12.0 HUMAN AND ECOLOGICAL HEALTH RISK ASSESSMENT

12.1 Introduction

To support the environmental assessment of the Project as outlined in the Environmental Impact Statement (EIS) Guidelines issued by the Canadian Environmental Assessment Agency (the Agency) and in the Terms of Reference (ToR) approved by the Ontario Minister of the Environment, human and ecological health risk assessments have been completed to better understand the potential risks to human and ecological receptors associated with the Project.

To determine the potential effects that the various Project phases may have on air, water and soil quality, predictive air dispersion and deposition modelling (see Appendix F) and water quality modelling (see Appendix J) were conducted. Results have also been used as inputs to the human and ecological health risk assessments presented below.

12.2 Risk Assessment Approach

A risk assessment is a process used to assess the potential risks to human and ecological receptors resulting from one or more environmental stressors. In doing so, the risk assessment takes into account the chemicals to be evaluated, their toxicity and the manner in which receptors may be exposed. As risk assessments are considered "forward looking", they predict what could happen under a certain set of circumstances. They are based on assumptions concerning how much a chemical might be present and how ecological and human receptors may be exposed to that chemical. Risk assessments typically employ assumptions that result in estimates of exposure that overestimate the potential for human health and ecological risks. These are often referred to as "worst case" exposure conditions. This does not mean that actual conditions are expected to reflect these worst case assumptions; rather, it means that the exposure assumptions used in the assessment are meant to represent conditions that overestimate the extent of exposure and risk. Worst case exposure assumptions are used to focus on those chemicals and exposure conditions that may represent a risk and screen out those that do not. If potential risks are within acceptable limits using "worst case" assumptions, then it can be concluded that risks will also be within acceptable limits when using assumptions more in line with exposure conditions likely to be experienced in the potentially affected area surrounding the Project. In contrast, if the potential for unacceptable risks are identified using worst case assumptions, then it is important to examine the assumptions used in the assessment to better understand the sources of those risks and whether mitigative measures are warranted under the circumstances.

The human health risk assessment (HHRA) has followed the general approach recommended by *Health Canada Part I and V: Guidance on Human Health Preliminary/Detailed Quantitative Risk Assessment* (PQRA/DQRA) Version 2.0(Health Canada 2010; 2012). The ecological health risk assessment (EHRA) has followed the guidance established under the Federal Contaminated Sites Action Plan (Azimuth, 2012) and supplementary guidance provided by Environment Canada (i.e., a Framework for Ecological Risk Assessment: General Guidance) (CCME, 1996; 1997). In addition, guidance from the Ontario Ministry of the Environment

(MOE, 2011) *Rationale for the Development of Soil, and Ground Water Standards for Use at Contaminated Sites in Ontario* has also been relied upon where relevant.

Based on this guidance, the principal elements of the human and ecological health risk assessments followed these broad steps:

- Problem formulation: developing an understanding of the nature and source of potential contaminants, the exposure pathways that might be operational and populations that might be affected.
- Exposure assessment: quantifying the degree of exposure via different routes of exposure for the receptor populations of interest.
- Hazard/toxicity assessment: developing an understanding of effects that can be caused by exposure to the potential parameters of concern and the concentrations and exposure durations over which those effects occur.
- Risk characterization: providing quantitative or qualitative estimates of health risk and comparing those risks to acceptable benchmarks.

This approach has been applied to both the human and ecological health risk assessments discussed in the following sections.

12.3 Human Health Risk Assessment

12.3.1 Problem Formulation

The problem formulation provides the framework and methodology for the HHRA and consists of identifying the relevant components of the HHRA. These components include reviewing relevant Project site information, identifying and screening the parameters of concern for human health, identifying and characterizing human receptors present in the study area and identifying the potential exposure pathways that are operational. The following sections (12.3.1.1 to 12.3.1.3) describe in more detail the problem formulation for the HHRA.

12.3.1.1 Study Objectives and Methodology

The objectives of the HHRA are to qualitatively and quantitatively evaluate the potential for adverse health effects to human receptors resulting from the air emissions and water discharges related to Project activities.

The HHRA has followed the general methodology recommended by Health Canada - *Part I and V: Guidance on Human Health Preliminary/Detailed Quantitative Risk Assessment* (PQRA/DQRA) Version 2.0 (Health Canada 2010; 2012).

