9.0 ASSESSMENT OF POTENTIAL HEALTH EFFECTS

9.1 Public Health Assessment

9.1.1 Introduction

This section of the Environmental Assessment Certificate (EAC) Application/Environmental Impact Statement (EIS) (hereafter referred to as the EA) has been prepared by Golder Associates Ltd. It addresses the effects of the Proposed BURNCO Aggregate Project (hereafter referred to as the 'Proposed Project') identified in the construction, operation, reclamation and closure phases on valued components (VCs) related to the Public Health assessment.

The assessment of the Proposed Project effects on public health is comprised of a human health risk assessment (the subject of the current section). An assessment of the Proposed Project effects on community health and wellbeing from the perspective of the social indicators of health was not completed for this assessment, as negligible interactions between the Proposed Project and community health VCs or sub-components were identified. A project's effects on community health and wellbeing often stem from population changes within communities due to a project's labour requirements, and behaviour changes associated with change in lifestyle due to project associated in-migration or higher income levels. No Proposed Project-related population change was identified in relation to the construction or operations phases of the Proposed Project. Most of the workforce is expected to be sourced from the existing workforce in communities within daily commuting distance of the Proposed Project, allowing employees to remain part of their home communities. As income associated with the Proposed Project construction and operations will be within the range expected for an experienced workforce, there is not expected to be lifestyle or behavioural changes due to the Proposed Project. As negligible interaction between the Proposed Project and community health and wellbeing was identified, no assessment of community health and wellbeing from the perspective of the social indicators of health was undertaken.

In this section, consideration has been given to mitigation measures proposed to lessen any identified effects to acceptable levels and any residual effects have been characterized.

This section should be read in conjunction with the following technical appendices provided in Volume 4, Part G – Section 22.0:

- Appendix 9.1-A: Baseline Data Collection and Results
- Appendix 9.1-B: Air Screening
- Appendix 9.1-C: Chemical Data Screening for Multimedia Risk Assessment
- Appendix 9.1-D: Soil Deposition Model
- Appendix 9.1-E: Particulate Matter Literature Review

9.1.2 Regulatory and Policy Setting

This section provides a summary of the regulatory and policy setting of the Proposed Project as it relates to the human health risk assessment.

The human health risk assessment for the Proposed Project was undertaken in accordance with applicable provincial and federal legislation. Specifically, the methods used in this risk assessment were based on risk assessment guidance provided by Health Canada (2010, 2012), the British Columbia Ministry of Environment (2008a, 2012), the United States Environmental Protection Agency (USEPA 1989) and other applicable risk assessment and health assessment guidance documents and manuals.

The purpose of the human health risk assessment was to quantify the potential health risks to people from Baseline (present-day), Application (predicted using modelling) case and Cumulative (interactions between Proposed Project-related residual effects and incremental effects of past, present and reasonably foreseeable projects and activities) case environmental quality in the Proposed Project Area to determine any impacts resulting from the Proposed Project. The purpose of the assessment was also to identify whether monitoring will be needed.

9.1.3 Assessment Methodology

This section provides a description of the assessment methodology used in preparing the EA related to the human health risk assessment. Volume 2, Part B - Section 4.0: Assessment Methods of this EA provides for a full description of the overall assessment methodology and scope including: selection of VCs, establishing boundaries, describing existing conditions, identification of Proposed Project VC interactions, identifying mitigation measures, evaluating residual effects and assessing cumulative effects.

The human health risk assessment was comprised of three components:

1) An air quality risk assessment, which evaluated the acute and chronic effects associated with certain airborne or gaseous substances that are only present in air;

2) A particulate matter risk assessment, which evaluated the acute and chronic effects associated with particulate matter (including total suspended particulates) present in air; and

3) A multimedia assessment, which evaluated risk associated with exposure to chemicals that might be present in air, soil, sediment, water and food.

The number of components conducted for the human health risk assessment was dependent upon which environmental media were retained for further evaluation in the risk assessment (i.e., the media for inclusion in the risk assessment were identified by the substances that increase as a result of the Proposed Project and exceed a health-based environmental quality standard or guideline).

The human health risk assessment applied a comparative approach that considered the following cases:

- **Base Case** – The Base Case was defined to include existing conditions. Predictions of health risks associated with the Base Case were presented for any parameter that screened into the human health risk

assessment (i.e., parameters for which the Proposed Project was expected to result in a change to environmental concentrations that people may be exposed to and which exceeded a health-based standard or guideline) to provide context for the risk estimates generated for the Application Case.

- **Application Case** – The Proposed Project reflected the components described in Volume 2, Part B – Section 4.0 which were designed to mitigate the potential negative effects and enhance the potential positive effects wherever possible. The Application Case included the Base Case plus the predicted impact of the Proposed Project. The risks estimated for this case were based on those changes predicted for air quality and water quality, and associated predictions for changes in dust deposition, soil, vegetation, and fish tissue that may result from the Proposed Project.
- **Cumulative Case** – The Cumulative Case includes the assessment of interactions between Proposed Project-related residual effects and incremental effects of past, present and reasonably foreseeable projects and activities. A qualitative assessment of the Cumulative Case was conducted for the public health risk assessment.

Although the overall Environmental Assessment methods (Volume 2, Part B - Section 4.0) have, in general, been applied in the assessment of the effects of the Proposed Project on human health, some modifications and refinements to the methods have been made to accommodate the specific nature of the risk assessment, and include the following elements:

- In contrast to some other disciplines, such as air quality, there is no stand-alone baseline report or baseline assessment for the human health risk assessment. Rather, the baseline data that were collected specifically for this assessment (e.g., soil and vegetation) are presented in Volume 4, Part G – Section 22.0: Appendix 9.1-A. Also, data and information from the other disciplines noted in this section were used as inputs for the human health risk assessment and, therefore, the baseline reports prepared for other disciplines are also relevant to human health risk assessment;
- The identification of direct interactions between the Proposed Project and the changes in environmental quality that could potentially impact human health is not explicitly identified. Rather, the evaluation of Proposed Project-VC interaction focused on identifying linkages where the potential exists for the Proposed Project to affect health through predicted changes to air quality, water quality or other components of the physical environment. These linkages were then assessed to determine the significance of Proposed Project-related effects; and
- Relative to other sections, the human health risk assessment used a slightly different approach to the classification of residual effects and evaluation of significance, because several of the criteria (e.g., geographical extent, duration, frequency and reversibility) were already incorporated into the risk estimates and, therefore, are not independent variables. The evaluation of significance is described in more detail in Section 9.1.8.1.

9.1.3.1 Valued Component Selection and Rationale

This section describes the VCs and measureable indicators identified for this assessment related to the human health risk assessment. The VCs identified reflect issues and guidelines, potential First Nations concerns, issues identified by BC Environmental Assessment Office and Canadian Environmental Assessment Agency, First Nations, other stakeholders, professional judgment and key sensitive resources, species or social and heritage values. People are the VCs for the human health risk assessment. All identified candidate public health VCs were carried forward in the effects assessment (e.g., no public health VCs were excluded from the assessment). Additional details regarding the methods used to select VCs is provided in Part B, Volume 2 – Section 4.2.4.

Human health risk assessment is focused on the protection of people's health (i.e., the assessment endpoint). The human health risk assessment focused on locations where people are known to be present (e.g., communities, First Nations seasonal hunting/harvesting camps and recreational areas) and are in proximity to the Proposed Project site, as it is the health of the people living at these locations that could potentially be impacted by emissions from the Proposed Project.

Assessment indicators represent the key issues of concern with respect to the potential effects of the Proposed Project and were used to evaluate effects on a VC. The indicators used in the human health risk assessment are provided in Table 9.1-1. Measurement indicators represent properties of the environment that, when changed, could result in or contribute to an effect on an assessment endpoint. Indicators may be quantitative or qualitative and either be based on direct measurements of the environment or integration of multiple changes of the environment.

Table 9.1-1: Valued Components and Measurable Indicators: Public Health

Valued Component	Rationale	Indicators
People	Public health issues including changes to water quality, air quality and country foods will be incorporated from across relevant disciplines.	▪ Hazard quotients for non-carcinogens ▪ Incremental lifetime cancer risk for carcinogens ▪ Qualitative literature assessment for particulate matter

9.1.3.2 Assessment Boundaries

9.1.3.2.1 Spatial Boundaries

Effects on human health were evaluated on a regional basis, which includes the local study area (LSA) and regional study area (RSA) (see Table 9.1-2). The spatial boundaries for the human health component was selected to correspond with the related biophysical and social study areas including water quality, air quality, country foods (traditional and non-traditional land and resource use), and noise. The LSA, RSA and specific receptor locations selected for inclusion in the risk assessment are shown in Figure 9.1-1.

Table 9.1-2: Spatial Boundaries: Public Health

Study Area	Description
Local Study Area	The LSA is 20 by 20 km, centered on the Proposed Project. The LSA extends along the barge route corridor, 1 km on either side of the corridor to the edge of the RSA. This is the area within which air quality effects can be predicted or measured with reasonable certainty (Refer to Figure 9.1-1).

Study Area	Description
Regional Study Area	The RSA corresponds to the wider area that was used for the air dispersion modelling domain, approximately 80 by 80 km centered on the Proposed Project. The RSA includes the receptor locations identified in consultation with the Socio-Economic team (Refer to Figure 9.1-1).

Note:
LSA – Local Study Area; RSA – Regional Study Area.

9.1.3.2.2 Temporal Boundaries

Based on the Proposed Project schedule, the temporal boundaries for the human health risk assessment are as follows:

- Project construction – up to 2 years;
- Project operations – 16 years; and
- Project reclamation and closure – on-going during operations and extending 1 year beyond operations.

For a full description of the temporal boundaries of the Proposed Project please refer to Volume 2, Part B – Section 4.0.

The human health risk assessment evaluated both long-term (chronic) and short-term (acute) effects of chemical exposures on human health. For the long-term human health assessment, it was assumed that people lived their whole lives within the RSA (i.e., up to 80 years), rather than only for the length of the Proposed Project. However, the contribution of chemical emissions to existing or natural conditions (e.g., plants and soil) in the region was assumed to occur only for the life of the Proposed Project (i.e., 2 years of construction and 16 years of operations) and that the peak concentrations achieved during this time persist for a person's lifetime. Exposure durations of 24 hours or less were evaluated in the short-term (acute) exposure air quality assessment and in the particulate matter assessment.

Air quality predictions and deposition rates considered in the risk assessment were based on the operating phase in year 12 of the Proposed Project, when emissions were identified as being the highest. As such, the risk estimates provided for the Application Case are reasonable, worst-case estimates of potential effects of the Proposed Project on human health. Risk estimates were not provided for each phase of the Proposed Project (i.e., construction, operations, reclamation and closure). Instead, the risk estimates provided for the Application Case were assumed to apply over the life of the Proposed Project.

9.1.3.2.3 Administrative Boundaries

The Proposed Project is located in BC; therefore, relevant standards and guidance from the BC MoE were applied in the human health risk assessment. Federal health risk assessment guidance from Health Canada was also used, as review of the EA will be conducted by a joint Provincial-Federal process.

9.1.3.2.4 Technical Boundaries

There are no applicable technical boundaries related to the human health risk assessment.

9.1.3.3 Assessment Methods

This section describes the methods for evaluating potential effects of the Proposed Project on the VCs (i.e., people) identified for Public Health. Risk assessment was the primary tool used to characterize the residual effects on Public Health from the Proposed Project. The framework of risk assessment, described in more detail in Section 9.1.3.3, provides a structured and clear approach for evaluating potential adverse effects to receptors (i.e., people) from environmental stressors (e.g., particulate matter in air).

9.1.3.3.1 Describing Existing Conditions

Unlike other technical disciplines, field data were not used to directly measure existing risks to public health, and a stand-alone baseline assessment was not conducted. Instead, existing risks in the Base Case were estimated using the same risk assessment approach and methods used to evaluate risks for the Application Case. Base Case risk estimates are provided in the Residual Effects Analysis (Section 9.1.8) to provide context to the predicted risks for the Application Case.

Data used to characterize existing conditions or to make predictions about Base Case and Application Case conditions included the following:

- Soil and vegetation (berries) data collected for the human health assessment from the Proposed Project Area, which were analyzed for metals. Methods used to collect this information and the sample locations are provided in Volume 4, Part G – Section 22.0: Appendix 9.1-A.
- Air quality predictions for metals, particulate matter (consisting of particulate matter less than 10 microns [PM_{10}] and particulate matter less than 2.5 microns [$PM_{2.5}$]), nitrogen dioxide and sulphur dioxide, are provided in the Air Quality section (Volume 2, Part B - Section 5.7). Specific data used as inputs to the health risk assessment are presented in Volume 4, Part G – Section 22.0: Appendix 9.1-B.
- Surface water quality data and predictions for metals and conventional parameters from the surface water quality assessment as outlined in the Surface Water Resources section (Volume 2, Part B - Section 5.5). Specific data used as inputs to the health risk assessment are presented in Volume 4, Part G – Section 22.0: Appendix 9.1-C.
- Air deposition rates for metals provided in the Air Quality section (Volume 2, Part B - Section 5.7). Derivation of deposition rates were also presented in the Air Quality section (Volume 2, Part B - Section 5.7). Base Case data collection methods and sampling sites for air quality information and the data used to develop the deposition rates are presented in the Air Quality Baseline Report (Volume 4, Part G - Appendix 9.1-D).
- Fish tissue data collected from McNab Creek, which were analyzed for metals. The data used as input to the health assessment are presented in Volume 4, Part G - Appendix 9.1-A along with methods used to collect

this information and the sample locations. The data were used to gain a better understanding of baseline conditions at the site.

- Mussel and crab collected from the Proposed Project Area and a reference area, which were analyzed for metals. Five mussel samples were also analyzed for polycyclic aromatic hydrocarbons. The data were used to gain a better understanding of baseline conditions at the site. Methods used to collect this information and the sample locations are presented in the Baseline in Volume 4, Part G - Appendix (9.1-A).

Additional information on the Base Case data and predictions from other disciplines incorporated into the human health risk assessment are provided in Volume 4, Part G - Appendices 9.1-A to 9.1-D.

9.1.3.3.2 Identifying Project Interactions

For human health, the Proposed Project interactions identified by the other biophysical disciplines (i.e., air quality, water quality) were reviewed to identity whether the potential exists for the Proposed Project to affect human health through predicted changes to air quality, water quality, or other components of the physical environment. The key pathways for consideration in the human health risk assessment were predicted changes to air quality and water quality, and specific Proposed Project interactions have been described in Volume 2, Part B - Section 5.7 (air quality), and Volume 2, Part B - Section 5.5 (water quality) and are summarized below in Table 9.1-3.

Table 9.1-3: Project - Environment Interactions Initially Considered in the HHRA

Project – Environment Interaction	Effects Pathway and Rationale	Is this Scoped Into the HHRA?
Air emissions during operations are a result of fugitive emissions from the mining, material handling and marine vessel exhaust.	The primary mode of human exposure to atmospheric emissions is likely to be via the inhalation pathway.	**YES.** Acute and chronic inhalation assessments are included in the HHRA based on predicted air quality concentrations for the operations phase.
	Exposure could also result from deposition of contaminants on soil, plant surfaces (e.g., berries) and other country foods, and subsequent contact with, or ingestion of these items.	**YES.** Soil deposition modelling was carried out and predicted soil concentrations were compared to screening criteria to determine whether further assessment of multimedia exposure was needed. This assessment included both the construction and operations phases of the Proposed Project.
Surface water changes resulting from fugitive emissions from the mining, material handling and transport.	The primary mode of human exposure to surface water is likely through the ingestion and dermal contact pathways.	**YES**. The highest predicted water concentrations predicted during all phases of the Proposed Project were considered in the HHRA for applicable human health pathways.
	Exposure could also result from changes in surface water quality to changes in fish and shellfish tissue quality, and subsequent ingestion of these items	
Above-water noise during construction or operations	Health Canada recommends the following three specific criteria for assessing the health effects of noise; high annoyance, sleep disturbance and speech intelligibility.	**NO.** The effects of changes to the noise levels as a result of the Proposed Project have been evaluated in Volume 2, Part B - Section 9.2 of the EA.
Freshwater sediment changes resulting from fugitive emissions from the	The primary mode of human exposure to freshwater sediments is likely through the dermal contact pathway.	**NO.** Changes to freshwater sediment quality are not expected to occur as a result of the

Project – Environment Interaction	Effects Pathway and Rationale	Is this Scoped Into the HHRA?
mining of material and handling and transport.		Proposed Project (see Volume 2, Part B - Section 5.5 of this EA)
Disturbance of contaminated marine soils or sediments	Direct and indirect (e.g., through uptake into marine resources) exposures could arise as a result of either changes in the mobility of contaminants.	**NO**. Potential adverse effects from vessel propeller wash on marine water and sediment quality in the Project Area are considered negligible. The effect of vessel propeller wash on sediment is discussed further in Volume 2, Part B - Section 5.1.
Marine discharges during operations	Proposed Project operations have the potential to affect marine water and sediment quality in the vicinity of the Proposed Project.	**NO.** The effects of changes in marine resources from the Proposed Project have been evaluated in Volume 2, Part B - Section 5.2 of the EA.
Visual and light quality	Scenic components of the environment have a value to individuals. Sky glow and light trespass are the parameters used to assess the potential changes in light attributable to the Proposed Project.	**NO.** The effects of changes in visual quality (including changes in light) from the Proposed Project have been evaluated in Volume 2, Part B - Section 7.4 of the EA.
Infrastructure and Community Service	Potential effects on infrastructure and community services includes the demand for services (e.g., health, emergency) and physical infrastructure (e.g., housing and temporary accommodation, water, waste) due to the project and associated availability and affordability of these services and amenities.	**NO.** The effects of changes in infrastructure and community service from the Proposed Project have been evaluated in Volume 2, Part B - Section 7.1 and 7.2 and Section 9.3 of the EA.

9.1.3.3.3 Risk Assessment Framework

Health risks were evaluated based on the existing (i.e., Base Case) and predicted (i.e., Application Case) quality of soil, water and air using a risk assessment framework (Figure 9.1-2). The Base Case scenario provides context for understanding the incremental effects predicted for the Application Case.

Figure 9.1-2 presents the framework for the human health risk assessment. The components of a risk assessment are described in the following sections.

9.1.3.3.3.1 Problem Formulation

The problem formulation is used to develop an understanding of how emissions from the Proposed Project might affect human health. The problem formulation helps to focus the assessment on the chemicals, people and exposure pathways of greatest concern, specifically the following:

- Chemicals of potential concern (COPCs);
- People who are likely to be exposed to COPCs; and
- Exposure pathways that account for the majority of exposure to the chemicals emitted.

9.1.3.3.3.2 Exposure Assessment

The exposure assessment involved characterizing the degree to which VCs were exposed to COPCs through the identified exposure pathways. For people, exposure was calculated for most chemicals as a total daily dose (i.e., amount taken in per day) from the relevant pathways in a multimedia evaluation (e.g., inhalation, ingestion of drinking water and dietary items, direct contact with soil and surface water). Exposure to certain airborne or gaseous substances (e.g., nitrogen dioxide) only occurs via the inhalation pathway, and therefore was calculated as the concentrations of these chemicals in air.

