Human Health and Ecological Risk Assessment for Fox-C Dew Line Site

Ekalugad Fjord

Baffin Island

Submitted to:

Public Works and Government Services Canada
Western Region

Jacques Whitford

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HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT FOR THE FOX-C (EKALUGAD FJORD) DISTANT EARLY WARNING (DEW) LINE SITE

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EXECUTIVE SUMMARY

Jacques Whitford Limited (Jacques Whitford) performed a human health and ecological risk assessment (HHERA) of the Fox-C (Ekalugad Fjord) Distant Early Warning (DEW) line site on Baffin Island, Nunavut. The primary objective of this study was to evaluate whether known concentrations of chemicals in surface soil and water at the site would present a significant risk to human or ecological health based on future use of the property in its current condition and after remediation.

Ekalugad Fjord is located on the northern coast of Baffin Island, above Quarmaratalik Cove. The site was an intermediate DEW Line site (FOX-C) until 1963.

Study Background

The current study undertook a human and ecological risk assessment of the FOX-C site. It is supported by new contaminants data for the site, based on a Phase III Environmental Site Assessment (Earth Tech 2004) which included analysis for hydrocarbons, as well as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and inorganic substances in soils, as well as a limited number of analyses for ground water, lake and river sediments, lake water and fish. A restricted number of background soil samples were also collected. The ERA considered a broad range of ecological receptors and incorporated the new data, while retaining the previously collected data for FOX-C. The HHRA also evaluated both Phase II and the newly generated Phase III data supplied and described by Earth Tech (2004).

Data Compilation

The soil and water sample data from the Phase II and Phase III sampling programs were screened for use in this risk assessment. For the purposes of the risk assessment for both human and ecological receptors, only soil samples that accurately reflect concentrations in the upper 10 to 15 cm from ground surface are relevant to potential exposures.

The Phase II and Phase III data were screened on the basis of depth and any sample that did not intersect the surface and/or extended to a depth of greater than 0.3 m below ground surface (mbgs) was excluded. This was done to ensure that the data used were representative of surface soil and not heavily influenced by subsurface soil characteristics.

Screening of Chemicals of Potential Concern (CoPCs)

CoPCs included for consideration were the chemicals identified by Earth Tech in their Phase III Reports as exceeding generic CCME soil quality guidelines (CCME 1999). Generic CCME guidelines may be based on either ecological or human health protection and provide a protective initial screening of the site data. For the human health risk assessment, these chemicals were screened specifically against human health based generic guidelines and for the ecological risk assessment, they were screened specifically against ecologically based generic guidelines. In order of preference, these guidelines are taken from CCME (CCME 1999),

Ontario Ministry of the Environment (OMOE 1996a), or the United States Environmental Protection Agency (US EPA).

Based on the human health based criteria screening, the chemicals carried forward to the quantitative human health risk assessment of the Upper Site were beryllium, copper, lead and total petroleum hydrocarbon (TPH) F2, F3 and F4 fractions. Those carried forward in the Lower Site HHRA included beryllium and the TPH F3 Fraction.

The chemicals carried forward in the ERA include the F1 to F4 TPH fractions, phenanthrene, beryllium, copper, cadmium, chromium (total), copper, lead and zinc. The same CoPCs were carried forward in the ERA for both the Upper and Lower Sites.

Exposure Scenarios

The study area is defined as the area including and surrounding the investigated areas at FOX-C, was divided into two distinct sites: the Upper Site and Lower Site.

Upper Site

Infrastructure at the Upper Site includes the module train; warehouse and garage; Inuit house (dormitory); petroleum, oil, lubricant (POL) pumphouse; quonset hut; collapsed communications antenna; POL tanks; storage shed; paint shed; and four dump sites.

Lower Site

The Lower Site includes a wooden hut; POL tanks; and storage shed. For the purposes of the HHERA, the area of the Lower Site was estimated to be 2 ha, which also includes the various areas where drums have been discarded around the site. The Lower and Upper Sites are connected by an access road.