12.3.1.2 Study Area and Potential Exposure Pathways

The local study area as defined in the Air Quality Technical Support Document (TSD) consists of natural areas with few access restrictions other than those in place at the Project site. In close vicinity to the Project site are areas that are used for recreational and/or traditional uses including hunting, trapping, fishing, camping and canoeing. Within the vicinity of the Project site there are also various cottages and hunter/trapper cabins that are occupied seasonally. Therefore, in the vicinity of the Project site, a hunter/angler or seasonal cottager who visit the area for recreational activities such as fishing, hunting, camping, etc. are expected to be present. In addition a member of a First Nations group may visit the surrounding Project site area for the purpose of hunting, fishing and gathering of traditional vegetation.

These receptors could come into contact with emissions and discharges originating from the Project site through various pathways including the following:

- direct inhalation of airborne emissions;
- deposition of emissions to soil with subsequent direct contact (e.g., dermal contact, incidental ingestion and inhalation of re-entrained dust);
- direct ingestion of surface water;
- incidental ingestion and dermal contact of surface water;
- ingestion of fish and wild game; and
- ingestion of plants (e.g., berries, below-ground and above-ground plants).

12.3.1.3 Parameters of Potential Concern

Air

Air emissions will be generated as a result of activities occurring during all phases of the Project. Some of the main sources of emissions include blasting, material handling in the open pit, crushing, road traffic, managing mine rock, ore and overburden, and exhaust from back-up power generation. A detailed assessment of the air emissions arising from the Project can be found in Appendix F. For each of the substances that are expected to be emitted in appreciable quantities, dispersion modelling was conducted providing predicted airborne concentrations at the maximum points of impingement (i.e., outside of the Project site), as well as the locations of different receptors in the study area for different averaging times (1-hour, 24-hours and annual). Modelling also included deposition modelling to understand potential impacts to soil quality resulting from the deposition of contaminants of concern to soil.

Predicted off-property maximum ground level concentrations for the substances expected to be emitted from the Project are provided in Appendix F. These substances include air parameters with specific air quality criteria, as well as various inorganic chemicals of emissions anticipated from the Project activities. The parameters include nitrogen oxides and nitrogen dioxide (NO_x, NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), total suspended particulates (TSP), fine particulate matter less than 10 micrometers (µm) and 2.5 µm (PM_{10} and $PM_{2.5}$), hydrogen cyanide (HCN), calcium oxide (CaO), copper sulphate ($CuSO_4$), volatile organic compounds (VOCs) and metals. In addition, a number of sensitive receptor locations (i.e., cottages) were identified, and the maximum ground level concentrations for the substances expected to be emitted from the Project at these locations were modeled (see Appendix F). Modeled parameters were compared to ambient air quality criteria and were used as inputs to a direct evaluation of human health risk.

Soil

Air emissions resulting from the Project and related activities may deposit as particulates to the soil. Human receptors could become susceptible to substances in soils via various pathways including consumption of traditional vegetation (e.g., berries) grown in the soil, consumption of wild game (e.g., moose) that has consumed vegetation grown in the soil and/or soil organisms or mammals/birds present in the area and via direct contact and inhalation of soil particles.

Therefore, to determine what the predicted concentrations of inorganics in the soil could be as a result of air deposition from the Project, depositional modelling was conducted at the maximum point of impingement (i.e., outside of the Project site) and at the receptor locations deemed "sensitive", as they are occupied by seasonal cottagers and campers. Predicted concentrations of inorganics in soil at both locations (i.e., maximum point of impingement and at the nearest sensitive receptor location) were compared to background soil concentrations that are considered protective of human health exposure pathways including direct contact, and inhalation of particles as well as being protective of plants and soil organisms and mammals and birds.

Surface Water

Surface water quality modelling was conducted to predict changes that may occur as a result of the Project (see Appendix J). The maximum predicted concentrations of major ions, nutrients and metals occurring during each of the Project phases were compared to the Ontario Drinking Water Standard and Canadian Water Quality Guidelines which are protective of human health. In cases where the human health benchmark is based on an aesthetic objective or an operational guideline which does not impact human health, and the predicted concentrations in surface water exceeded these guidelines, then the most recent Provincial Water Quality Objective (OMOEE PWQO) or the Canadian Water Quality Guidelines (CCME WQG), or the British Columbia Ministry of the Environment Water Quality Guideline (BC MOE WQG) was used or if not available the 95th percentile baseline concentration was used for comparison.