9.1.3.3.3.3 Toxicity Assessment

The toxicity assessment involved the identification of exposure doses that are considered to be without risk of adverse effects or an acceptably low level of risk of adverse effects as determined by an applicable regulatory agency. These exposure doses are referred to as toxicity reference values (TRVs).

For people, toxicity assessment involves determination of the rate of intake of a chemical that can be tolerated either acutely (over time periods less than 24-hour), or over a lifetime without experiencing adverse health effects. The human health risk assessment included consideration of both carcinogenic and non-carcinogenic effects.

9.1.3.3.3.4 Risk Characterization

For the air quality and multimedia assessments, the potential for adverse human health effects were assessed by comparing the estimated exposures (from the Exposure Assessment) with those exposures that were determined to be acceptable (i.e., TRVs from the Toxicity Assessment). The characterization of risk included consideration of uncertainty and conservatism in the risk assessment. The resulting ratio for non-carcinogens is typically termed a hazard quotient (HQ) and determined according to the following equation:

$$HQ = \frac{Predicted\ Dose\ or\ Concentration}{Toxicity\ Reference\ Value}$$

For human health, the incremental lifetime cancer risk (ILCR) was also estimated for COPCs known to be carcinogenic. An ILCR is calculated using the following equation:

$$ILCR = Predicted\ Dose\ or\ Concentration \times Slope\ Factor\ or\ Unit\ Risk$$

An HQ approach is not appropriate for the assessment of health effects from particulate matter exposure because no threshold exists below which there are no changes to health effects. If particulate matter is identified as a COPC based on the results of the problem formulation, a qualitative assessment will be undertaken to assess potential health effects from increased particulate matter concentrations as a result of the Proposed Project. The qualitative assessment will include a literature review of key epidemiological studies focused on human health effects from particulate matter associated with dust rather than combustion sources.

9.1.3.3.3.5 Guidelines and Standards

The environmental quality guidelines and standards used in the human health risk assessment are summarized below by media type.

Surface Water

- *British Columbia Contaminated Site Regulation* (BC CSR), Schedule 6: Generic Numerical Water Standards for Drinking Water and Schedule 10: Generic Numerical Soil and Water Standards for Drinking Water (including amendments to January 31, 2014; BC MoE 2014a);
- Health Canada Guidelines for Canadian Drinking Water Quality (October 2014; Health Canada 2014); and
- US EPA Regional Screening Levels (RSL) for Residential Tapwater (November 2015; USEPA 2015).

Soil

- BC CSR, Schedule 4: Generic Numerical Soil Standards for Residential and Industrial Land Use, Schedule 5: Matrix Numerical Soil Standards for Residential and Industrial Land Use and Schedule 10: Generic Numerical Soil and Water Standards for Residential and Industrial Land Use (including amendments to January 31, 2014; BC MoE 2014a);
- Canadian Council of Ministers of the Environment (CCME), Canadian Soil Quality Guidelines for the Protection of Human Health (CCME 1999a, including updates to 2015); and
- BC MoE, Regional Background Soil Concentrations (BC MoE 2005; 2010). In the absence of BC CSR standards and CCME guidelines, the regional background soil concentrations for the Lower Mainland were used. Regional background concentrations were also used as a secondary screen to determine whether a chemical that exceeded a guideline/standard and increased by greater than 10% should be retained for the risk assessment.

Air

- BC MoE, BC Ambient Air Quality Objectives (BC MoE 2016);
- Agency of Toxic Substances and Disease Registry, Minimal Risk Levels (ATSDR 2016);
- California Office of Environmental Health Hazard Assessment, Acute, 8-hour and Chronic Reference Exposure Levels (Cal OEHHA 2015);
- CCME, National Ambient Air Quality Objectives (NAAQO) (CCME 1999b) and Canadian Ambient Air Quality Standards for fine particulate matter and ozone (CCME 2012);
- Ontario Ministry of the Environment (OMoE), Ambient Air Quality Criteria (OMoE 2012);
- Texas Commission on Environmental Quality (TCEQ), Effects Screening Levels (TCEQ 2015);
- US EPA RSLs for Residential Air (November 2015; USEPA 2015); and
- World Health Organization (WHO), Air Quality Guidelines for Europe (WHO 2000) and Air Quality Guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide, Global update (WHO 2006).

Additional guidance considered in the assessment included:

- British Columbia Drinking Water Protection Act and Drinking Water Protection Regulation;
- Health Canada (2010). Useful Information for Environmental Assessments. Available at http://www.hcsc.gc.ca/ewh-semt/pubs/eval/environ_assess-eval/index-eng.php.
- BC MoE (2009). 2005 British Columbia Emissions Inventory of Criteria Air Contaminants. July 2009. Available at: http://www.bcairquality.ca/reports/2005_emissions_inventory.html
- Metro Vancouver ambient air quality objectives, updated May 15, 2015. Available at http://www.metrovancouver.org/services/air-quality/AirQualityPublications/CurrentAmbientAirQualityObjectives.pdf.

9.1.3.3.4 Evaluation of Residual Effects

Potential Project-related residual effects were characterized as the basis for determining the significance of potential residual adverse effects.

Risk estimates (e.g., HQs) from the human health risk assessment were used to evaluate the Proposed Project-related residual effects. Table 9.1-4 provides general definitions for the potential magnitude of risk associated with HQ and ILCR results. The category names of low, moderate, and high are not intended to convey the overall determinations of risk or environmental significance, which can only be made once the uncertainties and conservatism in the analyses have been evaluated.

Table 9.1-4: Criteria Used to Assess Magnitude of Potential Risk for Human Health

Parameter		Levels of Magnitude of Potential Risk			
		Negligible	Low[2]	Moderate[2]	High[2]
Non-Carcinogenic Substances	Air Quality Assessment	No change from Base Case, below applicable guidelines, or HQ[1] ≤ 1	1< HQ ≤ 5	5 < HQ ≤ 10	HQ > 10
	Multimedia Assessment	No change from Base Case, below applicable guidelines, or HQ ≤ 0.2	0.2 [1]<HQ ≤ 5	5 < HQ ≤ 10	HQ > 10
Carcinogenic Substances		No change from Base Case, below applicable guidelines, or ILCR ≤ 1×10^{-5}	1×10^{-5} <ILCR ≤ 5×10^{-5}	5×10^{-5} <ILCR ≤1×10^{-4}	ILCR > 1×10^{-4}

Notes:
1. In a multimedia assessment, an HQ of 1 is applied as the criterion for negligible risk when all exposure media and pathways, including background dietary intake, are considered (Health Canada 2012). However, because only one pathway was retained in the multimedia assessment (exposure to titanium via swimming; see Section 9.1.5.6) an HQ of 0.2 was used to define negligible risk for titanium exposure. For the air quality assessment, concentrations in air (including contribution from background sources) are compared to screening criteria specific to the inhalation pathway for the purpose of calculating an HQ, and no apportionment is required to account for intake from other media. Therefore an HQ of 1 was considered appropriate as a criterion for negligible risk.
2. Criteria for moderate and high magnitude of potential risk were based on professional judgement.
   ≤ – less than or equal to; < – less than; > – greater than; COPC – chemical of potential concern; HQ – hazard quotient, represents the target ratio of the predicted chemical exposure relative to its health-based benchmarks; ILCR – incremental lifetime cancer risks, additional or extra risk of developing cancer due to exposure to a chemical (from the Proposed Project) incurred over the lifetime of an individual.

For chemicals or locations where risk estimates were above the criterion for negligible risk (e.g., HQ >1 for non-carcinogens), further evaluation was carried out in the form of a magnitude of risk analysis. The magnitude of risk analysis compares the risk estimates from the Base Case and Proposed Project contribution, and identifies sources of conservatism (see example in Table 9.1-5).

Table 9.1-5: Overview of the Magnitude of Risk Evaluation

Analysis Criteria	Discussion
Comparison of peak, 95th and 75th percentile concentrations to air screening criteria	Compare exposure concentrations to the air screening criterion to estimate the magnitude of risk.
Comparison of Application Case to Base Case	For each scenario, identify the magnitude of the estimated risk level for the Base Case compared to the target risk level and compare to the risk estimates above to determine whether the Application Case risks are higher than Base Case risks and by how much.
Frequency of Exceedances	Identify the number of instances that the air screening criterion is exceeded in a given time period (i.e., hourly, daily, yearly).
Conservatism and uncertainty in predictions	Identify the sources of uncertainty related to the predictions. For example, uncertainty related to emission rates and mitigating factors. Indicate whether an overall overestimate, underestimate or reasonable estimate of COPC concentrations was likely.
Conservatism in the toxicity reference values or air screening criteria	Identify the sources of uncertainty in the toxicity reference value.
Potential health effects	Identify the potential health effects associated with the COPC and, if available, the levels at which effects were observed in epidemiological studies.
Magnitude of risk	Provide an overall rating of the magnitude of risk based upon the uncertainties described above (i.e., negligible, low, moderate or high).

Note:
COPC – chemical of potential concern

9.1.3.3.5 Evaluating Significance of Residual Effects

The effects analysis methods for the human health risk assessment were different in some notable ways from those used by other components. For example, the multimedia assessment of potential effects to human health results in the generation of risk factors that inherently consider the geographic extent, duration, and frequency of the predicted changes to the environment that may result from Proposed Project activities. As such, these attributes cannot be used to determine environmental significance, as they can with other components.

Instead, environmental significance for human health is evaluated based on:

1) The potential magnitude of risk, as indicated by the HQ and ILCR results, considering the residual effects criteria in Table 9.1-4, as well as the considerations and discussions applied to assessing magnitude of risks in Section 9.1.3.3.3.4; and

2) The degree of conservatism and uncertainty in the analysis.

Note that HQs or ILCRs by themselves do not fully reflect the potential for harm, because the magnitude of any HQ or ILCR calculation is a function of the exposure and effects assessments, each of which depends on the realism or conservatism applied during the modelling procedure. Together, potential magnitude and conservatism (i.e., includes qualitative assessment of likelihood of risk) were used to determine overall risk, which, in turn, is used to evaluate environmental significance. The second (conservatism and uncertainty) component of the above assessment of environmental significance was defined based on a review of the assumptions used to generate the risk predictions and the conservatism incorporated therein, as outlined in the magnitude of risk tables and the prediction confidence and uncertainty discussed in Section 9.1.6.

As noted above some of the criteria used to determine significance in other sections of the environmental assessment have limited or no application to human health risk assessment, and as described below:

- **Direction** - indicates whether an effect is considered negative (i.e., less favourable) or positive (i.e., beneficial). Potential adverse health effects as the result of exposure to COPCs are considered to be negative effects;

- **Geographic extent** - refers to the area affected and is categorised into two scales, local and regional. Local effects are those confined to the communities in the LSA. Regional effects include the LSA but do not extend beyond the RSA. Receptor locations are identified within the LSA and RSA and are assessed in the human health risk assessment. As a result, because the geographic locations are set and risk estimates are calculated for each of these locations. As a result, geographic extent is fixed in the risk assessment and cannot be used to determine significance of residual effect;

- **Duration** - is defined as the amount of time from the beginning of an effect to when the effect on a VC has ended or dissipated to the point of not being detectable and is expressed relative to project phases. Exposure duration is not an independent variable in the human health risk assessment as it is necessary to assume an exposure duration in order to calculate an estimate of a daily exposure dose resulting from chronic exposure to the COPCs. As a result, duration cannot be used to determine significance of residual effect;

- **Frequency** - refers to number of times an effect is expected to occur over a given period. For the acute and chronic air quality and particulate matter assessments, the frequency of exceedances of a screening criterion is incorporated into the magnitude of risk ranking. For the human health multimedia assessment, the frequency of exposure is not an independent variable as it is necessary to assume a particular exposure frequency to calculate an estimate of a daily exposure dose in accordance with risk assessment guidance, resulting from chronic exposure to the COPCs. As a result, frequency cannot be used to determine significance of residual effect for the multimedia assessment;

- **Reversibility** - is the probability and time required to return to a state that is similar to baseline or comparable to similar environments not affected by the project. The human health risk assessment does not include an assessment of reversibility of potential health effects and this not something that can be determined for people; and

- **Likelihood** - of the predicted project effects occurring is high if the project proceeds. An evaluation of likelihood is incorporated into the magnitude of risk ranking.

Potential adverse residual effects on VCs were characterized as **significant**, **not significant**, or **negligible** (and not significant), defined as follows:

- **Negligible-Not Significant** residual effects were either not measurable, within the range of natural variability, or so small they may be safely disregarded. They do not warrant further consideration and are not carried forward into a cumulative effects assessment.
- Residual effects may be characterized as **not significant** if they are determined to be measurable but not likely to result in substantial changes to the viability of the VC (i.e., the ability of the population, ecosystem or community to work and function over time within the defined spatial and temporal boundary).
- Residual effects may be characterized as **significant** if there is a reasonable expectation that the effect of the Proposed Project would:
  - Exceed established environmental standards, guidelines, or objectives;
  - Be beyond the natural variability of the environmental or social conditions; and/or
  - Affect the viability of the VC (i.e., the ability of the community to work and function over time within the defined spatial and temporal boundary).

Non-negligible residual adverse effects (i.e., significant and non-significant) will be considered for inclusion in a cumulative effects assessment.

9.1.3.3.6 Level of Confidence

An inherent uncertainty is associated with risk assessment predictions. The magnitudes of the uncertainties are in large part a function of the quality, quantity, and variability of available data. When information is uncertain, it is standard practice in a risk assessment to make assumptions that are biased towards safety (i.e., conservative assumptions that tend to overestimate exposure and the potential for adverse effects). The conservatism employed in the human health risk assessment also builds on the conservatism inherent in the predictions of the air and water quality assessments that serve as primary inputs to the risk assessment. Uncertainty was discussed on a substance by substance basis in the assessment of potential residual effects.

The overall level of confidence was characterized for each predicted effect based on the underlying uncertainty identified throughout the assessment. The level of confidence associated with the significance determination was classified, based on professional judgement, as either low, moderate or high confidence.

9.1.4 Traditional Ecological and Community Knowledge Incorporation

TEK/CK information was gathered from a Project-specific study undertaken by *Sḵwx̱wú7mesh* (Squamish Nation) and from publicly-available sources.

TEK/CK sources were reviewed for information that could contribute to an understanding of country foods (traditional and non-traditional land and resource use) harvested by Aboriginal Groups. The main sources of this information include:

- Occupation and Use Study (OUS) undertaken by Skwxwú7mesh (Traditions 2015 a,b)
- An expert report produced on behalf of Tsleil-Waututh Nation for another project (Morin 2015)
- Regulatory documents for other projects in close proximity to the Proposed Project Area (e.g., Eagle Mountain – WGP 2015 a,b; PMV 2015; WLNG 2015).

TEK/CK sources available at the time of writing provided no specific information on harvest locations, abundance or quality of country foods, or other environmental knowledge regarding country foods harvested in the RSA. Following is a general discussion of Aboriginal Groups' harvesting of marine resources within Howe Sound.

Ingestion of fish from McNab Creek, ingestion of game meat and ingestion of plants were included as potential exposure pathways considered for the multimedia risk assessment. S*kwxwú7mesh* Nation reports harvesting the following fish species in McNab Creek: all five species of salmon, steelhead and Dolly Varden char. Ungulates, particularly elk, are the primary species of game meat harvested by S*kwxwú7mesh* Nation in the NcNab River Valley, traditionally and currently (Traditions 2015 a,b). Tsleil-Waututh Nation also reports harvesting in Howe Sound, but not specifically at McNab Creek (WLNG 2015). Both S*kwxwú7mesh* Nation and Tsleil-Waututh Nation report harvesting plants in Howe Sound. Edible plants that S*kwxwú7mesh* report harvesting include various berry and fruit species, and edible roots, such as skunk cabbage, blue camas, chocolate lily, bracken fern, licorice fern, wild carrot, arrow-head, and wild onion (Kennedy and Bouchard 1976b in Millennia 1997). Section 9.1.3.3.2 Identifying Project Interactions provides a summary of how potential exposure pathways were scoped in the human health risk assessment.

For a full summary of Aboriginal Group use of lands and resources for traditional purposes and occupancy of Howe Sound refer to Part C of this Application. Details regarding hunting and fishing for non-traditional purposes are summarized in Volume 2, Part B - Section 7.3: Non-Traditional Land and Resource Use of this EA.

9.1.5 Risk Assessment Results

The human health risk assessment consisted of the following three components:

1) An acute and chronic air quality risk assessment;
2) An acute and chronic particulate matter risk assessment; and
3) A multimedia risk assessment.

The air quality risk assessment evaluated exposure to substances that were emitted to air, and addressed human health risks due to short-term or acute exposure and long-term or chronic exposure.

The particulate matter risk assessment evaluated exposure to particulate matter (including total suspended particulates) in air, and addressed human health risks due to short-term or acute and long-term or chronic exposure.

The multimedia risk assessment considered risks to human health posed by chemical concentrations and/or chemical changes in air, water, soil, sediment, and food, and addressed human health risks due to long-term exposure.

The following section provides the results of the problem formulation, exposure assessment, and toxicity assessment. Residual effects (i.e., risk characterization results) are presented in Section 9.1.8.

9.1.5.1 Air Quality Risk Assessment

The objective of the acute inhalation assessment was to evaluate chemicals potentially emitted from the Proposed Project that may pose an adverse health effect following short-term or acute exposure duration (e.g., 1-hour or 24-hour) and long-term or chronic exposure duration to human receptors.

9.1.5.1.1 Receptor Selection

Effects on human health were evaluated on a regional basis. Receptor locations included in the human health inhalation risk assessment are summarized below in Table 9.1-6 and Figure 9.1-2.

Table 9.1-6: Human Health Receptor Locations

Number	Description	Type
1	Squamish	Community residences
2	Porteau Cove	Recreational area
3	Bowen Island	Community residences
4	Lions Bay	Community residences
5	Langdale	Community residences
6	Horseshoe Bay	Community residences
7	New Brighton	Community residences
8	Britannia Beach	Community residences
9	Furry Creek	Community residences
10	Gibsons	Community residences
11	Ch'iyakmesh	First Nations residences
12	First Nations Cultural Site	First Nations residences
14	Potlach Creek	First Nations residences
15	KWUM KWUM	First Nations residences
16	Tetrahedron Park	Recreational area
17	Anvil Island	Community residences
18	Ekin's Point	Community residences
19	Kaikalahun	First Nations residences

Number	Description	Type
20	McNab Creek Strata	Community residences
21	Camp Artaban	Recreational area
22	Camp Latona	Recreational area
23	Residence on Gamier Island	Community residence

In addition to the receptor locations listed above, the short-term air quality assessment also considered visitors that may spend short amounts of time at a hypothetical “worst-case” location outside the Proposed Project Area. The hypothetical “worst case” location did not overlap with any of the receptor locations and therefore, use or access by the public is considered to be on an infrequent basis. This location is referred to as the Maximum Point of Impingement (MPOI).

