Appendix 9.2.2A
Human Health and Ecological Risk Assessment

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ACRONYMS

Abbreviations and Units of Measure	Definition
AAQO	Ambient Air Quality Objectives
ADD	Average Daily Dose
AEGL	Acute Exposure Guideline Level
ATSDR	Agency for Toxic and Substances and Disease Registry
BC	British Columbia
BC EAA	British Columbia *Environmental Assessment Act*
BC EAO	British Columbia Environmental Assessment Office
BC MELP	British Columbia Ministry of Environment, Lands and Parks
BC MOE	British Columbia Ministry of Environment
CAC	criteria air contaminant
CalEPA	California Environmental Protection Agency
CCME	Canadian Council of Ministers of the Environment
CEA Act	*Canadian Environmental Assessment Act*
CH_4	methane
cm^2	square centimetres
CO	carbon monoxide
CO_2	carbon dioxide
COPC	Chemical of Potential Concern
CWS	Canada-wide Standards
EA	environmental assessment
EC	Environment Canada
Eco-SSL	Ecological Soil Screening Level
EPC	Exposure Point Concentration
ER	Exposure Ratio
ERA	ecological risk assessment
g/d	grams per day
g/s	grams per second
HC	Health Canada
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
ILCR	Incremental Lifetime Cancer Risk
IRIS	Integrated Risk Information System
kg	kilogram

Abbreviations and Units of Measure	Definition
L/d	litres per day
LOAEL	Lowest Observable Adverse Effect Level
LSA	Local Study Area
m	metre
m^3/d	cubic metres per day
MDL	method detection limit
µg/g	micrograms per gram
mg/cm^2	milligrams per square centimetres
mg/m^3	milligrams per cubic metre
mg/kg/d	milligrams per kilogram body weight per day
mg/L	milligrams per litre
n/a	not available/applicable
NAAQO	National Ambient Air Quality Objectives
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
NOAEL	No Observable Adverse Effect Level
PAH	polycyclic aromatic hydrocarbon
PIRI	Partnership in Risk Based Corrective Action Implementation
PM	particulate matter
$PM_{2.5}$	particulate matter no greater than 2.5 micrometres in aerodynamic diameter
PM_{10}	particulate matter no greater than 10 micrometres in aerodynamic diameter
Project (the)	Proposed Blackwater Gold Project
RAF	Relative Absorption Factor
RAIS	Risk Assessment Information System
RfC	Reference Concentration
RfD	Reference Dose
RSA	Regional Study Area
SARA	*Species at Risk Act*
SO_2	sulphur dioxide
TC	tolerable concentration
TCEQ	Texas Commission on Environmental Quality
TRV	toxicological reference value
UCL	Upper Confidence Limit
US EPA	United States Environmental Protection Agency
VC	valued component
VOC	volatile organic compound

EXECUTIVE SUMMARY

This section assesses the potential project-specific and cumulative effects and risks to humans and other organisms that may be exposed to Chemicals of Potential Concern (COPCs) associated with the proposed Blackwater Gold Project (the Project). The environmental health component of the Proponent's Application for an Environmental Assessment Certificate was completed pursuant to Section 16 of the British Columbia *Environmental Assessment Act* (BC *EAA).* An Environmental Impact Statement for an environmental assessment was prepared pursuant to the *Canadian Environmental Assessment Act* (*CEA) 2012* (Application) to determine potential adverse impacts to the biophysical environment and to the health of people and other ecological organisms from hypothetical cumulative exposures to COPCs in all environmental media. The assessment also quantifies and prioritizes potential carcinogenic and non-carcinogenic health effects in accordance with risk assessment methodologies from Health Canada (HC), Environment Canada (EC), and British Columbia Ministry of Environment (BC MOE).

Risk assessment methods were used to develop a comprehensive understanding of the source of COPCs, their release mechanisms, their fate and transport mechanisms after being released to the environment, and the methods by which sensitive receptors might be exposed.

According to the British Columbia Ministry of Environment's (BC MOE) "*Quantitative Human Health Risk Assessment* – Phase 1 Review of Methods and Framework Recommendation" (BC MOE, 1993), Human Health Risk Assessment (HHRA) is defined as "the process whereby all available scientific information is brought together to produce a description of the nature and magnitude of the risk associated with exposure of human receptors to an environmental chemical." This information includes:

- Problem formulation: Identification of receptors, exposure pathways, and chemicals present in the environment;
- Toxicity assessment: an evaluation of the types of toxicity that the chemical can produce and an evaluation of the conditions of exposure—dose and duration—under which the chemical's toxicity can be produced;
- Exposure assessment: an identification of the conditions—dose, timing, and duration—under which the population whose risk is being evaluated is or could be exposed to the chemical; and
- Risk characterization: an estimate of the risk and uncertainty in that risk (BC MOE, 1993).

The approach adopted in evaluating the potential risks to human health of the Project was consistent with the approach recommended by HC (2010a), which has established a four-step paradigm for conducting health-based risk assessments. This paradigm has also been adopted by Canadian federal and provincial health and environmental agencies (e.g., BC MOE, Atlantic Partnership in Risk Based Corrective Action Implementation (PIRI), and the Ontario Ministry of the Environment).

The ecological risk assessment (ERA) for the Project was completed according to the "Recommended Guidance and Checklist for Tier 1 Ecological Risk Assessment of Contaminated Sites in British Columbia" (BC Ministry of Environment, Lands and Parks (BC MELP), 1998), and the Canadian Council of Ministers of the Environment's (CCME) "A Framework for Ecological Risk Assessment" (CCME, 1997). BC MELP (1998) defines ERAs as the determination of the probability of an effect occurring to an ecological system.

The first step of the risk assessment was to evaluate whether a particular chemical was currently present at levels that could pose a potential unacceptable health risk to human and ecological receptors. Considerations included the fate and behaviour of the chemicals in the environment and the toxicity based on various sources of exposure (i.e., air, water, soil, and food) and routes of exposure (i.e., inhalation, ingestion, and dermal) to the human and ecological receptors.

COPCs that were carried forward into the assessment were:

• Aluminum	• Dibenz(a,h)anthracene
• Arsenic	• Ethylbenzene
• Benzene	• Indeno(1,2,3-cd)pyrene
• Benzo(a)anthracene	• Lead
• Benzo(a)pyrene	• Mercury
• Benzo(b)fluoranthene	• Molybdenum
• Benzo(g,h,i)perylene	• Selenium
• Benzo(k)fluoranthene	• Toluene
• Cadmium	• Vanadium
• Chromium	• Xylene
• Chrysene	• Zinc
• Copper	• Criteria Air Contaminants (CO, NO2, SO2, PM2.5, PM10)
• Cyanide	

Human Health Risk Assessment

The exposure scenario assessed for non-carcinogenic chemicals involved an Aboriginal toddler accompanying an adult who spent all his time in the region engaged in traditional harvesting of country foods (i.e., hunting or fishing) or recreational activities (i.e., hiking) within the study areas of the proposed Project. The toddler could potentially be exposed to concentrations of COPCs via direct contact with soil and surface water, inhalation of dust and emissions, or ingestion of soil, surface water, vegetation, wild game and fish. Similarly, the assessment of carcinogenic chemicals focused on an Aboriginal adult who spends the same amount of time in the study areas and also engages in traditional activities. He/she could also potentially be exposed to concentrations of COPCs via direct contact with soil and surface water, inhalation of dust and emissions, or ingestion of soil, surface water, wild game and fish.

The findings of the HHRA are described below with regard to criteria air contaminants (CACs) and COPCs.

CACs

- Predicted 1-hour, 8-hour, and 24-hour ground-level NO_2, SO_2, $PM_{2.5}$, PM_{10} and CO concentrations do not result in any acute short-term exposure HQ values above 1.0 for any of the receptor locations. The highest HQ values for NO_2, SO_2, $PM_{2.5}$, PM_{10} and CO are 0.051, 0.00067, 0.065, 0.19 and 0.023, respectively, at Tatelkuz Lake Resort and Tatelkus Lake IR 28. Adverse health effects for human receptors are unlikely to occur following acute short-term exposures to NO_2, SO_2 $PM_{2.5}$, $PM_{2.5}$ and CO.
- Predicted annual ground-level NO_2, SO_2 and $PM_{2.5}$ concentrations do not result in any chronic HQ values above 1.0 for any of the receptor locations. The highest HQ values for annual chronic exposure to NO_2, SO_2 and $PM_{2.5}$ are 0.14, 0.041, and 0.53, respectively, at Tatelkuz Lake Resort and Tatelkus Lake IR 28. There is no consistent pattern in regards to the total HQ values between the baseline conditions and the effects assessment. However, since the total HQ values in the baseline condition and effects assessment remain less than 1.0, adverse health effects for human receptors are unlikely to occur following chronic exposures to NO_2, SO_2 and $PM_{2.5}$.

COPCs

- The risk estimate for chronic exposures to arsenic is above HC's target risk level of 1.0×10^{-5} for the adult receptor (for both adult alone and composite lifetime receptor) at each human receptor location. ILCRs ranged from 2.0×10^{-4} at Laidman Lake Ecolodge and Pan Phillips Resort to 2.1×10^{-4} at Tatelkuz Lake Resort, Tatelkus Lake IR 28, and Blackwater Spruce Ranch. Both the baseline and effects assessment had ILCR values greater than 1.0×10^{-5} for human receptors. The primary exposure pathway that contributes the most to the carcinogenic risks for arsenic exposure is through ingestion of surface water and fish. However, effects assessment ILCRs are noted to be lower when compared to the baseline ILCRs. This is expected since the predicted surface water concentrations for the EA are low and within BC Freshwater Guidelines or site specific water quality objectives. Moreover, although there are exceedances, uncertainties exist in the risk assessment process, both in the derivation of TRVs as well as the exposure assessment assumptions that may tend to overestimate the risk. Actual exposures are expected to be substantially lower than those presented in this assessment. Also, conservative assumptions were considered throughout the assessment with regards to exposure duration. For example, the adult receptor was assumed to spend their entire lifetime within the LSA. In addition 100% of the arsenic was assumed to be in its most toxic trivalent form and not in the less toxic pentavalent form. Releases of arsenic in drainage and dust from the mine site are expected to be in the pentavalent form. These assumptions are expected to overestimate the level of risks to the adult receptor from exposure to arsenic for both baseline and effects exposures.
- Risks associated with most non-carcinogenic COPCs for both chronic and acute exposure are noted to be below HC's risk target level of 0.2 for non-carcinogenic effects. Non-carcinogenic risk from arsenic is greater than HC's target risk level of 0.2 with a value of 0.99 but is lower than the baseline HQ level of 1.2. Cyanide marginally exceeds

the target risk level of 0.2 with a value of 0.31. Risks associated with the remaining carcinogenic COPCs, including PAHs as a mixture, for both the adult alone and composite adult (i.e., amortized over lifetime) receptor is below HC's risk target level of $1.0x10^{-5}$ for carcinogenic effects except for arsenic where the risk due to the Project is lower than the baseline. The health risk to human receptors from exposure to COPCs from the Project is not significant.

Ecological Risk Assessment

The ecological receptors that were selected and evaluated in this assessment are:

- Mammals (large and small carnivores/omnivores, large and small herbivores, and small insectivores);
- Birds (raptors, songbirds, and waterbirds/waterfowl);
- Amphibians;
- Fish;
- Invertebrates (soil and aquatic); and
- Plants (terrestrial and aquatic).

The findings of the ERA for the COPCs that exceed the criterion are described below.

Mammals

- ERs for aluminum exceed 1.0 for grizzly bear, caribou, and snowshoe hare with values of 2.2, 2.9 and 7.2 respectively and are below 1.0 for marten and short-tailed shrew. Based on the results of each individual exposure pathway for aluminum, the primary contributing exposure pathway of risk is via the ingestion of plant tissue for grizzly bear, caribou, and hare. The Project emissions increased the ER values for aluminum.
- ERs for copper exceed 1.0 for the short-tailed shrew with a value of 2.4 and are below 1.0 for grizzly bear, caribou, marten, and snowshoe hare. Based on the results of each individual exposure pathway for copper, the primary contributing exposure pathway of risk is via ingestion of soil invertebrates for the shrew. There were incremental increases from the baseline to the effects assessment. ER values are less than 1.0 for short-tailed shrew in the baseline and greater than the criterion of 1.0 in the effects assessment. The Project emissions increased the ER values for copper.
- ERs for molybdenum marginally exceed 1.0 for snowshoe hare with a value of 1.8 and are below 1.0 for grizzly bear, caribou, marten, and short-tailed shrew. Based on the results of each individual exposure pathway for molybdenum, the primary contributing exposure pathway of risk is via the ingestion of plant tissue for snowshoe hare. As demonstrated in the baseline and effects assessment result tables (**Table 3.2-1** and **Table 4.4-28**), exceedances are present in both cases with ER values of 5.8 for the baseline and 1.8 for the EA. The Project does not increase the ER values for molybdenum.
- ERs for vanadium marginally exceed 1.0 for the snowshoe hare and the short-tailed shrew with a value of 1.1 and 1.3, respectively and are below 1.0 for grizzly bear, caribou, and marten. Based on the results of each individual exposure pathway for

vanadium, the primary contributing exposure pathway of risk is via ingestion of plants for the snowshoe hare and via the ingestion of soil and soil invertebrates for the shrew. The Project emissions marginally increase the ER values for vanadium.

Birds

- ERs for zinc exceed 1.0 for the olive-sided flycatcher and the ring-necked duck with values of 3.8 and 1.7, respectively and are below 1.0 for red-tailed hawk and Pacific loon. Based on the results of each individual exposure pathway for zinc, the primary contributing exposure pathway of risk is via the ingestion of soil invertebrates for the olive-sided flycatcher and via ingestion of aquatic invertebrates for the ring-necked duck. As demonstrated in the baseline and effects assessment result tables, exceedances are present in both cases and no major differences exist between the baseline and EA. The Project does not increase the ER values for zinc.

Amphibians

- Toxicity data for amphibians (e.g., western toad) exposed to COPCs are extremely limited. A review of the scientific literature identified no appropriate toxicity limits for amphibian exposure to COPCs in soil. Available toxicological literature on amphibians focuses mainly on organic compounds (e.g., pesticides, fertilizers) affecting early life stages (eggs and tadpoles). COPCs emitted from the proposed Project are not expected to be 100% bioavailable, and the absence of any acceptable TRVs results in uncertainties and low levels of confidence for measuring health risks to amphibians from COPCs for the exposure pathways expected for this receptor.

Fish

- ERs for copper marginally exceed 1.0 for fish. There are incremental increases between the baseline and the effects assessment. ER values are less than 1.0 for fish in the baseline with a value of 0.29 and greater than the criterion of 1.0 in the effects assessment with a value of 1.2. The primary contributing exposure pathway of risk is via direct contact with surface water. Although ERs are greater than 1.0 in the EA, water quality downstream of the mine site is expected to be within BC Freshwater Quality Guidelines or site-specific water quality objectives and should be protective of aquatic life. As a result, it is important to note that the magnitude of the ER is marginal for copper in fish and does not indicate that adverse health effects in fish will be observed. ERs for the remaining COPCs are noted to be orders of magnitude lower than 1.0.

Soil Invertebrates and Terrestrial Plants

- ERs for molybdenum marginally exceed 1.0 for soil invertebrates and terrestrial plants with a value of 1.3 for both receptors. There is a slight variation in the ER values detected between the baseline and the effects assessment, but generally speaking, no major differences are observed. The primary contributing exposure pathway of risk is via direct contact with soil. The Project does not increase the ER values for molybdenum. ERs for the remaining COPCs are noted to be orders of magnitude lower than 1.0.

Aquatic Invertebrates and Aquatic Plants

- ERs for copper exceed 1.0 for the aquatic invertebrates and aquatic plants with values of 19.3 and 4.5, respectively. There is a difference detected between the baseline and effects assessment. Baseline ER values are 4.8 for aquatic invertebrates and 1.1 for aquatic plants. The primary contributing exposure pathway of risk is via direct contact with surface water. Although ERs are greater than 1.0 in the effects assessment, water quality downstream of the mine site is expected to be within BC Freshwater Quality Guidelines or site-specific water quality objectives and should be protective of aquatic life. As a result, it is important to note that the magnitude of the ER for copper in aquatic Invertebrates and plants does not indicate that adverse health effects in fish will be observed. ERs for the remaining COPCs are orders of magnitude lower than 1.0.

ERs greater than 1.0 for ecological receptors, although possible, do not indicate adverse health effects are certain. Uncertainties exist in the risk assessment process, both in the derivation of TRVs as well as in the exposure assessment assumptions that may tend to overestimate the risk. Actual exposures are likely to be substantially lower than those presented in this assessment. As with the human health risk assessment, the ecological risk assessment assumed that COPC metals were present in their most bioavailable form. This is a conservative assumption for particulate metals released from the Project as most of the metal would be present as low bioavailable sulphide or alumino-silicate minerals partially encapsulated with gangue minerals. As such, bioavailability to ecological receptors would be limited. Moreover, concentrations of aluminum, copper and vanadium in NAG waste rock and overburden at the Project are similar to or lower than average Earth's crust values. Receiving water quality is predicted to meet BC Freshwater Quality Guidelines or site-specific water quality objectives. There will be no surface water discharge from the Project to receiving waters during operations or early closure. Air emissions and dust releases will be limited and meet provincial and federal standards. Overall, the risk to ecological receptors from exposure to COPCs is not significant.

1.0 INTRODUCTION

This section assesses the potential project specific and cumulative effects and risks to humans and other organisms that may be exposed to COPCs associated with the proposed Project. The environmental health component of the Proponent's Application for an Environmental Assessment Certificate was completed pursuant to Section 16 of the BC *EAA.* An Environmental Impact Statement for an EA was prepared pursuant to the *CEA Act 2012* (Application) to determine potential adverse impacts to the biophysical environment and to the health of people and other ecological organisms from hypothetical cumulative exposures to COPCs in all environmental media. The assessment also quantifies and prioritizes potential carcinogenic and non-carcinogenic health effects in accordance with risk assessment methodologies from HC, EC, and BC MOE.

The environmental health assessment utilizes information from each of the biophysical EA disciplines to identify potential receptors as the basis for determining exposure risk. The risk assessment assumes that there is a relationship between the health of people, ecological organisms, and the health of the surrounding land. This view is based on an understanding that health depends on the surrounding environment, particularly biophysical components such as air, soil, vegetation, water, fish, and wildlife. Any release of chemicals that affects environmental health may have further implications for human health.

1.1 Spatial Boundaries

The footprint, Local Study Area (LSA), and Regional Study Area (RSA) boundaries were selected to cover the geographic extent in which the potential environmental, economic, social, heritage, and health effects of the Project were expected to be measurable. These boundaries define the areas in which the Project was expected to interact with each valued component (VC).

Potential sources for the release of project related COPCs include air emissions and liquid effluent emissions (i.e., run-off, surface water and sediment discharged into the surrounding environment). However, the Surface Water discipline has indicated that the water quality in receiving streams (after mixing) downstream of the Tailings Storage Facility (TSF) is expected to meet BC Freshwater Guidelines or site specific water quality objectives. Therefore, this is not expected to result in harmful accumulation and release of metals from downstream surface water or sediments. Conceptual management of mine water is discussed in detail in **Section 2.2** and in the Mine Water Management Plan, **Section 12.2.1** and **Section 5.3.3** discusses potential effects on water quality in detail. Further, any sediment that is exported will be of similar chemistry to baseline sediments in area streams and thus, no changes in sediment quality are expected (Sediment Quality **Section 5.3.4**). Therefore, the remaining significant source for the release of COPCs is through air emissions.

Since the major source for the release of COPCs is assumed to be via air emissions, the environmental health LSA for the mine site will be the same as the Air Quality LSA (**Section 5.2.4**).

The LSA used for characterization and assessment of environmental health is described for the mine site and off site areas as follows:

- Mine site: an area 40 km x 40 km centred on the proposed open pit; and
- Off site: 3 km wide corridor centred on the footprint of the proposed road access routes and transmission line.
- The environmental health RSA for the mine site will be the same as the Air Quality RSA (**Section 5.2.4**) and is described as follows:

There is no Regional Study Area as there are no significant sources of air emissions around the Project area. The only major project within 50 km was the Chu Molybdenum mine and that application has been 'withdrawn'.

There is no cumulative effects study area as it is considered the same as the RSA defined above.

1.2 Temporal Boundaries

The temporal boundary for the environmental health effects assessment is from pre-construction (baseline) through construction, operations, closure and post-closure. Baseline air, soil, water and country food quality was required to evaluate whether human and ecological exposure was resulting in adverse health effects during the pre-construction phase.

The assessment of air quality depends on air dispersion models that are used to evaluate the impacts of the ambient air quality from the corresponding facility or the project assessed. The air dispersion model relies on the completeness, preciseness and/or representativeness of the combination of input data sets. The model is designed to incorporate substantial conservatism in the methods to ensure that potential impacts are not understated. Several assumptions were made to simplify the modeling procedures while increasing the likelihood of overestimating actual concentrations. These assumptions can be found in Air Quality **Section 5.2.4 and Appendix 5.2.4A**. Based on the results of the air dispersion modeling, the maximum air emissions are expected during the operations phase. Given that majority of the emissions are expected during this phase, the HHERA model considered the operations phase only, as the main contributor of air emissions. For human receptors, chronic exposures were assumed to occur for an individual living within the LSA for their entire lifetime (i.e., 80 years). This assumption was considered to be highly conservative as the operation phases of the Project will be less than an individual's lifetime.

In the case of surface water quality, a mass balance model was used to produce quantitative water quality predictions at various locations and during all phases of mining, from construction through post-closure. Numerous conservative assumptions were made for the model. A water balance schedule was developed for the mine site and watersheds for input in the mass balance water quality model for the four phases. The results of the water quality parameters modeled and details regarding the conservative assumptions and water balance schedule can be found in the surface water quality section (**Section 5.3.3**, Surface Water Quality). The modelled results were compared to relevant provincial and federal water quality guidelines (WQGs) and the proposed site-specific

water quality objectives. Guidelines and standards for comparison with the model output data were determined by regulations, when applicable, and with respect to the most sensitive receptors in the downstream environment. Due to the installation of water treatment facility, the water quality in receiving streams (after mixing) downstream of the TSF is expected to meet BC Freshwater Guidelines or site specific water quality objective and thus, is not expected to result in harmful accumulation and release of metals from downstream surface water or sediments. The HHERA, model takes into account all phases of the project under worse case conditions (i.e., low flows and higher than expected metals loadings) for predicted surface water quality using the 95% UCL over the entire lifetime of the project.

2.0 INFORMATION SOURCES AND METHODS

2.1 Information Sources

Environmental risk "is the chance that human health or the environment will suffer harm as the result of the presence of environmental hazards" (United States Environmental Protection Agency (US EPA), 1985).

According to the BC MOE's "*Quantitative Human Health Risk Assessment* – Phase 1 Review of Methods and Framework Recommendation" (BC MOE, 1993), a human health risk assessment (HHRA) is defined as "the process whereby all available scientific information is brought together to produce a description of the nature and magnitude of the risk associated with exposure of human receptors to an environmental chemical." This information includes:

- Problem formulation: Identification of receptors, exposure pathways, and chemicals of potential concern to human and ecological receptors;
- Toxicity assessment: an evaluation of the types of toxicity that the chemical can produce and an evaluation of the conditions of exposure—dose and duration—under which the chemical's toxicity can be produced;
- Exposure assessment: an identification of the conditions—dose, timing, and duration—under which the population whose risk is being evaluated is or could be exposed to the chemical; and
- Risk characterization: an estimate of the risk and uncertainty in that risk (BC MOE, 1993).

The approach adopted in evaluating the potential risks to human health of the Project was consistent with the approach recommended by HC (2010a), which has established a four-step paradigm for conducting health-based risk assessments. This paradigm has also been adopted by Canadian federal and provincial health and environmental agencies (e.g., BC MOE, Atlantic Partnership in RBCA Implementation [PIRI], and the Ontario Ministry of the Environment).

The ecological risk assessment (ERA) for the Project was completed according to the "Recommended Guidance and Checklist for Tier 1 Ecological Risk Assessment of Contaminated Sites in British Columbia" (BC MELP, 1998), and CCME's "A Framework for Ecological Risk

Assessment" (CCME, 1997). BC MELP (1998) defines ERAs as "the determination of the probability of an effect occurring to an ecological system."

2.2 Methods

Risk assessment methods were used to develop a comprehensive understanding of the source of COPCs, their release mechanisms, their fate and transport mechanisms after being released to the environment, and the methods by which sensitive receptors might be exposed. Further details describing the risk assessment methods used in this assessment are described in the Blackwater Gold Project Baseline Environmental Health Section (**Appendix 9.1A**).

The following data were used in this assessment:

- Predicted annual and maximum air concentrations and air deposition at human receptor locations within the LSA;
- Predicted maximum air concentrations and air deposition within the LSA for ecological receptors;
- Predicted chemical concentrations in the surface water in lakes and creeks near the proposed mine site;
- Predicted chemical concentrations in soil, plants, fish, and wild game meat within the LSA; and
- Actual measured chemical baseline concentrations in soil, surface water, plants, fish, and sediments within the LSA.

The environmental health assessment involves integrating information from each of the disciplines (i.e., Air Quality, Surface Water and Sediment Quality, Freshwater Aquatics, Terrestrial Environment, and Wildlife Environment). Based on this, a conservative scenario human health and ecological risk assessment was completed. Details for data modelling, collection and analysis, and sampling locations are further described in the aforementioned discipline sections. A summary of the predicted and measured data from each discipline used for this Environmental Health assessment is provided in **Annex 9.2.2A**. Risks were assessed using conservative information available from each of the disciplines. If risks were acceptable for the conservative (i.e., reasonable worst case) scenario, then risks for all other lesser exposure scenarios would also be acceptable.

In order to evaluate the overall exposure of project-related emissions, mathematical models were used to predict changes in the COPC concentration in the different media from baseline conditions. The chemical composition of the surface waters in rivers and creeks forming the watershed in the vicinity of the Project may potentially be altered as a result of seepage and surface discharges into any given waterbody. Chemicals in the surface water may be found in either the dissolved or suspended solid state. However, as mentioned above (**Section 1.1**, the water quality in receiving streams (after mixing) downstream of the TSF is expected to meet BC Freshwater Guidelines or site specific water quality objectives and thus, is not expected to result in harmful accumulation and release of chemicals from downstream surface water or sediments.

Atmospheric depositions can further increase in COPC concentrations in waterbodies and sediments, but its overall contribution is expected to be much smaller than direct intake from discharge sites or site run-off.

To evaluate the COPC loading to a surface water body from its associated watershed, waterbody parameters (i.e., surface area, watershed surface area, velocity of watershed, etc.) from the Davidson Creek watershed were evaluated with respects to human exposure. The water body parameters for Davidson Creek were selected and used in the HHERA based on the fact that the mine site occupies the upper portions of the Davidson creek catchment. The mine site will influence water quality in Davidson creek during the post-closure phase through direct discharge. The mine discharge will meet BC freshwater quality guidelines or site specific water quality objectives protective of aquatic life. During the construction, operation and closure phases the mine site will aim to act as a zero discharge facility. The closest permament resident to the mine site is located approximately 15km away.

Surface water quality data (i.e., COPC concentrations) from various hydrology nodes from various waterbodies within the study area were evaluated and used in the human health exposure model. The watershed parameters for Davidson Creek were provided by in **Section 5.3.3** (Surface Water Quality) for use in the human health model calculations. Most of the parameters used in the HHERA model are site-specific. Where site-specific parameters were not available, default or estimated values provided by US EPA, 2005 were used. It should be noted that the use of default parameters adds an uncertainty to the assessment as the values may not accurately represent site-specific conditions. As a result, this uncertainty may or overestimate the predicted risks from the HHERA model. Site-specific and default water body parameters used in the model are presented in **Annex 9.2.2E**, HHERA Model Calculations.

3.0 ENVIRONMENTAL HEALTH BASELINE

The Environmental Health Baseline Report (**Appendix 9.1A**) provided the information that facilitates evaluation of the human and ecological health risks associated with the Project. The report described the risk assessment process used to evaluate human and ecological health in anticipation of determining the potential effects that may arise from the Project.

Risk assessment methods were used to develop a comprehensive understanding of the source of COPCs, their release mechanisms, their fate and transport mechanisms once released to the environment, and the methods by which sensitive receptors might be exposed.

The baseline risk assessment addresses potential risks to human and ecological receptors present in the vicinity of the Project. The assessment focuses on risks to receptors through relevant exposure media (i.e., soil, surface water, and country foods) based on available historical and most current site data. Based on the findings of this risk assessment, conclusions were made about the potential risk to human health and ecological receptors.

3.1 Human Health Risk Assessment

A conservative or reasonable worst-case approach was taken in identifying the primary exposure scenarios of concern for the Project.

The non-carcinogenic exposure scenario consisted of an Aboriginal toddler who was accompanying an adult who spent his entire life within the study areas of the Project engaged in traditional harvesting of country foods (i.e., hunting or fishing) or recreational activities (i.e., hiking). The toddler could potentially be exposed to background concentrations of COPCs via direct contact with soil, inhalation of resuspended dust, or ingestion of soil, surface water, vegetation, wild game, or fish. Similarly, the assessment of carcinogenic chemicals focused on an Aboriginal adult who spends the same amount of time in the study areas and also engages in traditional activities. He/she could also potentially be exposed to background concentrations of COPCs via direct contact with soil, inhalation of resuspended dust, or ingestion of soil, surface water, wild game, or fish.

Chemical screening in the baseline risk assessment identified the following COPCs as requiring further assessment:

- Aluminum;
- Arsenic;
- Cadmium; and
- Molybdenum.

The findings of the baseline human health risk assessment are summarized below.

Maximum baseline concentrations for arsenic and molybdenum exceeded human health–based soil criteria, while maximum baseline concentrations for aluminum, arsenic, and cadmium exceeded human health–based surface water criteria.

The total Hazard Quotients (HQs) calculated for aluminum, cadmium, and molybdenum were noted to be below HC's target risk of 0.2 for the toddler receptor, suggesting that adverse health effects would not likely occur.

Arsenic was noted to be above HC's target risk of 0.2 for the toddler receptor. The exposure pathways responsible for the exceedance for the non-carcinogenic receptor were soil ingestion, surface water ingestion, and fish ingestion. Although there was an exceedance in the HQ values, it should be noted that uncertainties existed in the risk assessment process, both in the derivation of Toxicological Reference Values (TRVs) as well as in the exposure assessment assumptions (e.g., consumption rates). Actual exposures were likely to be substantially lower than those presented in this assessment.

The risk estimate for arsenic was noted to be above HC's target risk level of 1.0×10^{-5} for the adult receptor. The main exposure pathways responsible for the exceedance for the carcinogenic receptor were noted to be surface water ingestion and fish ingestion. Although there were

exceedances in the carcinogenic risks, it should be noted that uncertainties existed in the risk assessment process, both in the derivation of TRVs as well as in the exposure assessment assumptions (i.e., consumption rates). Actual exposures were likely to be substantially lower than those presented in this assessment.

For Criteria Air Contaminants (CACs), HQs were calculated by dividing measured CAC concentrations by each parameter's respective TRV. HQ values were noted to be below 1.0 for all CACs.

Table 3.1-1 and **Table 3.1-2** present the baseline assessment findings for non-carcinogenic and carcinogenic risks to Aboriginal human receptors as a potential effect of the Project. The HQ values for the CAC emissions are presented in **Table 3.1-3**.

Table 3.1-1: Summary of Baseline Risks for Non-Carcinogenic COPCs

Metal COPC	HQ								Total HQ
	Soil			Surface Water		Plant	Fish	Wild Game	
	Ingestion	Dermal	Inhalation	Ingestion	Dermal	Ingestion	Ingestion	Ingestion	
Aluminum	n/a	n/a	n/a	0.015	$1.6x10^{-4}$	0.12	0.0028	0.00039	0.14
Arsenic	**0.33**	0.0089	0.00097	0.16	0.0017	0.022	**0.71**	0.0053	**1.24**
Cadmium	0.0038	$6.5x10^{-5}$	$7.4x10^{-7}$	0.0015	$3.0x10^{-5}$	0.013	0.025	$4.6x10^{-5}$	0.044
Molybdenum	0.0011	$9.2x10^{-6}$	$6.9x10^{-7}$	0.0014	$1.4x10^{-5}$	0.006	0.0011	0.00018	0.0097

Notes: Bold and underlined text represents HQ values greater than 0.2
COPC = Chemical of Potential Concern; HQ = Hazard Quotient.

Table 3.1-2: Summary of Baseline Risks for Carcinogenic COPCs

Metal COPC	ILCR								Total ILCR
	Soil			Surface Water		Plant	Fish	Wild Game	
	Ingestion	Dermal	Inhalation	Ingestion	Dermal	Ingestion	Ingestion	Ingestion	
Arsenic	$7.8x10^{-6}$	$2.1x10^{-6}$	$1.8x10^{-8}$	**$3.8x10^{-5}$**	$4.7x10^{-7}$	$4.2x10^{-6}$	**$2.1x10^{-4}$**	$1.6x10^{-6}$	**$2.7x10^{-4}$**

Notes: Bold and underlined text represents ILCR values greater than 1x10-5
COPC = Chemical of Potential Concern; ILCR = Incremental Lifetime Cancer Risk

Table 3.1-3: Hazard Quotients for Exposure to Criteria Air Contaminants

CAC	HQ
NO_2	0.080
SO_2	0.040
$PM_{2.5}$	0.50
PM_{10}	0.18
CO	0.011

Notes: CAC = Criteria Air Contaminant; HQ = Hazard Quotient; NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; PM2.5 = particulate matter no greater than 2.5 micrometres in aerodynamic diameter;
PM10 = particulate matter no greater than 10 micrometres in aerodynamic diameter; CO = carbon monoxide

3.2 Ecological Risk Assessment

The baseline report also presented the results of the evaluation of potential adverse effects from COPCs on ecological receptors. The report used both historical and the most current sampling data available and is consistent with the methodology recommended by EC and CCME (1996, 1997). For the purposes of presentation of baseline information, terrestrial ecological receptors of primary concern selected were large mammals (e.g., grizzly bear, caribou), small mammals (e.g., marten, hare, and shrew), birds (e.g., raptors, songbirds, waterfowl), amphibians (e.g., western toad), fish (e.g., rainbow trout), terrestrial and aquatic plants, and soil and aquatic invertebrates.

Based on the screening conducted for soil, the maximum baseline concentrations for arsenic and molybdenum exceeded their respective ecological guidelines and were carried forward as COPCs in soil for the baseline. The remaining chemicals found in soil were below their respective ecological guidelines and were not considered to be ecological concerns.

Based on the screening for surface water, the maximum concentrations for aluminum, arsenic, cadmium, chromium, copper, lead, vanadium, and zinc exceeded their respective criteria and were carried forward as the COPCs in the baseline assessment. The remaining chemicals found in surface water were below their respective guidelines and were not considered ecological concerns.

In addition, the screening conducted for sediment concentrations identified arsenic, cadmium, chromium, copper, lead, mercury, and zinc compounds as COPCs in sediment and were carried forward in the ERA. The remaining chemicals found in sediments were not considered to be ecological concerns in the assessment.

The findings of the ERA are discussed below.

Maximum baseline concentrations for arsenic and molybdenum exceeded ecological soil criteria for mammals. Additionally, maximum baseline concentrations for arsenic and zinc exceeded surface water criteria for mammals. Following risk assessment modelling, Exposure Ratios (ERs)

for molybdenum were noted to be above 1.0 for grizzly bear, caribou, and hare and to be below 1.0 for marten and shrew. ERs for arsenic and zinc were less than 1.0 for all mammals assessed. It should be noted that ERs greater than 1.0 do not necessarily indicate that adverse effects are certain. The main driver of risk for mammals was likely due to the high background concentrations of molybdenum in the soil within the study areas of the Project and the conservative TRVs used.

For birds, maximum baseline concentrations for arsenic, molybdenum, and zinc exceeded their respective soil and surface water criteria. Furthermore, maximum baseline concentrations for arsenic, cadmium, chromium, copper, lead, mercury, and zinc exceeded their respective sediment criteria. Following risk assessment modelling, exposure ratios for zinc were noted to be greater than 1.0 for the olive-sided flycatcher and the ring-necked duck. The ERs for the remaining COPCs were less than 1.0 for birds. It should be noted that ERs greater than 1.0 do not necessarily indicate that adverse effects are certain. The main driver of risk for birds was believed to be the high background concentrations of zinc in surface water and the overly conservative TRVs used. The ERs for the remaining COPCs were below 1.0.

Amphibians in the vicinity of the Project were not expected to be exposed continuously to the maximum baseline concentrations of arsenic and molybdenum in soil. Available toxicological literature on amphibians focuses mainly on organic compounds (e.g., pesticides and fertilizers) affecting early life stages (i.e., eggs and tadpoles). Given that the metals assessed are not 100% bioavailable and in the absence of any acceptable TRVs, it is not possible to conclude that ecological health risks from arsenic and molybdenum in soil are expected for this receptor.

For freshwater aquatic organisms, maximum baseline surface water concentrations exceeded criteria for aluminum, arsenic, cadmium, chromium, copper, lead, vanadium, and zinc. ERs were noted to be greater than 1.0 for copper in aquatic invertebrates and aquatic plants. The ERs for the remaining COPCs are less than 1.0 for freshwater aquatic organisms. It should be noted that ERs greater than 1.0 do not necessarily suggest that adverse effects were certain. The main driver of risk was believed to be the high background concentrations of copper and zinc in surface water and their conservative TRVs. The ERs for the remaining COPCs were below 1.0 for freshwater aquatic organisms.

For terrestrial plants and soil invertebrates, the maximum baseline concentrations for arsenic and molybdenum exceeded soil criteria. The ERs for both COPCs were noted to be above 1.0 for both receptors. The main source of risks was believed to be the high background concentrations of both arsenic and molybdenum in soil. However, as discussed previously, an ER greater than 1.0 does not indicate adverse effects are certain.

The risk assessment process was mainly developed for contaminated sites, active or abandoned. For this Project however, the numerical value attached to the level of risk has to be understood in the context of a natural environment. It is understood that the background concentration of certain chemicals is higher than the recommended guidelines, but the wildlife in contact with the elevated concentration media does not readily appear to be negatively affected.

Table 3.2-1 summarizes the baseline risk estimates for mammals.

Table 3.2-1: Baseline Risk Estimates for Mammals

Receptor/COPC	Exposure Estimate (mg/kg/d)	TRV (mg/kg/d)a	ER
Grizzly bear			
Arsenic	0.024	0.09	0.25
Molybdenum	0.18	0.02	9.0
Zinc	7.16	26.7	0.27
Caribou			
Arsenic	0.029	0.12	0.24
Molybdenum	0.23	0.03	7.7
Zinc	9.00	33.8	0.27
Marten			
Arsenic	0.051	0.43	0.12
Molybdenum	0.011	0.11	0.097
Zinc	7.56	123.1	0.061
Snowshoe hare			
Arsenic	0.072	0.43	0.17
Molybdenum	0.57	0.11	5.2
Zinc	22.58	123.07	0.18
Short-tailed shrew			
Arsenic	0.40	1.24	0.32
Molybdenum	0.046	0.31	0.15
Zinc	53.6	351.6	0.15

Notes: Adjusted TRV based on body weight of species. Bold and underlined results = exceedances.
COPC = Chemical of Potential Concern; mg/kg/d = milligrams per kilogram body weight per day;
TRV = Toxicological Reference Value; ER = exposure ratio

Table 3.2-2 summarizes the baseline risk estimates for birds.

Table 3.2-2: Baseline Risk Estimates for Birds

Receptor/COPC	Exposure Estimate (mg/kg/d)	TRV (mg/kg/d)a	ER
Red-tailed hawk			
Arsenic	0.029	2.24	0.013
Molybdenum	0.006	3.5	0.0016
Zinc	5.96	14.5	0.41
Olive-sided flycatcher			
Arsenic	0.47	2.24	0.21
Molybdenum	0.049	3.5	0.014
Zinc	67.8	14.5	4.7
Ring-necked duck			
Arsenic	0.52	2.24	0.23
Cadmium	1.2	1.45	0.83
Chromium	0.44	1	0.44
Copper	0.93	47	0.02
Lead	0.56	3.85	0.15
Mercury	0.00029	0.45	0.00064
Zinc	39.8	14.5	2.7
Pacific loon			
Arsenic	0.10	2.24	0.045
Zinc	3.55	14.5	0.24

Notes: [a] Adjusted TRV based on body weight of species. **Bold** and underlined results = exceedances.
COPC = Chemical of Potential Concern; mg/kg/d = milligrams per kilogram body weight per day;
TRV = Toxicological Reference Value; ER = exposure ratio

Table 3.2-3 summarizes the baseline risk estimates for rainbow trout.

Table 3.2-3: Baseline Risk Estimates for Rainbow Trout

COPC	Exposure Estimate (mg/L)	TRV (mg/L)	ER
Aluminum	0.29	3.29	0.088
Arsenic	0.0015	0.892	0.0017
Cadmium	0.000063	0.0017	0.037
Chromium	0.00062	0.069	0.009
Copper	0.0011	0.0038	0.29
Lead	0.00062	0.019	0.033
Vanadium	0.0007	0.08	0.0088
Zinc	0.015	0.036	0.42

Notes: **Bold** and underlined results = exceedances; COPC = Chemical of Potential Concern;
TRV = Toxicological Reference baseline Value; ER = exposure ratio

Table 3.2-4 summarizes the risk estimates for soil invertebrates.

Table 3.2-4: Baseline Risk Estimates for Soil Invertebrates

COPC	Exposure Estimate (mg/kg/d)	TRV (mg/kg/d)	ER
Arsenic	21.4	18	1.2
Molybdenum	5.06	2	2.5

Notes: **Bold** and underlined results = exceedances; COPC = Chemical of Potential Concern; mg/kg/d = milligrams per kilogram body weight per day; TRV = Toxicological Reference Value; ER = exposure ratio

Table 3.2-5 summarizes the baseline risk estimates for aquatic invertebrates.

Table 3.2-5: Baseline Risk Estimates for Aquatic Invertebrates

COPC	Exposure Estimate (mg/L)	TRV (mg/L)	ER
Aluminum	0.29	1.9	0.15
Arsenic	0.0016	0.45	0.0035
Cadmium	0.000063	0.00015	0.42
Chromium	0.00062	0.044	0.014
Copper	0.0011	0.00023	4.8
Lead	0.00062	0.012	0.052
Vanadium	0.0007	1.9	0.00037
Zinc	0.015	0.047	0.32

Notes: **Bold** and underlined results = exceedances; COPC = Chemical of Potential Concern; mg/kg/d = milligrams per kilogram body weight per day; TRV = Toxicological Reference Value; ER = exposure ratio

Table 3.2-6 summarizes the baseline risk estimates for terrestrial plants.

Table 3.2-6: Baseline Risk Estimates for Terrestrial Plants

COPC	Exposure Estimate (mg/kg/d)	TRV (mg/kg/d)	ER
Arsenic	21.4	18	1.2
Molybdenum	5.06	2	2.5

Notes: **Bold** and underlined results = exceedances; COPC = Chemical of Potential Concern; mg/kg/d = milligrams per kilogram body weight per day; TRV = Toxicological Reference Value; ER = exposure ratio

Table 3.2-7 summarizes the baseline risk estimates for aquatic plants.

Table 3.2-7: Baseline Risk Estimates for Aquatic Plants

COPC	Exposure Estimate (mg/L)	TRV (mg/L)	ER
Aluminum	0.29	0.46	0.63
Arsenic	0.0016	0.048	0.033
Cadmium	0.000063	0.002	0.032
Chromium	0.00062	0.40	0.0015
Copper	0.0011	0.001	1.1
Lead	0.00062	0.5	0.0012
Vanadium	0.0007	0.08	0.0088
Zinc	0.015	0.03	0.50

Notes: **Bold** and underlined results = exceedances; COPC = Chemical of Potential Concern; mg/kg/d = milligrams per kilogram body weight per day; TRV = Toxicological Reference Value; ER = exposure ratio

4.0 POTENTIAL EFFECTS OF THE PROJECT

Potential effects of the Project on environmental health exposures are assessed by predicting the changes in concentrations of the above selected COPCs to receptors identified. Health risks to be assessed are those related to emissions of airborne contaminants from the operations phase.

The methodology used in the assessment is based on standard risk assessment paradigms used by BC MOE and HC (2010a), BC MELP (1998), and CCME (1997) among others, The same methods were used in the Baseline assessment. Throughout the assessment, a number of simplifying assumptions were made regarding the exposure scenarios considered, emission estimates, and the range of contaminants to consider. An initial screening was undertaken whereby reasonable worst-case assumptions were used. This process eliminated the majority of contaminants and permitted subsequent modelling efforts to focus on those contaminants and exposure conditions that have the greatest risk to human and ecological health. Where simplifying assumptions have been made, the consequences of those assumptions in terms of introducing uncertainty to the assessment were evaluated.

4.1 Problem Formulation

The first step of the risk assessment is to evaluate whether a particular chemical is currently present at levels that could pose a potential unacceptable health risk to human and ecological receptors. Considerations included the fate and behaviour of the chemicals in the environment and the toxicity based on various sources of exposure (i.e., air, water, soil, and food) and routes of exposure (i.e., inhalation, ingestion, and dermal) to the human and ecological receptors. In addition, the problem formulation evaluates which exposure pathways are operational, leading to direct or indirect exposure to sensitive receptors. For example, if a chemical is considered toxic, the risk may still remain negligible if the concentration of the chemical in the source media is low

or if there is no possibility that a receptor can be exposed to the chemical. The problem formulation step involves three key elements:

- Identification of Chemicals of Potential Concern: Screening and identification of COPCs;
- Identification of potential receptors: Identification of persons or ecological receptors that may be affected by chemical exposures originating from the Project, with special attention directed at sensitive species or susceptible individuals (e.g., infants and young children, the elderly); and
- Identification of exposure pathways*:* determination of potential routes of exposure, taking into account the properties of the chemical, its manner of release, and its behaviour in the environment.

4.1.1 Identification and Selection of Chemicals of Potential Concern

The selection of COPCs is based on an understanding of those chemicals expected to be emitted as a result of the equipment being used (i.e., heavy equipment) or the activities being performed (i.e., earthworks, paving, etc.).

The COPCs that may be released include, but were not limited to, diesel exhaust from heavy machinery operation, emissions (i.e*.,* natural gas–fired heaters), and particulates (i.e*.,* road dust, particulate matter less than 10 microns (PM_{10}) and particulate matter less than 2.5 microns ($PM_{2.5}$)). Such substances may have an effect on human and ecological receptors in the vicinity of the LSA.

An inventory of predicted emissions of the Project is provided by the Air Quality discipline. These emissions may migrate off site and have human and ecological health implications for potential receptors. Particulate emissions (i.e*.,* PM_{10} and $PM_{2.5}$) result from the combustion of fuel and vehicle traffic. Diesel exhaust emissions result from the operation of diesel machinery including air compressors, vehicles, and generators. Emissions such as oxides of nitrogen (NO_x), sulphur dioxide (SO_2), polycyclic aromatic hydrocarbons (PAHs), carbon monoxide (CO), carbon dioxide (CO_2), benzene, toluene, ethylbenzene, xylene, methane (CH_4), and volatile organic compounds (VOCs) originate from the burning of fossil fuels (e.g*.,* diesel, gasoline, natural gas) in vehicles and equipment.

For this assessment, it was assumed that VOCs and diesel baseline emissions were negligible since the Project was located in an undisturbed area with no significant sources of air emissions around the RSA. The only major project identified within 50 km was the Chu Molybdenum mine. However, that application has been withdrawn and the mine will not proceed.

For assessing the air pathway in the HHERA, the operations phase of the Project was selected conservatively, because it represents the phase with maximum air emissions for the mine site when compared to the construction, closure and post-closure phases. The operations phase involves drilling, blasting, the generation and storage of the tailings, expansion of the open pit, hauling of ore, and creation of waste rock dumps. Heavy equipment used for the mining and transport of the ore would be at the highest during operations which will release the greatest

emissions from vehicular traffic. Generation of particulates would be greatest as the ore is mined and crushed. Therefore, when compared to the construction, closure and post closure phases, it is expected that the operations phase represents the maximum air emissions for the mine site.

The construction phase of the Project involves the construction of camp sites and facilities for staff working at the mine site, stripping of the overburden, and drainage controls. This phase will also involve land disturbance, construction of haul roads, equipment laydown areas, truck shops and offices. The activities involved with the construction phase are short-term when compared to the life of the mine. Once mining is completed during the operations phase, the closure and post closure activities involve water from mining to be pumped from the Tailings Storage Facility (TSF) in order to commence filling the pit. Additionally, maintenance of in stream flows in Davidson Creek will continue through the closure and post closure phases. In the case of surface water quality, all project phases were considered for the HHERA model.

The assessment of air quality depends on air dispersion models that are used to evaluate the impacts of the ambient air quality from the corresponding facility or the project assessed. Based on the results of the air dispersion modeling, the maximum air emissions are expected during the operations phase. Air emissions during closure and post-closure are significantly less. Given that the majority of the emissions are expected during the operations phase, the HHERA model considered the operations phase only, as the main contributor of air emissions. This would impact all exposure pathways described in the HHERA. For human receptors, chronic exposures were assumed to occur for an individual living within the LSA for their entire lifetime (i.e., 80 years). This assumption was considered to be highly conservative as the operation phase of the Project will be less than an individual's lifetime.

In the case of surface water quality, a mass balance model was used to produce quantitative water quality predictions at various locations and during all phases of the Project, from construction through post-closure. Numerous conservative assumptions were made for the model. A water balance schedule was developed for the mine site and watersheds for input in the mass balance water quality model for the four phases. The modelled results were compared to relevant provincial and federal water quality guidelines (WQGs) and the proposed site-specific water quality objectives. Guidelines and standards for comparison with the model output data were determined by regulations, when applicable, and with respect to the most sensitive receptors in the downstream environment. Due to the water treatment applied at the mine site, the water quality in receiving streams (after mixing) downstream of the TSF is expected to meet BC Freshwater Guidelines or site specific water quality objective and thus, is not expected to result in harmful accumulation and release of metals from downstream surface water or sediments. The HHERA, model takes into account all phases of the project under worse case conditions (i.e., low flows and higher than expected metals loadings) for predicted surface water quality using the 95% UCL over the entire lifetime of the Project.

Due to the installation of water treatment facility, the water quality in receiving streams (after mixing) downstream of the TSF is expected to meet BC Freshwater Guidelines or site specific water quality objective and thus, is not expected to result in harmful accumulation and release of metals from downstream surface water or sediments.

Rather than conduct assessments for all of the potential substances that may be released by the Project, emphasis was given to chemicals directly associated with operation of the facilities and that have a potential to migrate regionally. COPCs were also defined as those that represent the highest toxic potential in the mixture of emissions.

In addition, emitted chemicals that represent the greatest concern were also selected for the assessment. Chemicals of greatest concern were defined as, , chemicals viewed as a concern by the regulatory authorities.. The criteria air pollutants (i.e., NO_2, SO_2, CO, $PM_{2.5}$, and PM_{10}) were considered a concern for assessment because they are federally regulated. **Table 4.1-1** summarizes the chemicals that are viewed as COPCs and that had emission rates above zero; these chemicals were selected for the assessment.

Table 4.1-1: Predicted Air Emissions from the Project

COPC	Predicted Emission Rates (g/s)
Cyanide	3.53558
Arsenic	0.32852
Selenium	0.24090
Molybdenum	0.12893
Cadmium	0.01419
Benzene	0.005048
Toluene	0.002046
Xylenes	0.001880
Ethylbenzene	0.000479
Mercury	0.000057534
Benzo(a)anthracene	0.000000049
Chrysene	0.000000035
Benzo(g,h,i)perylene	0.000000032
Indeno(1,2,3-cd)pyrene	0.000000030
Benzo(b)fluoranthene	0.000000029
Benzo(k)fluoranthene	0.000000025
Benzo(a)pyrene	0.000000025
Dibenz(a,h)anthracene	0.000000023

Notes: COPC = Chemical of Potential Concern; g/s = grams per second

In addition, COPCs that were screened for assessment under the Environmental Health Baseline Section will also be included in this EA. **Table 4.1-2** summarizes the COPCs that are carried forward into the assessment. Details describing the baseline screening process of COPCs are discussed further in the Environmental Health Baseline Section 9.1A of this EA.

Table 4.1-2: COPCs Carried Forward into Environmental Health Assessment

COPCs	CACs	Baseline COPCs for Human Receptors*	Baseline COPCs for Ecological Receptors*
Benzene	CO	Aluminum	Aluminum***
Benzo(a)anthracene	NO_2	Arsenic	Arsenic**, ***
Benzo(a)pyrene	SO_2	Cadmium	Cadmium***
Benzo(b)fluoranthene	$PM_{2.5}$	Molybdenum	Chromium***
Benzo(g,h,i)perylene	PM_{10}		Copper***
Benzo(k)fluoranthene			Lead***
Chrysene			Mercury****
Dibenz(a,h)anthracene			Molybdenum**
Ethylbenzene			Vanadium***
Indeno(1,2,3-cd)pyrene			Zinc***
Toluene			
Arsenic			
Cadmium			
Cyanide			
Mercury			
Molybdenum			
Selenium			

Notes: COPC = Chemical of Potential Concern;
* = COPCs from Environmental Health Baseline Section (**Appendix 9.1A**);
** = Chemical was selected as COPC in soil for ecological receptors
*** = Chemical was selected as COPC in surface water for ecological receptors
**** = Chemical was selected as COPC in sediments for ecological receptors

4.1.2 Identification of Human Receptors

The receptors that were selected and evaluated in the Environmental Health Baseline Section (**Appendix 9.1A**) will also be selected and evaluated in this assessment. Because of the current unrestricted access within the Project RSA, it would be expected that potential receptors could include all age groups (as defined by HC, 2010a), including infants (0 to 6 months), toddlers (7 months to 4 years), children (5 to 11 years), teens (12 to 19 years), and adults (20+ years). Depending on age, lifestyle, and genetic and environmental factors, different individuals will have vastly different potentials to be exposed to COPCs. To account for this uncertainty, health risks were evaluated using biological characteristics for the most sensitive age class i.e., toddler for non-carcinogens and adult for carcinogens (HC, 2010a).

In general, Aboriginal families are considered to have local, year-round participation in such traditional activities as hunting, fishing, and the gathering and consumption of country foods. To ensure that exposures were not underestimated, Aboriginal families were assumed to exhibit exaggerated and unique lifestyle characteristics (e.g., high consumption rates of country foods,

continual year-round residency), which result in higher exposures when compared to non-Aboriginal groups.

There may be other recreational land users (i.e., non-Aboriginal receptors) that are also believed to spend time within the RSA. Non-Aboriginal receptors or transient individuals who use the study areas for merely recreational purposes (i.e., non-traditional land uses) were considered to spend less time than a year-round residential receptor and to consume less country food than the Aboriginal individual. Therefore, the risk assessment focused on the Aboriginal receptor to represent the reasonable worst-case scenario.

The critical non-carcinogenic receptor was assumed to be an Aboriginal toddler accompanying an adult engaged in traditional harvesting of country foods (hunting, fishing, plant-gathering) or recreational activities (e.g., hiking) within the RSA. Health risks from non-carcinogenic COPCs were evaluated using toddler characteristics, as toddlers ingest more soil and water per unit body mass and have higher rates of hand-to-mouth activities than any other age class, thereby increasing their exposure to COPCs in soil.

The critical carcinogenic receptor was assumed to be an Aboriginal adult who likely has the longest exposure duration (i.e., longest time living within the RSA) and who also engages in traditional activities as described above. Health risks from carcinogenic COPCs were typically evaluated using adult characteristics, as most cancers develop over a longer period of time (i.e., long latencies), usually over the entire lifespan. The risk assessment evaluated the risks for the adult alone and also a composite adult receptor that incorporates the higher relative exposure during earlier life stages (i.e., infant, toddler, child and youth) with the adult exposures.

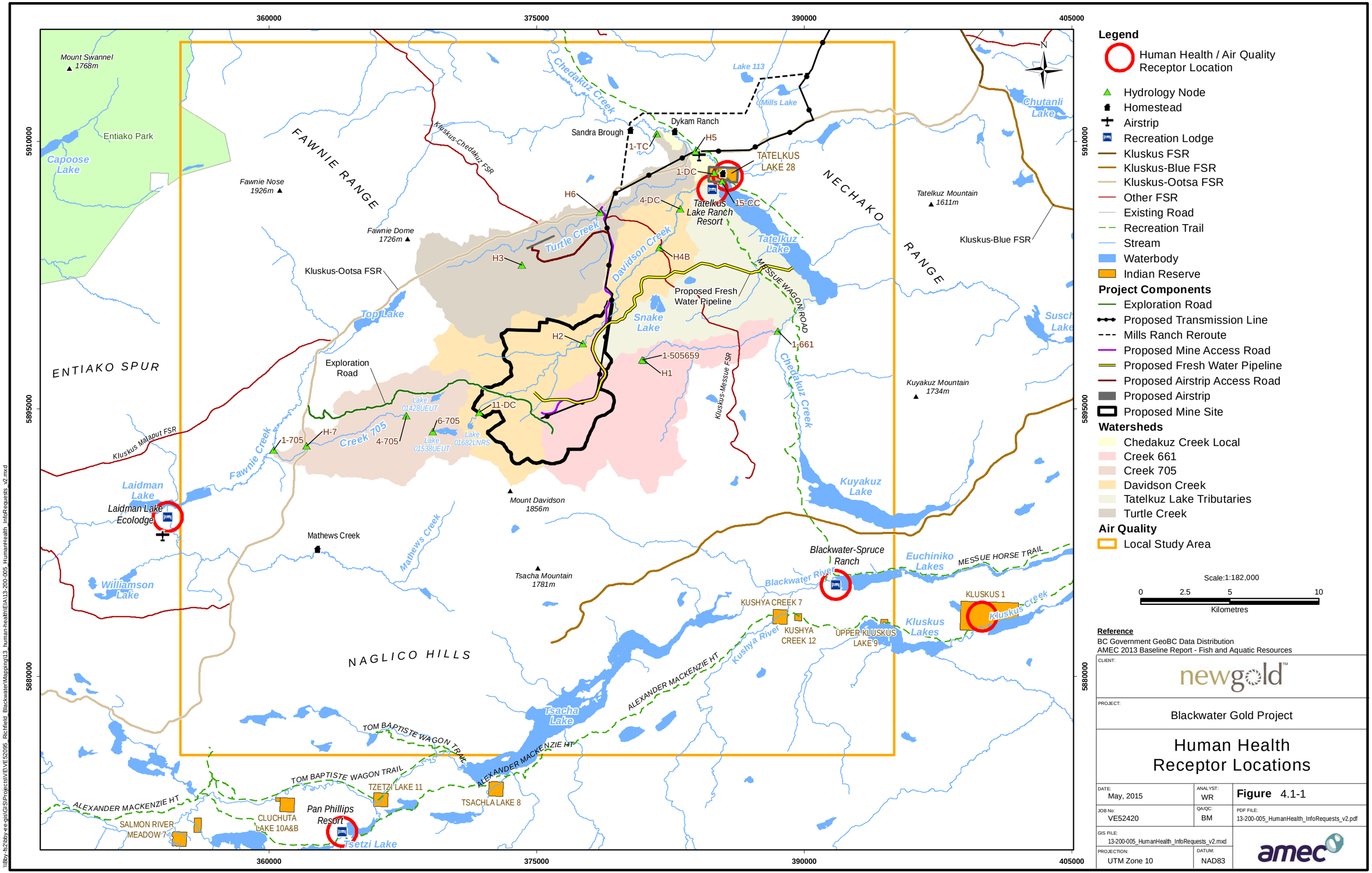
The specific locations at which receptors reside are presented in **Table 4.1-3** and in **Figure 4.1-1.** Human receptor locations were provided by the Air Quality discipline. It should be noted that Blackwater Spruce Ranch, Tatelkuz Lake Resort and Tatelkus Lake IR 28 are within the LSA while Laidman Lake Ecolodge and Pan Phillips receptor locations are situated outside of the LSA, near the boundary. Despite being outside of the LSA, the latter two locations were selected because they are representative of other locations to the west and south of the Mine Site, respectively. Each receptor location was selected based on their orientation in relation to the Mine Site in order to cover potential exposure from air emission in all directions (i.e. North, East, South and West). Other sites (i.e., Kluskus 1 IR) noted to be at a greater distance from the Mine Site when compared to the identified receptor locations are expected to be exposed to lower concentrations of COPCs in ambient air. Therefore, overall risks are also expected to be lower, given the increased distance from the Mine Site.

Table 4.1-3: Human Receptor Locations

Receptor Identification	Description	UTM NAD83	
		Easting	Northing
Blackwater-Spruce Ranch	Recreation Lodge	391762.24	5885118.90
Laidman Lake Ecolodge	Recreation Lodge	354315.00	5888940.00
Pan Phillips Resort	Hunting and Fishing Lodge	364095.36	5871294.83
Tatelkuz Lake Resort and Tatelkus Lake IR 28	Recreation Lodge and Indian Reserve	384861.70	5907288.67

Note: Tatelkuz Lake Resort and Tatelkus Lake IR 28 are adjacent locations for human receptors and were dealt as one for the purposed of the HHERA.

Human receptor characteristics and food ingestion values for the human receptors were obtained from HC (2010a) (**Table 4.1-4**). However, where available, values for food ingestion rates from Chan et al (2011) were employed for subsistence users and populations (**Table 4.1-5**) residing near the geographic center of BC. Chan et al. (2011) conducted a First Nations food, nutrition, and environment study with the active participation of some BC First Nations. The study describes the traditional diet of First Nations people found on the land and waters around their communities. Additional details for the characterization of potential human receptors are provided in the Environmental Health Baseline Section (**Appendix 9.1A**). These assumptions provide the basis of the exposure assessment.



Legend

- Human Health / Air Quality Receptor Location
- Hydrology Node
- Homestead
- Airstrip
- Recreation Lodge
- Kluskus FSR
- Kluskus-Blue FSR
- Kluskus-Ootsa FSR
- Other FSR
- Existing Road
- Recreation Trail
- Stream
- Waterbody
- Indian Reserve

Project Components

- Exploration Road
- Proposed Transmission Line
- Mills Ranch Reroute
- Proposed Mine Access Road
- Proposed Fresh Water Pipeline
- Proposed Airstrip Access Road
- Proposed Airstrip
- Proposed Mine Site

Watersheds

- Chedakuz Creek Local
- Creek 661
- Creek 705
- Davidson Creek
- Tatelkuz Lake Tributaries
- Turtle Creek

Air Quality

- Local Study Area

Scale:1:182,000

0 2.5 5 10

Kilometres

Reference

BC Government GeoBC Data Distribution
AMEC 2013 Baseline Report - Fish and Aquatic Resources

CLIENT: newgold™

PROJECT: Blackwater Gold Project

Human Health Receptor Locations

DATE: May, 2015	ANALYST: WR	**Figure** 4.1-1
JOB No: VE52420	QA/QC: BM	PDF FILE: 13-200-005_HumanHealth_InfoRequests_v2.pdf
GIS FILE: 13-200-005_HumanHealth_InfoRequests_v2.mxd		
PROJECTION: UTM Zone 10	DATUM: NAD83	amec

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Table 4.1-4: Summary of Human Health Receptor Characteristics for the Project

Receptor Characteristic	Receptor Parameters		Source
	Toddler	Adult	
Age	7 months to 4 years	>20 years	HC, 2010a
Exposure duration (years)	4.5	60	Based on 80-year lifespan
Body weight (kg)	16.5	70.7	Richardson, 1997
Soil ingestion rate (g/d)	0.08	0.02	CCME, 2006
Surface water ingestion rate (L/d)	0.6	1.5	Richardson, 1997
Inhalation rate (m^3/d)	8.3	16.6	Allan et al., 2008
Food ingestion (g/d)			
Root vegetables	105	188	Richardson, 1997
other vegetables	67	137	Richardson, 1997
Fish[1]	85	270	Richardson, 1997
Wild Game[1]	95	220	Richardson, 1997
Skin surface area (cm^2)			
Hands	430	890	Richardson, 1997
Arms (upper and lower)	890	2,500	Richardson, 1997
Legs (upper and lower)	1,690	5,720	Richardson, 1997
Total Body	6,130	17,640	Richardson, 1997
Soil loading to exposed skin (mg/cm^2)			
Soil adhesion to skin (based on hands)	0.1	0.1	Kissel et al., 1996, 1998
Soil adhesion to skin (other than hands)	0.01	0.01	Kissel et al., 1996, 1998

Notes: [1]Ingestion rates for Canadian First Nations populations;
CCME = Canadian Council of Ministers of the Environment; cm^2 - square centimetres;
g/d = grams per day; HC = Health Canada; kg = kilogram; L/d = litres per day;
m^3/d = cubic metres per day; mg/cm^2 = milligrams per cubic centimetre

Table 4.1-5: Estimated Consumption Rates of Major Traditional Foods by First Nations Populations in BC

Fish Consumption (g/d)			Wild Game (g/d)			Plant Vegetation (g/d)		
Traditional Food	Receptor Parameters		Traditional Food	Receptor Parameters		Traditional Food	Receptor Parameters	
	Toddler	Adult		Toddler	Adult		Toddler	Adult
Salmon, any	21.61	68.60	Moose Meat	33.20	105.40	Labrador Tea Leaves	0.23	0.48
Sockeye Salmon	12.00	38.11	Deer Meat	8.39	26.64	Rat Root	0.039	0.08
Chinook Salmon	6.59	20.92	Elk Meat	2.76	8.78	Balsam Tree	0.0049	0.01
Coho Salmon	4.12	13.08	Moose Liver	1.38	4.39		-	-
Trout, any	3.60	11.43	Moose Kidney	1.15	3.66		-	-
Chum Salmon	2.19	6.97	Deer Liver	0.92	2.93		-	-
Pink Salmon	1.65	5.23	Rabbit Meat	0.92	2.93		-	-
Rainbow Trout	1.20	3.81	Caribou Meat	0.53	1.67		-	-
Lake Trout	0.60	1.91	Grouse	0.52	1.64		-	-
Dolly Varden	0.60	1.91	Beaver Meat	0.46	1.46		-	-
Steelhead Trout	0.27	0.87	Black Bear Fat	0.18	0.57		-	-
Whitefish	0.27	0.87	Sheep Meat	0.18	0.56		-	-
Herring	0.20	0.64	Black Bear Meat	0.12	0.37		-	-
Northern Pike	0.10	0.32	Ducks	0.07	0.21		-	-
			Geese	0.07	0.21		-	-
Total Fish	55.02	174.67	Total Wild Game	50.85	161.42	Total Plant Vegetation	0.28	0.57

Note: [a] Toddler consumption rates are extrapolated as a percentage of the adult food consumption rates (according to the same proportions as described in HC (2010a).
g/d = grams per day

4.1.3 Identification of Ecological Receptors

The ecological receptors that were selected and evaluated in the Environmental Health Baseline Section (**Appendix 9.1A**) will also be selected and evaluated in this assessment.

VCs are limited to three groups of ecological receptors that may be exposed to concentrations of COPCs readily bioavailable in media:

1. Aquatic receptors directly exposed to concentrations of chemicals readily bioavailable in surface water and/or sediment;
2. Wildlife exposed to concentrations of chemicals via ingestion of surface water and food items or by direct soil contact; and
3. Terrestrial plants and soil invertebrates exposed by direct soil contact.

Several VCs representing major ecosystem components were identified for inclusion in the ERA, including mammals, birds, amphibians, fish, invertebrates (soil and aquatic), and vegetation (terrestrial and aquatic).

Table 4.1-6 summarizes the selection of ecological receptors that will be evaluated in this assessment. Justification for the selection of each receptor is provided in the Environmental Health Baseline Section (**Appendix 9.1A**).

Table 4.1-6: Ecological Receptors

Description	Surrogate Receptor Identification
Mammals	
Large carnivorous/omnivorous	Grizzly bear (*Ursus arctos*)
Large herbivorous	Caribou (Rangifer tarandus)
Small carnivorous/omnivorous	Marten (Martes americana)
Small herbivorous	Snowshoe hare (Lepus americanus)
Small insectivorous	Short-tailed shrew (*Blarina brevicauda)*
Birds	
Raptors	Red-tailed hawk (Buteo jamaicensis)
Songbirds	Olive-sided flycatcher *(Contopus cooperi)*
Waterbirds/Waterfowl	Ring-necked duck *(Aythya collaris)*
Waterbirds/Waterfowl	Pacific loon (Gavia pacifica)
Amphibians	Western toad (Anaxyrus boreas)
Fish	Rainbow trout (Oncorhynchus mykiss)
Soil Invertebrates	Evaluated as generic group
Aquatic Invertebrates	Evaluated as generic group
Terrestrial Plants	Evaluated as generic group
Aquatic Plants	Evaluated as generic group

Other species or groups of organisms not selected as VCs may also inhabit the LSA, and may potentially be exposed to COPCs. However, given the number of species potentially present in the area, it is neither practical nor appropriate to consider all species. Rather, the selected species would be representative surrogate species occupying similar ecological niches as the other species or groups that were not selected as VCs.

Receptors selected for assessment represent VCs that were defined as resources or environmental features that are important to human populations have economic, cultural, and/or social value or have intrinsic ecological significance. The VCs have local, regional, provincial, national, and/or international profiles and serve as a baseline from which the effects of development can be evaluated, including changes in management or regulatory policies. Because it is not possible to evaluate all ecological species that may potentially be present at a site, representative receptors are selected based on several criteria (CCME, 1996), including:

- Threatened or endangered species;
- Sensitivity to chemicals;
- Biological and ecological relevance;
- Ability to measure or predict effects; and
- Social relevance (i.e., species of recreational, commercial, or social importance).

VCs are not always identified at the species level; rather, VCs can represent major groups of receptors deemed to be important and are sometimes defined at the trophic level. For example, benthic invertebrates may be identified as an important ecological component due to their role as filter feeders and prey for fish; individual species of invertebrates are not typically identified as VCs.