12.3.2 Exposure Assessment

12.3.2.1 Inhalation Exposure to Ambient Air

Exposure point concentrations were modelled for the receptors located at the maximum point of impingement (i.e., outside of the Project site) and at the sensitive receptor locations. For the purposes of modelling, it has been assumed that the modelled concentrations of each of the compounds in outdoor air are equal to that in indoor air. Therefore, exposure to the emitted compounds has been assumed to occur continuously (i.e., 24-hours per day).

Potential exposure to operations-related emissions is based on the results of air dispersion modelling which relies on an understanding of the emission rates of different contaminants from various sources and the dispersion characteristics of those contaminants under different atmospheric and physical settings. The exposure point concentrations used in the risk calculations are estimates and represent the maximum estimate of emissions. Depending on the parameter of potential concern, exposures were modelled for 1-hour, 24-hour and annual averaging times. The emission estimates and dispersion modelling used to develop the exposure point concentrations are described in Appendix F. For the purpose of evaluating exposure via direct inhalation, it was assumed a receptor would be exposed to the maximum predicted concentration on a continuous basis for the duration of the Project.

12.3.2.2 Direct and Indirect Exposure to Soil

As indicated above, airborne emissions resulting from the Project and Project-related activities have the potential to deposit onto soil, thereby affecting soil quality and the health of any organisms that inhabit the soil or consume plants that grow in the soil. To understand potential risk associated with this exposure pathway, deposition modelling was undertaken to provide a maximum deposition rate in terms of grams per square metre per year. Assuming incidental mixing within the first 1 cm of soil, the model was used to develop an understanding of the incremental change in background soil quality over the 15-year operational phase of the facility. As there was no appreciable change to background soil quality resulting from deposition, it was concluded that exposure via this pathway would not result in “unacceptable” risk and therefore it was not considered further.

12.3.2.3 Direct and Indirect Exposure to Surface Water

Surface water quality modelling, which examined loadings and flow conditions in the surrounding water bodies, was used to predict concentrations of major ions, nutrients and metals occurring during each of the phases of the Project. Maximum predicted concentrations were compared to relevant benchmarks for the protection of both human and aquatic health. In terms of human health, the essential elements calcium, iron, magnesium, phosphorus and sodium did not have applicable human health benchmarks. However, these are essential elements and are not predicted to be present at concentrations that would pose a risk to human health. With respect to strontium, potential risks were evaluated by assuming that surface water would be used as a source of drinking water with a consumption rate of 1.5 litres per day consistent with Health Canada recommendations. Under such assumptions, strontium is not predicted to be present at concentrations that would present an unacceptable risk to human health.

Human health benchmarks for surface water are considered protective of all exposure pathways relevant to surface water including direct ingestion, dermal contact during swimming and indirect ingestion through fish consumption. As the concentrations of those substances attributable to the Project in surface water are predicted to be below human health benchmarks, it is concluded that there are no unacceptable health risks associated with discharge to surface water.

As mercury is not expected to be present in process elements in appreciable quantities, exposure to this contaminant was not evaluated. It is noted, however, that the construction of the watercourse realignments will result in the flooding of former terrestrial lands. While the areas to be inundated are prone to flooding under existing conditions, it is possible that the decay of terrestrial vegetation would result in the production of methyl mercury that could be taken up by resident fish. However, the removal of vegetation prior to flooding will eliminate the potential for methyl mercury production.

12.3.3 Hazard/Toxicity Assessment

The hazard/toxicity assessment describes the nature of the potential adverse health effects associated with exposure to each of the identified parameters of concern. It also provides recommended toxicity reference values (TRVs) used for evaluating the relationship between predicted levels of exposure and the potential health effects associated with that exposure. To quantitatively address the potential health effects associated with exposure, TRVs from regulatory agencies with well-documented and reviewed sources have been used in this assessment.

12.3.4 Risk Characterization

As exposure via inhalation has been identified as the primary pathway for exposure to those substances emitted from the Project and associated activities, the exposure point concentrations used in determining the potential risks to receptors are represented by the modelled air concentrations at the maximal point of impingement and sensitive receptor locations (see Appendix F). Non-carcinogenic acute risks resulting from inhalation exposure at the maximum point of impingement and sensitive receptor location were calculated using 1-hour averaging times, while chronic non-carcinogenic risk and carcinogenic exposures are based on 24-hour and annual averaging times, respectively.