Due to the northern location of the FOX-C and the probable use of the site by Inuit for traditional purposes, the conventional land use categories (residential, parkland, commercial, and industrial) were expanded to incorporate the traditional Inuit land use. The parameters of this land use are discussed in detail in Gartner Lee and Cantox (1998), and were developed after consultation with residents of the Eastern Arctic, the Quikiqtaaluk Corporation and DIAND.

The current assessment adopted the traditional land use for the FOX-C site, as set out by Gartner Lee and Cantox (1998). The traditional land use designation consists of Inuit families residing on the land, in tents for periods up to 3 months. It was assumed that during this period the Inuit engage in traditional hunting, fishing and gathering activities. It was also assumed that all time spent on site was in the non-snow covered months, which results in the most extensive exposure scenario for the human receptors. Detailed exposure values are discussed in Section 4.3, and in the Gartner Lee and Cantox report (1998).

Based on this land uses, the following conceptual models were developed:

Human Health

The conceptual model that forms the basis for the derivation of the human health soil quality site-specific threshold limits is as follows:

Traditional Site Use Scenario:

- A toddler aged six months to four years is exposed to surface soil contaminated with non-carcinogenic beryllium, copper, lead and the F3 TPH fraction by inadvertent ingestion / dermal contact / dust inhalation, water ingestion and dermal contact, and the ingestion of land foods (caribou, hare and fish);

- A person visits the site yearly from birth to 75 years of age and is exposed to beryllium, which is also a known carcinogen, by inadvertent ingestion / dermal contact / dust inhalation, water ingestion and dermal contact, and the ingestion of land foods (caribou, hare and Arctic charr) throughout their lifetime.

Ecological Health

The risks of exposure to contaminated soils were the focus of the ecological risk assessment (ERA). The potential exposure media for intake of metals included direct ingestion of soils, as well as metal uptake from eating terrestrial plant material, drinking water, ingesting terrestrial invertebrates, and terrestrial mammals. The major exposure pathway considered was ingestion. Inhalation and dermal absorption were also possible exposure pathways, but these were considered to be relatively minor by comparison to ingestion, and were not included as direct pathways in the ERA. Soil that adheres to fur or feathers is, for the most part, ingested by preening/licking activity and was included in the estimate of direct soil ingestion.

The receptors selected in the ERA are ermine, Arctic hare, ptarmigan, lemming, Snowy owl, Arctic Fox, and caribou. These receptors were considered to be representative of indigenous wildlife at the FOX-C site. Other valued ecosystem components (VECs) were considered for the sites (discussed in section 5.2.4) but these receptors were chosen to be protective of all VECs potentially on site.

Risk Characterization

The above-noted exposure scenarios were evaluated to identify the potential for adverse effects to human or ecological receptors, with the following outcomes:

- Surface soil maximums of the identified chemicals are not anticipated to produce adverse effects in human receptors under the exposure scenarios included in the risk assessment.

- Surface soil exposure point concentrations (EPCs) of the identified chemicals are not anticipated to produce adverse effects in ecological receptors under the exposure scenarios included in the risk assessment.

Because no human health risk was found using the maximum soils CoPC concentrations, Site specific target levels (SSTLs) were developed for each CoPC based on ecological health site-specific threshold limits developed in this risk assessment. The SSTLs were compared to current site conditions (EPCs and maximum concentrations).

Remediation

Specific localized areas have been identified as "hot spots" where concentrations of selected CoPCs were elevated. Even though, these areas do not pose a significant human or ecological risk, they were selected to be removed for aesthetic reasons as well as to remove any remaining and obvious soil stained/contaminated areas. These areas will be excavated and removed from contact of all receptors. The consequential removal of these selected areas resulted in drops of EPCs for human health for the top site (most contaminated) of 41% (PCBs), 92% (TPH F2 fraction), 90% (copper) and 86% (lead). The EPC for human health represents a drop in the maximum concentrations found on site. This resulted in a subsequent drop in the calculated total hazard quotients associated with the top site of 91% (TPH F2 fraction), 19% (copper) and 76% (lead).

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GLOSSARY

Acceptable risk: A risk level that is considered by society or regulatory agencies as tolerable.

Background level: The normal ambient environmental concentration levels of a substance.

BTEX: benzene, toluene, ethylbenzene, xylenes - substances typically found in petroleum products such as gasoline, heating oil, automotive oil, etc.