The air quality assessment evaluated potential risks to people of various ages (infants, toddlers, children, teens and adults) who may visit the locations identified above and may be exposed to COPCs resulting from the Application Case of the Proposed Project.

Exposure Pathways

The acute and chronic inhalation exposure pathways were evaluated for the air quality risk assessment.

9.1.5.1.2 Chemical of Potential Concern Screening

For each constituent, 1-hour, 24-hour and annual concentrations were predicted for the receptor locations identified above in Table 9.1-6. Predicted concentrations were compared to the most conservative (i.e., lowest) of available 1-hour, 24-hour, and chronic health-based screening criteria, obtained from the following agencies:

- BC MoE;
- CCME;
- ATSDR;
- US EPA NAAQS;
- US EPA RSLs (chronic inhalation assessment only); and
- WHO.

The lowest health-based screening criterion with supporting information was generally selected for use in the screening process. Consideration was also given to relevant test species (i.e., human data versus animal data), study endpoint, quality and date of the study.

Where a health-based screening criterion was not available from the agencies listed above, available health-based criteria from the following agencies were used:

- OMoE;
- Cal OEHHA; and
- TCEQ.

The available 1-hour, 24-hour and chronic health-based screening criteria and the basis of these criteria are presented in Volume 4, Part G – Section 22.0: Appendix 9.1-B.

For the chronic air quality assessment, risk levels for which the screening levels/guidelines were derived were standardized to risk levels considered acceptable by Health Canada (2012), and the BC MoE (2014a). For non-carcinogens, this involved adjusting to a HQ of 1.0, and for carcinogens this involved adjusting to a risk level of 1×10^{-5} (i.e., one in 100,000). Further information on the approach used to develop the screening levels/guidelines/objectives for each of the agencies is provided in Volume 4, Part G – Section 22.0: Appendix 9.1-B.

Comparison of Predicted Maximum Concentrations to Acute Screening Criteria

Chemical concentrations based on 1-hour and 24-hour averaging periods were predicted for the selected receptor locations during the lifetime of the Proposed Project. The predicted maximum 1-hour and 24-hour concentrations of chemicals in air were compared to selected acute screening criteria and Base Case concentrations to determine whether further assessment was required. If the predicted maximum concentrations were greater than the selected screening criteria and the percent change from Base Case was greater than 10% then the chemical was retained as a COPC and considered further in the acute inhalation assessment.

Predicted maximum 1-hour concentrations were compared to the selected screening criteria in Volume 4, Part G – Section 22.0: Appendix 9.1-B (Table 9.1-B-3) of this EA, while maximum 24-hour concentrations were compared to the selected thresholds in Volume 4, Part G – Section 22.0: Appendix 9.1-B (Table 9.1-B-4) of this EA. Based on the screening process, exceedances of the 1-hour thresholds were predicted for aluminum and iron, and exceedances of the 24-hour screening criteria were predicted for iron and manganese at the MPOI. A summary of the COPCs retained for the acute inhalation assessment is presented in Table 9.1-7.

Table 9.1-7: Chemicals of Potential Concern Identified in the Short and Long Term Inhalation Assessment and Receptor Location

Chemical of Potential Concern	Application Case (Receptor Location)
1-Hour	
Aluminum	√ (MPOI only)
Iron	√ (MPOI only)
24-Hour	
Iron	√ (MPOI only)
Manganese	√ (MPOI only)
Annual	
None	NA

Notes:

√ = identified as a chemical of potential concern; MPOI – maximum point of impingement; NA – not applicable.

Comparison of Predicted Maximum Concentrations to Chronic Screening Criteria

Chemical concentrations based on annual averaging periods were predicted for the selected receptor locations during the lifetime of the Proposed Project. The predicted maximum annual concentrations of chemical in air were compared to selected chronic screening criteria and Base Case concentrations to determine whether further assessment was required. If the predicted maximum concentrations were greater than the selected screening criteria and the percent change from Base Case was greater than 10% then the chemical was retained as a COPC and considered for further in the acute inhalation risk assessment.

Predicted maximum annual concentrations were compared to the selected screening criteria in Volume 4, Part G – Section 22.0: Appendix 9.1-B (Table 9.1-B-6). Based on the screening process, no COPCs were retained for the chronic inhalation risk assessment.

9.1.5.2 Short Term (Acute) Inhalation Assessment

9.1.5.2.1 Toxicity Assessment

Toxicity assessment involved the classification of the toxic effects of chemicals and the estimation of the amounts of chemicals that can be received by an organism without adverse health effects. For short-term (acute) human inhalation exposures assessed in the air quality assessment, the toxicity assessment involved identification of health-based regulatory exposure limits or toxicity benchmarks consistent with the exposure averaging time for the evaluation of acute risks.

The short-term inhalation criteria used in the risk characterization were selected as outlined in Section 9.1.4 above. The toxicological basis of the selected screening criteria is presented in Volume 4, Part G – Section 22.0: Appendix 9.1-B.

9.1.5.2.2 Exposure Assessment

The exposure assessment is the process of estimating the exposure of a person to a substance through a specific exposure scenario. Short-term exposures were assessed for 1-hour and 24-hour averaging times, for the receptor locations identified in Table 9.1-6, and included both recreational and residential areas. Maximum predicted 1-hour and 24-hour ground level air concentrations during construction and operations (Application Case) were compared to acute screening criteria, as described in Section 9.1.5.5.2.

9.1.5.3 Long-Term (Chronic) Inhalation Assessment

No COPCs were identified for the long-term inhalation assessment.

9.1.5.4 Particulate Matter Assessment

This section includes the methods used to evaluate what effects emissions from existing and approved developments and the Proposed Project could have on short-term (acute) and long-term (chronic) exposure and human health from particulate matter.

9.1.5.4.1 Chemical of Potential Concern Screening

For both PM_{10} and $PM_{2.5}$, 24-hour and annual concentrations were predicted for the receptor locations identified above in Table 9.1-6. Predicted concentrations were compared to the most conservative (i.e., lowest) of available 24-hour and chronic health-based criteria, preferentially obtained from the following agencies:

- BC MoE;
- CCME;
- US EPA (chronic inhalation assessment only); and
- WHO.

The World Health Organization (WHO) states that the risk for various health outcomes increases with exposure to particulate matter and that a threshold below which no adverse effects are expected is not likely to exist (WHO 2006). Given that a threshold has not been identified, WHO (2006) suggest that setting a standard needs to be aimed at achieving the lowest particulate matter concentration possible given the local context and priorities of the region.

The available 24-hour and chronic health-based criteria and the basis of these criteria are presented in Volume 4, Part G – Section 22.0: Appendix 9.1-B.

Predicted maximum Application Case 24-hour and annual concentrations were compared to the selected 24-hour and chronic criteria, respectively (Volume 4, Part G – Section 22.0: Appendix 9.1-B).

A parameter was retained for further evaluation if the predicted maximum Application Case concentration (i.e., maximum concentration during Proposed Project operations, at any of the selected receptor locations) was greater than the selected screening level and increased by greater than 10% above predicted Base Case concentrations. A parameter that was retained for further assessment was classified as a COPC and was evaluated at each selected receptor location.

Based on the screening results presented in Volume 4, Part G – Section 22.0: Appendix 9.1-B, the COPCs retained for the particulate matter assessment are presented below in Table 9.1-8.

Table 9.1-8: Particulate Matter Chemicals of Potential Concern Retained for Further Assessment

Chemical of Potential Concern	Application Case (Operations)
24-Hour	
PM_{10}	√ (MPOI only)
$PM_{2.5}$	√ (MPOI only)
Annual	
$PM_{2.5}$	√ All locations evaluated

Notes:

√ = identified as a chemical of potential concern ; MPOI – maximum point of impingement; PM_{10} – particulate matter less than 10 microns; $PM_{2.5}$ – particulate matter less than 2.5 microns.

For the long-term inhalation exposure, although $PM_{2.5}$ did not increase by more than 10% above background and concentrations at all receptor locations were below the regulatory air quality objective of 8 µg/m^3, $PM_{2.5}$ was conservatively retained as a COPC for the following reasons:

1) A threshold below which no adverse effects are expected is not likely to exist for $PM_{2.5}$ (WHO 2006). The World Health Organization (WHO) states that the risk for various health outcomes increases with exposure and that a threshold below which no adverse effects are expected is not likely to exist (WHO 2006). Given that a threshold has not been identified, WHO (2006) suggest that setting a standard needs to be aimed at achieving the lowest particulate matter concentration possible given the local context and priorities of the region.

2) Concentrations of $PM_{2.5}$ exceeded the BC MoE Planning Goal of 6 µg/m^3 (although not a regulatory objective) at all receptor locations assessed (Volume 4, Part G – Section 22.0: Table 9.1-B-6 in Appendix 9.1-B)

3) The maximum predicted increase was close to 10% at the McNab Creek Strata residence (Volume 4, Part G – Section 22.0: Table 9.1-B-6 in Appendix 9.1-B

9.1.5.5 Particulate Matter Assessment

9.1.5.5.1 Toxicity Assessment

Toxicity assessment involved the classification of the toxic effects of chemicals and the estimation of the amounts of chemicals that can be received by an organism without adverse health effects. For short-term (acute) and long-term (chronic) human inhalation exposures (assessed in the air quality assessment), toxicity assessment involved identification of health-based regulatory exposure limits or toxicity benchmarks consistent with the exposure averaging time for the evaluation of acute and chronic risks.

The short-term and long-term inhalation criteria used in the risk characterization were selected as outlined in Section 9.1.4 above. The toxicological basis of the selected criteria are presented in Volume 4, Part G – Section 22.0: Appendix 9.1-B.

9.1.5.5.2 Exposure Assessment

There is no prescribed method for assessing health risks of particulate matter, nor does the assessment of particulate matter lend itself to risk assessment methods in the same manner as other parameters. For many years, particulate matter in the air has been understood to be a serious health concern (Shwarze 2006). Many epidemiological studies have been conducted that identify the relationship between particulate matter and adverse health outcomes (WHO 2006). The studies have shown that there is a broad range of health effects, but predominantly there is a relationship between particulate matter and mortality and hospitalizations for respiratory and cardiac health effects (WHO 2006). However, there remains uncertainty regarding the causal linkage between particulate matter and health effects and in particular how varying compositions of particulate matter contribute to health effects (Shwarze 2006; Rohr 2012). An increasing number of health effects have been linked to airborne particulate matter and research has shown that there are risks to health at levels already found in many cities across the world (WHO 2006). Current research generally suggests that the composition of particulate matter would be a better predictor of adverse health effects than the mass of particulate matter (Stanek et al. 2011). Particulate matter is comprised of a mixture of different chemicals and biological components and as such, differs from individual chemicals (WHO 2006). In addition, particulate matter is considered to be a stressor that can cause negative health outcomes at any exposure level and therefore lacks a threshold that can act as a guideline (WHO 2006). Therefore, for particulate matter the guideline values are concentrations that correspond to a tolerable level of risk and are not fully protective of public health (WHO 2006).

The effects on human health as a result of exposure to particulate matter due to emissions from existing and approved developments and the Proposed Project were evaluated qualitatively for $PM_{2.5}$ and PM_{10}. The following approach was used as part of the qualitative assessment for the short-term inhalation exposure to particulate matter:

- Comparison of the maximum, 95th and 75th percentile air concentrations to acute exposure limits to provide additional context to predicted risk;
- Comparison of Application Case concentrations to Base Case concentrations;
- Comparison of the number of exceedances predicted to occur in a year for the Application Case and Proposed Project contribution;
- Evaluation of the conservatism in the air modelling approach used to predict future concentrations;
- Evaluation of the conservatism in the acute exposure limits for that parameter;
- Evaluation of the potential acute health effects that may occur at the predicted concentrations; and
- A review of relevant literature which discusses the effects of particulate matter on human health.

For the long-term particulate matter assessment, only one year of data were modelled. Therefore, there is only one single annual concentration for each of the receptor location assessed and summary statistics (95th and 75th percentile air concentrations and frequency of exceedance of chronic screening criterion) could not be calculated.

The remaining assessment components listed above for the acute particulate matter assessment were also conducted for the chronic particulate matter assessment.

The results of the particulate matter assessment are provided in Section 9.1.6.1.2 and the literature review is presented in Volume 4, Part G – Section 22.0: Appendix 9.1-E.

9.1.5.6 Multimedia Assessment

9.1.5.6.1 Receptor Selection

Human health receptors identified for the multimedia risk assessment included community residents, First Nations residents, and recreational users. For the purposes of the multimedia assessment, it was assumed that receptors may access the LSA and the RSA for recreational purposes including fishing, hunting and harvesting plants. Details regarding the parks and protected areas, as well as hunting and fishing within the RSA, are summarized in Volume 2, Part B - Section 7.3: Non-Traditional Land and Resource Use of this EA.

The receptor locations selected for the human health risk assessment are summarized in Table 9.1-6, and shown in Figure 9.1-1. Human health receptor locations were selected within the RSA based on identified land uses (e.g., camping sites, communities, identified First Nations residential and cultural areas) and proximity to the Proposed Project. Land uses (including existing public land use) were identified during the assessment of Non-Traditional Land and Resource Use provided in Volume 2, Part B –Section 7.3. It was assumed that recreational users may be present in these areas on a seasonal basis. Members of nearby First Nations communities may use areas within the RSA for fishing, hunting and harvesting plants. It is not anticipated that the Proposed Project Area will be fenced, so it is possible that members of the general public will access the Proposed Project site during site preparation, operations or decommissioning. It was conservatively assumed that McNab Strata residents may use the pit lake for swimming during operations and closure. In addition, the McNab Creek Strata holds two licenses for use of McNab Creek, one of which is for use as a potable water source. As such, ingestion of surface water was considered in this assessment.

Employees, contractors and visitors working for the Proposed Project were not included as receptors in the risk assessment because worker health and safety is covered under company and occupational health and safety plans and through monitoring that is conducted as needed. It is understood that the proponent must also comply with Canadian labour and occupational health and safety regulations and the Health and Safety Reclamation Code for Mines in BC (BC Ministry of Energy, Mines and Petroleum Resources 2008).

9.1.5.6.2 Chemical of Potential Concern Screening

The screening approach for the multimedia assessment focused on those media where chemical concentrations could change as a result of the Proposed Project. Changes to chemical concentrations in surface water (potentially used for drinking water or swimming), and soil could occur as a result of the Proposed Project. Changes to chemical concentrations in game meat and vegetation as a result of the Proposed Project are possible; however, there are no human health based screening criteria available for game meat and plants. In the absence of screening criteria for these media, changes to soil quality as the result of aerial deposition was used a surrogate to determine whether there would be potential for changes in vegetation and game meat concentrations. Fish

could also potentially be impacted by the Proposed Project; however, changes to water quality would be necessary for this to occur. Therefore, soil and surface water were screened to identify COPCs for the multimedia assessment. Air quality data were screened against chronic criteria as part of the air quality assessment (Section 9.1.4).

The chemical screening process used to determine the COPCs in soil and surface water, as discussed in the following subsections.

Chemical Screening Process for Chemicals in Soil

The baseline soil quality for the Proposed Project is presented in Volume 4, Part G – Section 22.0: Appendix 9.1-A of this EA. Soil data were collected during the August 2013 field program at nine sample locations and analyzed for chemical content; these soil concentrations represent baseline soil quality. Future concentrations in soil as the result of the Proposed Project were predicted based on annual wet and dry deposition rates. The maximum annual wet and dry deposition rates for metals were predicted at each of the receptor locations shown in Figure 9.1-1. There are no regulatory guidelines or risk-based concentrations that can be directly compared to deposition rates. Thus, the deposition rates were used to predict surface soil concentrations which were then compared to soil quality guidelines.

Incremental soil concentrations were calculated using protocols provided in the Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (USEPA 2005). A detailed description is provided in Volume 4, Part G – Section 22.0: Appendix 9.1-D. The calculated incremental soil concentrations were added to the maximum measured baseline soil concentrations to predict Base and Application Case soil concentrations.

Predicted soil concentrations were compared to Base Case concentrations to determine whether there was a 10% or greater increase in the Application Case. Comparison to an increase of 10% above existing concentrations was considered to represent a conservative evaluation of whether a measurable Proposed Project-related impact to soil was likely to occur. Given spatial and temporal variability in soil concentrations, variability in field sampling and laboratory analysis and the conservatism applied in the predictive deposition modelling, any predicted increase of less than 10% above existing concentrations was considered unlikely to reflect a change in environmental quality as a result of the Proposed Project. Predicted soil concentrations were also compared to the health-based guidelines outlined above in Section 9.1.3 and in Volume 4, Part G – Section 22.0: Appendix 9.1-C. As a secondary screening, any parameter that exceeded the selected soil screening criterion was also compared to regional background soil concentrations, available from the BC MoE (2005, 2010).

Overall, an exceedance of an environmental quality screening value does not necessarily indicate an adverse human health effect; screening against these guidelines provides an indication that further assessment of potential human health effects may be required. Chemicals in soil were retained as COPCs if the predicted soil concentrations: (1) exceeded the Base Case concentrations by more than 10%, (2) exceeded a soil screening level, and (3) was above regional background concentrations.

The comparison of predicted metal soil concentrations to Base Case concentrations and to the selected soil environmental quality guidelines are provided in Volume 4, Part G – Section 22.0: Appendix 9.1-C (Table 9.1-C-2). The predicted metal concentrations (incremental + existing) were less than the applicable environmental soil quality guidelines, with the exception of arsenic. However, soil concentrations of arsenic were not predicted to

increase by more than 10% above Base Case concentrations, and were also below the BC MoE regional background concentrations. Therefore, no COPCs in soil were retained for the multimedia assessment.

Chemical Screening Process for Chemicals in Surface Water

Surface water concentrations were predicted using a conservative modeling scenario (based on 95th percentile or maximum concentrations) to establish an upper bound estimate for the Application Case. Detailed methods and results of the water quality modelling are presented in Volume 2, Part B - Section 5.5. Predicted Application Case surface water concentrations were compared to Base Case concentrations (95th percentile of the measured baseline concentrations). As with soil, predicted surface water concentrations were compared to Base Case predictions to determine whether there was a 10% or greater increase from existing concentrations to determine whether a measurable Proposed Project-related impact to water was likely to occur. Predicted surface water concentrations were compared to the applicable drinking water guidelines outlined in Section 9.1.3.3.3.5. Chemicals in surface water were retained as COPCs if the predicted water concentrations exceeded the Base Case concentrations by greater than 10% and also exceeded an environmental quality guideline for protection of drinking water.

The comparison of predicted Application Case concentrations to Base Case and environmental quality guidelines for drinking water is provided in Volume 4, Part G – Section 22.0: Appendix 9.1-C. Concentrations were predicted for the pit lake, two locations on McNab Creek (MCF-1 and MCF-7) and two other locations (MCF-6 and MCF-12). Figure 9.1-3 provides the locations where chemical concentrations were predicted. Metal concentrations were either predicted to increase by less than 10% from Base Case or were less than the health-based drinking water guidelines for all parameters with screening criteria. Ammonia, hardness, alkalinity and titanium were predicted to increase by greater than 10% in at least one location; however, no screening criteria were available for these parameters. Further detail is provided below:

- Ammonia, which does not have a screening guideline, was predicted to increase by greater than 10% above Base Case at the pit lake, MCF-6 and MCF-12. Ammonia is produced in the body and is readily metabolized by people (Health Canada 2014). At 1.5 mg/L, ammonia may pose odour issues and at 35 mg/L, ammonia in water may have a distinct taste. However, ammonia does not cause adverse human health effects at the concentrations noted above (WHO 2011). The predicted surface water concentrations of ammonia are well below these levels (maximum predicted concentration - 0.035 mg/L), therefore ammonia was not retained for the multimedia assessment.