Both non-carcinogenic and carcinogenic human health risks were calculated using TRVs from recognized regulatory agencies such as Health Canada, the World Health Organization (WHO), U.S. EPA and California Office of Environmental Health Hazard Assessment. The TRVs for the parameters of concern in the assessment were generally available from more than one source. To select the most appropriate acute and chronic TRVs, information presented from each of the regulatory agencies, for each of the parameters of concern was reviewed using a weight of evidence approach. In general, TRVs can consider both acute (short-term) and chronic (long-term) exposure. Acute TRVs are generally threshold concentrations that can be tolerated without evidence of adverse effects based on a short duration of exposure (minutes to hours). For the purpose of this assessment, acute exposures are evaluated for a 1-hour exposure period where such TRVs exist. In contrast, chronic TRVs define the daily dose or exposure that can be tolerated over an extended period (years to a lifetime) without adverse effects. In addition to TRVs for specific parameters of concern, existing air quality objectives, and guidelines for air quality parameters with established criteria have been relied upon with the understanding that these represent desirable or acceptable levels of air quality in a community. For further discussion on the TRVs and their selection, refer to Appendix W.

Acceptable levels of risk are based on an incremental lifetime cancer risk (ILCR) of one in one million for carcinogens or a hazard quotient (HQ – defined as the predicted level of exposure divided by an allowable limit) of 0.2 for non-carcinogenic compounds where it is assumed there is a threshold below which adverse health outcomes do not manifest (i.e., less than 10^{-6} or less than 0.2). The use of an HQ of 0.2 for non-carcinogens is conservative as it assumes a receptor is exposed to the same compound from multiple sources concurrently (e.g., drinking water, consumer products, etc.) and is designed to ensure that the TRV is not exceeded when there is the possibility of multiple sources of exposure. For criteria pollutants where the only source of exposure is ambient air and the point of comparison is an air quality guideline, an exposure ratio (ER) of 1.0 or less is used to denote an acceptable level of risk. When levels of exposure exceed the allowable exposure limits (i.e., ILCR, HQ or ER), adverse health outcomes are not necessarily expected. Rather, considering the uncertainties inherent in the assessment and the safety/uncertainty factors often employed, there is erosion in the margin of safety between the estimated levels of exposure and the concentration that is known to cause adverse effects. Under such a situation, it is prudent to re-examine the basis of all of the assumptions used to generate the estimates of risk and exposure.

At the point of impingement, which represents the maximal theoretical exposure, maximum predicted concentrations of particulate matter (both PM_{10} and $PM_{2.5}$) have ERs greater than 1.0 (4.5 and 1.1 for PM_{10} and $PM_{2.5}$ respectively for 24-hour exposure periods). The ERs are based on concentrations predicted using the worst case emissions coupled with the worst case dispersion conditions using five years of historical meteorological data. In terms of understanding the potential for health risk, it is illustrative to examine the frequency with which the concentration of particulate is predicted to be greater than the risk-based threshold. As an example, for the five year meteorological dataset used for modelling an ER of greater than 1.0 is predicted for $PM_{2.5}$ only 0.22% of the time (four days at four separate locations). As such, periods when concentrations of particulate result in an ER of greater than 1.0 are expected to be infrequent and transitory and not indicative of an unacceptable health risk.

For calcium oxide, a hazard quotient greater than 0.2 (HQ = 0.4) has been noted at the maximum point of impingement. HQs at the sensitive receptor location were less than 0.2. The increased HQ is a slight erosion in the margin of safety, however, adverse effects are not expected. Similar to the criteria air contaminants in which an exposure ratio of 1.0 is used to evaluate health risk rather than a HQ of 0.2, calcium oxide is a sensory irritant and not a systemic toxicant. In addition, adverse effects are not expected as an HQ greater than 0.2 is expected to be infrequent and transitory.

With respect to manganese, the maximum predicted concentration for manganese at the maximum point of impingement results in a hazard quotient greater than 0.2 (HQ of 0.3 for manganese) but is well below 0.2 at the nearest sensitive receptor location. As manganese is a relatively abundant crustal element, its source is the result of fugitive emissions associated with material handling. Adverse health effects associated with exposure to this element is considered unlikely based on the conservative nature of the assumptions that have been made regarding dispersion conditions and exposure. In addition, it is important to note that concentrations at the sensitive receptor locations are well below the Ambient Air Quality Criterion that is permitted under Ontario Regulation 419/05 (see Appendix F).