The exception is when at-risk species (i.e., endangered or otherwise threatened) are present (e.g., western toad). According to the *Species at Risk Act* (*SARA*) (Government of Canada, 2002), species at risk are categorized as:

- *Extinct:* a wildlife species that no longer exists anywhere in the world;
- *Extirpated:* a wildlife species that no longer exists in the wild in Canada, but exists elsewhere;
- *Endangered*: a wildlife species that is facing imminent extirpation or extinction;
- *Threatened*: a wildlife species likely to become an endangered species if nothing is done to reverse the factors leading to its extirpation or extinction; and
- *Special concern*: a wildlife species that may become a threatened or endangered species because of a combination of biological characteristics and identified threats.

4.1.4 Identification of Operable Pathways

After identifying the receptors within the LSA, the method by which human and ecological receptors could be exposed to the contamination (the source-to-receptor exposure pathway) needed to be identified.

The potential exposure and uptake pathways for human and ecological receptors that are located within the LSA and that will be evaluated in this assessment are summarized in **Table 4.1-7** and **Table 4.1-8** respectively. Details and the justification of the selection of exposure and uptake pathways for each receptor are provided in the Environmental Health Baseline Section (**Appendix 9.1A**).

Table 4.1-7: Operable Human Receptors Exposure Pathways

Environmental Media	Exposure Pathway
Emissions	Inhalation
Surface water	Ingestion
Surface water	Dermal contact (i.e., swimming or fishing)
Soil	Inadvertent ingestion
Soil	Inhalation of re-suspended soil particles
Soil	Dermal contact
Vegetation	Ingestion
Fish	Ingestion
Wild Game	Ingestion

Table 4.1-8: Operable Ecological Receptors Exposure Pathways

Ecological Receptor	Environmental Media	Exposure Pathway
Grizzly bear (*Ursus arctos*)	Soil	Ingestion
	Water	Ingestion
	Vegetation	Ingestion
	Small Mammals	Ingestion
Caribou (*Rangifer tarandus*)	Soil	Ingestion
	Water	Ingestion
	Vegetation	Ingestion
Marten (*Martes americana*)	Soil	Ingestion
	Water	Ingestion
	Vegetation	Ingestion
	Small Mammals	Ingestion
Snowshoe hare (*Lepus americanus)*	Soil	Ingestion
	Water	Ingestion
	Vegetation	Ingestion
Short-tailed shrew (*Blarina brevicauda)*	Soil	Ingestion
	Water	Ingestion
	Vegetation	Ingestion
	Soil Invertebrates	Ingestion
Red-tailed hawk *(Buteo jamaicensis)*	Soil	Ingestion
	Water	Ingestion
	Small Mammals	Ingestion
Olive-sided flycatcher *(Contopus cooperi)*	Soil	Ingestion
	Water	Ingestion

Ecological Receptor	Environmental Media	Exposure Pathway
	Soil Invertebrates	Ingestion
Ring-necked duck *(Aythya collaris)*	Sediments	Ingestion
	Water	Ingestion
	Aquatic Invertebrates	Ingestion
	Vegetation	Ingestion
Pacific loon *(Gavia pacifica)*	Sediments	Ingestion
	Water	Ingestion
	Fish	Ingestion
Western toad (*Anaxyrus boreas)*	Soil	Direct contact
	Water	Direct Contact
	Soil Invertebrates	Ingestion
Rainbow trout (*Oncorhynchus mykiss*)	Water	Direct contact
Soil Invertebrates	Soil	Direct contact
Aquatic Invertebrates	Water	Direct contact
Terrestrial Plants	Soil	Uptake by roots
Aquatic Plants	Water	Direct contact

An analysis of the potential exposure pathways for human and ecological receptors at the site is summarized in Site Conceptual Exposure Models presented in **Annex 9.2.2B**. The potential exposure media in the area of the LSA included air, soil, surface water, vegetation, fish, and wild game.

4.2 Toxicity Assessment

4.2.1 Human Receptors

The toxicity assessment includes:

- Hazard identification, which describes the potential adverse effects associated with a chemical and whether they are likely to occur in humans; and
- Dose-response evaluation, which quantifies the relationship between chemical dose and the incidence of adverse health effects in the exposed populations.

Exposure limits or TRVs were usually developed by regulatory agencies (i.e., HC, US EPA) based on a technical review of all of the available scientific information and application of professional judgment. These limits are considered protective of the most sensitive toxicological endpoints in individuals and include an adjustment of uncertainty factors. In general, such exposure limits were developed to protect the most sensitive individuals in a population, including sensitive life stages (e.g., pregnant women, the elderly) and individuals with compromised health (e.g., asthmatics). Typically, exposures below these exposure limits would not be associated with adverse health

effects and thus, would not represent a concern. As exposures increased to levels above prescribed exposure limits, the probability of increased health risk increased. **Annex 9.2.2C** provides the details of the potential adverse effects on humans with exposure to COPCs. TRVs representing concentrations of COPCs protective of most ecological receptors were identified.

Carcinogens

Compounds with known or potential carcinogenic effects were assumed not to have a dose below which no adverse effect occurs. For carcinogens, the oral TRV was called a slope factor or unit risk, which was an upper-bound estimate of the probability of a carcinogenic response per unit intake or concentration of a constituent over a lifetime. According to the US EPA (2013), either central or upper-bound estimates may be appropriate for evaluation of the carcinogenic risk or the selection of the estimate to be used was dependent on the type of assessment that may be required. Central estimates are applicable for characterizing a typical individual's risk, while upper-bound estimates conservatively exaggerated the risk to ensure that the risk was not underestimated if the underlying model was correct. Central estimates were useful for assessing aggregate risk across a population and for comparing or ranking environmental hazards. Upper-bound estimates provided information about the precision of the comparison or ranking. Slope factors or unit risks (upper-bound estimates) from HC (2010b), US EPA (2013), California EPA (CalEPA, 2013), and Risk Assessment Information System (RAIS, 2013) were used. A discussion of the toxicological reference values exposure limits for the COPCs used in the current assessment is found in **Annex 9.2.2C**. **Table 4.2-1** provides a summary of the cancer slope factors and unit risks used for the carcinogenic COPCs.

Non-Carcinogens

Compounds with known or potential non-carcinogenic effects were assumed to have a dose below which no adverse effect occurs, or conversely, above which an effect may (but not always) be seen. This dose was called the threshold dose. In laboratory experiments, this dose is known as the No Observable Adverse Effect Level (NOAEL) and is the lowest dose at which an adverse effect is not seen. HC has used these types of values to derive the TRV for chronic exposures to compounds with potential non-carcinogenic effects. The TRV provided reasonable certainty that if the specified exposure dose was below the threshold, then non-carcinogenic health effects were not expected to occur even if daily exposures were to occur for a lifetime.

It should be noted that the chemicals may exhibit different toxicological mechanisms of action depending on the route of exposure (i.e., ingestion, dermal, inhalation). Different TRVs were often provided for oral and inhalation exposure routes, depending on whether toxicity studies have been conducted and assessed for that route. In general, very few studies were available for dermal TRVs. The oral TRV value was adopted for all compounds that did not have a published dermal TRV. Similarly, for inhalation exposures of non-carcinogens, a tolerable concentration (TC) was derived using the same principles and used as the TRV for inhalation exposures. A discussion of the TRV exposure limits for the COPCs used in the current assessment is found in **Annex 9.2.2C**. **Table 4.2-1** provides a summary of the TRVs used for the non-carcinogenic COPCs.

Criteria Air Contaminants

For the CACs (i.e., SO_2, NO_2, CO, and PMs), the exposure limits were the lowest criteria of either the respective ambient air quality objectives from BC Ambient Air Quality Objectives (AAQO) and

the Canadian National Ambient Air Quality Objectives (NAAQO). **Table 4.2-2** provides a summary of the TRVs used in this assessment and references for the CACs

Table 4.2-1: Toxicological Reference Values for COPCs

COPC	Oral TRV (mg/kg-d)	Dermal TRV (mg/kg-d)	Acute Inhalation TRV (mg/m^3)	Chronic Inhalation TRV (mg/m^3)	Cancer Slope Factor		Unit Risk
					Oral	Dermal	Inhalation
					(1/mg/kg-d)		(1/mg/m^3)
Benzene*	0.0005[b]	0.0005[i]	0.03[a]	0.001[b]	0.0834[c]	0.0834[i]	0.033[c]
Benzo(a)anthracene*	n/a	n/a	n/a	n/a	0.73[d, e]	0.73[i]	0.11[d]
Benzo(a)pyrene*	n/a	n/a	n/a	0.0000005[a]	.2.3[c]	2.3[i]	0.031[c]
Benzo(b)fluoranthene*	n/a	n/a	n/a	n/a	0.73[d, e]	0.73[i]	0.11[d]
Benzo(g,h,i)perylene	0.0071[a]	0.0071[i]	n/a	0.012[h]	n/a	n/a	n/a
Benzo(k)fluoranthene*	n/a	n/a	n/a	n/a	7.3[d, e]	7.3[i]	0.11[f]
Chrysene*	n/a	n/a	n/a	n/a	0.0073[d, e]	0.0073[i]	0.11[d]
Dibenz(a,h)anthracene*	n/a	n/a	n/a	n/a	7.3[d, e]	7.3[i]	1.2[f]
Ethylbenzene	0.1[c]	0.1[i]	143[h]	1[c]	n/a	n/a	n/a
Indeno(1,2,3-cd)pyrene*	n/a	n/a	n/a	n/a	0.73[d, e]	0.73[i]	0.11[d]
Toluene	0.22[c]	0.22[i]	3.8[b]	3.75[c]	n/a	n/a	n/a
Xylene	1.5[c]	1.5[i]	22[f]	0.18[c]	n/a	n/a	n/a
Aluminum	1[g]	1[i]	n/a	0.005[g]	n/a	n/a	n/a
Arsenic*	0.0003[d, e, g]	0.0003[i]	0.0002[f]	0.000015[f]	1.8[c]	1.8[i]	6.4[c]
Cadmium	0.001[c, **]	0.001[i]	n/a	0.00001[e]	n/a	n/a	9.8[c]
Cyanide	0.02[c]	0.02[i]	0.34[f]	0.0008[d, g]	n/a	n/a	n/a
Mercury	0.0003[c]	0.0003[i]	n/a	0.00003[f]	n/a	n/a	n/a
Molybdenum	0.023[c]	0.023[i]	n/a	0.005[e]	n/a	n/a	n/a
Selenium	0.0062[c]	0.0062[i]	n/a	0.0002[e]	n/a	n/a	n/a

Notes: * = COPC is a carcinogen;
[a] = Michigan DEQ (2013); [b] = Agency for Toxic and Substances and Disease Registry (ATSDR) (2007)
[c] = Health Canada (2010b); ** = provisional value provided by Health Canada (2010)
[d] = United States Environmental Protection Agency– Integrated Risk Information System (US EPA, 2013);
[e] = Texas Commission on Environmental Quality (TCEQ) (2013); [f] = California Environmental Protection Agency (CalEPA) (2013);
[g] = Risk Assessment Information System (RAIS, 2013); [h] = United States Environmental Protection Agency Acute Exposure Guideline Level (US EPA, 2008);
[i] = oral TRV adopted as dermal TRV; [j] = Extrapolation from inhalation TRV;
COPC = Chemical of Potential Concern; TRV = toxicological reference value; n/a = not applicable;
mg/kg-d = milligrams per kilogram per day;
mg/m^3 = milligrams per cubic metre

Table 4.2-2: Summary of Toxicological Reference Values for Criteria Pollutants

CAC	Averaging Period	BC AAQO (mg/m^3)[a]	NAAQO (mg/m^3)[b]
NO_2	1-hour	n/a	0.4
	24-hour	n/a	0.2
	Annual	n/a	0.06
SO_2	1-hour	0.45	0.9
	24-hour	0.16	0.3
	Annual	0.025	0.06
$PM_{2.5}$	24-hour	0.025	0.03
	Annual	0.008	n/a
PM_{10}	24-hour	0.05	n/a
CO	1-hour	14.3	35
	8-hour	5.5	15

Notes: [a]BC regulations as a geometric mean; [b] NAAQO acceptable levels
AAQO = Ambient Air Quality Objectives; BC = British Columbia; CAC = criteria air contaminant; mg/m^3 = milligrams per cubic metre; n/a = not available; NAAQO = Canadian National Ambient Air Quality Objectives; NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; $PM_{2.5}$ = particulate matter no greater than 2.5 micrometres in aerodynamic diameter; PM_{10} = particulate matter no greater than 10 micrometres in aerodynamic diameter

Relative Absorption Factor

To estimate the potential risk to human health that may be posed by the presence of a COPC in various environmental media (such as soil, sediment, water, or air), it was first necessary to estimate the human exposure dose of each COPC. The exposure dose was similar to the administered dose or applied dose of a laboratory experiment. The exposure dose was then combined with an estimate of the toxicity of the compound to produce an estimate of risk posed to human health.

Relative Absorption Factor (RAF) was a correction factor used to adjust the human potential dose so that it was expressed in the same terms as the doses used to generate the dose-response curve in the dose-response study. The RAF was the ratio between the estimated human absorption factor for the specific medium and route of exposure, and the known or estimated absorption factor for the laboratory study from which the dose-response value was derived.

$$RAF = \frac{fraction\ absorbed\ in\ humans\ for\ the\ environmental\ exposure}{fraction\ absorbed\ in\ the\ dose-response\ study}$$

The use of an RAF allowed the risk assessor to make appropriate adjustments if the efficiency of absorption between environmental exposure and experimental exposure was known or expected to differ because of physiological effects and/or matrix or vehicle effects. RAFs can be less than or greater than one, depending on the particular circumstances at hand. If it is believed that

absorption from the site-specific exposure is the same as absorption in the laboratory study, then the RAF = 1.0.

A summary of RAFs used in the assessment is provided in **Table 4.2-3**. It should be noted that relative absorption values were obtained directly from HC (2010a and 2010b), TCEQ (2013), CalEPA (2013) and RAIS (2013).

Table 4.2-3: Summary of Relative Absorption Factors

COPC	Oral Soil	Dermal Soil	Inhalation
Benzene	1[a]	0.03[b]	1[c]
Benzo(a)anthracene	1[a]	0.148[b]	1[c]
Benzo(a)pyrene	1[a]	0.148[b]	1[c]
Benzo(b)fluoranthene	1[a]	0.148[b]	1[c]
Benzo(g,h,i)perylene	1[a]	0.148[b]	1[c]
Benzo(k)fluoranthene	1[a]	0.148[b]	1[c]
Chrysene	1[a]	0.148[b]	1[c]
Dibenz(a,h)anthracene	1[a]	0.148[b]	1[c]
Ethylbenzene	1[a]	0.03[b]	1[c]
Indeno(1,2,3-cd)pyrene	1[a]	0.148[b]	1[c]
Toluene	1[a]	0.03[b]	1[c]
Xylene	1[a]	0.03[b]	1[c]
Aluminum	1[d]	0.02[c]	1[c]
Arsenic	1[a]	0.03[b]	1[c]
Cadmium	1[a]	0.01[b]	1[c]
Chromium	1[a]	0.1[b]	1[c]
Copper	1[a]	0.06[b]	1[c]
Cyanide	1[a]	0.1[b]	1[c]
Mercury	0.07[d]	1[b]	1[c]
Molybdenum	1[a]	0.01[b]	1[c]
Selenium	1[a]	0.01[b]	1[c]

Note: [a] = HC 2010a default value of 1; [b] = HC 2010b;[c] = CalEPA 2013, [d] = RAIS 2013, [d] = TCEQ 2013
COPC = Chemical of Potential Concern

4.2.2 Ecological Receptors

Similar to human receptors, the toxicity assessment for ecological receptors includes:

- Hazard identification, which describes the potential adverse effects associated with a chemical and whether they are likely to occur in ecological receptors; and
- Dose-response evaluation, which quantifies the relationship between chemical dose and the incidence of adverse effects in the exposed populations.

For each receptor, TRVs representing concentrations of COPCs protective of most ecological receptors were identified. Exposure limits were usually developed by regulatory agencies (i.e., US EPA Ecological Soil Screening Levels (Eco-SSL; US EPA, 2005)) based on a technical review of all of the available scientific information and application of professional judgment. These limits considered the most sensitive toxicological endpoints and include an adjustment of uncertainty factors. Typically, exposures below these exposure limits would not be associated with adverse health effects and thus would not represent a concern. As exposures increased to levels above prescribed exposure limits, the probability of increased health risk increased.

Annex 9.2.2C provides the basis for each TRV and potential adverse effects on the ecological receptors associated with exposure to COPCs. **Table 4.3-1** provides a summary of the TRVs used for the ecological receptors.

4.3 Exposure Assessment

The purpose of the exposure assessment is to estimate the amount of the COPC that might be received by a human or ecological receptor. The exposure assessment includes an analysis of the pathways through which receptors may be exposed to COPCs and an estimate of the concentrations to which they may be exposed. For COPCs to have adverse effects on human and ecological receptors, the COPC must have contact with the organisms or receptors. The route by which this occurs is referred to as an exposure pathway and is dependent on the nature of the chemical and the nature of the receptor. A complete exposure pathway is one that meets the following criteria:

- A source of COPCs must be present;
- Release and transport mechanisms and media must be available to move the COPC from the source to the ecological receptors;
- An opportunity must exist for the human and ecological receptors to contact the affected media; and
- A means must exist by which the COPC is taken up by receptors, such as ingestion, inhalation, or direct contact with skin or membranes.

Table 4.3-1: Toxicological Reference Value Derivations for Ecological Receptors

COPCs	Mammals (mg/kg)	Birds (mg/kg)	Fish (mg/L)	Soil Invertebrates (mg/kg)	Terrestrial Plants (mg/kg)	Aquatic Invertebrates (mg/L)	Aquatic Plants (mg/L)
Aluminum	19.3	110	3.29	67.5	50	1.9	0.46
Arsenic	1.04	2.24	0.89	17	17	0.45	0.048
Benzene	26.36	26.36	525	18	31	98	525
Benzo(a)anthracene	0.62	2.0	0.00065	18	0.5	0.00065	0.00065
Benzo(a)pyrene	1.0	2.0	0.0003	18	20	0.0003	0.0003
Benzo(b)fluoranthene	0.62	2.0	0.0003	18	20	0.0042	0.0003
Benzo(g,h,i)perylene	0.62	2.0	0.0003	18	6.6	0.00002	0.0003
Benzo(k)fluoranthene	0.62	0.2	0.0003	18	20	0.0014	0.0003
Cadmium	1.0	1.45	0.0017	140	32	0.00015	0.002
Chromium	3.28	1.0	0.068	10	10	0.044	0.397
Chrysene	0.62	0.62	0.0003	18	20	0.0007	0.0003
Copper	11.7	47.0	0.0038	80	70	0.00023	0.001
Cyanide	68.7	1.43	0.0078	6	5	0.0078	0.03
Dibenz(a,h)anthracene	0.62	0.62	0.0003	18	20	0.00004	0.0003
Ethylbenzene	408.0	408.0	0.44	18	55	12.92	438
Indeno(1,2,3-cd)pyrene	0.62	0.50	0.0003	18	0.031	0.00014	0.0003
Lead	8	3.85	0.018	1700	120	0.012	0.5
Mercury	0.032	0.01	0.00023	2.5	34.9	0.00096	0.005
Molybdenum	0.26	3.5	0.88	2	2	0.88	0.88
Selenium	0.2	0.5	0.088	4.1	0.52	0.092	0.1
Toluene	26.0	26.0	1.27	80	2000	25.23	245
Vanadium	0.21	11.4	0.08	210	55	1.9	0.08
Xylene	2.1	2.1	2.68	8	5	62.3	62.3
Zinc	160.0	14.5	0.036	120	160	0.046	0.03

Notes: COPCs = Chemical of Potential Concern
mg/kg = milligrams per kilogram; mg/L = milligrams per Litre;

Exposure assessment consists of several steps, including the description of the fate and transport of COPCs in the environment, an examination of potential exposure pathways, and an estimation of exposure levels for each receptor.

4.3.1 Exposure Point Concentrations

Exposure point concentrations (EPCs) are chemical concentrations in air, soil, surface water, sediments and foods to which receptors were assumed to be exposed.

Sampling and analysis of measured concentration of soil, surface water, sediments and country foods was completed in the biophysical baseline study that represents the existing baseline conditions prior to the development of the Project. For the EA, the 95% UCL was used as the EPC (**Annex 9.2.2A**).

The EA also evaluated the predicted concentrations of the COPCs in the airshed assuming maximum production from the Project during the operations phase. The effects assessment considered the EPCs as the sum of the current baseline conditions plus the incremental increases during the operations phase. Air dispersion modelling determined the ground-level air concentrations for each of the COPCs outside of the Project footprint. These air concentrations were predicted within the LSA at four locations (as presented in **Table 4.3-1**). The HHERA also evaluated the predicted estimates of the COPCs in the surface water for all phases of the Project. The EPCs in the EA were the 95% UCL of measured baseline concentrations to which were added the COPC loading from predicted air emissions during the operations phase and predicted surface water during all phases of the project.

4.3.2 Average Daily Doses

Based on the EPCs for the soil, surface water, vegetation, fish, and wildlife, average daily doses (ADD) for the toddler (non-carcinogen), adult (carcinogen), and ecological receptors were derived. ADD for each of the COPCs for the human and ecological receptors are presented in **Annex 9.2.2D**.

4.4 Risk Characterization

4.4.1 Human Receptors

Risk characterization, the final step in the risk assessment process, integrates the results of the exposure and toxicity assessments for each COPC in order to estimate the potential for carcinogenic and non-carcinogenic human health effects from exposure to that COPC. This section summarizes the results of the risk characterization for each receptor evaluated in the risk assessment.

The risk characterization compares estimated site-specific risk levels to target risk levels. HC's allowable Incremental Lifetime Cancer Risk (ILCR) target is set at 10^{-5}, or 1 in 100,000 (HC, 2010a). For non-carcinogens, HC's target HQ is set at 0.2 (HC, 2010a).

Approach for Non-Carcinogenic Risk Characterization

For the assessment of non-carcinogenic health effects, the calculated ADD (**Annex 9.2.2D**) is compared to the non-carcinogenic TRV (**Annex 9.2.2C**). The non-carcinogenic TRV is defined as an estimate of compound intake that is unlikely to cause adverse health effects even if exposure occurs for an entire lifetime.

The potential for exposures to result in adverse non-carcinogenic health effects is estimated by comparing the daily dose with the TRV. The resulting ratio, which is unitless, is known as the

HQ for that compound. The HQ for ingestion and dermal pathways is calculated using the following formula:

$$HQ = \frac{ADD}{TRV}$$

where:

HQ	=	Hazard Quotient (unitless)
ADD	=	Average Daily Dose (mg/kg-d)
TRV	=	Toxicological Reference Value (mg/kg-d)

The HQ for inhalation exposure pathway is calculated using the following formula:

$$HQ = \frac{EPC}{TRV}$$

where:

HQ	=	Hazard Quotient (unitless)
EPC	=	Exposure Point Concentration (mg/m^3)
TRV	=	Toxicological Reference Value (mg/m^3)

For total exposures to receptors at receptor locations within the LSA (including onsite exposures plus background), HC accepts that when the HQ for a given COPC and pathway does not exceed 1.0, no unacceptable risks exist. If the total exposure results in HQ values greater than 1.0, it may indicate some potential risk, but the importance of this risk must be evaluated in light of the degree of conservatism incorporated in the health risk assessment. It is important to note that the magnitude of the HQ does not necessarily correspond to the magnitude of expected health effects.

Approach for Carcinogenic Risk Characterization

For the assessment of carcinogenic health effects, the risk estimate (i.e., ILCR) was determined for ingestion, dermal contact, and inhalation exposure pathways as follows:

$$ILCR = ADD \, x \, CSF$$

where:

ILCR	=	Incremental Lifetime Cancer Risk (unitless)
ADD	=	Average Daily Dose (mg/kg-d)
CSF	=	Cancer Slope Factor (mg/kg-d)

The ILCR for inhalation exposure pathway is calculated using the following formula:

$$ILCR = EPC \ x \ F \ x \ UR$$

where:

ILCR	=	Incremental Lifetime Cancer Risk (unitless)
EPC	=	Exposure Point Concentration (mg/m^3)
F	=	Fraction of Time Exposed
UR	=	Cancer Unit Risk (mg/m^3)

The ADD is the total chemical exposures via the ingestion, dermal or inhalation routes. The TRV would be the cancer slope factor for that particular carcinogen. Based on HC (2010a), an ILCR greater than 10^{-5}, or 1 in 100,000, is considered to represent an unacceptable level of risk. Cancer risks will be deemed to be essentially negligible (*de minimus*) where estimated ILCR is less than 1.0×10^{-5} or 1 in 100,000 (HC 2010a).

Criteria Air Contaminants

HQs were calculated by dividing the annual concentrations of CACs by each parameter's respective TRV. The HQ values for the CAC emissions are presented in **Table 4.4-1**.

Predicted 1-hour, 8-hour, and 24-hour ground-level NO_2, SO_2, $PM_{2.5}$, PM_{10} and CO concentrations did not result in any acute short-term exposure HQ values above 1.0 for any of the receptor locations. The highest acute HQ values for NO_2, SO_2, $PM_{2.5}$, and CO are 0.051, 0.00067, 0.065, 0.19 and 0.023, respectively, at Tatelkuz Lake Resort and Tatelkus Lake IR 28. Adverse health effects for human receptors are unlikely to occur following acute short-term exposures to NO_2, SO_2 $PM_{2.5}$, PM_{10} and CO.

Predicted annual ground-level NO_2, SO_2 and $PM_{2.5}$ concentrations did not result in any chronic HQ values above 1.0 for any of the receptor locations. The highest HQ values for chronic exposure to NO_2, SO_2, and $PM_{2.5}$are 0.14, 0.041 and 0.53, respectively, at Tatelkuz Lake Resort and Tatelkus Lake IR 28. There is no consistent pattern in regards to the total HQ values between the baseline conditions and the effects assessment. However, since the total HQ values in the baseline condition and effects assessment remain less than 1.0, adverse health effects for human receptors are unlikely to occur following chronic exposures to NO_2, SO_2 and $PM_{2.5}$.

Table 4.4-1: Hazard Quotients for Acute and Chronic Exposures to Criteria Air Contaminants

Receptor Location	NO_2			SO_2			$PM_{2.5}$		PM_{10}	CO	
	Acute	Acute	Chronic	Acute	Acute	Chronic	Acute	Chronic	Acute	Acute	Acute
	1-hr	24-hr	Annual	1-hr	24-hr	Annual	24-hr	Annual	24-hr	1-hr	8-hr
Blackwater-Spruce Ranch	0.031	0.015	0.14	0.00033	0.00027	0.040	0.046	0.51	0.18	0.00024	0.022
Laidman Lake Ecolodge	0.013	0.0070	0.13	0.000016	0.00018	0.040	0.023	0.50	0.18	0.00013	0.022
Pan Phillips Resort	0.013	0.0043	0.13	0.000091	0.000054	0.040	0.013	0.50	0.18	0.00012	0.022
Tatelkuz Lake Resort and Tatelkus Lake IR 28	0.051	0.022	0.14	0.00067	0.00064	0.041	0.065	0.53	0.19	0.00048	0.023

Notes: NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; CO = carbon monoxide
$PM_{2.5}$ = particulate matter no greater than 2.5 micrometres in aerodynamic diameter;
PM_{10} = particulate matter no greater than 10 micrometres in aerodynamic diameter

Aluminum

Non-carcinogenic chronic exposures to aluminum results in total HQ values lower than 1.0 for all receptor locations with the highest HQ value of 0.050 at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Table 4.4-2**). There is no consistent change in pattern in regards to the total HQ values between the baseline conditions and the effects assessment. However, since the total HQ values in the baseline condition and effects assessment remain less than 0.2 in both situations, adverse health effects for human receptors are unlikely to occur following chronic exposures to aluminum. Based on the results for each individual exposure pathway, the primary contributing exposure pathway of risks for aluminum exposure is via the ingestion of vegetation (**Annex 9.2.2D**).

Table 4.4-2: Non-Carcinogenic Risk Estimate for Chronic Aluminum Exposures

Receptor Location	Total HQ
Blackwater-Spruce Ranch	0.046
Laidman Lake Ecolodge	0.044
Pan Phillips Resort	0.044
Tatelkuz Lake Resort and Tatelkus Lake IR 28	0.050

Notes: HQ = Hazard Quotient

Arsenic

Non-carcinogenic chronic exposures to arsenic results in total HQ values higher than 0.2 for all receptor locations. Tatelkuz Lake Resort and Tatelkus Lake IR 28 was observed to have the highest HQ value of 0.99 (**Table 4.4-3**). The primary exposure pathway that contributes the most to the non-carcinogenic risks for arsenic exposure is through the ingestion of fish and surface water (**Annex 9.2.2D**).

Table 4.4-3: Non-Carcinogenic Risk Estimate for Chronic Arsenic Exposures

Receptor Location	Total HQ
Blackwater-Spruce Ranch	**0.96**
Laidman Lake Ecolodge	**0.94**
Pan Phillips Resort	**0.93**
Tatelkuz Lake Resort and Tatelkus Lake IR 28	**0.99**

Notes: **Bold** and underlined text represents HQ values greater than 0.2
HQ = Hazard Quotient

Non-carcinogenic short-term acute inhalation exposures to arsenic in the ambient air results in HQ values lower than 1.0 for all receptor locations with the highest HQ value of 0.063 at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Table 4.4-4**).

Table 4.4-4: Non-Carcinogenic Risk Estimate for Acute Arsenic Exposures in the Ambient Air

Receptor Location	HQ
Blackwater-Spruce Ranch	0.070
Laidman Lake Ecolodge	0.031
Pan Phillips Resort	0.027
Tatelkuz Lake Resort and Tatelkus Lake IR 28	0.095

Notes: HQ = Hazard Quotient

Carcinogenic risks from exposure to arsenic for the adult receptor are shown in **Table 4.4-5**. The total ILCR values, for both adult alone and composite lifetime receptors, at each receptor location are above HC's target risk level of 1.0×10^{-5}. Both the baseline and effects assessment had ILCR values greater than 1.0×10^{-5} for human receptors. The Project does not increase the health risks. EA ILCRs were noted to be lower when compared to the Baseline ILCRs. This is expected since the predicted surface water concentrations for the EA were low and expected to be within BC Freshwater Guidelines. The primary exposure pathway that contributes the most to the carcinogenic risks for arsenic exposure is through ingestion of fish and surface water at each receptor location (**Annex 9.2.2D**).

Table 4.4-5: Incremental Lifetime Cancer Risk Estimate for Exposure to Arsenic for the Adult Receptor

Receptor Location	Total ILCR (Adult Alone)	Total ILCR (Amortized over Lifetime)
Blackwater-Spruce Ranch	**2.1×10^{-4}**	**3.4×10^{-4}**
Laidman Lake Ecolodge	**2.0×10^{-4}**	**3.4×10^{-4}**
Pan Phillips Resort	**2.0×10^{-4}**	**3.4×10^{-4}**
Tatelkuz Lake Resort and Tatelkus Lake IR 28	**2.1×10^{-4}**	**3.4×10^{-4}**

Notes: **Bold** and underlined text represents ILCR values greater than 1.0×10^{-5}
ILCR = Incremental Lifetime Cancer Risk

Benzene

Non-carcinogenic chronic exposures to benzene results in total HQ values of less than 0.2 for all receptor locations. Tatelkuz Lake Resort and Tatelkus Lake IR 28 had the highest HQ value of 0.0007 (**Table 4.4-6**). The primary exposure pathway that contributes the most to the non-carcinogenic risks for benzene exposure is through inhalation of air emissions (**Annex 9.2.2D**).

Table 4.4-6: Non-Carcinogenic Risk Estimate for Chronic Benzene Exposures

Receptor Location	Total HQ
Blackwater-Spruce Ranch	0.000059
Laidman Lake Ecolodge	0.000013
Pan Phillips Resort	0.0000057
Tatelkuz Lake Resort and Tatelkus Lake IR 28	0.00070

Notes: HQ = Hazard Quotient

Non-carcinogenic short-term acute inhalation exposures to benzene in the ambient air results in HQ values lower than 1.0 for all receptor locations with the highest HQ value of 0.00044 at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Table 4.4-7**).

Table 4.4-7: Non-Carcinogenic Risk Estimate for Acute Benzene Exposures in the Ambient Air

Receptor Location	HQ
Blackwater-Spruce Ranch	0.000087
Laidman Lake Ecolodge	0.000034
Pan Phillips Resort	0.000040
Tatelkuz Lake Resort and Tatelkus Lake IR 28	0.00044

Notes: HQ = Hazard Quotient

Carcinogenic risks from exposure to benzene for the adult receptor are shown in **Table 4.4-8**. The total ILCR values at each receptor location are below HC's target risk level of 1.0×10^{-5}, for both adult alone and composite lifetime receptors, with the highest ILCR value of 2.3×10^{-9} and 1.4×10^{-9} at Tatelkuz Lake Resort and Tatelkus Lake IR 28. Similar to the non-carcinogenic scenario, the primary exposure pathway that contributes the most to the carcinogenic risk estimates for the adult receptor is exposure to benzene through the inhalation of air emissions (**Annex 9.2.2D**).

Table 4.4-8: Incremental Lifetime Cancer Risk Estimate for Exposure to Benzene for the Adult Receptor

Receptor Location	Total ILCR (Adult Alone)	Total ILCR (Amortized over Lifetime)
Blackwater-Spruce Ranch	$1.9x10^{-10}$	$1.2x10^{-10}$
Laidman Lake Ecolodge	$4.2x10^{-11}$	$2.5x10^{-11}$
Pan Phillips Resort	$1.9x10^{-11}$	$1.1x10^{-11}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$2.3x10^{-9}$	$1.4x10^{-9}$

Notes: ILCR = Incremental Lifetime Cancer Risk

Benzo(a)anthracene

Carcinogenic risks from exposure to benzo(a)anthracene emitted from the proposed Project for the adult receptor are shown in **Table 4.4-9**. The total ILCR values, for both adult alone and composite lifetime receptors, at each receptor location are below HC's target risk level of 1.0×10^{-5} with the highest ILCR value of 2.2×10^{-9} and 3.2×10^{-9} at Tatelkuz Lake Resort and Tatelkus Lake IR 28. The primary exposure pathway that contributes the most to the carcinogenic risk estimates for the adult receptor is exposure to benzo(a)anthracene through the ingestion of fish (**Annex 9.2.2D**).

Table 4.4-9: Incremental Lifetime Cancer Risk Estimate for Exposure to Benzo(a)anthracene for the Adult Receptor

Receptor Location	Total ILCR (Adult Alone)	Total ILCR (Amortized over Lifetime)
Blackwater-Spruce Ranch	$5.1x10^{-11}$	$7.3x10^{-11}$
Laidman Lake Ecolodge	$9.6x10^{-12}$	$1.4x10^{-12}$
Pan Phillips Resort	$4.7x10^{-12}$	$6.7x10^{-12}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$2.2x10^{-9}$	$3.2x10^{-9}$

Notes: ILCR = Incremental Lifetime Cancer Risk

Benzo(a)pyrene

Carcinogenic risks from exposure to benzo(a)pyrene emitted from the proposed Project for the adult receptor are shown in **Table 4.4-10**. The total ILCR values at each receptor location, for both adult alone and composite lifetime receptors are below HC's target risk level of 1.0×10^{-5} with the highest ILCR value of 4.9×10^{-11} and 7.1×10^{-11} at Tatelkuz Lake Resort and Tatelkus Lake IR 28. The primary exposure pathway that contributes the most to the carcinogenic risk estimates for the adult receptor is exposure to benzo(a)pyrene through the ingestion of fish (**Annex 9.2.2D**).

Table 4.4-10: Incremental Lifetime Cancer Risk Estimate for Exposure to Benzo(a)pyrene for the Adult Receptor

Receptor Location	Total ILCR (Adult Alone)	Total ILCR (Amortized over Lifetime)
Blackwater-Spruce Ranch	$1.0x10^{-11}$	$1.5x10^{-11}$
Laidman Lake Ecolodge	$1.6x10^{-12}$	$2.3x10^{-12}$
Pan Phillips Resort	$5.6x10^{-13}$	$8.1x10^{-13}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$4.9x10^{-11}$	$7.1x10^{-11}$

Notes: ILCR = Incremental Lifetime Cancer Risk

Benzo(b)fluoranthene

Carcinogenic risks from exposure to benzo(b)fluoranthene emitted from the proposed Project for the adult receptor are shown in **Table 4.4-11**. The total ILCR values, for both adult alone and composite lifetime receptors, at each receptor location are below HC's target risk level of 1.0×10^{-5} with the highest ILCR value of 4.1×10^{-13} and 6.1×10^{-13} at Tatelkuz Lake Resort and Tatelkus Lake IR 28. The primary exposure pathway that contributes the most to the carcinogenic risk estimates for the adult receptor is exposure to benzo(b)fluoranthene through the ingestion of fish (**Annex 9.2.2D**).

Table 4.4-11: Incremental Lifetime Cancer Risk Estimate for Exposure to Benzo(b)fluoranthene for the Adult Receptor

Receptor Location	Total ILCR (Adult Alone)	Total ILCR (Amortized over Lifetime)
Blackwater-Spruce Ranch	$8.7x10^{-14}$	$1.3x10^{-13}$
Laidman Lake Ecolodge	$1.4x10^{-14}$	$2.0x10^{-14}$
Pan Phillips Resort	$4.7x10^{-15}$	$7.0x10^{-15}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$4.1x10^{-13}$	$6.1x10^{-13}$

Notes: ILCR = Incremental Lifetime Cancer Risk

Benzo(g,h,i)perylene

Non-carcinogenic exposures to benzo(g,h,i)perylene being emitted from the proposed Project results in total HQ values that are orders of magnitude less than 0.2 for all receptor locations with the highest HQ value of 5.8×10^{-11} at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Table 4.4-12**). The primary exposure pathway that contributes the most to the non-carcinogenic risks for benzo(g,h,i)perylene exposure is through inhalation of air emissions (**Annex 9.2.2D**).

Table 4.4-12: Non-Carcinogenic Risk Estimate for Chronic Benzo(g,h,i)perylene Exposures

Receptor Location	Total HQ
Blackwater-Spruce Ranch	$1.2x10^{-11}$
Laidman Lake Ecolodge	$1.9x10^{-12}$
Pan Phillips Resort	$6.6x10^{-13}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$5.8x10^{-11}$

Notes: HQ = Hazard Quotient

Benzo(k)fluoranthene

Carcinogenic risks from exposure to benzo(k)fluoranthene emitted from the proposed Project for the adult receptor are shown in **Table 4.4-13**. The total ILCR values, for both adult alone and composite lifetime receptors, at each receptor location are below HC's target risk level of 1.0×10^{-5} with the highest ILCR value of 8.0×10^{-11} and 1.2×10^{-10} at Tatelkuz Lake Resort and Tatelkus Lake IR 28. The primary exposure pathway that contributes the most to the carcinogenic risk estimates for the adult receptor is exposure to benzo(k)fluoranthene through the ingestion of moose (**Annex 9.2.2D**).

Table 4.4-13: Incremental Lifetime Cancer Risk Estimate for Exposure to Benzo(k)fluoranthene for the Adult Receptor

Receptor Location	Total ILCR (Adult Alone)	Total ILCR (Amortized over Lifetime)
Blackwater-Spruce Ranch	$1.7x10^{-11}$	$2.5x10^{-11}$
Laidman Lake Ecolodge	$2.6x10^{-12}$	$3.8x10^{-12}$
Pan Phillips Resort	$9.1x10^{-13}$	$1.3x10^{-13}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$8.0x10^{-11}$	$1.2x10^{-10}$

Notes: ILCR = Incremental Lifetime Cancer Risk

Cadmium

Non-carcinogenic exposures to cadmium results in total HQ values lower than 0.2 for all receptor locations with the highest HQ value of 0.023 at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Table 4.4-14**). There is no consistent pattern in regards to the total HQ values between the baseline conditions and the effects assessment. However, since the total HQ values in the baseline condition and effects assessment remain less than 0.2 in both situations, adverse health effects for human receptors are unlikely to occur following chronic exposures to cadmium. Based on the results for each individual exposure pathway, the primary contributing exposure pathway of risks for cadmium exposure is via the ingestion of fish (**Annex 9.2.2D**).

Table 4.4-14: Non-Carcinogenic Risk Estimate for Chronic Cadmium Exposures

Receptor Location	Total HQ
Blackwater-Spruce Ranch	0.021
Laidman Lake Ecolodge	0.020
Pan Phillips Resort	0.020
Tatelkuz Lake Resort and Tatelkus Lake IR 28	0.023

Notes: HQ = Hazard Quotient

Chrysene

Carcinogenic risks from exposure to chrysene emitted from the proposed Project for the adult receptor are shown in **Table 4.4-15**. The total ILCR values, for both adult alone and composite lifetime receptors, at each receptor location are orders of magnitude below HC's target risk level of 1.0×10^{-5} with the highest ILCR value of 4.4×10^{-12} and 6.9×10^{-12} at Tatelkuz Lake Resort and Tatelkus Lake IR 28. The primary exposure pathway that contributes the most to the carcinogenic risk estimates for the adult receptor is exposure to chrysene through the ingestion of fish (**Annex 9.2.2D**).

Table 4.4-15: Incremental Lifetime Cancer Risk Estimate for Exposure to Chrysene for the Adult Receptor

Receptor Location	Total ILCR (Adult Alone)	Total ILCR (Amortized over Lifetime)
Blackwater-Spruce Ranch	1.2×10^{-12}	1.9×10^{-12}
Laidman Lake Ecolodge	2.7×10^{-13}	4.2×10^{-13}
Pan Phillips Resort	1.2×10^{-13}	1.8×10^{-13}
Tatelkuz Lake Resort and Tatelkus Lake IR 28	4.4×10^{-12}	6.9×10^{-12}

Notes: ILCR = Incremental Lifetime Cancer Risk

Cyanide

Non-carcinogenic exposures to cyanide results in total HQ values higher than 0.2 for all receptor locations. The highest HQ value of 0.31 is found at all locations (**Table 4.4-16**). Based on the results for each individual exposure pathway, the primary contributing exposure pathway of risks for cyanide exposure is via ingestion of surface water at each receptor location and via inhalation of air emissions (**Annex 9.2.2D**).

Table 4.4-16: Non-Carcinogenic Risk Estimate for Chronic Cyanide Exposures

Receptor Location	Total HQ
Blackwater-Spruce Ranch	**0.31**
Laidman Lake Ecolodge	**0.31**
Pan Phillips Resort	**0.31**
Tatelkuz Lake Resort and Tatelkus Lake IR 28	**0.31**

Notes: **Bold** and underlined text represents HQ values greater than 0.2
HQ = Hazard Quotient

Non-carcinogenic short-term acute inhalation exposures to cyanide in the ambient air resulted in HQ values that are lower than 1.0 for all receptor locations with the highest HQ value of 0.00041 at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Table 4.4-17**).

Table 4.4-17: Non-Carcinogenic Risk Estimate for Acute Cyanide Exposures in the Ambient Air

Receptor Location	HQ
Blackwater-Spruce Ranch	0.000094
Laidman Lake Ecolodge	0.000059
Pan Phillips Resort	0.000039
Tatelkuz Lake Resort and Tatelkus Lake IR 28	0.00041

Notes: HQ = Hazard Quotient

Dibenz(a,h)anthracene

Carcinogenic risks from exposure to dibenz(a,h)anthracene emitted from the proposed Project for the adult receptor are shown in **Table 4.4-18**. The total ILCR values at each receptor location, for both adult alone and composite lifetime receptors, are below HC's target risk level of 1.0×10^{-5} with the highest ILCR value of 2.2×10^{-9} and 3.2×10^{-9} at Tatelkuz Lake Resort and Tatelkus Lake IR 28. The primary exposure pathway that contributes the most to the carcinogenic risk estimates for the adult receptor is exposure to dibenz(a,h)anthracene through the ingestion of moose (**Annex 9.2.2D**).

Table 4.4-18: Incremental Lifetime Cancer Risk Estimate for Exposure to Dibenz(a,h)anthracene for the Adult Receptor

Receptor Location	Total ILCR (Adult Alone)	Total ILCR (Amortized over Lifetime)
Blackwater-Spruce Ranch	$4.6x10^{-10}$	$6.7x10^{-10}$
Laidman Lake Ecolodge	$7.1x10^{-11}$	$1.0x10^{-10}$
Pan Phillips Resort	$2.5x10^{-11}$	$3.6x10^{-11}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$2.2x10^{-9}$	$3.2x10^{-9}$

Notes: ILCR = Incremental Lifetime Cancer Risk

Ethylbenzene

Non-carcinogenic chronic exposures to ethylbenzene being emitted from the proposed Project results in total HQ values that are orders of magnitude lower than 0.2 for all receptor locations with the highest HQ value of 0.000000043 at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Table 4.4-19**). The primary exposure pathway that contributes the most to the non-carcinogenic risks for ethylbenzene exposure is through inhalation of air emissions at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Annex 9.2.2D**).

Table 4.4-19: Non-Carcinogenic Risk Estimate for Chronic Ethylbenzene Exposures

Receptor Location	Total HQ
Blackwater-Spruce Ranch	$8.5x10^{-9}$
Laidman Lake Ecolodge	$1.8x10^{-9}$
Pan Phillips Resort	$8.1x10^{-10}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$4.3x10^{-8}$

Notes: HQ = Hazard Quotient

Non-carcinogenic short-term acute inhalation exposures to ethylbenzene in the ambient air results in HQ values that are orders of magnitude lower than 1.0 for all receptor locations with the highest HQ value of 5.4 $x10^{-9}$ at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Table 4.4-20**).

Table 4.4-20: Non-Carcinogenic Risk Estimate for Acute Ethylbenzene Exposures in the Ambient Air

Receptor Location	HQ
Blackwater-Spruce Ranch	$2.9x10^{-9}$
Laidman Lake Ecolodge	$1.2x10^{-9}$
Pan Phillips Resort	$1.2x10^{-9}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$5.4x10^{-9}$

Notes: HQ = Hazard Quotient

Indeno(1,2,3-cd)pyrene

Carcinogenic risks from exposure to indeno(1,2,3-cd)pyrene emitted from the proposed Project for the adult receptor are shown in **Table 4.4-21**. The total ILCR values, for both adult alone and composite lifetime receptors, at each receptor location are orders of magnitude below HC's target risk level of 1.0×10^{-5} with the highest ILCR value of 3.4×10^{-13} and 5.2×10^{-13} at Tatelkuz Lake Resort and Tatelkus Lake IR 28. The primary exposure pathway that contributes the most to the carcinogenic risk estimates for the adult receptor is exposure to indeno(1,2,3-cd)pyrene through the ingestion of moose (**Annex 9.2.2D**).

Table 4.4-21: Incremental Lifetime Cancer Risk Estimate for Exposure to Indeno(1,2,3-cd)pyrene for the Adult Receptor

Receptor Location	Total ILCR (Adult Alone)	Total ILCR (Amortized over Lifetime)
Blackwater-Spruce Ranch	$7.1x10^{-14}$	$1.1x10^{-13}$
Laidman Lake Ecolodge	$1.1x10^{-14}$	$1.7x10^{-14}$
Pan Phillips Resort	$3.9x10^{-15}$	$5.9x10^{-15}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$3.4x10^{-13}$	$5.2x10^{-13}$

Notes: ILCR = Incremental Lifetime Cancer Risk

Mercury

Non-carcinogenic exposures to mercury results in total HQ values lower than 0.2 at all receptor locations. The highest HQ value of 0.084 is found at all receptor locations (**Table 4.4-22**). Adverse health effects for human receptors are unlikely to occur following chronic exposures to mercury. Based on the results for each individual exposure pathway, the primary contributing exposure pathway of risks for mercury exposure is via the ingestion of fish (**Annex 9.2.2D**).

Table 4.4-22: Non-Carcinogenic Risk Estimate for Chronic Mercury Exposures

Receptor Location	Total HQ
Blackwater-Spruce Ranch	0.084
Laidman Lake Ecolodge	0.084
Pan Phillips Resort	0.084
Tatelkuz Lake Resort and Tatelkus Lake IR 28	0.084

Notes: HQ = Hazard Quotient

Molybdenum

Non-carcinogenic exposures to molybdenum results in total HQ values that are orders of magnitude lower than 0.2 for all receptor locations (**Table 4.4-23**). There is no consistent pattern in regards to the total HQ values between the baseline conditions and the effects assessment. However, since the total HQ values in the baseline condition and effects assessment remain less than 0.2 in both situations, adverse health effects for human receptors are unlikely to occur following chronic exposures to molybdenum. Based on the results for each individual exposure pathway, the primary contributing exposure pathway of risks for molybdenum exposure is via the ingestion of fish and surface water (**Annex 9.2.2D**).

Table 4.4-23: Non-Carcinogenic Risk Estimate for Chronic Molybdenum Exposures

Receptor Location	Total HQ
Blackwater-Spruce Ranch	0.022
Laidman Lake Ecolodge	0.022
Pan Phillips Resort	0.022
Tatelkuz Lake Resort and Tatelkus Lake IR 28	0.022

Notes: HQ = Hazard Quotient

Selenium

Non-carcinogenic exposures to selenium results in total HQ values lower than 0.2 for all receptor locations (**Table 4.4-24**). Adverse health effects for human receptors are unlikely to occur following chronic exposures to selenium. Based on the results for each individual exposure pathway, the primary contributing exposure pathway of risks for selenium exposure is via the ingestion of fish (**Annex 9.2.2D**).

Table 4.4-24: Non-Carcinogenic Risk Estimate for Chronic Selenium Exposures

Receptor Location	Total HQ
Blackwater-Spruce Ranch	0.19
Laidman Lake Ecolodge	0.19
Pan Phillips Resort	0.19
Tatelkuz Lake Resort and Tatelkus Lake IR 28	0.19

Notes: HQ = Hazard Quotient

Toluene

Non-carcinogenic exposures to toluene results in total HQ values that are orders of magnitude lower than 0.2 for all receptor locations with the highest HQ value of 0.00000032 at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Table 4.4-25**). Adverse health effects for human receptors are unlikely to occur following chronic exposures to toluene. Based on the results for each individual exposure pathway, the primary contributing exposure pathway of risks for toluene exposure is via inhalation of air emissions (**Annex 9.2.2D**).

Table 4.4-25: Non-Carcinogenic Risk Estimate for Chronic Toluene Exposures

Receptor Location	Total HQ
Blackwater-Spruce Ranch	$2.3x10^{-8}$
Laidman Lake Ecolodge	$4.9x10^{-9}$
Pan Phillips Resort	$2.2x10^{-9}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$3.2x10^{-7}$

Notes: HQ = Hazard Quotient

Non-carcinogenic short-term acute inhalation exposures to toluene in the ambient air results in HQ values that are orders of magnitude lower than 1.0 for all receptor locations with the highest HQ value of 0.0000047 at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Table 4.4-26**).

Table 4.4-26: Non-Carcinogenic Risk Estimate for Acute Toluene Exposures in the Ambient Air

Receptor Location	HQ
Blackwater-Spruce Ranch	$1.0x10^{-6}$
Laidman Lake Ecolodge	$4.0x10^{-7}$
Pan Phillips Resort	$4.2x10^{-7}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$4.7x10^{-6}$

Notes: HQ = Hazard Quotient

Xylene

Non-carcinogenic chronic exposures to xylene emitted from the proposed Project results in total HQ values that are orders of magnitude lower than 0.2 for all receptor locations with the highest HQ value of 0.0000066 at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Table 4.4-27**). The primary exposure pathway that contributes the most to the non-carcinogenic risks for xylene exposure is through inhalation of air emissions at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Annex 9.2.2D**).

Table 4.4-27: Non-Carcinogenic Risk Estimate for Chronic Xylene Exposures

Receptor Location	Total HQ
Blackwater-Spruce Ranch	$4.8x10^{-7}$
Laidman Lake Ecolodge	$1.0x10^{-7}$
Pan Phillips Resort	$4.5x10^{-8}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$6.6x10^{-6}$

Notes: HQ = Hazard Quotient

Non-carcinogenic short-term acute inhalation exposures to xylene in the ambient air result in HQ values that are orders of magnitude lower than 1.0 for all receptor locations with the highest HQ value of 4.9×10^{-7} at Tatelkuz Lake Resort and Tatelkus Lake IR 28 (**Table 4.4-28**).

Table 4.4-28: Non-Carcinogenic Risk Estimate for Acute Xylene Exposures in the Ambient Air

Receptor Location	HQ
Blackwater-Spruce Ranch	$1.4x10^{-7}$
Laidman Lake Ecolodge	$5.4x10^{-8}$
Pan Phillips Resort	$5.5x10^{-8}$
Tatelkuz Lake Resort and Tatelkus Lake IR 28	$4.9x10^{-7}$

Notes: HQ = Hazard Quotient

Carcinogenic PAHs

The total PAHs include all the individual PAHs listed in **Table 4.4-29**. Since PAHs are assumed to occur in the environment as a mixture, exposure to the mixtures of PAHs are assumed to occur in the environment as a mixture and should be assessed according to CCME's (2008) potency equivalency factor (PEF). The exposures to the individual carcinogenic PAHs are adjusted by their toxic potency relative to benzo(a)pyrene and potency equivalents are then summed. As a result, benzo(a)pyrene acts as a surrogate chemical for all other PAHs present in the mixture and assumes the potency of the entire PAH fraction. Health Canada (2010a) states that not all PAHs listed by CCME (2008) are required to be assess and that non-carcinogenic PAHs should be evaluated individually.

Table 4.4-29: Canadian Council of Ministers of the Environment Potency Equivalency Factors for Carcinogenic PAHs

Polycyclic Aromatic Hydrocarbon	Potency Equivalence Factors Relative to Benzo(a)pyrene
Benzo[a]pyrene	1.0
Benzo[a]anthracene	0.1
Benzo[b]fluoranthene	1.0
Benzo[g,h,i]perylene	0.01
Benzo[k]fluoranthene	0.1
Chrysene	0.01
Dibenzo[a,h]anthracene	1.0
Indeno[1,2,3-cd]pyrene	0.1

Carcinogenic risks from exposure to all carcinogenic PAHs in a mixture that is emitted from the proposed Project for the adult receptor are shown in **Table 4.4-30**. The total ILCR values, for both adult alone and composite lifetime adult receptors, at each receptor location are orders of magnitude below HC's target risk level of 1.0×10^{-5} with the highest ILCR value of 6.4×10^{-9} and 6.7×10^{-9} at Tatelkuz Lake Resort and Tatelkus Lake IR 28. The primary exposure pathway that contributes the most to the carcinogenic risk estimates for the adult receptor is exposure to carcinogenic PAHs through the ingestion of moose (**Annex 9.2.2D**).

Table 4.4-30: Incremental Lifetime Cancer Risk Estimate for Exposure to Carcinogenic PAHs for the Adult Receptor

Receptor Location	Total ILCR (Adult Alone)	Total ILCR (Amortized over Lifetime)
Blackwater-Spruce Ranch	9.2×10^{-10}	8.1×10^{-10}
Laidman Lake Ecolodge	1.5×10^{-10}	1.3×10^{-10}
Pan Phillips Resort	5.2×10^{-11}	4.8×10^{-11}
Tatelkuz Lake Resort and Tatelkus Lake IR 28	6.4×10^{-9}	6.8×10^{-9}

Notes: ILCR = Incremental Lifetime Cancer Risk

4.4.2 Ecological Receptors

Characterization of risk to ecological receptors can employ qualitative or quantitative methods. Exposure ratios (ERs) provide a quantitative estimate of overall risk. The ER is a unitless value, defined as the ratio of the magnitude of exposure to magnitude of a standard effect:

$$\text{Exposure Ratio} = \frac{\text{Exposure Estimate}}{\text{TRV}}$$

Where:

TRV = Toxicological Reference Value

ERs are interpreted as follows:

If the ER is less than 1.0, no unacceptable risks to ecological receptors would be expected, as concentrations are below levels known to cause adverse effects. Conversely, if the ER exceeds 1.0, it may be inferred that adverse effects to individuals are possible.

Given a certain magnitude and type of effect associated with a particular TRV or assessment endpoint, inferences about potential effects can be made. For example, if the level of exposure exceeds a TRV based on a 25% reduction in a growth-based endpoint, it can be inferred that one possible outcome may be diminished growth of individuals, potentially (but not necessarily) leading to a reduction in population abundance of that receptor. It is important to note that exceeding an ER of 1.0 does not necessarily mean adverse effects will occur. Rather, it suggests that there is less confidence that adverse effects will not occur. For a variety of reasons, adverse effects demonstrated in laboratory studies often fail to manifest in the field as a measurable or meaningful effect. It is also important to recognize that the magnitudes of ERs are not directly associated with the magnitudes of potential effects. That is, a large ER (>10) should not be interpreted as a ten-fold greater risk than an ER of 1.0.

For those COPCs with ERs greater than 1.0, potential risks at a population level cannot be ruled out and should be evaluated further. Evidence that may be considered other than chemical analysis may include evidence of toxicity at the proposed Project site (e.g., senescent vegetation), toxicity of media in laboratory exposures (i.e., bioassays), the absence of species formerly present or commonly found at similar sites, or diminished populations compared to a reference location. However, any exceedances of the ER criterion should not be considered as representative of unhealthy conditions at the site. All exposure estimates are based on predicted values and laboratory analysis of the different media (soil, water, plants, etc.) which do not distinguish between bioavailable and non-bioavailable forms of COPCs. Therefore, ER values based on these predicted values and laboratory results may be overestimated.

Mammals

Risks to mammals exposed to COPCs that are emitted by the proposed Project were characterized by comparing the ADD for each COPC to TRVs for mammals. **Table 4.4-3**1 summarizes the risk estimates for mammals. The following discussion focuses on the COPCs where the ER exceeds the criterion. **Annex 9.2.2D** provides additional details for exposure pathways and risk estimates for mammal receptors.

Table 4.4-31: Exposure Ratios for Mammals

COPCs	Grizzly Bear	Caribou	Marten	Snowshoe Hare	Short-tailed Shrew
Aluminum	**2.2**	**2.9**	0.0010	**7.2**	0.0016
Arsenic	0.011	0.014	0.024	0.034	0.24
Benzene	$2.3x10^{-9}$	$2.6x10^{-9}$	$3.8x10^{-9}$	$4.6x10^{-9}$	$5.8x10^{-9}$
Benzo(a)anthracene	$1.2x10^{-8}$	$1.6x10^{-8}$	$1.8x10^{-9}$	$4.0x10^{8}$	$5.2x10^{-9}$
Benzo(a)pyrene	$7.8x10^{-10}$	$1.7x10^{-9}$	$1.2x10^{-11}$	$2.5x10^{-9}$	$3.7x10^{-11}$
Benzo(b)fluoranthene	$6.6x10^{-11}$	$8.5x10^{-11}$	$1.1x10^{-12}$	$2.1x10^{-10}$	$7.5x10^{-11}$
Benzo(g,h,i)perylene	$8.5x10^{-12}$	$1.0x10^{-11}$	$2.3x10^{-11}$	$2.6x10^{-11}$	$1.9x10^{-9}$
Benzo(k)fluoranthene	$2.0x10^{-9}$	$2.6x10^{-9}$	$1.8x10^{-12}$	$6.5x10^{-9}$	$2.2x10^{-10}$
Cadmium	0.024	0.031	0.0011	0.077	0.72
Chromium	0.013	0.017	0.0061	0.043	0.020
Chrysene	$3.3x10^{-9}$	$4.1x10^{-9}$	$5.4x10^{-9}$	$1.0x10^{-8}$	$1.9x10^{-8}$
Copper	0.011	0.014	0.0047	0.036	**2.4**
Cyanide	0.00013	0.00014	0.00024	0.00024	$4.5x10^{-4}$
Dibenz(a,h)anthracene	$5.5x10^{-8}$	$7.2x10^{-8}$	$6.4x10^{-13}$	$1.8x10^{-7}$	$8.9x10^{-11}$
Ethylbenzene	$2.4x10^{-8}$	$2.6x10^{-11}$	$7.9x10^{-7}$	$5.6x10^{-11}$	$9.5x10^{-4}$
Indeno(1,2,3-cd)pyrene	$8.2x10^{-11}$	$1.1x10^{-10}$	$6.2x10^{-13}$	$2.7x10^{-10}$	$9.2x10^{-11}$
Lead	0.0089	0.011	0.0035	0.029	0.20
Mercury	0.19	0.25	0.017	0.63	0.035
Molybdenum	0.55	0.72	0.024	**1.8**	0.13
Selenium	0.054	0.070	0.0031	0.18	0.10
Toluene	$3.5\ x10^{-7}$	$1.1x10^{-9}$	$1.1x10^{-5}$	$2.2x10^{-9}$	$2.2x10^{-2}$
Vanadium	0.35	0.45	0.27	**1.1**	**1.3**
Xylene	$1.8x10^{-6}$	$2.7x10^{-8}$	$5.9x10^{-5}$	$6.1x10^{-8}$	$6.4x10^{-2}$
Zinc	0.026	0.033	0.045	0.081	0.27

Notes: **Bold** and underlined results = exceedances.
COPCs = Chemical of Potential Concern.

ERs for aluminum exceed 1.0 for grizzly bear, caribou, and snowshoe hare and are below 1.0 for marten and short-tailed shrew. Based on the results of each individual exposure pathway for aluminum, the primary contributing exposure pathway of risk is via the ingestion of plant tissue for grizzly bear, caribou, and snowshoe hare (**Annex 9.2.2D**).

ERs for copper exceed 1.0 for the short-tailed shrew and are below 1.0 for grizzly bear, caribou, marten, and snowshoe hare. Based on the results of each individual exposure pathway for copper, the primary contributing exposure pathway of risk is via ingestion of soil invertebrates for the shrew (**Annex 9.2.2D**).

ERs for molybdenum exceed 1.0 for snowshoe hare and are below 1.0 for grizzly bear, caribou, marten, and short-tailed shrew. Based on the results of each individual exposure pathway for molybdenum, the primary contributing exposure pathway of risk is via the ingestion of plant tissue for snowshoe hare (**Annex 9.2.2D**).

ERs for vanadium exceed 1.0 for the snowshoe hare and the short-tailed shrew and are below 1.0 for grizzly bear, caribou, and marten. Based on the results of each individual exposure pathway

for vanadium, the primary contributing exposure pathway of risk is via ingestion of plants for the hare and via the ingestion of soil and soil invertebrates for the shrew (**Annex 9.2.2D**).

ERs for the remaining COPCs are noted to be orders of magnitude lower than 1.0 for each mammal receptor listed in **Table 4.4-31**.

Birds

Risks to bird exposed to COPCs that are emitted by the proposed Project were characterized by evaluating the risk estimates for each COPC for birds. **Table 4.4-32** summarizes the risk estimates for birds. The following discussion focuses only on the COPCs where the ER exceeds the criterion. **Annex 9.2.2D** provides additional details for exposure pathways and risk estimates for bird receptors.

ERs for zinc exceed 1.0 for the olive-sided flycatcher and the ring-necked duck and are below 1.0 for red-tailed hawk and Pacific loon. Both the baseline and EA has ER values greater than 1.0 for the olive-sided flycatcher and the ring-necked duck. Based on the results of each individual exposure pathway for zinc, the primary contributing exposure pathway of risk is via the ingestion of soil invertebrates for the olive-sided flycatcher and via ingestion of aquatic invertebrates and aquatic vegetation for the ring-necked duck (**Annex 9.2.2D**).

ERs for the remaining COPCs were noted to be orders of magnitude lower than 1.0 for each bird receptor listed in **Table 4.4-32**.

Table 4.4-32: Exposure Ratios for Birds

COPCs	Red-tailed Hawk	Olive-sided Flycatcher	Ring-necked Duck	Pacific Loon
Aluminum	0.00010	0.00033	0.34	0.11
Arsenic	0.0058	0.13	0.084	0.018
Benzene	$2.1x10^{-9}$	$6.7x10^{-9}$	$1.4x10^{-3}$	$1.3x10^{-8}$
Benzo(a)anthracene	$4.2x10^{-10}$	$2.0x10^{-9}$	$1.8x10^{-6}$	$2.1x10^{-6}$
Benzo(a)pyrene	$4.3x10^{-12}$	$2.3x10^{-11}$	$3.9x10^{-8}$	$4.7x10^{-8}$
Benzo(b)fluoranthene	$2.0x10^{-13}$	$2.9x10^{-11}$	$7.2x10^{-9}$	$6.9x10^{-10}$
Benzo(g,h,i)perylene	$4.8x10^{-12}$	$7.4x10^{-10}$	$3.7x10^{-10}$	$2.25x10^{-11}$
Benzo(k)fluoranthene	$3.5x10^{-12}$	$8.5x10^{-10}$	$3.4x10^{-8}$	$3.2x10^{-9}$
Cadmium	0.00040	0.63	0.30	0.0036
Chromium	0.011	0.067	0.14	0.019
Chrysene	$4.2x10^{-9}$	$2.4x10^{-8}$	$2.3x10^{-6}$	$2.4x10^{-6}$
Copper	0.00073	0.76	0.011	0.017
Cyanide	0.0065	0.026	0.0065	0.0086
Dibenz(a,h)anthracene	$3.9x10^{-13}$	$1.1x10^{-10}$	$2.4x10^{-9}$	$2.8x10^{-10}$
Ethylbenzene	$6.3x10^{-7}$	$1.2x10^{-3}$	$1.7x10^{-10}$	$2.9x10^{-10}$
Indeno(1,2,3-cd)pyrene	$4.7x10^{-13}$	$1.4x10^{-10}$	$9.9x10^{-10}$	$9.0x10^{-11}$
Lead	0.0039	0.53	0.020	0.0025
Mercury	0.045	0.15	0.024	0.014
Molybdenum	0.00095	0.011	0.26	0.0015
Selenium	0.00066	0.13	0.057	0.0094
Toluene	$9.1\ x10^{-6}$	$2.7x10^{-2}$	$8.9x10^{-9}$	$1.0x10^{-8}$
Vanadium	0.0026	0.027	0.011	0.0028
Xylene	$4.7x10^{-5}$	$8.1x10^{-2}$	$2.4x10^{-8}$	$3.1x10^{-7}$
Zinc	0.39	3.8	1.7	0.084

Notes: **Bold** and underlined results = Exceedances;
COPCs = Chemical of Potential Concern

Amphibians

Toxicity data for amphibians (e.g., western toad) exposed to COPCs is extremely limited. A review of the scientific literature identified no appropriate toxicity limits for amphibian exposure to COPCs in soil. Available toxicological literature on amphibians focuses mainly on organic compounds (e.g., pesticides, fertilizers) affecting early life stages (eggs and tadpoles). Amphibians in the vicinity of the proposed Project are not expected to be continuously exposed to the maximum concentrations of COPCs emitted by the proposed Project and deposit on soil and surface water. COPCs emitted from the proposed Project are not expected to be 100% bioavailable, and the absence of any acceptable TRVs, results in uncertainties and low levels of confidence for measuring health risks to amphibians from COPCs for the exposure pathways expected for this receptor.

Fish

Risks to freshwater fish (e.g., rainbow trout) exposed to COPCs in surface water that are emitted by the proposed Project were characterized by comparing the exposure point concentrations for each COPC to TRVs for fish. **Table 4.4-33** summarizes the risk estimates for fish. The following discussion focuses only on the COPCs where the ER values exceed the criterion. **Annex 9.2.2D** provides additional details for exposure pathways and risk estimates for fish receptors.

ERs for copper exceed 1.0 for the fish. There is a difference in the ER values detected between the baseline and the effects assessment. An incremental increase detected in the ER values, mainly resulting from air deposition, is identified for copper in the effects assessment. The primary contributing exposure pathway of risk is via direct contact with surface water. ERs for the remaining COPCs are noted to be less than 1.0.

Soil Invertebrates and Terrestrial Plants

Risks to soil invertebrates and terrestrial plants exposed to COPCs in soil emitted by the proposed Project were characterized by evaluating the risk estimates for each COPC. **Table 4.4-34** summarizes the risk estimates for soil and terrestrial invertebrates. The following discussion focuses only on the COPCs where the ER values exceed the criterion. **Annex 9.2.2D** provides additional details for exposure pathways and risk estimates.

ERs for molybdenum exceed 1.0 for soil invertebrates and terrestrial plants. There is a slight difference in the ER values detected between the baseline and the effects assessment. An incremental increase detected in the ER values, mainly resulting from air deposition, is identified for molybdenum in the effects assessment. The primary contributing exposure pathway of risk is via direct contact with soil. ERs for the remaining COPCs are noted to be orders of magnitude lower than 1.0.

Table 4.4-33: Exposure Ratios for Fish

COPCs	Fish
Aluminum	0.038
Arsenic	0.0029
Benzene	$1.9x10^{-9}$
Benzo(a)anthracene	$3.7x10^{-6}$
Benzo(a)pyrene	$6.58x10^{-8}$
Benzo(b)fluoranthene	$1.1x10^{-8}$
Benzo(g,h,i)perylene	$3.4x10^{-10}$
Benzo(k)fluoranthene	$5.6x10^{-9}$
Cadmium	0.065
Chromium	0.011
Chrysene	$2.7x10^{-6}$
Copper	1.2
Cyanide	0.24
Dibenz(a,h)anthracene	$7.4x10^{-10}$
Ethylbenzene	$1.5x10^{-7}$
Indeno(1,2,3-cd)pyrene	$1.6x10^{-10}$
Lead	0.041
Mercury	0.035
Molybdenum	0.011
Selenium	0.015
Toluene	$2.3x10^{-7}$
Vanadium	0.0040
Xylene	$1.2x10^{-7}$
Zinc	0.26

Notes: **Bold** and underlined results = Exceedances;
COPCs = Chemical of Potential Concern

Table 4.4-34: Exposure Ratios for Soil Invertebrates and Terrestrial Plants

COPCs	Soil Invertebrates	Terrestrial Plants
Aluminum	0.000045	0.000061
Arsenic	0.66	0.66
Benzene	$1.5x10^{-11}$	$8.5x10^{-12}$
Benzo(a)anthracene	$3.5x10^{-10}$	$1.3x10^{-8}$
Benzo(a)pyrene	$4.2x10^{-12}$	$3.8x10^{-12}$
Benzo(b)fluoranthene	$5.7x10^{-12}$	$5.1x10^{-12}$
Benzo(g,h,i)perylene	$1.45x10^{-10}$	$4.0x10^{-10}$
Benzo(k)fluoranthene	$1.7x10^{-11}$	$1.5x10^{-11}$
Cadmium	0.0037	0.016
Chromium	0.96	0.96
Chrysene	$1.4x10^{-9}$	$1.3x10^{-9}$
Copper	$1.5x10^{-1}$	$1.7x10^{-1}$
Cyanide	$1.3x10^{-11}$	$1.5x10^{-11}$
Dibenz(a,h)anthracene	$6.8x10^{-12}$	$6.1x10^{-12}$
Ethylbenzene	$4.0x10^{-12}$	$1.3x10^{-12}$
Indeno(1,2,3-cd)pyrene	$7.1x10^{-12}$	$4.1x10^{-9}$
Lead	0.0080	0.11
Mercury	0.10	0.0072
Molybdenum	1.3	**1.3**
Selenium	0.061	0.48
Toluene	$1.3x10^{-11}$	$3.0x10^{-12}$
Vanadium	0.13	0.49
Xylene	$7.6x10^{-11}$	$1.2x10^{-10}$
Zinc	0.38	0.28

Notes: Bold and underlined results = Exceedances;
COPCs = Chemical of Potential Concern

Aquatic Invertebrates and Aquatic Plants

Risks to aquatic invertebrates and aquatic plants exposed to COPCs in surface water that are emitted by the proposed Project were characterized by comparing the point of exposure concentrations for each COPC to TRVs for aquatic invertebrates and aquatic plants. **Table 4.4-35** summarizes the risk estimates for soil and terrestrial invertebrates. The following discussion focuses only on the COPCs where the ER values exceed the criterion. **Annex 9.2.2D** provides additional details for exposure pathways and risk estimates.