- Hardness does not have a screening guideline and was predicted to increase by greater than 10% above the Base Case at the pit lake, MCF-6 and MCF-12. Similarly, alkalinity which does not have a screening guideline was predicted to increase by greater than 10% above the Base Case at MCF-1. Hardness and alkalinity are not commonly assessed in risk assessments. Human and animal toxicity data are lacking for hardness and alkalinity. Health Canada (1979) indicates that a maximum acceptable level has not been set for hardness because public acceptance of hardness varies considerably. Health Canada (1979) state that water quality is considered poor when hardness reaches 200 mg/L and maximum hardness concentrations in predicted water quality are well below this maximum acceptable level, ranging from 3.8 to 58 mg/L. Hardness was therefore not retained for further assessment in this risk assessment. Alkalinity is an index of the capacity of water to buffer changes in pH. In Canadian surface waters, alkalinity is closely linked to hardness due to the

presence of carbonates and bicarbonates in the water (Health Canada 1979) and therefore, similarly to hardness, was not retained for further assessment in this risk assessment.

- An environmental quality guideline for protection of drinking water was not available for titanium and the surface water concentrations were predicted to increase by 11% over Base Case in the pit lake during year 1 of the operations phase. Titanium was not predicted to increase by more than 10% above Base Case at the locations within McNab Creek, or in the closure/post-closure phase. Therefore, titanium was retained as a surface water COPC for the pit lake only.

9.1.5.6.3 Exposure Pathways

The objective of the exposure pathway screening process was to identify potential routes by which people could be exposed to chemicals and the relative significance of these pathways to total exposure. A chemical represents a potential health risk only if people can come in contact with the chemical through an exposure pathway at a concentration that could potentially lead to adverse effects. If there is no pathway for a receptor to come in contact with the chemical, then there cannot be a risk, regardless of the chemical concentration. Potential exposure pathways considered for the multimedia assessment are summarized in Table 9.1-9.

Table 9.1-9: Exposure Pathways Considered in the Multimedia Risk Assessment

Exposure Pathway	Description
Ingestion of potable water	People may be exposed to COPCs in drinking water. Municipally treated or well water is available at the First Nations and community residential locations; water concentrations are not expected to be affected by the Proposed Project at these locations.
Dermal contact with potable water	The McNab Creek Strata holds two licenses for use of McNab Creek, one of which is for use as a potable water source. As such, ingestion of surface water as drinking water was considered as a potential pathway for residents of the McNab Creek Strata. However, no COPCs were identified in surface water from McNab Creek.
Incidental ingestion of surface water	People may be exposed to waterborne chemicals through incidental ingestion and dermal contact during recreational activities such as swimming or fishing in McNab creek. However, no COPCs were identified in McNab Creek.
Dermal contact with surface water	In addition, it was conservatively assumed that people could swim in the pit lake as the Proposed Project Area will not be fenced. Swimmers could be exposed to surface water through incidental ingestion and dermal contact. Titanium was identified as a COPC in the pit lake (operations phase only).
Incidental ingestion of sediment	People may be exposed to COPCs in sediment during recreational activities; No COPCs were identified in surface water for McNab Creek and sediment quality is not expected to be impacted (see Volume 2, Part B - Section 5.5). Only titanium was identified as a COPC to move forward in the assessment for surface water in the pit lake; however, the pit lake does not contain soft bottom sediments, therefore dermal contact with sediments and ingestion of sediments were not retained as operable pathways.
Dermal contact with sediment	
Incidental ingestion of soil	Airborne COPCs may deposit to soil and people may incidentally ingest soil or come in dermal contact with soil. Changes to soil concentrations as a result of the Proposed Project were modelled. Soil concentrations as a result of the Proposed Project were compared to Base Case soil concentrations and screening guidelines and no COPCs were identified.
Dermal contact with soil	
Inhalation of dust	Airborne COPCs may deposit to soil and people may inhale soil dust. Soil concentrations predicted as a result of the Proposed Project were compared to Base Case soil concentrations and environmental quality guidelines/standards and no COPCs were identified.

Exposure Pathway	Description
Inhalation of air	People may be exposed to airborne COPCs released to air from the Proposed Project. Inhalation of COPCs in air has been evaluated in the acute and chronic inhalation assessments.
Ingestion of fish	People may be exposed to COPCs in fish from McNab Creek. No surface water COPCs were identified in McNab Creek, because metals concentration were not predicted to increase by greater than 10%, and did not exceed applicable health-based criteria. Therefore, chemical changes in fish tissue concentrations are not expected as a result of the Proposed Project. Titanium was identified as a COPC in the pit lake during the operations phase; However, because there will be no fish in the pit lake during operations, this pathway was not retained.
Ingestion of game meat	People may consume game harvested from areas near the Proposed Project. Wild game meat is a component of the traditional diet of First Nations residents, and can represent a significant component of their overall meat intake. Soil was used as a surrogate for screening potential changes to concentrations in game meat. As no COPCs were retained in soil, and concentration in soil were not predicted to increase from Base Case to Application Case, concentrations in game meat are also not expected to increase and this pathway was not retained for further evaluation.
Ingestion of plants	People may consume plants that have been affected by airborne deposition or that have taken up COPCs from the soil. Soil was used as a surrogate for screening potential changes to vegetation. As no COPCs were retained in soil, and concentration in soil were not predicted to increase from Base Case to Application Case, concentrations in vegetation are also not expected to increase and this pathway was not retained for further evaluation.

Notes:
% – percent; COPC – chemical of potential concern.

Based on the results of the pathway screening, only one pathway was retained for the assessment:

- Exposure of recreational receptors to titanium in surface water from the pit lake.

9.1.5.6.4 Problem Formulation Summary

In summary, the problem formulation for the multimedia assessment identified only one operable exposure pathway for the multimedia risk assessment: exposure of recreational receptors to titanium in surface water. The operable pathway was based on an increase in surface water titanium concentrations of greater than 10% relative to the Base Case in the pit lake. A health-based water quality guideline was not available for titanium so it was conservatively retained for further assessment. A conceptual exposure model is provided in Figure 9.1-4 summarizing the potential interactions of COPCs, exposure pathways and receptors of concern evaluated in the human health risk assessment.

9.1.5.6.5 Exposure Assessment

An exposure assessment is the process of estimating the amount of a chemical that a person consumes (referred to as a dose) or inhales (referred to as a concentration) through applicable exposure pathways on a daily basis for their lifetime. The dose of a chemical depends on the concentrations in various media (e.g., water, soil, food), the amount of time a person is in contact with these media and the biological characteristics of the person (e.g., ingestion rates, body weights, dietary preferences). The exposure assessment for recreational users

involved estimating the exposure dose of titanium through incidental ingestion and dermal contact with surface water.

Exposure equations, receptor assumptions, and exposure parameters are presented below.

Exposure Equations

Oral and dermal exposure was determined as a dose; this value is called the estimated daily intake and is typically expressed as milligrams of chemical per kilogram of body weight per day (mg/kg BW/day). Equations used to calculate the estimated daily intake for titanium are provided below:

Incidental Ingestion of Surface Water

$$Dose(mg/kg\ bw/day) - \frac{C_W \times IR_W \times RAF_{Oral} \times D_1\ x\ D_2 \times D_3}{BW}$$

Where:

C_W	- concentration of chemical in water (mg/L)
IR_W	- incidental surface water intake rate (L/hour)
RAF_{Oral}	- relative absorption factor from the gastrointestinal tract (unitless)
D_1	- hours per day exposed
D_2	- days per week exposed/7 days
D_3	- weeks per year exposed/52 weeks
BW	- body weight (kg)

Dermal Contact with Water

$$Dose(mg/kg\ bw/day) - \frac{C_W \times RAF_{Derm} \times Kp \times (\sum SA) \times 0.001 \times D_1 \times D_2 \times D_3}{BW}$$

Where:

C_W	- concentration of chemical in surface water (mg/L)
RAF_{Derm}	- relative absorption factor for skin (unitless)
K_p	- dermal permeability coefficient (cm/hour)
SA	- surface area of exposed skin (cm^2)
0.001	- unit correction factor (constant) (L/cm^3)
D_1	- hours per day exposed
D_2	- days per week exposed/7 days
D_3	- weeks per year exposed/52 weeks
BW	- body weight (kg)

Exposure Concentrations

The selected exposure concentration (Cw) of for the Application Case was the maximum predicted titanium concentration in surface water (0.0056 mg/L), which was predicted to occur in the pit lake during Year 1 of the of the Proposed Project. Risks were also estimated for the Base Case for comparison purposes. The Base Case exposure concentration for titanium was 0.005 mg/L (95^{th} percentile Base Case concentration).

Exposure parameters

For the recreational scenario, it was assumed that a recreational user (visitor or nearby resident) would access the pit lake two days per week to swim. Recreational users were assumed to be people of all ages. A toddler was selected as the most sensitive receptor for the purpose of calculating risk estimates. Exposure parameters are presented in Table 9.1-10.

Table 9.1-10: Toddler Recreational User Receptor Characteristics

Parameter	Toddler	Source
	>6 months to <5 years	
Body weight (kg)	16.5	Health Canada 2012
Incidental Surface Water Ingestion rate (L/hour)	0.049	USEPA 2011
Skin surface area available for dermal contact (cm^2)	6130	Health Canada 2012
Dermal permeability coefficient (K_p) for titanium (cm/hour)	0.001	USEPA 2004
Oral RAF for titanium	1	Health Canada 2012
Hours per day (hour/day)	1	Site-specific Assumption
Days per week exposed (days/7days)	2/7	Site-specific Assumption
Weeks per year exposed (weeks/52 weeks)	52/52[(a)]	Site-specific Assumption

Notes:

> – greater than; < – less than; cm/hour – centimetres per hour; kg – kilogram; US EPA – United States Environmental Agency.

(a) Short duration (sub-chronic, 14 to 90 days) exposures should not be amortized beyond days per week as per Health Canada (2012) guidance; therefore an exposure term of 52 weeks/52 weeks is applied.

9.1.5.6.6 Toxicity Assessment

A toxicity assessment was conducted to select appropriate toxicity reference values for the multimedia assessment. Because only ingestion and dermal contact with water were retained as operable pathways, the toxicity assessment focused on the oral and dermal exposures to titanium.

Exposure to Titanium

The principal route of exposure for titanium is through the consumption of food containing titanium (WHO 1982). Titanium has several applications including use in sunscreen, cosmetics, medications and tablet-coating formulations.

Titanium compounds are poorly absorbed from the gastrointestinal tract, although the extent of absorption is unknown. It has been estimated that gastrointestinal absorption of titanium is about 3% based on average titanium concentrations found in human urine (10 µg/litre) and assumed daily titanium intake rates (500 µg), though large variations in daily titanium intake rates have been observed (WHO 1982). An absorption rate of 3% indicates that most ingested titanium is eliminated unabsorbed. The main excretion pathway for humans is likely urinary and fecal excretion. Excretion by other routes is unknown. There is no evidence of titanium being an essential element.

The highest concentration of titanium is usually found in the lungs followed by the kidney and liver. There is an indication that titanium accumulates with age in the lungs but not in other organs. Titanium has been shown to cross the blood-brain barrier as well as cross the placenta into the fetus.

Toxicity of Titanium

Dose-effect and dose-response relationships have not been established but results of long-term toxicity studies showed that titanium did not significantly affect the life span of mice administered titanium as a soluble salt in drinking-water at a concentration of 5 mg/litre from weaning to natural death (Schroeder et al 1964; as cited in WHO 1982). Adverse effects were also not seen in guinea-pigs, rabbits, cats, or dogs fed technical grade titanium dioxide for 390 days (Lehman and Herget 1927; as cited in WHO 1982).

Titanium dioxide administered by injection to rats behaved as an inert substance (Sethi et al 1973, Huggins and Froehlich 1966; as cited in WHO 1982). Similarly, Titanium metal implanted in the muscle tissue of dogs for 7 months (Beder and Eade 1956; as cited in WHO 1982) and used as plating and fixation of fractures in dogs for 120 -180 days (Beder et al. 1957; as cited in WHO 1982) demonstrated the inertness of titanium.

Titanium dioxide was classified as a possible carcinogen (Group 2B) by the International Agency for Research on Cancer. No classifications were available from Health Canada or the US EPA, and a slope factor has not been derived for titanium by these agencies. Titanium was assessed as a non-carcinogen in the multimedia assessment.

Reference Dose for Chronic Exposure

The National Sanitation Foundation (NSF 2005) has derived an oral reference dose (RfD) for titanium based on a free-standing no observed adverse effects level (free-standing NOAEL; i.e., no effects were observed at the highest test concentration) from a 2-year titanium dioxide feeding study in rats. Male and female rates were fed 0, 1, 340, or 2680 mg/kg/day of titanium (in the form of titanium dioxide), and none of the doses produced an observed adverse effect (National Cancer Institute 1978; as cited in NSF 2005). An uncertainty factor of 1000 (10 for interspecies extrapolation, 10 for intraspecies extrapolation, and 10 for database deficiencies) was applied to the NOAEL of 2680 mg/kg/day to derive an RfD of 2.68 mg/kg/day. The NSF (NSF 2005) rounded this RfD to 3 mg/kg/day. An RfD for titanium was not available from Health Canada, the US EPA or ATSDR.

The NSF oral RfD of 3 mg/kg/day was used in the multimedia risk assessment. A dermal RfD was not available, therefore the oral RfD was used for the dermal pathway (Health Canada 2010).

9.1.6 Effects Assessment

9.1.6.1 Residual Effects Assessment

To assess the Base Case and Application Case, the human health risk assessment incorporated data and predictions for water quality and air quality/deposition, as well as information on existing populations and the environment.

9.1.6.1.1 Air Quality Assessment

9.1.6.1.1.1 Summary of Hazard Quotients

Hazard quotients were calculated for parameters identified as COPCs in the 1-hour and 24-hour assessment by comparing the concentrations predicted for each location with toxicity benchmarks for the Base Case, Application Case and Proposed Project contribution.

1-Hour Assessment

For the COPCs that were identified in the acute inhalation assessment (i.e., aluminum, iron and manganese), a HQ was calculated as follows:

$$HQ - \frac{COPC\ Concentration\ in\ Air\ (\mu g/m^3)}{Acute\ Inhalation\ Threshold\ (\mu g/m^3)}$$

The HQ values calculated for the Base Case, Application Case and Proposed Project Contribution are presented in Table 9.1-11 and Table 9.1-12.

Table 9.1-11: Hazard Quotients for Maximum 1-Hour Predicted Aluminum Concentrations

Receptor Location	Base Case	Application Case	Proposed Project Contribution
Squamish	0.017	0.017	0.00016
Porteau Cove	0.017	0.017	0.00039
Bowen Island	0.017	0.017	0.00017
Lions Bay	0.017	0.017	0.00018
Langdale	0.017	0.017	0.00057
Horseshoe Bay	0.017	0.017	0.00010
New Brighton	0.017	0.017	0.00077
Britannia Beach	0.017	0.017	0.00031
Furry Creek	0.017	0.017	0.00040
Gibsons	0.017	0.017	0.00026
Ch'iyakmesh	0.017	0.017	0.00007
Unknown First Nations	0.017	0.017	0.00030
Unknown residence	0.017	0.017	0.00036
Potlach Creek	0.017	0.018	0.0010
KWUM KWUM	0.017	0.017	0.00080
Tetrahedron Park	0.017	0.017	0.000090
Anvil Island	0.017	0.018	0.0012
Ekin's Point	0.017	0.027	0.010
Kaikalahun	0.017	0.017	0.00067
McNab Creek Strata	0.017	0.057	0.040
Camp Artaban	0.017	0.017	0.00040
Camp Latona	0.017	0.027	0.010
Residence on Gambier Island	0.017	0.017	0.00077
MPOI	0.017	**1.7**	**1.7**

Notes:
Bold and underlined values exceed the target hazard quotient of 1.0.
MPOI – maximum point of impingement.

Table 9.1-12: Hazard Quotients for Maximum 1-Hour Predicted Iron Concentrations

Receptor Location	Base Case	Application Case	Proposed Project Contribution
Squamish	0.033	0.034	0.00086
Porteau Cove	0.033	0.035	0.0021
Bowen Island	0.033	0.034	0.00091
Lions Bay	0.033	0.034	0.00089
Langdale	0.033	0.036	0.0033
Horseshoe Bay	0.033	0.034	0.00052
New Brighton	0.033	0.038	0.0045
Britannia Beach	0.033	0.035	0.0017
Furry Creek	0.033	0.035	0.0021
Gibsons	0.033	0.035	0.0015
Ch'iyakmesh	0.033	0.033	0.00035
Unknown First Nations	0.033	0.035	0.0016
Unknown residence	0.033	0.035	0.0020
Potlach Creek	0.033	0.038	0.0050
KWUM KWUM	0.033	0.037	0.0039
Tetrahedron Park	0.033	0.034	0.00043
Anvil Island	0.033	0.040	0.0073
Ekin's Point	0.033	0.11	0.081
Kaikalahun	0.033	0.037	0.0038
McNab Creek Strata	0.033	0.16	0.13
Camp Artaban	0.033	0.035	0.0016
Camp Latona	0.033	0.12	0.087
Residence on Gambier Island	0.033	0.036	0.0032
MPOI	0.033	**4.0**	**4.0**

Notes:
Bold and underlined values exceed the target hazard quotient of 1.0.
MPOI – maximum point of impingement.

For the Application Case, 1-hour HQs were greater than 1.0 at the MPOI for aluminum and iron. Further analysis of these parameters is provided in Section 9.1.6.1.1.2.

24-Hour Assessment

The HQ values calculated for maximum 24-hour exposure to iron and manganese for the Base Case, Application Case and Proposed Project Contribution and are presented in Table 9.1-13 and Table 9.1-14.

Table 9.1-13: Hazard Quotients for Maximum 24-Hour Predicted Iron Concentrations

Receptor Location	Base Case	Application Case	Proposed Project Contribution
Squamish	0.070	0.070	0.00060
Porteau Cove	0.070	0.071	0.0017
Bowen Island	0.070	0.070	0.00056
Lions Bay	0.070	0.070	0.00055
Langdale	0.070	0.072	0.0020
Horseshoe Bay	0.070	0.070	0.00032
New Brighton	0.070	0.072	0.0020
Britannia Beach	0.070	0.071	0.0016
Furry Creek	0.070	0.072	0.0022
Gibsons	0.070	0.071	0.00098
Ch'iyakmesh	0.070	0.070	0.00033
Unknown First Nations	0.070	0.071	0.0014
Unknown residence	0.070	0.071	0.0018
Potlach Creek	0.070	0.075	0.0050
KWUM KWUM	0.070	0.074	0.0040
Tetrahedron Park	0.070	0.070	0.00033
Anvil Island	0.070	0.073	0.0038
Ekin's Point	0.070	0.12	0.048
Kaikalahun	0.070	0.071	0.0018
McNab Creek Strata	0.070	0.20	0.13
Camp Artaban	0.070	0.071	0.0011
Camp Latona	0.070	0.13	0.057
Residence on Gambier Island	0.070	0.071	0.0018
MPOI	0.070	**2.8**	**2.7**

Notes:
Bold and underlined values exceed the target hazard quotient of 1.0.
MPOI – maximum point of impingement.