Predicted hazard quotients for hydrogen cyanide based on maximum predicted concentrations are greater than 0.2 (HQ = 0.85) for the receptor located at the maximum point of impingement. As discussed above, acceptable health risks for non-carcinogens are based on a HQ of 0.2 on the assumption that exposure to a particular substance of concern can originate from multiple sources. In using a HQ of 0.2 to define acceptable risk, 80% of exposure is "reserved" for other potential exposure pathways. In the case of hydrogen cyanide, the principal source of exposure in a non-occupational setting is cigarette smoke, which can contribute 200 - 8,000 micrograms per day for an average smoker. In developing an ambient air standard for hydrogen cyanide for use under Ontario Regulation 419/05, the Ontario Ministry of the Environment used a hazard quotient of 1.0 to define an acceptable level of risk for hydrogen cyanide (MOE, 2005). Notwithstanding potential exposure via other sources such a cigarette smoke, considering the conservatism inherent in developing an acceptable ambient air standard for hydrogen cyanide, the MOE deemed a HQ of 1.0 suitably conservative for this compound. On a similar basis, considering the conservative nature of the dispersion modelling and the transient manner in which people may be exposed, adverse health effects associated with exposure to hydrogen cyanide are considered unlikely.

12.3.5 Summary of Human Health Risk Assessment

In conclusion, unacceptable health risks to human health receptors are not expected to occur as a result of the Project based on the following:

- Air dispersion modelling was completed to evaluate potential exposure at the maximum point of impingement and at the nearest sensitive receptor locations. Results of the modelling indicate exposure ratios greater than 1.0 for PM_{10}, $PM_{2.5}$ and hazard quotients greater than 0.2 for, calcium oxide, manganese and hydrogen cyanide at the maximum point of impingement. However, the periods when this may occur during the Project life will be infrequent and will be localized to the immediate vicinity of the Project site. At the nearest sensitive receptor locations, exposure ratios and hazard quotients for all parameters were all less than 1.0 and 0.2 respectively. Considering the inherent conservatism associated with the dispersion modelling used to develop exposure estimates and the toxicological reference values, adverse health outcomes associated with Project-related emissions are not anticipated.
- Project-related emissions that subsequently deposit to soil were predicted not to alter soil concentrations at the maximum point of impingement above values representative of background for Ontario soils. As such, indirect exposure of Project-related emissions that would result from consumption of local vegetation and/or game that consume such vegetation is not predicted to result in unacceptable health risk.
- Potential health risk associated with discharges to surface water was evaluated through an examination of changes to water quality in the receiving environment under different flow conditions. Resulting water quality, when compared to health-based benchmarks was not found to result in unacceptable health risks to users or consumers of such

surface water. While it is understood that watercourse realignments will result in the flooding of former terrestrial lands, the areas to be inundated are prone to flooding. Nevertheless there is the possibility that the decay of terrestrial vegetation would result in the production of methyl mercury that could be taken up by resident fish. However, the removal of vegetation prior to flooding will eliminate the potential for methyl mercury production.

12.4 Ecological Risk Assessment

12.4.1 Problem Foundation

Ecological Health Risk Assessments (EHRAs) are typically conducted using an iterative approach involving increasingly stringent tiers of evaluation. The level of detail of a risk assessment adopted for a particular situation is typically equal to the degree and extent of potential effects to ecological receptors and the uncertainty inherent in the assessment. Where evidence indicates that adverse effects may occur to one or more ecological receptors, a more detailed assessment may be required. Sections 12.4.1.1 to 12.4.1.3 further describe the problem formulation for the current EHRA.

12.4.1.1 Study Objectives and Methodology

The objectives of the current EHRA are to qualitatively and quantitatively evaluate the potential for adverse health effects to ecological receptors resulting from the Project activities. The EHRA has followed the methodology guidance established under the Federal Contaminated Sites Action Plan (Azimuth, 2012) and supplementary guidance provided by Environment Canada - A Framework for Ecological Risk Assessment: General Guidance (CCME, 1996, 1997).

