal proportions in dust during the Construction and Operational phases is either based on the metal composition of road dust (i.e., quarry rock) or of the materials excavated (i.e., ore and waste rock), depending on the location of the soil sampling site (Table 5.4-3).

The quarry rock metal concentrations (n = 383) were obtained from SRK (2016a); the Madrid South waste rock metal concentrations (n = 258) were obtained from Appendix V3-4D (SRK 2016e); the Madrid North waste rock metal concentrations (n = 344) were obtained from Appendix V3-4C (SRK 2016d); the Boston ore metal concentrations (n = 27) were obtained from SRK (2016c). Doris ore metal concentration data was not available, thus the maximum metal concentration from the other material types (quarry rock, ore, and waste rock piles) was adopted.

Beryllium concentrations in quarry rock, Madrid South waste rock and ore, and Boston waste rock samples were not analyzed; therefore, the median beryllium concentration in Boston ore samples was adopted. Mercury concentrations in quarry rock samples were not analyzed; therefore, the median mercury concentration in Boston ore samples was adopted. Tin concentrations in quarry rock, Madrid South waste rock and ore, and Boston waste rock and ore samples were not analyzed; therefore, the median tin concentration in Madrid North ore samples was adopted.

The metal proportions for the various material types 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 and Operational phases of the Phase 2 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-m^2 to kg-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)

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	-	0.206	0.511	0.647	0.645	0.0263	0.110	0.159	2.39	1.60	1.18
Antimony	-	-	0.5	-	0.000000711	0.00000176	0.00000223	0.00000223	0.00000384	0.0000160	0.000000548	0.00000823	0.00000550	0.00000406
Arsenic	0.01	-	0.067	0.000303	0.00000355	0.00000882	0.0000111	0.0000111	0.00214	0.00891	0.00000274	0.0000412	0.0000275	0.0000203
Barium	-	-	0.5	-	0.0000213	0.0000529	0.0000669	0.0000668	0.0000658	0.000274	0.0000164	0.000247	0.000165	0.000122
Beryllium	-	-	0.002	0.000417	0.00000234	0.00000582	0.00000736	0.00000734	0.00000181	0.00000754	0.00000181	0.0000272	0.0000182	0.0000134
Bismuth	-	-	5	-	0.000000711	0.00000176	0.00000223	0.00000223	0.000000548	0.00000228	0.000000548	0.00000823	0.00000550	0.00000406
Boron	-	-	5	-	0.000142	0.000353	0.000446	0.000445	0.000110	0.000457	0.000110	0.00165	0.00110	0.000813
Cadmium	-	0.005	0.0033	0.000238	0.000000711	0.00000176	0.00000223	0.00000223	0.000000548	0.00000228	0.000000548	0.00000823	0.00000550	0.00000406
Calcium	-	-	-	-	0.227	0.564	0.714	0.712	0.373	1.55	0.175	2.63	1.76	1.30
Chromium	-	-	0.041	-	0.00107	0.00264	0.00334	0.00334	0.000712	0.00297	0.000821	0.0123	0.00825	0.00609
Cobalt	-	-	0.02	-	0.000249	0.000617	0.000780	0.000779	0.000247	0.00103	0.000192	0.00288	0.00193	0.00142
Copper	-	-	1	-	0.000782	0.00194	0.00245	0.00245	0.000466	0.00194	0.000602	0.00906	0.00605	0.00447
Iron	-	-	-	-	0.348	0.864	1.09	1.09	0.356	1.48	0.268	4.03	2.70	1.99
Lead	-	-	-	0.0833	0.00000426	0.0000106	0.0000134	0.0000134	0.0000121	0.0000503	0.00000329	0.0000494	0.0000330	0.0000244
Magnesium	-	-	-	-	0.163	0.406	0.513	0.512	0.175	0.731	0.126	1.89	1.27	0.934
Manganese	0.2	-	0.2	-	0.00661	0.0164	0.0207	0.0207	0.00767	0.0320	0.00509	0.0766	0.0512	0.0378
Mercury	-	-	0.025		0.0000000711	0.000000176	0.000000223	0.000000223	0.0000000548	0.000000228	0.0000000548	0.000000823	0.000000550	0.000000406
Molybdenum	-	-	3	-	0.00000355	0.00000882	0.0000111	0.0000111	0.00000712	0.0000297	0.00000274	0.0000412	0.0000275	0.0000203
Nickel	0.05	0.02	0.059	0.0042	0.000512	0.00127	0.00161	0.00160	0.00110	0.00457	0.000394	0.00593	0.00396	0.00293
Phosphorus	-	-	-	20	0.00156	0.00388	0.00491	0.00490	0.000767	0.00320	0.00120	0.0181	0.0121	0.00894
Potassium	-	-	2	-	0.000711	0.00176	0.00223	0.00223	0.00219	0.00914	0.000548	0.00823	0.00550	0.00406
Selenium	-	-	0.2	-	0.00000355	0.00000882	0.0000111	0.0000111	0.00000438	0.0000183	0.00000274	0.0000412	0.0000275	0.0000203
Silver	-	-	0.01	-	0.000000711	0.00000176	0.00000223	0.00000223	0.00000329	0.0000137	0.000000548	0.00000823	0.00000550	0.00000406
Sodium	-	-	-	-	0.00178	0.00441	0.00557	0.00556	0.00219	0.00914	0.00137	0.0206	0.0138	0.0102
Strontium	-	-	2	-	0.0000995	0.000247	0.000312	0.000312	0.000323	0.00135	0.0000767	0.00115	0.000770	0.000569
Thallium	-	-	0.1	-	0.000000711	0.00000176	0.00000223	0.00000223	0.000000548	0.00000228	0.000000548	0.00000823	0.00000550	0.00000406
Titanium	-	-	5	-	0.0156	0.0388	0.0491	0.0490	0.0000548	0.000228	0.0120	0.181	0.121	0.0894
Uranium	-	0.03	0.2	-	0.000000711	0.00000176	0.00000223	0.00000223	0.000000548	0.00000228	0.000000548	0.00000823	0.00000550	0.00000406
Vanadium	-	-	2	-	0.000711	0.00176	0.00223	0.00223	0.000148	0.000617	0.000548	0.00823	0.00550	0.00406
Zinc	-	-	2	-	0.000419	0.00104	0.00132	0.00131	0.000329	0.00137	0.000323	0.00486	0.00325	0.00240