Table 9.1-14: Hazard Quotients for Maximum 24-Hour Predicted Manganese Concentrations

Receptor Location	Base Case	Application Case	Proposed Project Contribution
Squamish	0.070	0.070	0.00031
Porteau Cove	0.070	0.071	0.00090
Bowen Island	0.070	0.070	0.00029
Lions Bay	0.070	0.070	0.00028
Langdale	0.070	0.071	0.0010
Horseshoe Bay	0.070	0.070	0.00017
New Brighton	0.070	0.071	0.0010
Britannia Beach	0.070	0.070	0.00080
Furry Creek	0.070	0.071	0.0011
Gibsons	0.070	0.070	0.00050

Receptor Location	Base Case	Application Case	Proposed Project Contribution
Ch'iyakmesh	0.070	0.070	0.00017
Unknown First Nations	0.070	0.070	0.00072
Unknown residence	0.070	0.071	0.00095
Potlach Creek	0.070	0.072	0.0026
KWUM KWUM	0.070	0.072	0.0021
Tetrahedron Park	0.070	0.070	0.00017
Anvil Island	0.070	0.072	0.0020
Ekin's Point	0.070	0.093	0.024
Kaikalahun	0.070	0.071	0.00093
McNab Creek Strata	0.070	0.14	0.065
Camp Artaban	0.070	0.070	0.00056
Camp Latona	0.070	0.098	0.029
Residence on Gambier Island	0.070	0.071	0.00095
MPOI	0.070	**1.6**	**1.5**

Notes:
Bold and underlined values exceed the target hazard quotient of 1.0.
MPOI – maximum point of impingement.

For the Application Case, 24-hour HQs were greater than 1.0 at the MPOI for iron and manganese. Further analysis of these parameters is provided in Section 9.1.6.1.1.2.

9.1.6.1.1.2 Further Analyses of Parameters with Hazard Quotients Greater than One

For parameters and locations where HQ values were greater than 1.0 for the Application Case, the frequency of exceedance of the 1-hour and 24-hour maximum concentrations of each COPC over the course of the year was calculated to determine the magnitude of risk. For aluminum, iron and manganese at the MPOI receptor location, the frequency of exceedances is summarized in Table 9.1-15. Results of the assessment of magnitude of risk for the acute air quality assessment (1-hour and 24-hour) at the MPOI are presented in Table 9.1-16 to Table 9.1-19.

Table 9.1-15: Predicted 1-hour and 24-hour Concentrations and Frequency of Exceedances at the Maximum Point of Impingement

Parameter	Criteria	Application Case				Proposed Project Contribution			
		Maximum Concentration (µg/m3)	95th Percentile Concentration (µg/m3)	75th Percentile Concentration (µg/m3)	Frequency of Exceedance (Number of Exceedances in a Year)	Maximum Concentration (µg/m3)	95th Percentile Concentration (µg/m3)	75th Percentile Concentration (µg/m3)	Frequency of Exceedance (Number of Exceedances in a Year)
1-Hour									
Aluminum	20 (a)	33	10	5.7	42	33	9.6	5.3	40
	50 (b)				0				0
Iron	10	40	13	7.0	1166	40	12	6.7	1,042
24-Hour									
Iron	4	11	8.5	6.0	252	11	8.2	5.7	224
Manganese	0.1	0.16	0.12	0.085	51	0.15	0.11	0.078	41

Notes:
µg/m^3 – microgram per cubic metre.
(a) – Criteria for aluminum chloride; the species that the emitted aluminum will form is not known, so criteria for both aluminum chloride and metal/insoluble aluminum are presented.
(b) – Criteria for metal/insoluble aluminum

Table 9.1-16: Further Analysis of Aluminum and Determination of Magnitude of Risk (Acute 1-Hour Assessment)

Analysis Criteria for Aluminum (1-Hour)	Discussion
Comparison of maximum, 95th and 75th percentile concentrations to acute limits	The maximum predicted 1-hour concentration at the MPOI (33 µg/m^3) exceeded the acute exposure limit of 20 µg/m^3, primarily a result of the Proposed Project contribution. There were no exceedances at the other receptor locations evaluated. The 75th (5.7 µg/m^3) and 95th (10 µg/m^3) percentile concentrations did not exceed the acute exposure limit at the MPOI. The Proposed Project Contribution concentrations were similar to the Application Case concentrations, with the maximum concentration at the MPOI exceeding the acute exposure limit and the 95th and 75th percentile concentrations not exceeding the acute exposure limit.
Comparison of Application Case HQs to Base Case	At the MPOI, the HQ for the Base Case was 0.017 and increased to 1.7 for the Application Case. The Proposed Project Contribution HQ was 1.7 at the MPOI.
Frequency of exceedances	There were 42 hourly exceedances of the screening criterion at the MPOI for the Application Case, based on a year of modelling using the TCEQ criterion of 20 µg/m^3 for aluminum chloride.
Conservatism and uncertainty in air predictions	The primary emission sources of aluminum are land clearing, aggregate extraction and initial processing, conveying from pit to processing, transfer to the barge and tug transport. The Proposed Project air emission rates were assumed to emit the worst case concentration every day of the year, which may not be the case in reality. Air quality modelling was conducted using data for year 12 of the operations phase, which was expected to be the year with maximum emission rates from the Proposed Project.
Conservatism in the 1-hour screening criterion for aluminum	The TCEQ provides a screening criterion of 20 µg/m^3 for aluminum chloride and 50 µg/m^3 for metal and insoluble aluminum. Exceedances of the aluminum chloride criteria were identified in this assessment. The species that the emitted aluminum will form is not known so the more conservative screening criterion was used for this assessment. The criteria are based on a health endpoint; however, supporting documentation was not available from TCEQ. Due to the lack of supporting documentation, the conservatism incorporated into the derivation of the acute criteria is unknown.
Potential acute health effects of aluminum	The acute toxicity of metallic aluminum and aluminum compounds is low. In short-term studies using rats, mice or dogs to various aluminum compounds in the diet or drinking water, only minimal effects were observed at the highest administered doses (HSDB 2014a). Adequate acute inhalation studies have not been identified (HSDB 2014a) and no supporting documentation for the TCEQ criteria is available. The ATSDR completed a toxicological review of aluminum (ATSDR 2008) and no studies were located on the effects of acute inhalation exposure to aluminum. Some epidemiological studies on occupationally exposed workers have shown a link between respiratory effects and aluminum exposure. However, workers are often exposed to other chemicals at the same time as the aluminum exposure, making it difficult to determine if the effects were solely related to aluminum. Some occupational exposure studies have also reported neurological effects, however the association is inconclusive (ATSDR 2008). In a sub-chronic study by Mussi et al. (1984; as cited in ATSDR 2008), no adverse hematological, hepatic or renal effects were reported from exposure to 1000 to 6200 µg aluminum/m^3 for 6 months. Some short-term animal studies have reported respiratory effects from inhalation exposure to aluminum. In a 3-day exposure study by Drew et al. (1974; as cited in ATSDR 2008), hamsters were exposed to 31,000 or 33,000 µg aluminum/m^3 for 3, 6, 10, or 27 days. Pulmonary effects were observed, but the severity decreased with increasing number of exposed days. Hamsters exposed to ≥7000 µg aluminum/m^3 for 3 days showed significant increases in absolute lung weights, however no effects were observed at 3000 µg aluminum/m^3 (Drew et al. 1974; as cited in ATSDR 2008).

Analysis Criteria for Aluminum (1-Hour)	Discussion
Magnitude of risk	The predicted peak 1-hour concentration for aluminum exceeds the acute exposure limit at the MPOI for the Application Case and is primarily a result of Proposed Project contributions. There were more than 40 hourly exceedances of the screening criterion at the MPOI. The highest aluminum concentration predicted at the MPOI was 33 µg/m^3. The effects reported in the above studies occur at much higher concentrations than that predicted at the MPOI. Furthermore, the effects are associated with a longer exposure duration than that considered in this acute (1-hr) assessment. The screening criterion used in the assessment was for aluminum chloride. Predicted concentrations were below the next most conservative criterion, which was for metal and insoluble aluminum. The location of the MPOI did not overlap with any of the receptor locations and therefore, use or access by the public is considered to be on an infrequent basis. The magnitude of risk for aluminum is considered to be low at the MPOI and negligible at all the other locations evaluated.

Notes:
µg/m^3 – microgram per cubic metre; ATSDR – Agency for Toxic Substances and Disease Registry; HQ – hazard quotient; HSDB – Hazardous Substances Data Bank; MPOI – maximum point of impingement; TCEQ – Texas Commission on Environmental Quality.

Table 9.1-17: Further Analysis of Iron and Determination of Magnitude of Risk (Acute 1-Hour Assessment)

Analysis Criteria for Iron (1-Hour)	Discussion
Comparison of maximum, 95th and 75th percentile concentrations to acute limits	The maximum predicted 1-hour concentration at the MPOI (40 µg/m^3) exceeded the acute exposure limit of 10 µg/m^3. The 95th percentile concentration (13 µg/m^3) also exceeded the acute exposure limit at the MPOI, while the 75th percentile (7.0 ug/m^3) concentration did not. The Proposed Project Contribution concentrations were similar to the Application Case concentrations.
Comparison of the Application Case HQs to Base Case	At the MPOI, the HQ for the Base Case was 0.033 and increased to 4.0 for the Application Case. The Proposed Project Contribution HQ was also 4.0.
Frequency of exceedances	There were 1,166 hourly predicted exceedances of the screening criterion at the MPOI for the Application Case, based on a year of modelling.
Conservatism and uncertainty in air predictions	The primary emission sources of iron are land clearing, aggregate extraction and initial processing, conveying from pit to processing, transfer to the barge and tug transport. The Proposed Project air emission rates were assumed to emit the worst case concentration every day of the year, which may not be the case in reality. Air quality modelling was conducted using data for year 12 of the operations phase, which was expected to be the year with maximum emission rates from the Proposed Project.
Conservatism in the 1-hour criterion for iron	A single 1-hour screening criterion was identified for iron and is an effects screening level obtained from the TCEQ. The TCEQ 1-hour criterion (10 µg/m^3) used in this assessment is based on a health endpoint as iron (III) sulphate and soluble iron salts; however, supporting documentation was not available from TCEQ. Due to the lack of supporting documentation, the conservatism incorporated into the derivation of the acute criterion is unknown.
Potential acute health effects of iron	Acute inhalation effects of ferric salts as dusts and mists include irritation of the respiratory tract and irritation of the skin (HSDB 2014b). In a literature review completed by the US EPA (2006), no reliable human studies were available on the acute toxicity of iron inhalation. In an animal study, rabbits exposed to 3100 µg/m^3 iron for 6 hours/day, 5 days/week for 2 months exhibited alterations in the lungs (histopathological changes, lung spots, increased lung weights) (Johansson et al. 1992; as cited in USEPA 2006).

Analysis Criteria for Iron (1-Hour)	Discussion
Magnitude of risk	The maximum and 95th percentile concentrations exceeded the acute criterion at the MPOI for the Application Case, primarily a result of the Proposed Project contribution. There were 1,166 predicted hourly exceedances of the criterion at the MPOI. The maximum concentration was 40 µg/m^3 (Application Case), which is well below the concentrations at which effects are expected to occur. The conservatism in the acute criterion is not known as supporting documentation is not available from TCEQ. The location of the MPOI did not overlap with any of the receptor locations and therefore, use or access by the public is considered to be on an infrequent basis. The magnitude of risk for iron is considered to be low at the MPOI and negligible at all the other locations evaluated.

Notes:
µg/m^3 – microgram per cubic metre; HQ – hazard quotient; HSDB – Hazardous Substances Data Bank; MPOI – maximum point of impingement; TCEQ – Texas Commission on Environmental Quality; TLV-TWA – Threshold Limit Value-Time Weighted Average; US EPA – United States Environmental Protection Agency.

Table 9.1-18: Further Analysis of Iron and Determination of Magnitude of Risk (Acute 24-Hour Assessment)

Analysis Criteria for Iron (24-Hour)	Discussion
Comparison of maximum, 95th and 75th percentile concentrations to acute limits	The maximum predicted 24-hour concentration at the MPOI (11 µg/m^3) exceeded the acute exposure limit of 4 µg/m^3. The 75th (6.0 µg/m^3) and 95th (8.5 µg/m^3) percentile concentrations also exceeded the acute exposure limit at the MPOI. The Proposed Project Contribution concentrations were similar to the Application Case concentrations and maximum, 75th and 95th percentile concentrations exceeded the acute exposure limit.
Comparison of Construction Case and Application Case HQs to Base Case	At the MPOI, the HQ for the Base Case was 0.070 and increased to 2.8 for the Application Case. The Proposed Project Contribution HQ was 2.7 at the MPOI.
Frequency of exceedances	There were 252 daily exceedances of the criterion at the MPOI for the Application Case, based on a year of modelling.
Conservatism and uncertainty in air predictions	The primary emission sources of iron are land clearing, aggregate extraction and initial processing, conveying from pit to processing, transfer to the barge and tug transport. The Proposed Project air emission rates were assumed to emit the worst case concentration every day of the year, which may not be the case in reality. Air quality modelling was conducted using data for year 12 of the operations phase, which was expected to be the year with maximum emission rates from the Proposed Project.
Conservatism in the 24-hour criterion for iron	A single 24-hour criterion was identified for iron from the OMoE. The OMoE 24-hour criterion (4 µg/m^3) used in this assessment is based on a health endpoint; however, supporting documentation was not available. Due to the lack of supporting documentation from OMoE, the conservatism incorporated into the derivation of the criterion is unknown.
Potential acute health effects of iron	Acute inhalation effects of ferric salts as dusts and mists include irritation of the respiratory tract and irritation of the skin (HSDB 2014b). In a literature review completed by the US EPA (2006), no reliable human studies were identified on the acute inhalation toxicity of iron. In an animal study, rabbits exposed to 3100 µg/m^3 iron for 6 hours/day, 5 days/week for 2 months exhibited alterations in the lungs (histopathological changes, lung spots, increased lung weights) (Johansson et al. 1992; as cited in USEPA 2006).

Analysis Criteria for Iron (24-Hour)	Discussion
Magnitude of risk	The predicted maximum 24-hour, 95th and 75th percentile concentrations for iron exceed the acute exposure limit at the MPOI for the Application Case, primarily a result of the Proposed Project contribution. There were over 250 daily exceedances of the criterion at the MPOI. The maximum concentration was 11 µg/m^3 (Application Case), which is well below the concentrations at which effects are expected to occur. The conservatism in the acute criterion is not known, as supporting documentation is not available from OMoE. The location of the MPOI did not overlap with any of the receptor locations and therefore, use or access by the public is considered to be on an infrequent basis. The magnitude of risk for iron is considered to be low at the MPOI and negligible at all the other locations evaluated.

Notes:
µg/m^3 – microgram per cubic metre;; HQ – hazard quotient; HSDB – Hazardous Substances Data Bank; MPOI – maximum point of impingement; TCEQ – Texas Commission on Environmental Quality; TLV-TWA – Threshold Limit Value-Time Weighted Average; US EPA – United States Environmental Protection Agency.

Table 9.1-19: Further Analysis of Manganese and Determination of Magnitude of Risk (Acute 24-Hour Assessment)

Analysis Criteria for Manganese (24-Hour)	Discussion
Comparison of maximum, 95th and 75th percentile concentrations to acute limits	The maximum predicted 24-hour concentration at the MPOI (0.16 µg/m^3) exceeded the acute exposure limit of 0.1 µg/m^3. The 95th (0.12 µg/m^3) percentile concentration also exceeded the acute exposure limit at the MPOI, while the 75th (0.085 µg/m^3) percentile concentration did not. The Proposed Project Contribution concentrations were similar to the Applications Case concentrations, with maximum and 95th percentile concentrations exceeding the acute exposure limit and 75th percentile concentrations not exceeding the acute exposure limit.
Comparison of the Application Case HQs to Base Case	At the MPOI, the HQ for the Base Case was 0.070 and increased to 1.6 for the Application Case. The Proposed Project Contribution HQ was 1.5 at the MPOI.
Frequency of exceedances	There were 51 daily exceedances of the criterion at the MPOI for the Application Case, based on a year of modelling.
Conservatism and uncertainty in air predictions	The primary emission sources of manganese are land clearing, aggregate extraction and initial processing, conveying from pit to processing, transfer to the barge and tug transport. The Proposed Project air emission rates were assumed to emit the worst case concentration every day of the year, which may not be the case in reality. Air quality modelling was conducted using data for year 12 of the operations phase, which was expected to be the year with maximum emission rates from the Proposed Project.
Conservatism in the 24-hour criterion for manganese	A criterion of 0.1 µg/m^3 was adopted from the OMoE. The criterion is based on manganese as a metal/parameter in $PM_{2.5}$ and is derived from an occupational study where workers were exposed to manganese dioxide dust for an average of 5.3 years in a dry-cell battery factory (OMoE 2011). The point of departure (POD) was selected as 84 µg/m^3 (benchmark concentration lower confidence limit corresponding to a 5% response level) for a logistic dose-response model of eye-hand coordination scores. The POD was adjusted for continuous exposure (30 µg/m^3) and an uncertainty factor of 300 (10 for human variability, 3 for database limitations and differences in toxicity associated with different species of manganese, 3 for the vulnerability of the developing nervous system and 3 for subchronic to chronic exposure extrapolation) was applied. The way in which this 24-hour criterion was derived is typical of that which would be used to derive a chronic value and is therefore a conservative approach.

Analysis Criteria for Manganese (24-Hour)	Discussion
Potential acute health effects of manganese	Neurotoxicity is the primary symptom of manganese toxicity resulting from chronic exposure (HSDB 2014c). The ATSDR has reviewed the toxicity of manganese (ATSDR 2012) and indicates that there is limited information regarding the acute inhalation toxicity of manganese. Manganism, a term used to define the neurotoxic effects of manganese, has been reported in several epidemiological studies. Exposure concentrations ranged from 70 to 970 µg manganese/m^3. Some workers may show symptoms within 1 to 3 months (Rodier 1955; as cited in ATSDR 2012), but symptoms are generally not observed until several years after exposure. The highest manganese concentration predicted at the MPOI was 0.98 µg/m^3 (Application Case). The concentrations corresponding with effects reported in the above studies are much higher than that predicted at the MPOI.
Magnitude of risk	The predicted maximum 24-hour and 95th percentile concentrations for manganese exceeded the acute exposure limit at the MPOI for the Application Case, primarily a result of the Proposed Project contribution. There were more than 50 daily exceedances of the criterion at the MPOI. The maximum predicted concentration of manganese was 0.16 µg/m^3 (Application Case), which is much lower than the concentrations where effects are expected to occur. Furthermore, the effects are associated with a longer exposure duration than that considered in this acute (24-hour) assessment. The location of the MPOI did not overlap with any of the receptor locations and therefore, use or access by the public is considered to be on an infrequent basis. The magnitude of risk for manganese is considered to be low at the MPOI and negligible at all the other locations evaluated.