12.4.1.2 Study Area and Potential Exposure Pathways

The Project site is in an area that is moderately hilly within a mixed boreal wood forest (i.e., poplar, birch, pine and spruce forest) characterized with bogs, fens and lakes that are relatively shallow (i.e., <10 m deep). The local study area as defined in the Air Quality TSD (see Appendix F) is inhabited by various terrestrial ecological receptors including soil invertebrates (e.g., earthworms), terrestrial plants (e.g., trees such as balsam fir, red maple, black ash, etc., small trees, shrubs and woody vines such as bunchberry, Labrador tea, choke cherry and sweet blueberry, ferns and allies, graminoids, forbs, mosses and lichens), mammals (e.g., beaver, black bear, fisher, moose, red fox, white-tailed deer, etc.) and birds (e.g., American bittern, American robin, barred owl, blue-wing teal, Canada goose, etc.), as detailed in Chapter 6 and in Appendices K to M. With respect to aquatic receptors, the water bodies at and around the Project site are inhabited with aquatic vegetation (submergent and emergent), benthic communities and higher trophic level receptors including a variety of fishes such as: blacknose shiner, spotail shiner and the Iowa darter which are small-bodied fish and larger sport fish including: northern pike, yellow perch, walleye, whitefish and smallmouth bass (see Chapter 6 and Appendix N).

A receptor is defined as an organism or group of organisms that have the potential to be affected by a chemical or other stressors. Receptors selected for assessment typically represent ecological receptors, resources or environmental features that have economic and/or social value, or intrinsic ecological significance. The relevant ecological receptors have local, regional, provincial, national, and/or international profiles, and serve as a baseline from which the impacts of development can be evaluated, including changes in management or regulatory policies.

In the current assessment, the groups of ecological receptors considered are as follows.

Terrestrial Plants

Consistent with CCME (1996; 1997) guidance, plants are typically assessed as a group rather than as separate species. Plants are potentially exposed to parameters of concern in soil via root uptake and, in some cases, foliar uptake from aerial deposition. As no parameters of concern have been identified in soil, then root uptake is considered an incomplete pathway. With respect to foliar uptake from aerial deposition, this is not expected to be a significant pathway on the basis of wash-off due to precipitation.

Soil Invertebrates

In terms of sensitivity to toxic parameters, earthworms are considered to be one of the most sensitive receptors for soil contaminants. Earthworms are in near-constant direct dermal contact with soil and are important in ensuring soil fertility. Their feeding and burrowing activities breakdown organic matter and release nutrients and improve aeration, drainage and aggregation of soil. Earthworms are also important components of the diets of many birds and mammals.

Birds

The local and regional study areas as defined in the air quality technical support document provides suitable habitat for a number of avian species including: owls, raptors, waterfowl, upland game birds, songbirds and woodpeckers. These types of birds are typically represented by the following species: barn owl and red-tailed hawk which are assumed to consume 100% small mammals; belted kingfisher which are assumed to consume 100% fish; wild turkey which are assumed to consume 100% plants; and the American robin and yellow-bellied sapsucker which are assumed to consume 100% soil invertebrates.

Mammals

Within the local and regional study areas there are several mammals that have been observed, or have the possibility to occur due to appropriate habitat conditions. Some of the smaller mammals include: deer mouse; woodland/meadow jumping mouse; meadow/rock vole; southern bog lemming; red squirrel, etc. Larger mammals include: beaver, black bear, gray wolf, red fox, snowshoe hare, etc. Lastly, with respect to ungulates, moose have been observed and there is also appropriate habitat for white-tailed deer.

Aquatic Plants

Aquatic plants are an important component of freshwater ecological systems. Aquatic plants take a variety of forms, including submerged, emergent, and free-floating forms. Aquatic plants, including algae, oxygenate water and form the basis of the aquatic food chain. Similar to terrestrial plants, aquatic plants are typically evaluated as a group rather than individual species.

Aquatic Invertebrates

Aquatic invertebrates are an important group of organisms in most freshwater systems. Aquatic invertebrates, as a group, play a critical role in the ecology of aquatic systems, as primary consumers, detritivores, and as prey for higher trophic level organisms. Additionally, aquatic invertebrates as a group tend to be one of the most sensitive to environmental contaminants, so protection of invertebrates also tends to result in protection of other species. Invertebrates are often used as "indicators" of environmental degradation, because of their rapid and predictable response to various environmental contaminants and other stressors.