Table 4.4-35: Exposure Ratios for Aquatic Invertebrates and Aquatic Plants

COPCs	Aquatic Invertebrates	Aquatic Plants
Aluminum	0.065	0.27
Arsenic	0.0057	0.054
Benzene	$1.0x10^{-8}$	$1.9x10^{-9}$
Benzo(a)anthracene	$3.7x10^{-6}$	$3.7x10^{-6}$
Benzo(a)pyrene	$6.6x10^{-8}$	$6.6x10^{-8}$
Benzo(b)fluoranthene	$8.2x10^{-10}$	$1.1x10^{-8}$
Benzo(g,h,i)perylene	$5.1x10^{-9}$	$3.4x10^{-10}$
Benzo(k)fluoranthene	$1.2x10^{-9}$	$5.6x10^{-9}$
Cadmium	0.73	0.055
Chromium	0.017	0.0019
Chrysene	$1.2x10^{-6}$	$2.7x10^{-6}$
Copper	19.3	4.5
Cyanide	0.24	0.062
Dibenz(a,h)anthracene	$5.6x10^{-9}$	$7.4x10^{-10}$
Ethylbenzene	$5.1x10^{-9}$	$1.5x10^{-10}$
Indeno(1,2,3-cd)pyrene	$3.56x10^{-10}$	$1.6x10^{-10}$
Lead	0.063	0.0016
Mercury	0.0084	0.0016
Molybdenum	0.011	0.011
Selenium	0.014	0.013
Toluene	$1.2x10^{-8}$	$1.2x10^{-9}$
Vanadium	0.00017	0.0040
Xylene	$5.0x10^{-9}$	$5.0x10^{-9}$
Zinc	0.20	0.31

Notes: **Bold** and underlined results = Exceedances;
COPCs = Chemical of Potential Concern

ERs for copper exceed 1.0 for the aquatic invertebrates and aquatic plants. There is an incremental increase in the ER values detected between the baseline and the effects assessment. The primary contributing exposure pathway of risk is via direct contact with surface water. ERs for the remaining COPCs are orders of magnitude lower than 1.0.

4.5 Quantitative Interpretation of Risk Hazard to Human Receptors

4.5.1 Human Receptors

The average daily doses for the Aboriginal receptors are presented for each pathway in the **Annex 9.2.2D**. A worked example of the exposure and risk calculations for the Aboriginal receptors and environmental media is presented in **Annex 9.2.2E**. Summaries of the calculated risks associated with CACs and non-carcinogenic and carcinogenic COPCs for the Aboriginal receptors are provided above (**Table 4.4-1** to **Table 4.4-28**). The findings of the HHRA are discussed below.

Criteria Air Contaminants

- Predicted 1-hour, 8-hour, and 24-hour ground-level NO_2, SO_2, $PM_{2.5}$, PM_{10} and CO concentrations do not result in any acute short-term exposure HQ values above 1.0 for any of the receptor locations. The highest acute HQ values for NO_2, SO_2, $PM_{2.5}$, PM_{10} and CO are 0.051, 0.00067, 0.065, 0.19 and 0.023, respectively, at Tatelkuz Lake Resort and Tatelkus Lake IR 28. Adverse health effects for human receptors are unlikely to occur following acute short-term exposures to NO_2, SO_2 $PM_{2.5}$, $PM_{2.5}$ and CO.
- Predicted annual ground-level NO_2, SO_2 and $PM_{2.5}$ concentrations do not result in any chronic HQ values above 1.0 for any of the receptor locations. The highest HQ values for annual chronic exposure to NO_2, SO_2 and $PM_{2.5}$ are 0.14, 0.041, and 0.53, respectively, at Tatelkuz Lake Resort and Tatelkus Lake IR 28. There is no consistent pattern in regards to the total HQ values between the baseline conditions and the effects assessment. However, since the total HQ values in the baseline condition and effects assessment remain less than 1.0, adverse health effects for human receptors are unlikely to occur following chronic exposures to NO_2, SO_2 and $PM_{2.5}$.

COPCs

- The risk estimate for chronic exposures to arsenic is above HC's target risk level of 1.0×10^{-5} for the adult receptor (for both adult alone and composite lifetime adult receptor) at each human receptor location. ILCRs ranged from 2.0×10^{-4} at Laidman Lake Ecolodge and Pan Phillips Resort to 2.1×10^{-4} at Tatelkuz Lake Resort, Tatelkus Lake IR 28, and Blackwater Spruce Ranch. Both the baseline and effects assessment had ILCR values greater than 1.0×10^{-5} for human receptors. The primary exposure pathway that contributes the most to the carcinogenic risks for arsenic exposure is through ingestion of surface water and fish. Effects assessment ILCRs are noted to be lower when compared to the Baseline ILCRs. This is expected since the predicted surface water concentrations for the EA are low and within BC Freshwater Guidelines or site specific water quality objectives. However, although there are exceedances, uncertainties exist in the risk assessment process, both in the derivation of TRVs as well as the exposure assessment assumptions that may tend to overestimate the risk. Actual exposures are likely to be substantially lower than those presented in this assessment. Also, conservative assumptions were considered throughout the assessment with regards to exposure duration. For example, the adult receptor was assumed to spend their entire lifetime within the LSA. Another aspect of the arsenic assessment is that 100% of the arsenic

was assumed to be in its most toxic trivalent form and not in the less toxic pentavalent form. These assumptions may overestimate the level of risks to the adult receptor.

- Current risks associated with most non-carcinogenic COPCs for both chronic and acute exposure are noted to be below HC's risk target level of 0.2 for non-carcinogenic effects. Arsenic HQ value of 0.99 is greater than the target risk level of 0.2, but less than the baseline level (1.2). Cyanide, with an HQ value of 0.31, slightly exceeds the target risk level of 0.2. Risks associated with the remaining carcinogenic COPCs, including PAHs as a mixture, for both the adult alone and composite lifetime adult (i.e., amortized over lifetime) receptor are below HC's risk target level of $1.0x10^{-5}$ for carcinogenic effects except for arsenic where the calculated risk due to the Project is lower than baseline. Arsenic from the Project therefore does not pose an increased carcinogenic risk to human receptors.

4.5.2 Ecological Receptors

The average daily doses for the ecological receptors are presented for each pathway in **Annex 9.2.2D**. A worked example of exposure and risk calculations for ecological receptors is presented in **Annex 9.2.2E**. Summaries of the ERs associated with COPCs for ecological receptors are provided above (**Table 4.4-31** to **Table 4.4-35**).

The findings of the ERA for the COPCs that exceed the criterion are discussed below.

Mammals

ERs for aluminum exceed 1.0 for grizzly bear, caribou, and snowshoe hare with values of 2.2, 2.9 and 7.2 and are below 1.0 for marten and short-tailed shrew. Based on the results of each individual exposure pathway for aluminum, the primary contributing exposure pathway of risk is via the ingestion of plant tissue for grizzly bear, caribou, and hare. There are incremental increases between the baseline and the effects assessment. ER values are less than 1.0 for grizzly bear, caribou, and snowshoe hare in the baseline and greater than the criterion of 1.0 in the effects assessment. The Project emissions increases the ER values for aluminum.

Aluminum is the most common metal in the earth's crust representing an average of about 8.2% by weight. Aluminum concentrations in the waste rock from the Project are generally lower than the crustal average with an average and 95th percentile of 3.9% and 8.3%, respectively (890 samples). Similarly, aluminum in the overburden from the Project is lower than the crustal average with a maximum of 5.5% (95 samples). Aluminum is present in the Project wastes primarily as alumino-silicates minerals that exhibit slow weathering properties at neutral pH. Segregation (and control of potentially acid generating wastes by submergence in the TSF) will limit oxidation and aluminum concentrations in interstitial water in the remaining NAG waste stored on surface that might be available to plants. Similarly, dust from NAG waste should exhibit low aluminum concentrations and leaching characteristics. Dust from potentially acid generating tailings and PAG waste rock will be controlled by keeping the wastes wet in the TSF. Taken together, the Project is not expected to increase the amount of bioavailable aluminum in plants.

ERs for copper exceed 1.0 for the short-tailed shrew with a value of 2.4 and are below 1.0 for grizzly bear, caribou, marten, and snowshoe hare. Based on the results of each individual exposure pathway for copper, the primary contributing exposure pathway of risk is via ingestion of soil invertebrates for the shrew. There are incremental increases between the baseline and the effects assessment. ER values are less than 1.0 for short-tailed shrew in the baseline and greater than the criterion of 1.0 in the effects assessment. The Project emissions increase the ER values for copper.

Similar factors discussed previously for aluminum limit the bioavailability of copper from the Project. Copper concentrations in the waste rock from the Project are generally similar to the crustal average (60 ppm) with an average and 95th percentile of 50 and 136 ppm, respectively (890 samples). Copper concentrations in the overburden are also similar to the crustal average with an average and 95th percentile of 37 and 105 ppm, respectively (95 samples). Leaching rates of copper from NAG waste rock and overburden are predicted to be low. The Project is not expected to increase the amount of bioavailable copper in soil invertebrates.

ERs for molybdenum marginally exceed 1.0 for snowshoe hare with a value of 1.8 and are below 1.0 for grizzly bear, caribou, marten, and short-tailed shrew. Based on the results of each individual exposure pathway for molybdenum, the primary contributing exposure pathway of risk is via the ingestion of plant tissue for snowshoe hare. As demonstrated in the baseline and effects assessment result tables (**Table 3.2-1** and **Table 4.4-28**), exceedances are present in both cases with ER values of 5.8 for the baseline and 1.8 for the EA. The Project does not increase the ER values for molybdenum.

ERs for vanadium marginally exceed 1.0 for the snowshoe hare and the short-tailed shrew with a value of 1.1 and 1.3, respectively and are below 1.0 for grizzly bear, caribou, and marten. Based on the results of each individual exposure pathway for vanadium, the primary contributing exposure pathway of risk is via ingestion of plants for the snowshoe hare and via the ingestion of soil and soil invertebrates for the shrew. The Project emissions increase the ER values for vanadium.

Similar factors discussed previously for aluminum limit the bioavailability of vanadium from the Project. Vanadium concentrations in the waste rock from the Project are generally lower than the crustal average (120 ppm) with an average and 95th percentile of 57 and 139 ppm, respectively (890 samples). Vanadium concentrations in overburden are also low with an average and 95th percentile of 58 and 122 ppm, respectively (95 samples). The Project is not expected to increase the amount of bioavailable vanadium in plants, soil or soil invertebrates.

Birds

ERs for zinc exceed 1.0 for the olive-sided flycatcher and the ring-necked duck with values of 3.8 and 1.7 and are below 1.0 for red-tailed hawk and Pacific loon. Based on the results of each individual exposure pathway for zinc, the primary contributing exposure pathway of risk is via the ingestion of soil invertebrates for the olive-sided flycatcher and via ingestion of aquatic invertebrates for the ring-necked duck. As demonstrated in the baseline and effects assessment

result tables, exceedances are present in both cases and no major differences exist between the baseline and EA. The Project does not increase the ER values for zinc.

Amphibians

Toxicity data for amphibians (e.g., western toad) exposed to COPCs are extremely limited. A review of the scientific literature identified no appropriate toxicity limits for amphibian exposure to COPCs in soil. Available toxicological literature on amphibians focuses mainly on organic compounds (e.g., pesticides, fertilizers) affecting early life stages (eggs and tadpoles). COPCs emitted from the proposed Project are not expected to be 100% bioavailable. The absence of any acceptable TRVs results in uncertainties and low levels of confidence for measuring health risks to amphibians from COPCs for the exposure pathways expected for this receptor.

Fish

ERs for copper marginally exceed 1.0 for fish. There are incremental increases between the baseline and the effects assessment. ER values are less than 1.0 for fish in the baseline with a value of 0.29 and greater than the criterion of 1.0 in the effects assessment with a value of 1.2. The primary contributing exposure pathway of risk is via direct contact with surface water. Although ERs were greater than 1.0 in the EA, receiving water quality downstream of the Project is predicted to be within BC Freshwater Quality Guidelines or site specific water quality objectives and should be protective of aquatic life. As a result, it is important to note that the small magnitude of the ER for copper in fish does not indicate that adverse health effects in fish will be observed. ERs for the remaining COPCs were noted to be orders of magnitude lower than 1.0.

Soil Invertebrates and Terrestrial Plants

ERs for molybdenum marginally exceed 1.0 for soil invertebrates and terrestrial plants with a value of 1.3 for both receptors. There is a slight variation in the ER values detected between the baseline and the effects assessment, but generally speaking, no major differences are observed. The primary contributing exposure pathway of risk is via direct contact with soil. The Project does not increase the ER values for molybdenum. ERs for the remaining COPCs are noted to be orders of magnitude lower than 1.0.

Aquatic Invertebrates and Aquatic Plants

ERs for copper exceed 1.0 for the aquatic invertebrates and aquatic plants with values of 19.3 and 4.5. There is a difference detected between the baseline and EA. Baseline ER values are 4.8 for aquatic invertebrates and 1.1 for aquatic plants. The primary contributing exposure pathway of risk is via direct contact with surface water. Although ERs are greater than 1.0 in the EA, receiving water quality downstream of the Project is predicted to be within BC Freshwater Quality Guidelines or site specific water quality objectives and should be protective of aquatic life. As a result, it is important to note that the magnitude of the ER for copper in aquatic Invertebrates and plants does not indicate that adverse health effects in fish will be observed. ERs for the remaining COPCs are orders of magnitude lower than 1.0.

ERs greater than 1.0, although possible, do not indicate adverse health effects are certain for ecological receptors. Uncertainties exist in the risk assessment process, both in the derivation of TRVs as well as in the exposure assessment assumptions that may tend to overestimate the risk. Actual exposures are likely to be substantially lower than those presented in this assessment.

4.6 Uncertainty Analysis

Uncertainties exist at each stage of the risk assessment process. They represent limitations in knowledge about the actual value of a parameter (e.g., receptor contact rates were assumed, but the actual rate may vary considerably from the assumed value). The lack of knowledge may be associated with either incomplete datasets (e.g., dermal penetration of chemicals was estimated rather than actually measured) or through the normal variability that may exist in the data used in the risk assessment. Uncertainties arise from several areas; therefore, a discussion of uncertainty is necessary to identify areas where information gaps exist and where there is potential to affect the risk assessment.

4.6.1 Human Health Risk Assessment

Problem Formulation

There are several uncertainties associated with the problem formulation aspect of the assessment.

- The assessment assumes that human receptors would inhabit the area within the LSA for the entire lifetime and be exposed daily through inhalation of chemicals in the air or re-suspended particulates, consumption of wild game, ingestion of vegetation and soil, ingestion of surface water, and dermal contact with the soil;
- It is not known which portions of the country foods human receptors will eat (i.e., fillet fish vs whole fish, muscle tissue vs fat, organs and carcass parts). As a result, uniform distribution of chemicals was assumed in the soil, plant tissues, fish, and meat, especially the edible portions such as the muscles, which may under or overestimate the overall risks;
- Conservatism in air and surface water predictions which may overestimate the overall risks;
- An equilibrium is rapidly established in the tissues of the meat and vegetation, and individuals will always consume the maximum concentrations in the tissue;
- There are currently no potable uses of surface water or groundwater near the mine site. However, the potential exists that individuals who live in the RSA may consume the water; therefore, the assessment assumes humans would consume the local surface water on a continuous basis; and
- The assessment assumed that individuals will be eating wild game as part of their normal diet. However, there is no analysis of game meat quality but rather the assessment relied on mathematical modelling to predict the tissue concentrations. As a result, there is an

uncertainty related to the contribution of game meat ingestion to the overall COPC intake.

These uncertainties contribute to conservatism in the risk analysis.

Toxicity Assessment

Datasets of toxicological information for many chemicals are incomplete. As a result, toxicity values based on these datasets often have varying degrees of uncertainty associated with them, leading to over- or under-estimation of risks. There are a number of reasons for such uncertainties:

- Use of animal models to predict effects on humans. For the extrapolation of animal exposures to human exposures, the exposure limits for chemicals are typically based on animal experiments where exposures to chemicals are administered. Statistical manipulations are performed to derive an appropriate TRV. Therefore, these procedures to derive the TRV imply that humans and animals will respond in similar fashion. In addition, the derivation also requires an assumption that the effects observed at the high doses that were used in the animal experiments would be equally or proportionally similar to effects at the low doses that human exposures would typically occur. These TRVs also require an assumption that the chemical exposures yield effects that follow similar physiological mechanisms of action in both animals and humans. These include the detoxification processes as well as the toxicological implications. All of these toxicological uncertainties may contribute to either an over- or under-estimation of the potential risks for the humans exposed to the chemicals;
- Use of short-term toxicity studies (e.g., maximum two years for rodent studies) to predict effects from long-term exposures in humans;
- Prediction of the adverse health effects of low dose exposures in humans based on high or maximum tolerated doses in laboratory animals; and
- Use of results of toxicity testing on homogenous inbred animal populations to predict the effects on the heterogeneous human population.

Exposure Assessment

Exposure limits developed by leading regulatory agencies typically incorporate large safety/ uncertainty factors to compensate for uncertainties. The exposure assessment makes assumptions regarding the exposure regimes that the human receptors undergo. Uncertainties in the exposure assessment include:

- Use of statistical parameters (e.g., arithmetic mean) of the exposure (e.g., body weight, ingestion rate) that may result in over- or under-estimation of risks (depending on the distribution of the data). The use of statistical measures for calculating exposures may lead to either an over- or under-estimating of the potential health risks;

- Assumption that the point estimates of the COPCs physical-chemical parameters in the assessment would be consistent in a real world situation. The physical-chemical characteristics are typically laboratory-derived data under controlled situations and their values may change in the actual environment where external variables such as temperature fluxes and atmospheric air pressure changes may change the parameter values;
- Use of default parameters instead of using site-specific parameters adds uncertainty to the assessment as default values may not accurately represent site-specific conditions. As a result, this uncertainty may overestimate the predicted risks from the HHERA model; and
- Assumption that the elimination of chemicals in the individuals is zero. This is especially important since some elimination and depuration would occur during the lifespan of an individual. This assumption will consequently overestimate the risks.

Risk Characterization

Characterization of the risk for carcinogens may have some degree of uncertainty with it, particularly in the derivation of the cancer slope or unit risk factors. These factors, which are used to estimate the incremental lifetime cancer risk, are often an upper bound estimate of the probability of response. Risk factors based on animal data are considered equally with those based on human exposures. As a result, these two factors may contribute to the overestimation of risk.

4.6.2 Ecological Risk Assessment

Uncertainty in risk assessment is introduced by the necessary use of assumptions concerning various aspects or characteristics of the system that cannot be measured accurately. Incomplete understanding of environmental processes is inherent in any ERA. Uncertainty is acknowledged, documented, and primarily addressed by the use of conservative assumptions that ensure risk is overestimated rather than underestimated.

Regardless of the level of modelling and sampling effort expended in characterizing COPC concentrations at a site, some inherent uncertainty always remains with respect to actual levels of chemicals in various environmental media.

Problem Formulation

There are several uncertainties associated with the problem formulation aspect of the assessment. These uncertainties originate from conservatism and uncertainty in air and surface water predictions and from the following assumptions:

- Receptors with large home range will only be exposed to COPCs within the RSA;
- Ecological receptors (i.e., mammals and birds) would inhabit the area within the RSA for the entire lifetime and be exposed daily through the consumption of mammals, ingestion

of vegetation and soil, ingestion of surface water, and direct contact with the soil and surface water;

- Uniform distribution of chemicals across the LSA;
- Ecological receptors will always consume the 95th UCL concentrations in their foods;
- Receptors will be eating small mammals and invertebrates as part of their diet. As there is no analysis of small mammal meat quality, there is an uncertainty related to the contribution of small mammal ingestion to the overall COPC intake.

Toxicity Assessment

Because of the inherent uncertainty in predicting toxicological responses from literature studies rather than directly measuring toxicity at the site, there is uncertainty associated with TRVs. In most cases, TRVs were assumed to be conservative (i.e., no toxicity is anticipated if site concentrations are below TRVs). This was because most TRVs were based on the most sensitive species tested or a similar low effect level (e.g., 10th or 25th percentile of species sensitivity distribution), while the toxicity tests they were based on are typically conducted under conditions that maximize toxicity (i.e., the use of soluble metal salts). Uncertainties may occur when using the established TRVs for each chemical associated with the assessment of the proposed Project. This was taken into consideration when test subjects exposed to COPCs in a controlled environment resulted in similar behaviour and effects as those species exposed to COPCs in the actual environment.

Exposure Assessment

Uncertainty in the exposure assessment was related primarily to assumptions regarding the presence of VCs. The regional area is characterized according to the CCME guideline primarily as residential/parkland. Conservative assumptions were made to ensure ecological receptors that might use the proposed Project area were provided with a degree of protection.

Risk Characterization

For the most part, the ERs generated in the risk characterization phase of the ERA should be considered to be quite conservative. ERs greater than 1.0 do not necessarily mean a toxicological effect is occurring. There was greater inherent uncertainty associated with results of this assessment than with higher-tier assessments, because results were based primarily on modelled or estimated concentrations and TRVs were derived from literature studies rather than from direct measurements of exposure and effects. At the Project, no direct measurements of exposure were made and no toxicity studies were performed. In many cases, toxicity at a site is considerably diminished compared to effects predicted from laboratory studies for a variety of reasons. Higher-tier assessments incorporate site-specific toxicity data in a lines-of-evidence approach, which can reduce the level of uncertainty in this phase of the assessment.

5.0 RESIDUAL EFFECTS

Environmental impact assessments typically use descriptors to qualify the potential impacts of the Project. These descriptors include direction, magnitude, geographic extent, duration/ frequency, and reversibility. However, unlike other disciplines, these descriptors are not used in the evaluation of the environmental health risk. In the determination of the environmental health risk estimates, these descriptors are inherently incorporated in the fate/transport and exposure modelling.

Direction is considered part of the risk assessment process as it is intended to evaluate the potential negative health effects. In the human health risk assessment component, the risks for non-carcinogenic and carcinogenic effects are determined. In the ecological risk assessment component, the risks to adverse effects on ecological populations due to the exposure to the COPCs are determined. These effects are all considered negative.

The HQ and ER define the magnitude of the risk as a proportion of a tolerable dose/ concentration, while the ILCR indicates the magnitude of the incidental increase in the cancer rate.

Geographic extent is addressed by the definition of the various receptor locations in the RSA and determination of locations that have higher risk estimates than others. The dispersion modelling of the air emissions from the Project defines the extent of the potential impacts following exposure.

Duration and frequency are included in the calculations of exposure as these are exposure terms in the mathematical models (**Annex 9.2.2D**). The duration and frequency of exposure in the human health risk assessment component use the one-hour maximum, 24-hour maximum, or annual average modelled concentrations and their corresponding TRVs. Also, the human health risk assessment considered both acute (i.e., less than 24 hours) and chronic (i.e., lifetime) exposures in the evaluation.

Effects on environmental health from short-term exposures are generally considered to be reversible. For these short-term exposures, the receptor may experience an adverse health effect (e.g., eye irritation) for the duration of the exposure. However, when the exposure has ended, the environment effect would resolve itself (e.g., eyes no longer irritated). In general, the potential health risks from acute exposures can be decreased further by reducing or limiting the ambient air COPC concentrations.

The health risks associated with long-term or chronic exposures, including cancer health risks, are considered to be generally irreversible.

As noted previously, human health risks associated with all non-carcinogenic COPCs for both chronic and acute exposure are noted to be below HC's risk target level of 1.0 for non-carcinogenic effects. Risks associated with the remaining carcinogenic COPCs, including PAHs as a mixture, for both the adult alone and composite adult (i.e., amortized over lifetime) receptor are below HC's risk target level of 1.0×10^{-5} for carcinogenic effects except for arsenic where the calculated risk due to the Project is lower than baseline. Arsenic from the Project therefore does not pose an

increased carcinogenic risk. Overall, the risk to human health from exposure to COPCs from the Project is not significant.

ERs greater than 1.0 for ecological receptors, although possible, do not indicate adverse health effects are certain. Uncertainties exist in the risk assessment process, both in the derivation of TRVs as well as in the exposure assessment assumptions that may tend to overestimate the risk. Actual exposures are likely to be substantially lower than those presented in this assessment. As with the human health risk assessment, the ecological risk assessment assumed that COPC metals were present in their most bioavailable form. This is a conservative assumption for particulate metals released from the Project as most of the metal would be present as low bioavailable sulphide or alumino-silicate minerals partially encapsulated with gangue minerals. As such, bioavailability to ecological receptors would be limited. Moreover, concentrations of aluminum, copper and vanadium in NAG waste rock and overburden at the Project are similar to or lower than average Earth's crust values. Receiving water quality is predicted to meet BC Freshwater Quality Guidelines or site-specific water quality objectives. There will be no surface water discharge from the Project to receiving waters during operations or early closure. Air emissions and dust releases will be limited and meet provincial and federal standards. Overall, the risk to ecological receptors from exposure to COPCs is not significant.

6.0 ASSESSMENT OF CUMULATIVE EFFECTS

A cumulative effects assessment for environmental health is not considered as significant adverse residual effects are not predicted to result from the construction, operation, or decommissioning of the Project.

7.0 MONITORING AND FOLLOW-UP

Air, soil, surface water, vegetation, fish, and wild game tissue sampling will be continue within the LSA in order to track long-term trends in the concentration of COPCs in the vicinity of the Project. The risk assessment indicated that the following metals and environmental components in particular should be monitored to confirm predictions:

- Arsenic in surface water and fish
- Aluminum in plant tissue
- Copper in soil and surface water
- Vanadium in soil and plant tissue

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ANNEXES

Annex 9.2.2A
Data for Human Health and Ecological Risk Assessment

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

		WQ1			WQ10			WQ11			WQ12			WQ13			
Analyte	**Units**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**
Dissolved Metals																	
Aluminum-D	mg/L	2.00E-03	3.45E-01	2.55E-01	2.00E-03	2.56E-01	1.35E-01	2.00E-03	4.92E-01	3.27E-01	2.00E-03	1.68E-01	9.94E-02	2.00E-03	5.00E-02	3.55E-02	2.00E-03
Antimony-D	mg/L	5.00E-05	9.00E-05	4.68E-05	5.00E-05	2.75E-05	2.94E-05	5.00E-05	2.50E-05	2.99E-05	5.00E-05	2.50E-05	2.69E-05	5.00E-05	6.00E-05	3.30E-05	5.00E-05
Arsenic-D	mg/L	1.00E-04	7.60E-04	4.82E-04	1.00E-04	5.00E-04	4.50E-04	1.00E-04	1.40E-04	2.63E-04	1.00E-04	2.15E-04	2.19E-04	1.00E-04	6.00E-04	4.91E-04	1.00E-04
Barium-D	mg/L	5.00E-05	5.06E-03	3.44E-03	5.00E-05	7.73E-03	6.58E-03	5.00E-05	1.25E-02	8.63E-03	5.00E-05	8.29E-03	6.29E-03	5.00E-05	8.95E-03	7.56E-03	5.00E-05
Beryllium-D	mg/L	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04
Boron-D	mg/L	1.00E-03	3.60E-03	1.26E-03	1.00E-03	1.00E-03	8.34E-04	1.00E-03	2.00E-03	1.65E-03	1.00E-03	1.00E-03	7.39E-04	1.00E-03	2.00E-03	9.01E-04	1.00E-03
Cadmium-D	mg/L	1.50E-05	3.24E-05	1.67E-05	1.50E-05	8.45E-06	8.84E-06	1.50E-05	1.45E-05	1.37E-05	1.50E-05	7.50E-06	1.03E-05	1.50E-05	2.57E-05	2.78E-05	1.50E-05
Calcium-D	mg/L	5.00E-01	3.00E+00	2.39E+00	5.00E-01	1.60E+01	9.81E+00	5.00E-01	2.20E+01	1.15E+01	5.00E-01	7.89E+00	6.33E+00	5.00E-01	2.23E+01	1.84E+01	5.00E-01
Chromium-D	mg/L	3.00E-04	3.60E-04	2.24E-04	3.00E-04	4.00E-04	2.18E-04	3.00E-04	4.40E-04	2.95E-04	3.00E-04	3.15E-04	1.86E-04	3.00E-04	1.50E-04	1.63E-04	3.00E-04
Cobalt-D	mg/L	2.00E-05	5.00E-05	3.46E-05	2.00E-05	4.00E-05	2.21E-05	2.00E-05	6.40E-05	4.15E-05	2.00E-05	4.00E-05	2.65E-05	2.00E-05	4.00E-05	2.89E-05	2.00E-05
Copper-D	mg/L	1.00E-04	7.00E-04	4.23E-04	1.00E-04	7.00E-04	3.24E-04	1.00E-04	2.54E-03	1.52E-03	1.00E-04	6.00E-04	3.06E-04	1.00E-04	6.35E-04	3.81E-04	1.00E-04
D-Hardness as CaCO3	mg/L	6.00E+00	1.00E+01	8.20E+00	6.00E+00	4.61E+01	3.32E+01	6.00E+00	6.90E+01	4.04E+01	6.00E+00	2.59E+01	2.06E+01	6.00E+00	7.62E+01	6.47E+01	6.00E+00
Iron-D	mg/L	1.00E-04	2.15E-01	1.60E-01	1.00E-04	1.29E-01	8.17E-02	1.00E-04	2.11E-01	1.44E-01	1.00E-04	2.74E-01	1.62E-01	1.00E-04	1.83E-01	1.18E-01	1.00E-04
Lead-D	mg/L	5.00E-05	1.36E-04	7.69E-05	5.00E-05	5.80E-05	4.23E-05	5.00E-05	3.90E-05	6.24E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05
Lithium-D	mg/L	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03
Magnesium-D	mg/L	5.00E-01	7.12E-01	4.52E-01	5.00E-01	3.12E+00	1.94E+00	5.00E-01	4.39E+00	2.31E+00	5.00E-01	1.36E+00	1.08E+00	5.00E-01	4.84E+00	4.14E+00	5.00E-01
Manganese-D	mg/L	5.00E-05	1.48E-02	9.47E-03	5.00E-05	3.46E-03	2.65E-03	5.00E-05	3.36E-03	2.00E-03	5.00E-05	1.49E-02	8.34E-03	5.00E-05	4.63E-02	2.63E-02	5.00E-05
Mercury-D	mg/L	5.00E-06	1.08E-05	5.11E-06	5.00E-06	1.00E-05	4.52E-06	5.00E-06	1.44E-05	6.08E-06	5.00E-06	4.00E-06	3.79E-06	5.00E-06	4.00E-06	3.46E-06	5.00E-06
Molybdenum-D	mg/L	5.00E-05	2.98E-04	1.43E-04	5.00E-05	8.44E-04	5.18E-04	5.00E-05	3.50E-04	1.77E-04	5.00E-05	6.00E-04	4.28E-04	5.00E-05	6.27E-04	5.35E-04	5.00E-05
Nickel-D	mg/L	5.00E-05	4.16E-04	2.81E-04	5.00E-05	3.11E-04	1.82E-04	5.00E-05	2.94E-04	2.15E-04	5.00E-05	1.40E-04	9.76E-05	5.00E-05	3.34E-04	2.53E-04	5.00E-05
Phosphorous-D	mg/L	1.00E-02	1.60E-02	1.14E-02	1.00E-02	1.10E-02	7.40E-03	1.00E-02	1.40E-02	8.15E-03	1.00E-02	1.00E-02	5.83E-03	1.00E-02	2.00E-02	9.01E-03	1.00E-02
Potassium-D	mg/L	5.00E-01	2.50E-01	2.96E-01	5.00E-01	5.00E-01	3.14E-01	5.00E-01	6.40E-01	4.00E-01	5.00E-01	2.50E-01	2.85E-01	5.00E-01	9.70E-01	7.99E-01	5.00E-01
Selenium-D	mg/L	1.00E-04	3.00E-04	2.86E-04	1.00E-04	3.00E-04	2.86E-04	1.00E-04	3.00E-04	2.82E-04	1.00E-04	3.00E-04	2.85E-04	1.00E-04	3.00E-04	2.88E-04	1.00E-04
Silicon-D	mg/L	1.00E-02	6.62E+00	4.95E+00	1.00E-02	6.74E+00	5.55E+00	1.00E-02	6.83E+00	5.80E+00	1.00E-02	4.01E+00	3.55E+00	1.00E-02	5.62E+00	4.73E+00	1.00E-02
Silver-D	mg/L	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05
Sodium-D	mg/L	5.00E-01	2.46E+00	1.83E+00	5.00E-01	3.70E+00	2.60E+00	5.00E-01	3.94E+00	2.57E+00	5.00E-01	2.30E+00	1.84E+00	5.00E-01	3.71E+00	3.23E+00	5.00E-01
Strontium-D	mg/L	5.00E-06	2.67E-02	2.12E-02	5.00E-06	9.81E-02	6.52E-02	5.00E-06	1.23E-01	6.87E-02	5.00E-06	6.44E-02	4.87E-02	5.00E-06	1.11E-01	9.26E-02	5.00E-06
Thallium-D	mg/L	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	3.26E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05
Tin-D	mg/L	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04
Titanium-D	mg/L	2.00E-04	4.86E-03	2.72E-03	2.00E-04	3.25E-03	1.56E-03	2.00E-04	5.98E-03	3.85E-03	2.00E-04	2.73E-03	1.44E-03	2.00E-04	1.04E-03	6.52E-04	2.00E-04
Uranium-D	mg/L	5.00E-05	1.80E-04	1.55E-04	5.00E-05	2.91E-04	2.00E-04	5.00E-05	2.96E-04	1.84E-04	5.00E-05	2.22E-04	1.75E-04	5.00E-05	1.24E-04	1.04E-04	5.00E-05
Vanadium-D	mg/L	5.00E-05	3.06E-04	1.76E-04	5.00E-05	3.12E-04	1.59E-04	5.00E-05	5.65E-04	3.15E-04	5.00E-05	2.40E-04	1.09E-04	5.00E-05	3.47E-04	2.02E-04	5.00E-05
Zinc-D	mg/L	5.00E-04	9.04E-03	5.12E-03	5.00E-04	5.00E-03	2.63E-03	5.00E-04	5.58E-03	2.42E-03	5.00E-04	5.40E-03	3.05E-03	5.00E-04	4.39E-03	2.28E-03	5.00E-04

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

		WQ1			WQ10			WQ11			WQ12			WQ13			
Analyte	**Units**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**
Dissolved Metals																	
Total Metals																	
Aluminum-T	mg/L	2.00E-03	5.50E-01	3.53E-01	2.00E-03	4.28E-01	2.15E-01	2.00E-03	7.61E-01	4.28E-01	2.00E-03	2.94E-01	1.67E-01	2.00E-03	1.73E-01	9.42E-02	2.00E-03
Antimony-T	mg/L	5.00E-05	1.30E-04	8.09E-05	5.00E-05	5.00E-05	3.02E-05	5.00E-05	2.50E-05	2.99E-05	5.00E-05	2.50E-05	2.69E-05	5.00E-05	6.00E-05	3.51E-05	5.00E-05
Arsenic-T	mg/L	1.00E-04	8.00E-04	5.97E-04	1.00E-04	6.30E-04	5.30E-04	1.00E-04	2.00E-04	2.93E-04	1.00E-04	3.30E-04	2.75E-04	1.00E-04	6.00E-04	5.57E-04	1.00E-04
Barium-T	mg/L	5.00E-05	7.77E-03	4.48E-03	5.00E-05	8.49E-03	7.24E-03	5.00E-05	1.26E-02	9.28E-03	5.00E-05	1.04E-02	7.04E-03	5.00E-05	1.06E-02	1.52E-02	5.00E-05
Beryllium-T	mg/L	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	1.00E-04	5.95E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04
Boron-T	mg/L	1.00E-03	3.60E-03	1.73E-03	1.00E-03	1.30E-03	1.00E-03	1.00E-03	2.80E-03	1.80E-03	1.00E-03	1.30E-03	9.04E-04	1.00E-03	2.70E-03	1.83E-03	1.00E-03
Cadmium-T	mg/L	1.50E-05	5.60E-05	2.43E-05	1.50E-05	1.72E-05	1.10E-05	1.50E-05	2.58E-05	1.49E-05	1.50E-05	2.19E-05	1.21E-05	1.50E-05	3.88E-05	3.03E-05	1.50E-05
Calcium-T	mg/L	5.00E-01	3.18E+00	2.46E+00	5.00E-01	1.60E+01	1.00E+01	5.00E-01	2.20E+01	1.18E+01	5.00E-01	7.89E+00	6.49E+00	5.00E-01	2.29E+01	1.90E+01	5.00E-01
Chromium-T	mg/L	3.00E-04	3.60E-04	2.76E-04	3.00E-04	4.10E-04	2.57E-04	3.00E-04	5.40E-04	3.18E-04	3.00E-04	5.30E-04	2.11E-03	3.00E-04	2.68E-04	1.75E-04	3.00E-04
Cobalt-T	mg/L	2.00E-05	9.20E-05	9.97E-05	2.00E-05	8.10E-05	4.01E-05	2.00E-05	1.14E-04	5.87E-05	2.00E-05	1.12E-04	4.91E-05	2.00E-05	8.35E-05	5.40E-05	2.00E-05
Copper-T	mg/L	1.00E-04	1.98E-03	1.39E-03	1.00E-04	7.00E-04	3.69E-04	1.00E-04	2.66E-03	1.57E-03	1.00E-04	7.00E-04	4.93E-04	1.00E-04	1.27E-03	5.82E-04	1.00E-04
Iron-T	mg/L	1.00E-04	4.07E-01	2.77E-01	1.00E-04	2.77E-01	1.59E-01	1.00E-04	3.76E-01	2.06E-01	1.00E-04	5.37E-01	2.64E-01	1.00E-04	3.33E-01	2.65E-01	1.00E-04
Lead-T	mg/L	5.00E-05	2.94E-04	1.09E-04	5.00E-05	1.54E-04	8.11E-05	5.00E-05	8.20E-05	6.74E-05	5.00E-05	1.43E-04	5.24E-05	5.00E-05	6.35E-05	5.05E-05	5.00E-05
Lithium-T	mg/L	1.00E-03	5.00E-04	5.00E-04	1.00E-03	7.00E-04	7.43E-04	1.00E-03	1.30E-03	7.87E-04	1.00E-03	5.00E-04	6.56E-04	1.00E-03	5.00E-04	6.74E-04	1.00E-03
Magnesium-T	mg/L	5.00E-01	7.32E-01	4.74E-01	5.00E-01	3.21E+00	1.98E+00	5.00E-01	4.39E+00	2.34E+00	5.00E-01	1.36E+00	1.11E+00	5.00E-01	5.21E+00	4.28E+00	5.00E-01
Manganese-T	mg/L	5.00E-05	2.27E-02	1.47E-02	5.00E-05	1.55E-02	8.84E-03	5.00E-05	9.18E-03	4.97E-03	5.00E-05	3.68E-02	2.37E-02	5.00E-05	5.73E-02	3.58E-02	5.00E-05
Mercury-T	mg/L	5.00E-06	1.26E-05	5.40E-06	5.00E-06	1.00E-05	4.71E-06	5.00E-06	2.10E-05	1.44E-03	5.00E-06	5.20E-06	4.36E-06	5.00E-06	4.00E-06	9.61E-04	5.00E-06
Molybdenum-T	mg/L	5.00E-05	3.36E-04	1.71E-04	5.00E-05	9.20E-04	5.64E-04	5.00E-05	3.68E-04	1.90E-04	5.00E-05	6.39E-04	4.74E-04	5.00E-05	6.94E-04	5.75E-04	5.00E-05
Nickel-T	mg/L	5.00E-05	5.20E-04	3.20E-04	5.00E-05	4.23E-04	2.13E-04	5.00E-05	4.04E-04	2.59E-04	5.00E-05	2.89E-04	1.46E-04	5.00E-05	4.44E-04	3.07E-04	5.00E-05
Phosphorous-T	mg/L	1.00E-03	2.81E-02	1.35E-02	1.00E-03	1.92E-02	1.03E-02	1.00E-03	2.38E-02	1.16E-02	1.00E-03	2.00E-02	9.15E-03	1.00E-03	2.69E-02	1.29E-02	1.00E-03
Potassium-T	mg/L	5.00E-01	2.50E-01	2.96E-01	5.00E-01	5.00E-01	3.27E-01	5.00E-01	7.00E-01	4.13E-01	5.00E-01	2.50E-01	2.93E-01	5.00E-01	1.04E+00	8.42E-01	5.00E-01
Selenium-T	mg/L	1.00E-04	3.00E-04	2.86E-04	1.00E-04	3.00E-04	2.86E-04	1.00E-04	3.00E-04	2.85E-04	1.00E-04	3.00E-04	2.85E-04	1.00E-04	3.00E-04	2.89E-04	1.00E-04
Silicon-T	mg/L	1.00E-02	6.71E+00	5.19E+00	1.00E-02	6.97E+00	5.82E+00	1.00E-02	7.01E+00	6.04E+00	1.00E-02	4.33E+00	3.89E+00	1.00E-02	6.00E+00	4.98E+00	1.00E-02
Silver-T	mg/L	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.92E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05
Sodium-T	mg/L	5.00E-01	2.46E+00	1.87E+00	5.00E-01	3.71E+00	2.66E+00	5.00E-01	3.94E+00	2.63E+00	5.00E-01	2.30E+00	1.88E+00	5.00E-01	4.01E+00	3.33E+00	5.00E-01
Strontium-T	mg/L	5.00E-06	2.91E-02	2.24E-02	5.00E-06	9.84E-02	6.71E-02	5.00E-06	1.23E-01	7.05E-02	5.00E-06	6.44E-02	5.01E-02	5.00E-06	1.11E-01	9.53E-02	5.00E-06
Thallium-T	mg/L	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	3.26E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05
T-Hardness as CaCO3	mg/L	6.00E+00	1.10E+01	8.68E+00	6.00E+00	4.85E+01	3.41E+01	6.00E+00	6.95E+01	4.12E+01	6.00E+00	2.61E+01	2.12E+01	6.00E+00	7.84E+01	6.69E+01	6.00E+00
Tin-T	mg/L	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04
Titanium-T	mg/L	2.00E-04	1.05E-02	6.18E-03	2.00E-04	6.61E-03	3.50E-03	2.00E-04	1.08E-02	5.45E-03	2.00E-04	6.35E-03	3.33E-03	2.00E-04	6.06E-03	3.28E-03	2.00E-04
Uranium-T	mg/L	5.00E-05	2.00E-04	1.70E-04	5.00E-05	3.01E-04	2.16E-04	5.00E-05	3.08E-04	1.96E-04	5.00E-05	2.40E-04	1.92E-04	5.00E-05	1.44E-04	1.14E-04	5.00E-05
Vanadium-T	mg/L	5.00E-05	5.20E-04	3.07E-04	5.00E-05	4.00E-04	2.68E-04	5.00E-05	7.80E-04	4.40E-04	5.00E-05	3.60E-04	1.95E-04	5.00E-05	6.00E-04	3.47E-04	5.00E-05

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

		WQ1			WQ10			WQ11			WQ12			WQ13			
Analyte	**Units**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**
Dissolved Metals																	
Zinc-T	mg/L	5.00E-04	9.36E-03	5.23E-03	5.00E-04	6.25E-03	3.17E-03	5.00E-04	5.56E-03	2.46E-03	5.00E-04	4.25E-03	2.81E-03	5.00E-04	2.19E-02	8.47E-03	5.00E-04
Cyanides																	
Cyanate	mg/L	2.00E-01	3.47E-01	4.85E-01	2.00E-01	1.00E-01	1.00E-01	2.00E-01	1.00E-01	1.00E-01	2.00E-01	1.00E-01	1.00E-01	2.00E-01	1.00E-01	1.00E-01	2.00E-01
Cyanide (Total)	mg/L	5.00E-03	1.40E-02	5.24E-03	5.00E-03	1.06E-02	4.83E-03	5.00E-03	1.64E-02	6.15E-03	5.00E-03	9.81E-03	4.35E-03	5.00E-03	8.30E-03	4.14E-03	5.00E-03
Cyanide (WAD)	mg/L	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03
Thiocyanate (SCN)	mg/L	5.00E-02	5.46E-01	4.47E-01	5.00E-02	2.50E-01	2.67E-01	5.00E-02	9.78E-01	6.97E-01	5.00E-02	6.86E-01	4.51E-01	5.00E-02	5.02E-01	3.82E-01	5.00E-02

Notes: Surface water samples Modelled by Knight Piesold

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

		WQ14		WQ15			WQ16			WQ17			WQ18			WQ19	
Analyte	**Units**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**
Dissolved Metals																	
Aluminum-D	mg/L	5.30E-02	2.14E-02	2.00E-03	8.83E-02	5.92E-02	2.00E-03	6.27E-02	3.36E-02	2.00E-03	1.28E-01	1.00E-01	2.00E-03	3.38E-02	2.58E-02	2.00E-03	5.60E-03
Antimony-D	mg/L	2.50E-05	7.26E-04	5.00E-05	2.50E-05	2.50E-05	5.00E-05	8.00E-05	5.17E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	6.90E-05	5.76E-05	5.00E-05	4.75E-05
Arsenic-D	mg/L	4.00E-04	2.48E-04	1.00E-04	7.15E-04	4.18E-04	1.00E-04	7.45E-04	5.13E-04	1.00E-04	5.60E-04	4.94E-04	1.00E-04	4.80E-04	4.59E-04	1.00E-04	4.90E-04
Barium-D	mg/L	1.46E-02	1.76E-02	5.00E-05	1.10E-02	9.15E-03	5.00E-05	8.16E-03	4.97E-03	5.00E-05	7.47E-03	7.83E-03	5.00E-05	7.03E-03	6.61E-03	5.00E-05	9.48E-03
Beryllium-D	mg/L	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05
Boron-D	mg/L	3.00E-03	2.80E-03	1.00E-03	1.70E-03	1.10E-03	1.00E-03	1.35E-03	8.99E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	1.80E-03	1.47E-03	1.00E-03	1.00E-03
Cadmium-D	mg/L	2.80E-05	1.41E-05	1.50E-05	7.50E-06	7.50E-06	1.50E-05	3.70E-05	1.73E-05	1.50E-05	7.50E-06	7.50E-06	1.50E-05	3.86E-04	2.88E-04	1.50E-05	7.50E-06
Calcium-D	mg/L	3.24E+01	3.54E+01	5.00E-01	1.14E+01	9.37E+00	5.00E-01	7.37E+00	6.53E+00	5.00E-01	1.06E+01	1.04E+01	5.00E-01	1.48E+01	1.49E+01	5.00E-01	3.50E+01
Chromium-D	mg/L	1.50E-04	1.64E-04	3.00E-04	1.50E-04	1.50E-04	3.00E-04	1.50E-04	1.50E-04	3.00E-04	1.50E-04	1.50E-04	3.00E-04	4.30E-04	3.57E-04	3.00E-04	1.50E-04
Cobalt-D	mg/L	4.50E-05	4.71E-05	2.00E-05	2.00E-05	1.44E-05	2.00E-05	3.00E-05	1.82E-05	2.00E-05	4.00E-05	3.88E-05	2.00E-05	6.20E-05	5.32E-05	2.00E-05	1.00E-05
Copper-D	mg/L	8.00E-04	1.96E-03	1.00E-04	7.75E-04	4.13E-04	1.00E-04	4.35E-04	2.68E-04	1.00E-04	5.80E-04	5.75E-04	1.00E-04	2.88E-03	2.13E-03	1.00E-04	5.00E-05
D-Hardness as CaCO3	mg/L	1.03E+02	8.21E+01	6.00E+00	2.74E+01	2.69E+01	6.00E+00	2.19E+01	2.18E+01	6.00E+00	3.88E+01	3.80E+01	6.00E+00	7.33E+01	7.47E+01	6.00E+00	1.10E+02
Iron-D	mg/L	8.00E-01	2.51E-01	1.00E-04	1.37E-01	1.07E-01	1.00E-04	1.43E-01	9.21E-02	1.00E-04	7.66E-02	6.99E-02	1.00E-04	1.56E-01	1.45E-01	1.00E-04	1.58E-02
Lead-D	mg/L	2.43E-04	1.10E-04	5.00E-05	2.50E-05	2.50E-05	5.00E-05	1.56E-04	1.04E-04	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05
Lithium-D	mg/L	5.00E-04	6.43E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	1.00E-03	9.40E-04	1.00E-03	5.00E-04
Magnesium-D	mg/L	7.49E+00	7.26E+00	5.00E-01	2.04E+00	1.57E+00	5.00E-01	1.38E+00	1.26E+00	5.00E-01	3.04E+00	2.99E+00	5.00E-01	9.12E+00	9.13E+00	5.00E-01	4.83E+00
Manganese-D	mg/L	6.69E-02	2.27E-02	5.00E-05	2.01E-02	1.48E-02	5.00E-05	5.53E-02	2.67E-02	5.00E-05	1.28E-02	1.15E-02	5.00E-05	7.19E-03	6.16E-03	5.00E-05	1.55E-03
Mercury-D	mg/L	4.00E-06	3.34E-06	5.00E-06	2.50E-06	2.50E-06	5.00E-06	2.50E-06	2.50E-06	5.00E-06	4.00E-06	3.82E-06	5.00E-06	4.00E-06	3.82E-06	5.00E-06	2.50E-06
Molybdenum-D	mg/L	6.85E-04	8.40E-04	5.00E-05	6.77E-04	5.93E-04	5.00E-05	8.40E-04	7.31E-04	5.00E-05	2.13E-03	2.33E-03	5.00E-05	7.58E-04	7.31E-04	5.00E-05	7.38E-04
Nickel-D	mg/L	3.65E-04	6.20E-04	5.00E-05	1.49E-04	9.60E-05	5.00E-05	8.00E-05	5.38E-05	5.00E-05	2.38E-04	2.11E-04	5.00E-05	1.07E-03	8.95E-04	5.00E-05	2.50E-05
Phosphorous-D	mg/L	2.00E-02	9.75E-03	1.00E-02	6.75E-03	6.06E-03	1.00E-02	2.00E-02	1.04E-02	1.00E-02	5.00E-03	5.00E-03	1.00E-02	4.80E-02	4.53E-02	1.00E-02	5.00E-03
Potassium-D	mg/L	1.40E+00	8.38E-01	5.00E-01	4.08E-01	3.45E-01	5.00E-01	2.50E-01	2.50E-01	5.00E-01	2.50E-01	2.50E-01	5.00E-01	3.46E+00	3.11E+00	5.00E-01	7.00E-01
Selenium-D	mg/L	3.00E-04	2.82E-04	1.00E-04	3.00E-04	2.43E-04	1.00E-04	3.00E-04	2.43E-04	6.00E-04	3.00E-04	3.00E-04	6.00E-04	3.00E-04	3.00E-04	6.00E-04	3.00E-04
Silicon-D	mg/L	8.64E+00	9.23E+00	1.00E-02	2.99E+00	2.46E+00	1.00E-02	1.96E+00	1.70E+00	1.00E-02	6.65E+00	6.71E+00	1.00E-02	1.32E+01	1.26E+01	1.00E-02	6.84E+00
Silver-D	mg/L	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05
Sodium-D	mg/L	5.40E+00	3.94E+00	5.00E-01	2.42E+00	2.08E+00	5.00E-01	2.30E+00	2.09E+00	5.00E-01	3.68E+00	3.56E+00	5.00E-01	7.40E+00	6.87E+00	5.00E-01	2.98E+00
Strontium-D	mg/L	1.50E-01	1.77E-01	5.00E-06	8.24E-02	7.53E-02	5.00E-06	5.10E-02	4.48E-02	5.00E-06	6.19E-02	6.34E-02	5.00E-06	6.37E-02	6.49E-02	5.00E-06	1.23E-01
Thallium-D	mg/L	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05
Tin-D	mg/L	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05
Titanium-D	mg/L	1.15E-03	9.67E-04	2.00E-04	1.18E-03	7.95E-04	2.00E-04	9.70E-04	5.39E-04	2.00E-04	8.60E-04	6.86E-04	2.00E-04	1.86E-03	1.47E-03	2.00E-04	1.00E-04
Uranium-D	mg/L	2.50E-04	1.34E-04	5.00E-05	1.74E-04	1.55E-04	5.00E-05	2.78E-04	2.45E-04	5.00E-05	9.80E-05	9.64E-05	5.00E-05	1.30E-04	1.31E-04	5.00E-05	3.41E-04
Vanadium-D	mg/L	2.40E-04	1.10E-04	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.04E-04	1.83E-04	5.00E-05	1.41E-03	1.31E-03	5.00E-05	8.34E-04
Zinc-D	mg/L	1.23E-02	4.61E-03	5.00E-04	3.74E-03	2.51E-03	5.00E-04	5.90E-03	3.61E-03	5.00E-04	3.34E-03	2.87E-03	5.00E-04	9.58E-02	7.11E-02	5.00E-04	2.37E-03

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

		WQ14		WQ15			WQ16			WQ17			WQ18			WQ19	
Analyte	**Units**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**
Dissolved Metals																	
Total Metals																	
Aluminum-T	mg/L	1.37E-01	1.06E-01	2.00E-03	9.98E-02	7.64E-02	2.00E-03	4.08E-01	1.75E-01	2.00E-03	1.80E-01	1.39E-01	2.00E-03	8.16E-01	6.04E-01	2.00E-03	8.90E-03
Antimony-T	mg/L	2.50E-05	7.26E-04	5.00E-05	5.35E-05	3.51E-05	5.00E-05	9.00E-05	6.17E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	1.25E-04	9.90E-05	5.00E-05	4.75E-05
Arsenic-T	mg/L	8.00E-04	4.28E-04	1.00E-04	8.45E-04	4.43E-04	1.00E-04	1.07E-03	6.97E-04	1.00E-04	5.60E-04	5.07E-04	1.00E-04	1.22E-03	1.00E-03	1.00E-04	4.90E-04
Barium-T	mg/L	2.23E-02	1.98E-02	5.00E-05	1.15E-02	9.63E-03	5.00E-05	8.75E-03	6.33E-03	5.00E-05	7.67E-03	7.86E-03	5.00E-05	3.48E-02	2.71E-02	5.00E-05	9.23E-03
Beryllium-T	mg/L	5.00E-05	5.48E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05
Boron-T	mg/L	3.00E-03	3.37E-03	1.00E-03	1.70E-03	1.10E-03	1.00E-03	1.35E-03	8.59E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	2.00E-03	1.89E-03	1.00E-03	1.90E-03
Cadmium-T	mg/L	4.75E-05	1.90E-05	1.50E-05	7.50E-06	7.50E-06	1.50E-05	8.51E-05	4.19E-05	1.50E-05	7.50E-06	7.50E-06	1.50E-05	5.26E-04	3.91E-04	1.50E-05	7.50E-06
Calcium-T	mg/L	3.26E+01	3.71E+01	5.00E-01	1.17E+01	9.62E+00	5.00E-01	7.37E+00	6.63E+00	5.00E-01	1.08E+01	1.07E+01	5.00E-01	1.59E+01	1.59E+01	5.00E-01	3.50E+01
Chromium-T	mg/L	4.75E-04	2.82E-04	3.00E-04	1.50E-04	1.50E-04	3.00E-04	5.00E-04	2.67E-04	3.00E-04	1.50E-04	1.50E-04	3.00E-04	5.52E-03	4.11E-03	3.00E-04	1.50E-04
Cobalt-T	mg/L	1.65E-04	6.86E-05	2.00E-05	4.35E-05	2.82E-05	2.00E-05	1.20E-04	5.61E-05	2.00E-05	5.80E-05	5.34E-05	2.00E-05	1.38E-03	1.03E-03	2.00E-05	1.00E-05
Copper-T	mg/L	1.75E-03	2.05E-03	1.00E-04	7.75E-04	4.03E-04	1.00E-04	7.00E-04	3.42E-04	1.00E-04	6.80E-04	6.64E-04	1.00E-04	4.50E-03	3.34E-03	1.00E-04	9.50E-05
Iron-T	mg/L	1.09E+00	4.87E-01	1.00E-04	2.11E-01	1.57E-01	1.00E-04	6.39E-01	3.04E-01	1.00E-04	9.56E-02	9.28E-02	1.00E-04	3.02E+00	2.27E+00	1.00E-04	2.38E-02
Lead-T	mg/L	3.25E-04	1.16E-04	5.00E-05	2.50E-05	2.50E-05	5.00E-05	3.61E-04	1.84E-04	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.93E-04	2.23E-04	5.00E-05	2.50E-05
Lithium-T	mg/L	5.00E-04	6.43E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	1.00E-03	1.04E-03	1.00E-03	5.00E-04
Magnesium-T	mg/L	7.50E+00	7.60E+00	5.00E-01	2.14E+00	1.64E+00	5.00E-01	1.40E+00	1.28E+00	5.00E-01	3.11E+00	3.12E+00	5.00E-01	9.66E+00	9.65E+00	5.00E-01	4.83E+00
Manganese-T	mg/L	9.23E-02	4.16E-02	5.00E-05	4.07E-02	2.95E-02	5.00E-05	1.03E-01	5.30E-02	5.00E-05	1.32E-02	1.23E-02	5.00E-05	3.01E-01	2.24E-01	5.00E-05	2.15E-03
Mercury-T	mg/L	4.00E-06	3.34E-06	5.00E-06	1.05E-03	6.36E-04	5.00E-06	2.50E-06	2.50E-06	5.00E-06	4.00E-06	3.82E-06	5.00E-06	8.00E-06	6.75E-06	5.00E-06	2.50E-06
Molybdenum-T	mg/L	7.20E-04	9.41E-04	5.00E-05	6.94E-04	6.34E-04	5.00E-05	1.08E-03	8.60E-04	5.00E-05	2.50E-03	2.56E-03	5.00E-05	7.78E-04	7.94E-04	5.00E-05	7.44E-04
Nickel-T	mg/L	1.05E-03	6.93E-04	5.00E-05	2.09E-04	1.18E-04	5.00E-05	3.30E-04	1.41E-04	5.00E-05	2.50E-04	2.34E-04	5.00E-05	4.69E-03	3.58E-03	5.00E-05	6.55E-05
Phosphorous-T	mg/L	3.00E-02	2.70E-02	1.00E-03	2.29E-02	1.27E-02	1.00E-03	6.00E-02	2.27E-02	1.00E-03	1.00E-02	8.37E-03	1.00E-03	1.83E-01	1.14E-01	1.00E-03	1.00E-02
Potassium-T	mg/L	1.85E+00	1.13E+00	5.00E-01	4.08E-01	3.45E-01	5.00E-01	2.50E-01	2.50E-01	5.00E-01	2.50E-01	2.50E-01	5.00E-01	3.56E+00	3.21E+00	5.00E-01	7.00E-01
Selenium-T	mg/L	3.00E-04	3.45E-04	1.00E-04	3.00E-04	2.45E-04	1.00E-04	3.00E-04	2.43E-04	6.00E-04	3.00E-04	3.00E-04	6.00E-04	3.00E-04	3.00E-04	6.00E-04	3.00E-04
Silicon-T	mg/L	8.70E+00	1.08E+01	1.00E-02	3.38E+00	2.73E+00	1.00E-02	2.32E+00	1.97E+00	1.00E-02	6.97E+00	6.93E+00	1.00E-02	1.60E+01	1.51E+01	1.00E-02	6.84E+00
Silver-T	mg/L	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05
Sodium-T	mg/L	5.40E+00	6.23E+00	5.00E-01	2.42E+00	2.08E+00	5.00E-01	2.30E+00	2.06E+00	5.00E-01	3.76E+00	3.73E+00	5.00E-01	7.48E+00	7.03E+00	5.00E-01	2.98E+00
Strontium-T	mg/L	1.51E-01	1.82E-01	5.00E-06	8.57E-02	7.80E-02	5.00E-06	5.41E-02	4.75E-02	5.00E-06	6.39E-02	6.57E-02	5.00E-06	7.37E-02	7.21E-02	5.00E-06	1.24E-01
Thallium-T	mg/L	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05
T-Hardness as CaCO3	mg/L	1.04E+02	8.37E+01	6.00E+00	2.75E+01	2.71E+01	6.00E+00	2.19E+01	2.17E+01	6.00E+00	3.94E+01	3.93E+01	6.00E+00	7.96E+01	7.94E+01	6.00E+00	1.10E+02
Tin-T	mg/L	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05
Titanium-T	mg/L	4.75E-03	2.68E-03	2.00E-04	1.92E-03	1.22E-03	2.00E-04	7.90E-03	3.32E-03	2.00E-04	1.20E-03	9.84E-04	2.00E-04	6.21E-02	4.60E-02	2.00E-04	3.90E-04
Uranium-T	mg/L	2.85E-04	1.56E-04	5.00E-05	1.87E-04	1.67E-04	5.00E-05	9.40E-04	5.15E-04	5.00E-05	1.48E-04	1.31E-04	5.00E-05	2.04E-04	1.80E-04	5.00E-05	3.18E-03
Vanadium-T	mg/L	3.50E-04	3.56E-04	5.00E-05	1.80E-04	1.16E-04	5.00E-05	2.60E-04	1.17E-04	1.00E-04	2.00E-04	1.86E-04	1.00E-04	5.82E-03	4.62E-03	1.00E-04	8.00E-04

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

		WQ14		WQ15			WQ16			WQ17			WQ18			WQ19	
Analyte	**Units**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**
Dissolved Metals																	
Zinc-T	mg/L	1.38E-02	6.81E-03	5.00E-04	4.14E-03	2.72E-03	5.00E-04	7.25E-03	4.52E-03	5.00E-04	3.34E-03	2.87E-03	5.00E-04	1.18E-01	8.76E-02	5.00E-04	2.37E-03
Cyanides																	
Cyanate	mg/L	1.00E-01	1.00E-01	2.00E-01	1.00E-01	1.00E-01	2.00E-01	1.00E-01	1.00E-01								
Cyanide (Total)	mg/L	6.88E-03	3.95E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03
Cyanide (WAD)	mg/L	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03
Thiocyanate (SCN)	mg/L	5.43E-01	3.94E-01	5.00E-01	2.50E-01	2.50E-01	5.00E-01	2.50E-01	2.50E-01								

Notes: Surface water samples Modelled by Knight Piesold

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

			WQ20			WQ21			WQ22			WQ23			WQ24		
Analyte	**Units**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**
Dissolved Metals																	
Aluminum-D	mg/L	5.99E-03	2.00E-03	2.20E-03	1.66E-03	2.00E-03	3.00E-03	2.32E-03	2.00E-03	1.50E-02	1.35E-02	2.00E-03	1.19E-02	6.92E-03	2.00E-03	1.40E-02	1.07E-02
Antimony-D	mg/L	4.97E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	4.60E-05	3.65E-05	5.00E-05	6.63E-05	5.21E-05	5.00E-05	7.00E-05	6.21E-05	5.00E-05	7.00E-05	6.00E-05
Arsenic-D	mg/L	4.99E-04	1.00E-04	4.00E-04	3.50E-04	1.00E-04	4.60E-04	4.33E-04	1.00E-04	3.00E-04	3.08E-04	1.00E-04	1.27E-02	5.26E-03	1.00E-04	5.50E-03	3.30E-03
Barium-D	mg/L	9.57E-03	5.00E-05	1.11E-02	9.74E-03	5.00E-05	6.13E-03	5.79E-03	5.00E-05	7.64E-03	7.48E-03	5.00E-05	6.71E-03	4.59E-03	5.00E-05	7.92E-03	5.61E-03
Beryllium-D	mg/L	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05
Boron-D	mg/L	1.16E-03	1.00E-03	5.80E-03	3.58E-03	1.00E-03	3.60E-03	3.05E-03	1.00E-03	3.00E-03	2.41E-03	1.00E-03	7.25E-04	6.23E-04	1.00E-03	5.00E-04	5.00E-04
Cadmium-D	mg/L	7.50E-06	1.50E-05	7.50E-06	7.50E-06	1.50E-05	1.20E-05	9.97E-06	1.50E-05	7.50E-06	7.50E-06	1.50E-05	7.50E-06	7.50E-06	1.50E-05	1.43E-05	1.14E-05
Calcium-D	mg/L	3.68E+01	5.00E-01	2.31E+01	2.15E+01	5.00E-01	2.36E+01	2.16E+01	5.00E-01	1.39E+01	1.31E+01	5.00E-01	9.50E+00	8.31E+00	5.00E-01	1.04E+01	8.44E+00
Chromium-D	mg/L	1.50E-04	3.00E-04	3.60E-04	2.54E-04	3.00E-04	3.60E-04	2.74E-04	3.00E-04	3.38E-04	2.73E-04	3.00E-04	3.45E-04	2.59E-04	3.00E-04	3.00E-04	2.36E-04
Cobalt-D	mg/L	1.00E-05	2.00E-05	1.60E-05	1.33E-05	2.00E-05	1.00E-05	1.00E-05	2.00E-05	1.75E-05	1.49E-05	2.00E-05	1.40E-04	6.17E-05	2.00E-05	9.00E-05	5.57E-05
Copper-D	mg/L	5.00E-05	1.00E-04	1.60E-04	1.11E-04	1.00E-04	6.80E-04	4.04E-04	1.00E-04	6.25E-04	4.37E-04	1.00E-04	2.00E-04	1.48E-04	1.00E-04	2.00E-04	1.81E-04
D-Hardness as CaCO3	mg/L	1.15E+02	6.00E+00	7.02E+01	6.96E+01	6.00E+00	7.05E+01	6.79E+01	6.00E+00	4.18E+01	4.20E+01	6.00E+00	2.45E+01	2.37E+01	6.00E+00	1.72E+01	1.73E+01
Iron-D	mg/L	1.62E-02	1.00E-04	2.03E-01	1.15E-01	1.00E-04	1.45E-02	1.26E-02	1.00E-04	2.40E-01	1.85E-01	1.00E-04	4.32E+00	1.68E+00	1.00E-04	3.23E+00	1.85E+00
Lead-D	mg/L	2.50E-05	5.00E-05	3.64E-04	1.93E-04	5.00E-05	8.06E-04	5.07E-04	5.00E-05	1.49E-03	9.96E-04	5.00E-05	7.45E-05	4.44E-05	5.00E-05	6.08E-05	4.53E-05
Lithium-D	mg/L	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04
Magnesium-D	mg/L	5.08E+00	5.00E-01	6.93E+00	6.21E+00	5.00E-01	5.35E+00	4.94E+00	5.00E-01	3.97E+00	3.70E+00	5.00E-01	1.57E+00	1.42E+00	5.00E-01	1.70E+00	1.47E+00
Manganese-D	mg/L	1.74E-03	5.00E-05	3.65E-01	2.06E-01	5.00E-05	1.30E-03	8.30E-04	5.00E-05	1.05E-01	7.56E-02	5.00E-05	5.16E-01	2.14E-01	5.00E-05	1.01E+00	5.77E-01
Mercury-D	mg/L	2.50E-06	5.00E-06	2.50E-06	2.50E-06	5.00E-06	2.50E-06	2.50E-06	5.00E-06	2.50E-06	2.50E-06	5.00E-06	2.50E-06	2.50E-06	5.00E-06	2.50E-06	2.50E-06
Molybdenum-D	mg/L	7.49E-04	5.00E-05	1.12E-03	8.91E-04	5.00E-05	6.22E-04	5.83E-04	5.00E-05	3.18E-04	3.11E-04	5.00E-05	1.16E-03	8.86E-04	5.00E-05	2.28E-03	1.65E-03
Nickel-D	mg/L	2.50E-05	5.00E-05	1.46E-04	1.32E-04	5.00E-05	2.16E-04	2.05E-04	5.00E-05	1.20E-04	1.16E-04	5.00E-05	5.00E-05	3.47E-05	5.00E-05	6.00E-05	4.50E-05
Phosphorous-D	mg/L	5.00E-03	1.00E-02	8.60E-02	5.07E-02	1.00E-02	2.00E-02	1.68E-02	1.00E-02	1.75E-02	1.32E-02	1.00E-02	3.50E-01	1.39E-01	1.00E-02	1.10E-01	6.49E-02
Potassium-D	mg/L	8.44E-01	5.00E-01	1.16E+00	1.04E+00	5.00E-01	9.60E-01	8.73E-01	5.00E-01	1.30E+00	1.22E+00	5.00E-01	3.63E-01	3.12E-01	5.00E-01	5.00E-01	3.93E-01
Selenium-D	mg/L	3.00E-04	6.00E-04	3.00E-04	3.00E-04	6.00E-04	3.00E-04	3.00E-04	6.00E-04	3.00E-04	3.00E-04	6.00E-04	3.00E-04	3.00E-04	6.00E-04	3.00E-04	3.00E-04
Silicon-D	mg/L	7.24E+00	1.00E-02	9.63E+00	8.44E+00	1.00E-02	5.85E+00	5.16E+00	1.00E-02	6.49E+00	6.07E+00	1.00E-02	7.16E+00	5.37E+00	1.00E-02	2.42E+00	2.14E+00
Silver-D	mg/L	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05
Sodium-D	mg/L	3.01E+00	5.00E-01	4.08E+00	3.70E+00	5.00E-01	3.98E+00	3.73E+00	5.00E-01	3.88E+00	3.60E+00	5.00E-01	2.64E+00	2.53E+00	5.00E-01	2.20E+00	2.06E+00
Strontium-D	mg/L	1.24E-01	5.00E-06	1.13E-01	1.07E-01	5.00E-06	1.08E-01	1.01E-01	5.00E-06	7.22E-02	7.00E-02	5.00E-06	5.91E-02	5.32E-02	5.00E-06	6.21E-02	5.21E-02
Thallium-D	mg/L	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05
Tin-D	mg/L	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05
Titanium-D	mg/L	1.00E-04	2.00E-04	1.60E-04	1.33E-04	2.00E-04	1.60E-04	1.33E-04	2.00E-04	2.00E-04	1.94E-04	2.00E-04	6.00E-04	2.93E-04	2.00E-04	1.65E-04	1.37E-04
Uranium-D	mg/L	3.49E-04	5.00E-05	2.50E-05	2.50E-05	5.00E-05	1.06E-04	9.40E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.60E-04	1.64E-04	5.00E-05	3.50E-04	3.16E-04
Vanadium-D	mg/L	9.72E-04	5.00E-05	1.56E-04	1.39E-04	5.00E-05	1.32E-04	1.14E-04	5.00E-05	1.28E-04	1.13E-04	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05
Zinc-D	mg/L	2.79E-03	5.00E-04	8.68E-03	5.72E-03	5.00E-04	1.42E-02	8.46E-03	5.00E-04	8.98E-03	7.46E-03	5.00E-04	4.63E-03	2.97E-03	5.00E-04	4.01E-03	3.07E-03