Notes:
µg/m^3 – microgram per cubic metre; ATSDR – Agency for Toxic Substances and Disease Registry; HQ – hazard quotient; HSDB – Hazardous Substances Data Bank; MPOI – maximum point of impingement; OMoE – Ontario Ministry of the Environment; $PM_{2.5}$ – particulate matter less than 2.5 microns.

9.1.6.1.2 Particulate Matter

The particulate matter assessment evaluated the potential health effects resulting from inhalation exposure to $PM_{2.5}$ and PM_{10} in air emissions from the Proposed Project. The results of a literature review on the health effects of exposure to particulate matter are provided in Volume 4, Part G – Section 22.0: Appendix 9.1-E. A discussion of the particulate matter results predicted for the Proposed Project is presented below.

9.1.6.1.2.1 Short-Term (Acute)

Results for the short-term particulate matter assessment are presented for the Base and Application Cases. Additional information is provided on the particulate matter concentrations predicted to result from the Proposed Project emissions alone (Proposed Project Contribution) (i.e., without Base Case incorporated).

PM_{10}

Acute health effects were assessed using the 24-hour PM_{10} predictions and are discussed further in the qualitative literature review provided in Volume 4, Part G – Section 22.0: Appendix 9.1-E.

The 24-hour PM_{10} concentrations for the Base and Application Cases are presented below in Table 9.1-20. Table 9.1-20 also includes the predictions resulting from the Proposed Project Contribution.

Criteria for 24-hour PM_{10} concentrations were available from BC MoE, WHO, OMoE and the US EPA NAAQS (see Volume 4, Part G – Section 22.0: Appendix 9.1-B; Table 9.1-B-2). The BC MoE, WHO and OMoE 24-hour PM_{10} criteria were equivalent (50 µg/m^3) and this value was selected as the screening level for this assessment. The US NAAQS standard of 150 µg/m^3 was greater the other screening values.

Predicted maximum, 95th and 75th percentile 24-hour PM_{10} concentrations were therefore compared to the most conservative of the available health-based criteria (50 µg/m^3, BC MoE 2016, OMoE 2012 and WHO 2006). While supporting documentation was not available from the BC MoE, the WHO guideline was based on the relationship between 24-hour and annual mean particulate matter levels. The level was set based on a number of studies that suggest there is an increase in mortality of approximately 0.5% for every 10 µg/m^3 increment in 24-hour concentration. The guideline was, therefore, intended to act as an acceptable risk level as opposed to being fully protective of negative health outcomes. Predicted 24-hour maximum concentrations for the Base Case were below the screening guideline of 50 ug/m^3 at all the receptor locations evaluated. For the Application Case, the predicted 24-hour maximum and 95th and 75th percentile PM_{10} concentrations were below the guideline except at the MPOI (171.5 µg/m^3, 136.6 µg/m^3, and 100.7 µg/m^3, respectively). Exceedances of the guideline were predicted to occur 360 times in a year at the MPOI for the Application Case.

When considering the contribution of PM_{10} resulting from the Proposed Project Contribution, the maximum and 95th and 75th percentiles concentrations were well below the screening guideline except at the MPOI (145.3 µg/m^3, 110.3 µg/m^3, and 74.5 µg/m^3, respectively). It is not anticipated that people will spend much time at MPOI receptor location.

Further discussion within the context of the literature review results for particulate matter effects is provided below.

Table 9.1-20: Comparison of Predicted 24-hour Maximum, 75th and 95th Percentile Concentrations of PM_{10} for the Base Case, Application Case and Proposed Project Contribution with the WHO Guideline

Location	Base Case	Application Case				Proposed Project Contribution			
	Maximum Concentration [µg/m3]	Maximum Concentration [µg/m3]	95th Percentile Concentration [µg/m3]	75th Percentile Concentration [µg/m3]	Frequency of Exceedances (Number of Exceedances in a Year)	Maximum Concentration [µg/m3]	95th Percentile Concentration [µg/m3]	75th Percentile Concentration [µg/m3]	Frequency of Exceedances (Number of Exceedances in a Year)
Squamish	26.2	26.3	26.2	26.2	0	0.045	0.026	0.0087	0
Porteau Cove	26.2	26.3	26.3	26.2	0	0.12	0.054	0.019	0
Bowen Island	26.2	26.3	26.2	26.2	0	0.045	0.022	0.0050	0
Lions Bay	26.2	26.3	26.2	26.2	0	0.050	0.022	0.0070	0
Langdale	26.2	26.4	26.3	26.2	0	0.17	0.061	0.014	0
Horseshoe Bay	26.2	26.2	26.2	26.2	0	0.025	0.013	0.0028	0
New Brighton	26.2	26.4	26.3	26.2	0	0.15	0.061	0.016	0
Britannia Beach	26.2	26.3	26.3	26.2	0	0.11	0.047	0.017	0
Furry Creek	26.2	26.4	26.3	26.2	0	0.16	0.055	0.020	0
Gibsons	26.2	26.3	26.2	26.2	0	0.082	0.035	0.0065	0
Ch'iyakmesh	26.2	26.2	26.2	26.2	0	0.023	0.013	0.0055	0
Unknown First Nations	26.2	26.3	26.3	26.2	0	0.10	0.045	0.017	0
Unknown residence	26.2	26.5	26.3	26.2	0	0.32	0.095	0.038	0
Potlach Creek	26.2	26.5	26.4	26.3	0	0.34	0.14	0.071	0
KWUM KWUM	26.2	26.5	26.3	26.3	0	0.27	0.11	0.055	0
Tetrahedron Park	26.2	26.3	26.2	26.2	0	0.059	0.022	0.010	0
Anvil Island	26.2	26.5	26.3	26.3	0	0.33	0.10	0.041	0
Ekin's Point	26.2	32.2	28.6	27.1	0	6.0	2.4	0.92	0
Kaikalahun	26.2	26.4	26.3	26.2	0	0.18	0.095	0.038	0
McNab Creek Strata	26.2	36.7	31.8	29.3	0	10.5	5.6	3.0	0
Camp Artaban	26.2	26.3	26.3	26.2	0	0.14	0.057	0.025	0
Camp Latona	26.2	30.6	29.3	27.3	0	4.4	3.1	1.1	0
Residence on Gambier Island	26.2	30.6	29.3	27.3	0	0.19	0.094	0.034	0
MPOI	26.2	**171.5**	**136.6**	**100.7**	360	**145.3**	**110.3**	**74.5**	239
BC MoE [(a)]	50								

Notes:
Bold and underlined values indicate an exceedance of the WHO air quality guideline.
[a] BC MoE 2016.
µg/m^3 – microgram per cubic metre; MPOI – maximum point of impingement; PM_{10} – particulate matter less than 10 microns; BC MoE - British Columbia Ministry of Environment.

$PM_{2.5}$

The 24-hour predictions for $PM_{2.5}$, which are discussed further below, were used to assess the acute health effects associated with $PM_{2.5}$. A qualitative discussion on the health effects of acute exposure to $PM_{2.5}$ is provided in Volume 4, Part G – Section 22.0: Appendix 9.1-E.

The 24-hour $PM_{2.5}$ concentrations for the Base and Application Cases are presented below in Table 9.1-21. Table 9.1-21 also includes the predictions resulting from the Proposed Project Contribution phase of the Proposed Project (i.e., without background incorporated).

Criteria for the 24-hour $PM_{2.5}$ concentrations were also available from BC MoE, CCME, US NAAQS and the OMoE (see Volume 4, Part G – Section 22.0: Appendix 9.1-B, Table 9.1-B-5). The BC MoE 24-hour $PM_{2.5}$ criterion of 25 $\mu g/m^3$ is equivalent to the WHO guideline and was chosen for this assessment. The CCME, US NAAQS and OMoE values were not as conservative as the WHO value, therefore, these criteria were not selected for this assessment.

Predicted maximum and 95^{th} and 75^{th} percentile 24-hour $PM_{2.5}$ concentrations were compared to the most conservative of the available health-based criteria (25 $\mu g/m^3$, BC MoE 2016 and WHO 2006). While the BC MoE does not provide supporting documentation, the WHO guideline is based on the same toxicological endpoint as PM_{10} where exposure was associated with approximately a 0.5% increase in mortality per 10 $\mu g/m^3$ increase in PM_{10}. The PM_{10} guideline was converted using a $PM_{2.5}$:PM_{10} ratio of 0.5. The WHO (2006) determined that the $PM_{2.5}$:PM_{10} ratio is typical of that found in urban areas of developing countries and is at the lower end of the range found in urban areas in developed countries (0.5 to 0.8) and, therefore, the WHO selected the lower end of the range for the conversion (WHO 2006).

Predicted 24-hour maximum concentrations for the Base Case were below the screening guideline of 50 $\mu g/m^3$ at all receptor locations. For the Application Case, predicted 24-hour maximum and 95^{th} and 75^{th} percentile $PM_{2.5}$ concentrations were below the guideline except at the MPOI (86.7 $\mu g/m^3$, 68.7 $\mu g/m^3$, and 51 $\mu g/m^3$, respectively). Exceedances of the guideline were predicted to occur 366 times in a year at the MPOI for the Application Case. Exceedances only occurred at the MPOI where people are not expected to spend much of their time.

When considering the contribution of $PM_{2.5}$ resulting from the Proposed Project contribution, the maximum and 95^{th} and 75^{th} percentiles concentrations were well below the selected screening guideline except at the MPOI (72.5 $\mu g/m^3$, 54.5 $\mu g/m^3$, and 36.7 $\mu g/m^3$, respectively).

Further discussion within the context of the literature review results for particulate matter effects is provided below.

Table 9.1-21: Comparison of Predicted 24-hour Maximum, 75th and 95th Percentile Concentrations of $PM_{2.5}$ for the Base Case, Application Case and Proposed Project Contribution with the WHO Guideline

Location	Base Case	Application Case				Proposed Project Contribution			
	Maximum Concentration [µg/m3]	Maximum Concentration [µg/m3]	95th Percentile Concentration [µg/m3]	75th Percentile Concentration [µg/m3]	Frequency of Exceedances (Number of Exceedances in a Year)	Maximum Concentration [µg/m3]	95th Percentile Concentration [µg/m3]	75th Percentile Concentration [µg/m3]	Frequency of Exceedances (Number of Exceedances in a Year)
Squamish	14.3	14.3	14.3	14.3	0	0.011	0.0063	0.0024	0
Porteau Cove	14.3	14.3	14.3	14.3	0	0.029	0.013	0.0052	0
Bowen Island	14.3	14.3	14.3	14.3	0	0.011	0.0057	0.0015	0
Lions Bay	14.3	14.3	14.3	14.3	0	0.013	0.0063	0.0020	0
Langdale	14.3	14.3	14.3	14.3	0	0.040	0.015	0.0037	0
Horseshoe Bay	14.3	14.3	14.3	14.3	0	0.0064	0.0037	0.00089	0
New Brighton	14.3	14.3	14.3	14.3	0	0.035	0.017	0.0044	0
Britannia Beach	14.3	14.3	14.3	14.3	0	0.027	0.012	0.0046	0
Furry Creek	14.3	14.3	14.3	14.3	0	0.038	0.014	0.0052	0
Gibsons	14.3	14.3	14.3	14.3	0	0.019	0.0090	0.0017	0
Ch'iyakmesh	14.3	14.3	14.3	14.3	0	0.0059	0.0034	0.0016	0
Unknown First Nations	14.3	14.3	14.3	14.3	0	0.025	0.011	0.0044	0
Unknown residence	14.3	14.3	14.3	14.3	0	0.076	0.023	0.0088	0
Potlach Creek	14.3	14.3	14.3	14.3	0	0.079	0.034	0.017	0
KWUM KWUM	14.3	14.3	14.3	14.3	0	0.063	0.025	0.012	0
Tetrahedron Park	14.3	14.3	14.3	14.3	0	0.015	0.0054	0.0024	0
Anvil Island	14.3	14.3	14.3	14.3	0	0.081	0.024	0.0098	0
Ekin's Point	14.3	15.5	14.8	14.5	0	1.3	0.52	0.21	0
Kaikalahun	14.3	14.3	14.3	14.3	0	0.040	0.022	0.0084	0
McNab Creek Strata	14.3	17.2	15.9	15.1	0	2.9	1.6	0.80	0
Camp Artaban	14.3	14.3	14.3	14.3	0	0.033	0.014	0.0059	0
Camp Latona	14.3	15.2	14.9	14.5	0	0.92	0.62	0.22	0
Residence on Gambier Island	14.3	15.2	14.9	14.5	0	0.045	0.024	0.0082	0
MPOI	14.3	**86.7**	**68.7**	**51.0**	366	**72.5**	**54.5**	**36.7**	239
BC MoE[(a)]					25				

Notes:
Bold and underlined values indicate an exceedance of the WHO air quality guideline.
[a] BC MoE 2016.
$\mu g/m^3$ – microgram per cubic metre; MPOI – maximum point of impingement; $PM_{2.5}$ – particulate matter less than 2.5 microns; BC MoE –British Columbia Ministry of Environment.

9.1.6.1.2.2 Long-Term (Chronic)

PM_{10}

Annual maximum concentrations of PM_{10} were compared to the most conservative of the available health-based criterion (20 µg/m^3, WHO 2006). The maximum predicted annual concentrations were below the WHO guideline for all the receptor locations assessed. As predicted annual PM_{10} concentrations did not exceed the most conservative health-based criterion, PM_{10} concentrations were not evaluated further.

$PM_{2.5}$

The maximum predicted concentration of $PM_{2.5}$ was 6.2 µg/m^3 at all receptor locations except Camp Latona and Ekin's Point (both 6.3 µg/m^3) and the McNab Creek Strata (6.7 µg/m^3). With the exception of the McNab Creek Strata which was 9% higher than the predicted Base Case concentration (6.2 µg/m^3), Application Case concentrations at all receptor locations were similar to the Base Case concentration of 6.2 µg/m^3.

The BC MoE air quality objective of 8 µg/m^3 is an air management tool used to guide decisions on environmental impact assessments and authorizations, airshed planning efforts and regulatory development (BC MHLS 2009; BC MoE 2016). The BC MoE views the air quality objective of 8 µg/m^3 as an immediate target for all communities and indicates that communities are encouraged to maintain air quality levels below the air quality objective. In addition to the objective, the BC MoE also has a planning goal of 6 µg/m^3 which they indicate communities should strive to maintain levels less than or equal to the goal (BC MHLS 2009).

For the long-term particulate matter assessment, the planning goal of 6 µg/m^3 from the BC MoE (2016) was conservatively selected as the screening criterion. The planning goal is a voluntary target used to guide airshed planning efforts and encourage communities to maintain good air quality during economic growth and development (BC Ministry of Healthy Living and Sport [MLHS] 2009; BC MoE 2016). The primary reason for the proposal of a planning goal is to encourage a reduction in long-term exposure to $PM_{2.5}$ (BC MoE 2008b) because of the potential benefits associated with reducing $PM_{2.5}$ concentrations. $PM_{2.5}$ is a non-threshold pollutant and any exposure can potentially lead to health effects. However, the planning goal is not a regulatory objective, and although the predicted annual $PM_{2.5}$ concentrations at each receptor location exceeded this value in both the Base and Application Case, the concentrations were below the BC MoE (2016) air quality objective of 8 µg/m^3 which is considered to be a regulatory objective at all the receptor locations evaluated.

The BC MoE indicates that scientific studies have shown that higher mortality rates are associated with longer-term exposures to $PM_{2.5}$ (BC MoE 2008b), but have not provided information on the derivation of air criteria. Both the planning goal and the air quality objective are lower than the criteria provided by other jurisdictions (i.e., CCME, US EPA NAAQS and WHO). The predicted annual $PM_{2.5}$ concentrations were below the CCME Canadian Ambient Air Quality Standard (10 µg/m^3), US EPA NAAQS (12 µg/m^3) and WHO guideline (10 µg/m^3). A summary of the toxicological endpoints and derivations from CCME and US EPA NAAQS is provided below and in Volume 4, Part G – Section 22.0: Table 9.1-B-5 of Appendix 9.1-B.

9.1.6.1.2.3 Background Concentrations in Surrounding Areas

Details on the methods used to calculate background concentrations are provided in the Air Quality section (Part B, Section 5.7). Information that is relevant to the particulate matter assessment is summarized in this section.

Baseline modelling was not conducted for the Air Quality Assessment. Background concentrations were established using monitored data and a conservative value from monitoring stations was selected to represent the background concentration for the LSA (i.e., at all receptor locations).

Data from three air quality stations were used to characterize the background air quality of PM_{10} and $PM_{2.5}$. The three air quality monitoring stations in operation that record hourly particulate matter readings within the proximity of the Proposed Project site include:

- Langdale Elementary, located approximately 16 km to southwest;
- Horseshoe Bay, located approximately 23 km to southeast; and
- Squamish, located approximately 23 km to northeast.

PM_{10} recordings were available between January 2010 and December 2013 and $PM_{2.5}$ recordings were available between December 2011 and December 2013 at the Langdale Elementary monitoring station. The Horseshoe Bay monitoring station does not record PM_{10}. $PM_{2.5}$ recordings at Horseshoe Bay were available between January 2011 and December 2013. PM_{10} recordings were available between January 2010 and January 2011 and $PM_{2.5}$ recordings were available between February 2011 and December 2013 at the Squamish monitoring station.

The background concentration for 24-hour PM_{10} was 26.2 µg/m^3, which is the average of the 98th percentile values from the Langdale Elementary (19.9 µg/m^3) and Squamish (32.5 µg/m^3) stations. For 24-hour $PM_{2.5}$, the background concentration was determined by taking the 98th percentile value of Langdale Elementary for 2013 (14.3 µg/m^3), which was more conservative than the 2012 data (13.6 µg/m^3). Additional information on background concentrations of $PM_{2.5}$ and PM_{10} incorporated into the Base Case are provided in the Air Quality section (Part B, Section 5.7).

9.1.6.1.2.4 Conclusions

Sources of particulate matter include land clearing, aggregate extraction and initial processing, conveying from pit to processing, transfer to the barge and tug transport. Several dust mitigation measures will be applied during the operations phase of the Proposed Project, which include wet extraction technique, placement of a berm along the eastern boarder of the processing plant (Processing Area Dirt Berm) which will act as a wind barrier, enclosure of aggregate transfer points, maintaining a high moisture content of the material being handled, enclosure of crushers and screens at the processing plant and some underground conveying equipment. In addition, the two stock piles will be mist sprayed to keep dust at a minimum.