Fish

Fish can be exposed to contaminants in surface water and sediment, but regardless of the source, uptake across the gills occurs via the aqueous pathway; therefore, for the purposes of this assessment it was assumed that fish are exposed primarily via uptake of aqueous constituents across the gills. It is important to note that, unlike some other receptors, fish are mobile and capable of avoiding contaminants; fish in an unconfined water body can ameliorate their exposure to contaminants in surface water by moving to another location.

Ecological receptors may come into contact with air emissions and water discharges originating from the Project site through various pathways including the following:

- direct inhalation of airborne emissions;
- deposition to soil with subsequent direct contact (e.g., dermal contact, incidental ingestion and inhalation of re-entrained dust);
- direct ingestion of surface water;
- incidental ingestion and dermal contact of surface water;
- consumption of fish, soil/aquatic invertebrates and mammals; and
- consumption of plants (e.g., berries, below-ground and above-ground plants and aquatic plants).

12.4.1.3 Parameters of Potential Concern

Air

Air emissions will be generated as a result of activities occurring from all phases of the Project. Some of the main sources of emissions includes blasting, material handling in the open pit, crushing, road traffic, managing mine rock, ore and overburden, and exhaust from back-up power generation. A detailed assessment of the air emissions arising from the Project can be found in Appendix F. For each of the substances that are expected to be emitted in appreciable quantities, dispersion modelling was conducted providing predicted airborne concentrations at the maximum points of impingement (outside of the Project site), as well as the location of different receptors in the study area for different averaging times (1-hour, 24-hours and annual).

Soil

Air emissions resulting from the Project and Project-related activities may deposit as particulates to the soil. The presence of parameters of concern in soil could then be available for uptake by ecological receptors via various pathways including direct contact, consumption of terrestrial plants and consumption of mammals and birds that have consumed vegetation grown in the soil and/or soil organisms or mammals/birds present in the area.

Therefore, to determine what the predicted concentrations of inorganics in the soil are as a result of air deposition from the Project, depositional modelling was conducted at the maximum point of impingement outside of the Project site. Predicted concentrations of inorganics in soil were compared to background soil concentrations that are considered protective of plants and soil organisms and mammals and birds.

Surface Water

Surface water quality modelling was conducted to predict changes that may occur as a result of the Project and its various phases (see Appendix J). The maximum predicted concentrations of major ions, nutrients and metals occurring during each of the Project phases were compared to Aquatic Health Benchmarks and Human Health Benchmarks. The Aquatic Health Benchmarks have been set to the most recent PWQO or CWQG or the BCMOE Guidelines for parameters with no PWQO or CWQG. Where no guidelines exist, the baselines concentration (upper 95th percentile) of relevant parameters was used as the benchmark.

12.4.2 Exposure Assessment

12.4.2.1 Inhalation Exposure to Ambient Air

Ecological receptors could come into contact with airborne emissions via inhalation or through deposition to foliage and subsequent uptake. However, exposure via these pathways is thought to be minimal as a comparison of predicted airborne emissions to ambient air standards, which are protective of both human and ecological receptors based on direct inhalation, indicated that only particulate matter (<10 µm and <2.5 µm) had predicted airborne concentrations higher than their respective Ambient Air Quality Criteria (AAQC). It is worth noting that the AAQCs are a conservative screening tool for ecological receptors as the AAQCs for particulate matter are focused on protecting small decrements in human health (i.e., lung function) which would not affect an ecological receptor on a population level. Particulate matter typically consists of a variety of components including elemental and organic carbon, nitrates, ammonia, sulphates and trace metals. US EPA (2003) indicates that these fractions are not typically considered respirable; rather, predominant exposure is typically through the ingestion of dust which is accounted for through the soil ingestion pathways. As there are no expected appreciable changes to background soil quality resulting from deposition from the Project, exposure to parameters of potential concern via soil ingestion within the study area is not expected. As such, this exposure pathway is not considered further in the EHRA.

12.4.2.2 Direct and Indirect Exposure to Soil

Airborne emissions resulting from the Project and Project-related activities have the potential to deposit to soil thereby affecting soil quality and the health of any organisms that inhabit the soil or consume plants/soil organisms and/or mammals that reside in the potentially impacted area. Specifically, terrestrial receptors may be exposed to parameters of potential concern in soil through:

- root uptake of parameters of potential concern from soil and/or root contact by terrestrial plants;
- direct contact with parameters of potential concern in soil by terrestrial plants, invertebrates, small mammals and birds; and
- incidental ingestion of vegetation and prey items that have accumulated parameters of potential concern from the soil by mammals and birds.