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

			WQ20			WQ21			WQ22			WQ23			WQ24		
Analyte	**Units**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**
Dissolved Metals																	
Total Metals																	
Aluminum-T	mg/L	1.09E-02	2.00E-03	1.50E-01	8.18E-02	2.00E-03	2.38E-02	1.56E-02	2.00E-03	2.63E-02	2.12E-02	2.00E-03	1.80E-02	1.22E-02	2.00E-03	2.75E-02	2.04E-02
Antimony-T	mg/L	4.97E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	6.60E-05	4.55E-05	5.00E-05	7.38E-05	5.71E-05	5.00E-05	7.00E-05	6.08E-05	5.00E-05	7.00E-05	6.00E-05
Arsenic-T	mg/L	4.99E-04	1.00E-04	4.60E-04	3.92E-04	1.00E-04	4.60E-04	4.33E-04	1.00E-04	3.00E-04	3.08E-04	1.00E-04	1.27E-02	5.30E-03	1.00E-04	6.20E-03	3.71E-03
Barium-T	mg/L	9.32E-03	5.00E-05	1.39E-02	1.17E-02	5.00E-05	6.33E-03	6.18E-03	5.00E-05	9.01E-03	8.46E-03	5.00E-05	7.16E-03	4.94E-03	5.00E-05	8.66E-03	6.20E-03
Beryllium-T	mg/L	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05
Boron-T	mg/L	1.99E-03	1.00E-03	5.80E-03	3.67E-03	1.00E-03	3.60E-03	3.05E-03	1.00E-03	3.00E-03	2.98E-03	1.00E-03	7.25E-04	6.23E-04	1.00E-03	5.00E-04	5.00E-04
Cadmium-T	mg/L	7.50E-06	1.50E-05	3.44E-05	2.19E-05	1.50E-05	8.44E-05	5.03E-05	1.50E-05	2.98E-05	2.33E-05	1.50E-05	2.64E-05	1.64E-05	1.50E-05	5.91E-05	3.56E-05
Calcium-T	mg/L	3.67E+01	5.00E-01	2.40E+01	2.27E+01	5.00E-01	2.40E+01	2.24E+01	5.00E-01	1.40E+01	1.36E+01	5.00E-01	9.60E+00	8.39E+00	5.00E-01	1.07E+01	8.73E+00
Chromium-T	mg/L	1.50E-04	3.00E-04	3.60E-04	2.54E-04	3.00E-04	3.60E-04	2.74E-04	3.00E-04	3.38E-04	2.73E-04	3.00E-04	3.45E-04	2.59E-04	3.00E-04	3.00E-04	2.60E-04
Cobalt-T	mg/L	1.00E-05	2.00E-05	9.00E-05	5.15E-05	2.00E-05	1.00E-05	1.00E-05	2.00E-05	1.75E-05	1.49E-05	2.00E-05	1.60E-04	7.16E-05	2.00E-05	1.10E-04	6.71E-05
Copper-T	mg/L	9.93E-05	1.00E-04	2.28E-03	1.26E-03	1.00E-04	1.04E-03	8.01E-04	1.00E-04	6.25E-04	5.39E-04	1.00E-04	2.00E-04	1.64E-04	1.00E-04	3.00E-04	2.88E-04
Iron-T	mg/L	2.43E-02	1.00E-04	4.48E-01	2.45E-01	1.00E-04	3.78E-02	2.99E-02	1.00E-04	4.18E-01	3.09E-01	1.00E-04	4.38E+00	1.73E+00	1.00E-04	3.55E+00	2.04E+00
Lead-T	mg/L	2.50E-05	5.00E-05	6.92E-03	3.74E-03	5.00E-05	2.44E-03	1.42E-03	5.00E-05	1.79E-03	1.39E-03	5.00E-05	8.80E-05	5.09E-05	5.00E-05	7.38E-05	5.27E-05
Lithium-T	mg/L	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04
Magnesium-T	mg/L	5.05E+00	5.00E-01	6.93E+00	6.31E+00	5.00E-01	5.35E+00	5.03E+00	5.00E-01	3.97E+00	3.76E+00	5.00E-01	1.62E+00	1.45E+00	5.00E-01	1.70E+00	1.49E+00
Manganese-T	mg/L	2.24E-03	5.00E-05	3.80E-01	2.28E-01	5.00E-05	3.98E-02	2.38E-02	5.00E-05	1.18E-01	8.51E-02	5.00E-05	5.25E-01	2.23E-01	5.00E-05	1.01E+00	5.78E-01
Mercury-T	mg/L	2.50E-06	5.00E-06	5.20E-06	3.98E-06	5.00E-06	2.50E-06	2.50E-06	5.00E-06	2.50E-06	2.50E-06	5.00E-06	6.45E-06	4.45E-06	5.00E-06	5.43E-06	4.16E-06
Molybdenum-T	mg/L	7.58E-04	5.00E-05	1.12E-03	9.08E-04	5.00E-05	6.22E-04	5.89E-04	5.00E-05	3.28E-04	3.24E-04	5.00E-05	1.22E-03	9.23E-04	5.00E-05	2.47E-03	1.78E-03
Nickel-T	mg/L	6.94E-05	5.00E-05	5.34E-04	3.94E-04	5.00E-05	3.54E-04	2.92E-04	5.00E-05	2.73E-04	2.27E-04	5.00E-05	6.06E-04	3.35E-04	5.00E-05	6.00E-05	5.14E-05
Phosphorous-T	mg/L	9.47E-03	1.00E-03	1.26E-01	5.21E-02	1.00E-03	2.32E-02	1.58E-02	1.00E-03	1.84E-02	1.32E-02	1.00E-03	3.68E-01	1.25E-01	1.00E-03	1.30E-01	6.34E-02
Potassium-T	mg/L	7.64E-01	5.00E-01	1.16E+00	1.06E+00	5.00E-01	9.60E-01	8.99E-01	5.00E-01	1.30E+00	1.24E+00	5.00E-01	3.63E-01	3.12E-01	5.00E-01	5.00E-01	3.93E-01
Selenium-T	mg/L	3.00E-04	6.00E-04	3.00E-04	3.00E-04	6.00E-04	3.00E-04	3.00E-04	6.00E-04	3.00E-04	3.00E-04	6.00E-04	3.00E-04	3.00E-04	6.00E-04	3.00E-04	3.00E-04
Silicon-T	mg/L	7.15E+00	1.00E-02	9.63E+00	8.52E+00	1.00E-02	5.95E+00	5.26E+00	1.00E-02	6.49E+00	6.10E+00	1.00E-02	7.23E+00	5.49E+00	1.00E-02	2.49E+00	2.18E+00
Silver-T	mg/L	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05
Sodium-T	mg/L	3.01E+00	5.00E-01	4.08E+00	3.72E+00	5.00E-01	3.98E+00	3.74E+00	5.00E-01	3.88E+00	3.62E+00	5.00E-01	2.69E+00	2.55E+00	5.00E-01	2.20E+00	2.07E+00
Strontium-T	mg/L	1.25E-01	5.00E-06	1.18E-01	1.14E-01	5.00E-06	1.08E-01	1.04E-01	5.00E-06	7.47E-02	7.41E-02	5.00E-06	6.02E-02	5.44E-02	5.00E-06	6.53E-02	5.53E-02
Thallium-T	mg/L	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05
T-Hardness as CaCO3	mg/L	1.14E+02	6.00E+00	7.76E+01	7.65E+01	6.00E+00	7.26E+01	7.14E+01	6.00E+00	4.55E+01	4.57E+01	6.00E+00	2.50E+01	2.44E+01	6.00E+00	1.90E+01	1.91E+01
Tin-T	mg/L	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	1.40E-04	9.93E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05
Titanium-T	mg/L	4.40E-04	2.00E-04	8.58E-03	4.65E-03	2.00E-04	4.60E-04	3.11E-04	2.00E-04	6.00E-04	4.54E-04	2.00E-04	8.00E-04	3.85E-04	2.00E-04	3.65E-04	2.66E-04
Uranium-T	mg/L	3.46E-03	5.00E-05	4.60E-05	3.65E-05	5.00E-05	1.06E-04	9.40E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.80E-04	1.73E-04	5.00E-05	4.20E-04	3.64E-04
Vanadium-T	mg/L	9.60E-04	1.00E-04	1.60E-04	1.25E-04	1.00E-04	1.00E-04	9.50E-05	1.00E-04	1.75E-04	1.44E-04	5.00E-05	5.00E-05	4.49E-05	5.00E-05	5.00E-05	4.68E-05

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

			WQ20			WQ21			WQ22			WQ23			WQ24		
Analyte	**Units**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**
Dissolved Metals																	
Zinc-T	mg/L	2.79E-03	5.00E-04	9.16E-03	6.66E-03	5.00E-04	1.69E-02	9.92E-03	5.00E-04	8.98E-03	7.46E-03	5.00E-04	4.63E-03	2.97E-03	5.00E-04	4.01E-03	3.08E-03
Cyanides																	
Cyanate	mg/L																
Cyanide (Total)	mg/L	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03
Cyanide (WAD)	mg/L	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03
Thiocyanate (SCN)	mg/L																

Notes: Surface water samples Modelled by Knight Piesold

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

		WQ25			WQ26			WQ3			WQ4			WQ5			
Analyte	**Units**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**
Dissolved Metals																	
Aluminum-D	mg/L	2.00E-03	1.80E-02	1.66E-02	2.00E-03	2.31E-01	1.73E-01	2.00E-03	1.73E-01	8.23E-02	2.00E-03	2.35E-01	1.59E-01	2.00E-03	2.51E-01	1.73E-01	2.00E-03
Antimony-D	mg/L	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	8.00E-05	4.81E-05	5.00E-05	2.36E-04	1.59E-04	5.00E-05	2.50E-05	2.75E-05	5.00E-05
Arsenic-D	mg/L	1.00E-04	2.00E-04	2.16E-04	1.00E-04	2.55E-03	1.53E-03	1.00E-04	1.20E-03	9.01E-04	1.00E-04	1.87E-03	1.43E-03	1.00E-04	4.00E-04	4.20E-04	1.00E-04
Barium-D	mg/L	5.00E-05	8.74E-03	8.40E-03	5.00E-05	1.71E-02	1.11E-02	5.00E-05	5.35E-03	4.72E-03	5.00E-05	3.61E-03	2.87E-03	5.00E-05	5.62E-03	4.20E-03	5.00E-05
Beryllium-D	mg/L	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04
Boron-D	mg/L	1.00E-03	5.00E-04	5.00E-04	1.00E-03	1.63E-02	9.39E-03	1.00E-03	3.15E-03	1.45E-03	1.00E-03	2.00E-03	9.28E-04	1.00E-03	2.00E-03	1.19E-03	1.00E-03
Cadmium-D	mg/L	1.50E-05	1.39E-05	1.17E-05	1.50E-05	7.50E-06	7.50E-06	1.50E-05	9.07E-06	1.05E-05	1.50E-05	2.14E-04	1.33E-04	1.50E-05	2.54E-05	1.39E-05	1.50E-05
Calcium-D	mg/L	5.00E-01	9.20E+00	9.13E+00	5.00E-01	1.64E+01	1.14E+01	5.00E-01	1.42E+01	1.09E+01	5.00E-01	1.06E+01	7.49E+00	5.00E-01	8.56E+00	5.54E+00	5.00E-01
Chromium-D	mg/L	3.00E-04	1.50E-04	1.50E-04	3.00E-04	1.50E-04	1.50E-04	3.00E-04	9.00E-04	6.79E-04	3.00E-04	3.00E-04	1.92E-04	3.00E-04	5.00E-04	2.55E-04	3.00E-04
Cobalt-D	mg/L	2.00E-05	1.00E-05	1.00E-05	2.00E-05	3.00E-05	2.36E-05	2.00E-05	6.00E-05	2.85E-05	2.00E-05	3.00E-05	1.92E-05	2.00E-05	5.00E-05	3.55E-05	2.00E-05
Copper-D	mg/L	1.00E-04	2.00E-04	2.12E-04	1.00E-04	8.30E-04	5.89E-04	1.00E-04	8.00E-04	3.54E-04	1.00E-04	1.03E-03	7.13E-04	1.00E-04	6.55E-04	4.21E-04	1.00E-04
D-Hardness as CaCO3	mg/L	6.00E+00	1.97E+01	1.98E+01	6.00E+00	6.20E+01	0.00E+00	6.00E+00	4.69E+01	3.91E+01	6.00E+00	3.58E+01	2.48E+01	6.00E+00	3.19E+01	2.22E+01	6.00E+00
Iron-D	mg/L	1.00E-04	4.46E-02	4.52E-02	1.00E-04	1.20E-01	9.37E-02	1.00E-04	1.69E-01	9.46E-02	1.00E-04	1.50E-01	9.73E-02	1.00E-04	1.77E-01	1.22E-01	1.00E-04
Lead-D	mg/L	5.00E-05	5.88E-05	4.72E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.85E-05	5.00E-05	1.95E-04	9.22E-05	5.00E-05	4.42E-05	3.13E-05	5.00E-05
Lithium-D	mg/L	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03
Magnesium-D	mg/L	5.00E-01	1.24E+00	1.22E+00	5.00E-01	3.72E+00	2.51E+00	5.00E-01	3.35E+00	2.58E+00	5.00E-01	1.93E+00	1.24E+00	5.00E-01	2.53E+00	1.60E+00	5.00E-01
Manganese-D	mg/L	5.00E-05	6.35E-02	4.79E-02	5.00E-05	3.79E-03	3.38E-03	5.00E-05	7.63E-03	5.85E-03	5.00E-05	2.85E-02	1.25E-02	5.00E-05	8.17E-03	5.28E-03	5.00E-05
Mercury-D	mg/L	5.00E-06	4.38E-06	3.73E-06	5.00E-06	2.50E-06	2.50E-06	5.00E-06	4.75E-06	3.90E-06	5.00E-06	4.00E-06	3.62E-06	5.00E-06	7.10E-06	4.64E-06	5.00E-06
Molybdenum-D	mg/L	5.00E-05	7.05E-04	6.82E-04	5.00E-05	7.61E-04	5.82E-04	5.00E-05	8.30E-04	5.59E-04	5.00E-05	1.80E-04	8.99E-05	5.00E-05	2.66E-04	1.48E-04	5.00E-05
Nickel-D	mg/L	5.00E-05	7.00E-05	6.94E-05	5.00E-05	2.83E-04	2.34E-04	5.00E-05	7.51E-04	5.31E-04	5.00E-05	3.97E-04	2.99E-04	5.00E-05	2.81E-04	1.99E-04	5.00E-05
Phosphorous-D	mg/L	1.00E-02	5.00E-03	5.00E-03	1.00E-02	8.25E-03	6.85E-03	1.00E-02	5.00E-02	3.30E-02	1.00E-02	1.00E-02	6.85E-03	1.00E-02	1.00E-02	6.05E-03	1.00E-02
Potassium-D	mg/L	5.00E-01	2.50E-01	2.50E-01	5.00E-01	5.65E-01	4.23E-01	5.00E-01	6.00E-01	4.57E-01	5.00E-01	9.00E-01	5.10E-01	5.00E-01	2.50E-01	2.50E-01	5.00E-01
Selenium-D	mg/L	6.00E-04	3.00E-04	3.00E-04	1.00E-04	2.13E-04	1.42E-04	1.00E-04	3.00E-04	2.86E-04	1.00E-04	3.00E-04	2.85E-04	1.00E-04	3.00E-04	2.80E-04	1.00E-04
Silicon-D	mg/L	1.00E-02	2.46E+00	2.30E+00	1.00E-02	6.35E+00	5.17E+00	1.00E-02	9.52E+00	7.46E+00	1.00E-02	5.95E+00	5.02E+00	1.00E-02	6.34E+00	5.03E+00	1.00E-02
Silver-D	mg/L	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	1.20E-04	5.18E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05
Sodium-D	mg/L	5.00E-01	1.90E+00	1.88E+00	5.00E-01	3.65E+00	2.77E+00	5.00E-01	4.10E+00	3.17E+00	5.00E-01	4.52E+00	2.68E+00	5.00E-01	3.12E+00	2.24E+00	5.00E-01
Strontium-D	mg/L	5.00E-06	7.91E-02	7.76E-02	5.00E-06	9.91E-02	7.02E-02	5.00E-06	8.73E-02	6.84E-02	5.00E-06	5.50E-02	4.10E-02	5.00E-06	5.49E-02	3.61E-02	5.00E-06
Thallium-D	mg/L	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05
Tin-D	mg/L	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04
Titanium-D	mg/L	2.00E-04	1.00E-04	1.00E-04	2.00E-04	3.08E-03	2.22E-03	2.00E-04	3.68E-03	1.55E-03	2.00E-04	3.50E-03	1.88E-03	2.00E-04	2.70E-03	1.63E-03	2.00E-04
Uranium-D	mg/L	5.00E-05	1.38E-04	1.31E-04	5.00E-05	2.46E-04	2.02E-04	5.00E-05	2.00E-04	1.47E-04	5.00E-05	5.00E-05	3.46E-05	5.00E-05	8.00E-05	6.66E-05	5.00E-05
Vanadium-D	mg/L	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	1.59E-03	1.14E-03	5.00E-05	1.40E-04	6.99E-05	5.00E-05	3.41E-04	2.00E-04	5.00E-05
Zinc-D	mg/L	5.00E-04	5.13E-03	4.08E-03	5.00E-04	2.66E-03	2.13E-03	5.00E-04	8.86E-03	3.10E-03	5.00E-04	5.34E-02	4.42E-02	5.00E-04	4.11E-03	2.75E-03	5.00E-04

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

		WQ25			WQ26			WQ3			WQ4			WQ5			
Analyte	**Units**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**
Dissolved Metals																	
Total Metals																	
Aluminum-T	mg/L	2.00E-03	2.75E-02	2.42E-02	2.00E-03	3.18E-01	2.31E-01	2.00E-03	2.58E-01	1.47E-01	2.00E-03	8.01E-01	3.55E-01	2.00E-03	3.32E-01	2.28E-01	2.00E-03
Antimony-T	mg/L	5.00E-05	2.50E-05	2.50E-05	5.00E-05	5.65E-05	4.92E-05	5.00E-05	8.00E-05	5.59E-05	5.00E-05	2.63E-04	1.89E-04	5.00E-05	3.87E-05	2.89E-05	5.00E-05
Arsenic-T	mg/L	1.00E-04	2.00E-04	2.16E-04	1.00E-04	2.55E-03	1.59E-03	1.00E-04	1.22E-03	9.68E-04	1.00E-04	3.54E-03	2.25E-03	1.00E-04	5.00E-04	4.80E-04	1.00E-04
Barium-T	mg/L	5.00E-05	9.63E-03	9.42E-03	5.00E-05	1.71E-02	1.15E-02	5.00E-05	7.43E-03	5.47E-03	5.00E-05	8.50E-03	4.76E-03	5.00E-05	6.62E-03	4.63E-03	5.00E-05
Beryllium-T	mg/L	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04
Boron-T	mg/L	1.00E-03	5.00E-04	5.00E-04	1.00E-03	1.63E-02	9.48E-03	1.00E-03	3.45E-03	1.94E-03	1.00E-03	2.00E-03	1.43E-03	1.00E-03	3.65E-03	1.56E-03	1.00E-03
Cadmium-T	mg/L	1.50E-05	7.45E-05	5.31E-05	1.50E-05	1.30E-05	1.06E-05	1.50E-05	2.78E-05	1.30E-05	1.50E-05	2.20E-04	2.03E-04	1.50E-05	3.01E-05	2.02E-05	1.50E-05
Calcium-T	mg/L	5.00E-01	9.30E+00	9.23E+00	5.00E-01	1.74E+01	1.21E+01	5.00E-01	1.46E+01	1.12E+01	5.00E-01	1.11E+01	7.69E+00	5.00E-01	8.72E+00	5.68E+00	5.00E-01
Chromium-T	mg/L	3.00E-04	1.50E-04	1.50E-04	3.00E-04	2.48E-04	2.05E-04	3.00E-04	1.25E-03	8.56E-04	3.00E-04	5.60E-04	2.57E-04	3.00E-04	5.00E-04	2.67E-04	3.00E-04
Cobalt-T	mg/L	2.00E-05	1.75E-05	1.49E-05	2.00E-05	7.30E-05	5.59E-05	2.00E-05	1.04E-04	7.79E-05	2.00E-05	2.29E-04	9.01E-05	2.00E-05	1.31E-04	8.04E-05	2.00E-05
Copper-T	mg/L	1.00E-04	2.00E-04	2.00E-04	1.00E-04	8.30E-04	6.07E-04	1.00E-04	1.02E-03	8.62E-04	1.00E-04	1.47E-03	8.45E-04	1.00E-04	6.55E-04	4.67E-04	1.00E-04
Iron-T	mg/L	1.00E-04	8.27E-02	7.50E-02	1.00E-04	2.37E-01	1.74E-01	1.00E-04	3.20E-01	1.98E-01	1.00E-04	6.65E-01	2.67E-01	1.00E-04	3.54E-01	1.98E-01	1.00E-04
Lead-T	mg/L	5.00E-05	6.63E-05	5.21E-05	5.00E-05	8.30E-05	6.54E-05	5.00E-05	2.27E-04	1.17E-04	5.00E-05	9.69E-04	5.30E-04	5.00E-05	1.40E-04	7.41E-05	5.00E-05
Lithium-T	mg/L	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.39E-04	1.00E-03	5.00E-04	5.53E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03
Magnesium-T	mg/L	5.00E-01	1.25E+00	1.23E+00	5.00E-01	3.74E+00	2.54E+00	5.00E-01	3.35E+00	2.62E+00	5.00E-01	1.97E+00	1.28E+00	5.00E-01	2.53E+00	1.61E+00	5.00E-01
Manganese-T	mg/L	5.00E-05	6.59E-02	5.11E-02	5.00E-05	1.52E-02	1.19E-02	5.00E-05	2.72E-02	1.18E-02	5.00E-05	9.40E-02	4.06E-02	5.00E-05	2.80E-02	3.64E-02	5.00E-05
Mercury-T	mg/L	5.00E-06	4.38E-06	3.73E-06	5.00E-06	1.30E-03	7.42E-04	5.00E-06	9.15E-06	4.48E-06	5.00E-06	1.03E-05	4.91E-06	5.00E-06	7.10E-06	4.64E-06	5.00E-06
Molybdenum-T	mg/L	5.00E-05	7.18E-04	6.97E-04	5.00E-05	7.72E-04	6.03E-04	5.00E-05	8.83E-04	6.24E-04	5.00E-05	1.97E-04	1.04E-04	5.00E-05	2.77E-04	1.69E-04	5.00E-05
Nickel-T	mg/L	5.00E-05	1.00E-04	9.81E-05	5.00E-05	2.83E-04	2.41E-04	5.00E-05	8.79E-04	5.55E-04	5.00E-05	4.86E-04	3.57E-04	5.00E-05	3.53E-04	2.38E-04	5.00E-05
Phosphorous-T	mg/L	1.00E-03	2.50E-02	2.14E-02	1.00E-03	2.55E-02	1.66E-02	1.00E-03	5.30E-02	4.04E-02	1.00E-03	3.00E-02	1.23E-02	1.00E-03	1.43E-02	9.14E-03	1.00E-03
Potassium-T	mg/L	5.00E-01	2.50E-01	2.50E-01	5.00E-01	5.65E-01	4.23E-01	5.00E-01	7.00E-01	4.88E-01	5.00E-01	9.00E-01	5.73E-01	5.00E-01	2.50E-01	2.50E-01	5.00E-01
Selenium-T	mg/L	6.00E-04	3.00E-04	3.00E-04	1.00E-04	2.30E-04	1.59E-04	1.00E-04	3.00E-04	2.87E-04	1.00E-04	3.00E-04	2.85E-04	1.00E-04	3.00E-04	2.81E-04	1.00E-04
Silicon-T	mg/L	1.00E-02	2.51E+00	2.33E+00	1.00E-02	6.63E+00	5.50E+00	1.00E-02	9.53E+00	7.73E+00	1.00E-02	6.57E+00	5.38E+00	1.00E-02	6.38E+00	5.24E+00	1.00E-02
Silver-T	mg/L	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	1.27E-04	5.93E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05
Sodium-T	mg/L	5.00E-01	1.90E+00	1.92E+00	5.00E-01	3.69E+00	2.85E+00	5.00E-01	4.10E+00	3.22E+00	5.00E-01	4.52E+00	2.78E+00	5.00E-01	3.12E+00	2.28E+00	5.00E-01
Strontium-T	mg/L	5.00E-06	8.56E-02	8.45E-02	5.00E-06	9.93E-02	7.18E-02	5.00E-06	8.73E-02	7.05E-02	5.00E-06	6.23E-02	4.34E-02	5.00E-06	5.67E-02	3.74E-02	5.00E-06
Thallium-T	mg/L	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05
T-Hardness as CaCO3	mg/L	6.00E+00	2.17E+01	2.17E+01	6.00E+00	6.30E+01	6.30E+01	6.00E+00	4.72E+01	4.01E+01	6.00E+00	3.69E+01	2.55E+01	6.00E+00	3.26E+01	2.28E+01	6.00E+00
Tin-T	mg/L	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04
Titanium-T	mg/L	2.00E-04	2.75E-04	2.32E-04	2.00E-04	5.88E-03	4.00E-03	2.00E-04	6.83E-03	3.74E-03	2.00E-04	2.26E-02	7.84E-03	2.00E-04	6.89E-03	3.63E-03	2.00E-04
Uranium-T	mg/L	5.00E-05	1.38E-04	1.34E-04	5.00E-05	2.56E-04	2.13E-04	5.00E-05	2.62E-04	1.82E-04	5.00E-05	1.39E-04	6.66E-05	5.00E-05	1.16E-04	8.17E-05	5.00E-05
Vanadium-T	mg/L	5.00E-05	5.00E-05	4.37E-05	5.00E-05	1.28E-04	8.14E-05	5.00E-05	2.00E-03	1.39E-03	5.00E-05	6.30E-04	2.91E-04	5.00E-05	5.10E-04	3.13E-04	5.00E-05

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

		WQ25			WQ26			WQ3			WQ4			WQ5			
Analyte	**Units**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**
Dissolved Metals																	
Zinc-T	mg/L	5.00E-04	5.13E-03	4.08E-03	5.00E-04	2.66E-03	2.13E-03	5.00E-04	9.55E-03	3.49E-03	5.00E-04	7.01E-02	4.98E-02	5.00E-04	4.60E-03	4.41E-03	5.00E-04
Cyanides																	
Cyanate	mg/L				2.00E-01	1.00E-01	1.00E-01	2.00E-01	1.00E-01	1.00E-01	2.00E-01	1.00E-01	1.00E-01	2.00E-01	1.00E-01	1.00E-01	2.00E-01
Cyanide (Total)	mg/L	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	1.00E-02	4.25E-03	5.00E-03	9.69E-03	4.23E-03	5.00E-03	1.15E-02	4.99E-03	5.00E-03
Cyanide (WAD)	mg/L	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03
Thiocyanate (SCN)	mg/L				5.00E-01	2.50E-01	2.50E-01	5.00E-02	2.50E-01	2.67E-01	5.00E-02	4.90E-01	4.09E-01	5.00E-02	5.65E-01	4.34E-01	5.00E-02

Notes: Surface water samples Modelled by Knight Piesold

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

		WQ6		WQ7			WQ8			WQ9		
Analyte	**Units**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**
Dissolved Metals												
Aluminum-D	mg/L	2.02E-01	1.13E-01	2.00E-03	1.97E-01	1.04E-01	2.00E-03	1.21E-02	6.12E-03	2.00E-03	5.60E-02	2.64E-02
Antimony-D	mg/L	6.35E-05	4.35E-05	5.00E-05	5.00E-05	9.37E-05	5.00E-05	2.88E-05	2.88E-05	5.00E-05	5.10E-05	3.19E-05
Arsenic-D	mg/L	7.00E-04	5.48E-04	1.00E-04	5.00E-04	3.84E-04	1.00E-04	5.30E-04	5.26E-04	1.00E-04	6.00E-04	5.01E-04
Barium-D	mg/L	6.85E-03	5.55E-03	5.00E-05	9.16E-03	7.24E-03	5.00E-05	7.36E-03	6.40E-03	5.00E-05	8.14E-03	7.18E-03
Beryllium-D	mg/L	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05
Boron-D	mg/L	1.00E-03	7.02E-04	1.00E-03	2.00E-03	1.54E-03	1.00E-03	3.15E-03	1.57E-03	1.00E-03	2.00E-03	9.04E-04
Cadmium-D	mg/L	2.11E-05	1.10E-05	1.50E-05	2.25E-05	1.88E-05	1.50E-05	7.50E-06	7.50E-06	1.50E-05	2.39E-05	1.38E-05
Calcium-D	mg/L	7.78E+00	5.47E+00	5.00E-01	1.97E+01	1.26E+01	5.00E-01	2.42E+01	2.10E+01	5.00E-01	2.30E+01	1.88E+01
Chromium-D	mg/L	3.35E-04	1.91E-04	3.00E-04	4.00E-04	2.28E-04	3.00E-04	1.50E-04	1.50E-04	3.00E-04	1.50E-04	1.50E-04
Cobalt-D	mg/L	4.35E-05	2.32E-05	2.00E-05	8.15E-05	4.58E-05	2.00E-05	3.15E-05	1.89E-05	2.00E-05	4.10E-05	2.93E-05
Copper-D	mg/L	6.00E-04	3.40E-04	1.00E-04	9.30E-04	3.15E-03	1.00E-04	6.45E-04	4.95E-04	1.00E-04	7.10E-04	4.41E-04
D-Hardness as CaCO3	mg/L	2.30E+01	1.74E+01	6.00E+00	6.18E+01	4.51E+01	6.00E+00	8.00E+01	7.09E+01	6.00E+00	7.47E+01	6.45E+01
Iron-D	mg/L	1.15E-01	8.33E-02	1.00E-04	1.51E-01	1.16E-01	1.00E-04	5.68E-02	4.81E-02	1.00E-04	1.70E-01	1.03E-01
Lead-D	mg/L	6.40E-05	4.76E-05	5.00E-05	9.15E-05	1.00E-04	5.00E-05	5.15E-05	3.51E-05	5.00E-05	2.50E-05	3.37E-05
Lithium-D	mg/L	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04
Magnesium-D	mg/L	1.36E+00	9.38E-01	5.00E-01	4.25E+00	2.88E+00	5.00E-01	5.54E+00	4.84E+00	5.00E-01	5.15E+00	4.25E+00
Manganese-D	mg/L	7.66E-03	5.18E-03	5.00E-05	2.45E-02	1.57E-02	5.00E-05	2.30E-02	1.39E-02	5.00E-05	3.64E-02	2.08E-02
Mercury-D	mg/L	4.00E-06	3.32E-06	5.00E-06	4.00E-06	3.90E-06	5.00E-06	4.00E-06	3.37E-06	5.00E-06	4.00E-06	3.39E-06
Molybdenum-D	mg/L	5.48E-04	3.81E-04	5.00E-05	7.71E-04	5.10E-04	5.00E-05	5.95E-04	5.12E-04	5.00E-05	6.23E-04	5.43E-04
Nickel-D	mg/L	3.84E-04	2.36E-04	5.00E-05	5.01E-04	8.53E-04	5.00E-05	2.85E-04	2.28E-04	5.00E-05	3.32E-04	2.50E-04
Phosphorous-D	mg/L	1.00E-02	5.93E-03	1.00E-02	2.00E-02	1.21E+00	1.00E-02	2.00E-02	1.30E-02	1.00E-02	2.00E-02	1.05E-02
Potassium-D	mg/L	3.37E-01	2.92E-01	5.00E-01	8.20E-01	3.53E+00	5.00E-01	1.00E+00	8.48E-01	5.00E-01	9.00E-01	8.09E-01
Selenium-D	mg/L	3.00E-04	2.83E-04	1.00E-04	3.00E-04	3.15E-04	1.00E-04	3.00E-04	2.86E-04	1.00E-04	3.00E-04	2.86E-04
Silicon-D	mg/L	6.16E+00	5.03E+00	1.00E-02	6.67E+00	5.64E+00	1.00E-02	5.27E+00	4.24E+00	1.00E-02	5.43E+00	4.68E+00
Silver-D	mg/L	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05
Sodium-D	mg/L	2.84E+00	2.09E+00	5.00E-01	4.20E+00	1.08E+01	5.00E-01	4.10E+00	3.61E+00	5.00E-01	3.91E+00	3.31E+00
Strontium-D	mg/L	5.33E-02	4.08E-02	5.00E-06	1.07E-01	7.31E-02	5.00E-06	1.10E-01	9.95E-02	5.00E-06	1.10E-01	9.39E-02
Thallium-D	mg/L	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05
Tin-D	mg/L	5.00E-05	5.00E-05	1.00E-04	5.00E-05	1.55E-04	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	6.14E-05
Titanium-D	mg/L	2.57E-03	1.44E-03	2.00E-04	2.52E-03	1.31E-03	2.00E-04	4.15E-04	2.31E-04	2.00E-04	1.21E-03	6.14E-04
Uranium-D	mg/L	2.20E-04	1.69E-04	5.00E-05	2.80E-04	1.73E-04	5.00E-05	1.00E-04	8.62E-05	5.00E-05	1.31E-04	1.06E-04
Vanadium-D	mg/L	1.68E-04	7.95E-05	5.00E-05	5.11E-04	2.63E-04	5.00E-05	2.52E-04	1.29E-04	5.00E-05	3.72E-04	1.94E-04
Zinc-D	mg/L	4.48E-03	3.78E-03	5.00E-04	1.53E-02	1.36E-02	5.00E-04	4.92E-03	2.29E-03	5.00E-04	3.90E-03	1.92E-03

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

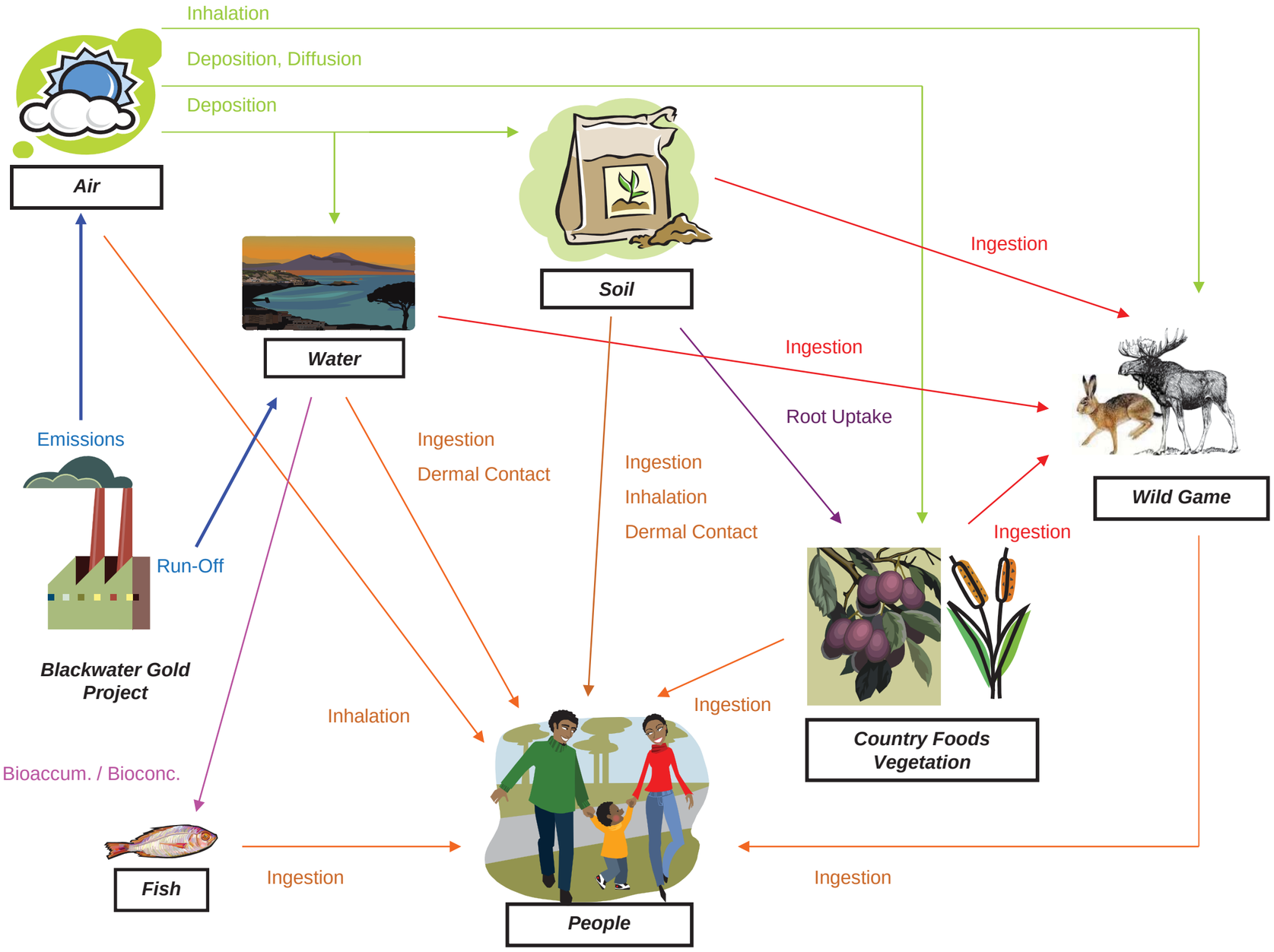
		WQ6		WQ7			WQ8			WQ9		
Analyte	**Units**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**
Dissolved Metals												
Total Metals												
Aluminum-T	mg/L	3.66E-01	1.80E-01	2.00E-03	7.84E-01	3.14E-01	2.00E-03	9.39E-02	3.65E-02	2.00E-03	1.86E-01	8.90E-02
Antimony-T	mg/L	7.00E-05	4.98E-05	5.00E-05	6.00E-05	9.73E-05	5.00E-05	5.00E-05	2.97E-05	5.00E-05	5.05E-05	3.40E-05
Arsenic-T	mg/L	8.35E-04	6.74E-04	1.00E-04	8.10E-04	5.54E-04	1.00E-04	6.45E-04	5.63E-04	1.00E-04	7.00E-04	5.53E-04
Barium-T	mg/L	9.48E-03	6.29E-03	5.00E-05	1.38E-02	9.60E-03	5.00E-05	8.95E-03	7.03E-03	5.00E-05	9.17E-03	7.87E-03
Beryllium-T	mg/L	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.38E-05	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	5.00E-05
Boron-T	mg/L	1.35E-03	1.08E-03	1.00E-03	2.40E-03	1.79E-03	1.00E-03	4.15E-03	1.87E-03	1.00E-03	2.00E-03	1.29E-03
Cadmium-T	mg/L	3.14E-05	1.43E-05	1.50E-05	5.91E-05	2.62E-05	1.50E-05	1.72E-05	9.55E-06	1.50E-05	2.72E-05	1.42E-05
Calcium-T	mg/L	7.78E+00	5.60E+00	5.00E-01	1.91E+01	1.26E+01	5.00E-01	2.42E+01	2.15E+01	5.00E-01	2.30E+01	1.94E+01
Chromium-T	mg/L	4.35E-04	2.19E-04	3.00E-04	1.04E-03	4.70E-04	3.00E-04	1.50E-04	1.58E-04	3.00E-04	3.00E-04	1.85E-04
Cobalt-T	mg/L	7.40E-05	3.57E-05	2.00E-05	3.32E-04	1.38E-04	2.00E-05	7.00E-05	3.19E-05	2.00E-05	8.00E-05	5.21E-05
Copper-T	mg/L	6.70E-04	3.96E-04	1.00E-04	1.43E-03	3.22E-03	1.00E-04	1.26E-03	7.64E-04	1.00E-04	7.00E-04	4.59E-04
Iron-T	mg/L	3.68E-01	1.69E-01	1.00E-04	8.03E-01	4.02E-01	1.00E-04	2.02E-01	9.46E-02	1.00E-04	2.94E-01	1.99E-01
Lead-T	mg/L	2.08E-04	1.03E-04	5.00E-05	4.42E-04	1.83E-04	5.00E-05	9.60E-05	8.82E-05	5.00E-05	7.10E-05	3.73E-05
Lithium-T	mg/L	5.00E-04	5.00E-04	1.00E-03	5.00E-04	6.52E-04	1.00E-03	5.00E-04	6.56E-04	1.00E-03	6.00E-04	7.37E-04
Magnesium-T	mg/L	1.36E+00	9.55E-01	5.00E-01	4.25E+00	4.19E+00	5.00E-01	5.54E+00	4.96E+00	5.00E-01	5.15E+00	4.36E+00
Manganese-T	mg/L	2.27E-02	1.08E-02	5.00E-05	5.85E-02	3.10E-02	5.00E-05	8.04E-02	3.30E-02	5.00E-05	4.28E-02	2.94E-02
Mercury-T	mg/L	7.40E-06	4.50E-06	5.00E-06	6.40E-06	6.32E-06	5.00E-06	4.00E-06	3.37E-06	5.00E-06	4.00E-06	3.37E-06
Molybdenum-T	mg/L	5.61E-04	4.16E-04	5.00E-05	8.42E-04	5.68E-04	5.00E-05	6.35E-04	5.57E-04	5.00E-05	6.70E-04	5.89E-04
Nickel-T	mg/L	4.65E-04	2.77E-04	5.00E-05	1.14E-03	4.72E-04	5.00E-05	4.50E-04	2.94E-04	5.00E-05	4.51E-04	2.91E-04
Phosphorous-T	mg/L	2.00E-02	9.83E-03	1.00E-03	4.00E-02	1.98E-01	1.00E-03	5.00E-02	2.03E-02	1.00E-03	4.00E-02	1.56E-02
Potassium-T	mg/L	3.72E-01	3.06E-01	5.00E-01	1.06E+00	1.62E+00	5.00E-01	1.02E+00	8.94E-01	5.00E-01	9.00E-01	8.45E-01
Selenium-T	mg/L	3.00E-04	2.84E-04	1.00E-04	3.00E-04	3.17E-04	1.00E-04	3.00E-04	2.87E-04	1.00E-04	3.00E-04	2.87E-04
Silicon-T	mg/L	6.16E+00	5.24E+00	1.00E-02	7.10E+00	5.99E+00	1.00E-02	5.62E+00	4.51E+00	1.00E-02	5.85E+00	4.91E+00
Silver-T	mg/L	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05
Sodium-T	mg/L	2.84E+00	2.12E+00	5.00E-01	4.20E+00	1.07E+01	5.00E-01	4.12E+00	3.66E+00	5.00E-01	4.00E+00	3.38E+00
Strontium-T	mg/L	5.38E-02	4.19E-02	5.00E-06	1.10E-01	7.68E-02	5.00E-06	1.09E-01	1.02E-01	5.00E-06	1.13E-01	9.70E-02
Thallium-T	mg/L	2.50E-05	2.98E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05	5.00E-05	2.50E-05	2.50E-05
T-Hardness as CaCO3	mg/L	2.31E+01	1.78E+01	6.00E+00	6.38E+01	4.88E+01	6.00E+00	8.10E+01	7.30E+01	6.00E+00	7.54E+01	6.63E+01
Tin-T	mg/L	5.00E-05	5.00E-05	1.00E-04	5.00E-05	2.06E-04	1.00E-04	5.00E-05	5.00E-05	1.00E-04	5.00E-05	6.11E-05
Titanium-T	mg/L	6.17E-03	2.85E-03	2.00E-04	2.49E-02	9.64E-03	2.00E-04	4.26E-03	1.62E-03	2.00E-04	6.42E-03	3.24E-03
Uranium-T	mg/L	2.70E-04	1.93E-04	5.00E-05	2.85E-04	2.13E-04	5.00E-05	1.03E-04	9.30E-05	5.00E-05	1.41E-04	1.15E-04
Vanadium-T	mg/L	4.00E-04	1.66E-04	5.00E-05	1.87E-03	8.28E-04	5.00E-05	4.15E-04	2.03E-04	5.00E-05	7.00E-04	3.39E-04

Table 9.2.2A-3: Surface Water Concentrations (mg/L)

		WQ6		WQ7			WQ8			WQ9		
Analyte	**Units**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**	**Minimum**	**95th Percentile**	**95th UCL**
Dissolved Metals												
Zinc-T	mg/L	7.21E-03	4.27E-03	5.00E-04	2.45E-02	1.68E-02	5.00E-04	6.15E-03	2.96E-03	5.00E-04	3.90E-03	1.99E-03
Cyanides												
Cyanate	mg/L	1.00E-01	1.00E-01	2.00E-01	1.00E-01	1.00E-01	2.00E-01	1.00E-01	1.00E-01	2.00E-01	1.00E-01	1.00E-01
Cyanide (Total)	mg/L	8.95E-03	4.11E-03	5.00E-03	1.04E-02	4.29E-03	5.00E-03	5.24E-03	3.03E-03	5.00E-03	8.30E-03	4.09E-03
Cyanide (WAD)	mg/L	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03	5.00E-03	2.50E-03	2.50E-03
Thiocyanate (SCN)	mg/L	2.50E-01	2.67E-01	5.00E-02	7.03E-01	4.85E-01	5.00E-02	2.50E-01	2.66E-01	5.00E-02	5.85E-01	4.19E-01

Notes: Surface water samples Modelled by Knight Piesold

Annex 9.2.2B
Site Conceptual Exposure Model



CLIENT: newgold		DWN BY: MY	PROJECT: Blackwater Gold Project	DATE: November 2013
		CHK'D BY: JK		PROJECT NO: VE52277
AMEC Environment & Infrastructure 4445 Lougheed, Suite 600, Burnaby, B.C., V5C 0E4 Tel. 604-294-3811 Fax 604-294-4664	amec	DATUM: N/A PROJECTION: N/A SCALE: N/A	TITLE: Human Health Conceptual Site Exposure Model	REV. NO.: A FIGURE No. 1

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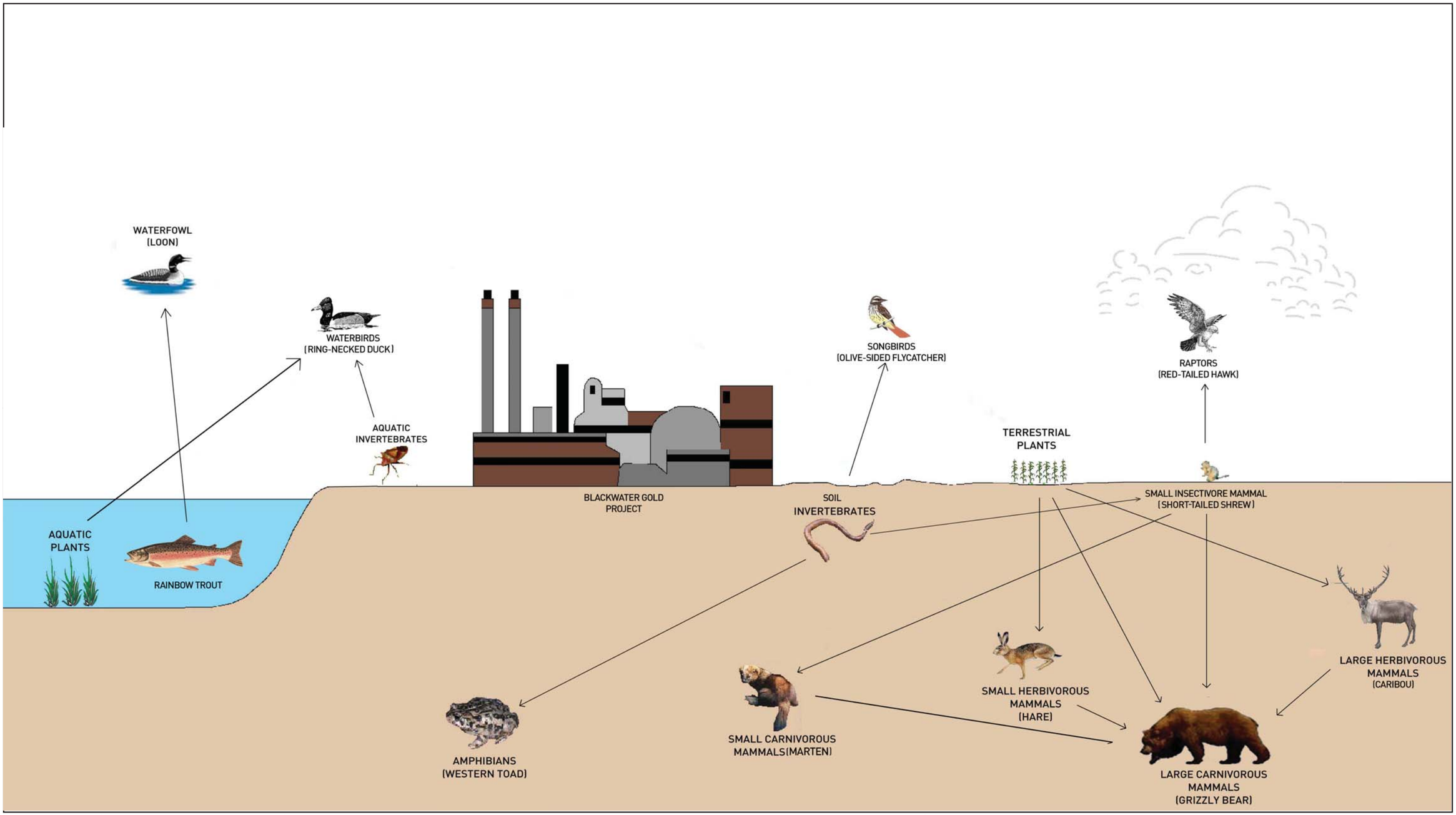

Notes: A. Ingestion of soil (Not Shown) B. Ingestion of Water (Not shown) C. Direct Contact With Soil (Not Shown) D. Direct Contact with Water (Not Shown) E. Inhalation of Air (Not Shown) F. Inhalation of Dust (Not Shown)

CLIENT: newgold

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DWN BY:	MY
CHK'D BY:	JK
DATUM:	N/A
PROJECTION:	N/A
SCALE:	N/A

PROJECT: Blackwater Gold Project

TITLE: Ecological Conceptual Site Exposure Model

DATE:	November 2013
PROJECT NO:	VE52277
REV. NO.:	A
FIGURE No.	2

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Annex 9.2.2C
Toxicological Profiles

1.0 HUMAN HEALTH

1.1 Arsenic

Arsenic is a natural element that is widely distributed throughout the earth's crust. It is often found naturally in groundwater, through erosion and weathering of soils, minerals, and ores. Arsenic compounds are used commercially and industrially in the manufacture of a variety of products and may enter drinking water sources directly from industrial effluents and indirectly from atmospheric deposition (Health Canada 2006).

Trivalent (As^{+3}) arsenic compounds are generally more toxic than pentavalent (As^{+5}) compounds. Also, the more water soluble forms of arsenic compounds are usually more toxic and more likely to have systemic effects than the less soluble compounds which are more likely to cause chronic pulmonary effects if inhaled.

Arsine gas (AsH_3), one of the most toxic inorganic arsenic compounds causes acute effects like nausea, vomiting, shortness of breath and haemolytic reactions. It should be noted that laboratory animals are generally less sensitive than humans to the toxic effects of inorganic arsenic. In addition, the critical effects appear to be immunosuppression and hepato-renal dysfunction in rodents whereas in humans, the skin, vascular system, and peripheral nervous system are the primary target organs (Amdur *et al.,* 1991).

The skin is the most critical organ when it comes to toxic effects. For chronic exposure to arsenic in drinking water, skin lesions are common and there are many documented cases of skin cancer related to the consumption of arsenic in the drinking water (Amdur *et al.*, 1991). Sensory loss of the peripheral nervous system is one the most common effects of acute exposure to arsenic. Liver injury is more characteristic of chronic exposure which manifests as jaundice and may progress to cirrhosis and liver cancer. US EPA IRIS (2013) classified this chemical as Group A, known human carcinogen. The cancer weight of evidence classification is based on all routes of exposure.

US EPA IRIS (2013) lists an oral RfD of 0.0003 mg/kg/d based on the prevalence of skin cancer and black-foot disease in an exposed population study (Tseng 1977).

California EPA (2013) lists a chronic inhalation Reference Exposure Level of 0.00015 mg/m³based on epidemiological studies of lung cancer on smelter workers.

Health Canada (2010) lists an oral cancer slope factor of 1.8 $(mg/kg/d)^{-1}$and an inhalation unit risk of 6.4 mg/m^3. The oral cancer slope factor and inhalation unit risk were used for assessing the risks. A summary of the toxicological reference values is presented in **Table 9.2C-1**.

Table 9.2C-1. Toxicological Reference Values for Arsenic

	Tolerable Daily Intake			Cancer Slope Factor		Unit Risk	Relative Absorption Factor		
	mg/kg-day		mg/m^3	1/(mg/kg-day)		1/(mg/m^3)			
Agency	**Oral**	**Dermal**	**Chronic Inhalation**	**Oral**	**Dermal**	**Inhalation**	**Ingestion**	**Dermal**	**Inhalation**
CalEPA			0.000015						1
Health Canada				1.8	1.8	6.4		0.03	
RAIS							0.95		
US EPA IRIS	0.0003								
TRV for Assessment	**0.0003**	**0.0003***	**0.000015**	**1.8**	**1.8***	**6.4**	**0.95**	**0.03**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System; RAIS – Risk Assessment Information System.

Literature Cited

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California Environmental Protection Agency (CalEPA). 2013. Toxicity Criteria Database. Available at http://www.oehha.ca.gov/risk/chemicalDB/ (accessed April 2013).

Health Canada. 2006. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document. Arsenic. Water Quality and Health Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario.

Health Canada. 2010. Federal contaminated site risk assessment in Canada. Part II: Health Canada toxicological reference values (TRVs). Cat. H46-2/04-368E.

Risk Assessment Information System (RAIS). 2011. Oak Ridge National Laboratory Risk Assessment Information System. Available at http://risk.lsd.ornl.gov/. Accessed: August 2013.

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US EPA. IRIS (Integrated Risk Information System) 2013. A-Z List of Substances. Available at http://www.epa.gov/iris/. Accessed August 2013.

1.2 Benzene

Benzene is absorbed into the body via ingestion, inhalation and skin application. Experimental data indicate that animals can absorb up to 95% of oral doses and that

humans can absorb up to 80% of inhaled benzene (after 5 minutes of exposure) (Sabourin *et al.* 1987; Srobova *et al.* 1950). Humans may absorb benzene vapours through the skin as well as the lungs although it is minimal compared to the total dose absorbed by the inhalation and oral routes (Susten 1985).

Numerous studies indicate that the metabolism of benzene is required for its toxicity (Kalf *et al.* 1987). The liver is the main site for the metabolism of benzene where it is biotransformed by enzymes (e.g., cytochrome P450) into benzene oxide and other metabolites which will cause toxicity through oxidative damage or binding to cellular macromolecules.

Breathing very high concentrations (i.e., 10,000 to 20,000 ppm) of benzene can result in death, while lower doses (up to 400 ppm) can cause drowsiness, dizziness, rapid heart rate, headaches, tremors, confusion, and unconsciousness. Oral ingestion of high concentrations (up to 400 ppm) of benzene can cause vomiting, irritation of the stomach, dizziness, sleepiness, convulsions, rapid heart rate, and death (ATSDR 2007).

The major target organ of long-term exposures to benzene is the blood. Benzene causes harmful effects on the bone marrow such as cell death and can cause a decrease in the number of red blood cells leading to anemia. A continuation of studies for 6 days to 23 weeks at 300 ppm showed continued decreases in numbers of mature B- and T-lymphocytes produced in the bone marrow, spleen, and thymus (Rozen and Snyder 1985). Abnormalities of humoral and cell-mediated immune responses following benzene exposure are presumably caused by a defect in the lymphoid stem cell precursors of both T- and B-lymphocytes. Bone marrow cellularity increased three-fold, and the number of thymic T-cells increased 15-fold in benzene-exposed mice between the 6^{th} and the 30^{th} exposure. It can also cause excessive bleeding and can affect the immune system, increasing the chance for infection (ATSDR 2007).

Benzene does produce developmental effects (i.e., fetal toxicity, but not malformations) in the offspring of treated animals. However, these effects are observed mainly at maternally toxic doses (Nawrot and Staples 1979; Seidenberg *et al.* 1986; Keller and Snyder 1988).

Benzene is carcinogenic in humans and animals by inhalation and in animals by the oral route of exposure. Occupational exposure to benzene has been associated mainly with increased incidences of myeloblastic or erythroblastic leukemias and myeloid and lymphoid leukemias among workers (Aksoy 1989).

A summary of the toxicological reference values used in this assessment is shown in **Table 9.2C-2.**

Table 9.2C-2. Toxicological Reference Values for Benzene

	Tolerable Daily Intake			Cancer Slope Factor		Unit Risk	Relative Absorption Factor		
	mg/kg-day		mg/m^3	1/(mg/kg-day)		1/(mg/m^3)			
Agency	**Oral**	**Dermal**	**Chronic Inhalation**	**Oral**	**Dermal**	**Inhalation**	**Ingestion**	**Dermal**	**Inhalation**
ATSDR	0.0005		0.001						
CalEPA							1		1
Health Canada				0.0834		0.0033		0.03	
TRV for Assessment	**0.0005**	**0.0005***	**0.001**	**0.0834**	**0.0834***	**0.0033**	**1**	**0.03**	**1**

Notes: * - Oral TRV adopted as dermal TRV.; ATSDR – Agency for Toxic Substances and Disease Registry; CalEPA – California Environmental Protection Agency

Literature Cited

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Benzene (Update). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service

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Rozen, M.G. and C.A. Snyder. 1985. Protracted Exposure of C57BL/6 Mice to 300 ppm Benzene Depresses B- and T- lymphocytes Numbers and Mitogen Responses. Evidence for Thymic and Bone Marrow Proliferation in Response to the Exposures. Toxicol. Lett. 20(3): 13-26.

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Srbova, J., J. Teisinger and S. Skramovsky. 1950. Absorption and Elimination of Inhaled Benzene in Man. Arch Ind Hyg Occup Med, 2: 1-8.

Susten, A.S., B.L. Dames, J.R. Burg, R.W. Niemeler. 1985. Percutaneous Penetration of Benzene in Hairless Mice: An Estimate of Dermal Absorption During Tire-building Operations. Am J Ind Med, 7: 323-335.

1.3 Cadmium

Cadmium is not at present believed to be an essential nutrient for animals or humans. The main source of cadmium intake is food. In the population in general, most of the cadmium exposure is through food and water that is contaminated by cadmium. This is especially true for food ingestion because cadmium is more readily absorbed by vegetation than other metals. Cadmium is still a relatively rare element. It is uniformly distributed in the Earth's crust, where it is generally estimated to be present at an average concentration of between 0.15 and 0.2 mg/kg. (Fleischer *et al*. 1974).

An oral RfD of 0.001 mg/kg/day for cadmium, recommended by Health Canada (2010), was used as the exposure limits for the current assessment. The RfD value is based on kidney effects observed from occupational exposures in humans. TCEQ recommends an RfC of 0.00001 mg/m^3 for cadmium for human health. No studies are referenced.

Inhalation of high levels of cadmium refinery dust may severely damage the lungs and can cause death. However, the studies linking carcinogenicity to cadmium inhalation exposure were deemed inconclusive because of too many confounding factors, like cigarette smoking and the presence of other carcinogens in the ambient air. Acute exposure may induce flu-like symptoms called metal fever (ATSDR, 1999).

A list of the toxicological reference values are presented in **Table 9.2C-3**.

Table 9.2C-3. Toxicological Reference Values for Cadmium

	Tolerable Daily Intake			Unit Risk	Relative Absorption Factor		
	mg/kg-day		mg/m^3	1/(mg/m^3)			
Agency	**Oral**	**Dermal**	**Chronic Inhalation**	**Inhalation**	**Ingestion**	**Dermal**	**Inhalation**
CalEPA							1
Health Canada	0.001			9.8		0.01	
MDEQ					0.5		
TCEQ			0.00001				
TRV for Assessment	**0.001**	**0.001***	**0.00001**	**9.8**	**0.5**	**0.01**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; MDEQ- Michigan Department of Environmental Quality.
TCEQ – Texas Commission on Environmental Quality.

Literature Cited

Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological Profile for Cadmium. US Department of Health and Human Services. Public Health Service.

California Environmental Protection Agency (CalEPA). 2013. Toxicity Criteria Database. Available at http://www.oehha.ca.gov/risk/chemicalDB/ (accessed April 2013).

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Health Canada. 2010. Federal contaminated site risk assessment in Canada. Part II: Health Canada toxicological reference values (TRVs). Cat. H46-2/04-368E.

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US EPA. IRIS (Integrated Risk Information System) 1994. A-Z List of Substances. Available at http://www.epa.gov/iris/. Accessed August 2013.

1.4 Cyanide

Cyanides are used in a number of chemical processes including fumigation, case hardening of iron and steel, electroplating and concentration of ores. Cyanide is released into air mainly as hydrogen cyanide gas and, to a lesser extent, as particulate cyanide. Hydrogen cyanide is a highly volatile liquid used to prepare acrylonitrile which is used in the production of acrylic fibers, synthetic rubbers and plastics.

Under certain conditions, cyanide can persist in the environment. However, under most conditions, cyanide is easily broken-down through photolytic degradation and phytoremediation. Cyanide does not accumulate in plant tissue (Ebbs *et al.* 2005)

US EPA (2005) states that there is inadequate information to assess the carcinogenic potential of cyanide. A chronic oral RfD of 0.02 mg/kg-d is listed by Health Canada (2010) and used as the oral TRV for this assessment.

The US EPA IRIS also lists an RfC of 0.0008 mg/m^3 based on thyroid enlargement, altered iodine uptake and CNS symptoms (i.e., headache, weakness, sensory changes) in workers who were exposed to HCN for 5-15 years in three electroplating factories (El Ghawabi *et al.* 1975). A list of the toxicological reference values are presented in **Table 9.2C-4**.

Table 9.2C-4. Toxicological Reference Values for Cyanide

	Tolerable Daily Intake		Tolerable Concentration	Relative Absorption Factor		
	mg/kg-day		mg/m^3			
Agency	**Oral**	**Dermal**	**Chronic Inhalation**	**Ingestion**	**Dermal**	**Inhalation**
CalEPA				1		1
Health Canada	0.02	0.02			0.1	
US EPA IRIS			0.0008			
TRV for Assessment	**0.02**	**0.02***	**0.0008**	**1**	**0.1**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System

Literature Cited

California Environmental Protection Agency (CalEPA). 2013. Toxicity Criteria Database. Available at http://www.oehha.ca.gov/risk/chemicalDB/ (accessed April 2013).

Ebbs, S., Ghosh, R., Bushey, J., Dzombak, D. 2005. Cyanide Phytoremediation: Removal From and Fate in Soil-Water-Plant Systems. Proceedings of 2005 International Phytotechnologies Conference.

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NTP (National Toxicology Program). (1993) Technical report on toxicity studies of sodium cyanide (CAS No. 143-33-9) administered in drinking water to F344/N rats and B6C3FI mice. NIH Publication 94-3386. Public Health Service, National Institutes of

Health, U.S. Department of Health and Human Services, National Toxicology Program.

U.S. EPA (Environmental Protection Agency). (2005) Guidelines for carcinogen risk assessment. Risk Assessment Forum, Washington, DC; EPA/630/P-03/001B. Available online at http://www.epa.gov/iris/backgrd.html

US EPA. IRIS (Integrated Risk Information System) 2013. A-Z List of Substances. Available at http://www.epa.gov/iris/. Accessed August 2013.

1.5 Ethylbenzene

Ethylbenzene is widely distributed in the environment. It is primarily used for the production of styrene. Ethylbenzene is also used as a solvent and in the manufacture of several organic compounds. Routine human activities, such as driving automobiles, boats, or aircraft, or using gasoline powered tools and equipment, release ethylbenzene to the environment. Environmental and background levels of ethylbenzene are generally small and therefore, have minimal impact on public health. Ethylbenzene is not considered highly persistent in the environment (ATSDR 2007).

An oral RfD of 0.1 mg/kg/day has been developed by US EPA IRIS (1991) based on a rat study by Wolf *et al.* (1956) where the endpoints were growth, mortality, appearance and behaviour, hematologic findings, terminal concentration of urea nitrogen in the blood, final average organ and body weights, histopathologic findings, and bone marrow counts. The obtained LOAEL of 408 mg/kg/day was associated with histopathologic changes in liver and kidney. An uncertainty factor of 1,000 reflected intraspecies and interspecies variability, and an extra factor of 10 was added for extrapolation of a subchronic effect level to a chronic level. This RfD has been adopted by Health Canada (2010) as the oral TRV.

US EPA IRIS (1991) derived an inhalation reference concentration (RfC) of 1 mg/m^3 based on an inhalation developmental toxicity study on rats and rabbits by Andrew *et al.* (1981) and Hardin *et al.* (1981). An uncertainty factor of 300 reflected a factor of 10 to protect unusually sensitive individuals, 3 to adjust for interspecies conversion and 10 to adjust for the absence of multigenerational reproductive and chronic studies. Health Canada (2010) also lists an inhalation tolerable concentration of 1 mg/m^3 which was used in this assessment.

A summary of the toxicological reference values is presented in **Table 9.2C-5.**

Table 9.2C-5. Toxicological Reference Values for Ethylbenzene

Agency	Tolerable Daily Intake				Relative Absorption Factor		
	mg/kg-day		mg/m^3				
	Oral	Dermal	Acute Inhalation	Chronic Inhalation	Ingestion	Dermal	Inhalation
ATSDR				0.3			
CalEPA					1		1
Health Canada	0.1			1		0.03	
US EPA IRIS	0.1			1			
US EPA (AEGL)			143				
TRV for Assessment	**0.1**	**0.1***	**143**	**1**	**0.97**	**0.03**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
ATSDR – Agency for Toxic Substances and Disease Registry; CalEPA – California Environmental Protection Agency; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System; US EPA (AEGL) - United States Environmental Protection Agency Acute Exposure Guideline Levels.

Literature Cited

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1.6 Mercury

Mercury and mercury containing compounds are widely used in fluorescent lamps, extraction of gold and silver from ores, batteries, dental amalgams, pulp and paper manufacturing, and lubricants. Acute exposure to elemental mercury can lead to shortness of breath within 24 hours and can lead to death from respiratory failure. Central nervous system (CNS) effects such as tremors or increased excitability are sometimes seen in acute exposures. Long term CNS effects can include nervousness, irritability, shortness of breath, and lack of ambition (Cal EPA 2008). US EPA lists mercury as a Class D- not classifiable as to human carcinogenicity.

Fawer *et al.* (1983) measured intention tremors in 26 male workers exposed to low levels of mercury vapours in various occupations exposed for an average of 15 years. The measures of tremors were significantly increased in exposed workers compared to controls.

Piikivi and Tolonen (1989a) used EEGs to study long term effects of long term mercury exposure in 41 chloralkali workers exposed for a mean of 15.6 years. Exposed workers (15%) were found to have significantly slower and attenuated brain activity compared to the controls and these effects correlated with cortical mercury content. Piikivi and Hanninen (1989b) also studied the subjective symptoms and psychological performances in 60 chloralkali workers exposed to mercury vapour for a mean of 13.7 years and found a statistically significant increase in subjective measures of memory disturbance and sleep disorders, as well as the workers reported more anger, fatigue and confusion.

The US EPA considers the RfC to be analogous to the RfD and thus it recommends an oral RfD of 0.0003 mg/kg-d based on neurological effects observed in occupational inhalation studies in humans. CalEPA and US EPA IRIS recommend a RfC of 0.0003 mg/m^3 based on the same neurological effects. Health Canada (2010) also provides an oral tolerable daily intake of 0.0003 mg/kg-d. A list of the toxicological reference values are presented in **Table 9.2C-6**.

Table 9.2C-6. Toxicological Reference Values for Mercury

	Tolerable Daily Intake		Tolerable Concentration	Relative Absorption Factor		
	mg/kg-day		mg/m^3	Percentage		
Agency	**Oral**	**Dermal**	**Chronic Inhalation**	**Ingestion**	**Dermal**	**Inhalation**
CalEPA			0.0003			1
Health Canada	0.0003				1.0	
US EPA IRIS	0.0003		0.0003			
TCEQ				0.07		
TRV for Assessment	**0.0003**	**0.0003***	**0.0003**	**0.07**	**1.0**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System; TCEQ – Texas Commission of Environmental Quality

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US EPA. IRIS (Integrated Risk Information System) 1994. A-Z List of Substances. Available at http://www.epa.gov/iris/. Accessed October 2013.