Cancer: a disease characterized by malignant, uncontrolled invasive growth of body tissue cells.

Carcinogen: A chemical or substance capable or suspected to be capable of producing cancer in living organisms.

CCME: Canadian Council of Ministers of the Environment. CCME publishes Canadian Environmental Quality Guidelines for soil and other environmental media. CCME also publishes a process for assessing and clean-up of contaminated sites.

Chronic exposure: The long-term, low-level exposure to substances, i.e., the repeated exposure or doses to a substance over a long period of time. It may cause latent damage that does not appear until a later period in time.

Chronic toxicity: The occurrence of symptoms, diseases, or other adverse health effects that develop and persist over time, after exposure to a substance delivered over a relatively long period of time.

Chronic daily intake: The intake of a substance, expressed in mg/kg-day, averaged over a long period of time.

Concentration: A quantitative measure of the amount of a substance present in a sample. Typically defined in milligrams per kilogram (mg/kg) for soil samples or milligrams per litre (mg/L) for water samples. mg/kg and mg/L are also equivalently expressed as parts per million (ppm)

Conservatism: The tendency towards caution or protection. Conservative assumptions made in a risk assessment are designed so as to over-predict the actual risks.

CoPC - Chemical of Potential Concern: A chemical that is carried forward into a risk assessment.

Dermal exposure: Exposure to a substance through skin absorption.

Dose: That amount of a substance taken in by a receptor on exposure; it is a measure of the amount of the substance received by the receptor, as a result of exposure expressed as an amount of exposure (in mg) per unit body weight of the receptor (in kg).

Dose-response: The quantitative relationship between the dose of a substance and observed health effect caused by exposure to such substance.

Dose-response evaluation: The process of quantitatively evaluating toxicity information and characterizing the relationship between the

dose of a substance and the expected incidence of adverse health effects in the exposed population.

Effect: The response observed in the body due to exposure to a substance (e.g., decreased body weight).

Endpoint: The specific effect (e.g., liver damage) upon which a toxicity value is determined.

Exposure: Receiving a dose of a substance; or coming in contact with a hazard.

Exposure assessment: The exposure assessment includes the identification of the receptors of interest, the identification of the relevant exposure pathways, and the quantification of the exposures from each pathway.

Exposure pathway: The mechanism by which a receptor can be exposed to a chemical hazard, such as ingestion of contaminated soil or inhalation of contaminated air.

Exposure Point Concentration (EPC): The calculated concentration of a substance that is representative of the concentration at the point of exposure (i.e., the concentration of a substance in soil, water or air that is carried forward in the risk assessment calculations for a particular exposure pathway).

Exposure Scenario: Combination of a hazard, pathway and a receptor.

Groundwater: The water contained in interconnected pores located below the water table.

Guidelines: Guidelines for environmental quality are defined by regulators for many substances to quickly and easily identify the concentration of a substance where no further investigation or study is required. If the concentration of a sample exceeds an established guideline, then further investigation is carried out to determine if action might be required.

Hazard: The inherent toxic potency of a substance independent of level of exposure.

Hazard identification: This is the first step in a risk assessment and is used to identify environmental hazards (e.g., CoPC) that may pose a health risk. The chemical hazards at a site are identified based on the results of data reviewed and field investigations, as well as an understanding of the toxicology of the substances of concern.

Hazard index (HI): Sum of the CoPC – specific hazard quotients for an exposure scenario.

Hazard quotient (HQ): The ratio between the calculated potential dose of a substance and the toxicity value for that substance. Values below 1.0 suggest the potential dose is below the toxicity value and no adverse health effects would be expected.

Human health risk: The likelihood (or probability) that a given exposure or series of exposures to a hazardous substance will cause adverse health impacts on individual receptors experiencing the exposures.

Hydrocarbons: Organic chemicals associated with fossil fuels such as petroleum products.

Incremental excess lifetime cancer risk (IELCR): An upper-bound estimate of the excess potential cancer risk, expressed as a probability of cancer incidence for an exposed individual over a lifetime.

Ingestion: Exposure to a substance through the mouth and into the gastrointestinal system.