It is noted that the predicted particulate matter concentrations are very conservative and likely overestimate risk. It is also unlikely that people will spend extended periods of time at the MPOI. The conservatism in the particulate matter predictions is discussed further in Section 9.1.5.3.2.4.

Potential health effects of particulate matter concentration changes as a result of the Proposed Project were assessed qualitatively by a review of key epidemiological studies focused on health effects of particulate matter associated with dust.

Overall, uncertainty remains in evaluating the predicted particulate matter concentrations as particulate matter guidelines were based on epidemiological studies, which include confounding factors that can affect the results. In addition, the literature suggests that no threshold exists for particulate matter and that health effects are present at background levels of particulate matter in some countries. The 24-hour PM_{10} and $PM_{2.5}$ maximum, 95^{th} and 75^{th} percentile concentrations exceeded applicable screening values in the Application Case at the MPOI. The location of the MPOI did not overlap with any of the receptor locations and, therefore, use or access by the public is considered to be on an infrequent basis and, therefore, health effects are not anticipated.

Epidemiology studies, though not always consistent, suggest that composition of the particulate matter is the most important predictor of health outcomes (Stanek et al. 2011). The relationships between health effects and exposure to respirable particulate matter were derived from epidemiology studies based on large urban centres making comparisons to small rural areas challenging. In addition, the database related to health effects from particulate matter relies heavily on studies where the particulates are derived from combustion sources. Few studies were available concerning possible health outcomes from wind-blown dust (i.e., road dust or dust from open pits) – particularly for fine particulates (i.e., $PM_{2.5}$); however, some studies have found adverse health effects. These studies would suggest that health effects are possible if people are using the MPOI location; however that is not anticipated. The magnitude of risk as a result of the Proposed Project expected to be negligible at the receptor locations assessed, with the exception of MPOI, because predicted concentrations are well below the most conservative screening values for human health. For the MPOI where predictions were higher than the screening value, it is expected that the magnitude of risk will be low given the conservatism built into the model predictions.

9.1.6.1.3 Multimedia Assessment

In the risk characterization, the potential long-term health effects associated with multimedia exposure were evaluated by calculating HQs. The target HQ is typically 1 when all pathways of exposure are considered, including background dietary intake. However, because oral and dermal exposure to surface water were the only pathways evaluated in the current multimedia assessment, a target HQ of 0.2 was applied, which assumes that receptors may receive 80% of their daily exposure of titanium through other sources.

Hazard quotients for the Base Case and Application Case were calculated for titanium by comparing the predicted levels of exposure with the exposure limits according to the following equation:

$$HQ = \frac{\text{estimated daily intake}\left(\text{mg/kg BW/day}\right)}{\text{RfD (mg/kg BW/day)}}$$

The ingestion and dermal contact HQs were summed to give a total HQ value for the swimming pathway.

A HQ less than or equal to 0.2 indicates that the estimated exposure is less than 20% of the RfD, signifying negligible health effects. When the HQ for a particular scenario is greater than 0.2, then that scenario poses a potential concern and requires further investigation. However, HQ values greater than 0.2 do not necessarily indicate that adverse health effects will occur because of the margin of safety that is included in their estimation.

Results of the risk characterization are presented in Table 9.1-22. The resulting HQs for the Base Case and Application Case were below the target HQ of 0.2, therefore risks were considered negligible.

Table 9.1-22 Hazard Quotients for Titanium (Swimming Exposure)

Chemical of Potential Concern	Base Case	Application Case
Titanium	1.6E-06	1.8E-06

9.1.7 Mitigation

The mitigation measures assumed by the air and water quality teams are included in the predictions used for the human health risk assessment. Information on the mitigation measures are summarized in Volume 2, Part B - Section 5.7 (air quality) and Part B, Section 5.5 (surface water resources). Monitoring plans specific to human health will not be developed as part of the EA. If necessary, monitoring plans will be developed in the corresponding EA studies to confirm the predictions associated with predicted changes in levels of chemical constituents in environmental media to which humans may be exposed. Monitoring criteria specific to human health will be developed in co-operation with the originating discipline study team.

9.1.8 Residual Effects Assessment

9.1.8.1 Significance of Residual Effects

This section presents the classification and evaluation of the significance of the predicted potential residual effects identified in Section 9.1.5.3.

Air Quality, Particulate Matter and Multimedia Assessment

The significance of the predicted risks to human health in the air quality, particulate matter and multimedia assessment are presented in Table 9.1-23.

Table 9.1-23: Significance of Predicted Risks to Human Health from Inhalation Exposure for the Application Case

Chemical of Potential Concern	Receptors	Magnitude of Risk	Conservatism and Rationale	Residual Effects Conclusion	Mitigation Needed?
Acute Inhalation Assessment (1-Hour)					
Aluminum	Maximum off-site location (MPOI)	Low	Air quality concentrations were predicted using maximum emission rates for the Proposed Project. The predicted peak concentration at the MPOI exceeded the acute exposure limit in the Application Case, at a frequency of 42 hours in a year. However, the predicted concentrations were below those reported in the literature to result in health effects, even for longer exposures. In addition, the maximum off-site location in the Application Case does not overlap with any of the receptor locations identified for the air assessment. The MPOI is not anticipated to have frequent, if any, use by people; therefore, it is unlikely that there would be people present during the hours in a year when concentrations are elevated.	Not significant[1]	No
Iron	Maximum off-site location (MPOI)	Low	Air quality concentrations were predicted using maximum emission rates for the Proposed Project. The predicted peak concentration at the MPOI exceeded the acute exposure limit in the Application Case, at a frequency of 1166 hours in a year. However, the predicted concentrations were below those reported in the literature to result in health effects, even for longer exposures. In addition, the maximum off-site location in the Application Case does not overlap with any of the other receptor locations evaluated in the EA (i.e., communities and recreational areas). The MPOI is not anticipated to have frequent, if any, use by people; therefore, it is unlikely that there would be people present during the hours in a year when concentrations are elevated.	Not significant[1]	No
All COPCs	All Other Receptor Locations	Negligible	Air quality concentrations were predicted using maximum emission rates for the Proposed Project. The predicted peak concentrations at the remaining receptor locations were below acute criteria, and therefore health effects as a result of short term (1-hour) exposure during construction and operations are not anticipated.	Negligible-Not Significant	No

Chemical of Potential Concern	Receptors	Magnitude of Risk	Conservatism and Rationale	Residual Effects Conclusion	Mitigation Needed?
Acute Inhalation Assessment (24-Hour)					
Iron	Maximum off-site location (MPOI)	Low	Air quality concentrations were predicted using maximum emission rates for the Proposed Project. The air modelling was based on the assumption that most equipment will be operating continuously at maximum capacity, which is an assumption that can lead to an overestimate of the potential Proposed Project impacts. The predicted peak concentrations at the MPOI were expected to exceed the acute exposure limit in the Application Case, at a frequency of 252 days in a year. However, the predicted concentrations were below those at which health effects are reported in the literature. The maximum off-site location in the Application Case does not overlap with any of the receptor locations in the EA (i.e., communities and recreational areas). The MPOI is not anticipated to have frequent, if any, use by people; therefore, it is unlikely that there would be people present for 24 hours on the days in a year when concentrations are elevated.	Not significant[1]	No

Chemical of Potential Concern	Receptors	Magnitude of Risk	Conservatism and Rationale	Residual Effects Conclusion	Mitigation Needed?
Manganese	Maximum off-site location (MPOI)	Low	Air quality concentrations were predicted using maximum emission rates for the Proposed Project. The air modelling was based on the assumption that most equipment will be operating continuously at maximum capacity, which is an assumption that can lead to an overestimate of the potential Proposed Project impacts. The predicted peak concentrations at the MPOI were anticipated to exceed the acute exposure limit in the Application Case, at a frequency of 51 days in a year. However, the predicted concentrations were below those at which health effects are reported in the literature. The maximum off-site location in the Application Case does not overlap with any of the other receptor locations evaluated in the EA (i.e., communities and recreational areas). The MPOI is not anticipated to have frequent, if any, use by people; therefore, it is unlikely that there would be people present for 24 hours on the days in a year when concentrations are elevated.	Not significant[1]	No
All COPCs	All Other Receptor Locations Evaluated	Negligible	Air quality concentrations were predicted using maximum emission rates for the Proposed Project. The air modelling was based on the assumption that most equipment will be operating continuously at maximum capacity, which is an assumption that can lead to an overestimate of the potential Proposed Project impacts. The predicted peak concentrations at the remaining receptor locations were below acute criteria, and therefore health effects as a result of short term (24-hour) exposure during construction and operations are not anticipated.	Negligible-Not Significant	No

Chemical of Potential Concern	Receptors	Magnitude of Risk	Conservatism and Rationale	Residual Effects Conclusion	Mitigation Needed?
Chronic Inhalation Assessment (Annual)					
All COPCs	All Other Receptor Locations Evaluated	Negligible	Air quality concentrations were predicted using maximum emission rates for the Proposed Project. The air modelling was based on the assumption that most equipment will be operating continuously at maximum capacity, which is an assumption that can lead to an overestimate of the potential Proposed Project impacts for the annual averaging period. The predicted peak annual concentrations at all receptor locations assessed were below chronic criteria, and therefore health effects as a result of long term (annual) exposure as a result of the Proposed Project are not anticipated.	Negligible-Not Significant	No
Particulate Matter Assessment (Acute – 24-Hour)					
$PM_{2.5}$	MPOI	Low	Conservatism in the air quality modelling (e.g., use of the maximum emission rates, assumption that all equipment will be operating continuously at maximum capacity), means that predicted concentrations are likely to have been overestimated. In addition, the assumption that receptors will spend a significant amount of time at the MPOI is overly conservative given that it is not located at any of the receptor locations identified for the Proposed Project.	Not significant[1]	No
PM_{10}	MPOI	Low	Conservatism in the air quality modelling (e.g., use of the maximum emission rates, assumption that all equipment will be operating continuously at maximum capacity), means that predicted concentrations are likely to have been overestimated. In addition, the assumption that receptors will spend a significant amount of time at the MPOI is overly conservative given that it is not located at any of the receptor locations identified for the Proposed Project.	Not significant[1]	No

Chemical of Potential Concern	Receptors	Magnitude of Risk	Conservatism and Rationale	Residual Effects Conclusion	Mitigation Needed?
$PM_{10}/PM_{2.5}$	All other locations evaluated	Negligible	Conservatism in the air quality modelling (e.g., use of the maximum emission rates, assumption that all equipment will be operating continuously at maximum capacity, which is an assumption that can lead to an overestimate of the potential Proposed Project impacts. The predicted peak concentrations at the remaining receptor locations were below acute criteria, and therefore health effects as a result of short term (24-hour) exposure during construction and operations are not anticipated.	Negligible-Not Significant	No
Particulate Matter Assessment (Chronic)					
$PM_{2.5}$	All receptor location evaluated	Negligible	Conservatism in the air quality modelling (e.g., use of the maximum emission rates, assumption that all equipment will be operating continuously at maximum capacity), means that predicted concentrations are likely to have been overestimated. In addition, all concentrations were below the regulatory air quality objective set by the province and below criteria set by the other jurisdictions used in this assessment. The greatest contributor to particulate matter concentrations predicted is the background levels which also exceeded the planning objective used for screening in this assessment.	Negligible-Not Significant	No
PM_{10}	All locations evaluated	Negligible	Air quality concentrations were predicted using maximum emission rates for the Proposed Project. The air modelling was based on the assumption that most equipment will be operating continuously at maximum capacity, which is an assumption that can lead to an overestimate of the potential Proposed Project impacts for the annual averaging period. The predicted peak annual concentrations at all the receptor locations assessed were below the chronic criterion, and therefore health effects as a result of long term (annual) exposure as a result of the Proposed Project are not anticipated.	Not Significant	No

Chemical of Potential Concern	Receptors	Magnitude of Risk	Conservatism and Rationale	Residual Effects Conclusion	Mitigation Needed?
Multimedia Assessment					
Titanium	Recreational Users	Negligible	The HQ for swimming pathways was below the target of 0.2, despite the high level of conservatism employed throughout the assessment. Exposure to chemicals in soil, vegetation, game, and fish was not retained for the multimedia assessment, based on the COPC and pathway screening conducted as part of the problem formulation.	Not Significant	No

Notes:
[1] Exceedances of acute exposure limits at the MPOI are not considered to be significant.
COPC – chemical of potential concern; EA – environmental assessment; HQ – hazard quotient; MPOI – maximum point of impingement; PM_{10} – particulate matter less than 10 microns; $PM_{2.5}$ – particulate matter less than 2.5 microns.

9.1.8.1.1 Uncertainty and Prediction Confidence

These sources of uncertainty and the predicted effect on the results of the risk assessment are described below. After identifying the major sources of uncertainty, a level of confidence was assigned to each residual effect. Important considerations with respect to prediction confidence included:

- The number of samples and quality of the baseline data were considered to be adequate for characterizing Base Case metal concentrations in environmental media (soil, and surface water).
- The maximum predicted surface water concentrations over the duration of the Proposed Project were applied in the multimedia exposure assessment for human health. Predicted concentrations in surface water were based on for a conservative modelling scenario, which may have overestimated surface water concentrations of titanium.
- The air quality and deposition rate predictions used the maximum emission rates from the Proposed Project; however, this assumption is conservative due to the fact that most equipment does not operate at its maximum capacity on a continuous basis. This assumption can lead to an overestimate of the potential Proposed Project effects for the longer averaging periods (24-hour and annual). Secondly, the effect of precipitation in reducing fugitive emissions from unpaved roads and wind erosion of stockpiles was not considered in the modelling, resulting in an overestimate of annual air quality predictions and deposition rates.
- The Base Case particulate matter concentrations were established using background data from Langdale Elementary where monthly median $PM_{2.5}$ concentrations are near 5 ug/m^3 and annual concentrations were calculated to be 6.2 ug/m^3. Langdale Elementary is located in an urban area and concentrations measured at the monitoring station will be influenced by anthropogenic sources such as emissions from vehicles, wood furnaces, natural gas combustion etc. The Proposed Project is located over 15 km north-east of the Elementary School and is 8 km away from the pulp and paper mill located at Port Mellon; therefore, the use of background data measured at Langdale Elementary is expected to result in conservative predictions.
- There is conservatism in the screening criteria chosen for screening in this assessment. Some examples include the use of screening criteria without supporting documentation or use of 1-hour or 24-hour criteria that were based on chronic values.

Overall, there were several model inputs and assumptions that were considered to result in over-prediction of exposure and resulting risks for human health.

9.1.8.1.2 Level of Confidence

The confidence in the residual effects predicted for COPCs in the human health risk assessment were considered to be high for metal parameters given that the risk estimates based upon conservative assumption. The particulate matter confidence is rated as moderate given that the current state of research on particulate matter does not provide enough evidence to relate specific health outcomes to isolated sources or factors and a threshold has not been identified for health effects associated with particulate matter. A summary of predicted confidence for each residual effect is presented in Table 9.1-24.

Table 9.1-24: Prediction Confidence for Each Residual Effect in the Human Health Risk Assessment

Chemical of Potential Concern	Receptor Location	Confidence for Each Residual Effect
Acute Inhalation (1-hour)		
Aluminum	Maximum off-site location (MPOI)	High
Iron	Maximum off-site location (MPOI)	High
All COPCs	All other locations assessed	High
Acute Inhalation (24-hour)		
Iron	Maximum off-site location (MPOI)	High
Manganese	Maximum off-site location (MPOI)	High
All COPCs	All other locations assessed	High
Particulate Matter Assessment (24-hour)		
PM_{10}	Maximum off-site location (MPOI)	Moderate
$PM_{2.5}$	Maximum off-site location (MPOI)	Moderate
$PM_{10}/PM_{2.5}$	All other locations evaluated	Moderate
Particulate Matter Assessment (Annual)		
PM_{10}	All locations evaluated	Moderate
$PM_{2.5}$	All locations evaluated	Moderate
Multimedia Assessment		
Titanium	Recreational User in the pit lake	High

Notes:
COPC – chemical of potential concern; MPOI – maximum point of impingement; PM_{10} – particulate matter less than 10 microns; $PM_{2.5}$ – particulate matter less than 2.5 microns.

9.1.8.2 Cumulative Effects Assessment

Cumulative effects result from interactions between Proposed Project-related residual effects and incremental effects of past, present and reasonably foreseeable projects and activities. Potential effects from past and present projects were assessed as part of the baseline conditions. Cumulative effects assessment methodology is described in Section 4.6.

Residual effects in the human health risk assessment were determined to be not significant. It was not possible to conduct a quantitative cumulative effects assessment for human health, as there is insufficient information available to conduct water and air quality modelling of other past, present and reasonably foreseeable projects and activities and this modelling has therefore, not been carried out.

Metals (aluminum, iron, and manganese) will be emitted to air in the form of particulate matter as fugitive dust from activities such as land clearing, and fugitive dust from aggregate extraction and processing; predicted aluminum and iron concentrations exceed 1-hour human health objectives at the MPOI and predicted iron and manganese concentrations exceed 24-hour human health objectives at the MPOI.