1.7 Molybdenum

Water-soluble molybdenum compounds are readily taken up through the lungs and gastrointestinal tract; but insoluble compounds are not. Following absorption, molybdenum is distributed throughout the body with the highest levels generally found in the liver, kidneys, spleen, and bone (Wennig and Kirsch, 1988).

There is no information available on the acute or subchronic oral toxicity of molybdenum in humans. In studies conducted in a region of Armenia where levels of molybdenum in the soil are high (77 mg Mo/kg), 18% of the adults examined in one town and 31% of those in another town were found to have elevated concentrations of uric acid in the blood and urine, increased blood xanthine oxidase activity, and gout-like symptoms such as arthralgia, articular deformities, erythema, and edema (Koval'skiy *et al*., 1961).

Excessive intake of molybdenum causes a physiological copper deficiency, and conversely, in cases of inadequate dietary intake of copper, molybdenum toxicity may occur at lower exposure levels.

The chronic RfD from Health Canada for molybdenum and molybdenum compounds is 0.023 mg/kg/day based on the toddler ingestion TRV. The recommended RfC from TCEQ (2011) is 0.005 mg/m^3. A list of the toxicological reference values are presented in Table 9.2C-7.

Table 9.2C- 7. Toxicological Reference Values for Molybdenum

	Tolerable Daily Intake		Tolerable Concentration	Relative Absorption Factor		
	mg/kg-day		mg/m^3	Percentage		
Agency	**Oral**	**Dermal**	**Chronic Inhalation**	**Ingestion**	**Dermal**	**Inhalation**
CalEPA						1
Health Canada	0.023				0.01	
RAIS				1		
TCEQ			0.005			
TRV for Assessment	**0.023**	**0.023***	**0.005**	**1**	**0.01**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; RAIS – Risk Assessment Information System; TCEQ – Texas Commission of Environmental Quality

Literature Cited

California Environmental Protection Agency (CalEPA). 2013. Toxicity Criteria Database. Available at http://www.oehha.ca.gov/risk/chemicalDB/ (accessed April 2013).

Health Canada. 2010. Federal contaminated site risk assessment in Canada. Part II: Health Canada toxicological reference values (TRVs). Cat. H46-2/04-368E.

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1.8 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) include hundreds of different chemicals that commonly occur as mixtures in the environment. They typically result from combustion processes, especially from diesel fuel, coke, and natural gas. They are composed of multiple aromatic carbon rings.

Because they often occur in the environment as these mixtures, there is limited toxicological data on PAH mixtures. Therefore, individual PAHs were typically evaluated as separate chemicals in the past for risk characterization without consideration of their potential for interactive effects.

Several epidemiologic studies have shown increased mortality due to lung cancer in humans exposed to coke oven emissions, roofing-tar emissions, and cigarette smoke. Each of these mixtures contains benzo(a)pyrene, chrysene, benzo(a)anthracene, benzo(b)fluoranthene, and dibenz(a,h)anthracene as well as other potentially carcinogenic PAHs and other carcinogenic and potentially carcinogenic chemicals, tumour promoters, initiators, and co-carcinogens such as nitrosamines, coal tar pitch, and creosote (ATSDR 1995). Multiple studies have shown that individual or mixture of those carcinogenic PAHs will induce tumours in laboratory animals by oral, inhalation and dermal pathways.

Of the myriad of PAHs, several have been classified as carcinogens. **Table 9.2C-8** lists the PAHs that were identified as COPCs and which various agencies have identified them as being carcinogens. Table 9.2C-17 list the toxicity equivalency factors (TEF) in terms of Benz(a)pyrene equivalent. They are able to initiate the formation of tumours after biotransformation by CY P450. This process lead to the formation of epoxide groups that will interact with DNA by forming adducts.

Table 9.2C-8. Carcinogenic Polycyclic Aromatic Hydrocarbons

Source	CCME[a]	NTP[b]	EPA[c]	IARC[d]	CA[e]
Benz[a]anthracene	X	X	X	X	X
Benzo[a]pyrene	X	X	X	X	X
Benzo[b]fluoranthene	X	X	X	X	X
Benzo(g,h,i)perylene	X	X	X	X	X
Benzo[k]fluoranthene	X	X	X	X	X
Chrysene	X		X		X
Dibenz[a,h]anthracene	X	X	X	X	X
Indeno[1,2,3-cd]pyrene	X	X	X	X	X

Notes: [a] – CCME Canadian Council Ministry of Environment 2010 Canadian soil quality guidelines for the protection of environmental and human health: Carcinogenic and Other PAHs..[b] NTP 2001. Report on Carcinogens, Eleventh Edition, US Department of Health and Human Services, Public Health Service, National Toxicology Program; [c] - US EPA, 2007; [d] - IARC 1983, Polynuclear Aromatic Compounds, Part 1, Chemical, Environmental and Experimental Data, IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Humans, vol. 32. Lyon, France: International Agency for Research on Cancer; [e] - California Environmental Protection Agency, (June 1999b) Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II Technical Support Document for Describing Available Cancer Potency Factors, Office of Environmental Health Hazard Assessment, http://www.oehha.org/air/cancer_guide/hsca2.html.

Toxicological reference values for each of the PAHs are shown below (**Table 9.2C-9 to Table 9.2C-16**).

Table 9.2C-9. Toxicological Reference Values for Benzo(a)anthracene

	Cancer Slope Factor 1/(mg/kg-day)		Unit Risk 1/(mg/m^3)	Relative Absorption Factor		
Agency	**Oral**	**Dermal**	**Inhalation**	**Ingestion**	**Dermal**	**Inhalation**
CalEPA				1		1
Health Canada					0.148	
US EPA IRIS	0.73		0.11			
TRV for Assessment	**0.73**	**0.73***	**0.11**	**1**	**0.148**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System.

Table 9.2C-10. Toxicological Reference Values for Benzo(a)pyrene

Agency	Tolerable Daily Intake			Cancer Slope Factor		Unit RIsk	Relative Absorption Factor		
	mg/kg-day		mg/m^3	1/(mg/kg-day)		1/(mg/m^3)			
	Oral	Dermal	Chronic Inhalation	Oral	Dermal	Inhalation	Ingestion	Dermal	Inhalation
CalEPA									1
Health Canada				2.3		0.031		0.148	
RAIS						3.08	1		
MDEQ			0.0000005						
US EPA IRIS				7.3				0.13	
TRV for Assessment			**0.0000005**	**2.3**	**2.3***	**0.031**	**1**	**0.148**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; RAIS – Risk Assessment Information System; MDEQ – Michigan Department of Environmental Quality; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System.

Table 9.2C-11. Toxicological Reference Values for Benzo(b)fluoranthene

Agency	Cancer Slope Factor		Unit Risk	Relative Absorption Factor		
	1/(mg/kg-day)		1/(mg/m^3)			
	Oral	Dermal	Inhalation	Ingestion	Dermal	Inhalation
CalEPA						1
RAIS				1		
Health Canada					0.148	
US EPA IRIS	0.73		0.11			
TRV for Assessment	**0.73**	**0.73***	**0.11**	**1**	**0.148**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; RAIS – Risk Assessment Information System; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System.

Table 9.2C-12. Toxicological Reference Values for Benzo(g,h,i)perylene

Agency	Tolerable Daily Intake			Relative Absorption Factor		
	mg/kg-day		mg/m^3			
	Oral	Dermal	Chronic Inhalation	Ingestion	Dermal	Inhalation
CalEPA						1
Health Canada					0.148	
RAIS				1	0.13	
MDEQ	0.0071		0.012			
US EPA IRIS						
TRV for Assessment	**0.0071**	**0.0071***	**0.012**	**1**	**0.148**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; RAIS – Risk Assessment Information System; MDEQ – Michigan Department of Environmental Quality; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System.

Table 9.2C-13. Toxicological Reference Values for Benzo(k)fluoranthene

Agency	Cancer Slope Factor 1/(mg/kg-day)		Unit Risk 1/(mg/m³)	Relative Absorption Factor		
	Oral	Dermal	Inhalation	Ingestion	Dermal	Inhalation
CalEPA						1
RAIS				1		
Health Canada					0.148	
US EPA IRIS	0.73		0.11			
TRV for Assessment	**0.73**	**0.73***	**0.11**	**1**	**0.148**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; RAIS – Risk Assessment Information System; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System.

Table 9.2C-14. Toxicological Reference Values for Chrysene

Agency	Cancer Slope Factor 1/(mg/kg-day)		Unit Risk 1/(mg/m³)	Relative Absorption Factor		
	Oral	Dermal	Inhalation	Ingestion	Dermal	Inhalation
CalEPA						1
RAIS				1		
Health Canada					0.148	
US EPA IRIS	0.73		0.11			
TRV for Assessment	**0.73**	**0.73***	**0.11**	**1**	**0.148**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; RAIS – Risk Assessment Information System; HC – Health Canada; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System.

Table 9.2C-15. Toxicological Reference Values for Dibenz(a,h)anthracene

Agency	Cancer Slope Factor 1/(mg/kg-day)		Unit Risk 1/(mg/m³)	Relative Absorption Factor		
	Oral	Dermal	Inhalation	Ingestion	Dermal	Inhalation
CalEPA						1
RAIS				1	0.13	
Health Canada					0.148	
US EPA IRIS	0.73		0.12			
TRV for Assessment	**0.73**	**0.73***	**0.12**	**1**	**0.148**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; RAIS – Risk Assessment Information System; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System.

Table 9.2C-16. Toxicological Reference Values for Indeno(1,2,3-cd)pyrene

	Cancer Slope Factor		Unit Risk	Relative Absorption Factor		
	1/(mg/kg-day)		1/(mg/m^3)			
Agency	**Oral**	**Dermal**	**Inhalation**	**Ingestion**	**Dermal**	**Inhalation**
CalEPA						1
Health Canada					0.148	
RAIS				1	0.13	
US EPA IRIS	0.73		0.11			
TRV for Assessment	**0.73**	**0.73***	**0.11**	**1**	**0.148**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; RAIS – Risk Assessment Information System; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System.

The total PAHs include all the individual PAHs listed in Table 9.2C-17. Since PAHs are assumed to occur in the environment as a mixture, exposure to the mixtures of PAHs are assumed to occur in the environment as a mixture and should be assessed according to CCME's (2008) potency equivalency factor (PEF). The exposures to the individual carcinogenic PAHs are adjusted by their toxic potency relative to benzo(a)pyrene and potency equivalents are then summed. As a result, benzo(a)pyrene acts as a surrogate chemical for all other PAHs present in the mixture and assumes the potency of the entire PAH fraction. Health Canada (2010a) states that not all PAHs listed by CCME (2008) are required to be assess and that non-carcinogenic PAHs should be evaluated individually.

Table 9.2C-17. Toxicity Equivalency Factors for Carcinogenic PAHS

Cacinogenic PAHs Compounds	TEF
Benz(a)anthracene	0.1
Benzo(b+j)fluoranthene	0.1
Benzo(k)fluoranthene	0.1
Benzo(g,h,i)perylene	0.01
Benzo(a)pyrene	1
Chrysene	0.01
Dibenz(a,h)anthracene	1
Indeno(1,2,3-c,d)pyrene	0.1

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California Environmental Protection Agency (California EPA). 2002. Air Toxics Hot Spots Program Risk Assessment Guidelines. Part II. Technical Support Document for Describing Available Cancer Potency Factors. Office of Environmental Health Hazard Assessment. Air Toxicology and Epidemiology Section.

RAIS (Risk Assessment Information System). 1994. Oak Ridge National Laboratory Risk Assessment Information System. Available at http://risk.lsd.ornl.gov. Accessed: August 2013.

US EPA. IRIS (Integrated Risk Information System) 1994. A-Z List of Substances. Available at http://www.epa.gov/iris/. Accessed August 2013.

1.9 Selenium

Selenium is a trace mineral that is essential to good health but required only in small amounts. The toxic potential for selenium and selenium compounds is related to their chemical form and to their solubility. Selenium occurs in nature and biological systems as selenate, selenite, elemental selenium and selenide.

Symptoms of selenosis include a garlic odour on the breath, gastrointestinal disorders, hair loss, sloughing of nails, fatigue, irritability and neurological damage. Extreme cases of selenosis can result in cirrhosis of the liver, pulmonary edema and death (Civil and McDonald, 1978; Carter, 1966; Koppel *et al*., 1986).

Health Canada (2010) recommends an oral RfD of 0.0062 mg/kg-d based on the toddler ingestion TRV. TCEQ (2011) recommends an inhalation RfC of 0.0002 mg/m^3 but does not list supporting documentation. Health Canada (2010) derived a dermal absorption factor for selenium, but no supporting studies are mentioned. A list of the toxicological reference values are presented in **Table 9.2C-17**.

Table 9.2C-18. Toxicological Reference Values for Selenium

	Tolerable Daily Intake		Tolerable Concentration	Relative Absorption Factor		
	mg/kg-day		mg/m^3			
Agency	**Oral**	**Dermal**	**Chronic Inhalation**	**Ingestion**	**Dermal**	**Inhalation**
CalEPA						1
Health Canada	0.0062				0.01	
RAIS				1		
TCEQ			0.0002			
TRV for Assessment	**0.0062**	**0.0062***	**0.0002**	**1**	**0.01**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; RAIS – Risk Assessment Information System; TCEQ – Texas Commission of Environmental Quality

Literature Cited

California Environmental Protection Agency (CalEPA). 2013. Toxicity Criteria Database. Available at http://www.oehha.ca.gov/risk/chemicalDB/ (accessed April 2013).

Carter, R.F. 1966. Acute selenium poisoning. Med. J. Aust. 1: 525-528.

Civil, I.E. and M.J. McDonald. 1978. Acute selenium poisoning: Case report. N. Zealand Med. J. 87: 354-356.

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Koppel, C., H. Baudisch, K.-H. Beyer, et al. 1986. Fatal poisoning with selenium dioxide. Clin. Toxicol. 24: 21-35.

Risk Assessment Information System (RAIS). 2011. Oak Ridge National Laboratory Risk Assessment Information System. Available at http://risk.lsd.ornl.gov. Accessed: August 2013.

Texas Commission on Environmental Quality (TCEQ). 1999. Risk Reduction Rule, Title 30, Texas Administrative Code Chapter 335, Subchapter S. Available at: http://www.tceq.state.tx.us/remediation/rrr.html. Accessed: December 2011.

1.10 Toluene

Adverse effects on the nervous system are the critical effects of concern from inhalation exposure to toluene as evidenced by results from studies of workers acutely or chronically exposed to toluene in workplace air, studies of volunteers under controlled acute exposure conditions, and studies of chronic solvent abusers predominantly exposed to toluene (ATSDR, 2000).

Observed effects include reversible neurological symptoms from acute exposure progressing from fatigue, headache, and decreased manual dexterity to narcosis with increasing exposure level, degenerative changes in white matter in chronic solvent abusers, and subtle changes in neurological functions including cognitive and neuromuscular performance, hearing, and color discrimination in chronically exposed workers. Studies of toluene-exposed animals provide supporting data showing changes in behavior, hearing loss, and subtle changes in brain structure, brain electrophysiology, and brain chemistry (ATSDR, 2000).

Inhalation exposure of volunteers to 40 ppm of toluene for 6 hours did not produce statistically significant differences in the results of tests measuring nasal mucus flow and lung function or in subjective evaluations of air quality, but irritation of the nose was noted at 100 ppm (Andersen *et al.* 1983). No changes in lung function were reported for volunteers exposed to 100 ppm toluene for 6 hours, 30 minutes of which were spent exercising (Rahill *et al.* 1996). Individuals exposed to 800 ppm toluene for 3 hours (Von Oettingen *et al.* 1942) or 1,862 ppm for 2 hours (Meulenbelt *et al.* 1990) had no self-reported respiratory effects. However, irritation of the nose and throat was reported in printers exposed to 100 ppm toluene for 6.5 hours (Baelum *et al.* 1985), and in volunteers exposed to 200 ppm toluene for 7 to 8 hours (Carpenter *et al.* 1944). Eight workers from a print factory exposed to <200

ppm toluene for more than 18 months had normal chest x-rays and did not report breathing difficulty (Guzelian *et al.* 1988).

US EPA IRIS (2005) has developed an RfD of 0.08 mg/kg/day based on increased liver and kidney weights in rats. Cal EPA recommends an oral RfC of 0.3 mg/m^3 based on neurotoxicity effects observed in humans. Health Canada (2010) recommends an oral tolerable daily intake of 0.22 mg/kg-d and a tolerable inhalation concentration of 3.75 mg/m^3 for toluene. These values were used in the assessment.

A summary of the toxicological reference values is presented in **Table 9.2C-18**.

Table 9.2C-19. Toxicological Reference Values for Toluene

	Tolerable Daily Intake		Tolerable Concentration		Relative Absorption Factor		
	mg/kg-day		mg/m^3				
Agency	**Oral**	**Dermal**	**Acute Inhalation**	**Chronic Inhalation**	**Ingestion**	**Dermal**	**Inhalation**
ATSDR			3.8				
US EPA IRIS	0.08						
Health Canada	0.22			3.75		0.03	
CalEPA				0.3	1		1
TRV for Assessment	**0.22**	**0.22***	**3.8**	**3.75**	**1**	**0.03**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
ATSDR – Agency for Toxic Substances and Disease Registry; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System.; CalEPA – California Environmental Protection Agency

Literature Cited

Agency for Toxic Substances and Disease Registry (ATSDR). 2000. Toxicological Profile for Toluene. Update. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Accessed December 2010.

Andersen, I., G.R. Lundqvist and L. Molhave. 1983. Human Response to Controlled Levels of Toluene in Six-hour Exposures. Scand J Work Environ Health 9:405-418.

Baelum, J., I. Andersen and G.R. Lundqvist. 1985. Response of Solvent-exposed Printers and Unexposed Controls to Six-hour Toluene Exposure. Scand J Work Environ Health 11:271-280.

California Environmental Protections Agency EPA (2011). Available at: http://oehha.ca.gov/risk /ChemicalDB/start.asp. Accessed December 2011.

Carpenter, C.P., S.B. Shaffer and C.S. Weil. 1944. Studies on the Inhalation of 1,3-butadiene; with a Comparison of its Narcotic Effect with Benzol, Toluol, and Styrene, and a Note on the Elimination of Styrene by the Human. J Ind Hyg Toxicol 26(3):69-78.

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Rahill, A.A., B. Weiss, P.E. Marrow. 1996. Human Performance During Exposure to Toluene. Aviat Space Environ Med, 67: 640-647.

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US EPA. IRIS (Integrated Risk Information System) 1994. A-Z List of Substances. Available at http://www.epa.gov/iris/. Accessed October 2013.

1.11 Xylene

Xylenes (mixtures of *ortho*-, *meta*-, and *para*-isomers) are used as industrial solvents, synthetic intermediates, and solvents in commercial products such as paints, coatings, adhesive removers, and paint thinners; they are also a component of gasoline. Xylenes are released to the atmosphere primarily as fugitive emissions from industrial sources (e.g., petroleum refineries, chemical plants), in automobile exhaust, and through volatilization from their use as solvents. Discharges into waterways and spills on land result primarily from use, storage, and transport of petroleum products and waste disposal. Xylene also occurs naturally in petroleum and coal tar and is formed during forest fires, to a small extent. It is a colourless, flammable liquid with a sweet odour (ATSDR 2007).

Results of studies in animals indicate that large amounts of xylene can cause changes in the liver and harmful effects on the kidneys, lungs, heart, and nervous system. The primary effects of xylene exposure involve the nervous system by all routes of exposure, the respiratory tract by inhalation exposure, and, at higher oral exposure levels, hepatic, renal, and body weight effects. Isomers of xylene have similar toxicokinetic properties and elicit similar toxicological effects, with no single isomer consistently exhibiting the greatest potency, depending on the end point. There is no definitive evidence for carcinogenic effects of xylene in humans (ATSDR 2007).

An oral RfD of 0.2 mg/kg/day has been developed by US EPA IRIS (2009) based on a 2-year oral study in rats by NTP (1986) where the endpoints observed were decreased body weight and decreased survival with a NOAEL of 250 mg/kg/day. An uncertainty factor of 1,000 reflected intraspecies and interspecies variability, and an extra factor of 10 was added for database uncertainty.

US EPA IRIS (2009) derived an inhalation RfC of 0.1 mg/m^3 based on a subchronic inhalation study on rats and rabbits by Korsak, *et al*. (1994) where the endpoint was impaired motor coordination. An uncertainty factor of 300 reflected a factor of 3 to adjust for interspecies, a factor of 10 for intraspecies uncertainty, plus a factor of 3 for extrapolation from subchronic to chronic duration and another factor of 3 was applied for uncertainties in the database. Health Canada (2010) provides a tolerable daily intake of 1.5 mg/kg-d and a tolerable inhalation concentration of 0.18 mg/m^3 for xylene. These values were used in the assessment.

A summary of the toxicological reference values is presented in **Table 9.2-C19**.

Table 9.2C-20. Toxicological Reference Values for Xylene

	Tolerable Daily Intake		Tolerable Concentration		Relative Absorption Factor		
	mg/kg-day		mg/m^3				
Agency	**Oral**	**Dermal**	**Acute Inhalation**	**Chronic Inhalation**	**Ingestion**	**Dermal**	**Inhalation**
CalEPA			22		1		
Health Canada	1.5			0.18		0.03	
US EPA IRIS	0.2			0.1			1
TRV for Assessment	**1.5**	**1.5***	**22**	**0.18**	**1**	**0.03**	**1**

Notes: * - Oral TRV adopted as dermal TRV.
CalEPA – California Environmental Protection Agency; US EPA IRIS – United States Environmental Protection Agency Integrated Risk Information System.

Literature Cited

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NTP (National Toxicology Program) (1986) NTP technical report on the toxicology and carcinogenesis of xylenes (mixed) (60% m-xylene, 13.6% p-xylene, 17.0% ethylbenzene, and 9.1% o-xylene) in F344/N rats and B6C3F1 mice (gavage studies). Research Triangle Park, NC. NTP TR 327, NIH Publ. No. 86-2583.

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2.0 ECOLOGICAL HEALTH

2.1 Aluminum

Aluminum is the most commonly occurring metallic element, comprising eight percent of the earth's crust. Studies of environmental toxicology in recent years have revealed that aluminum can be a cause of many diseases in animals. It can also exert harmful effects on plant roots. Aluminum has also been shown that high concentrations have detrimental effects on all water organisms (*Barabaz* et al., 2001). Moreover, soil acidification, resulting from abrupt aggravation of air pollution by acidic nitrogen and sulphur oxides, caused the mobilisation of toxic aluminium ions, which evoked numerous harmful changes in soil environment such as plant poisoning, forest drying or a dramatic decrease in cereal crops cultivated on acidified soils (*Barabaz* et al., 2001).

2.1.1 Mammals

In mammals and birds, aluminum is usually ingested with consumption of foods and evokes diversified toxic actions. In mammals, aluminum may lead to disturbances in blood function (i.e., erythropoiesis, leucocytosis, and lymphopenia), gastrointestinal systems and osseous systems (change in mineral bone structure) (*Barabaz* et al., 2001).

Ondreicka *et al.* (1966) (as cited in ORNL [Sample *et al.* 1998]) studied the effects of aluminum on reproduction in the mouse over the course of three generations. One dose was administered, and although there were no observed effects in the number of offspring per litter, growth of generations two and three were significantly reduced. The LOAEL was calculated to be 19.3 mg/kg-d.

2.1.2 Birds

In birds, aluminum affects egg shells and the metabolism of calcium and phosphorus causing diminished calcium absorption and decreased metabolic rates, resulting in aluminum absorption into bones. Carriere *et al.* (1986) (as cited in ORNL [Sample *et al.* 1998]) studied the effects of aluminum on reproduction in the Ringed Dove over a four month study. A single dose level of 1000 ppm was used which gave no significant differences. The calculated NOAEL was 109.7 mg/kg-d.

2.1.3 Soil Invertebrates

Juma and Tebatabai (1977) evaluated the effects of aluminum on alkaline phosphatase activities in microbes. At 675 ppm, enzyme activity was reduced. A NOEC was calculated to be 67.5 mg/kg and was used as the TRV for soil invertebrates as no value for higher trophic level organisms was available.

2.1.4 Terrestrial Plants

Numerous studies have shown that aluminum can be both beneficial and harmful for plants. The beneficial effect pf aluminum on plants includes the stimulation of iron and phosphorus absorption by root systems, decrease of toxic effects of copper and manganese and plant protection against phytopathogenic fungi. Aluminum can also increase plant resistance to unfavourable environmental conditions, such as drought, high and low temperatures and soil salinity (*Barabaz* et al., 2001). Conversely, detrimental aluminum effects on vegetation can lead to death as a result of changes in the morphology of root systems. Aluminum can also cause inhibition of cell divisions and elongation and disturbance of normal growth of the root system (*Barabaz* et al., 2001).

ORNL (Sample *et al.* 1998) states a screening benchmark of 50 mg/kg based on a study by MacKay *et al.* (1990) on white clover (*Trifolium repens L.*) in silt loam. Seedling establishment was reduced by approximately 30% after exposure to 50 ppm. This screening benchmark of 50 mg/kg was used as the TRV.

2.1.5 Fish

In fish, aluminum accumulates in gills which cause the inhibition of ion exchange and respiration. Studies conducted by Suter *et al*. (1996) provide a lowest chronic value (LCV) of 3.288 mg/L aluminum for fish. A reduction in toxicity associated with increased water hardness was evident for fish. This LCV was adopted as the TRV for aluminum exposure to fish.

2.1.6 Aquatic Invertebrates

ORNL (Sample *et al.* 1998) provides a lowest chronic value of 1.9 mg/L for daphnids based on studies by McCauley *et al.* (1986). This chronic value was adopted as the TRV for the assessment.

2.1.7 Aquatic Plants

The US EPA (1988) provides a lowest chronic value of 0.46 mg/L for aluminum based on studies involving aquatic plants (e.g.,*Selenastrum capricornutum*). This chronic value was adopted as the TRV for the assessment.

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Suter, G.W.II; Tsao, C.L.; Sample, B.E., 1996. Toxicological benchmarks for screening potential contaminants of concern for effects on aquatic biota: June, 1996 Revision. US Department of Energy, Office of Environmental Management, Washington, DC.

US EPA, 1988. Ambient Water Quality Criteria for Aluminum. 1988. EPA 440/5-86-008.

2.2 Arsenic

Arsenic is naturally present in rock and soils, with concentrations in soils reflecting the geology of the region as well as anthropogenic inputs. Higher concentrations are associated with igneous and sedimentary rocks, particularly with sulphidic ores (American Petroleum Institute (API), 1998). Arsenic is used in multiple manufacturing and industrial processes, including the production of wood-treating chemicals, herbicides, pesticides, desiccants, metal alloys, glass, pharmaceuticals, and semiconductors. Elevated arsenic soil concentrations are often associated with mining activities, smelters, pesticide/herbicide manufacturing facilities, and agricultural lands (API, 1998).

2.2.1 Mammals

Arsenic-containing compounds vary in toxicity to mammals depending on their valence state, form (inorganic or organic), physical state (gas, solution, or powder), and factors such as solubility, particle size, rates of absorption and elimination, and presence of impurities. Inorganic arsenic is generally considered more toxic than organic arsenic. The toxicity of arsenic in the trivalent form (arsenic (III)) is several times greater than that of the pentavalent form (arsenic (V)), primarily due to arsenic (III)'s higher potential for cellular

uptake. Metalloid arsenic is generally regarded as non-poisonous, due to its insolubility in water and body fluids (ATSDR, 2007).

Chronic toxicity due to inorganic exposures may result in dermal or neurological symptoms. Dermal effects may include hyperpigmentation or hyperkeratosis on the palms, soles, and torso. Peripheral neuropathy may appear with symmetrical paresthesia. Neurotoxicity begins with sensory changes, paresthesia, and muscle tenderness, followed by weakness that progresses from proximal to distal muscle groups. Chronic hepatic and renal damage is common, with jaundice occurring due to liver injury.

An Eco-SSL for mammals has been calculated by the US EPA (2005). This was based on a comparison of the geometric mean of the NOAEL values for growth and reproduction from a number of studies with the LOAEL for reproduction, growth, or survival. The geometric mean of NOAEL values was 2.47 mg arsenic/kg (body weight)/d. However, this value is higher than the lowest bounded LOAEL. Therefore, the TRV was established at 1.04 mg/kg/d, representing the highest NOAEL that was still lower than the lowest LOAEL for reproduction, growth, or survival.

2.2.2 Birds

The clinical effects of arsenic toxicity in avian species are similar to that in mammals, but birds are generally more sensitive to the adverse effects of arsenic. Recent research suggests that physiological scaling factors developed for mammals may not be appropriate for interspecies extrapolation to birds (Sample *et al*., 1996). The TRV for birds was based on studies collated by the US EPA (2005). The adopted arsenic TRV for all birds listed in this assessment is 2.24 mg/kg/d.

2.2.3 Soil Invertebrates

Studies collated by the US EPA (2005) illustrated a screening benchmark value for arsenic in terrestrial plants of 18 mg/kg. This value was adopted as the TRV. The screening benchmark is intended to protect terrestrial biota from direct soil contact exposures to arsenic.

2.2.4 Terrestrial Plants

Studies collated by the US EPA (2005) illustrated a screening benchmark value for arsenic in terrestrial plants of 18 mg/kg. This value was adopted as the TRV. The screening benchmark is intended to protect plants and other terrestrial biota from exposures to direct soil contact.

2.2.5 Fish

Defoe (1982) completed an early life-stage test with fathead minnows exposed to arsenic that resulted in a chronic value of 0.892 mg/L. This chronic value of 0.892 mg/L was adopted as the TRV for arsenic exposure to fish.

2.2.6 Aquatic Invertebrates

Vocke *et al*. (1980) completed a 14-day EC_{50} study involving freshwater organisms exposed to arsenic. The findings of the test resulted in an EC_{50} value of 0.048 mg/L, which was adopted as the TRV for arsenic exposure to aquatic invertebrates.

2.2.7 Aquatic Plants

Vocke *et al*. (1980) completed a 14-day EC_{50} study involving freshwater organisms *(Scenedesmus obliquus*) exposed to arsenic. The findings of the test resulted in an EC_{50} value of 0.048 mg/L, which was adopted as the TRV for arsenic exposure to aquatic plants.

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2.3 Benzene

Benzene occurs from both natural and anthropogenic sources, but is primarily produced from petroleum products. Benzene in the atmosphere exists predominantly in the vapour phase (Eisenreich et al. 1981). Benzene released to soil surfaces partitions to the atmosphere through volatilization and to surface water through runoff. Since studies suggest that benzene exists primarily in the vapour phase, air to leaf transfer is considered to be the major pathway of vegetation contamination (Hattemer-Frey et al. 1990).

2.3.1 Mammals

Pathways of benzene metabolism are generally similar among various mammal species. However, differences exist regarding capacity to metabolize benzene and relative proportions of various benzene metabolites formed. For example, following 6-hour exposures to low concentrations (7-10 ppm) of benzene vapours, mice retained 20% of the inhaled benzene, whereas rats and monkeys retained only 3-4% (Sabourin et al. 1987)

Nawrot and Staples (1979) studied benzene effects on reproduction in the mouse though oral doses of 0.3, 0.5 and 1.0 mL/kg/d over days 6-12 of gestation. Benzene exposures of 0.5 and 1.0 mL/kg/d significantly increased maternal mortality and embryonic resorption. Fetal weights were significantly reduced by all three dose levels. Although the study was conducted over a short time period, it was conducted throughout a critical life stage therefore, the 0.3 mL/kg/d was considered to be a chronic LOAEL. The chronic NOAEL of 26.35 mg/kg-d was estimated by multiplying the chronic LOAEL by an uncertainty factor of 0.1.

2.3.2 Birds

The clinical effects of benzene toxicity in avian species are similar to that in mammals. The TRV adopted for birds was the same as used for mammals described above (26.35 mg/kg-d).

2.3.3 Soil Invertebrates

The TRV was taken from CCME (2004) where the NOEC for earthworms (*Eisenia andrei*) was 63 mg/kg in studies commissioned by the CCME in 2001.

2.3.4 Terrestrial Plants

Plants have been reported to transform benzene to metabolites such as amino acids (Dumishidze and Ugrekhelidze, 1969) suggesting that they may also be involved with removing benzene from soil (Cross et al. 1979). Vegetation directly sprayed with benzene exhibited signs of cellular damage.

The CCME (2004) recommends a value of 31 mg/kg for plants and soil invertebrates for coarse soil and residential/parkland use based on a weight of evidence approach. The weight of evidence approach consisted of selecting the 25th percentile of the effects distribution data for 14 day studies with coarse soils for two plant species: the early northern wheatgrass (*Agropyron dasystachyum*) (IC25) and alfalfa (*Medicago sativa*) (IC25) with the estimated effect adjusted to account for benzene lost in the soil between the spiking of the soil and introduction of the organisms (ESG 2002). The 25th percentile was then divided by an uncertainty factor of 3 based on a limited number of species represented and greater than 50% of the data for soil invertebrate toxicity is below the 25th percentile of the distribution (CCME, 2004; EC, 2005).

2.3.5 Fish

The EC20 value for fish is derived from Black and Birge (1982) who conducted a series of screening tests for a large number of chemicals on several freshwater organisms. Larval fish survival was recorder to only 4 days post hatch, and LOECs and NOECs were not determined. The test EC20 values based on this study may therefore be high relative to those from conventional chronic tests.

2.3.6 Aquatic Invertebrates

The lowest chronic value for daphnids is provided by the EPA (1978) from life-cycle tests on Daphnids. The recommended TRV used for this assessment was 98 mg/L.

2.3.7 Aquatic Plants

A benchmark of 2900 µg/L was recommended based on the study by Galassi et al. (1988) whereby *Selenastrum capricornutum* were exposed for a 72-hour duration to benzene which resulted in an EC50 (growth) of 29000 µg/L (CCME, 1999). Application of an uncertainty factor of 10 led to the derivation of a LOEL (benchmark) of 2900 µg/L which was adopted for use in the current assessment.

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2.4 Cadmium

Cadmium is a naturally occurring rare element that does not have any known essential or beneficial biological function. In the environment, cadmium occurs as a divalent metal that is insoluble in water, but its chloride and sulphate salts are freely soluble (Eisler, 1985). If released or deposited on soil, cadmium is largely retained in the surface layers of soil. Cadmium is adsorbed to soil but to a much lesser extent than most other heavy metals. The availability of cadmium to organisms in the environment is dependent on a number of factors, including pH and chemical speciation (Eisler, 1985).

Cadmium's initial route of entry to the environment is often via the atmosphere. When released, it generally occurs as particulate matter and is subject to dry and wet deposition. Although anthropogenic releases are as small particles, most cadmium appears to be deposited relatively close to its source. Since it occurs naturally in the earth's crust, cadmium may also enter the atmosphere from the weathering of rocks, windblown soil, and volcanoes. However, these sources are minor compared with anthropogenic ones (US EPA, 2005).

2.4.1 Mammals

The main routes of cadmium absorption for mammals are via respiration and ingestion. Factors that are reported to affect dietary cadmium absorption from the GI tract include age, sex, chemical form, levels of protein, levels of calcium and the presence of other elements (Nriagu, 1981). Cadmium-induced effects associated with oral intake include nephrotoxicity and also possible effects on the liver, reproductive organs, and the haematopoietic, immune, skeletal, and cardiovascular systems (Shore and Douben, 1994).

Sutou *et al.* (1980) (as cited in ORNL [Sample *et al.* 1998]) studied the effects of cadmium on reproduction in the rat through oral ingestion of four dose levels. Fetal implantations were reduced by 28%, fetal survivorship was reduced by 50% and fetal resorptions were increased by 400% in the 10 mg/kg/d dose group. Adverse effects were not observed in the 1 mg/kg/d group and was determined to be the NOEC used as the TRV for mammals.

2.4.2 Birds

The clinical effects of cadmium toxicity in avian species are similar to that in mammals. The TRV for birds was based on studies collated by Sample *et al*. (1996). The study described exposure of cadmium to mallard ducks, resulting in significant decrease in eggs when compared to those in other groups. The adopted TRV for the birds exposed to cadmium is 1.45 mg/kg/d (Sample *et al*., 1996).

2.4.3 Soil Invertebrates

The US EPA (2005) recommends a NOEC of 140 mg/kg. This value was derived from 10 studies where the geometric mean of the maximum acceptable toxicant concentration or EC_{10} values for 3 test species under 6 different test conditions was calculated.

2.4.4 Terrestrial Plants

The US EPA (2005) recommends a NOEC of 32 mg/kg. This value was derived from 14 studies where the geometric mean of the maximum acceptable toxicant concentration for 14 test species under different test conditions was calculated.

2.4.5 Fish

A reduction in toxicity associated with increasing water hardness is evident for several fish species. The lowest chronic value for cadmium for fish of 0.0017 mg/L was based on studies collated by Sauter *et al*. (1976). This was adopted as the TRV for cadmium exposure to fish.

2.4.6 Aquatic Invertebrates

Carlson *et al*. (1982) provides an EC_{20} chronic value of 0.00015 mg/L for cadmium based on a life-cycle test on Daphnia magna. The EC_{20} value is defined at the highest tested concentration causing less than 20% reduction in the product of growth, fecundity, and survivorship in a chronic test. This benchmark value was adopted as the TRV for the assessment.

2.4.7 Aquatic Plants

Aquatic plants are affected by cadmium concentrations ranging from 0.002 mg/L to 7.4 mg/L. These values are in the same range as the values observed in fish and invertebrates. Conway (1977) provides a lowest chronic value (LCV) of 0.002 mg/L, based on a study involving the application of low cadmium concentrations to aquatic plants. The study observed a reduction in the population growth rate in aquatic plants. The LCV of 0.002 mg/L was adopted as the TRV for the assessment.

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2.5 Chromium

Chromium speciation is complex. Chromium is a metallic element that can exist in several valence states. In the aquatic environment, chromium is found in valence states of (III) or (VI). Among the factors that can affect the speciation of chromium in soil and water, and its subsequent uptake into animals and plants, are organic matter content, ferrous ion content, redox state, and pH (Outridge and Scheuhammer, 1993). In general, chromium (VI) is favoured by higher pH, aerobic conditions, low amounts of organic matter, and the presence of manganese and iron oxides, which oxidize chromium (III). Transformation of chromium (VI) to the trivalent form tends to occur in acidic, anoxic soils with high organic content (US EPA, 2008). Chromium (III) adsorbs onto clay particles, organic matter, metal oxyhydroxides, and other negatively-charged particles. Chromium (VI), on the other hand, does not interact significantly with clay or organic matter. As a result, chromium (VI) is more water-soluble and mobile than chromium (III) (Outridge and Scheuhammer, 1993).

2.5.1 Mammals

Chromium has, been shown to be an essential nutrient for animals (NRC, 1997). Chromium (III) has been shown to have antioxidative properties and it is integral in activating enzymes and maintaining the stability of proteins and nucleic acids. Its primarily metabolic role is to

potentiate the action of insulin through its presence in an organometallic molecule called the glucose tolerance factor (GTF) (US EPA, 2008). The hexavalent forms of chromium are absorbed three to five times better in the intestine compared to chromium (III) forms.

Chromium toxicosis in ruminants is associated with severe congestion and inflammation of the digestive tract, and kidney and liver damage, with the precipitating properties of chromium believed to be the basis of the tissue damage (Thompson et al., 1991).

MacKenzie *et al.* (1958) (as cited in ORNL [Sample *et* al. 1998]) studied the effects of chromium on body weight and food consumption in the rat over the course of one year. Chromium was administered orally in water in six dose concentrations. No significant effects were observed at any does level and the NOAEL was determined to be 3.28 mg/kg/d. This was adopted as the TRV for mammals.

2.5.2 Birds

Haseltine et al. (unpup data) examined the effects of chromium on reproduction in the black duck over 10 months. Duckling survival was reduced after exposure to 50 ppm and no significant differences were observed at the 10 ppm dose level. The NOAEL was calculated to be 1 mg/kg-d and as adopted as the TRV for this assessment.

2.5.3 Terrestrial Plants

Plants are reported to play a major role in the geochemistry of chromium as they contain a significant fraction of the biologically active pool of chromium, approximately three orders of magnitude greater than that found in animal tissues. In contrast to animals, chromium (III) uptake by plants occurs more rapidly than chromium (VI). It is uncertain, however, if chromium is an essential element for plant nutrition although some investigators have observed a stimulatory effect of chromium on plant growth (Outridge and Scheuhammer, 1993).

Turner and Rust (1971) investigated the effects of chromium on soybean seedling growth after 3 days in loam soil. Fresh shoot weight was reduced by 30% by 30 ppm while 10 ppm had no effects. The TRV used for terrestrial plants was equal to 10 mg/kg.

2.5.4 Soil Invertebrates

van Gestel *et al.* (1992) examined the effects of chromium on the growth of *Eisenia andrei* over 21 days of exposure. A concentration of 32 ppm reduced growth by 30%. A NOAEL was determined to be 10 mg/kg and this was adopted as the TRV for soil invertebrates.

2.5.5 Fish

Stevens and Chapman (1984) conducted toxicity tests with chromium and early life stages of rainbow trout. The test revealed a LCV of 0.068 mg/L chromium in fish. This chronic value was adopted as the TRV for chromium exposure in fish.

2.5.6 Aquatic Invertebrates

Chapman, *et al*. (1980) studied the chronic effects of chromium on *Daphnia magna*. The test revealed inhibited reproduction of *Daphnia magna.* A chronic value of 0.044 mg/L was developed from the freshwater life-cycle test. This chronic value was used as the TRV for aquatic invertebrates.

2.5.7 Aquatic Plants

The aquatic plant toxicity value for chromium was derived from a chronic test which resulted in 50% inhibition of growth of *Selenastrum capricornutum*. The chronic test value of 0.397 mg/L (US EPA, 1985) was adopted as the TRV for chromium in aquatic plants.

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2.6 Copper

Copper may be present as soluble compounds, including nitrates, sulfates, and chlorides, and insoluble compounds, such as oxides, hydroxides, carbonates, and sulphides (Bodek *et al*., 1988). Copper occurs naturally as sulphides, oxides, and sometimes as metallic copper. Weathering of copper minerals results in background levels of copper in natural surface waters. Soluble copper compounds strongly sorb to particles of organic matter, clay, soil, or sand, and demonstrate low mobility in soils (Bodek *et al.,* 1988). Most copper compounds have a high melting point and low vapour pressure, and are not expected to volatilize from moist or dry soil surfaces (Bodek *et al*., 1988). Copper has two oxidation states (cuprous and cupric).

2.6.1 Mammals

In mammals, the mechanism of copper toxicity is complex. Copper can increase cell permeability in erythrocytes leading to lysis and inhibition of intracellular enzymes. Thus, copper poisoning can lead to oxidative stress in erythrocytes and to accelerated loss of intracellular glutathione. In addition, copper ions can cause mitochondrial swelling and inhibit oxygen consumption, which leads to cell degeneration (US EPA, 2005). In copper deficient animals, failure to form collagen in the walls of arterioles leads to subcutaneous

bleeding and anemia. Other symptoms of acute copper toxicity in mammals include sporadic fever, tachycardia, hypotension, oliguria, uremia, coma, cardiovascular collapse, and death. Chronic copper poisoning in mammals may induce nausea, vomiting, epigastric pain, dizziness, jaundice, and general debility (Venugopal and Luckey, 1978).

The TRV of 11.7 mg/kg-d was adopted from the calculated NOAEL from Aulerich *et al.* (1982). This study examined reproduction in the mink over 357 days at 4 dose concentrations. Consumption of 50, 100, and 200 ppm supplemental copper increased mortality of mink kits. The 25 ppm dose concentration had no adverse affects.

2.6.2 Birds

The clinical effects of copper toxicity in avian species are similar to that in mammals. The adopted TRV for birds is 47 mg/kg/d based on the calculated NOAEL from the study that examined the effects of copper on growth and mortality in 1 day old chicks (Mehring *et al.* 1960). Eleven dose levels were tested and exposure was 10 weeks in duration. Growth was reduced by over 30% and there was 15% mortality at 749 ppm exposure.

2.6.3 Terrestrial Plants

In plants, copper is especially important in oxidation, photosynthesis, and protein and carbohydrate metabolism. Also, copper concentrations may affect nitrogen fixation, valence changes, and cell wall metabolism (Kabata-Pendias and Pendias, 1992). Since copper is unlikely to be transported across leaf cuticles, the primary route of uptake by plants is through soil as opposed to atmospheric deposition (Hutchinson, 1979).

The TRV of 70 mg/kg for terrestrial plants was adopted from the US EPA Eco-SSL (2007). This value was derived from the geometric mean of the maximum acceptable toxicant concentration and 10% effective concentration values for four species (black bindweed, citrus cultivar, perennial ryegrass and alfalfa) under different pH and % organic matter concentrations.

2.6.4 Soil Invertebrates

Neuhauser *et al.* (1984) evaluated the effects of soluble forms of copper on growth and reproduction for earthworms. After 6 weeks, both growth (weight) and cocoon production were decreased (75% and 85%) by 2000 ppm Cu, while 1000 ppm had no effect.

The TRV of 80 mg/kg for soil invertebrates was adopted from the US EPA Eco-SSL (2007). This value was derived from the geometric mean of the maximum acceptable toxicant concentration and 10% effective concentration values for six species including springtails, earthworms and nematodes, under different pH and % organic matter concentrations.

2.6.5 Fish

Sauter *et al*. (1976) conducted toxicity tests with copper and early life stages of brook trout. The test revealed a chronic value of 0.0038 mg/L copper in fish (Sauter *et al*., 1976). This chronic value was adopted as the TRV for copper exposure in fish.

2.6.6 Aquatic Invertebrates

Chapman *et al*. (1980) studied the chronic effects of copper on *Daphnia magna*. The test revealed inhibited reproduction of *Daphnia magna.* A chronic value of 0.00023 mg/L was developed from the freshwater life cycle test. This chronic value was used as the TRV for aquatic invertebrates.

2.6.7 Aquatic Plants

The aquatic plant toxicity value for copper of 0.001 mg/L was derived from a chronic study conducted by Steeman-Nielsen and Wium-Anderson (1970), which resulted in a lag in growth of algae (*Chlorella pyrenoidosa*). The chronic value of 0.001 mg/L was adopted as the TRV for chromium in aquatic plants.

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2.7 Cyanide

Cyanide is released into air mainly as hydrogen cyanide gas. Hydrogen cyanide may be produced naturally by microorganisms as well as from the cyanogenic degradation of glycosides. Many plants may synthesize cyanoglucosides, which upon decomposition may lead to the formation of free cyanide (HSDB).

Cyanide in soil is pH dependent. In acidic soils, the loss off hydrogen cyanide through volatilization may be the predominant mechanism of loss from soil surfaces. In subsurface soil, cyanides that are present in small concentrations may undergo some microbial degradation (Callahan et al., 1979); in addition, considering cyanide's low soil sorption characteristics and high water solubility, some may leach through the soil.

2.7.1 Mammals

In mammals, reported oral LD50 range from 2.1 mg/kg/bw to 10 mg/kg bw. Acute effects of cyanide toxicity in mammals can result in death within minutes after ingestion. Other effects include tremors, salivation, lacrimation, defecation, urination, laboured breathing, muscle incoordination, gasping and convulsions. Tewe and Maner (1981) studied the effects of potassium cyanide in the rat though oral ingestion of one dose level of 500 ppm. Consumption of 500 ppm of cyanide significantly reduced offspring growth and food consumption, however values were only slightly less than controls. Because the study considered exposure through a critical lifestage (i.e., reproduction), the dose was considered to be a chronic NOAEL and the adopted TRV used was 68.7 mg/kg-d.

2.7.2 Birds

An LD50 of 1.43 mg/kg/day for Mallard ducks (*Anas platyrhynchos*) from the study by Henny *et al*. (1994, as cited in the EC [1999]) was listed as the lowest avian toxicity value in the EC (1999) scientific supporting document for selected avian oral toxicity studies for free cyanide.

2.7.3 Soil Invertebrates

The soil invertebrate benchmark of 6 mg/kg is based on the 14 day LOEC (mortality) for the earthworm, *Eisenia foetida* (EC, 1999).

2.7.4 Terrestrial Plants

Environment Canada (1995a,b) (as cited in [CCME 1997]) studied the effects of cyanide on seedling emergence in radishes and lettuce. The average 5 day NOEC for lettuce seedlings was 5 mg/kg and was adopted as the TRV for this assessment.

2.7.5 Fish

A TRV of 0.0078 mg/kg-d was adopted from fish life cycle test in the brook trout by Koenst *et al*. (1977) as cited in ORNL (Sample *et al.* 1998).

2.7.6 Aquatic Invertebrates

A TRV of 0.0078 mg/kg-d was adopted from the lowest chronic value for all organisms as recommended in ORNL (Sample *et al.* 1998).

2.7.7 Aquatic Plants

The recommended value of 0.03 mg/L (free cyanide) is based on the incipient inhibition of cell propagation of 30 µg/L in the green alga, *Scenedesmus quadricauda* (Bringmann and Kuhn, 1977, 1978a,b, 1979 and 1980 as cited in the US EPA [1984] and Singleton [1986]). This value was listed as the lowest effects data for algae and aquatic plants in the studies the US EPA (1984) considered in the derivation of their cyanide ambient water quality guidelines for the protection of aquatic life. As it was not clear if this was an acute or chronic study, an uncertainty factor of 10 was applied.

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2.8 Ethylbenzene

Ethylbenzene is widely distributed in the environment, however is not considered highly persistent in the environment. Routine human activities, such as driving automobiles, boats, or aircraft, and using gasoline powered tools and equipment as well as paints, varnishes, and solvents release ethylbenzene to the environment. Ethylbenzene partitions primarily to air from water and soil. Once in air, ethylbenzene is broken down photochemically. If released to soil, ethylbenzene is expected to possess moderate mobility. In water, ethylbenzene breaks down by reacting with other compounds naturally present (ATSDR, 2010).

2.8.1 Mammals

Acute-duration and intermediate duration studies in animals suggest that the auditory system is a sensitive target of ethylbenzene toxicity. Significant losses of outer hair cells in the organ of corti have been observed in rats after acute-duration exposure ≥ 400 ppm and intermediate-duration inhalation exposure to ≥ 200 ppm ethylbenzene (ATSDR, 2010).

Results of chronic studies indicate that intermediate-duration oral exposure to ethylbenzene produces effects to the liver. Effects indicative of liver toxicity observed included increased activity of serum liver enzymes in males (≥ 250 mg/kg/day) and females (750 mg/mg/day), increased absolute and relative liver weights (≥ 250 mg/kg/day in males and females), and a dose-related increase in the incidence of centrilobular hepatocyte hypertrophy. Guinea pigs exposed to sub-lethal concentrations of ethylbenzene (≤ 10,000 ppm for < 100 minutes) showed “moderate” pulmonary edema and congestion. These findings had disappeared in animals after a 4–8-day recovery period, suggesting that these pathological effects in the lung are reversible (ATSDR, 2010).

A LOEL of 408 mg/kg/day based on histopathologic changes in the liver and kidney of rats and adjusted for continuous exposure (7 days/week) to 291 mg/kg/day and divided by an uncertainty factor of 100 was used in the CCME’s (2004, as cited in [EC 2005]) derivation of

their daily threshold effect dose for livestock of 2.91 mg/kg/day (EC 2005). This LOEL was based on the study by Wolf et al. (1956), whereby rats were orally given ethylbenzene at doses between 14 and 680 mg/kg in olive oil for approximately 36 weeks (5 day/week).

2.8.2 Birds

The clinical effects of ethylbenzene toxicity in avian species are similar to that in mammals. The mammalian TRV of 408 mg/kg/day as described above was used as the TRV for birds.

2.8.3 Soil Invertebrates

The TRV was adopted from the CCME (2004) where the NOEC in coarse and fine grained soils in earthworms (*Eisenia andrei)* was reported to be 16 mg/kg.

2.8.4 Terrestrial Plants

The recommended soil plant benchmark of 55 mg/kg is based on a weight of evidence approach, whereby 25th percentile effects distribution value for 14 day studies with coarse soils for two plant species: the early northern wheatgrass (*Agropyron dasystachyum*) (IC25) and alfalfa (*Medicago sativa*) (IC25), with the estimated effects adjusted to account for ethylbenzene lost in the soil between the spiking of the soil and introduction of the organisms (ESG 2002) and then divided by an uncertainty factor of 2 (CCME 2004; EC 2005.

2.8.5 Fish

A TRV of 0.44 mg/L was adopted from the lowest chronic value as recommended in ORNL (Sample *et al.* 1998).

2.8.6 Aquatic Invertebrates

A TRV of 12.922 mg/L was adopted from the lowest chronic value as recommended in ORNL (Sample *et al.* 1998). The lowest chronic value was estimated using an EC50 for *Daphnia magna* from EPA (1980).

2.8.7 Aquatic Plants

A TRV of 438 mg/L was adopted from the lowest chronic value as recommended in ORNL (Sample *et al.* 1998). The lowest chronic value was estimated from a 96 hour EC_{50} chlorophyll inhibition test in *Selenastrum capricornutum*.

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2.9 Lead

Lead is a natural occurring element found in all environmental media (i.e., air, soil, water). Lead is released to the environment from coal-fired power, plants, ceramic manufacturing, mining, ore processing, smelting of lead ores, refining, the production and use of lead alloys and compounds, recycling, combustion processes, industrial processes, and from disposal. Lead may also be deposited on land as dust and sludge, (NRCC, 1978, US EPA, 2005).

Leaching of lead can be relatively rapid from some soils, especially at highly contaminated sites or landfills (Kayser *et al*., 1982). Lead is most available from acidic sandy soils, which contain little organic material capable of binding lead. The solubility of lead in water depends heavily on pH. The uptake of lead by plants also depends on other factors, including cation exchange capacity, soil composition (e.g., organic matter and calcium content), metal concentrations, precipitation, light, and temperature. Lead uptake by plants is favoured at lower pH values and in soils with low organic carbon content (DeMayo *et al.,* 1982).

2.9.1 Mammals

Lead is not considered an essential element for mammals. Clinical signs of lead toxicity in domestic animals are manifested differently for different species, but the overall signs are of encephalopathy preceded and accompanied by gastrointestinal malfunction (Booth and MacDonald, 1982). Behavioural signs of poisoning include anxiety, apprehension, hyperexcitability, vocalization, rolling of eyes, apparent fear or terror, possible belligerence and maniacal behaviour (Booth and MacDonald, 1982).

Azar *et al.* (1973) (as cited in ORNL, Sample *et al.* [1998]) studied the effects of lead on reproduction in the rat over the course of 3 generations at five different dose concentrations. Exposure to 1000 and 2000 ppm resulted in reduced offspring weights and produced kidney damage in the young. The calculated NOAEL was 8 mg/kg-d and was used as the TRV for mammals.

2.9.2 Birds

Lead is also not considered an essential element for birds. Clinical signs of lead toxicity in birds are similar to that observed in mammals. Pattee (1984) (as cited in ORNL, Sample *et al.* [1998]) studied the effects of lead on reproduction in American Kestrels over a 7 month period. Two doses were administered (10 and 50 ppm) after which no significant effects were observed. The calculated NOAEL was 3.85 mg/kg-d and was used as the TRV for birds in this assessment.

2.9.3 Terrestrial Plants

Lead is not considered to be an essential element for plant growth and development. Lead inhibits growth, reduces photosynthesis (by inhibiting enzymes unique to photosynthesis), interferes with cell division and respiration, reduces water absorption and transpiration, accelerates abscission or defoliation and pigmentation, and reduces chlorophyll and ATP synthesis (US EPA 2005).

The TRV of 120 mg/kg was adopted from the US EPA Eco-SSL (2005). This value was equal to the geometric mean of the maximum acceptable toxicant concentration from four studies using four different test species (Loblolly pine, Red maple, Berseem clover and Ryegrass) and under three different soil pH and organic matter conditions.

2.9.4 Soil Invertebrates

The TRV of 7000 mg/kg was adopted from the US EPA Eco-SSL (2005). This value was equal to the geometric mean of the maximum acceptable toxicant concentration from four studies using one test species (*Folsomia candida*) and under three different pH test conditions.

2.9.5 Fish

Davies *et al*. (1976) conducted toxicity tests with lead and early life stages of rainbow trout. The test revealed a LCV of 0.018 mg lead/L in fish (Davies *et al*., 1976). This chronic value was adopted as the TRV for lead exposure in fish.

2.9.6 Aquatic Invertebrates

Chapman *et al*. (1980) studied the chronic effects of lead to *Daphnia magna*. The test revealed inhibited reproduction of *Daphnia magna.* A chronic value of 0.012 mg/L was developed from the freshwater life cycle test. This chronic value was used as the TRV for aquatic invertebrates.

2.9.7 Aquatic Plants

The aquatic plant toxicity value for lead of 0.5 mg/L was derived from a chronic study conducted by the US EPA (1985) that observed growth inhibition of aquatic plants. The chronic value of 0.5 mg/L was adopted as the TRV for lead in aquatic plants.

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2.10 Mercury

Mercury is a mutagen, teratogen, and carcinogen, with toxicity and environmental effects varying with the form of mercury, dose, and route of ingestion, and with the exposed organism's species, sex, age, and general condition (Eisler, 1987). Methylmercury is the most toxic form. Inorganic mercury is methylated primarily by bacteria in both anaerobic and aerobic environments. The organic mercury compounds are more readily absorbed and poorly excreted compared with inorganic forms. The primary targets of acute exposures are the central nervous system and kidneys in fish, birds, and mammals.

2.10.1 Mammals

Verschuuren *et al*. (1976) studied the effect of mercury on reproduction in the rat over 3 generations through oral ingestion of 3 dose levels. Exposure to 2.5 ppm methylmercury reduced pup viability. Adverse effects were not observed at lower doses and the NOEC was determined to be 0.032 mg/kg-d.

2.10.2 Birds

Heinz (1979) studied the effect of mercury on reproduction over 3 generations in the mallard duck through oral ingestion of one dose level (0.5 ppm). Significant effects were observed (fewer eggs and ducklings were produced) after exposure to 0.5 ppm and thus was used to calculate the chronic LOAEL. The NOAEL was calculated by multiplying this by an uncertainty factor of 0.1 to give 0.0064 mg/kg-d.

2.10.3 Fish

The TRV used was 0.00023 mg/L which is the chronic recommended by the Oak Ridge National Laboratory (Sample *et al.* 1998). This value was based chronic tests run on *Pimephales promeles* throughout their embryo-larval stage.

2.10.4 Terrestrial Plants

Panda *et al.* (1992) evaluated the effects of mercury on seedling height and germination in barley after exposure for 7 days. Seedling height was reduced by 19% at 64 ppm, and germination was reduced 20% at 103 ppm. The resulting NOEC was 34.9 ppm and was the TRV used for terrestrial plants.

2.10.5 Soil Invertebrates

The effects of mercury on the earthworm *Eisenia fetida* was studied by Beyer *et al.* (1985). Earthworms were cultivated in potting soil for 84 days. A concentration of 12.5 ppm reduced survival by 21% and the ability to regenerate excised segments was reduced by 69%. A concentration of 2.5 ppm had no effect and was used as the TRV.

2.10.6 Aquatic Plants

The TRV used was 0.005 mg/L which is the chronic value recommended by the Oak Ridge National Laboratory (Sample *et al.* 1998). This value was based on incipient inhibition of *Microcystis aeruginosa* in an 8 day test.

2.10.7 Aquatic Invertebrates

The TRV used was 0.00096 mg/L which is the chronic value recommended by the Oak Ridge National Laboratory (Sample *et al.* 1998). This value was based on life cycle tests in *Daphnia magna.*

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2.11 Molybdenum

Molybdenum is usually found in nature as molybdenite (MoS_2). It is an essential nutrient for plants and animals. In plants, it is necessary for the bacterial nitrogen fixing process, and it is a cofactor for several enzymes in animals. Because the bioavailability of molybdenum increases with pH, toxicity would also likely increase with pH.

2.11.1 Mammals

Schroeder and Mitchener (1971) studied the effects of molybdenum on reproduction in the mouse through oral ingestion in water over the course of 3 generations. Total exposures were 2.5825 mg/kg/d. Mice displayed reduced reproductive success with a high incidence of runts. The NOEAL of 0.26 mg/kg/d was determined by multiplying the chronic LOAEL by an uncertainty factor of 0.1. This was adopted as the TRV for mammals.

2.11.2 Birds

Lepore and Miller (1965) studied the effects of molybdenum on reproduction over the course of 21 days in the chicken through oral ingestion. Three dose levels were administered, and the lowest dose of 500 ppm reduced embryonic viability to zero giving a chronic LOEAL of 35.3 mg/kg/d. A NOEAL was calculated by multiplying the chronic LOAEL by an uncertainty factor of 0.1. The adopted TRV for birds is 3.5 mg/kg/d.

2.11.3 Soil Invertebrates

Kabata-Pendias and Pendias (1984) reported unspecified toxic effects for terrestrial biota with the addition of 2 mg/kg molybdenum. This value was adopted as the TRV for soil invertebrates. The benchmark is intended to protect plants and other terrestrial biota from direct soil contact.

2.11.4 Terrestrial Plants

Kabata-Pendias and Pendias (1984) reported unspecified toxic effects on plants with the addition of 2 mg/kg molybdenum. This value was adopted as the TRV for terrestrial plants. The benchmark is intended to protect plants and other terrestrial biota from direct soil contact.

2.11.5 Fish

For fish, the TRV used was 0.88 mg/L which is the lowest chronic value for all aquatic organisms recommended by the Oak Ridge National Laboratory (Sample *et al.* 1998). Details of the study was not provided.

2.11.6 Aquatic Plants

For aquatic plants, the TRV used was 0.88 mg/L which is the lowest chronic value for all aquatic organisms recommended by the Oak Ridge National Laboratory (Sample *et al.* 1998). Details of the study was not provided.

2.11.7 Aquatic Invertebrates

The TRV of 0.88 mg/L was based on the recommended lowest chronic value from the Oak Ridge National Laboratory (Sample *et al.* 1998.) The value was based on 28 day life cycle tests on *Daphnia magna.*

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2.12 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) constitute a class of organic substances made up of carbon and hydrogen atoms grouped into at least two condensed aromatic ring structures. These are divided into two categories: low molecular weight compounds composed of fewer than four rings and high molecular weight compounds of four or more rings (US EPA, 2007).

PAHs are found throughout the environment in air, soil, water, and sediment. PAHs enter the environment from both natural and anthropogenic sources. Natural sources include volcanic eruptions and forest fires (ATSDR, 1995). Primary anthropogenic sources are from the extraction, transport, and refining of petroleum products and combustion products resulting from their use. PAHs are also found in coal tar, roofing materials, and surface coatings (US EPA, 2007).

Microbial degradation of PAHs is a key process in environmental fate in soils. The rate of biodegradation is dependant on the nutrient content and bacterial community in the soil. PAHs in soils undergo a weathering process such that the lighter chain fractions are removed (primarily by volatilization) (US EPA, 2007). Heavier fractions bind more readily to the soil organic matter and remain behind in the top soil horizon.

In general, the more-soluble the PAH the higher the uptake by plants, while the reverse is true for uptake by earthworms and uptake in the gastrointestinal tract of animals (Wilcke, 2000).

2.12.1 Mammals

Animals may be exposed to PAHs in soils either as the result of direct ingestion or indirect ingestion in food items. In general, the acute toxicity of PAHs to animals increases as the molecular weights increase (Kulig and Pike, 2001). Animal studies have shown that exposure to PAHs can cause harmful effects on the skin, haematopoietic system, small intestine, kidneys, mammary gland and immune response (Shore and Rattner, 2001). Other adverse effects include tumours and effects on reproduction, development and immune system. PAHs are metabolized in the liver, where toxicity is associated with cytochrome P450-mediated conversion of the parent compound to toxic metabolic intermediates (Shore and Rattner, 2001).

With respect to the high molecular weight PAHs, the US EPA identified a geometric mean of the NOAEL values of 18 mg/kg bw/day for growth and reproduction. However, as this value is higher than the lowest bounded LOAEL for reproduction, growth or mortality, the US EPA set their TRV to the highest bounded NOAEL below the lowest bounded LOAEL for reproduction, growth or survival which is 0.615 mg/kg bw/day (US EPA, 2007).

The TRV of 0.615 mg/kg-d was used for the following high molecular weight PAHs:

- Benzo(a)anthracene;
- Benzo(a)pyrene;
- Benzo(b)fluoranthene;
- Benzo(g,h,i)perylene;
- Benzo(k)fluoranthene;
- Chrysene;
- Dibenz(a,h)anthracene; and
- Indeno(1,2,3-cd)pyrene.

2.12.2 Birds

Clinical effects of PAH toxicity in birds are similar to that observed in mammals. The TRV of 0.615 mg/kg-d provided by US EPA (2007), which was used for mammals, was also used for birds for the following PAHs:

- Chrysene; and
- Dibenz(a,h)anthracene.

The US EPA Ecotox database recommends a TRV of 2 mg/kg-d for the following PAHs based on egg mortality during 2 week long studies in the domestic chicken:

- Benzo(a)anthracene;
- Benzo(a)pyrene;
- Benzo(b)fluoranthene; and
- Benzo(g,h,i)perylene;

The US EPA Ecotox database recommends a TRV of 0.2 mg/kg-d for the following PAH based on egg mortality in the domestic chicken during 2 weeks of exposure:

- Benzo(k)fluoranthene;

The US EPA Ecotox database recommends a TRV of 0.5 mg/kg-d for the following PAH based on egg mortality in the domestic chicken after 2 weeks of exposure:

- Indeno(1,2,3-cd)pyrene.

2.12.3 Soil Invertebrates

The primary mode of toxicity for PAHs in soil dwelling terrestrial invertebrates is non-specific, non-polar narcosis (Sverdrup et al., 2002a). The uptake of PAHs by earthworms

occurs primarily by direct contact with the soluble phase of the soil solution (interstitial porewater) (Fairbrother, 2005).

A TRV of 20 mg/kg was used based on the CCME (2010a) recommendation for benzo(a)pyrene and was adopted for all PAHs in the assessment. This value for benzo(a)pyrene was based on three soil invertebrates (*Eisenia fetida, Enchytraeus crypticus,* and *Folsomia fimetaria*) (CCME, 2010b).

2.12.4 Terrestrial Plants

The most important source of PAHs for plants is the atmosphere where they enter via the gaseous phase or deposit bound to particles on the plant surface (Sims and Overcash, 1983; Wilcke, 2000). Shoots and leaves, above-ground plant parts and root surfaces generally contain larger PAH concentrations compared to seeds, below-ground plant parts and root interior parts (Sims and Overcash, 1983; Wilcke, 2000).

There is limited plant toxicity data available for many PAHs. A TRV of 1 mg/kg was used based on the CCME (2010a) recommendation for benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene and was adopted for all PAHs in the assessment.

2.12.5 Aquatic Plants and Invertebrates

The TRV of 0.00065 mg/L was adopted from ORNL (Sample *et al.* 1998) based on studies with *Daphnia magna* by Trucco *et al.* (1985) for the following PAH:

- Benzo(a)anthracene;

The TRV of 0.0003 mg/L was adopted from ORNL (Sample *et al.* 1998) for benzo(a)pyrene based on studies with *Daphnia magna* by Trucco *et al.* (1985). This value was adopted for the following PAHs as well:

- Benzo(b)fluoranthene;
- Benzo(g,h,i)perylene;
- Benzo(k)fluoranthene;
- Chrysene;
- Dibenz(a,h)anthracene; and
- Indeno(1,2,3-cd)pyrene.

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2.13 Selenium

Selenium may be released into the environment from natural sources or anthropogenic releases often associated with the manufacturing and production of glass, pigments, rubber, metal alloys, textiles, and petroleum. In plants, selenium is essential for growth but in general, agricultural crops have a low tolerance to selenium (Khattak *et al.* 1989). It is an essential trace element in mammals and birds, and toxicity is most likely to occur in animals grazing on seleniferous forage.

2.13.1 Mammals

Acute effects in animals following the ingestion of plants containing high levels of selenium include abnormal posture and movement, diarrhoea, laboured respiration, abdominal pain, prostration, and death (US EPA, 2007). Chronic effects in animals include alkali disease and bind staggers. In wildlife, elevated selenium concentrations in the diet are associated with adverse reproductive and developmental effects including reduced growth or survival of young (Ohlendorf, 1989).

Rosenfeld and Beath (1954) studied the effects of selenium on reproduction over 2 generations in the rat through oral ingestion at three dose levels. The number of second generation young were reduced by 50% among females exposed to the 2.5 mg/L dose. The calculated NOAEL was 0.2 mg/kg-d and was used as the TRV in this assessment.

2.13.2 Birds

Clinical effects of selenium toxicity in birds are similar to that observed in mammals. Heinz *et. al*. (1987) studied the effects of selenium on reproduction in the mallard duck through oral ingestion in their diet. 100 ppm reduced adult survival and 25 ppm reduced duckling survival. The chronic NOAEL was determined to be 5 ppm and calculated NOAEL was 0.5 mg/kg-d.

2.13.3 Soil Invertebrates

The US EPA recommends a NOEC of 4.1 mg/kg. This value was derived from 3 studies where the geometric mean of the 20% effective concentration (EC_{20}) for three test species was calculated.

2.13.4 Terrestrial Plants

In plants, selenium is an essential element for growth. In the environment, uptake and accumulation by plants is influenced by the concentration and form of selenium present in soils (Neal, 1990). Other factors that influence selenium content in plants include pH, soil mineralogical composition, and plant species (Neal, 1990). Primary indicator plants often demonstrate an offensive odour, the intensity of which may be a qualitative indicator of

selenium concentration (Rosenfeld and Beath, 1964). Toxicity is demonstrated by stunted growth, chlorosis, pink leaf veins, and pink root tissue (US EPA, 2007). Younger plants demonstrate increased susceptibility to selenium toxicity compared to mature plants (Rosenfeld and Beath, 1964).

The US EPA recommends a NOEC of 0.52 mg/kg. This value was derived from 8 studies where the geometric mean of the maximum acceptable toxicant concentration and 20% effective concentration (EC_{20}) values for 6 species under different test conditions was calculated.