To understand potential risks associated with this exposure pathway, depositional modelling was undertaken to provide a maximum deposition rate of different parameters of concern. Assuming incidental mixing within the first 1 cm of soil, this was used to develop an understanding of the incremental change in background soil quality over the 15-year operational phase of the facility. As there was no incremental change to background soil quality resulting from deposition, it was concluded that exposure via this pathway would not result in “unacceptable” risk to ecological receptors and therefore it was not considered further.

12.4.2.3 Direct and Indirect Exposure to Surface Water

Terrestrial receptors may be exposed to parameters of potential concern in surface water through ingestion via drinking water and through direct contact. Aquatic receptors may be exposed to parameters of concern in surface water through the ingestion of aquatic vegetation and prey items (see Appendix N for further details).

12.4.3 Risk Characterization

As there is no expected appreciable change to background soil quality resulting from deposition as a result of the Project, unacceptable risk to terrestrial receptors that may be exposed to soil within the study area is not expected.

To characterize the risk to aquatic receptors in an EHRA, the HQ can be calculated to provide a quantitative estimate of overall risk. If the HQ is less than 1.0, no unacceptable risks to aquatic receptors would be expected because concentrations are below levels known to cause adverse effects. Conversely, if the HQ exceeds 1.0, it may be inferred that adverse effects to individuals are possible.

For the parameters in surface water that exceeded the aquatic health benchmark, concentrations were compared to risk-based toxicological reference values which were obtained from a review of the literature. Specifically, maximum predicted concentrations of arsenic, calcium, iron, magnesium, sodium and strontium were all compared to toxicity reference values and resulted in calculated hazard quotients of less than 1. With the exception of phosphorus, although maximum predicted concentrations exceeded the aquatic health benchmark, adverse effects resulting from these predicted phosphorus levels in surface water are not expected as the model incorporates baseline data that was elevated as a result of the analytical process.

12.4.4 Summary of Ecological Health Risk Assessment

In conclusion, unacceptable health risks to ecological receptors are not expected to occur as a result of the Project based on the following:

- Ecological receptors could come into contact with airborne emissions via inhalation or through deposition to foliage and subsequent uptake. However, exposure via these pathways is minimal. A comparison of predicted airborne emissions to ambient air standards indicates that only particulate matter (<10 µm and <2.5 µm) had predicted airborne concentrations higher than their respective AAQC. However, the AAQCs are a conservative screening tool for ecological receptors as the AAQCs for particulate matter are focused on protecting small decrements in human health (i.e., lung function) which would not affect an ecological receptor on a population level.
- Project-related emissions that subsequently deposit to soil were predicted not to alter soil concentrations at the maximum point of impingement above values representative of background for Ontario soils. As such, exposure to ecological receptors via direct and indirect exposure to soil is not expected to result in adverse effects.
- Potential risks associated with discharges to surface water are not expected to cause adverse effects to aquatic receptors as hazard quotients for parameters of potential concern are less than the HQ threshold of 1.0 when compared to risk-based TRVs. Risks to terrestrial receptors resulting from exposure to surface water are also not expected to occur as concentrations are below human health benchmarks which are protective of all exposure pathways relevant to surface water including direct ingestion, dermal contact during swimming and indirect ingestion of fish.

12.5 Conclusions

In conclusion, unacceptable health risks to human health receptors are not expected to occur as a result of the Project. Although modelling predicts exposure ratios greater than 1.0 for PM_{10}, $PM_{2.5}$ and HQs greater than 0.2 for calcium oxide, manganese and hydrogen cyanide, based on maximum predicted concentrations, periods when this may occur will be infrequent, transient in nature and localized in the area outside of the Project site. As a result, exposure is expected to be much less than that predicted by modelling.

In terms of risk to ecological receptors, no unacceptable risks attributable to Project related emissions and discharges were identified for terrestrial receptors. With respect to the aquatic receptors, while modelling identified concentrations that are greater than aquatic health benchmarks for certain substances and receiving environments, when compared to risk-based toxicological reference values for relevant aquatic species, no unacceptable risks were identified.