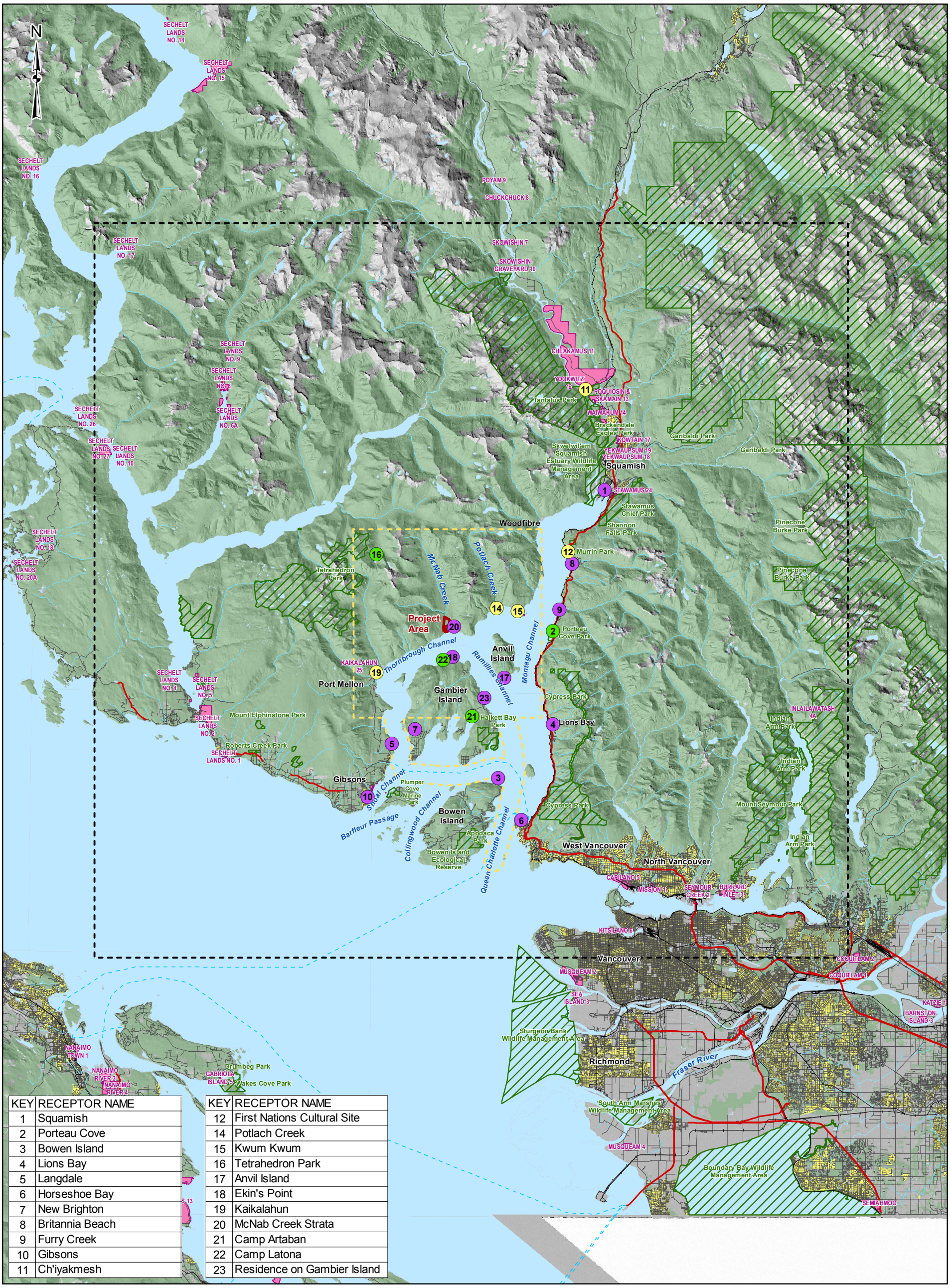
The air quality assessment (Volume 2, Part B – Section 5.7) presents an assessment of residual Proposed Project related effects of particulate matter for both short term (e.g. 24-hour) and long term (e.g. annual) averaging periods. Residual effects were classified as "not significant", therefore a cumulative effects assessment was undertaken for particulate emissions to air and is presented within Volume 2, Part B – Section 5.7 (not significant and significant residual effects are carried forward to the cumulative effects assessment as outlined in Volume 2, Part B – Section 4.5). Similar to the Proposed Project, emissions of aluminum, iron and manganese from past, present and reasonably foreseeable projects are expected to be emitted as particulates. And hence the cumulative effects assessment methodology and conclusions with respect to particulate matter is also applicable to emissions of aluminum, iron and manganese. The cumulative effects assessment undertaken for particulate matter concluded that the cumulative residual effect was assigned as negligible.

9.1.9 Conclusions

It is likely that risks have been over-estimated rather than under-estimated. In addition, as the potential VCs and pathways do not have significant residual effects for each COPC, it is considered unlikely that the Proposed Project will have a significant effect on human health. The results are summarized in Table 9.1-25.

Table 9.1-25 Results of Human Health Risk Assessment

Potential Effect	Proposed Project Phase Effect Occurs In	Contributing Proposed Project Activity	Proposed Mitigation	Residual Effect
Human Health – Air Quality	Application Case including construction, operation and closure.	Proposed Project activities contributing to emission of constituents to air.	None Confirmation that a Health and Safety Plan (Part E, Section 16.0) for workers covers the mitigation of exposure of workers to dust and particulate matter	Not significant
Human Health-Particulate Matter	Application Case including construction, operation and closure.	Proposed Project activities contributing to emission of constituents to air.	None Confirmation that a Health and Safety Plan (Part E, Section 16.0) for workers covers the mitigation of exposure of workers to dust and particulate matter	Not significant
Human Health – Multimedia	Application Case including construction, operations and closure.	Proposed Project activities contributing to deposition of particulate matter to terrestrial environments; and emission of substances to aquatic environments.	None	Negligible



KEY	RECEPTOR NAME
1	Squamish
2	Porteau Cove
3	Bowen Island
4	Lions Bay
5	Langdale
6	Horseshoe Bay
7	New Brighton
8	Britannia Beach
9	Furry Creek
10	Gibsons
11	Ch'iyakmesh

KEY	RECEPTOR NAME
12	First Nations Cultural Site
14	Potlach Creek
15	Kwum Kwum
16	Tetrahedron Park
17	Anvil Island
18	Ekin's Point
19	Kaikalahun
20	McNab Creek Strata
21	Camp Artaban
22	Camp Latona
23	Residence on Gambier Island

LEGEND

- Project Area
- Local Study Area
- Regional Study Area
- Park / Protected Area
- Vegetation
- Indian Reserve
- Residential Area
- Highway
- Road
- Railway
- Ferry

Receptor Type (Key Number)

- Recreational User
- First Nations Resident
- Community Resident

12 0 12

SCALE 1:400,000 KILOMETRES

REFERENCE

Sensitive receptors based on First Nation Reserves, recreational campgrounds, and sites determined by Golder Associates Ltd personnel. Parks/protected areas from the Province of British Columbia. Contours and indian reserves from GeoBase. Base data from CanVec © Department of Natural Resources Canada. All rights reserved. Hillshade provided by Government of British Columbia.
Projection: UTM Zone 10 Datum: NAD 83

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

LOCAL AND REGIONAL STUDY AREAS AND RECEPTOR LOCATIONS FOR HUMAN HEALTH RISK ASSESSMENT

Golder Associates

PROJECT NO. 11-1422-0046			PHASE No.		
DESIGN	AMN	08 Sept 2015	SCALE AS SHOWN		REV. 0
GIS	DL	09 Mar. 2016	**FIGURE 9.1-1**		
CHECK	AMN	09 Mar. 2016			
REVIEW	AW	09 Mar. 2016			

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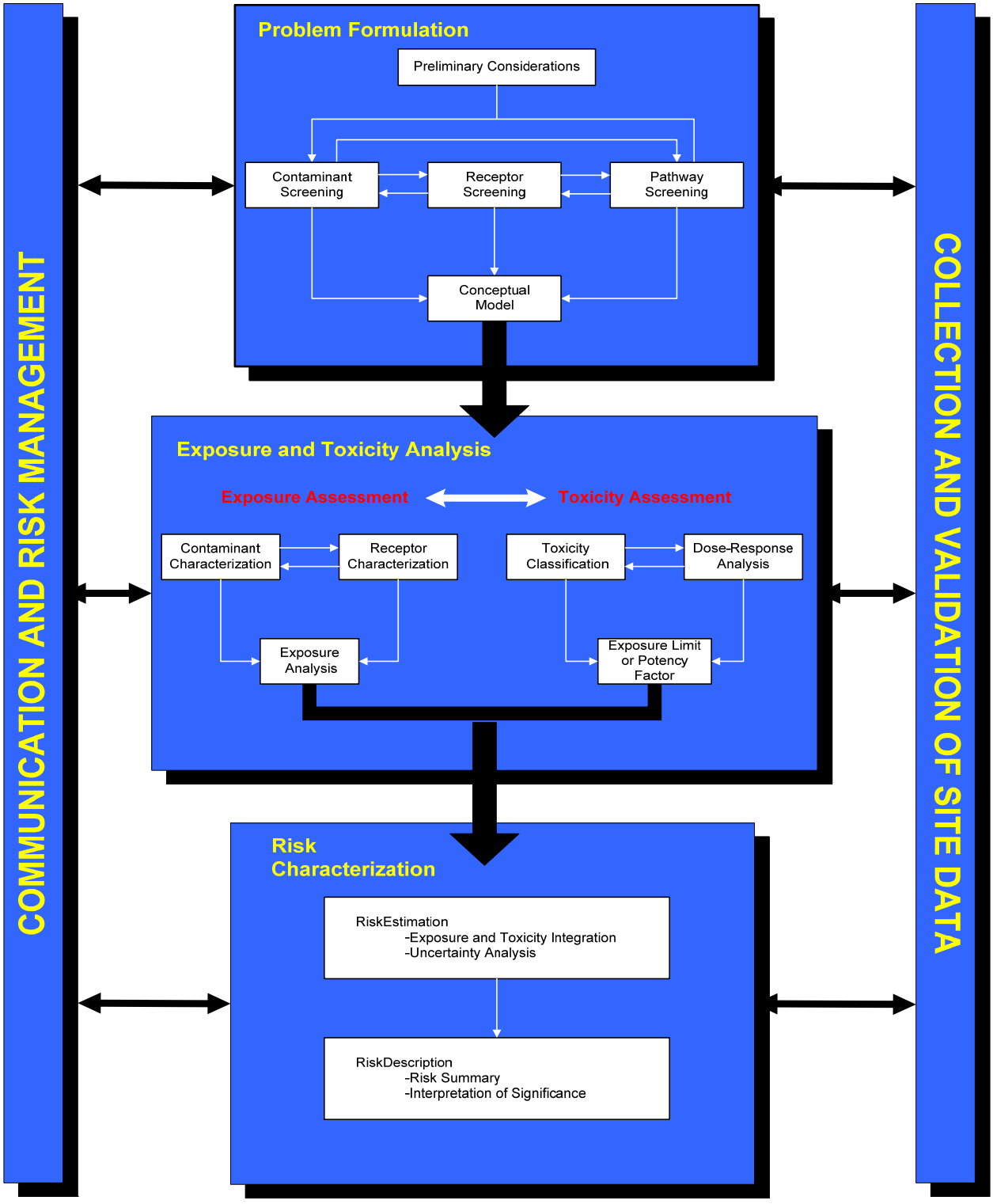
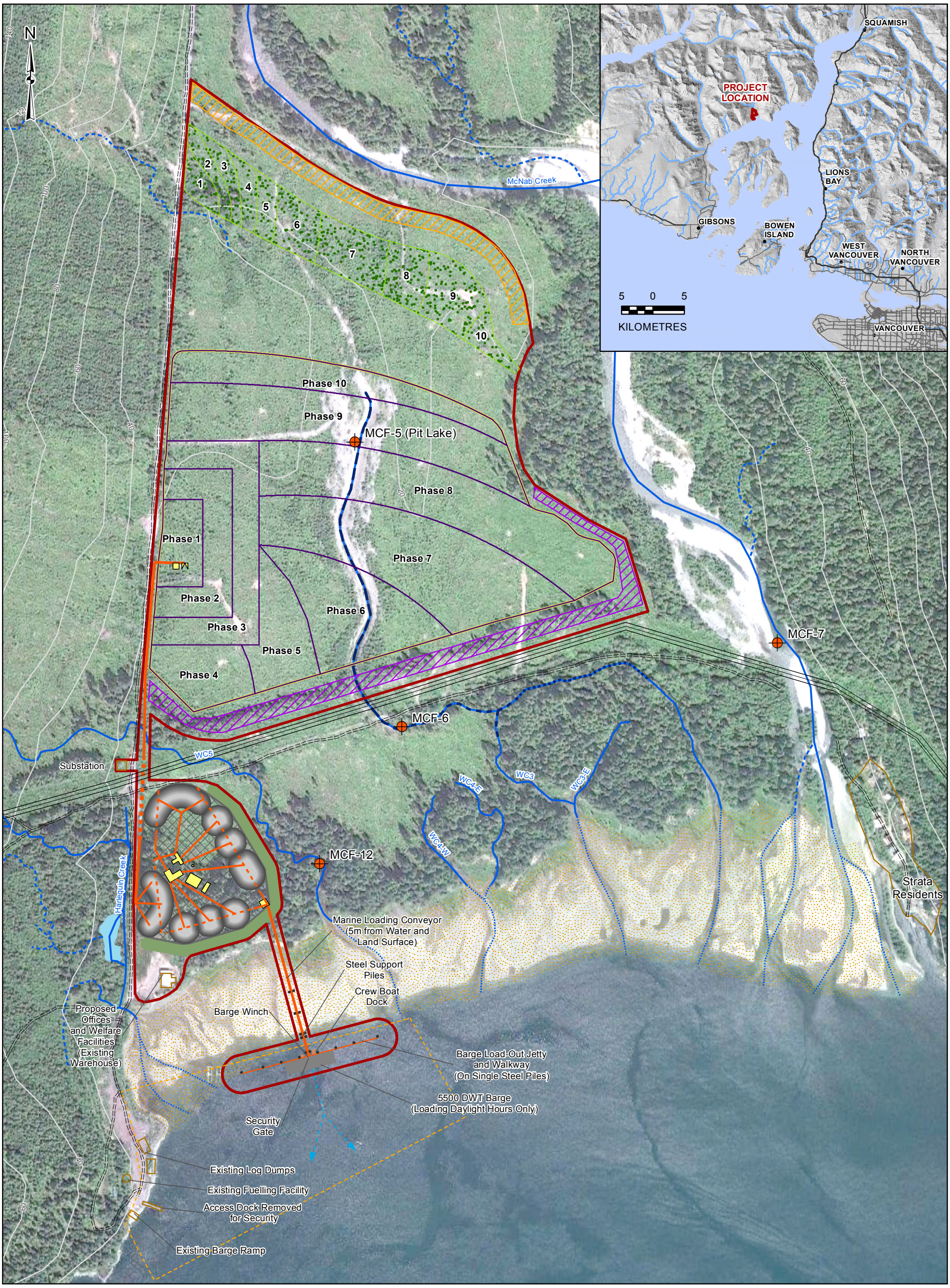


Figure 9.1-2: Framework for Human Health Risk Assessment



LEGEND

- Predicted Water Quality Location
- Project Area
- Proposed Aggregate Pit Phase
- Final Pit Lake Outline
- McNab Creek Flood Protection Dyke
- Pit Lake Containment Berm
- Product Stockpile
- Fines Storage Area
- Processing Area
- Existing Feature
- Existing Log Tenure Area
- Possible Processing Plant Configuration
- Processing Area Berm
- Intertidal Zone
- Elevated Conveyor
- Underground Conveyor
- Barge Load-out
- Transmission Line
- Road (Existing)
- Contour (20m)
- Barge Route
- Pile
- Permanent / Perennial Watercourse
- Intermittent Watercourse
- Intertidal Watercourse

Constructed Watercourse

- Phase 1 (1985)
- Phase 2 (1998)
- Phase 3 (2001 - 2003)

REFERENCE

Watercourses from the Province of British Columbia and field data. Base data from the Province of British Columbia. All rights reserved. Contours from TRIM positional data. Base Imagery from Google Maps 20100807. Projection: UTM Zone 10 Datum: NAD 83

200 0 200

SCALE 1:6,000 METRES

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

PREDICTED SURFACE WATER QUALITY LOCATIONS

Golder Associates

PROJECT NO. 11-1422-0046			PHASE No.	
DESIGN	LC	03 Nov 2014	SCALE AS SHOWN	REV. 0
GIS	DL	09 Mar. 2016		
CHECK	LC	09 Mar. 2016		
REVIEW	AW	09 Mar. 2016		

FIGURE 9.1-3

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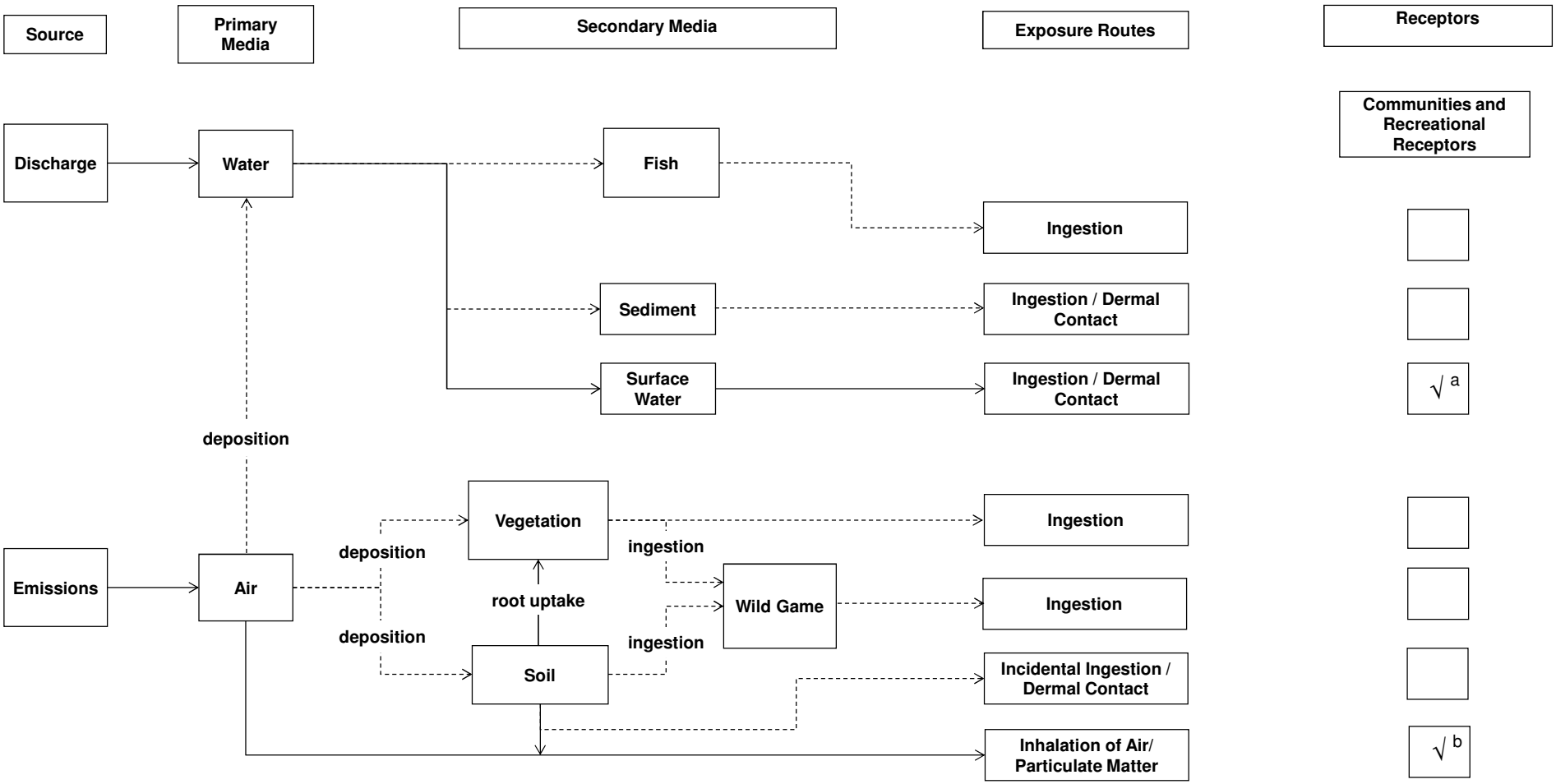

Legend

√ Complete Exposure Pathway

----- Incomplete Pathway (i.e., no impact related to the Project)

a) Pathway retained for the multimedia assessment
b) Pathway retained for the air /particulate matter assessment

Conceptual Exposure Model for the Human Health Risk Assessment
Proposed BURNCO Project

Golder Associates

PROJECT No. 11-1422-0046			FILE No. ----	
DESIGN	LM	10Feb2015	SCALE NTS	REV.
CHECK	AKN	16Mar2015	**FIGURE 9.1-4**	
REVIEW	AKW	16Mar2015		