2.13.5 Fish

In fish, selenium can cause reproductive effects, as reproductive organs are highly sensitive to its effects. The lowest chronic value from the Oak Ridge National Laboratory (Sample *et al.* 1998) is 0.08832 mg/L and was based on Goettl and Davies (1976) who conducted studies on the rainbow trout during early life stages.

2.13.6 Aquatic Invertebrates

The lowest chronic value recommended by ORNL (Sample *et al.* 1998) is 0.09165 mg/L which was based on 28 day test in *Daphnia magna*.

2.13.7 Aquatic Plants

The TRV for aquatic plants of 0.1 mg/L was from studies with the green algae (*Scenedesmus obliquus*) which exhibited reduce growth in a 14 day chronic test (Vocke *et al.* 1980) as cited in ORNL (Sample *et al.* 1998).

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2.14 Toluene

2.14.1 Mammals

A number of experimental studies investigating the reproductive and developmental toxicity of toluene have been conducted using rats, mice, and rabbits. These studies provide evidence that exposures to toluene during gestation cause fetotoxicity (Donald *et al*. 1991).

Nawrot and Staples (1979) studied toluene effects on reproduction in the mouse though oral doses of 0.3, 0.5 and 1.0 mL/kg/d over days 6-12 of gestation. Toluene exposures of 0.5 and 1.0 mL/kg/d significantly reduced fetal weights. Embryo mortality was also significantly reduced by all three dose levels. Although the study was conducted over a short time period, it was conducted throughout a critical lifestage therefore, the 0.3 mL/kg/d was considered to be a chronic LOAEL. The chronic NOAEL was calculated to be 26 mg/kg-d.

2.14.2 Birds

The clinical effects of toluene toxicity in avian species are similar to that in mammals. The TRV of 26 mg/kg-d used for mammals as described above was adopted as the TRV for birds.

2.14.3 Soil Invertebrates

The TRV for soil invertebrates was adapted from the CCME (2004). In studies commissioned by the CCME, the NOEC for earthworms (*Eisenia andrei) in* coarse grained soils was equal to 80 mg/kg.

2.14.4 Terrestrial Plants

Overcash *et al*. (1982) evaluated the phytotoxicity of toluene on plant growth in corn and soybean plants in two soil types. Corn fresh weight was reduced by 30% at 200 ppm and soybean by 32% at 20,000 ppm in clay soils. In sandy loam soils, soybean fresh weight was reduced 40% by 200 ppm and corn 68% by 20,000 ppm. The recommended NOEC from ORNL (Sample *et al.* 1998) is 2000 mg/kg and was used as the TRV for this assessment.

2.14.5 Fish

The lowest chronic value recommended by ORNL (Sample *et al.* 1998) for fish was based on a study by Devlin *et al.* (1982) on *Pimephales promelas.*

2.14.6 Aquatic Invertebrates

The lowest chronic value recommended by ORNL (Sample *et al.* 1998) for Daphnids is an estimate from an EPA study on *Daphnia magna* (1980).

2.14.7 Aquatic Plants

The TRV was adopted from the lowest chronic value cited in ORNL (Sample *et al.* 1998). This value was derived from 10 day tests on *Chlorella vulgaris* by Kauss and Hutchinson (1975).

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2.15 Vanadium

Major sources of environmental contamination of vanadium result from the combustion of fossil fuels, the burning of coal wastes, the disposal of coal wastes and fly ash, and releases from metallurgical works and smelters (National Research Council of Canada (NRCC), 1980; World Health Organization (WHO), 1988; Alloway, 1990). Vanadium also enters the environment from natural sources such as continental dust, marine aerosols, and volcanic emissions.

Vanadium is found in rocks and soil in the relatively insoluble trivalent form, and can also be present in the pentavalent form as vanadates (API, 1985). Weathering and decomposed parent rock increases vanadium availability in soils. Jacks (1976) observed that the bulk of vanadium deposited in the environment was retained in the soil, mainly in association with organic matter. Vanadium is fairly mobile in neutral or alkaline soils relative to other metals, but its mobility decreases in acidic soils (US EPA, 2005).

2.15.1 Mammals

Animals exposed to acutely toxic doses of vanadium compounds exhibit immediate distress, a hemorrhagic exudate from the nose, marked diarrhea, hindlimb paralysis, labored respiration, and convulsions that can lead to death (Gosselin *et al.,* 1984). In sub-chronic studies, fatty changes were seen in the liver of rats following subcutaneous injections of ammonium vanadate (Kaku *et al*., 1971).

Domingo *et al*. (1986) studied the effects of vanadium on reproduction in the rat over a 60 day period through oral ingestion. Significant differences in reproductive parameters including number of dead young, litter size and weight of young, were observed at all dose levels. Therefore, the calculated NOEAL and TRV used was 0.21 mg/kg-d.

2.15.2 Birds

The clinical effects of vanadium toxicity in avian species are similar to that in mammals. White and Dieter (1978) studied the effects of vanadium on mortality in the mallard duck through oral ingestion for over 10 weeks. No effects were observed at any dose level (2.84, 10.34 and 110 ppm) and therefore the NOEAL was calculated to be 11.4 mg/kg-d.

2.15.3 Soil Invertebrates

Environment Canada (1995) reported the effects of vanadium on the earthworm (*Eisenia foetida*) in artificial soil and published a NOEC of 210 mg/kg.

2.15.4 Terrestrial Plants

Environment Canada (1995) studied the effects of vanadium on seedling emergence in radishes and lettuce in artificial soils. The 5 day NOEC for lettuce was 55 mg/kg and was used as the TRV for terrestrial plants.

2.15.5 Fish

Holdway and Sprague (1979) conducted toxicity tests with vanadium and early life stages of rainbow trout. The test revealed a LCV of 0.08 mg/L of vanadium in fish. This chronic value was adopted as the TRV for vanadium exposure in fish.

2.15.6 Aquatic Invertebrates

Kimball (1978) studied the chronic effects of vanadium on *Daphnia magna*. The test observed inhibited reproduction of *Daphnia magna.* A chronic value of 1.9 mg/L was developed from the freshwater life cycle test. This chronic value was used as the TRV for aquatic invertebrates.

2.15.7 Aquatic Plants

The aquatic plant criterion of 0.08 mg/L for vanadium was provided by Suter *et al*. (1996). The criterion for vanadium is intended to be protective of aquatic plants and all sensitive aquatic organisms from direct contact with surface water containing vanadium. The value of 0.08 mg/L of vanadium was adopted as the TRV for vanadium in aquatic plants.

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2.16 Xylene

Xylenes are volatile solvents widely used in chemical synthesis, consumer products, and agricultural chemicals. Xylenes occur naturally in petroleum and coal tar and are formed during forest fires; chemical industries produce xylenes from petroleum (ATSDR, 1993). They are also present as constituents in gasoline (Ransley, 1984). The commercial technical product "mixed xylenes" generally contains about 40% *m*-xylene and 20% each of *o*-xylene, *p*-xylene, and ethylbenzene, as well as small quantities of toluene (Fishbein, 1985).

Because of its volatility, most of the xylene released to the environment will enter the atmosphere where it undergoes photodegradation (ATSDR, 1993).

2.16.1 Mammals

Male and female Sprague-Dawley rats were treated by gavage with 0, 100, 400, or 800 mg/kg/day of *m*- or *p*-xylene for 90 days (Hazleton Laboratories, 1986a, 1986b). The only effects resulting from exposure to *p*-xylene were a slight reduction in weight gain and excess salivation in high-dose males and females. The highest dose of *m*-xylene produced clinical signs of toxicity such as excess salivation, hyperactivity, convulsions, and epistaxis (RAIS, 1997). Decreased body weight gains were noted for mid- and high-dose males and for high-dose females. Additional effects at the high dose were slight changes of heart, kidney, and brain weights in males and increased calcium and cholesterol levels in females (RAIS, 1997).

Marks *et al.* (1982) examined the effect of mixed xylene isomers on reproduction in the mouse through oral gavage. Doses of 2.58 mg/kg-d or greater significantly reduced fetal weights and increased incidence of malformations. The highest dose that produced no adverse effects was 2.06 mg/kg-d. This NOAEL of 2.1 mg/kg-d was adopted as the TRV for mammals.

2.16.2 Birds

The clinical effects of xylene toxicity in avian species are similar to that in mammals. The TRV of 2.1 mg/kg-d used for mammals as described above was adopted as the TRV for birds.

2.16.3 Soil Invertebrates

ESG (2002) reported a NOEC of 8 mg/kg in the earthworm (*Eisenia andrei*) in coarse grained soils. This value was adopted as the TRV for soil invertebrates.

2.16.4 Terrestrial Plants

Environment Canada (1995) conducted seedling emergence tests on radishes and lettuce. The lowest concentration at which adverse effects were found were 5 mg/kg at which there

was a 25% reduction in seedling emergence for lettuce. This value was adopted as the TRV for plants.

2.16.5 Fish

The TRV for fish is based on the EC20 value determined by Black and Birge (1982) who studied the effects of multiple chemicals on several freshwater organisms as cited in ORNL (Sample *et al.* 1998). The TRV used is 2.68 mg/L.

2.16.6 Aquatic Invertebrates

The TRV of 62.308 mg/L for aquatic invertebrates is calculated from an LC50 for common carp from the EPA Ecotox database (formerly AQUIRE).

2.16.7 Aquatic Plants

The TRV of 62.31 mg/L was adopted from the recommended lowest chronic value for all aquatic organisms from ORNL (Sample *et al.* 1998).

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2.17 Zinc

Zinc is found in almost all minerals, and is the twenty-third most abundant element in the earth's crust. The principal ores of zinc are sphalerite, smithsonite, calamine, and franklinite (O'Neill, 2001). Elemental zinc is not found in the environment, but instead occurs in compounds in the 2+ oxidation state, often as zinc sulphide or zinc oxide. Zinc demonstrates low mobility in most soils, and is strongly adsorbed to soils at pH 5 or greater (Evans, 1989). The solubility of zinc increases with decreasing pH (Alloway, 1990). The bioavailability of zinc in soils is also influenced by total zinc content, pH, organic matter, microbial activity, moisture, and interactions with other macronutrients and micronutrients (Kiekens, 1990).

2.17.1 Mammals

In animals, zinc is an essential nutrient for regulating a number of metalloenzymes (ATSDR, 2005). Absorption of zinc occurs from all segments of the intestine, although the largest proportion of absorption occurs from the duodenum (ATSDR, 2005). Following absorption by the intestine, zinc is rapidly distributed to the liver, kidneys, prostate, muscles, bones, and pancreas. Zinc salts adversely affect tissues, interfere with the metabolism of other ions such as copper, calcium, and iron, and inhibit erythrocyte production and function.

Stahl *et al.* (1990) studied the effects of zinc on reproduction in white leghorn hens after ingestion of zinc in their diet. At 2028 ppm, there was a 20% reduction in egg hatchability and a dose of 228 ppm resulted in no adverse effects. Therefore, a NOAEL of 14.5 mg/kg-d was calculated.

2.17.2 Birds

The clinical effect of zinc toxicity in avian species is similar to that in mammals, but birds are generally more sensitive to the effects of zinc. Recent research suggests that physiological scaling factors developed for mammals may not be appropriate for interspecies extrapolation to birds (Sample *et al*., 1996). The adopted TRV for birds was 14.5 mg/kg/d (Sample *et al*., 1996).

2.17.3 Sol Invertebrates

The TRV of 120 mg/kg was adopted from the US EPA Eco-SSL (2007). This value was derived from the geometric mean of the maximum acceptable toxicant concentration value for two different species (springtail and nematode), under different pH and % organic matter concentrations.

2.17.4 Terrestrial Plants

Zinc is an essential trace element for higher plants and animals. Zinc is involved in carbohydrate and protein metabolism, and is required for the synthesis of indoleacetic acid. In plants, zinc deficiency is commonly indicated by stunted growth, interveinal chlorosis, and leaf symptomatology, such as small leaves, malformations, and dieback, while zinc excess commonly produces iron chlorosis (Kiekens, 1990).

The TRV of 160 mg/kg was adopted from the US EPA Eco-SSL (2007). This value was derived from the geometric mean of the maximum acceptable toxicant concentration value for three species (soybean, oats and lettuce), under different pH and % organic matter concentrations.

2.17.5 Fish

Sephar (1976) conducted toxicity tests with zinc and the life-cycle of *Jordanella floridae*. The test revealed a chronic value of 0.036 mg/L of zinc in fish. This chronic value was adopted as the TRV for zinc exposure in fish.

2.17.6 Aquatic Invertebrates

Chapman *et al*. (1980) studied the chronic effects of zinc to *Daphnia magna*. The test observed inhibited reproduction of *Daphnia magna.* A chronic value of 0.046 mg/L was developed from the freshwater life cycle test. This chronic value was used as the TRV for aquatic invertebrates.

2.17.7 Aquatic Plants

The aquatic plant toxicity value for zinc of 0.03 mg/L was derived from a chronic study conducted by Bartlett *et al*. (1974) which demonstrated growth inhibition of aquatic plants. The chronic value of 0.03 mg/L was adopted as the TRV for zinc in aquatic plants.

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Annex 9.2.2D
Average Daily Doses, Hazard Quotients, Incremental Lifetime Cancer Risks and Exposure Ratios

Table 9.2D-1 Human Health Average Daily Doses and Hazard Quotients for Aluminum

Receptor Location	ADD (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.1E-10	9.5E-13	9.8E-15	7.4E-03	7.6E-05	3.4E-02	3.4E-06	1.5E-08	1.7E-03	4.4E-02
Laidman Lake Ecolodge	2.2E-11	1.9E-13	1.9E-15	7.4E-03	7.6E-05	3.4E-02	6.7E-07	3.0E-09	1.7E-03	4.4E-02
Pan Phillips Resort	6.8E-12	5.8E-14	6.0E-16	7.4E-03	7.6E-05	3.4E-02	2.1E-07	9.3E-10	1.7E-03	4.4E-02
Tatelkuz Lake Resort	2.7E-10	2.3E-12	2.4E-14	7.4E-03	7.6E-05	3.4E-02	8.3E-06	3.7E-08	1.7E-03	4.4E-02

Receptor Location	HQ (ADD / TRV)										Total HQ
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.1E-10	9.5E-13	7.0E-12	2.8E-03	7.4E-03	7.6E-05	3.4E-02	3.4E-06	1.5E-08	1.7E-03	0.046
Laidman Lake Ecolodge	2.2E-11	1.9E-13	1.4E-12	5.6E-04	7.4E-03	7.6E-05	3.4E-02	6.7E-07	3.0E-09	1.7E-03	0.044
Pan Phillips Resort	6.8E-12	5.8E-14	4.3E-13	1.7E-04	7.4E-03	7.6E-05	3.4E-02	2.1E-07	9.3E-10	1.7E-03	0.044
Tatelkuz Lake Resort	2.7E-10	2.3E-12	1.7E-11	6.9E-03	7.4E-03	7.6E-05	3.4E-02	8.3E-06	3.7E-08	1.7E-03	0.050

Notes: ADD - Average Daily Dose; TRV - Toxicological Reference Value; EPC - Exposure Point Concentrations; HQ - Hazard Quotient; * - Calculated as Exposure Point Concentration x Fraction of Time Exposed / TRV

Table 9.2D-2 Human Health Average Daily Doses and Hazard Quotients for Arsenic (Non-Carcinogenic)

Receptor Location	ADD (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	5.7E-05	1.5E-06	5.1E-09	1.0E-04	1.0E-06	2.8E-06	1.4E-07	6.3E-10	1.2E-04	2.8E-04
Laidman Lake Ecolodge	5.7E-05	1.5E-06	5.1E-09	1.0E-04	1.0E-06	2.8E-06	2.8E-08	1.2E-10	1.2E-04	2.8E-04
Pan Phillips Resort	5.7E-05	1.5E-06	5.1E-09	1.0E-04	1.0E-06	2.8E-06	8.6E-09	3.9E-11	1.2E-04	2.8E-04
Tatelkuz Lake Resort	5.7E-05	1.5E-06	5.1E-09	1.0E-04	1.0E-06	2.8E-06	3.4E-07	1.5E-09	1.2E-04	2.8E-04

Receptor Location	HQ (ADD / TRV)										Total HQ
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.9E-01	4.9E-03	6.0E-04	2.3E-02	**3.4E-01**	3.4E-03	9.2E-03	4.7E-04	2.1E-06	**3.9E-01**	**0.96**
Laidman Lake Ecolodge	1.9E-01	4.9E-03	6.0E-04	4.5E-03	**3.4E-01**	3.4E-03	9.2E-03	9.2E-05	4.1E-07	**3.9E-01**	**0.94**
Pan Phillips Resort	1.9E-01	4.9E-03	6.0E-04	1.4E-03	**3.4E-01**	3.4E-03	9.2E-03	2.9E-05	1.3E-07	**3.9E-01**	**0.93**
Tatelkuz Lake Resort	1.9E-01	4.9E-03	6.0E-04	5.6E-02	**3.4E-01**	3.4E-03	9.2E-03	1.1E-03	5.1E-06	**3.9E-01**	**0.99**

Notes: Bold and Underline - Represent HQ values greater than 0.2**;** ADD - Average Daily Dose; TRV - Non-Carcinogenic Toxicological Reference Value; HQ - Hazard Quotient;

* - Calculated as Exposure Point Concentration x Fraction of Time Exposed / TRV

Table 9.2D-3 Human Health Average Daily Doses and Incremental Lifetime Cancer Risks for Arsenic (Carcinogenic)

Receptor Location	ADD (Adult Alone) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	2.5E-06	6.4E-07	1.6E-09	4.4E-05	5.2E-07	9.8E-07	7.8E-08	3.5E-10	6.5E-05	1.1E-04
Laidman Lake Ecolodge	2.5E-06	6.4E-07	1.6E-09	4.4E-05	5.2E-07	9.8E-07	1.5E-08	6.9E-11	6.5E-05	1.1E-04
Pan Phillips Resort	2.5E-06	6.4E-07	1.6E-09	4.4E-05	5.2E-07	9.8E-07	4.8E-09	2.1E-11	6.5E-05	1.1E-04
Tatelkuz Lake Resort	2.5E-06	6.4E-07	1.6E-09	4.4E-05	5.2E-07	9.8E-07	1.9E-07	8.6E-10	6.5E-05	1.1E-04

Receptor Location	ILCR (Adult Alone) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	4.5E-06	1.2E-06	4.4E-08	1.7E-06	**7.9E-05**	9.3E-07	1.8E-06	1.4E-07	6.3E-10	**1.2E-04**	**2.1E-04**
Laidman Lake Ecolodge	4.5E-06	1.2E-06	4.4E-08	3.3E-07	**7.9E-05**	9.3E-07	1.8E-06	2.8E-08	1.2E-10	**1.2E-04**	**2.0E-04**
Pan Phillips Resort	4.5E-06	1.2E-06	4.4E-08	1.0E-07	**7.9E-05**	9.3E-07	1.8E-06	8.6E-09	3.9E-11	**1.2E-04**	**2.0E-04**
Tatelkuz Lake Resort	4.5E-06	1.2E-06	4.4E-08	4.1E-06	**7.9E-05**	9.3E-07	1.8E-06	3.4E-07	1.5E-09	**1.2E-04**	**2.1E-04**

Receptor Location	ADD (Amortized over Lifetime) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	6.9E-06	9.3E-07	6.9E-06	6.1E-05	6.6E-07	1.1E-06	1.1E-07	5.1E-10	9.3E-05	1.7E-04
Laidman Lake Ecolodge	6.9E-06	9.3E-07	6.9E-06	6.1E-05	6.6E-07	1.1E-06	2.3E-08	1.0E-10	9.3E-05	1.7E-04
Pan Phillips Resort	6.9E-06	9.3E-07	6.9E-06	6.1E-05	6.6E-07	1.1E-06	7.0E-09	3.1E-11	9.3E-05	1.7E-04
Tatelkuz Lake Resort	6.9E-06	9.3E-07	6.9E-06	6.1E-05	6.6E-07	1.1E-06	2.8E-07	1.3E-09	9.3E-05	1.7E-04

Receptor Location	ILCR (Amortized over Lifetime) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	**1.2E-05**	1.7E-06	4.4E-05	1.3E-06	**1.1E-04**	1.2E-06	2.0E-06	2.1E-07	9.3E-10	**1.7E-04**	**3.4E-04**
Laidman Lake Ecolodge	**1.2E-05**	1.7E-06	4.4E-05	2.5E-07	**1.1E-04**	1.2E-06	2.0E-06	4.1E-08	1.8E-10	**1.7E-04**	**3.4E-04**
Pan Phillips Resort	**1.2E-05**	1.7E-06	4.4E-05	7.8E-08	**1.1E-04**	1.2E-06	2.0E-06	1.3E-08	5.7E-11	**1.7E-04**	**3.4E-04**
Tatelkuz Lake Resort	**1.2E-05**	1.7E-06	4.4E-05	3.1E-06	**1.1E-04**	1.2E-06	2.0E-06	5.1E-07	2.3E-09	**1.7E-04**	**3.4E-04**

Notes: Bold and Underline - Represent ILCR values greater than $1.0x10^{-5}$; ADD - Average Daily Dose; TRV - Carcinogenic Toxicological Reference Value; ILCR - Incremental Lifetime Cancer Risk;
* - Calculated as Exposure Point Concentration x Fraction of Time Exposed x TRV (Unit Risk)

Table 9.2D-4 Human Health Average Daily Doses and Hazard Quotients for Benzene (Non-Carcinogenic)

Receptor Location	ADD (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	3.3E-19	8.5E-21	2.9E-23	9.5E-12	2.2E-12	1.4E-15	9.1E-12	4.8E-14	7.2E-12	2.8E-11
Laidman Lake Ecolodge	7.1E-20	1.8E-21	6.3E-24	2.0E-12	4.8E-13	3.1E-16	2.0E-12	1.0E-14	1.6E-12	6.1E-12
Pan Phillips Resort	3.2E-20	8.3E-22	2.8E-24	9.3E-13	2.2E-13	1.4E-16	8.9E-13	4.7E-15	7.0E-13	2.7E-12
Tatelkuz Lake Resort	3.9E-18	1.0E-19	3.4E-22	1.1E-10	2.7E-11	1.7E-14	1.1E-10	5.7E-13	8.5E-11	3.3E-10

Receptor Location	HQ (ADD / TRV)										Total HQ
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	6.6E-16	1.7E-17	5.2E-20	5.9E-05	1.9E-08	4.5E-09	2.9E-12	1.8E-08	9.7E-11	1.4E-08	5.9E-05
Laidman Lake Ecolodge	1.4E-16	3.7E-18	1.1E-20	1.3E-05	4.1E-09	9.7E-10	6.2E-13	4.0E-09	2.1E-11	3.1E-09	1.3E-05
Pan Phillips Resort	6.4E-17	1.7E-18	5.0E-21	5.7E-06	1.9E-09	4.4E-10	2.8E-13	1.8E-09	9.5E-12	1.4E-09	5.7E-06
Tatelkuz Lake Resort	7.8E-15	2.0E-16	6.1E-19	7.0E-04	2.2E-07	5.3E-08	3.4E-11	2.2E-07	1.1E-09	1.7E-07	7.0E-04

Notes: ADD - Average Daily Dose; TRV - Non-Carcinogenic Toxicological Reference Value; HQ - Hazard Quotient; * - Calculated as Exposure Point Concentration x Fraction of Time Exposed / TRV

Table 9.2D-5 Human Health Average Daily Doses and Incremental Lifetime Cancer Risks for Benzene (Carcinogenic)

Receptor Location	ADD (Adult Alone) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.4E-20	3.7E-21	9.1E-24	4.1E-12	1.1E-12	5.1E-16	5.1E-12	2.7E-14	4.0E-12	1.4E-11
Laidman Lake Ecolodge	3.1E-21	8.0E-22	2.0E-24	9.0E-13	2.4E-13	1.1E-16	1.1E-12	5.8E-15	8.6E-13	3.1E-12
Pan Phillips Resort	1.4E-21	3.6E-22	8.9E-25	4.1E-13	1.1E-13	5.0E-17	5.0E-13	2.6E-15	3.9E-13	1.4E-12
Tatelkuz Lake Resort	1.7E-19	4.4E-20	1.1E-22	4.9E-11	1.3E-11	6.0E-15	6.0E-11	3.2E-13	4.7E-11	1.7E-10

Receptor Location	ILCR (Adult Alone) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.2E-21	3.1E-22	3.0E-26	1.9E-10	3.5E-13	9.4E-14	4.3E-17	4.2E-13	2.2E-15	3.3E-13	1.9E-10
Laidman Lake Ecolodge	2.6E-22	6.7E-23	6.5E-27	4.2E-11	7.5E-14	2.0E-14	9.2E-18	9.2E-14	4.9E-16	7.2E-14	4.2E-11
Pan Phillips Resort	1.2E-22	3.0E-23	2.9E-27	1.9E-11	3.4E-14	9.2E-15	4.2E-18	4.1E-14	2.2E-16	3.3E-14	1.9E-11
Tatelkuz Lake Resort	1.4E-20	3.7E-21	3.6E-25	2.3E-09	4.1E-12	1.1E-12	5.0E-16	5.0E-12	2.7E-14	3.9E-12	2.3E-09

Receptor Location	ADD (Amortized over Lifetime) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	4.0E-20	5.3E-21	4.0E-20	5.7E-12	1.6E-12	5.9E-16	7.5E-12	4.0E-14	5.7E-12	2.1E-11
Laidman Lake Ecolodge	8.6E-21	1.2E-21	8.6E-21	1.2E-12	3.4E-13	1.3E-16	1.6E-12	8.5E-15	1.2E-12	4.4E-12
Pan Phillips Resort	3.9E-21	5.2E-22	3.9E-21	5.6E-13	1.6E-13	5.8E-17	7.3E-13	3.9E-15	5.6E-13	2.0E-12
Tatelkuz Lake Resort	4.7E-19	6.3E-20	4.7E-19	6.8E-11	1.9E-11	7.0E-15	8.8E-11	4.7E-13	6.8E-11	2.4E-10

Receptor Location	ILCR (Amortized over Lifetime) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	3.3E-21	4.5E-22	1.3E-22	1.1E-10	4.8E-13	1.3E-13	4.9E-17	6.2E-13	3.3E-15	4.8E-13	1.2E-10
Laidman Lake Ecolodge	7.2E-22	9.6E-23	2.8E-23	2.5E-11	1.0E-13	2.9E-14	1.1E-17	1.3E-13	7.1E-16	1.0E-13	2.5E-11
Pan Phillips Resort	3.3E-22	4.4E-23	1.3E-23	1.1E-11	4.7E-14	1.3E-14	4.8E-18	6.1E-14	3.2E-16	4.7E-14	1.1E-11
Tatelkuz Lake Resort	3.9E-20	5.3E-21	1.6E-21	1.3E-09	5.7E-12	1.6E-12	5.8E-16	7.4E-12	3.9E-14	5.7E-12	1.4E-09

Notes: ADD - Average Daily Dose; TRV - Carcinogenic Toxicological Reference Value; ILCR - Incremental Lifetime Cancer Risk;

* - Calculated as Exposure Point Concentration x Fraction of Time Exposed x TRV (Unit Risk)

Table 9.2D-6. Human Health Average Daily Dosesand Incremental Lifetime Cancer Risks for Benzo(a)anthracene (Carcinogenic)

Receptor Location	ADD (Adult Alone) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	4.0E-19	4.5E-19	2.5E-22	1.1E-14	2.5E-13	6.4E-16	6.0E-12	3.4E-14	6.4E-11	7.0E-11
Laidman Lake Ecolodge	7.6E-20	8.4E-20	4.8E-23	2.1E-15	4.8E-14	1.2E-16	1.1E-12	6.4E-15	1.2E-11	1.3E-11
Pan Phillips Resort	3.7E-20	4.1E-20	2.3E-23	1.0E-15	2.3E-14	5.9E-17	5.6E-13	3.1E-15	5.8E-12	6.4E-12
Tatelkuz Lake Resort	1.8E-17	2.0E-17	1.1E-20	5.0E-13	1.1E-11	2.8E-14	2.7E-10	1.5E-12	2.8E-09	3.1E-09

Receptor Location	ILCR (Adult Alone) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	2.9E-19	3.7E-19	2.8E-23	2.6E-14	8.3E-15	1.8E-13	4.7E-16	4.4E-12	2.5E-14	4.6E-11	5.1E-11
Laidman Lake Ecolodge	5.5E-20	7.0E-20	5.2E-24	4.9E-15	1.6E-15	3.5E-14	8.8E-17	8.3E-13	4.7E-15	8.7E-12	9.6E-12
Pan Phillips Resort	2.7E-20	3.4E-20	2.6E-24	2.4E-15	7.6E-16	1.7E-14	4.3E-17	4.1E-13	2.3E-15	4.3E-12	4.7E-12
Tatelkuz Lake Resort	1.3E-17	1.6E-17	1.2E-21	1.1E-12	3.7E-13	8.1E-12	2.0E-14	1.9E-10	1.1E-12	2.0E-09	2.2E-09

Receptor Location	ADD (Amortized over Lifetime) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.1E-18	6.4E-19	1.1E-18	1.6E-14	3.6E-13	7.4E-16	8.9E-12	5.0E-14	9.2E-11	1.0E-10
Laidman Lake Ecolodge	2.1E-19	1.2E-19	2.1E-19	3.0E-15	6.7E-14	1.4E-16	1.7E-12	9.3E-15	1.7E-11	1.9E-11
Pan Phillips Resort	1.0E-19	5.9E-20	1.0E-19	1.4E-15	3.3E-14	6.8E-17	8.1E-13	4.6E-15	8.4E-12	9.3E-12
Tatelkuz Lake Resort	4.9E-17	2.8E-17	4.9E-17	6.9E-13	1.6E-11	3.2E-14	3.9E-10	2.2E-12	4.0E-09	4.4E-09

Receptor Location	ILCR (Amortized over Lifetime) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	8.1E-19	5.4E-19	1.2E-19	8.7E-14	1.1E-14	2.6E-13	5.4E-16	6.5E-12	3.6E-14	6.7E-11	7.3E-11
Laidman Lake Ecolodge	1.5E-19	1.0E-19	2.3E-20	1.6E-14	2.2E-15	4.9E-14	1.0E-16	1.2E-12	6.8E-15	1.3E-11	1.4E-11
Pan Phillips Resort	7.4E-20	4.9E-20	1.1E-20	8.0E-15	1.1E-15	2.4E-14	5.0E-17	5.9E-13	3.3E-15	6.1E-12	6.7E-12
Tatelkuz Lake Resort	3.6E-17	2.4E-17	5.4E-18	3.8E-12	5.1E-13	1.1E-11	2.4E-14	2.8E-10	1.6E-12	2.9E-09	3.2E-09

Notes: ADD - Average Daily Dose; TRV - Carcinogenic Toxicological Reference Value; ILCR - Incremental Lifetime Cancer Risk;

* - Calculated as Exposure Point Concentration x Fraction of Time Exposed x TRV (Unit Risk)

Table 9.2D-7.Human Health Average Daily Doses and Incremental Lifetime Cancer Risks for Benzo(a)pyrene (Carcinogenic)

Receptor Location	ADD (Adult Alone) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.8E-20	2.0E-20	1.1E-23	2.2E-16	6.5E-15	1.5E-16	1.4E-12	8.1E-15	3.0E-12	4.5E-12
Laidman Lake Ecolodge	2.7E-21	3.0E-21	1.7E-24	3.4E-17	1.0E-15	2.4E-17	2.2E-13	1.3E-15	4.7E-13	7.0E-13
Pan Phillips Resort	9.5E-22	1.1E-21	6.0E-25	1.2E-17	3.5E-16	8.3E-18	7.8E-14	4.4E-16	1.6E-13	2.4E-13
Tatelkuz Lake Resort	8.4E-20	9.3E-20	5.3E-23	1.0E-15	3.1E-14	7.3E-16	6.8E-12	3.9E-14	1.4E-11	2.1E-11

Receptor Location	ILCR (Adult Alone) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	4.0E-20	5.1E-20	3.4E-25	2.6E-15	5.0E-16	1.5E-14	3.5E-16	3.3E-12	1.9E-14	6.9E-12	1.0E-11
Laidman Lake Ecolodge	6.3E-21	8.0E-21	5.4E-26	4.0E-16	7.7E-17	2.3E-15	5.5E-17	5.1E-13	2.9E-15	1.1E-12	1.6E-12
Pan Phillips Resort	2.2E-21	2.8E-21	1.9E-26	1.4E-16	2.7E-17	8.1E-16	1.9E-17	1.8E-13	1.0E-15	3.8E-13	5.6E-13
Tatelkuz Lake Resort	1.9E-19	2.4E-19	1.6E-24	1.2E-14	2.4E-15	7.1E-14	1.7E-15	1.6E-11	8.9E-14	3.3E-11	4.9E-11

Receptor Location	ADD (Amortized over Lifetime) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	4.8E-20	2.8E-20	4.8E-20	3.0E-16	9.1E-15	1.8E-16	2.1E-12	1.2E-14	4.3E-12	6.5E-12
Laidman Lake Ecolodge	7.6E-21	4.4E-21	7.6E-21	4.6E-17	1.3E-15	2.8E-17	3.3E-13	1.9E-15	6.8E-13	1.0E-12
Pan Phillips Resort	2.6E-21	1.5E-21	2.6E-21	1.6E-17	4.5E-16	9.6E-18	1.1E-13	6.4E-16	2.4E-13	3.5E-13
Tatelkuz Lake Resort	2.3E-19	1.3E-19	2.3E-19	1.4E-15	4.0E-14	8.5E-16	1.0E-11	5.7E-14	2.1E-11	3.1E-11

Receptor Location	ILCR (Amortized over Lifetime) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.1E-19	7.4E-20	1.5E-21	1.5E-15	6.8E-16	2.1E-14	4.1E-16	4.8E-12	2.7E-14	1.0E-11	1.5E-11
Laidman Lake Ecolodge	1.7E-20	1.2E-20	2.3E-22	2.3E-16	1.1E-16	3.0E-15	6.4E-17	7.5E-13	4.3E-15	1.6E-12	2.3E-12
Pan Phillips Resort	6.1E-21	4.0E-21	8.2E-23	8.2E-17	3.7E-17	1.0E-15	2.2E-17	2.6E-13	1.5E-15	5.4E-13	8.1E-13
Tatelkuz Lake Resort	5.3E-19	3.5E-19	7.2E-21	7.2E-15	3.3E-15	9.2E-14	2.0E-15	2.3E-11	1.3E-13	4.8E-11	7.1E-11

Notes: ADD - Average Daily Dose; TRV - Carcinogenic Toxicological Reference Value; ILCR - Incremental Lifetime Cancer Risk;

* - Calculated as Exposure Point Concentration x Fraction of Time Exposed x TRV (Unit Risk)

Table 9.2D-8. Human Health Average Daily Doses and Incremental Lifetime Cancer Risks for Benzo(b)fluoranthene

Receptor Location	ADD (Adult Alone) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	2.4E-20	2.6E-20	1.5E-23	3.8E-17	1.4E-15	7.9E-18	7.4E-14	4.2E-16	4.1E-14	1.2E-13
Laidman Lake Ecolodge	3.7E-21	4.1E-21	2.3E-24	5.9E-18	2.1E-16	1.2E-18	1.2E-14	6.5E-17	6.3E-15	1.8E-14
Pan Phillips Resort	1.3E-21	1.4E-21	8.2E-25	2.0E-18	7.4E-17	4.3E-19	4.0E-15	2.3E-17	2.2E-15	6.3E-15
Tatelkuz Lake Resort	1.1E-19	1.3E-19	7.2E-23	1.8E-16	6.5E-15	3.8E-17	3.5E-13	2.0E-15	1.9E-13	5.6E-13

Receptor Location	ILCR (Adult Alone) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.7E-20	1.9E-20	1.7E-24	1.9E-15	2.7E-17	9.9E-16	5.8E-18	5.4E-14	3.0E-16	3.0E-14	8.6E-14
Laidman Lake Ecolodge	2.7E-21	3.0E-21	2.6E-25	2.9E-16	4.3E-18	1.5E-16	9.0E-19	8.4E-15	4.7E-17	4.6E-15	1.3E-14
Pan Phillips Resort	9.4E-22	1.1E-21	9.0E-26	1.0E-16	1.5E-18	5.4E-17	3.1E-19	2.9E-15	1.7E-17	1.6E-15	4.7E-15
Tatelkuz Lake Resort	8.3E-20	9.2E-20	7.9E-24	8.9E-15	1.3E-16	4.7E-15	2.7E-17	2.6E-13	1.5E-15	1.4E-13	4.1E-13

Receptor Location	ADD (Amortized over Lifetime) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	6.6E-20	3.8E-20	6.6E-20	5.2E-17	1.9E-15	9.1E-18	1.1E-13	6.1E-16	5.8E-14	1.7E-13
Laidman Lake Ecolodge	1.0E-20	6.0E-21	1.0E-20	8.1E-18	3.0E-16	1.4E-18	1.7E-14	9.5E-17	9.1E-15	2.6E-14
Pan Phillips Resort	3.6E-21	2.1E-21	3.6E-21	2.8E-18	1.0E-16	5.0E-19	5.9E-15	3.3E-17	3.2E-15	9.2E-15
Tatelkuz Lake Resort	3.1E-19	1.8E-19	3.1E-19	2.5E-16	9.1E-15	4.4E-17	5.2E-13	2.9E-15	2.8E-13	8.1E-13

Receptor Location	ILCR (Amortized over Lifetime) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	4.8E-20	3.2E-20	7.2E-21	6.2E-15	3.8E-17	1.4E-15	6.7E-18	7.9E-14	4.5E-16	4.3E-14	1.3E-13
Laidman Lake Ecolodge	7.5E-21	5.0E-21	1.1E-21	9.7E-16	5.9E-18	2.2E-16	1.0E-18	1.2E-14	7.0E-17	6.7E-15	2.0E-14
Pan Phillips Resort	2.6E-21	1.7E-21	3.9E-22	3.4E-16	2.1E-18	7.6E-17	3.6E-19	4.3E-15	2.4E-17	2.3E-15	7.0E-15
Tatelkuz Lake Resort	2.3E-19	1.5E-19	3.5E-20	3.0E-14	1.8E-16	6.7E-15	3.2E-17	3.8E-13	2.1E-15	2.0E-13	6.1E-13

Notes: ADD - Average Daily Dose; TRV - Carcinogenic Toxicological Reference Value; ILCR - Incremental Lifetime Cancer Risk;

* - Calculated as Exposure Point Concentration x Fraction of Time Exposed x TRV (Unit Risk)

Table 9.2D-9 Human Health Average Daily Doses and Hazard Quotients for Benzo(g,h,i)perylene (Non-Carcinogenic)

Receptor Location	ADD (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.3E-17	1.6E-18	1.1E-21	2.5E-18	8.0E-17	1.7E-18	2.1E-14	1.0E-16	2.1E-15	2.3E-14
Laidman Lake Ecolodge	2.0E-18	2.5E-19	1.7E-22	4.0E-19	1.2E-17	2.7E-19	3.3E-15	1.6E-17	3.3E-16	3.7E-15
Pan Phillips Resort	6.9E-19	8.8E-20	6.1E-23	1.4E-19	4.4E-18	9.5E-20	1.2E-15	5.7E-18	1.1E-16	1.3E-15
Tatelkuz Lake Resort	6.1E-17	7.7E-18	5.4E-21	1.2E-17	3.8E-16	8.4E-18	1.0E-13	5.0E-16	1.0E-14	1.1E-13

Receptor Location	HQ (ADD / TRV)										Total HQ
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.8E-15	2.0E-16	1.6E-19	8.8E-12	3.6E-16	1.1E-14	2.5E-16	3.0E-12	1.5E-14	3.0E-13	1.2E-11
Laidman Lake Ecolodge	2.8E-16	3.1E-17	2.6E-20	1.4E-12	5.6E-17	1.8E-15	3.8E-17	4.7E-13	2.3E-15	4.6E-14	1.9E-12
Pan Phillips Resort	9.7E-17	1.1E-17	9.0E-21	4.8E-13	2.0E-17	6.1E-16	1.3E-17	1.6E-13	8.0E-16	1.6E-14	6.6E-13
Tatelkuz Lake Resort	8.5E-15	9.5E-16	7.9E-19	4.2E-11	1.7E-15	5.4E-14	1.2E-15	1.4E-11	7.0E-14	1.4E-12	5.8E-11

Receptor Location	ADD (Adult Alone) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	5.5E-19	7.0E-19	3.5E-22	1.1E-18	4.1E-17	6.2E-19	1.2E-14	5.8E-17	1.2E-15	1.3E-14
Laidman Lake Ecolodge	8.6E-20	1.1E-19	5.4E-23	1.7E-19	6.4E-18	9.7E-20	1.8E-15	9.0E-18	1.8E-16	2.0E-15
Pan Phillips Resort	3.0E-20	3.8E-20	1.9E-23	6.1E-20	2.2E-18	3.4E-20	6.4E-16	3.1E-18	6.4E-17	7.1E-16
Tatelkuz Lake Resort	2.7E-18	3.4E-18	1.7E-21	5.3E-18	2.0E-16	3.0E-18	5.7E-14	2.8E-16	5.6E-15	6.3E-14

Receptor Location	ADD (Amortized over Lifetime) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.5E-18	1.0E-18	1.5E-18	1.5E-18	1.1E-16	7.2E-19	1.7E-14	8.5E-17	1.7E-15	1.9E-14
Laidman Lake Ecolodge	2.4E-19	1.6E-19	2.4E-19	2.4E-19	1.8E-17	1.1E-19	2.7E-15	1.3E-17	2.6E-16	3.0E-15
Pan Phillips Resort	8.3E-20	5.5E-20	8.3E-20	8.4E-20	6.1E-18	3.9E-20	9.4E-16	4.6E-18	9.2E-17	1.0E-15
Tatelkuz Lake Resort	7.3E-18	4.8E-18	7.3E-18	7.4E-18	5.4E-16	3.5E-18	8.3E-14	4.1E-16	8.1E-15	9.2E-14

Notes: ADD - Average Daily Dose; TRV - Non-Carcinogenic Toxicological Reference Value; HQ - Hazard Quotient; * - Calculated as Exposure Point Concentration x Fraction of Time Exposed / TRV

Table 9.2D-10 Human Health Average Daily Doses and Incremental Lifetime Cancer Risks for Benzo(k)fluoranthene (Carcinogen)

Receptor Location	ADD (Adult Alone) (mg/kg-d)									Total ADD
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	7.1E-20	9.0E-20	4.5E-23	1.8E-17	6.7E-16	2.4E-16	2.3E-12	1.3E-14	1.9E-14	2.3E-12
Laidman Lake Ecolodge	1.1E-20	1.4E-20	6.9E-24	2.9E-18	1.0E-16	3.8E-17	3.5E-13	2.0E-15	3.0E-15	3.6E-13
Pan Phillips Resort	3.8E-21	4.9E-21	2.4E-24	9.9E-19	3.6E-17	1.3E-17	1.2E-13	6.9E-16	1.0E-15	1.2E-13
Tatelkuz Lake Resort	3.4E-19	4.3E-19	2.1E-22	8.8E-17	3.2E-15	1.2E-15	1.1E-11	6.1E-14	9.1E-14	1.1E-11

Receptor Location	ILCR (Adult Alone) (ADD x CSF)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	5.2E-19	6.5E-19	4.9E-24	1.6E-15	1.3E-16	4.9E-15	1.8E-15	1.7E-11	9.3E-14	1.4E-13	1.7E-11
Laidman Lake Ecolodge	8.0E-20	1.0E-19	7.6E-25	2.5E-16	2.1E-17	7.6E-16	2.8E-16	2.6E-12	1.5E-14	2.2E-14	2.6E-12
Pan Phillips Resort	2.8E-20	3.5E-20	2.7E-25	8.8E-17	7.3E-18	2.6E-16	9.6E-17	9.0E-13	5.1E-15	7.5E-15	9.1E-13
Tatelkuz Lake Resort	2.5E-18	3.1E-18	2.3E-23	7.7E-15	6.4E-16	2.3E-14	8.5E-15	7.9E-11	4.5E-13	6.6E-13	8.0E-11

Receptor Location	ADD (Amortized over Lifetime) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	2.0E-19	1.3E-19	2.0E-19	2.5E-17	9.4E-16	2.8E-16	3.3E-12	1.9E-14	2.7E-14	3.4E-12
Laidman Lake Ecolodge	3.0E-20	2.0E-20	3.0E-20	3.9E-18	1.5E-16	4.4E-17	5.2E-13	2.9E-15	4.3E-15	5.2E-13
Pan Phillips Resort	1.1E-20	7.0E-21	1.1E-20	1.4E-18	5.1E-17	1.5E-17	1.8E-13	1.0E-15	1.5E-15	1.8E-13
Tatelkuz Lake Resort	9.3E-19	6.2E-19	9.3E-19	1.2E-16	4.5E-15	1.3E-15	1.6E-11	9.0E-14	1.3E-13	1.6E-11

Receptor Location	ILCR (Amortized over Lifetime) (ADD x CSF)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.4E-18	9.4E-19	2.2E-20	5.4E-15	1.8E-16	6.9E-15	2.1E-15	2.4E-11	1.4E-13	2.0E-13	2.5E-11
Laidman Lake Ecolodge	2.2E-19	1.5E-19	3.3E-21	8.4E-16	2.9E-17	1.1E-15	3.2E-16	3.8E-12	2.1E-14	3.1E-14	3.8E-12
Pan Phillips Resort	7.7E-20	5.1E-20	1.2E-21	2.9E-16	1.0E-17	3.7E-16	1.1E-16	1.3E-12	7.4E-15	1.1E-14	1.3E-12
Tatelkuz Lake Resort	6.8E-18	4.5E-18	1.0E-19	2.6E-14	8.8E-16	3.3E-14	9.8E-15	1.2E-10	6.6E-13	9.6E-13	1.2E-10

Notes: ADD - Average Daily Dose; TRV - Carcinogenic Toxicological Reference Value; ILCR - Incremental Lifetime Cancer Risk;

* - Calculated as Exposure Point Concentration x Fraction of Time Exposed x TRV (Unit Risk)

Table 9.2D-11 Human Health Average Daily Doses and Hazard Quotients for Cadmium

Receptor Location	ADD (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.3E-06	2.2E-08	2.2E-10	2.3E-06	4.6E-08	9.4E-06	3.6E-09	1.6E-11	6.5E-06	1.9E-05
Laidman Lake Ecolodge	1.3E-06	2.2E-08	2.2E-10	2.3E-06	4.6E-08	9.4E-06	7.2E-10	3.2E-12	6.5E-06	1.9E-05
Pan Phillips Resort	1.3E-06	2.2E-08	2.2E-10	2.3E-06	4.6E-08	9.4E-06	2.2E-10	9.8E-13	6.5E-06	1.9E-05
Tatelkuz Lake Resort	1.3E-06	2.2E-08	2.2E-10	2.3E-06	4.6E-08	9.4E-06	1.0E-08	4.6E-11	6.5E-06	1.9E-05

Receptor Location	HQ (ADD / TRV)										Total HQ
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.3E-03	2.2E-05	3.9E-05	1.3E-03	2.3E-03	4.6E-05	9.4E-03	3.6E-06	1.6E-08	6.5E-03	0.021
Laidman Lake Ecolodge	1.3E-03	2.2E-05	3.9E-05	2.6E-04	2.3E-03	4.6E-05	9.4E-03	7.2E-07	3.2E-09	6.5E-03	0.020
Pan Phillips Resort	1.3E-03	2.2E-05	3.9E-05	7.8E-05	2.3E-03	4.6E-05	9.4E-03	2.2E-07	9.8E-10	6.5E-03	0.020
Tatelkuz Lake Resort	1.3E-03	2.2E-05	3.9E-05	3.7E-03	2.3E-03	4.6E-05	9.4E-03	1.0E-05	4.6E-08	6.5E-03	0.023

Notes: ADD - Average Daily Dose; TRV - Non-Carcinogenic Toxicological Reference Value; HQ - Hazard Quotient; * - Calculated as Exposure Point Concentration x Fraction of Time Exposed / TF

Table 9.2D-12 Human Health Average Daily Doses and Incremental Lifetime Cancer Risks for Chrysene (Carcinogenic)

Receptor Location	ADD (Adult Alone) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.8E-17	2.2E-17	1.1E-20	2.6E-14	5.8E-13	1.1E-15	1.1E-11	5.9E-14	1.5E-10	1.6E-10
Laidman Lake Ecolodge	3.8E-18	4.9E-18	2.4E-21	5.7E-15	1.3E-13	2.4E-16	2.3E-12	1.3E-14	3.2E-11	3.4E-11
Pan Phillips Resort	1.7E-18	2.1E-18	1.1E-21	2.5E-15	5.6E-14	1.0E-16	1.0E-12	5.6E-15	1.4E-11	1.5E-11
Tatelkuz Lake Resort	6.4E-17	8.1E-17	4.0E-20	9.5E-14	2.1E-12	3.9E-15	3.8E-11	2.1E-13	5.3E-10	5.7E-10

Receptor Location	ILCR (Adult Alone) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.3E-19	1.6E-19	1.2E-22	7.7E-14	1.9E-16	4.3E-15	8.0E-18	7.8E-14	4.3E-16	1.1E-12	1.2E-12
Laidman Lake Ecolodge	2.8E-20	3.6E-20	2.7E-23	1.7E-14	4.2E-17	9.3E-16	1.7E-18	1.7E-14	9.3E-17	2.3E-13	2.7E-13
Pan Phillips Resort	1.2E-20	1.6E-20	1.2E-23	7.3E-15	1.8E-17	4.1E-16	7.6E-19	7.4E-15	4.1E-17	1.0E-13	1.2E-13
Tatelkuz Lake Resort	4.6E-19	5.9E-19	4.4E-22	2.8E-13	6.9E-16	1.5E-14	2.9E-17	2.8E-13	1.5E-15	3.9E-12	4.4E-12

Receptor Location	ADD (Amortized over Lifetime) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	4.9E-17	3.2E-17	4.9E-17	3.6E-14	8.2E-13	1.3E-15	1.6E-11	8.6E-14	2.1E-10	2.3E-10
Laidman Lake Ecolodge	1.1E-17	7.0E-18	1.1E-17	7.9E-15	1.8E-13	2.7E-16	3.4E-12	1.9E-14	4.6E-11	4.9E-11
Pan Phillips Resort	4.7E-18	3.1E-18	4.7E-18	3.5E-15	7.8E-14	1.2E-16	1.5E-12	8.2E-15	2.0E-11	2.2E-11
Tatelkuz Lake Resort	1.8E-16	1.2E-16	1.8E-16	1.3E-13	3.0E-12	4.6E-15	5.6E-11	3.1E-13	7.6E-10	8.2E-10

Receptor Location	ILCR (Amortized over Lifetime) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	3.6E-19	2.4E-19	5.4E-19	2.6E-13	2.7E-16	6.0E-15	9.2E-18	1.1E-13	6.3E-16	1.5E-12	1.9E-12
Laidman Lake Ecolodge	7.8E-20	5.1E-20	1.2E-19	5.6E-14	5.8E-17	1.3E-15	2.0E-18	2.5E-14	1.4E-16	3.3E-13	4.2E-13
Pan Phillips Resort	3.4E-20	2.2E-20	5.1E-20	2.4E-14	2.5E-17	5.7E-16	8.8E-19	1.1E-14	6.0E-17	1.5E-13	1.8E-13
Tatelkuz Lake Resort	1.3E-18	8.5E-19	1.9E-18	9.2E-13	9.6E-16	2.2E-14	3.3E-17	4.1E-13	2.3E-15	5.5E-12	6.9E-12

Notes: ADD - Average Daily Dose; TRV - Carcinogenic Toxicological Reference Value; ILCR - Incremental Lifetime Cancer Risk;

* - Calculated as Exposure Point Concentration x Fraction of Time Exposed x TRV (Unit Risk)

Table 9.2D-13 Human Health Average Daily Doses and Hazard Quotients for Cyanide

Receptor Location	ADD (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	4.1E-18	3.6E-19	3.6E-22	6.1E-03	6.2E-05	N/A	2.6E-15	1.5E-17	4.6E-10	6.1E-03
Laidman Lake Ecolodge	9.0E-19	7.8E-20	8.0E-23	6.1E-03	6.2E-05	N/A	5.7E-16	3.2E-18	1.0E-10	6.1E-03
Pan Phillips Resort	1.9E-19	1.6E-20	1.7E-23	6.1E-03	6.2E-05	N/A	1.2E-16	6.8E-19	2.1E-11	6.1E-03
MPOI	1.9E-17	1.7E-18	1.7E-21	6.1E-03	6.2E-05	N/A	1.2E-14	6.9E-17	2.2E-09	6.1E-03

Receptor Location	HQ (ADD / TRV)										Total HQ
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	2.1E-16	1.8E-17	8.1E-19	9.9E-04	**3.0E-01**	3.1E-03	N/A	1.3E-13	7.3E-16	2.3E-08	**0.31**
Laidman Lake Ecolodge	4.5E-17	3.9E-18	1.8E-19	2.2E-04	**3.0E-01**	3.1E-03	N/A	2.8E-14	1.6E-16	5.0E-09	**0.31**
Pan Phillips Resort	9.6E-18	8.2E-19	3.7E-20	4.6E-05	**3.0E-01**	3.1E-03	N/A	6.0E-15	3.4E-17	1.1E-09	**0.31**
Tatelkuz Lake Resort	9.7E-16	8.3E-17	3.8E-18	4.7E-03	**3.0E-01**	3.1E-03	N/A	6.1E-13	3.4E-15	1.1E-07	**0.31**

Notes: Bold and Underline - Represent HQ values greater than 0.2**;** ADD - Average Daily Dose; N/A -= Not Applicable; TRV - Non-Carcinogenic Toxicological Reference Value; HQ - Hazard Quotient;

* - Calculated as Exposure Point Concentration x Fraction of Time Exposed / TRV

Table 9.2D-14 Human Health Average Daily Doses and Incremental Lifetime Cancer Risks for Dibenz(a,h)anthracene

Receptor Location	ADD (Adult Alone) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	2.9E-20	3.6E-20	1.8E-23	2.4E-18	1.3E-16	6.7E-15	6.2E-11	3.5E-13	4.8E-15	6.3E-11
Laidman Lake Ecolodge	4.4E-21	5.6E-21	2.8E-24	3.8E-19	2.0E-17	1.0E-15	9.7E-12	5.5E-14	7.4E-16	9.7E-12
Pan Phillips Resort	1.6E-21	2.0E-21	9.8E-25	1.3E-19	7.1E-18	3.6E-16	3.4E-12	1.9E-14	2.6E-16	3.4E-12
Tatelkuz Lake Resort	1.4E-19	1.7E-19	8.6E-23	1.2E-17	6.3E-16	3.2E-14	3.0E-10	1.7E-12	2.3E-14	3.0E-10

Receptor Location	ILCR (Adult Alone) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	2.1E-19	2.6E-19	2.2E-23	1.6E-14	1.8E-17	9.6E-16	4.9E-14	4.5E-10	2.6E-12	3.5E-14	4.6E-10
Laidman Lake Ecolodge	3.2E-20	4.1E-20	3.4E-24	2.5E-15	2.8E-18	1.5E-16	7.6E-15	7.1E-11	4.0E-13	5.4E-15	7.1E-11
Pan Phillips Resort	1.1E-20	1.4E-20	1.2E-24	8.9E-16	9.6E-19	5.2E-17	2.7E-15	2.5E-11	1.4E-13	1.9E-15	2.5E-11
Tatelkuz Lake Resort	1.0E-18	1.3E-18	1.0E-22	7.8E-14	8.5E-17	4.6E-15	2.3E-13	2.2E-09	1.2E-11	1.7E-13	2.2E-09

Receptor Location	ADD (Amortized over Lifetime) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	7.9E-20	5.2E-20	7.9E-20	3.4E-18	1.9E-16	7.7E-15	9.1E-11	5.2E-13	6.8E-15	9.2E-11
Laidman Lake Ecolodge	1.2E-20	8.1E-21	1.2E-20	5.2E-19	2.9E-17	1.2E-15	1.4E-11	8.0E-14	1.1E-15	1.4E-11
Pan Phillips Resort	4.3E-21	2.8E-21	4.3E-21	1.8E-19	1.0E-17	4.2E-16	5.0E-12	2.8E-14	3.7E-16	5.0E-12
Tatelkuz Lake Resort	3.8E-19	2.5E-19	3.8E-19	1.6E-17	8.9E-16	3.7E-14	4.4E-10	2.5E-12	3.3E-14	4.4E-10

Receptor Location	ILCR (Amortized over Lifetime) (ADD x TRV)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	5.8E-19	3.8E-19	9.5E-20	5.4E-14	2.4E-17	1.4E-15	5.6E-14	6.7E-10	3.8E-12	5.0E-14	6.7E-10
Laidman Lake Ecolodge	9.0E-20	5.9E-20	1.5E-20	8.5E-15	3.8E-18	2.1E-16	8.8E-15	1.0E-10	5.9E-13	7.8E-15	1.0E-10
Pan Phillips Resort	3.1E-20	2.1E-20	5.2E-21	3.0E-15	1.3E-18	7.3E-17	3.1E-15	3.6E-11	2.1E-13	2.7E-15	3.6E-11
Tatelkuz Lake Resort	2.8E-18	1.8E-18	4.5E-19	2.6E-13	1.2E-16	6.5E-15	2.7E-13	3.2E-09	1.8E-11	2.4E-13	3.2E-09

Notes: ADD - Average Daily Dose; TRV - Carcinogenic Toxicological Reference Value; ILCR - Incremental Lifetime Cancer Risk;

* - Calculated as Exposure Point Concentration x Fraction of Time Exposed x TRV (Unit Risk)

Table 9.2D-15 Human Health Average Daily Doses and Hazard Quotients for Ethylbenzene

Receptor Location	ADD (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	2.3E-19	6.0E-21	2.1E-23	1.0E-12	9.1E-13	1.7E-15	1.0E-11	5.6E-14	4.4E-12	1.7E-11
Laidman Lake Ecolodge	5.1E-20	1.3E-21	4.5E-24	2.2E-13	2.0E-13	3.6E-16	2.3E-12	1.2E-14	9.7E-13	3.7E-12
Pan Phillips Resort	2.2E-20	5.8E-22	2.0E-24	9.6E-14	8.8E-14	1.6E-16	1.0E-12	5.4E-15	4.3E-13	1.6E-12
Tatelkuz Lake Resort	1.2E-18	3.1E-20	1.0E-22	5.1E-12	4.6E-12	8.5E-15	5.3E-11	2.9E-13	2.3E-11	8.5E-11

Receptor Location	HQ (ADD / TRV)										Total HQ
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	2.3E-18	6.0E-20	3.7E-23	8.3E-09	1.0E-11	9.1E-12	1.7E-14	1.0E-10	5.6E-13	4.4E-11	8.5E-09
Laidman Lake Ecolodge	5.1E-19	1.3E-20	8.0E-24	1.8E-09	2.2E-12	2.0E-12	3.6E-15	2.3E-11	1.2E-13	9.7E-12	1.8E-09
Pan Phillips Resort	2.2E-19	5.8E-21	3.5E-24	8.0E-10	9.6E-13	8.8E-13	1.6E-15	1.0E-11	5.4E-14	4.3E-12	8.1E-10
Tatelkuz Lake Resort	1.2E-17	3.1E-19	1.9E-22	4.2E-08	5.1E-11	4.6E-11	8.5E-14	5.3E-10	2.9E-12	2.3E-10	4.3E-08

Notes: ADD - Average Daily Dose; TRV - Non-Carcinogenic Toxicological Reference Value; HQ - Hazard Quotient; * - Calculated as Exposure Point Concentration x Fraction of Time Exposed / TRV

Table 9.2D-16 Human Health Average Daily Doses and Incremental Lifetime Cancer Risks Indeno (1,2,3-cd) pyrene

Receptor Location	ADD (Adult Alone) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	3.0E-20	3.8E-20	1.9E-23	5.3E-19	3.3E-17	9.8E-18	9.3E-14	5.2E-16	1.1E-15	9.5E-14
Laidman Lake Ecolodge	4.6E-21	5.9E-21	2.9E-24	8.3E-20	5.2E-18	1.5E-18	1.5E-14	8.1E-17	1.7E-16	1.5E-14
Pan Phillips Resort	1.6E-21	2.0E-21	1.0E-24	2.9E-20	1.8E-18	5.4E-19	5.1E-15	2.8E-17	6.0E-17	5.2E-15
Tatelkuz Lake Resort	1.4E-19	1.8E-19	9.0E-23	2.5E-18	1.6E-16	4.7E-17	4.5E-13	2.5E-15	5.3E-15	4.6E-13

Receptor Location	ILCR (Adult Alone) (ADD x CSF)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	2.2E-20	2.7E-20	2.1E-24	1.9E-15	3.9E-19	2.4E-17	7.2E-18	6.8E-14	3.8E-16	8.1E-16	7.1E-14
Laidman Lake Ecolodge	3.4E-21	4.3E-21	3.2E-25	3.0E-16	6.0E-20	3.8E-18	1.1E-18	1.1E-14	5.9E-17	1.3E-16	1.1E-14
Pan Phillips Resort	1.2E-21	1.5E-21	1.1E-25	1.0E-16	2.1E-20	1.3E-18	3.9E-19	3.7E-15	2.1E-17	4.4E-17	3.9E-15
Tatelkuz Lake Resort	1.0E-19	1.3E-19	9.9E-24	9.1E-15	1.8E-18	1.2E-16	3.4E-17	3.3E-13	1.8E-15	3.9E-15	3.4E-13

Receptor Location	ADD (Amortized over Lifetime) (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	8.2E-20	5.4E-20	8.2E-20	7.3E-19	4.6E-17	1.1E-17	1.4E-13	7.6E-16	1.6E-15	1.4E-13
Laidman Lake Ecolodge	1.3E-20	8.5E-21	1.3E-20	1.1E-19	7.3E-18	1.8E-18	2.1E-14	1.2E-16	2.5E-16	2.2E-14
Pan Phillips Resort	4.5E-21	2.9E-21	4.5E-21	4.0E-20	2.5E-18	6.2E-19	7.5E-15	4.2E-17	8.6E-17	7.6E-15
Tatelkuz Lake Resort	3.9E-19	2.6E-19	3.9E-19	3.5E-18	2.2E-16	5.5E-17	6.6E-13	3.7E-15	7.6E-15	6.7E-13

Receptor Location	ILCR (Amortized over Lifetime) (ADD x CSF)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	6.0E-20	4.0E-20	9.0E-21	6.4E-15	5.3E-19	3.4E-17	8.3E-18	1.0E-13	5.6E-16	1.2E-15	1.1E-13
Laidman Lake Ecolodge	9.4E-21	6.2E-21	1.4E-21	9.9E-16	8.3E-20	5.3E-18	1.3E-18	1.6E-14	8.7E-17	1.8E-16	1.7E-14
Pan Phillips Resort	3.3E-21	2.1E-21	4.9E-22	3.5E-16	2.9E-20	1.8E-18	4.5E-19	5.4E-15	3.0E-17	6.3E-17	5.9E-15
Tatelkuz Lake Resort	2.9E-19	1.9E-19	4.3E-20	3.0E-14	2.6E-18	1.6E-16	4.0E-17	4.8E-13	2.7E-15	5.5E-15	5.2E-13

Notes: ADD - Average Daily Dose; TRV - Carcinogenic Toxicological Reference Value; ILCR - Incremental Lifetime Cancer Risk;

* - Calculated as Exposure Point Concentration x Fraction of Time Exposed x TRV (Unit Risk)

Table 9.2D-17 Human Health Average Daily Doses and Hazard Quotients for Mercury

Receptor Location	ADD (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	8.5E-08	1.0E-07	1.1E-10	5.2E-07	7.6E-08	3.4E-07	2.1E-12	1.2E-14	2.3E-05	2.5E-05
Laidman Lake Ecolodge	8.5E-08	1.0E-07	1.1E-10	5.2E-07	7.6E-08	3.4E-07	5.9E-13	3.3E-15	2.3E-05	2.5E-05
Pan Phillips Resort	8.5E-08	1.0E-07	1.1E-10	5.2E-07	7.6E-08	3.4E-07	9.6E-14	5.4E-16	2.3E-05	2.5E-05
Tatelkuz Lake Resort	8.5E-08	1.0E-07	1.1E-10	5.2E-07	7.6E-08	3.4E-07	9.4E-12	5.3E-14	2.3E-05	2.5E-05

Receptor Location	HQ (ADD / TRV)										Total HQ
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	2.8E-04	3.5E-03	6.3E-07	1.1E-07	1.7E-03	2.5E-04	1.1E-03	7.1E-09	4.0E-11	7.7E-02	8.4E-02
Laidman Lake Ecolodge	2.8E-04	3.5E-03	6.3E-07	3.0E-08	1.7E-03	2.5E-04	1.1E-03	2.0E-09	1.1E-11	7.7E-02	8.4E-02
Pan Phillips Resort	2.8E-04	3.5E-03	6.3E-07	4.9E-09	1.7E-03	2.5E-04	1.1E-03	3.2E-10	1.8E-12	7.7E-02	8.4E-02
Tatelkuz Lake Resort	2.8E-04	3.5E-03	6.3E-07	4.8E-07	1.7E-03	2.5E-04	1.1E-03	3.1E-08	1.8E-10	7.7E-02	8.4E-02

Notes: ADD - Average Daily Dose; TRV - Non-Carcinogenic Toxicological Reference Value; HQ - Hazard Quotient; * - Calculated as Exposure Point Concentration x Fraction of Time Exposed / TRV

Table 9.2D-18 Human Health Average Daily Doses and Hazard Quotients for Molybdenum (Non-Carcinogenic)

Receptor Location	ADD (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.2E-05	1.1E-07	1.1E-09	3.7E-04	3.7E-06	1.1E-04	8.6E-08	3.9E-10	1.3E-05	5.1E-04
Laidman Lake Ecolodge	1.2E-05	1.1E-07	1.1E-09	3.7E-04	3.7E-06	1.1E-04	1.7E-08	7.6E-11	1.3E-05	5.1E-04
Pan Phillips Resort	1.2E-05	1.1E-07	1.1E-09	3.7E-04	3.7E-06	1.1E-04	5.3E-09	2.4E-11	1.3E-05	5.1E-04
Tatelkuz Lake Resort	1.2E-05	1.1E-07	1.1E-09	3.7E-04	3.7E-06	1.1E-04	2.1E-07	9.5E-10	1.3E-05	5.1E-04

Receptor Location	HQ (EDI / TRV)										Total HQ
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	5.3E-04	4.6E-06	3.8E-07	2.7E-05	1.6E-02	1.6E-04	4.9E-03	3.7E-06	1.7E-08	5.4E-04	0.022
Laidman Lake Ecolodge	5.3E-04	4.6E-06	3.8E-07	5.3E-06	1.6E-02	1.6E-04	4.9E-03	7.4E-07	3.3E-09	5.4E-04	0.022
Pan Phillips Resort	5.3E-04	4.6E-06	3.8E-07	1.6E-06	1.6E-02	1.6E-04	4.9E-03	2.3E-07	1.0E-09	5.4E-04	0.022
Tatelkuz Lake Resort	5.3E-04	4.6E-06	3.8E-07	6.6E-05	1.6E-02	1.6E-04	4.9E-03	9.2E-06	4.1E-08	5.4E-04	0.022

Notes: ADD - Average Daily Dose; TRV - Non-Carcinogenic Toxicological Reference Value; HQ - Hazard Quotient; * - Calculated as Exposure Point Concentration x Fraction of Time Exposed / TRV

Table 9.2D-19 Human Health Average Daily Doses and Hazard Quotients for Selenium (Non-Carcinogenic)

Receptor Location	ADD (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.2E-06	1.0E-08	1.1E-10	3.3E-05	3.3E-07	8.5E-06	9.1E-08	4.1E-10	1.1E-03	1.2E-03
Laidman Lake Ecolodge	1.2E-06	1.0E-08	1.1E-10	3.3E-05	3.3E-07	8.5E-06	1.8E-08	7.9E-11	1.1E-03	1.2E-03
Pan Phillips Resort	1.2E-06	1.0E-08	1.1E-10	3.3E-05	3.3E-07	8.5E-06	5.4E-09	2.4E-11	1.1E-03	1.2E-03
Tatelkuz Lake Resort	1.2E-06	1.0E-08	1.1E-10	3.3E-05	3.3E-07	8.5E-06	2.4E-07	1.1E-09	1.1E-03	1.2E-03

Receptor Location	HQ (ADD / TRV)										Total HQ
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	2.0E-04	1.7E-06	9.5E-07	1.2E-03	5.4E-05	2.6E-05	1.4E-03	1.5E-05	6.5E-08	1.8E-01	0.19
Laidman Lake Ecolodge	2.0E-04	1.7E-06	9.5E-07	2.4E-04	5.4E-05	2.6E-05	1.4E-03	2.8E-06	1.3E-08	1.8E-01	0.19
Pan Phillips Resort	2.0E-04	1.7E-06	9.5E-07	7.5E-05	5.4E-05	2.6E-05	1.4E-03	8.8E-07	3.9E-09	1.8E-01	0.19
Tatelkuz Lake Resort	2.0E-04	1.7E-06	9.5E-07	3.3E-03	5.4E-05	2.6E-05	1.4E-03	3.8E-05	1.7E-07	1.8E-01	0.19

Notes: ADD - Average Daily Dose; TRV - Non-Carcinogenic Toxicological Reference Value; HQ - Hazard Quotient; * - Calculated as Exposure Point Concentration x Fraction of Time Exposed / TRV

Table 9.2D-20 Human Health Average Daily Doses and Hazard Quotients for Toluene

Receptor Location	ADD (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	1.2E-18	3.2E-20	1.1E-22	1.2E-11	6.0E-12	7.7E-15	4.8E-11	2.6E-13	2.6E-11	9.3E-11
Laidman Lake Ecolodge	2.6E-19	6.7E-21	2.3E-23	2.5E-12	1.3E-12	1.6E-15	1.0E-11	5.5E-14	5.5E-12	2.0E-11
Pan Phillips Resort	1.2E-19	3.0E-21	1.0E-23	1.1E-12	5.7E-13	7.3E-16	4.6E-12	2.5E-14	2.5E-12	8.8E-12
Tatelkuz Lake Resort	1.7E-17	4.4E-19	1.5E-21	1.6E-10	8.2E-11	1.1E-13	6.6E-10	3.6E-12	3.6E-10	1.3E-09

Receptor Location	HQ (ADD / TRV)										Total HQ
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	5.6E-18	1.4E-19	5.1E-23	2.3E-08	5.4E-11	2.7E-11	3.5E-14	2.2E-10	1.2E-12	1.2E-10	2.3E-08
Laidman Lake Ecolodge	1.2E-18	3.0E-20	1.1E-23	4.8E-09	1.1E-11	5.7E-12	7.4E-15	4.6E-11	2.5E-13	2.5E-11	4.9E-09
Pan Phillips Resort	5.3E-19	1.4E-20	4.9E-24	2.2E-09	5.2E-12	2.6E-12	3.3E-15	2.1E-11	1.1E-13	1.1E-11	2.2E-09
Tatelkuz Lake Resort	7.7E-17	2.0E-18	7.1E-22	3.1E-07	7.5E-10	3.7E-10	4.8E-13	3.0E-09	1.6E-11	1.6E-09	3.2E-07

Notes: ADD - Average Daily Dose; TRV - Non-Carcinogenic Toxicological Reference Value; HQ - Hazard Quotient; * - Calculated as Exposure Point Concentration x Fraction of Time Exposed / TRV

Table 9.2D-21 Human Health Average Daily Doses and Hazard Quotients for Xylene (Non-Carcinogenic)

Receptor Location	ADD (mg/kg-d)									Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	3.3E-18	8.5E-20	2.9E-22	1.3E-11	1.1E-11	2.6E-14	1.6E-10	8.8E-13	6.8E-11	2.5E-10
Laidman Lake Ecolodge	7.0E-19	1.8E-20	6.2E-23	2.7E-12	2.2E-12	5.5E-15	3.4E-11	1.9E-13	1.4E-11	5.4E-11
Pan Phillips Resort	3.1E-19	8.1E-21	2.8E-23	1.2E-12	1.0E-12	2.5E-15	1.5E-11	8.4E-14	6.4E-12	2.4E-11
Tatelkuz Lake Resort	4.6E-17	1.2E-18	4.0E-21	1.8E-10	1.5E-10	3.6E-13	2.2E-09	1.2E-11	9.3E-10	3.5E-09

Receptor Location	HQ (ADD / TRV)										Total HQ
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	2.2E-18	5.7E-20	1.0E-20	4.8E-07	8.5E-12	7.1E-12	1.7E-14	1.1E-10	5.9E-13	4.5E-11	4.8E-07
Laidman Lake Ecolodge	4.7E-19	1.2E-20	2.2E-21	1.0E-07	1.8E-12	1.5E-12	3.7E-15	2.3E-11	1.2E-13	9.5E-12	1.0E-07
Pan Phillips Resort	2.1E-19	5.4E-21	9.7E-22	4.5E-08	8.1E-13	6.7E-13	1.7E-15	1.0E-11	5.6E-14	4.3E-12	4.5E-08
Tatelkuz Lake Resort	3.0E-17	7.8E-19	1.4E-19	6.6E-06	1.2E-10	9.7E-11	2.4E-13	1.5E-09	8.1E-12	6.2E-10	6.6E-06

Notes: ADD - Average Daily Dose; TRV - Non-Carcinogenic Toxicological Reference Value; HQ - Hazard Quotient; * - Calculated as Exposure Point Concentration x Fraction of Time Exposed / TRV

Table 9.2D-22 Human Health Average Daily Doses and Incremental Lifetime Cancer Risks for Carcinogenic PAHs

Receptor Location	ADD (Adult Alone) (mg/kg-d)										Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	9.1E-19	3.5E-19	2.2E-22	1.5E-13	1.6E-15	3.8E-14	1.9E-14	1.1E-10	6.5E-13	1.1E-11	1.3E-10
Laidman Lake Ecolodge	1.5E-19	6.9E-20	4.1E-23	2.8E-14	3.1E-16	7.1E-15	3.0E-15	1.8E-11	1.0E-13	2.0E-12	2.0E-11
Pan Phillips Resort	5.8E-20	2.9E-20	1.7E-23	1.2E-14	1.4E-16	3.2E-15	1.0E-15	6.3E-12	3.5E-14	8.9E-13	7.2E-12
Tatelkuz Lake Resort	5.7E-18	3.2E-18	1.9E-21	1.5E-12	5.2E-14	1.2E-12	9.3E-14	5.7E-10	3.2E-12	3.0E-10	8.8E-10

Receptor Location	ILCR (Adult Alone) (ADD x CSF)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	6.6E-18	2.6E-18	6.7E-22	4.5E-13	1.2E-14	2.8E-13	1.4E-13	8.4E-10	4.7E-12	7.9E-11	9.2E-10
Laidman Lake Ecolodge	1.1E-18	5.0E-19	1.3E-22	8.6E-14	2.2E-15	5.2E-14	2.2E-14	1.3E-10	7.4E-13	1.5E-11	1.5E-10
Pan Phillips Resort	4.2E-19	2.1E-19	5.3E-23	3.6E-14	1.0E-15	2.4E-14	7.6E-15	4.6E-11	2.6E-13	6.5E-12	5.2E-11
Tatelkuz Lake Resort	4.2E-17	2.3E-17	5.8E-21	4.8E-12	3.8E-13	8.5E-12	6.8E-13	4.2E-09	2.4E-11	2.2E-09	6.4E-09

Receptor Location	ADD (Amortized over Lifetime) (mg/kg-d)										Total ADDs
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	7.8E-19	4.5E-19	7.8E-19	4.2E-13	2.2E-15	5.3E-14	8.0E-15	9.5E-11	5.4E-13	1.6E-11	1.1E-10
Laidman Lake Ecolodge	1.5E-19	9.0E-20	1.5E-19	8.3E-14	4.2E-16	9.9E-15	1.3E-15	1.5E-11	8.4E-14	2.9E-12	1.8E-11
Pan Phillips Resort	6.6E-20	3.9E-20	6.6E-20	3.5E-14	2.0E-16	4.5E-15	4.4E-16	5.2E-12	2.9E-14	1.3E-12	6.5E-12
Tatelkuz Lake Resort	7.5E-18	4.3E-18	7.5E-18	4.8E-12	7.2E-14	1.6E-12	4.1E-14	4.9E-10	2.8E-12	4.3E-10	9.3E-10

Receptor Location	ILCR (Amortized over Lifetime) (ADD x CSF)										Total ILCR
	Soil Ingestion	Soil Dermal	Soil Inhalation	Air* Inhalation	Surface Water Ingestion	Surface Water Dermal	Lab Tea Ingestion	Moose Ingestion	Hare Ingestion	Fish Ingestion	
Blackwater-Spruce Ranch	5.7E-18	3.3E-18	2.4E-18	1.3E-12	1.6E-14	3.9E-13	5.9E-14	6.9E-10	3.9E-12	1.1E-10	8.1E-10
Laidman Lake Ecolodge	1.1E-18	6.6E-19	4.8E-19	2.5E-13	3.1E-15	7.2E-14	9.1E-15	1.1E-10	6.1E-13	2.1E-11	1.3E-10
Pan Phillips Resort	4.8E-19	2.8E-19	2.0E-19	1.1E-13	1.4E-15	3.3E-14	3.2E-15	3.8E-11	2.1E-13	9.3E-12	4.8E-11
Tatelkuz Lake Resort	5.5E-17	3.2E-17	2.3E-17	1.5E-11	5.3E-13	1.2E-11	3.0E-13	3.6E-09	2.0E-11	3.1E-09	6.8E-09

Notes: ADD - Average Daily Dose; TRV - Carcinogenic Toxicological Reference Value; ILCR - Incremental Lifetime Cancer Risk;

* - Calculated as Exposure Point Concentration x Fraction of Time Exposed x TRV (Unit Risk)

Table 9.2D-23 Human Health Acute Risks for Arsenic

Receptor Location	1 Hour		
	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)
Blackwater-Spruce Ranch	1.4E-05	0.0002	7.0E-02
Laidman Lake Ecolodge	6.2E-06	0.0002	3.1E-02
Pan Phillips Resort	5.5E-06	0.0002	2.7E-02
Tatelkuz Lake Resort	1.9E-05	0.0002	9.5E-02

Notes: mg/m^3 - milligrams per cubic metre; TRV - Toxicological Reference Value; HQ - Hazard Quiotient

Table 9.2D-24 Human Health Acute Risks for Benzene

Receptor Location	1 Hour		
	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)
Blackwater-Spruce Ranch	2.6E-06	0.03	8.7E-05
Laidman Lake Ecolodge	1.0E-06	0.03	3.4E-05
Pan Phillips Resort	1.2E-06	0.03	4.0E-05
Tatelkuz Lake Resort	1.3E-05	0.03	4.4E-04

Notes: mg/m^3 - milligrams per cubic metre; TRV - Toxicological Reference Value; HQ - Hazard Quiotient

Table 9.2D-25 Human Health Acute Risks for Cyanide

Receptor Location	1 Hour		
	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)
Blackwater-Spruce Ranch	3.2E-05	0.34	9.4E-05
Laidman Lake Ecolodge	2.0E-05	0.34	5.9E-05
Pan Phillips Resort	1.3E-05	0.34	3.9E-05
Tatelkuz Lake Resort	1.4E-04	0.34	4.1E-04

Notes: mg/m^3 - milligrams per cubic metre; TRV - Toxicological Reference Value; HQ - Hazard Quiotient

Table 9.2D-26 Human Health Acute Risks for Ethylbenzene

Receptor Location	1 Hour		
	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)
Blackwater-Spruce Ranch	4.2E-07	143	2.9E-09
Laidman Lake Ecolodge	1.7E-07	143	1.2E-09
Pan Phillips Resort	1.7E-07	143	1.2E-09
Tatelkuz Lake Resort	7.7E-07	143	5.4E-09

Notes: mg/m^3 - milligrams per cubic metre; TRV - Toxicological Reference Value; HQ - Hazard Quiotient

Table 9.2D-27 Human Health Acute Risks for Toluene

Receptor Location	1 Hour		
	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)
Blackwater-Spruce Ranch	3.9E-06	3.8	1.0E-06
Laidman Lake Ecolodge	1.5E-06	3.8	4.0E-07
Pan Phillips Resort	1.6E-06	3.8	4.2E-07
Tatelkuz Lake Resort	1.8E-05	3.8	4.7E-06

Notes: mg/m^3 - milligrams per cubic metre; TRV - Toxicological Reference Value; HQ - Hazard Quiotient

Table 9.2D-28 Human Health Acute Risks for Xylene

Receptor Location	1 Hour		
	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)
Blackwater-Spruce Ranch	3.0E-06	22	1.4E-07
Laidman Lake Ecolodge	1.2E-06	22	5.4E-08
Pan Phillips Resort	1.2E-06	22	5.5E-08
Tatelkuz Lake Resort	1.1E-05	22	4.9E-07

Notes: mg/m^3 - milligrams per cubic metre; TRV - Toxicological Reference Value; HQ - Hazard Quiotient

Table 9.2D-29 Human Health Acute Risks for CO

Receptor Location	1 Hour			24 Hours		
	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)
Blackwater-Spruce Ranch	0.0034	14.3	2.4E-04	0.12	5.5	2.2E-02
Laidman Lake Ecolodge	0.0019	14.3	1.3E-04	0.12	5.5	2.2E-02
Pan Phillips Resort	0.0017	14.3	1.2E-04	0.12	5.5	2.2E-02
Tatelkuz Lake Resort	0.0068	14.3	4.8E-04	0.12	5.5	2.3E-02

Notes: mg/m^3 - milligrams per cubic metre; TRV - Toxicological Reference Value; HQ - Hazard Quiotient

Table 9.2D-30 Human Health Acute and Chronic Risks for NO_2

Receptor Location	1 Hour			24 Hours			Annual		
	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)
Blackwater-Spruce Ranch	0.012	0.4	3.1E-02	0.0030	0.2	1.5E-02	0.0082	0.06	1.4E-01
Laidman Lake Ecolodge	0.0053	0.4	1.3E-02	0.0014	0.2	7.0E-03	0.0081	0.06	1.3E-01
Pan Phillips Resort	0.0052	0.4	1.3E-02	0.0009	0.2	4.3E-03	0.0080	0.06	1.3E-01
Tatelkuz Lake Resort	0.020	0.4	5.1E-02	0.0043	0.2	2.2E-02	0.0087	0.06	1.4E-01

Notes: mg/m^3 - milligrams per cubic metre; TRV - Toxicological Reference Value; HQ - Hazard Quiotient

Table 9.2D-31 Human Health Acute and Chronic Risks for $PM_{2.5}$

Receptor Location	24 Hours			Annual		
	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)
Blackwater-Spruce Ranch	0.0012	0.025	4.6E-02	0.0041	0.008	5.1E-01
Laidman Lake Ecolodge	0.0006	0.025	2.3E-02	0.0040	0.008	5.0E-01
Pan Phillips Resort	0.0003	0.025	1.3E-02	0.0040	0.008	5.0E-01
Tatelkuz Lake Resort	0.0016	0.025	6.5E-02	0.0042	0.008	5.3E-01

Notes: mg/m^3 - milligrams per cubic metre; TRV - Toxicological Reference Value; HQ - Hazard Quiotient

Table 9.2D-32 Human Health Acute Risks for PM_{10}

Receptor Location	24 Hours		
	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)
Blackwater-Spruce Ranch	0.0091	0.05	1.8E-01
Laidman Lake Ecolodge	0.0090	0.05	1.8E-01
Pan Phillips Resort	0.0090	0.05	1.8E-01
Tatelkuz Lake Resort	0.0094	0.05	1.9E-01

Notes: mg/m^3 - milligrams per cubic metre; TRV - Toxicological Reference Value; HQ - Hazard Quiotient

Table 9.2D-33 Human Health Acute and Chronic Risks for SO_2

Receptor Location	1 Hour			24 Hours			Annual		
	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)	Concentration in Air (mg/m^3)	TRV (mg/m^3)	HQ (Air Concentation / TRV)
Blackwater-Spruce Ranch	1.5E-04	0.45	3.3E-04	4.3E-05	0.16	2.7E-04	1.0E-03	0.025	4.0E-02
Laidman Lake Ecolodge	7.3E-05	0.45	1.6E-04	2.8E-05	0.16	1.8E-04	1.0E-03	0.025	4.0E-02
Pan Phillips Resort	4.1E-05	0.45	9.1E-05	8.6E-06	0.16	5.4E-05	1.0E-03	0.025	4.0E-02
Tatelkuz Lake Resort	3.0E-04	0.45	6.7E-04	1.0E-04	0.16	6.4E-04	1.0E-03	0.025	4.1E-02

Notes: mg/m^3 - milligrams per cubic metre; TRV - Toxicological Reference Value; HQ - Hazard Quiotient

Table 9.2D-34: Average Daily Dose and Risk Estimates for Grizzly Bear

Parameter	Dose from Water	Dose from Soil	Dose from Plants	Dose from Small Mammals	Total Dose	Average Daily Dose	TRV	HQ
	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	
Aluminum	1.1E-02	2.0E-06	42.6	1.4E-07	42.7	42.7	19.30	**2.2**
Arsenic	1.5E-04	8.2E-03	3.4E-03	1.4E-07	1.2E-02	1.2E-02	1.04	1.1E-02
Benzene	5.4E-08	1.8E-13	6.9E-09	1.1E-12	6.1E-08	6.1E-08	26.36	2.3E-09
Benz(a)anthracene	1.3E-10	4.4E-12	7.4E-09	2.6E-11	7.6E-09	7.6E-09	0.62	1.2E-08
Benzo(a)pyrene	1.1E-12	5.2E-14	7.8E-10	2.9E-13	7.8E-10	7.8E-10	0.62	1.3E-09
Benzo(b)fluoranthene	1.8E-13	7.1E-14	4.0E-11	3.5E-15	4.0E-11	4.0E-11	0.62	6.5E-11
Benzo(g,h,i)perylene	5.5E-15	1.8E-12	3.2E-12	2.6E-13	5.2E-12	5.2E-12	0.62	8.5E-12
Benzo(k)fluoranthene	9.0E-14	2.1E-13	1.2E-09	1.0E-14	1.2E-09	1.2E-09	0.62	2.0E-09
Cadmium	6.7E-06	3.6E-04	2.3E-02	1.8E-07	2.4E-02	2.4E-02	1	2.4E-02
Chromium	4.1E-05	6.7E-03	3.7E-02	7.6E-07	4.4E-02	4.4E-02	3.28	1.3E-02
Chrysene	4.4E-11	1.8E-11	1.9E-09	9.6E-11	2.0E-09	2.0E-09	0.62	3.3E-09
Copper	5.9E-03	8.3E-03	1.2E-01	5.8E-04	1.3E-01	1.3E-01	11.7	1.1E-02
Cyanide	9.0E-03	5.3E-14	0.0	0.0	9.0E-03	9.0E-03	68.7	1.3E-04
Dibenz(a,h)anthracene	1.2E-14	8.5E-14	3.4E-08	3.5E-15	3.4E-08	3.4E-08	0.62	5.5E-08
Ethylbenzene	3.5E-09	5.0E-14	5.0E-09	9.8E-06	9.8E-06	9.8E-06	408	2.4E-08
Indeno(1,2,3-cd)pyrene	2.6E-15	8.8E-14	5.0E-11	3.5E-15	5.0E-11	5.0E-11	0.62	8.1E-11
Lead	5.2E-05	9.4E-03	6.1E-02	1.0E-06	7.1E-02	7.1E-02	8	8.9E-03
Mercury	1.1E-05	1.7E-04	6.0E-03	2.3E-08	6.2E-03	6.2E-03	0.03	1.9E-01
Molybdenum	5.4E-04	1.8E-03	1.4E-01	7.3E-08	1.4E-01	1.4E-01	0.26	5.5E-01
Selenium	4.8E-05	1.7E-04	1.1E-02	2.4E-07	1.1E-02	1.1E-02	0.2	5.4E-02
Toluene	1.6E-08	1.6E-13	8.5E-09	9.0E-06	9.0E-06	9.0E-06	26	3.5E-07
Vanadium	2.4E-05	1.9E-02	5.5E-02	1.5E-06	7.4E-02	7.4E-02	0.21	3.5E-01
Xylene	1.7E-08	4.2E-13	2.9E-08	3.8E-06	3.8E-06	3.8E-06	2.1	1.8E-06
Zinc	6.6E-04	3.2E-02	4.0	2.1E-01	4.2	4.2	160	2.6E-02

bolded and underlined text represents ER values greater than 1.0

Table 9.2D-35: Average Daily Dose and Risk Estimates for the Caribou

Parameter	Dose from Water	Dose from Soil	Dose from Plants	Total Dose	Average Daily Dose	TRV	HQ
	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	
Aluminum	1.2E-02	2.4E-06	55.4	55.5	55.5	19.30	**2.9**
Arsenic	1.6E-04	9.7E-03	4.5E-03	1.4E-02	1.4E-02	1.04	1.4E-02
Benzene	6.0E-08	2.2E-13	8.9E-09	6.9E-08	6.9E-08	26.36	2.6E-09
Benz(a)anthracene	1.4E-10	5.2E-12	9.6E-09	9.8E-09	9.8E-09	0.62	1.6E-08
Benzo(a)pyrene	1.2E-12	6.2E-14	1.0E-09	1.0E-09	1.0E-09	0.62	1.6E-09
Benzo(b)fluoranthene	2.0E-13	8.4E-14	5.2E-11	5.2E-11	5.2E-11	0.62	8.5E-11
Benzo(g,h,i)perylene	6.0E-15	2.2E-12	4.1E-12	6.3E-12	6.3E-12	0.62	1.0E-11
Benzo(k)fluoranthene	9.9E-14	2.5E-13	1.6E-09	1.6E-09	1.6E-09	0.62	2.6E-09
Cadmium	7.3E-06	4.3E-04	3.0E-02	3.1E-02	3.1E-02	1	3.1E-02
Chromium	4.5E-05	7.9E-03	4.8E-02	5.6E-02	5.6E-02	3.28	1.7E-02
Chrysene	4.8E-11	2.1E-11	2.4E-09	2.5E-09	2.5E-09	0.62	4.1E-09
Copper	6.5E-03	9.8E-03	1.5E-01	1.7E-01	1.7E-01	11.7	1.4E-02
Cyanide	9.9E-03	6.3E-14	0.0E+00	9.9E-03	9.9E-03	68.7	1.4E-04
Dibenz(a,h)anthracene	1.3E-14	1.0E-13	4.4E-08	4.4E-08	4.4E-08	0.62	7.2E-08
Ethylbenzene	3.9E-09	6.0E-14	6.5E-09	1.0E-08	1.0E-08	408	2.5E-11
Indeno(1,2,3-cd)pyrene	2.9E-15	1.0E-13	6.5E-11	6.5E-11	6.5E-11	0.62	1.1E-10
Lead	5.8E-05	1.1E-02	8.0E-02	9.1E-02	9.1E-02	8	1.1E-02
Mercury	1.2E-05	2.1E-04	7.8E-03	8.1E-03	8.1E-03	0.03	2.5E-01
Molybdenum	5.9E-04	2.1E-03	1.8E-01	1.9E-01	1.9E-01	0.26	7.1E-01
Selenium	5.3E-05	2.1E-04	1.4E-02	1.4E-02	1.4E-02	0.2	7.0E-02
Toluene	1.7E-08	1.8E-13	1.1E-08	2.8E-08	2.8E-08	26	1.1E-09
Vanadium	2.7E-05	2.2E-02	7.2E-02	9.4E-02	9.4E-02	0.21	4.5E-01
Xylene	1.8E-08	5.0E-13	3.7E-08	5.6E-08	5.6E-08	2.1	2.7E-08
Zinc	7.2E-04	3.7E-02	5.2	5.2	5.2	160	3.2E-02

Table 9.2D-36: Average Daily Dose and Risk Estimates for the Marten

Parameter	Dose from Water	Dose from Soil	Dose from Small Mammals	Total Dose	Average Daily Dose	TRV	HQ
	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	
Aluminum	2.0E-02	6.0E-06	4.5E-06	2.0E-02	2.0E-02	19.30	1.0E-03
Arsenic	2.7E-04	2.4E-02	4.5E-06	2.5E-02	2.5E-02	1.04	2.4E-02
Benzene	1.0E-07	5.4E-13	3.5E-11	1.0E-07	1.0E-07	26.36	3.8E-09
Benz(a)anthracene	2.4E-10	1.3E-11	8.7E-10	1.1E-09	1.1E-09	0.62	1.8E-09
Benzo(a)pyrene	2.0E-12	1.6E-13	9.4E-12	1.2E-11	1.2E-11	0.62	1.9E-11
Benzo(b)fluoranthene	3.4E-13	2.1E-13	1.1E-13	6.6E-13	6.6E-13	0.62	1.1E-12
Benzo(g,h,i)perylene	1.0E-14	5.4E-12	8.6E-12	1.4E-11	1.4E-11	0.62	2.3E-11
Benzo(k)fluoranthene	1.7E-13	6.2E-13	3.4E-13	1.1E-12	1.1E-12	0.62	1.8E-12
Cadmium	1.2E-05	1.1E-03	5.9E-06	1.1E-03	1.1E-03	1	1.1E-03
Chromium	7.5E-05	2.0E-02	2.5E-05	2.0E-02	2.0E-02	3.28	6.1E-03
Chrysene	8.1E-11	5.3E-11	3.2E-09	3.3E-09	3.3E-09	0.62	5.4E-09
Copper	1.1E-02	2.5E-02	1.9E-02	5.5E-02	5.5E-02	11.7	4.7E-03
Cyanide	1.7E-02	1.6E-13	0.0	1.7E-02	1.7E-02	68.7	2.4E-04
Dibenz(a,h)anthracene	2.2E-14	2.5E-13	1.2E-13	3.9E-13	3.9E-13	0.62	6.4E-13
Ethylbenzene	6.5E-09	1.5E-13	3.2E-04	3.2E-04	3.2E-04	408	7.9E-07
Indeno(1,2,3-cd)pyrene	4.8E-15	2.6E-13	1.1E-13	3.8E-13	3.8E-13	0.62	6.2E-13
Lead	9.7E-05	2.8E-02	3.3E-05	2.8E-02	2.8E-02	8	3.5E-03
Mercury	2.0E-05	5.2E-04	7.7E-07	5.4E-04	5.4E-04	0.03	1.7E-02
Molybdenum	1.0E-03	5.2E-03	2.4E-06	6.2E-03	6.2E-03	0.26	2.4E-02
Selenium	8.9E-05	5.2E-04	7.8E-06	6.1E-04	6.1E-04	0.2	3.1E-03
Toluene	2.9E-08	4.6E-13	3.0E-04	3.0E-04	3.0E-04	26	1.1E-05
Vanadium	4.5E-05	5.6E-02	4.8E-05	5.6E-02	5.6E-02	0.21	2.6E-01
Xylene	3.1E-08	1.2E-12	1.2E-04	1.2E-04	1.2E-04	2.1	5.9E-05
Zinc	1.2E-03	9.4E-02	7.1	7.2	7.2	160	4.5E-02

bolded and underlined text represents ER values greater than 1.0

Table 9.2D-37: Average Daily Dose and Risk Estimates for the Snowshoe Hare

Parameter	Dose from Water	Dose from Soil	Dose from Plants	Total Dose	Average Daily Dose	TRV	HQ
	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	
Aluminum	2.0E-02	6.0E-06	139.0	139.0	139.0	19.30	**7.2**
Arsenic	2.7E-04	2.4E-02	1.1E-02	3.6E-02	3.6E-02	1.04	3.4E-02
Benzene	1.0E-07	5.4E-13	2.2E-08	1.2E-07	1.2E-07	26.36	4.6E-09
Benz(a)anthracene	2.4E-10	1.3E-11	2.4E-08	2.4E-08	2.4E-08	0.62	4.0E-08
Benzo(a)pyrene	2.0E-12	1.6E-13	2.5E-09	2.5E-09	2.5E-09	0.62	4.1E-09
Benzo(b)fluoranthene	3.4E-13	2.1E-13	1.3E-10	1.3E-10	1.3E-10	0.62	2.1E-10
Benzo(g,h,i)perylene	1.0E-14	5.4E-12	1.0E-11	1.6E-11	1.6E-11	0.62	2.6E-11
Benzo(k)fluoranthene	1.7E-13	6.2E-13	4.0E-09	4.0E-09	4.0E-09	0.62	6.5E-09
Cadmium	1.2E-05	1.1E-03	7.6E-02	7.7E-02	7.7E-02	1	7.7E-02
Chromium	7.5E-05	2.0E-02	1.2E-01	1.4E-01	1.4E-01	3.28	4.3E-02
Chrysene	8.1E-11	5.3E-11	6.1E-09	6.2E-09	6.2E-09	0.62	1.0E-08
Copper	1.1E-02	2.5E-02	3.8E-01	4.2E-01	4.2E-01	11.7	3.6E-02
Cyanide	1.7E-02	1.6E-13	0.0E+00	1.7E-02	1.7E-02	68.7	2.4E-04
Dibenz(a,h)anthracene	2.2E-14	2.5E-13	1.1E-07	1.1E-07	1.1E-07	0.62	1.8E-07
Ethylbenzene	6.5E-09	1.5E-13	1.6E-08	2.3E-08	2.3E-08	408	5.6E-11
Indeno(1,2,3-cd)pyrene	4.8E-15	2.6E-13	1.6E-10	1.6E-10	1.6E-10	0.62	2.7E-10
Lead	9.7E-05	2.8E-02	2.0E-01	2.3E-01	2.3E-01	8	2.9E-02
Mercury	2.0E-05	5.2E-04	2.0E-02	2.0E-02	2.0E-02	0.03	6.3E-01
Molybdenum	1.0E-03	5.2E-03	4.6E-01	4.7E-01	4.7E-01	0.26	**1.8**
Selenium	8.9E-05	5.2E-04	3.4E-02	3.5E-02	3.5E-02	0.2	1.7E-01
Toluene	2.9E-08	4.6E-13	2.8E-08	5.7E-08	5.7E-08	26	2.2E-09
Vanadium	4.5E-05	5.6E-02	1.8E-01	2.4E-01	2.4E-01	0.21	**1.1**
Xylene	3.1E-08	1.2E-12	9.4E-08	1.2E-07	1.2E-07	2.1	5.9E-08
Zinc	1.2E-03	9.4E-02	12.9	13.0	13.0	160	8.1E-02

bolded and underlined text represents ER values greater than 1.0

Table 9.2D-38: Average Daily Dose and Risk Estimates for Short-tailed Shrew

Parameter	Dose from Water	Dose from Soil	Dose from Soil Invertebrates	Total Dose	Average Daily Dose	TRV	HQ
	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	mg/kg-d	
Aluminum	3.1E-02	1.3E-05	4.2E-04	3.1E-02	3.1E-02	19.3	1.6E-03
Arsenic	4.2E-04	5.1E-02	2.0E-01	2.5E-01	2.5E-01	1.04	2.4E-01
Benzene	1.5E-07	1.1E-12	1.2E-10	1.5E-07	1.5E-07	26.36	5.8E-09
Benz(a)anthracene	3.6E-10	2.7E-11	2.8E-09	3.2E-09	3.2E-09	0.62	5.2E-09
Benzo(a)pyrene	3.0E-12	3.3E-13	3.3E-11	3.6E-11	3.6E-11	0.62	5.9E-11
Benzo(b)fluoranthene	5.2E-13	4.4E-13	4.5E-11	4.6E-11	4.6E-11	0.62	7.5E-11
Benzo(g,h,i)perylene	1.5E-14	1.1E-11	1.2E-09	1.2E-09	1.2E-09	0.62	1.9E-09
Benzo(k)fluoranthene	2.5E-13	1.3E-12	1.3E-10	1.4E-10	1.4E-10	0.62	2.2E-10
Cadmium	1.9E-05	2.3E-03	7.1E-01	7.2E-01	7.2E-01	1	7.2E-01
Chromium	1.1E-04	4.2E-02	2.5E-02	6.7E-02	6.7E-02	3.28	2.0E-02
Chrysene	1.2E-10	1.1E-10	1.1E-08	1.2E-08	1.2E-08	0.62	1.9E-08
Copper	1.7E-02	5.2E-02	28.0	28.0	28.0	11.7	**2.4**
Cyanide	2.5E-02	3.3E-13	6.0E-03	3.1E-02	3.1E-02	68.7	4.5E-04
Dibenz(a,h)anthracene	3.3E-14	5.3E-13	5.4E-11	5.5E-11	5.5E-11	0.62	8.9E-11
Ethylbenzene	1.0E-08	3.2E-13	3.9E-01	3.9E-01	3.9E-01	408	9.5E-04
Fluoranthene	2.2E-08	9.6E-10	9.8E-08	1.2E-07	1.2E-07	65.6	1.8E-09
Fluorene	2.2E-11	1.8E-13	1.8E-11	4.1E-11	4.1E-11	7.8	5.3E-12
Formaldehyde	7.2E-03	5.9E-09	6.0E-07	7.2E-03	7.2E-03	9.4	7.6E-04
Indeno(1,2,3-cd)pyrene	7.3E-15	5.5E-13	5.6E-11	5.7E-11	5.7E-11	0.62	9.2E-11
Lead	1.5E-04	5.9E-02	1.6	1.6	1.6	8	2.0E-01
Mercury	3.1E-05	1.1E-03	0.0	1.1E-03	1.1E-03	0.03	3.5E-02
Molybdenum	1.5E-03	1.1E-02	2.2E-02	3.5E-02	3.5E-02	0.26	1.3E-01
Selenium	1.4E-04	1.1E-03	4.9E-02	5.0E-02	5.0E-02	0.5	1.0E-01
Toluene	4.4E-08	9.8E-13	5.6E-01	5.6E-01	5.6E-01	26	2.2E-02
Vanadium	6.8E-05	1.2E-01	1.6E-01	2.8E-01	2.8E-01	0.21	**1.3**
Xylene	4.7E-08	2.6E-12	1.3E-01	1.3E-01	1.3E-01	2.1	6.4E-02
Zinc	1.8E-03	2.0E-01	43.4	43.6	43.6	160	2.7E-01

bolded and underlined text represents ER values greater than 1.0

Table 9.2D-39: Average Daily Dose and Risk Estimates for Ring Neck Duck

Parameter	Dose from Water	Dose from Sediment	Dose from Aquatic Invertebrates	Dose from Aquatic Plants	Total Dose	Average Daily Dose	TRV	HQ
	mg/kd-d	mg/kd-d	mg/kd-d	mg/kd-d	mg/kd-d	(mg/kg-d)	mg/kg-d	
Aluminum	1.1E-02	17.8	8.3	11.0	37.2	37.2	109.7	3.4E-01
Arsenic	1.5E-04	4.3E-02	1.2E-01	2.7E-02	1.9E-01	1.9E-01	2.24	8.4E-02
Benzene	5.6E-08	2.7E-09	2.8E-07	3.7E-02	3.7E-02	3.7E-02	26.36	1.4E-03
Benz(a)anthracene	1.3E-10	3.6E-08	3.7E-06	1.2E-08	3.7E-06	3.7E-06	2	1.8E-06
Benzo(a)pyrene	1.1E-12	7.5E-10	7.7E-08	1.6E-10	7.8E-08	7.8E-08	2	3.9E-08
Benzo(b)fluoranthene	1.9E-13	1.4E-10	1.4E-08	2.6E-11	1.4E-08	1.4E-08	2	7.2E-09
Benzo(g,h,i)perylene	5.7E-15	7.1E-12	7.3E-10	7.0E-13	7.4E-10	7.4E-10	2	3.7E-10
Benzo(k)fluoranthene	9.3E-14	6.5E-11	6.7E-09	1.6E-11	6.7E-09	6.7E-09	0.2	3.4E-08
Cadmium	6.9E-06	1.7E-03	4.3E-01	1.4E-02	4.4E-01	4.4E-01	1.45	3.0E-01
Chromium	4.2E-05	2.7E-02	9.4E-02	1.9E-02	1.4E-01	1.4E-01	1	1.4E-01
Chrysene	4.5E-11	1.4E-08	1.4E-06	4.4E-09	1.4E-06	1.4E-06	0.62	2.3E-06
Copper	6.1E-03	2.6E-02	4.5E-01	3.2E-02	5.1E-01	5.1E-01	47	1.1E-02
Cyanide	9.3E-03	8.7E-10	1.3E-08	7.7E-07	9.3E-03	9.3E-03	1.43	6.5E-03
Dibenz(a,h)anthracene	1.2E-14	1.4E-11	1.5E-09	1.6E-12	1.5E-09	1.5E-09	0.62	2.4E-09
Ethylbenzene	3.7E-09	5.9E-10	6.0E-08	6.1E-09	7.0E-08	7.0E-08	408	1.7E-10
Indeno(1,2,3-cd)pyrene	2.7E-15	4.8E-12	4.9E-10	4.7E-13	5.0E-10	5.0E-10	0.5	1.0E-09
Lead	5.4E-05	1.5E-02	4.2E-02	2.1E-02	7.7E-02	7.7E-02	3.85	2.0E-02
Mercury	1.1E-05	9.4E-05	0.0E+00	4.6E-05	1.5E-04	1.5E-04	0.01	2.4E-02
Molybdenum	5.6E-04	1.9E-03	5.5E-03	9.2E-01	9.2E-01	9.2E-01	3.5	2.6E-01
Selenium	5.0E-05	8.1E-04	2.7E-02	2.6E-04	2.8E-02	2.8E-02	0.5	5.7E-02
Toluene	1.6E-08	1.8E-09	1.8E-07	3.2E-08	2.3E-07	2.3E-07	26	8.9E-09
Vanadium	2.5E-05	4.9E-02	6.8E-02	3.9E-03	1.2E-01	1.2E-01	11.4	1.1E-02
Xylene	1.7E-08	2.7E-09	3.7E-09	2.7E-08	5.1E-08	5.1E-08	2.1	2.4E-08
Zinc	6.8E-04	4.8E-01	23.1	7.7E-01	24.3	24.3	14.5	**1.7**

bolded and underlined text represents ER values greater than 1.0

Table 9.2D-40: Average Daily Dose and Risk Estimates for Pacific Loon

Parameter	Dose from Water	Dose from Sediment	Dose from Fish	Total Dose	Average Daily Dose	TRV	HQ
	mg/kd-d	mg/kd-d	mg/kd-d	mg/kd-d	(mg/kg-d)	mg/kg-d	
Aluminum	7.6E-03	11.7	6.1E-01	12.3	12.3	109.7	1.1E-01
Arsenic	1.0E-04	2.8E-02	1.1E-02	4.0E-02	4.0E-02	2.24	1.8E-02
Benzene	3.8E-08	1.8E-09	3.0E-07	3.4E-07	3.4E-07	26.36	1.3E-08
Benz(a)anthracene	8.9E-11	2.4E-08	4.3E-06	4.3E-06	4.3E-06	2	2.1E-06
Benzo(a)pyrene	7.4E-13	5.0E-10	9.4E-08	9.5E-08	9.5E-08	2	4.7E-08
Benzo(b)fluoranthene	1.3E-13	9.2E-11	1.3E-09	1.4E-09	1.4E-09	2	6.9E-10
Benzo(g,h,i)perylene	3.8E-15	4.7E-12	4.0E-11	4.5E-11	4.5E-11	2	2.3E-11
Benzo(k)fluoranthene	6.3E-14	4.3E-11	6.0E-10	6.4E-10	6.4E-10	0.2	3.2E-09
Cadmium	4.6E-06	1.1E-03	4.0E-03	5.2E-03	5.2E-03	1.45	3.6E-03
Chromium	2.8E-05	1.8E-02	5.2E-04	1.9E-02	1.9E-02	1	1.9E-02
Chrysene	3.0E-11	9.0E-09	1.5E-06	1.5E-06	1.5E-06	0.62	2.4E-06
Copper	4.1E-03	1.7E-02	7.9E-01	8.1E-01	8.1E-01	47	1.7E-02
Cyanide	6.2E-03	5.7E-10	6.0E-03	1.2E-02	1.2E-02	1.43	8.5E-03
Dibenz(a,h)anthracene	8.3E-15	9.5E-12	1.6E-10	1.7E-10	1.7E-10	0.62	2.8E-10
Ethylbenzene	2.5E-09	3.9E-10	1.2E-07	1.2E-07	1.2E-07	408	2.9E-10
Indeno(1,2,3-cd)pyrene	1.8E-15	3.2E-12	4.2E-11	4.5E-11	4.5E-11	0.5	9.0E-11
Lead	3.6E-05	9.7E-03	3.1E-06	9.8E-03	9.8E-03	3.85	2.5E-03
Mercury	7.6E-06	6.2E-05	2.3E-05	9.2E-05	9.2E-05	0.01	1.4E-02
Molybdenum	3.8E-04	1.3E-03	3.6E-03	5.3E-03	5.3E-03	3.5	1.5E-03
Selenium	3.3E-05	5.3E-04	4.1E-03	4.7E-03	4.7E-03	0.5	9.4E-03
Toluene	1.1E-08	1.2E-09	2.5E-07	2.6E-07	2.6E-07	26	1.0E-08
Vanadium	1.7E-05	3.2E-02	1.6E-07	3.2E-02	3.2E-02	11.4	2.8E-03
Xylene	1.2E-08	1.7E-09	6.5E-07	6.6E-07	6.6E-07	2.1	3.1E-07
Zinc	4.6E-04	3.2E-01	9.0E-01	1.2	1.2	14.5	8.4E-02

Table 9.2D-41: Average Daily Dose and Risk Estimates for the Fly Catcher

Parameter	Dose from Water	Dose from Soil	Dose from Soil Invertebrates	Total Dose	Average Daily Dose	TRV	HQ
	mg/kd-d	mg/kd-d	mg/kd-d	mg/kd-d	(mg/kg-d)	mg/kg-d	
Aluminum	3.6E-02	1.1E-05	5.4E-04	3.6E-02	3.6E-02	109.7	3.3E-04
Arsenic	4.8E-04	4.4E-02	2.5E-01	3.0E-01	3.0E-01	2.24	1.3E-01
Benzene	1.8E-07	9.7E-13	1.5E-10	1.8E-07	1.8E-07	26.36	6.7E-09
Benz(a)anthracene	4.2E-10	2.3E-11	3.5E-09	4.0E-09	4.0E-09	2	2.0E-09
Benzo(a)pyrene	3.5E-12	2.8E-13	4.2E-11	4.6E-11	4.6E-11	2	2.3E-11
Benzo(b)fluoranthene	6.0E-13	3.8E-13	5.7E-11	5.8E-11	5.8E-11	2	2.9E-11
Benzo(g,h,i)perylene	1.8E-14	9.6E-12	1.5E-09	1.5E-09	1.5E-09	2	7.4E-10
Benzo(k)fluoranthene	2.9E-13	1.1E-12	1.7E-10	1.7E-10	1.7E-10	0.2	8.5E-10
Cadmium	2.2E-05	1.9E-03	9.0E-01	9.1E-01	9.1E-01	1.45	6.3E-01
Chromium	1.3E-04	3.5E-02	3.1E-02	6.7E-02	6.7E-02	1	6.7E-02
Chrysene	1.4E-10	9.4E-11	1.4E-08	1.5E-08	1.5E-08	0.62	2.4E-08
Copper	1.9E-02	4.4E-02	35.4	35.5	35.5	47	7.6E-01
Cyanide	2.9E-02	2.8E-13	7.6E-03	3.7E-02	3.7E-02	1.43	2.6E-02
Dibenz(a,h)anthracene	3.9E-14	4.5E-13	6.9E-11	6.9E-11	6.9E-11	0.62	1.1E-10
Ethylbenzene	1.2E-08	2.7E-13	4.9E-01	4.9E-01	4.9E-01	408	1.2E-03
Indeno(1,2,3-cd)pyrene	8.5E-15	4.7E-13	7.1E-11	7.2E-11	7.2E-11	0.5	1.4E-10
Lead	1.7E-04	5.0E-02	2.0	2.0	2.0	3.85	5.3E-01
Mercury	3.6E-05	9.2E-04	0.0	9.6E-04	9.6E-04	0.01	1.5E-01
Molybdenum	1.8E-03	9.3E-03	2.8E-02	3.9E-02	3.9E-02	3.5	1.1E-02
Selenium	1.6E-04	9.2E-04	6.2E-02	6.3E-02	6.3E-02	0.5	1.3E-01
Toluene	5.1E-08	8.3E-13	7.1E-01	7.1E-01	7.1E-01	26	2.7E-02
Vanadium	7.9E-05	9.9E-02	2.1E-01	3.1E-01	3.1E-01	11.4	2.7E-02
Xylene	5.4E-08	2.2E-12	1.7E-01	1.7E-01	1.7E-01	2.1	8.1E-02
Zinc	2.1E-03	1.7E-01	55.0	55.2	55.2	14.5	**3.8**

bolded and underlined text represents ER values greater than 1.0

Table 9.2D-42: Average Daily Dose and Risk Estimates for Red Tail Hawk

Parameter	Dose from Water	Dose from Soil	Dose from Small Mammals	Total Dose	Average Daily Dose	TRV	HQ
	mg/kd-d	mg/kd-d	mg/kd-d	mg/kd-d	(mg/kg-d)	mg/kg-d	
Aluminum	1.1E-02	3.19E-06	3.61E-06	1.1E-02	1.13E-02	109.7	1.03E-04
Arsenic	1.5E-04	1.29E-02	3.61E-06	1.3E-02	1.31E-02	2.24	5.84E-03
Benzene	5.6E-08	2.87E-13	2.81E-11	5.6E-08	5.61E-08	26.36	2.13E-09
Benz(a)anthracene	1.3E-10	6.89E-12	6.91E-10	8.3E-10	8.31E-10	2	4.15E-10
Benzo(a)pyrene	1.1E-12	8.22E-14	7.49E-12	8.7E-12	8.66E-12	2	4.33E-12
Benzo(b)fluoranthene	1.9E-13	1.12E-13	9.10E-14	3.9E-13	3.93E-13	2	1.97E-13
Benzo(g,h,i)perylene	5.7E-15	2.86E-12	6.81E-12	9.7E-12	9.68E-12	2	4.84E-12
Benzo(k)fluoranthene	9.3E-14	3.31E-13	2.69E-13	6.9E-13	6.93E-13	0.2	3.46E-12
Cadmium	6.9E-06	5.67E-04	4.69E-06	5.8E-04	5.79E-04	1.45	3.99E-04
Chromium	4.2E-05	1.05E-02	2.00E-05	1.1E-02	1.06E-02	1	1.06E-02
Chrysene	4.5E-11	2.80E-11	2.51E-09	2.6E-09	2.59E-09	0.62	4.21E-09
Copper	6.1E-03	1.30E-02	1.53E-02	3.4E-02	3.44E-02	47	7.32E-04
Cyanide	9.3E-03	8.39E-14	0.00E+00	9.3E-03	9.27E-03	1.43	6.49E-03
Dibenz(a,h)anthracene	1.2E-14	1.34E-13	9.25E-14	2.4E-13	2.39E-13	0.62	3.88E-13
Ethylbenzene	3.7E-09	7.93E-14	2.57E-04	2.6E-04	2.57E-04	408	6.29E-07
Indeno(1,2,3-cd)pyrene	2.7E-15	1.39E-13	9.11E-14	2.3E-13	2.33E-13	0.5	4.66E-13
Lead	5.42E-05	1.48E-02	2.66E-05	1.49E-02	1.49E-02	3.85	3.88E-03
Mercury	1.13E-05	2.73E-04	6.11E-07	2.85E-04	2.85E-04	0.01	4.45E-02
Molybdenum	5.59E-04	2.75E-03	1.90E-06	3.31E-03	3.31E-03	3.5	9.47E-04
Selenium	4.98E-05	2.73E-04	6.18E-06	3.29E-04	3.29E-04	0.5	6.58E-04
Toluene	1.62E-08	2.46E-13	2.36E-04	2.36E-04	2.36E-04	26	9.07E-06
Vanadium	2.50E-05	2.94E-02	3.84E-05	2.95E-02	2.95E-02	11.4	2.59E-03
Xylene	1.72E-08	6.62E-13	9.91E-05	9.91E-05	9.91E-05	2.1	4.72E-05
Zinc	6.79E-04	4.96E-02	5.61E+00	5.66E+00	5.66E+00	14.5	3.91E-01

Table 9.2D-43: Average Daily Dose and Risk Estimates for Fish

COPC	Water Concentration	TRV	HQ
	(mg/L)	mg/L	
Aluminum	1.2E-01	3.29	3.8E-02
Arsenic	2.6E-03	0.892	2.9E-03
Benzene	1.0E-06	525	1.9E-09
Benz(a)anthracene	2.4E-09	0.00065	3.7E-06
Benzo(a)pyrene	2.0E-11	0.00030	6.6E-08
Benzo(b)fluoranthene	3.4E-12	0.00030	1.1E-08
Benzo(g,h,i)perylene	1.0E-13	0.00030	3.4E-10
Benzo(k)fluoranthene	1.7E-12	0.00030	5.6E-09
Cadmium	1.1E-04	0.00170	6.5E-02
Chromium	7.6E-04	0.06863	1.1E-02
Chrysene	8.2E-10	0.0003	2.7E-06
Copper	3.5E-02	0.0038	**1.2**
Cyanide	1.8E-03	0.0078	2.4E-01
Dibenz(a,h)anthracene	2.2E-13	0.0003	7.4E-10
Ethylbenzene	6.6E-08	0.44	1.5E-07
Indeno(1,2,3-cd)pyrene	4.8E-14	0.0003	1.6E-10
Lead	7.8E-04	0.019	4.1E-02
Mercury	8.1E-06	0.00023	3.5E-02
Molybdenum	9.7E-03	0.88	1.1E-02
Selenium	1.3E-03	0.08832	1.5E-02
Toluene	2.9E-07	1.27	2.3E-07
Vanadium	3.2E-04	0.08	4.0E-03
Xylene	3.1E-07	2.68	1.2E-07
Zinc	9.4E-03	0.036	2.6E-01

bolded and underlined text represents ER values greater than 1.0

Table 9.2D-44: Average Daily Dose and Risk Estimates for Aquatic Invertebrates and Aquatic Plants

COPC		TRV		HQ	
	Water Concnetration	Aqua Invertebrates	Aqua Plants	Aqua Invertebrates	Aqua Plants
	mg/L	mg/L	mg/L		
Aluminum	1.2E-01	1.9	0.46	6.5E-02	2.7E-01
Arsenic	2.6E-03	0.45	0.048	5.7E-03	5.4E-02
Benzene	1.0E-06	98	2.9	1.0E-08	3.5E-07
Benz(a)anthracene	2.4E-09	0.00065	0.00065	3.7E-06	3.7E-06
Benzo(a)pyrene	2.0E-11	0.0003	0.0003	6.6E-08	6.6E-08
Benzo(b)fluoranthene	3.4E-12	0.0042	0.0003	8.2E-10	1.1E-08
Benzo(g,h,i)perylene	1.0E-13	0.00002	0.0003	5.1E-09	3.4E-10
Benzo(k)fluoranthene	1.7E-12	0.0014	0.0003	1.2E-09	5.6E-09
Cadmium	1.1E-04	0.00015	0.002	7.3E-01	5.5E-02
Chromium	7.6E-04	0.044	0.397	1.7E-02	1.9E-03
Chrysene	8.2E-10	0.0007	0.0003	1.2E-06	2.7E-06
Copper	4.4E-03	0.00023	0.001	**19.3**	**4.5**
Cyanide	1.8E-03	0.0078	0.03	2.4E-01	6.1E-02
Dibenz(a,h)anthracene	2.2E-13	0.00004	0.0003	5.6E-09	7.4E-10
Ethylbenzene	6.6E-08	12.922	438	5.1E-09	1.5E-10
Indeno(1,2,3-cd)pyrene	4.8E-14	0.00014	0.0003	3.5E-10	1.6E-10
Lead	7.8E-04	0.012	0.5	6.3E-02	1.6E-03
Mercury	8.1E-06	0.001	0.005	8.4E-03	1.6E-03
Molybdenum	9.7E-03	0.88	0.88	1.1E-02	1.1E-02
Selenium	1.3E-03	0.092	0.1	1.4E-02	1.3E-02
Toluene	2.9E-07	25.229	245	1.2E-08	1.2E-09
Vanadium	3.2E-04	1.9	0.08	1.7E-04	4.0E-03
Xylene	3.1E-07	62.308	62.308	5.0E-09	5.0E-09
Zinc	9.4E-03	0.047	0.03	2.0E-01	3.1E-01

bolded and underlined text represents ER values greater than 1.0

Table 9.2D-45: Average Daily Dose and Risk Estimates for Terrestrial Plants and Soil Invertebrates

COPC		TRV		HQ	
	Soil Concentraion	Soil Invertebrates	Terrestrial Plants	Soil Invertebrates	Terrestrial Plants
	mg/kg	mg/kg	mg/kg		
Aluminum	2.9E-03	67.5	50	4.3E-05	5.8E-05
Arsenic	11.8	18	18	6.6E-01	6.6E-01
Benzene	2.6E-10	63	31	4.2E-12	8.5E-12
Benz(a)anthracene	6.3E-09	20	1	3.2E-10	6.3E-09
Benzo(a)pyrene	7.5E-11	20	1	3.8E-12	7.5E-11
Benzo(b)fluoranthene	1.0E-10	20	1	5.1E-12	1.0E-10
Benzo(g,h,i)perylene	2.6E-09	20	1	1.3E-10	2.6E-09
Benzo(k)fluoranthene	3.0E-10	20	1	1.5E-11	3.0E-10
Cadmium	5.2E-01	140	32	3.7E-03	1.6E-02
Chromium	9.6	10	10	9.6E-01	9.6E-01
Chrysene	2.6E-08	20	1	1.3E-09	2.6E-08
Copper	11.9	80	70	1.5E-01	1.7E-01
Cyanide	7.7E-11	6	5	1.3E-11	1.5E-11
Dibenz(a,h)anthracene	1.2E-10	20	1	6.1E-12	1.2E-10
Ethylbenzene	7.3E-11	16	55	4.5E-12	1.3E-12
Indeno(1,2,3-cd)pyrene	1.3E-10	20	1	6.4E-12	1.3E-10
Lead	13.6	1700	120	8.0E-03	1.1E-01
Mercury	2.5E-01	2.5	34.9	1.0E-01	7.2E-03
Molybdenum	2.5	2	2	**1.3**	**1.3**
Selenium	2.5E-01	4.1	0.52	6.1E-02	4.8E-01
Toluene	2.2E-10	80	2000	2.8E-12	1.1E-13
Vanadium	26.9	210	55	1.3E-01	4.9E-01
Xylene	6.1E-10	8	5	7.6E-11	1.2E-10
Zinc	45.4	120	160	3.8E-01	2.8E-01

bolded and underlined text represents ER values greater than 1.0

Annex 9.2.2E
Human and Ecological Health Model Calculations

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1.0 PREDICTION OF COPC CONCENTRATIONS IN ENVIRONMENTAL MEDIA

Quantifying the potential risks to human and ecological health due to chemical emissions from the Project first required estimating the concentration of each chemical of potential concern (COPC) in the relevant environmental media (e.g., soil, native vegetation, wildlife). Based on predicted maximum annual ground-level air concentrations of each COPC and using equations and assumptions provided by the United States Environmental Protection Agency Office of Solid Waste (US EPA 2005), chemical concentrations were estimated in the following environmental media:

- Soil;
- Native vegetation;
- Wildlife;
- Fish; and
- Surface water.

Details regarding the mathematical modeling to assess the potential human and ecological health risks follow. A worked example with arsenic as the COPC is shown.

1.1 Calculation of COPC Concentrations in Soil

1.1.1 Calculation of COPC Deposition Term

Deposition rates per unit area of soil for the COPCs (air modeling) were converted to deposition rates per unit mass of soil by using the following equation:

$$Ds = \frac{\left(\left(dep.AQT / 1.0\ x\ 10^{4}\right) \cdot 1.0\ x\ 10^{6}\right) \Big/ \left((Zs)/100\right)}{\left(BD \cdot 1000\right)}^{-7}$$

where:

Ds	=	Deposition term (mg/kg-yr)
Dep.AQT	=	Deposition value from air modeling (kg/ha-yr)
$1.0x10^4$	=	Conversion: ha to m^2
$1.0x10^6$	=	Conversion: kg to mg
Zs	=	Mixing depth (2 cm; default value for untilled soils from US EPA 2005)
100	=	Conversion: cm to m
BD	=	Soil bulk density (g/cm^3)
1000	=	Conversion: g/cm^3 to kg/m^3

So for arsenic:

$$Ds = \frac{\left(\left(1.57\times10^{-07}/1.0\ x\ 10^{4}\right)\cdot 1.0\times10^{6}\right)\Big/\left((2)/100\right)}{\left(1.4\cdot 1000\right)} = 5.62\times10^{-7}$$

1.1.2 Calculation of COPC Losses in Soil

Then, in order to calculate the concentration of COPC in soil, the losses have to be evaluated. There are five mechanisms by which chemicals can be lost from soil. They are biotic and abiotic degradation, erosion, surface runoff, leaching, and volatilization. These mechanisms need to be accounted for in the determination of the final soil concentration.

1.1.2.1 Calculation of COPC Losses from Soil Due to Biotic and Abiotic Degradation

The COPC loss constant due to biotic and abiotic degradation (*ksg*) is COPC-specific. Values were obtained from US EPA (2005).

$$ksg_{arsenic} = 0\ yr^{-1}$$

1.1.2.2 Calculation of COPC Losses from Soil Due to Erosion

The COPC loss constant due to erosion (*kse*) is typically COPC- and site-specific. However, US EPA (2005) recommends a default value of 0 for all COPCs based on the assumption that impacted soil erodes both onto the site and away from the site.

$$kse_{arsenic} = 0\ yr^{-1}$$

1.1.2.3 Calculation of COPC Losses from Soil Due to Surface Runoff

$$ksr = \frac{RO}{\theta_{sw}\cdot Z_s}\cdot\left(\frac{1}{1+\left(Kds\cdot BD/\theta_{sw}\right)}\right)$$

where:

Ksr	=	COPC soil loss constant due to runoff (y^{-1})
RO	=	Average annual surface runoff from pervious areas (9.1 cm/y; assumed value based on Bothe, R.A et al. 1993)
θ_{sw}	=	Soil volumetric water content (0.12 mL/cm^3; default value from AENV 2010)
Z_s	=	Soil mixing zone depth (2 cm; default value for untilled soils from US EPA 2005)
Kds	=	Soil-water partition coefficient (29 mL/g; COPC-specific from US EPA 2005)
BD	=	Soil bulk density (1.4 g/cm^3; default value for fine soils from AENV 2010)

So for arsenic:

$$ksr = \frac{9.1 cm/yr}{0.12 mL/cm^3 \cdot 2 cm} \cdot \left(\frac{1}{1 + \left(29 mL/g \cdot 1.4 g/cm^3 / 0.12 mL/cm^3 \right)} \right) = 0.112\ yr^{-1}$$

1.1.2.4 Calculation of COPC Losses from Soil Due to Leaching

$$ksl = \frac{P + I - RO - Ev}{\theta_{sw} \cdot Z_s \cdot \left[1.0 + \left(BD \cdot Kds / \theta_{sw} \right) \right]}$$

where:

Ksl = COPC soil loss constant due to leaching (y^{-1})
P = Average annual precipitation (60.0 cm/y; site-specific long-term (1971-2000) average value for Prince George BC from EC 2009)
I = Average annual irrigation (0 cm/y; assumed)
RO = Average annual surface runoff from pervious areas (9.1 cm/y; assumed)
Ev = Average annual evapotranspiration (43.9 cm/y; site-specific value for Prince George from Valentine *et al.* 1978)
θ_{sw} = Soil volumetric water content (0.12 mL/cm^3; default value from AENV 2010)
Z_s = Soil mixing zone depth (2 cm; default value for untilled soils from US EPA 2005)
Kds = Soil-water partition coefficient (29 mL/g; COPC-specific from | US EPA 2005)
BD = Soil bulk density (1.4g/cm^3; default value for fine soils from AENV 2010)

Therefore:

$$ksl = \frac{60 cm/yr + 0 cm/yr - 9.1 cm/yr - 43.9 cm/yr}{0.12 mL/cm^3 \cdot 2 cm \cdot \left[1.0 + \left(1.4 g/cm^3 \cdot 29 mL/g / 0.12 mL/cm^3 \right) \right]} = 0.086\ yr^{-1}$$

1.1.2.5 Calculation of COPC Losses from Soil Due to Volatilization

$$ksv = \left[\frac{3.1536 \times 10^7 \cdot H}{Z_s \cdot Kds \cdot R \cdot T_a \cdot BD} \right] \cdot \left(\frac{D_a}{Z_s} \right) \cdot \left[1 - \left(\frac{BD}{\rho_{soil}} \right) - \theta_{sw} \right]$$

where:

ksv	=	COPC soil loss constant due to volatilization (y^{-1})
3.1536 x 10^7	=	Conversion factor (3.1536 x 10^7 sec/y)
H	=	Henry's Law Constant (4.8x10^{-04} atm-m^3/mol; COPC-specific from US EPA 2005)
Z_s	=	Soil mixing zone depth (2 cm; default value for untilled soils from US EPA 2005)
Kds	=	Soil-water partition coefficient (29 mL/g; COPC-specific from US EPA 2005)
R	=	Universal gas constant (8.205x10^{-05} atm-m^3/mol-K)
T_a	=	Ambient air temperature (298 K; default value provided by US EPA 2005))
BD	=	Soil bulk density (1.4 g/cm^3; default value for fine soils from AENV 2010)
D_a	=	Diffusivity of COPC in air (0.0772 cm^2/sec; COPC-specific from US EPA 2005)
θ_{sw}	=	Soil volumetric water content (0.12 mL/cm^3; default value from AENV 2010)
ρ_{soil}	=	Solids particle density (2.7 g/cm^3; default value provided by US EPA 2005)

Therefore:

$$ksv = \left[\frac{3.1536\times10^{7}\ \text{sec}/\ yr\cdot 4.8\times10^{-04} atm-m^3/mol}{2cm\cdot 29mL/g\cdot 8.21\times10^{-05} atm-m^3/mol-K\cdot 298K\cdot 1.4g/cm^3}\right]\cdot\left(\frac{0.0772 cm^2/\text{sec}}{2cm}\right)\cdot\left[1-\left(\frac{1.4g/cm^3}{2.7g/cm^3}\right)-0.12mL/cm^3\right]=170000\,yr^{-1}$$

1.1.2.6 Calculation of COPC Losses from Soil Due to All Processes

$$ks = ksg + kse + ksr + ksl + ksv$$

where:

ks	=	COPC soil loss constant due to all processes (y^{-1})
ksg	=	COPC soil loss constant due to degradation (0 y^{-1})
kse	=	COPC soil loss constant due to erosion (0 y^{-1})
ksr	=	COPC soil loss constant due to runoff (0.112 y^{-1})
ksl	=	COPC soil loss constant due to leaching (0.086 y^{-1})
ksv	=	COPC soil loss constant due to volatilization (170000 y^{-1})

Therefore:

$$ks = 0\ yr^{-1} + 0\ yr^{-1} + 0.112\ yr^{-1} 0.086\ yr^{-1} + 170000\ yr^{-1} = 1.7\times10^{5}\ yr^{-1}$$

1.1.3 Calculation of COPC Concentration in Soil

US EPA (2005) recommends using different equations depending on whether or not the COPC being modeled is carcinogenic or non-carcinogenic.

1.1.3.1 Non-Carcinogenic COPCs

$$Cs_{tD} = \frac{Ds \cdot [1 - \exp(-ks \cdot tD)]}{ks}$$

where:

Cs_{tD}	=	soil concentration at time *tD* (mg/kg)
Ds	=	Deposition term (5.62 x 10^{-7} mg/kg/year; see above for arsenic)
tD	=	total time period over which deposition occurs (assumed to be 50 years based on the estimated life for the Project)
ks	=	COPC soil loss constant due to all processes (1.7 x 10^{5} y^{-1}; see above)

Therefore:

$$Cs_{tD} = \frac{5.62 \times 10^{-7} mg/kg/yr \cdot [1 - \exp(-1.7 \times 10^{5} - 1yr^{-1} \cdot 50yr)]}{1.7 \times 10^{5} yr^{-1}} = 3.3x10^{-12} mg/kg$$

1.2 Calculation of COPC Concentrations In Native Vegetation

1.2.1 Calculation of COPC Particle Deposition to Plant Surface

There are no specific models available that specifically predict the concentration of COPCs into specific constituents of the plant e.g., berries. Therefore, for the purpose of this assessment, it was assumed that the assimilation of COPCs in plants would be specific to all above ground produce. The human receptor would then consume the entire above ground produce.

The first step in this modeling was to predict the plant concentration due to three specific pathways – deposition on the plant, absorption from the air, and uptake/translocation from the root. The plant concentration due to direct deposition is presented as follows:

$$Pd = \frac{1000 \cdot Q \cdot (1 - Fv) \cdot [Dydp + (Fw \cdot Dywp)] \cdot Rp \cdot [1.0 - \exp(-kp \cdot Tp)]}{Yp \cdot kp}$$

where:

Pd	=	Plant concentration due to direct (wet/dry) deposition (mg/kg)
1000	=	Conversion factor (1,000 mg/g)
Q	=	COPC emission rate (0.329 g/sec; COPC-specific from air modeling)
Fv	=	Fraction of COPC air concentration in vapour phase (0.006; value from US EPA 2005)
Dydp	=	Unitized yearly average dry deposition from particle phase (4.793x10^{-8} sec/m^2-y; COPC-specific from air modeling)

Fw = Fraction of COPC wet deposition that adheres to plant surfaces (0.6; default value recommended by US EPA 2005)

Dywp = Unitized yearly wet deposition from particle phase ($4.793x10^{-8}$ sec/m^2-y; COPC-specific from air modeling)

Rp = Interception fraction of the edible portion of the plant (0.39; default value recommended by US EPA 2005)

kp = Plant surface loss coefficient (18 y^{-1}; default value recommended by US EPA 2005)

Tp = Length of plant exposure to deposition per harvest of the edible portion of plant (0.16 years; default value recommended by US EPA 2005)

Yp = Yield or standing crop biomass of the edible portion of the plant (productivity) (0.252 kg/m^2; default value recommended by US EPA 2005)

Therefore:

$$Pd = \frac{1000mg/g \cdot 0.329g/\sec \cdot (1-0.006) \cdot \left[4.793x10^{-08}\ \sec/m^2/yr + \left(0.6 \cdot 4.793x10^{-08}\ \sec/m^2/yr\right)\right] \cdot 0.39 \cdot \left[1.0 - \exp\left(-18yr^{-1} \cdot 0.16yr\right)\right]}{0.252kg/m^2 \cdot 18yr^{-1}} = 1.1.x10^{-06}\ mg/kg$$

1.2.2 Calculation of COPC Vapour Transfer from Air to Plant Tissue

$$Pv = Q \cdot Fv \cdot \frac{Cyv \cdot Bv \cdot VG}{\rho_a}$$

where:

Pv = Plant concentration due to air-to-plant transfer (mg/kg)

Q = COPC emission rate (0.329 g/sec; COPC-specific from air modeling)

Fv = Fraction of COPC air concentration in vapour phase (0.006; value from US EPA 2005)

Cyv = Unitized yearly average air concentration from vapour phase (0.00103 μg-sec/g-m^3; COPC-specific from air modeling)

Bv = COPC air-to-plant biotransfer factor for above-ground produce (0; COPC-specific, recommended by US EPA 2005)

VG = Empirical correction factor for above-ground produce (1.0; if log Kow is < 4, then US EPA [2005] recommends 1.0, if log K_{ow} is > 4, then US EPA 2005, recommends 0.01)

ρa = Density of air (1,200 g/m^3; default recommended by US EPA 2005)

Therefore:

$$Pv = 0.329g/\sec \cdot 0.006 \cdot \frac{0.00103\mu g - \sec/g - m^3 \cdot 0 \cdot 1.0}{1200g/m^3} = 0mg/kg$$

1.2.3 Calculation of COPC Root Uptake from Soil to Plant Tissue Above Ground

$$\mathrm{Pr}_{ag} = CsD \cdot Br_{ag}$$

where:

Pr_{ag}	=	Concentration of COPC in above-ground produce due to root uptake (mg/kg)
Br_{ag}	=	Plant-soil bioconcentration factor for above-ground produce (0.00633; COPC-specific from US EPA 2005)
Cs_{tD}	=	Average soil concentration over exposure duration (3.3×10^{-12} mg/kg; for arsenic)

Therefore:

$$\mathrm{Pr}_{ag} = 3.3\times10^{-12} mg/kg \cdot 0.00633 = 2.09\times10^{-14} mg/kg$$

1.2.4 Calculation of COPC Root Uptake from Soil to Plant Tissue below Ground

$$\mathrm{Pr}_{bg} = Cs \cdot Br_{rootveg} \cdot VG_{rootveg}$$

In this case, we don't include the amount of COPC in below-ground parts of the plant because it was assumed that the below ground parts were not considered as a food source for this assessment.

1.2.5 Calculation of Overall COPC Concentration in Plants

$$Pi = \left(Pd + Pv + \mathrm{Pr}_{ag}\right) \cdot 0.15$$

where:

Pi	=	Overall concentration of COPC in plant (mg/kg)
Pd	=	Concentration of COPC in plant due to direct (wet/dry) deposition (1.1×10^{-6} mg/kg; see above for arsenic)
Pv	=	Concentration of COPC in plant due to air-to-plant transfer (0 mg/kg; for arsenic)
Pr_{ag}	=	Concentration of COPC in above-ground produce due to root uptake (2.09×10^{-14} mg/kg; for arsenic)
0.15	=	Conversion factor from wet weight to dry weight.

Therefore:

$$Pi = \left(1.1\times10^{-6} mg/kg + 0 mg/kg + 2.09\times10^{-14} mg/kg\right) \cdot 0.15 = 1.1\times10^{-6} mg/kg$$

1.3 Calculation of COPC Concentrations in Wild Game

1.3.1 Calculation of COPC Concentration in Forage that Wild Game Consumes in their Diet

COPC concentrations in wild game tissue are estimated on the basis of the amount of COPCs that the animals consume in their diet, which consists entirely of forage. Therefore, the first step would be to predict the concentration of COPC in the forage. The equations to estimate COPC concentrations in forage are identical to those equations used to estimate COPC concentrations in native vegetation, but with differences in the values of the following variables:

Rp = Interception fraction of the edible portion of the plant (0.5; default value recommended by US EPA 2005)
Tp = Length of plant exposure to deposition per harvest of the edible portion of plant (0.12 years; default value recommended by US EPA 2005)
Yp = Yield or standing crop biomass of the edible portion of the plant (productivity) (0.24 kg DW/m^2; default value recommended by US EPA 2005)
Bv = COPC air-to-plant biotransfer factor for above-ground produce (0; COPC-specific default recommended by US EPA 2005)
Br = Plant-soil bioconcentration factor for above-ground produce (0.00633; COPC-specific from US EPA 2005)

Using these revised values produces an estimated COPC concentration in forage of 1.39 $x10^{-6}$ mg/kg for arsenic.

1.3.2 Calculation of COPC Concentration in Wild Game Tissue

$$A_{game} = \left(\left(F \cdot Qp \cdot P\right) + \left(Qs \cdot CsD \cdot Bs\right) + \left(Q_W \cdot C_W \cdot B_W\right)\right) \cdot Ba \cdot MF$$

where:

A_{game} = Concentration of COPC in game (mg/kg)
F = Fraction of forage grown on contaminated soil and ingested by the animal (1; recommended default from US EPA 2005)
Qp = Quantity of forage ingested by the animal per day (43.9 kg/day; recommended default from US EPA 2005 based on beef cattle ingestion)
P = Concentration of COPC in forage ingested by the animal (1.39x10^{-6} mg/kg; for arsenic)
Qs = Quantity of soil ingested by the animal (1.317 kg/day; recommended default from US EPA 2005)
Cs_{tD} = Average soil concentration over exposure duration (3.3x10^{-12} mg/kg; for arsenic)
Bs = Soil bioavailability factor (1; recommended default from US EPA 2005)
Qw = Quantity of water ingested by the animal (20.8 L/d from Sample *et al.* 1997)

Cw = Average water concentration over exposure duration (1.6 x 10^{-10} mg/kg; see below for arsenic)
Bw = Water bioavailability factor (1; recommended default from US EPA 2005)
Ba = Biotransfer factor for wild game (0.002 day/kg; assumed same as beef cattle from US EPA 2005)
MF = Metabolism factor (1; recommended default from US EPA 2005)

Therefore:

$$A_{game} = \left(\left(1 \cdot 43.9 kg/day \cdot 1.39 \times 10^{-6}\ mg/kg\right) + \left(1.3 kg/day \cdot 3.3 \times 10^{-12} mg/kg \cdot 1\right) + \left(20.8 L/day \cdot 1.6x10^{-10} mg/l \cdot 1\right)\right) \cdot 0.002 day/kg \cdot 1 = 6.1x10^{-5} mg/kg$$

The same equation was used to calculate the COPC concentration in snowshoe hare. Resulting tissue concentrations were **8.2 x 10^{-7} mg/kg for hare.**

$$A_{game} = \left(\left(F \cdot Qp \cdot P\right) + \left(Qs \cdot CstD \cdot Bs\right) + \left(Q_W \cdot C_W \cdot B_W\right)\right) \cdot Ba \cdot MF$$

where:

A_{game} = Concentration of COPC in game (mg/kg)
F = Fraction of forage grown on contaminated soil and ingested by the animal (1; recommended default from US EPA 2005)
Qp = Quantity of forage ingested by the animal per day (0.745 kg/day; recommended default from US EPA 2005 based on hare ingestion)
P = Concentration of COPC in total plants ingested by the hare (1.10x10^{-6} mg/kg; for arsenic)
Qs = Quantity of soil ingested by the hare (0.0223 kg/day; recommended default from US EPA 2005)
Cs_{tD} = Average soil concentration over exposure duration (3.3x10^{-12} mg/kg; for arsenic)
Bs = Soil bioavailability factor (1; recommended default from US EPA 2005)
Qw = Quantity of water ingested by the animal (0.134 L/d from Sample *et al.* 1997)
Cw = Average water concentration over exposure duration (1.6 x 10^{-10} mg/kg; see below for arsenic)
Bw = Water bioavailability factor (1; recommended default from US EPA 2005)
Ba = Biotransfer factor for wild game (0.002 day/kg; assumed same as beef cattle from US EPA 2005)
MF = Metabolism factor (1; recommended default from US EPA 2005)

Therefore:

$$A_{game} = \left(\left(1 \cdot 0.745 kg/day \cdot 1.10 \times 10^{-6}\ mg/kg\right) + \left(0.02 kg/day \cdot 3.3 \times 10^{-12} mg/kg \cdot 1\right) + \left(0.13 L/day \cdot 1.6x10^{-10} mg/l \cdot 1\right)\right) \cdot 0.002 day/kg \cdot 1 = 8.210^{-7} mg/kg$$

1.4 Calculation of COPC Concentration in Water

1.4.1 Calculation of COPC Loading to Water

COPC loading to water is estimated on the basis of the amount of COPCs that are present in the surrounding environment and the contribution of each loading pathways to the watershed.

$$L_T = L_{DEP} + L_{DIF} + L_{RI} + L_R + L_E$$

where:

L_T = COPC total load to the waterbody
L_{DEP} = Total particle phase and vapour phase direct deposition of COPC to the waterbody
L_{DIF} = Vapour phase COPC diffusion to the waterbody
L_{RI} = Run-off load from impervious area
L_R = Run-off load from pervious area
L_E = Soil erosion load

LT	total COPC load to the waterbody (including deposition, runoff, erosion)	g/y	37.3	See calculation below
Ldep	total (wet/dry) particle phase and wet vapour phase COPC direct deposition load to waterbody	g/y	2.21	See calculation below
Ldif	vapour phase COPC diffusion (dry deposition) load to waterbody	g/y	0.00122	See calculation below
Lri	runoff load from impervious surfaces	g/y	35.1	See calculation below
Lr	runoff load from pervious surfaces	g/y	0.000208	See calculation below
Le	soil erosion load	g/y	0.00000464	See calculation below

1.4.2 Direct Deposition to the Waterbody

$$L_{DEP} = Q \cdot [Fv \cdot Dytwv + (1 - Fv) \cdot Dytwp] \cdot Aw$$

where:

Ldep	total (wet/dry) particle phase and wet vapour phase COPC direct deposition load to waterbody	g/y	2.21	
Q	COPC emission rate	g/sec	0.329	Air modeling
Fv	fraction of COPC air concentration in vapour phase	unitless	0.006	US EPA (2005)
Dytwv	unitized yearly (waterbody and watershed) average total (wet/dry) deposition from vapour phase	sec/m^2-y	4.793×10^{-8}	Air modeling
Dytwp	unitized yearly (waterbody and watershed) average total (wet/dry) deposition from particle phase	sec/m^2-y	4.793×10^{-8}	Air modeling

Aw	waterbody surface area	m^2	$7.83x10^7$	Total surface area for Davidson Creek

1.4.3 Dry Deposition to Waterbody

$$Ldif = \frac{Kv \cdot Q \text{ x } Fv \cdot Cywv \cdot Aw \cdot 10^{-06}}{H / RTwk}$$

where:

Ldif	vapour phase COPC diffusion (dry deposition) load to waterbody	g/y	0.00122	
Kv	overall COPC transfer rate coefficient	m/y	134	See below
Q	COPC emission rate	g/sec	0.329	Air modeling
Fv	fraction of COPC air concentration in vapour phase	unitless	0.006	US EPA (2005)
Cywv	unitized yearly (waterbody & watershed) average air concentration from vapour phase	µg-sec/g-m^3	0.0010398	Air modeling
Aw	waterbody surface area	m^2	$7.83x10^7$	Total surface area of Davidson Creek
10^{-6}	conversion factor	g/µg	$1.0x10^{-6}$	
H	Henry's Law constant	atm-m^3/mol	$4.8x10^{-4}$	
R	Universal Gas constant	atm-m^3/mol-K	$8.2x10^{-5}$	
Twk	waterbody temperature	K	298	US EPA (2005)

1.4.4 Runoff from Impervious Surfaces

$$Lri = Q \cdot [Fv \text{ x } Dywwv + (1.0 - Fv) \cdot Dytwp] \cdot Ai$$

where:

Lri	runoff load from impervious surfaces	g/y	35.1	
Q	COPC emission rate	g/sec	0.329	Air modeling
Fv	fraction of COPC air concentration in vapour phase	unitless	0.006	US EPA (2005)
Dywwv	unitized yearly (waterbody and watershed) average wet deposition from vapour phase	sec/m^2-y	$4.793x10^{-8}$	Air modeling
Dytwp	unitized yearly (waterbody and watershed) average total (wet/dry) deposition from vapour phase	sec/m^2-y	$4.793x10^{-8}$	Air modeling

Ai	impervious watershed area receiving COPC deposition	m^2	$2.55x10^7$	Assumed 10% of total watershed area of Davidson Creek

1.4.5 Runoff from Pervious Surfaces

$$Lr = \frac{RO \cdot (AL - Ai) \cdot Cs \cdot BD \cdot 0.01}{\theta sw + (Kds \cdot BD)}$$

where:

Lr	runoff load from pervious surfaces	g/y	0.000208	
RO	average annual surface runoff from pervious areas	cm/y	9.1	Seasonal runoff
AL	total watershed area receiving COPC deposition	m^2	$2.55x10^8$	Area of Davidson Creek watershed
Ai	impervious watershed area receiving COPC deposition	m^2	$2.55x10^8$	Assumed 10% of total surface area of watershed
Cs	COPC concentration in soil (in watershed soils)	mg/kg	$3.3x10^{-12}$	See previous calculations
BD	soil bulk density	g/cm^3	1.4	Fine grained soil - AENV (2010)
θsw	soil volumetric water content	mL/cm^3	0.12	Fine grained soil - AENV (2010)
Kds	soil-water partition coefficient	cm^3/g	29	COPC-specific from US EPA 2005
0.01	conversion factor	$kg\text{-}cm^2/mg\text{-}m^2$	0.01	

1.4.6 Soil Erosion Load

$$Le = \frac{Xe \cdot (AL - Ai) \cdot SD \cdot ER \cdot Cs \cdot Kds \cdot BD \cdot 0.001}{\theta sw \cdot Kds \cdot BD}$$

where:

Le	soil erosion load	g/y	$4.64x10^{-6}$	
Xe	unit soil loss	$kg/m^2\text{-}y$	2.29	See calculations below
AL	total watershed area receiving COPC deposition	m^2	$2.55x10^8$	Area of Davidson Creek watershed
Ai	impervious watershed area receiving COPC deposition	m^2	$2.55x10^7$	Assumed 10% of total surface area of watershed
SD	sediment delivery ratio (watershed)	unitless	0.0305	See calculations below
ER	soil enrichment ratio	unitless	1	US EPA (2005)
Cs	COPC concentration in soil	mg/kg	$3.3x10^{-12}$	See previous calculations
BD	soil bulk density	g/cm^3	1.4	Fine grained soil - AENV (2010)

θsw	soil volumetric water content	mL/cm^3	0.12	Fine grained soil - AENV (2010)
Kds	soil-water partition coefficient	cm^3/g	29	COPC-specific from US EPA 2005
0.001	conversion factor	kg-cm^2/mg-m^2	0.001	

1.4.7 Unit Soil Loss

$$Xe = \frac{\mathrm{RF} \cdot \mathrm{K} \cdot \mathrm{LS} \cdot \mathrm{C} \cdot \mathrm{PF} \cdot 907.18}{4047}$$

where:

Xe	unit soil loss	kg/m^2-y	2.29	
RF	USLE rainfall (or erosivity) factor	1/y	175	US EPA (2005)
K	USLE erodibility factor	ton/acre	0.39	US EPA (2005)
LS	USLE length-slope factor	unitless	1.5	US EPA (2005)
C	USLE cover management factor	unitless	0.1	US EPA (2005)
PF	USLE supporting practice factor	unitless	1	US EPA (2005)
907.18	conversion factor	kg/ton	907.18	
4047	conversion factor	m^2/acre	4047	

1.4.8 Sediment Delivery Ratio

$$SD = a \cdot AL^{-b}$$

where:

SD	sediment delivery ratio (watershed)	unitless	0.0305	
a	empirical intercept coefficient	unitless	0.6	Average of US EPA (2005) recommended values
b	empirical slope coefficient	unitless	0.125	US EPA (2005)
AL	total watershed area receiving COPC deposition	m^2	2.55x10^8	Area of Davidson Creek watershed

1.4.9 Benthic Burial Rate Constant

$$kb = \frac{\mathrm{Xe} \cdot \mathrm{AL} \cdot \mathrm{SD} \cdot 1\,\mathrm{x}\,10^3 - \mathrm{Vfx} \cdot \mathrm{TSS}}{\mathrm{Aw} \cdot \mathrm{TSS}} x \frac{\mathrm{TSS} \cdot 1.0\,\mathrm{x}\,10^{-6}}{\mathrm{BS} \cdot \mathrm{dbs}}$$

where:

kb	benthic burial rate constant	1/y	0.372	
Xe	unit soil loss	kg/m^2-y	2.29	See above
AL	total watershed area (evaluated) receiving deposition	m^2	2.55x10^8	Area of Davidson Creek watershed
SD	sediment delivery ratio (watershed)	unitless	0.0305	See above
Vfx	average volumetric flow rate through waterbody	m^3/y	1.27x10^7	Average Flow for Davidson Creek; Surface Water Hydrology
TSS	total suspended solids concentration	mg/L	1.5	Average TSS concentration in Davidson Creek watershed
Aw	waterbody surface area	m^2	7.83x10^7	Total surface area of Davidson Creek
BS	benthic solids concentration	g/cm^3	1	US EPA (2005)
dbs	depth of upper benthic sediment layer	m	0.03	US EPA (2005)
1.00 x 10^{-6}	conversion factor	kg/mg	0.000001	
1.00 x 10^3	conversion factor	g/kg	1000	

1.4.10 Gas Transfer Constant

$$KG = ((\mathrm{Cd}^{0.5}) \times \mathrm{W}) \times (\mathrm{k}^{0.33} / \lambda z) \times ((\mu a / (\rho a \times \mathrm{Da}))^{-0.67}) \times 3.1536 \times 10^7$$

where:

KG	gas phase transfer coefficient	m/y	3.29x10^5	
Cd	drag coefficient	unitless	0.0011	US EPA (2005)
W	average annual wind speed	m/sec	2.64	Prince George Station - climate norm http://www.climate.weatheroffice.ec.gc.ca/climate_normals
k	von Karman's constant	unitless	0.4	US EPA (2005)
λz	dimensionless viscous sublayer thickness	unitless	4	US EPA (2005)
μa	viscosity of air corresponding to air temperature	g/cm-sec	0.000181	US EPA (2005)
ρa	density of air corresponding to water temperature	g/cm^3	0.0012	US EPA (2005)
Da	diffusivity of COPC in air	cm^2/sec	0.0772	US EPA (2005)
3.15 x 10^7	units conversion factor	sec/y	31536000	

1.4.11 Liquid Phase Transfer Coefficient

$$KL = \frac{[1.0 \times 10^{-4} \times Dw \times u]^{0.5} \times 3.1536 \times 10^{7}}{dz}$$

where:

KL	liquid phase transfer coefficient	m/y	118	
Dw	diffusivity of COPC in water	cm^2/sec	0.0000096	US EPA (2005)
u	current velocity	m/sec	1.07	Velocity of Davidson Creek watershed; Data on file from Instream Flow Study (Fisheries Section)
1.00×10^{-4}	conversion factor	m^2/cm^2	0.0001	
dz	total waterbody depth	m	1.03	Calculated as dwc + dbs
3.15×10^{7}	conversion factor	sec/y	31536000	

1.4.12 Overall Transfer Rate Coefficient

$$Kv = \left([(KL^{-1}) + ((KG \times \frac{H}{R \times Twk})^{-1})]^{-1} \right) \left(\theta^{Twk-293} \right)$$

where:

Kv	overall COPC transfer rate coefficient	m/y	134	
KL	liquid phase transfer coefficient	m/y	118	See calculation above
KG	gas phase transfer coefficient	m/y	3.26×10^{5}	See calculation above
H	Henry's Law constant	atm-m^3/mol	4.8×10^{-4}	US EPA (2005)
R	Universal Gas constant	atm-m^3/mol	0.00008205	
Twk	waterbody temperature	K	298	US EPA (2005)
θ	temperature correction factor	unitless	1.026	US EPA (2005)

1.4.13 Water Column Volatilization Rate Constant

$$kv = \frac{Kv}{dz \times (1 + Kdsw \times TSS \times 1.0 \times 10^{-6})}$$

where:

kv	water column volatilization rate constant	1/y	26.7	
Kv	overall COPC transfer rate coefficient	m/y	134	See calculation above
dz	total waterbody depth	m	1.03	Calculated as dwc + dbs
Kdsw	suspended sediments/surface water partition coefficient	L water/kg susp sed	89.25	US EPA (2005)
TSS	total suspended solids concentration	mg/L	1.50	TSS concentration in watershed
1.0×10^{-6}	conversion factor	kg/mg	0.000001	

1.4.14 Total Waterbody Dissipation Rate Constant

$$kwt = (\text{fwc x kv}) + (\text{fbs x kb})$$

where:

kwt	overall total waterbody dissipation rate constant	1/y	22.7	
fwc	fraction of total waterbody COPC concentration in the water column	unitless	0.849	See calculation below
kv	water column volatilization rate constant	1/y	134	See calculation above
fbs	fraction of total waterbody COPC concentration in benthic sediment	unitless	0.151	See calculation below
kb	benthic burial rate constant	1/y	0.372	See calculation above

1.4.15 Bed Sediment Porosity

$$\theta_{BS} = 1 - \frac{BS}{\rho_S}$$

where:

θbs	bed sediment porosity	Lwater/ Lsediment	0.6	
ρs	bed sediment density	kg/L	2.65	US EPA (2005)
BS	benthic solids concentration	kg/L	1	US EPA (2005)

1.4.16 Fraction of Total Waterbody Concentration in the Water Column

$$fwc = \frac{(1 + Kdsw \times TSS \times 1.0 \times 10^{-6}) \times dwc / dz}{(1 + Kdsw \times TSS \times 1.0 \times 10^{-6}) \times dwc / dz + (qbs + Kdbs \times BS) \times dbs / dz}$$

where:

fwc	fraction of total waterbody COPC concentration in the water column	unitless	0.849	
Kdsw	suspended sediments/surface water partition coefficient	L/kg	29	US EPA (2005)
TSS	total suspended solids concentration	mg/L	1.5	Average TSS concentration in Davidson Creek watershed
1.0×10^{-6}	conversion factor	kg/mg	0.000001	
dz	total waterbody depth	m	1.03	Calculated as dwc + dbs
θbs	bed sediment porosity	Lwater/Lsediment	0.6	See calculations above
Kdbs	bed sediment/sediment pore water partition coefficient	L/kg	29	US EPA (2005)
BS	benthic solids concentration	g/cm^3	1	US EPA (2005)
dwc	depth of water column	m	1.0	Average depth of water for Davidson Creek
dbs	depth of upper benthic sediment layer	m	0.03	US EPA (2005)

1.4.17 Total Waterbody Concentration

$$Cwtot = \frac{LT}{(Vfx \times fwc) + (kwt \times Aw) \times (dwc + dbs)}$$

where:

Cwtot	total waterbody COPC concentration (including water column and bed sediment)	g/m^3	2.1x10^{-9}	
LT	total COPC load to the waterbody (including deposition, runoff, erosion)	g/y	37.3	See calculation above
Vfx	average volumetric flow rate through waterbody	m^3/y	1.27x10^7	Average Flow for Davidson Creek; Surface Water Hydrology
fwc	fraction of total waterbody COPC concentration in the water column	unitless	0.849	See calculation above
kwt	overall total waterbody COPC dissipation rate constant	1/y	22.7	See calculation above
Aw	waterbody surface area	m^2	7.83x10^7	Total surface area of Davidson Creek
dwc	depth of water column	m	1.0	Average depth of water for Davidson Creek
dbs	depth of benthic sediment layer	m	0.03	US EPA (2005)

1.4.18 Concentration in the Sediment

$$Csed = \text{fbs x Cwtot x} \frac{Kdbs}{\theta_{BS} + Kdbs\ x\ BS} x \frac{dwc + dbs}{dbs}$$

where:

Csed	COPC concentration in bed sediment	mg/kg	5.21x10^{-8}	
fbs	fraction of total waterbody COPC concentration in benthic sediment	unitless	0.151	See calculations above
Cwtot	total waterbody COPC concentration, including water column and bed sediment	mg/L	2.1x10^{-9}	See calculations above
Kdbs	bed sediment/sediment pore water partition coefficient	L/kg	29	US EPA (2005)
θbs	bed sediment porosity	L/L	0.6	US EPA (2005)
BS	benthic solids concentration	g/cm^3	1	US EPA (2005)
dwc	depth of water column	m	1.0	Average depth of water for Davidson Creek
dbs	depth of upper benthic sediment layer	m	0.03	US EPA (2005)

1.4.19 Dissolved Phase Water Concentration

$$Cdw = \frac{Cwctot}{1 + \text{Kdsw x TSS x } 1.0 \text{ x } 10^{-6}}$$

where:

Cdw	dissolved phase water concentration	mg/L	$1.8x10^{-9}$	
Cwctot	total COPC concentration in water column	mg/L	$2.1x10^{-9}$	See calculations below
Kdsw	suspended sediments/surface water partition coefficient	L/kg	29	US EPA (2005)
TSS	total suspended solids concentration	mg/L	1.5	Average TSS concentration in Davidson Creek watershed
1.0×10^{-6}	conversion factor	kg/mg	1.0×10^{-6}	

1.4.20 Calculation of COPC Concentration in Water Column

$$Cwctot = fwc \; x \; Cwtot \; x \; \frac{dwc + dbs}{dwc}$$

where:

Cwctot	total COPC concentration in water column	mg/L	$1.8x10^{-9}$	
fwc	fraction of total waterbody COPC concentration in the water column	unitless	0.849	US EPA (2005)
Cwtot	total waterbody COPC concentration, including water column and bed sediment	mg/L	$2.1x10^{-9}$	See calculations above
dwc	depth of water column	m	1.0	Average depth of water for Davidson Creek
dbs	depth of upper benthic sediment layer	m	0.03	US EPA (2005)

The COPC concentration in the water column is used in the calculation of the Average Daily Dose, since the contaminants present in the sediments were not assumed to be ingested by either toddler or adult human receptors.

2.0 PREDICTION OF AVERAGE DAILY DOSES FOR HUMANS

2.1 Receptor Characteristics

The receptors were assumed to be an adult Aboriginal resident accompanied by a young Aboriginal toddler resident who may participate in traditional (i.e., hunting) and recreational (i.e., hiking) activities within the study areas of the proposed Project. A summary of the exposure pathways that were considered complete for the human receptors and included in the exposure assessment were:

- Direct contact with soil (ingestion and dermal contact);
- Inhalation of re-suspended soil particles;
- Inhalation of emissions;
- Ingestion of surface water
- Direct contact with surface water;
- Ingestion of vegetation (i.e., roots, and leaves);
- Ingestion of wild game; and
- Ingestion of fish (i.e., generic freshwater fish).

These assumptions provide the basis of the exposure assessment. **Table 9.2.2E- 1** and **Table 9.2.2E- 2** have been adapted from HC (2010) and Chan et al. (2011) and provide a summary of the characteristics of potential receptors. With respect to dermal exposures, it was assumed that receptors would be exposed through direct dermal contact with an individual's hands, arms, and legs.

Average daily doses (ADD) were calculated for each COPC for the application scenario at each receptor location. ADDs were calculated for toddlers (receptor for non-carcinogenic risks) and adults (receptor for carcinogenic risks). A worked example using arsenic as the COPC is described in this section.

Table 9.2.2E- 1: Summary of Human Health Receptor Characteristics

Receptor Characteristic	Receptor Parameters		Source
	Toddler	Adult	
Age	7 months - 4 years	>20 years	Health Canada 2010
Exposure duration (years)	4.5	60	Based on 80 year lifespan
Body weight (kg)	16.5	70.7	Health Canada 2010
Soil ingestion rate (g/d)	0.08	0.02	CCME 2006
Surface water ingestion rate (L/d)	0.6	1.5	Health Canada 2010
Inhalation rate (m^3/d)	8.3	16.6	Health Canada 2010

Receptor Characteristic	Receptor Parameters		Source
	Toddler	Adult	
Food ingestion (g/d)			
Traditional above-ground plants[1]	0.28	0.57	Chan et al 2011
Fish[1]	55.02	174.67	Chan et al 2011
Wild Game[1, 2]	50.85	161.42	Chan et al 2011
Wild Game (Moose meat)[2]	38.1	121.1	Assumption
Wild Game (Hare meat)[3]	12.7	40.4	Assumption
Skin surface area (cm^2)			
Hands	430	890	Health Canada 2010
Arms (upper and lower)	890	2,500	Health Canada 2010
Legs (upper and lower)	1,690	5,720	Health Canada 2010
Total Area	3,010	9,110	Health Canada 2010
Total Body	6,130	17,640	Health Canada 2010
Soil loading to exposed skin (mg/cm^2)			
Soil adhesion to skin (based on hands)	0.1	0.1	Health Canada 2010
Soil adhesion to skin (other than hands)	0.01	0.01	Health Canada 2010

Note: [1]ingestion rates for First Nations Populations in BC; [2] 75% of wild game ingestion rate as moose ingestion; [3] 25% of wild game ingestion rate as hare ingestion.

CCME - Canadian Council of Ministers of the Environment; AENV – Alberta Environment; cm^2 - centimetres squared; g/d - grams per day; kg - kilogram; L/d - litres per day; m^3/d - cubic metres per day; mg/cm^3 - milligrams per cubic centimetre

2.2 Calculation of COPC Intake Due to Ingestion of Soil

$$ADD = \frac{Conc_{soil} \cdot IngR_{soil} \cdot F \cdot RAF \cdot EF \cdot ED \cdot CF}{AT \cdot BW}$$

where:

ADD = Average Daily Dose (mg/kg/-d)
$Conc_{soil}$ = COPC concentration in soil (11.8 mg/kg)
$IngR_{soil}$ = Ingestion rate for soil (20 mg/day for adult receptor; 80 mg/day for toddlers; default recommended by CCME (2006))
F = Fraction of COPC absorbed from site (1; 100% of COPCs assumed to be available from the Project site)
RAF = Relative absorption factor for COPC 1 (value specific to arsenic)
EF = Exposure frequency (365 days/year; conservative assumption)
ED = Exposure duration (4.5 years for toddlers; 60 years for adults; 80 years for overall lifespan); default values recommended by Health Canada (2010)
CF = Conversion factor (1.0×10^{-6} kg/mg)

AT = Averaging time (1,642.5 days for toddlers, 29,200 for overall lifespan; exposure frequency multiplied by exposure duration); values recommended by Health Canada (2010)

BW = Body weight (16.5 kg for toddlers, 70.7 kg for adults; values recommended by Health Canada (2010)

Therefore:

$$ADD_{non-cancer} = \frac{11.8 mg/kg \cdot 80 mg/day \cdot 1 \cdot 1 \cdot 365 days/yr \cdot 4.5 yr \cdot 1.0 x10^{-6} kg/mg}{1642.5 days \cdot 16.5 kg} = 5.7 x10^{-0} mg/kg - day$$

$$ADD_{cancer} = \frac{11.8\ mg/kg \cdot 20\ mg/day \cdot 1 \cdot 1 \cdot 365\ days/yr \cdot 60 yr \cdot 1.0 x10^{-6} kg/mg}{29200\ days \cdot 70.7\ kg} = 2.5 x10^{-6} mg/kg - day$$

2.3 Calculation of COPC Intake Due to Dermal Contact with Soil

$$ADD = \frac{\left(Conc_{soil} \cdot SA \cdot AF\right) \cdot F \cdot RAF \cdot EF \cdot ED \cdot CF}{AT \cdot BW}$$

where:

ADD = Average Daily Dose (mg/kg/-d)

Conc$_{soil}$ = COPC concentration in soil (11.8 mg/kg)

SA = Exposed skin surface area (3,010 cm^2 for toddlers, 9,110 cm^2 for adults)

AF = adherence factor (0.1 mg/cm^2/event; default value for skin soil loading to hands recommended by Health Canada (2010) – used as a conservative assumption for all skin surfaces)

F = Fraction of COPC absorbed from site (1; 100% of COPCs assumed to be available from the Project site)

RAF = Relative absorption factor for COPC (0.03; COPC-specific value)

EF = Exposure frequency (365 days/year; conservative assumption)

ED = Exposure duration (4.5 years for toddlers; 60 years for adults; 80 years for overall lifespan); default values recommended by Health Canada (2010)

CF = Conversion factor (1.0 x 10^{-6} kg/mg)

AT = Averaging time (1,642.5 days for toddlers, 29,200 for overall lifespan; exposure frequency multiplied by exposure duration); values recommended by Health Canada (2010)

BW = Body weight (16.5 kg for toddlers, 70.7 kg for adults; values recommended by Health Canada (2010)

Therefore:

$$ADD_{non-cancer} = \frac{\left(11.8 mg/kg \cdot 3010 cm^2 \cdot 0.1 mg/cm^2/day\right) \cdot 1 \cdot 0.03 \cdot 365 days/yr \cdot 4.5 yr \cdot 1.0 x10^{-6} kg/mg}{1642.5 days \cdot 16.5 kg} = 1.5 x10^{-6} mg/kg - day$$

$$ADD_{cancer} = \frac{(11.8mg/kg \cdot 9110cm^2 \cdot 0.1mg/cm^2/day) \cdot 1 \cdot 0.03 \cdot 365days/yr \cdot 60yr \cdot 1.0x10^{-6}kg/mg}{29200days \cdot 70.7kg} = 6.4x10^{-7}mg/kg-day$$

2.4 Calculation of COPC Intake Due to Inhalation of Soil

$$ADD = \frac{Conc_{soil} \cdot P_{air} \cdot InhR \cdot F \cdot RAF \cdot EF \cdot ED \cdot CF}{AT \cdot BW}$$

where:

ADD	=	Average Daily Dose (mg/kg/-d)
Conc$_{soil}$	=	COPC concentration in soil (11.8 mg/kg)
P$_{air}$	=	*Assumed* average airborne concentration of respirable particulate matter (0.00076 mg/m^3; assumed respirable particulate matter value in air; recommended by Health Canada (2010))
InhR	=	Inhalation rate (9.3 m^3/day for toddlers, 16.6 m^3/day for adult receptor; default recommended by Health Canada (2010)
F	=	Fraction of COPC absorbed from site (1; 100% of COPCs assumed to be available from the Project site)
RAF	=	Relative absorption factor for COPC (1; default recommended by Health Canada (2010) for all oral COPC exposures)
EF	=	Exposure frequency (365 days/year; conservative assumption)
ED	=	Exposure duration (4.5 years for toddlers; 60 years for adults; 80 years for overall lifespan); default values recommended by Health Canada (2010)
CF	=	Conversion factor (1.0 x 10^{-6} kg/mg)
AT	=	Averaging time (1,642.5 days for toddlers, 29,200 for overall lifespan; exposure frequency multiplied by exposure duration); values recommended by Health Canada (2010)
BW	=	Body weight (16.5 kg for toddlers, 70.7 kg for adults; values recommended by Health Canada (2010))

$$ADD_{non-cancer} = \frac{11.8mg/kg \cdot 0.00076mg/m^3 \cdot 9.3m^3/day \cdot 1 \cdot 1 \cdot 365days/yr \cdot 4.5yr \cdot 1.0 \times 10^{-6}kg/mg}{1642.5days \cdot 16.5kg} = 5.1 \times 10^{-9}mg/kg-day$$

$$ADD_{cancer} = \frac{11.8mg/kg \cdot 0.00076mg.m^3 \cdot 15.8m^3/day \cdot 1 \cdot 1 \cdot 365days/yr \cdot 60yr \cdot 1.0x10^{-6}kg/mg}{29200days \cdot 70.7kg} = 1.6x10^{-9}mg/kg-day$$

2.5 Calculation of COPC Intake Due to Ingestion of Native Vegetation

$$ADD = \frac{Conc_{veg} \cdot IngR_{veg} \cdot F \cdot RAF \cdot EF \cdot ED \cdot CF}{AT \cdot BW}$$

where:

ADD = Average Daily Dose (mg/kg/-d)
Conc$_{veg}$ = COPC concentration in native vegetation (0.162 mg/kg)
IngR$_{veg}$ = Ingestion rate for medicinal plants (0.28 g/day for toddlers, 0.57 g/day for adults; based on Chan et al., 2011)
F = Fraction of COPC absorbed from site (1; 100% of COPCs assumed to be available from the project site)
RAF = Relative absorption factor for COPC 1
EF = Exposure frequency (365 days/year; conservative assumption)
ED = Exposure duration (4.5 years for toddlers; 60 years for adults; 80 years for overall lifespan); default values recommended by Health Canada (2010)
CF = Conversion factor (1.0 x 10^{-3} kg/mg)
AT = Averaging time (1,642.5 days for toddlers, 29,200 for overall lifespan; exposure frequency multiplied by exposure duration); values recommended by Health Canada (2010)
BW = Body weight (16.5 kg for toddlers, 70.7 kg for adults; values recommended by Health Canada (2010)

Therefore:

$$ADD_{non-cancer} = \frac{0.162mg/kg \cdot 0.28g/day \cdot 1 \cdot 1 \cdot 365days/yr \cdot 4.5yr \cdot 1.0 \times 10^{-3}kg/g}{1642.5days \cdot 16.5kg} = 2.8 \times 10^{-6}mg/kg-day$$

$$ADD_{cancer} = \frac{0.162mg/kg \cdot 0.57g/day \cdot 1 \cdot 1 \cdot 365days/yr \cdot 60yr \cdot 1.0x10^{-3}kg/g}{29200days \cdot 70.7kg} = 9.8x10^{-7}mg/kg-day$$

2.6 Calculation of COPC Intake Due to Ingestion of Wildlife Game (Moose)

$$ADD = \frac{Conc_{game} \cdot IngR_{game} \cdot F \cdot RAF \cdot EF \cdot ED \cdot CF}{AT \cdot BW}$$

where:

ADD = Average Daily Dose (mg/kg/day)

Conc$_{game}$ = COPC concentration in wildlife game (6.1 x 10^{-5} mg/kg) (section 1.3.2 above)
IngR$_{game}$ = Ingestion rate for wildlife game (moose) (38.1 g/day for toddlers ingesting moose, 121.1 g/day for adults ingesting moose; Chat *et al* (2011))
F = Fraction of COPC absorbed from site (1; 100% of COPCs assumed to be available from the Project site)
RAF = Relative absorption factor for COPC 1
EF = Exposure frequency (365 days/year; conservative assumption)
ED = Exposure duration (4.5 years for toddlers; 60 years for adults; 80 years for overall lifespan); default values recommended by Health Canada (2010)
CF = Conversion factor (1.0 x 10^{-3} kg/mg)
AT = Averaging time (1,642.5 days for toddlers, 29,200 for overall lifespan; exposure frequency multiplied by exposure duration); values recommended by Health Canada (2010)
BW = Body weight (16.5 kg for toddlers, 70.7 kg for adults; values recommended by Health Canada (2010)

Therefore:

$$ADD_{non-cancer} = \frac{6.1\times10^{-5} mg/kg \cdot 38.1 g/day \cdot 1 \cdot 1 \cdot 365 days/yr \cdot 4.5 yr \cdot 1.0\times10^{-3} kg/g}{1642.5 days \cdot 16.5 kg} = 1.4\times10^{-7} mg/kg-day$$

$$ADD_{cancer} = \frac{6.1\times10^{-5} mg/kg \cdot 121.1 g/day \cdot 1 \cdot 1 \cdot 365 days/yr \cdot 60 yr \cdot 1.0x10^{-3} kg/g}{29200 days \cdot 70.7 kg} = 7.8x10^{-8} mg/kg-day$$

The same equation was used to calculate intake from snowshoe hare. Resulting ADDs were 6.3 x 10^{-10} mg/kg-d and 3.5 x 10^{-10} mg/kg-d for toddlers and adults, respectively.

2.7 Calculation of COPC Intake Due to Ingestion of Fish

$$ADD = \frac{Conc_{fish} \cdot IngR_{fish} \cdot F \cdot RAF \cdot EF \cdot ED \cdot CF}{AT \cdot BW}$$

where:

ADD = Average Daily Dose (mg/kg/day)
Conc$_{game}$ = COPC concentration in fish (0.035 mg/kg) (Site specific data)
IngR$_{game}$ = Ingestion rate for fish (55 g/day for toddlers, 174.7 g/day for adults; based on Chan *et al* 2011)
F = Fraction of COPC absorbed from site (1; 100% of COPCs assumed to be available from the Project site)
RAF = Relative absorption factor for COPC, 1
EF = Exposure frequency (365 days/year; conservative assumption)

ED = Exposure duration (4.5 years for toddlers; 60 years for adults; 80 years for overall lifespan); default values recommended by Health Canada (2010)
CF = Conversion factor (1.0 x 10^{-3} kg/mg)
AT = Averaging time (1,642.5 days for toddlers, 29,200 for overall lifespan; exposure frequency multiplied by exposure duration); values recommended by Health Canada (2010)
BW = Body weight (16.5 kg for toddlers, 70.7 kg for adults; values recommended by Health Canada (2010)

Therefore:

$$ADD_{non-cancer} = \frac{0.035mg/kg \cdot 55g/day \cdot 1 \cdot 1 \cdot 365days/yr \cdot 4.5yr \cdot 1.0 \times 10^{-3} kg/g}{1642.5days \cdot 16.5kg} = 1.2 \times 10^{-4} mg/kg - day$$

$$ADD_{cancer} = \frac{0.035mg/kg \cdot 174.7g/day \cdot 1 \cdot 1 \cdot 365days/yr \cdot 60yr \cdot 1.0x10^{-3} kg/g}{29200days \cdot 70.7kg} = 6.5 \times 10^{-5} mg/kg - day$$

2.8 Calculation of COPC Intake Due to Ingestion of Water from the Creek, Lakes and Rivers

$$ADD = \frac{\left[(Ctw \cdot IngR \cdot RAF \cdot F \cdot EF1)\right] \cdot ED}{(AT \cdot BW)}$$

where:

ADD = Average Daily Dose (mg/kg/day)
Ctw = COPC concentration in water column (0.00277 mg/L)
IngR = Water ingestion rate (0.6 L/day for toddlers, 1.5 L/day for adults; default recommended by Health Canada (2010))
RAF = Relative absorption factor for COPC, 1
F = Fraction of COPC absorbed from site (1; 100% of COPCs assumed to be available from the project site)
EF1 = Exposure frequency from river water (assumed to be 182.5 days/year for toddlers, 182.5 days/year for adults)
ED = Exposure duration (4.5 years for toddlers; 60 years for adults; 80 years for overall lifespan); default values recommended by Health Canada (2010)
AT = Averaging time (1,642.5 days for toddlers, 10,950 for adults; exposure frequency multiplied by exposure duration); values recommended by Health Canada (2010)
BW = Body weight (16.5 kg for toddlers, 70.7 kg for adults; default recommended by Health Canada (2010)

Therefore:

$$ADD_{non-cancer} = \frac{[(0.00277mg/L \cdot 0.6L/d \cdot 1 \cdot 182.5d/y)] \cdot 4.5y}{821.25\,d \cdot 16.5\,kg} = 1.0x10^{-4}\,mg/kg-day$$

$$ADD_{cancer} = \frac{[(0.00277mg/L \cdot 1.5L/d \cdot 1 \cdot 182.5d/y)] \cdot 60y}{10950d \cdot 70.7\,kg} = 5.9x10^{-5}\,mg/kg-day$$

2.9 Estimation of Potential Exposure via Dermal Contact with Surface Water

The equation used to estimate potential exposures to the local Aboriginal receptors via dermal contact with surface water is the following:

$$ADD = \frac{DA_{event} \cdot SA \cdot F \cdot EF \cdot ED \cdot t_1}{AT \cdot BW}$$

where:

ADD	=	Average Daily Dose (mg/kg/-d)
DA_{event}	=	Dermal absorbed dose per event (mg/cm^2-event)
SA	=	Skin surface area (centimeters squared (cm^2) / event)
F	=	Event frequency (event(s)/day)
EF	=	Exposure frequency from river water (assumed to be 182.5 days/year for toddlers, 182.5 days/year for adults)
ED	=	Exposure duration (4.5 years for toddlers; 60 years for adults; 80 years for overall lifespan); default values recommended by Health Canada (2010)
t_1	=	Swimming event duration (hours)
AT	=	Averaging time (1,642.5 days for toddlers, 14,600 for overall lifespan; exposure frequency multiplied by exposure duration); values recommended by Health Canada (2010)
BW	=	Body weight (kg)

The value DA_{event} is found using the below formula:

$$DA_{event} = Kp \cdot (C_{sw}/1000) \cdot t_1$$

where:

DA_{event}	=	Dermal absorbed dose per event (mg/cm^2-event)
Kp	=	Permeability constant (0.001cm/h, COPC specific value, US EPA 2005)
C_{sw}	=	Chemical concentration in surface water (2.77 x 10^{-3} mg/L)
t_1	=	Swimming event duration (hours)

$$DA_{event} = 0.001cm/h \cdot (2.77 \times 10^{-3} mg/L \div 1000) \cdot 1h = 2.77 \times 10^{-9}$$

Therefore:

$$ADD_{non-carcinogenic} = \frac{2.77 \times 10^{-9} mg/cm^2 \cdot 6{,}130 cm^2 \cdot 1 \cdot 182.5 d/y \cdot 4.5 y \cdot 1 h}{821.25 d \cdot 16.5 kg} = 1.0 \times 10^{-6}$$

$$ADD_{carcinogenic} = \frac{2.77 \times 10^{-9} mg/cm^2 \cdot 17{,}640 cm^2 \cdot 1 \cdot 182.5 d/y \cdot 60 y \cdot 1 h}{14600 d \cdot 70.7 kg} = 5.2 \times 10^{-7}$$

3.0 HUMAN HEALTH RISK CHARACTERIZATION

After daily doses for each COPC were estimated for each relevant exposure pathway, non-cancer and cancer risks were evaluated using equations and assumptions provided by Health Canada (2010).

Non-carcinogenic risks were evaluated by the calculation of a Hazard Quotient using the average daily doses that were determined for toddlers, along with toxicological reference values for each COPC. Carcinogenic risks were assessed by the Incremental Lifetime Cancer Risks based on the average daily doses that were determined for adults, along with unit risk or cancer slope factors for each COPC.

3.1 Calculation of the Hazard Quotient

$$Hazard\ Quotient_{ingestion} = \frac{Average\ \ Daily\ Dose}{Toxicological\ \ Reference\ Value}$$

Therefore, the calculation for Hazard Quotient for toddlers from exposure to arsenic via soil ingestion is:

$$Hazard\ Quotient_{ingestion} = \frac{5.7\times10^{-5}\ mg/kg/day}{3.0\times10^{-4}\ mg/kg/day} = 1.9\,x10^{-1}$$

The HQ for air inhalation exposure pathway, using Tatelkuz Lake Resort as the receptor location example, is calculated using the following formula:

$$Hazard\ Quotient_{inhalation} = \frac{Exposure\ \ Po\,\text{int}\ Concentration}{Toxicological\ \ Reference\ Value}$$

Therefore, the calculation for Hazard Quotient for toddlers from exposure to arsenic via air inhalation is:

$$Hazard\ Quotient_{inhalation} = \frac{8.4\times10^{-7}\ mg/m^3}{1.5\times10^{-5}\ mg/m^3} = 5.6\,x10^{-2}$$

3.2 Calculation of the Incremental Lifetime Cancer Risk

$$Incremental\ Lifetime\ Cancer\ Risk_{ingestion} = Average\ Daily\ Dose\times Cancer\ Slope\ Factor$$

Therefore, the calculation of Incremental Lifetime Cancer Risks for adult from exposure to arsenic via soil ingestion:

$$Incremental\ Lifetime\ Cancer\ Risk_{ingestion} = 2.5x10^{-6}\ mg/kg/day\times1.8\,(mg/kg/day)^{-1} = 4.5\,x10^{-6}$$

The ILCR for air inhalation exposure pathway to arsenic, using Tatelkuz Lake Resort as the receptor location example, is calculated using the following formula:

$$Incremental\ Lifetime\ Cancer\ Risk_{inhalation} = Exposure\ Point\ Concentration \times Fraction\ of\ Time\ \ Exposed \times Unit\ Risk$$

Therefore, the calculation for ILCR from exposure to arsenic via air inhalation is:

$$Incremental\ Lifetime\ Cancer\ Risk_{inhalation} \quad = \quad 8.4x10^{-7}\ mg/m^3 \times 1 \times 6.4\ (mg/m^3)^{-1} \quad = \quad 5.4\ x\ 10^{-6}$$

4.0 PREDICTION OF COPC CONCENTRATIONS IN ENVIRONMENTAL MEDIA FOR ECOLOGICAL RISK ASSESSMENT

4.1 Calculation of COPC Concentration in Native Vegetation

There are no specific models available that specifically predict the concentration of COPCs into specific constituents parts of the plant *e.g.,* berries, leaves, and roots. Therefore, for the purpose of this assessment, it was assumed that the assimilation of COPCs in plants would be specific to all above ground produce. The human receptor would then consume the entire above ground produce.

The first step in this modeling was to predict the plant concentration due to three specific pathways – deposition on the plant, absorption from the air, and uptake/translocation from the root. A worked example of arsenic concentrations in plants due to direct deposition is presented as follows:

Calculation of COPC Root Uptake from Soil to Plant Tissue above Ground is as follows:

$$\mathrm{Pr}_{ag} = Cs \cdot Br_{ag}$$

Where:

Pr_{ag}	=	Concentration of COPC in above-ground produce due to root uptake (mg/kg)
Br_{ag}	=	Plant-soil bioconcentration factor for above-ground produce (0.03752; COPC-specific from U.S. EPA, 2005)
Cs	=	Average soil concentration over exposure duration (11.8 mg/kg; for arsenic)

Therefore:

$$\mathrm{Pr}_{ag} = 11.8\,mg/kg \cdot 0.03752 = 0.44\,mg/kg$$

4.2 Calculation of COPC Concentration in Invertebrates

Calculation of COPC Uptake from Soil to Invertebrates Tissue is as follows:

$$\mathrm{C}_{\mathrm{inv}} = e^{(0.706*(\ln Cs))-1.4121}$$

Where:

Cinv = Concentration of COPC in invertebrate tissue (mg/kg)
Cs = Average soil concentration over exposure duration (11.8 mg/kg; for arsenic)

The equation is taken from US EPA Eco-SSl Arsenic (2005).

$$C_{inv} = e^{(0.706*(\ln 11.8 mg/kg))-1.4121}$$

$$C_{inv} = 1.4 mg/kg$$

4.3 Calculation of COPC Concentration in Small Mammals

Calculation of COPC Uptake from Soil to Small Mammals Tissue is as follows

$$C_{sm} = e^{(0.8188*(\ln C_s))-4.847}$$

Where:

Csm = Concentration of COPC in small mammals tissue (mg/kg)
Cs = Average soil concentration over exposure duration (11.8 mg/kg; for arsenic)

The equation is taken from US EPA Eco-SSl for Arsenic (2005).

$$C_{sm} = e^{(0.8188*(\ln 11.8 mg/kg))-4.847}$$

$$C_{sm} = 0.000068 mg/kg$$

5.0 CALCULATIONS OF AVERAGE DAILY DOSES FOR ECOLOGICAL RECEPTORS

Worked examples for calculating average daily doses for ecological receptors in the assessment is provided in this section. Arsenic was used as the example COPC.

5.1 Mammals

5.1.1 Grizzly Bear

For grizzly bears, ADDs (in mg/kg/d) were calculated by summing the uptake via ingestion of soil, plant tissue, small and large mammals, and surface water. Estimated doses of COPCs in the grizzly bear were calculated using standard exposure equations incorporating uptake from ingestion of soil and food (Sample and Suter, 1994).

Due to a large home range and a diverse concentration of suitable food resources, it was difficult to identify a definitive breakdown of a grizzly bear's diet in the vicinity of the proposed Project. Although diets vary among individual populations of grizzly bears, vegetation and plants were reported to contribute 91% of the diets of grizzly bears in BC (Hobson et al., 2000). It was assumed that a 450 kg grizzly bear consumes 91% of its diet as vegetation, and the remaining 9% of its diet as meat sources (e.g., small mammals) (BC MOE, 1996). For the estimation of the ADD, no area-use factor was incorporated in the equations; i.e., 100% of the diet was assumed to be taken from or near the site.

Table 9.2.2E- 2 lists the exposure parameters for the grizzly bear receptor. A worked example using arsenic for grizzly bear ADD was calculated using the following equation:

$$ADD_{ingestion} = \frac{C_{soil} \cdot IR_{soil}}{BW} + \frac{C_{plant} \cdot IR_{plant}}{BW} + \frac{C_{mammal} \cdot IR_{mammal}}{BW} + \frac{C_{sw} \cdot IR_{sw}}{BW}$$

where:

ADD	=	Average Daily Dose (mg/kg/d)
C_{soil}	=	Concentration of arsenic in soil (mg/kg)
IR_{soil}	=	Soil ingestion rate (kg/d)
C_{plant}	=	Concentration of arsenic in plant tissue (mg/kg)
IR_{plant}	=	Plant tissue ingestion rate (kg/d)
C_{mammal}	=	Concentration of arsenic in small mammal (mg/kg)
IR_{mammal}	=	Small mammal ingestion rate (kg/d)
C_{sw}	=	Concentration of arsenic in surface water (mg/L)
IR_{sw}	=	Surface water ingestion rate (L/d)
BW	=	Body weight (kg)

Therefore:

$$ADD_{ingestion} = \frac{11.8mg/kg \cdot 0.313kg/d}{450kg} + \frac{0.16mg/kg \cdot 3.48kg/d}{450kg} + \frac{0.000066mg/kg \cdot 0.938kg/d}{450kg} + \frac{0.00277mg/L \cdot 24.2L/d}{450kg}$$

$$ADD_{ingestion} = 0.012mg/kg - d$$

Table 9.2.2E- 2: Exposure Parameters for Mammals

Mammal Receptor	Body Weight (kg) [a]	Total Food Intake (kg/d) [b]	Ingestion Rate				
			Soil (kg/d) [c]	**Surface Water (L/d) [d]**	**Plant T issue (kg/d) [e]**	**Soil Invertebrates (kg/d) [e]**	**Meat from Mammals (kg/d) [e]**
Grizzly bear	450	10.4	0.31	24.2	9.46	n/a	0.938
Caribou	175	4.79	0.14	10.3	4.79	n/a	n/a
Marten	1	0.069	0.002	0.099	n/a	n/a	0.069
Snowshoe hare	1	0.069	0.002	0.099	0.069	n/a	n/a
Short-tailed shrew	0.015	0.0022	0.000065	0.0023	n/a	0.0022	n/a

Notes: [a]Based on Sample et al., 1996. Reference values for mammalian species; [b]Estimated using allometric equation for total food intake for mammals (total food intake kg = 0.0687 x body weight$^{0.822}$) (US EPA, 1993); [c]Conservatively estimated at 3% of total dietary intake for grizzly bear, caribou, marten, snowshoe hare, and short-tailed shrew (US EPA, 1993); [d]Estimated using allometric equation for total water intake for mammals (total water intake L = 0.099 x body weight$^{0.90}$) (US EPA, 1993); [e]Based on assumed percentage of total food in the diet.

kg = kilogram; kg/d = kilograms per day; L/d = litres per day; n/a = not available/not applicable.

5.1.2 Caribou

Caribou are potentially exposed to concentrations of COPCs via ingestion of soil, plant tissue, and surface water located in the vicinity of the Project study areas. For caribou, an ADD (in mg/kg/d) was calculated by summing the uptake via ingestion of soil, plant tissue, and surface water.

Caribou are forest-dwelling, and occupy various cover types. Large males typically weigh 180 kg to 270 kg, while females are considerably smaller, usually weighing 90 kg to 135 kg (BC MELP, 2000). It was assumed that a 175 kg caribou (between average male and female weight) consumed 100% of its diet as vegetation. The total caribou ingestion rates of 4.79 kg/d for food and 10.3 L/d for water were estimated using body weight scaling equations recommended by the US EPA (1993). The soil ingestion rate was conservatively estimated at 3% of total food intake (US EPA, 1993).

Table 9.2.2E- 2 lists the exposure parameters for the caribou receptor. A worked example using arsenic for caribou ADD was calculated using the following equation:

$$ADD_{ingestion} = \frac{C_{soil} \cdot IR_{soil}}{BW} + \frac{C_{plant} \cdot IR_{plant}}{BW} + \frac{C_{sw} \cdot IR_{sw}}{BW}$$

where:

ADD	=	Average Daily Dose (mg/kg/d)
C_{soil}	=	Concentration of arsenic in soil (mg/kg)
IR_{soil}	=	Soil ingestion rate (kg/d)
C_{plant}	=	Concentration of arsenic in plant tissue (mg/kg)
IR_{plant}	=	Plant tissue ingestion rate (kg/d)
C_{sw}	=	Concentration of arsenic in surface water (mg/L)
IR_{sw}	=	Surface water ingestion rate (L/d)
BW	=	Body weight (kg)

Therefore:

$$ADD_{ingestion} = \frac{11.8mg/kg \cdot 0.144kg/d}{175kg} + \frac{0.16mg/kg \cdot 4.79kg/d}{175kg} + \frac{0.0027mg/L \cdot 10.3L/d}{175kg}$$

5.1.1.1.1 $ADD_{ingestion} = 0.014mg/kg - d$

5.1.3 Marten

On average, martens weigh about 1 kg, and can reach lengths of 63 cm (BC MWLAP, 2003). Although martens are opportunistic feeders, their primary prey are small mammals (e.g., shrew, voles, and mice). Martens are potentially exposed to concentrations of COPCs via ingestion of soil, small mammals, and surface water located in the vicinity of the proposed Project. An ADD (in

mg/kg/d) was calculated by summing the uptake via ingestion of soil, small mammals, and surface water.

It was assumed that a 1 kg marten consumes 100% of its diet as small mammals. The total ingestion rates for the marten used in the assessment of 0.069 kg/d of food and 0.099 L/d of water were provided by Sample et al. (1996). The soil ingestion rate for the marten was conservatively estimated at 3% of total food intake (US EPA, 1993).

Table 9.2.2E- 3 lists the exposure parameters for the marten. A worked example using arsenic for the marten ADD was calculated using the following equation:

$$ADD_{ingestion} = \frac{C_{soil} \cdot IR_{soil}}{BW} + \frac{C_{sm\,mammals} \cdot IR_{sm\,mammals}}{BW} \frac{C_{sw} \cdot IR_{sw}}{BW}$$

where:

ADD	=	Average Daily Dose (mg/kg/d)
C_{soil}	=	Concentration of arsenic in soil (mg/kg)
IR_{soil}	=	Soil ingestion rate (kg/d)
$C_{sm\ mammals}$	=	Concentration of arsenic in small mammals (mg/kg)
$IR_{sm\ mammals}$	=	Small mammals ingestion rate (kg/d)
C_{sw}	=	Concentration of arsenic in surface water (mg/L)
IR_{sw}	=	Surface water ingestion rate (L/d)
BW	=	Body weight (kg)

therefore:

$$ADD_{ingestion} = \frac{11.8mg/kg \cdot 0.0021kg/d}{1kg} + \frac{0.000068mg/kg \cdot 0.069kg/d}{1kg} + \frac{0.0027mg/L \cdot 0.099L/d}{1kg}$$

5.1.1.1.2 $ADD_{ingestion} = 0.025mg/kg - d$

5.1.4 Snowshoe Hare

Snowshoe hares eat a variety of plant materials, and their diet varies with the seasons. It is assumed that a 1 kg snowshoe hare (Sample et al., 1996) consumes 100% of its diet as vegetation. The total ingestion rates for the snowshoe hare of 0.069 kg/d of food and 0.099 L/d of water were estimated using body weight scaling equations recommended by the US EPA (1993). The soil ingestion rate was conservatively estimated at 3% of total food intake (US EPA 1993).

Table 9.2.2E- 2 lists the exposure parameters for the snowshoe hare. A worked example using arsenic for snowshoe hare ADD was calculated using the following equation:

$$ADD_{ingestion} = \frac{C_{soil} \cdot IR_{soil}}{BW} + \frac{C_{plant} \cdot IR_{plant}}{BW} + \frac{C_{sw} \cdot IR_{sw}}{BW}$$

where:

ADD	=	Average Daily Dose (mg/kg/d)
C_{soil}	=	Concentration of arsenic in soil (mg/kg)
IR_{soil}	=	Soil ingestion rate (kg/d)
C_{plant}	=	Concentration of arsenic in plant tissue (mg/kg)
IR_{plant}	=	Plant tissue ingestion rate (kg/d)
C_{sw}	=	Concentration of arsenic in surface water (mg/L)
IR_{sw}	=	Surface water ingestion rate (L/d)
BW	=	Body weight (kg)

therefore:

$$ADD_{ingestion} = \frac{11.8mg/kg \cdot 0.0021kg/d}{1kg} + \frac{0.16mg/kg \cdot 0.069kg/d}{1kg} + \frac{0.0027mg/L \cdot 0.099L/d}{1kg}$$

5.1.1.1.3 $$ADD_{ingestion} = 0.036mg/kg - d$$

5.1.5 Short-Tailed Shrew

Short-tailed shrew is potentially exposed to concentrations of COPCs via ingestion of soil, invertebrates, and surface water located within the vicinity of the proposed Project. An ADD (in mg/kg/d) was calculated by summing the uptake via ingestion of soil, invertebrates, and surface water.

It was assumed that a 0.015 kg shrew consumes 100% of its diet as invertebrates. The total ingestion rates for the short-tailed shrew used in the assessment of 0.0022 kg/d of food and 0.0023 L/d of water were provided by Sample et al. (1996). The soil ingestion rate for the short-tailed shrew was conservatively estimated at 3% of total food intake (US EPA, 1993).

Table 9.2.2E- 3 lists the exposure parameters for the shrew. A worked example using arsenic for short-tailed shrew ADD was calculated using the following equation:

$$ADD_{ingestion} = \frac{C_{soil} \cdot IR_{soil}}{BW} + \frac{C_{invertebraes} \cdot IR_{invertebraes}}{BW} \frac{C_{sw} \cdot IR_{sw}}{BW}$$

where:

ADD	=	Average Daily Dose (mg/kg/d)
C_{soil}	=	Concentration of arsenic in soil (mg/kg)
IR_{soil}	=	Soil ingestion rate (kg/d)
$C_{invertebrates}$	=	Concentration of arsenic in invertebrates (mg/kg)

$IR_{invertebrates}$ = Invertebrates ingestion rate (kg/d)
C_{sw} = Concentration of arsenic in surface water (mg/L)
IR_{sw} = Surface water ingestion rate (L/d)
BW = Body weight (kg)
therefore:

$$ADD_{ingestion} = \frac{11.8mg/kg \cdot 0.000065kg/d}{0.015kg} + \frac{1.38mg/kg \cdot 0.0022kg/d}{0.015kg} + \frac{0.0027mg/L \cdot 0.0023L/d}{0.015kg}$$

$$ADD_{ingestion} = 0.25mg/kg - d$$

5.2 Birds

5.2.1 Red-Tailed Hawk

The red-tailed hawk is potentially exposed to concentrations of COPCs via ingestion of soil, small mammals, and surface water in the vicinity of the proposed Project. An ADD (in mg/kg/d) was calculated by summing the uptake via ingestion of soil, small mammals, and surface water.

It was assumed that a 1.2 kg red-tailed hawk (Sample et al., 1996) consumes 100% of its diet as small mammals. The total ingestion rates for the red-tailed hawk used in the assessment of 0.065 kg/d of food and 0.067 L/d of water were estimated using body-weight scaling equations recommended by the US EPA (1993). The soil ingestion rate for the red-tailed hawk was conservatively estimated at 2% of total food intake (Sample and Suter, 1994).

Table 9.2.2E- 3 lists the exposure parameters for the shrew. A worked example using arsenic for red-tailed hawk ADD was calculated using the following equation:

$$ADD_{ingestion} = \frac{C_{soil} \cdot IR_{soil}}{BW} + \frac{C_{smmammals} \cdot IR_{smmammals}}{BW} + \frac{C_{sw} \cdot IR_{sw}}{BW}$$

where:

ADD = Average Daily Dose (mg/kg/d)
C_{soil} = Concentration of arsenic in soil (mg/kg)
IR_{soil} = Soil ingestion rate (kg/d)
$C_{sm\ mammals}$ = Concentration of arsenic in small mammals (mg/kg)
$IR_{sm\ mammals}$ = Small mammals ingestion rate (kg/d)
C_{sw} = Concentration of arsenic in surface water (mg/L)
IR_{sw} = Surface water ingestion rate (L/d)
BW = Body weight (kg)

therefore:

$$ADD_{ingestion} = \frac{11.8mg/kg \cdot 0.0013kg/d}{1.2kg} + \frac{0.000068mg/kg \cdot 0.065kg/d}{1.2kg} + \frac{0.0027mg/L \cdot 0.067L/d}{1.2kg}$$

$$ADD_{ingestion} = 0.013mg/kg - d$$

Table 9.2.2E- 3: Exposure Parameters for Birds

Mammal Receptor	Body Weight (kg)	Total Food Intake (kg/d) [a]	Ingestion Rate							
			Soil (kg/d) [b]	**Surface Water (L/d)**	**Sediment (kg/d) [b]**	**Plant Tissue (kg/d) [d]**	**Soil Invertebrates (kg/d) [d]**	**Meat from Small Mammals (kg/d) [d]**	**Meat from Fish (kg/d) [d]**	**Aquatic Invertebrates (kg/d) [d]**
Red-tailed hawk	1.2	0.065	0.0013	0.067	n/a	n/a	n/a	0.065	n/a	n/a
Olive-sided flycatcher	0.037	0.0068	0.00014	0.0065[c]	n/a	n/a	0.0068	n/a	n/a	n/a
Ring-necked duck	1.2	0.065	n/a	0.067	0.0013	0.022	n/a	n/a	n/a	0.044
Pacific loon	4.0	0.14	n/a	0.15[c]	n/a	n/a	n/a	n/a	0.14	n/a

Note: [a]Estimated using allometric equation for total food intake for birds (total food intake kg = 0.00582 x body weight$^{0.651}$) (US EPA, 1993);
[b]Conservatively estimated at 2% of total dietary intake (US EPA, 1993);
[c]Estimated using allometric equation for total water intake for birds (total water intake L = 0.059 x body weight$^{0.67}$) (US EPA, 1993);
[d]Based on estimated percentage of total food in the diet.
kg = kilogram; kg/d = kilograms per day; L/d = litres per day; n/a = not available/not applicable.

Olive-Sided Flycatcher

Olive-sided flycatchers are potentially exposed to concentrations of COPCs via ingestion of soil, soil invertebrates, and surface water in the vicinity of the proposed Project. An ADD (in mg/kg/d) was calculated by summing the uptake via ingestion of soil, soil invertebrates, and surface water.

The olive-sided flycatcher is a medium-sized songbird, 18 cm to 20 cm in length (COSEWIC, 2007). It was assumed that a 0.037 kg olive-sided flycatcher (Sample et al. 1996) consumes 100% of its diet as soil invertebrates. The total ingestion rates for the olive-sided flycatcher used in the assessment of 0.0068 kg/d of food and 0.0065 L/d of water were estimated using body-weight scaling equations recommended by the US EPA (1993). The soil ingestion rate for the olive-sided flycatcher was conservatively estimated at 2% of total food intake (US EPA, 1993).

Table 9.2.2E- 3 lists the exposure parameters for the shrew. A worked example using arsenic for olive-sided flycatcher ADD was calculated using the following equation:

$$ADD_{ingestion} = \frac{C_{soil} \cdot IR_{soil}}{BW} + \frac{C_{invertebrates} \cdot IR_{invertebrates}}{BW} + \frac{C_{sw} \cdot IR_{sw}}{BW}$$

where:

ADD	=	Average Daily Dose (mg/kg/d)
C_{soil}	=	Concentration of arsenic in soil (mg/kg)
IR_{soil}	=	Soil ingestion rate (kg/d)
$C_{invertebrates}$	=	Concentration of arsenic in soil invertebrates (mg/kg)
$IR_{invertebrates}$	=	Soil invertebrates ingestion rate (kg/d)
C_{sw}	=	Concentration of arsenic in surface water (mg/L)
IR_{sw}	=	Surface water ingestion rate (L/d)
BW	=	Body weight (kg)

therefore:

$$ADD_{ingestion} = \frac{11.8mg/kg \cdot 0.00014kg/d}{0.037kg} + \frac{1.38mg/kg \cdot 0.0068kg/d}{0.037kg} + \frac{0.0027mg/L \cdot 0.0065L/d}{0.037kg}$$

$$ADD_{ingestion} = 0.3mg/kg - d$$

5.2.2 Ring-Necked Duck

The predominant pathways by which the ring-necked duck may be exposed to concentrations of COPCs at the proposed Project study areas include ingestion of sediments, surface water, vegetation, and aquatic invertebrates. An ADD (in mg/kg/d) was calculated by summing the uptake via sediments, surface water, vegetation, and aquatic invertebrates.

It was assumed that a 1.2 kg ring-necked duck consumes 67% of its diet as vegetation and 33% as aquatic invertebrates (Sample and Suter, 1994). The total ingestion rates for the ring-necked duck used in this assessment of 0.065 kg/d of food and 0.067 L/d of water were estimated using body-weight scaling equations recommended by the US EPA (1993). The ingestion rate of sediments for the ring-necked duck was conservatively estimated at 2% of total food intake (US EPA, 1993).

Table 9.2.2E- 3 lists the exposure parameters for the shrew. A worked example using arsenic for ring-necked duck ADD was calculated using the following equation:

$$ADD_{ingestion} = \frac{C_{sediments} \cdot IR_{sediments}}{BW} + \frac{C_{aqinvertebraes} \cdot IR_{aqinvertebraes}}{BW} + \frac{C_{vegetaion} \cdot IR_{vegetation}}{BW} + \frac{C_{sw} \cdot IR_{sw}}{BW}$$

where:

ADD	=	Average Daily Dose (mg/kg/d)
$C_{sediments}$	=	Concentration of arsenic in sediments (mg/kg)
$IR_{sediments}$	=	Sediment ingestion rate (kg/d)
$C_{aq\ invertebrates}$	=	Concentration of arsenic in aquatic invertebrates (mg/kg)
$IR_{aq\ invertebrates}$	=	Aquatic invertebrate ingestion rate (kg/d)
$C_{vegetation}$	=	Concentration of arsenic in vegetation (mg/kg)
$IR_{vegetation}$	=	Vegetation ingestion rate (kg/d)
C_{sw}	=	Concentration of arsenic in surface water (mg/L)
IR_{sw}	=	Surface water ingestion rate (L/d)
BW	=	Body weight (kg)

therefore:

$$ADD_{ingestion} = \frac{39.3mg/kg \cdot 0.0013kg/d}{1.2kg} + \frac{3.22mg/kg \cdot 0.044kg/d}{1.2kg} + \frac{1.47mg/L \cdot 0.022L/d}{1.2kg} + \frac{0.0027mg/L \cdot 0.067L/d}{1.2kg}$$

$$ADD_{ingestion} = 0.19mg/kg - d$$

5.2.3 Pacific Loon

Waterfowl feed on a variety of fish. Pacific loons are heavy birds due to their solid bones, and their weight varies, ranging from 1.6 kg to 8 kg, with an average of about 3 kg to 4 kg (McIntyre and Barr, 1997). An ADD (in mg/kg/d) was calculated by summing the uptake via ingestion of fish and surface water.

It was assumed that a 4 kg Pacific loon consumes 100% of its diet as fish (McIntyre, 1988). The total ingestion rates for the Pacific loon used in this assessment of 0.144 kg/d of food and 0.15 L/d of water were estimated using body-weight scaling equations recommended by the US EPA (1993).

Table 9.2.2E- 3 lists the exposure parameters for the shrew. A worked example using arsenic for Pacific loon ADD was calculated using the following equation:

$$ADD_{ingestion} = \frac{C_{fish} \cdot IR_{fish}}{BW} + \frac{C_{sw} \cdot IR_{sw}}{BW}$$

where:

ADD = Average Daily Dose (mg/kg/d)
C_{fish} = Concentration of arsenic in fish (mg/kg)
IR_{fish} = Fish ingestion rate (kg/d)
C_{sw} = Concentration of arsenic in surface water (mg/L)
IR_{sw} = Surface water ingestion rate (L/d)
BW = Body weight (kg)

therefore:

$$ADD_{ingestion} = \frac{0.316mg/kg \cdot 0.144kg/d}{4kg} + \frac{0.0027mg/L \cdot 0.15L/d}{4kg}$$

$$ADD_{ingestion} = 0.04mg/kg - d$$

5.3 Fish

Fish are potentially exposed to COPCs in surface water. Rainbow trout are mobile, and thus integrate exposures from multiple locations. Rainbow trout found in freshwater within the study areas of the proposed Project are potentially exposed to concentrations of COPCs in surface water. Therefore, exposure estimates for fish are based on the 95th Upper Confidence Limit (UCL) of COPC concentrations in surface water (**Table 3.2-5**).

5.4 Invertebrates

5.4.1 Soil Invertebrates

Soil invertebrates are considered to be essentially immobile. Exposure estimates for this receptor are based on the 95th UCL of COPC concentrations in soil.

5.4.2 Aquatic Invertebrates

Aquatic invertebrates are primarily exposed to concentrations of COPCs in surface water. Although invertebrates are somewhat mobile, the range of movement of these organisms is generally small compared to the spatial extent of COPCs at most sites. Exposure estimates for aquatic invertebrates were based on the 95th UCL of COPC concentrations in surface water.

5.5 Vegetation

5.5.1 Terrestrial Plants

Because plants are immobile, exposure to chemicals cannot be averaged or integrated among areas of a site with higher and lower concentrations. Some fraction of individuals in a population at a site is potentially exposed to the highest concentrations of COPCs. Therefore, exposure estimates are based on upper estimates of concentrations. Although the maximum measured concentration can be used as a very conservative estimate of exposure, use of the maximum would ensure protection of 100% of individuals, which is inconsistent with the objectives of the assessment or standard practices in ERA. Instead, the 95th UCL of the distribution of COPC concentrations is a reasonable estimate of exposure. Sources of uncertainty associated with the exposure estimates for plants include the location of the vegetation in relation to the areas of greatest contamination and the efficiency of plant uptake. Most plants on the site will not be exposed to soil with the highest metal concentrations. Uptake by plant roots is dependent on the depth at which COPCs reside in soil. For parameters that are relatively immobile in soil, uptake only occurs in the upper soil layers where COPCs can be accessed by plant root systems.

5.5.2 Aquatic Plants

Aquatic plants in creeks and lakes within the study areas of the proposed Project are potentially exposed to concentrations of dissolved COPCs in surface water. Most aquatic plants are sessile, remaining fixed in one spatial location, with the exception of some macrophytes that reproduce vegetatively. Exposure estimates for aquatic plants were therefore based on the 95th UCL concentrations in surface water.

6.0 ECOLOGICAL RISKS CHARACTERIZATION

After daily doses for each COPC were estimated for each relevant exposure pathway, risks were evaluated by calculating Exposure Ratios (ER). Risks were evaluated by the calculation of an ER using the average daily doses that were determined for ecological receptors, along with toxicological reference values for each COPC. ERs provide a quantitative estimate of overall risk. The ER is a unitless value, defined as the ratio of the magnitude of exposure to magnitude of a standard effect:

$$Exposure\ Ratio = \frac{Average\ Daily\ Dose}{TRV}$$

Therefore, the calculation for Exposure Ratio of arsenic for grizzly bears from ingestion of foods was:

$$Exposure\ Ratio = \frac{1.2 \times 10^{-2}\ mg/kg/day}{1.04\ mg/kg/day} = 1.13x10^{-2}$$

ERs for the all ecological receptors were calculated using the equation described above.

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