Inhalation: Exposure to a substance through the respiratory tract system.

Intake: The amount of material inhaled, ingested, or dermally absorbed during a specified time period. It is a measure of exposure, expressed in mg CoPC /kg BW - day.

Lifetime average daily dose (LADD): The average dose of a substance over a lifetime, expressed as a mass of a substance per unit body weight per unit time.

Modeling: Use of mathematical algorithms to simulate and predict real events and processes.

Petroleum Hydrocarbons: A class of organic chemicals associated with petroleum products such as gasoline, lubricating oil and home heating oil.

Polycyclic Aromatic Hydrocarbons (PAHs): A class of organic chemicals often associated with the burning of wood, coal, heating oil, and many industrial processes.

Potency: A measure of the relative toxicity of a substance.

ppb (parts per billion): An amount of substance in a billion parts of another material; also expressed by µg/kg or µg /L.

ppm (parts per million): An amount of substance in a million parts of another material; also expressed by mg/kg or mg/L.

Receptor: Refers to members of a potentially exposed population, e.g., persons or organisms that are potentially exposed to a particular substance. Receptors do not represent real people, but rather are used hypothetically, to represent an individual who might be expected to have a maximum potential exposure.

Receptor identification: Identification of the receptors that may be exposed to the CoPC.

Reference dose (RfD): The maximum theoretical chronic dose of substance that the human body can absorb without experiencing chronic health effect; it is expressed in mg of substance per kg body weight per day. It is the estimate of lifetime daily exposure of a non-carcinogenic substance for the general human population which appears to be without an appreciable risk of deleterious effect; used interchangeably with Tolerable Daily Intake (TDI).

Risk assessment: The determination of the potential adverse health effects due to exposure to substances that may cause harm.

Risk management: The steps and processes taken to reduce, abate, or eliminate any unacceptable risks that have been identified by a risk assessment.

Risk: The probability or likelihood of an adverse consequence from a hazardous situation or hazard, or the potential for the realization of undesirable adverse consequences from impending events.

Risk characterization: The assessment of the predicted health risk from exposure to each substance by each receptor. The quantification of health risks is calculated for the identified pathways using generally accepted methods and appropriate assumptions about exposure. The risk characterization can determine if adverse health effects are expected from exposure to the substance at the exposure point.

Slope factor (SF): A plausible upper-bound probability estimate of a response per unit intake of a substance over a lifetime. It is used to estimate an upper bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen.

Surface Soil: Includes all samples taken at shallow depths (less than 20 cm) in an outdoor location and any soil type material that might have been collected inside a building.

Surface Water: Water from lakes, rivers and streams.

Threshold: The lowest dose or exposure of a substance at which a specified measurable effect is observed and below which such effect is not observed.

Tolerable Daily Intake (TDI): The maximum amount of a substance that the human body can absorb without experiencing chronic health effects; it is expressed in mg of substance per kg body weight per day. It is the estimate of lifetime daily exposure of a non-carcinogenic substance for the general human population that appears to be without an appreciable risk of deleterious effects; used interchangeably with Reference Dose (RfD).

Toxicity: The harmful effects produced by a substance. It is the quality or degree of being poisonous or harmful to human or ecological receptors.

Toxicity assessment: Toxicity reference values are obtained for the CoPC. The reference dose (RfD) is the estimate of lifetime daily exposure to a non-carcinogenic substance for the general human population that appears to be without appreciable risk of deleterious effects. It is expressed as mg substance/kg body weight/day. The slope factor (SF) is a plausible upper-bound estimate of the probability of a response per unit intake of a substance over a lifetime, expressed as $(mg/kg\ bw/day)^{-1}$. It is used to estimate an upper bound probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen.

Uncertainty: The degree of confidence in the estimate of a variable's magnitude or probability of occurrence.

Uncertainty assessment: A qualitative or quantitative assessment of the uncertainty associated with the risk estimation. Uncertainty may be associated with a number of components of the HHRA, including the exposure estimate, the toxicity reference value, and the assumed bioavailability of the CoPC from the exposure matrix.

Uncertainty factor (UF): Refers to a factor that is used to provide a margin of error when extrapolating from experimental animals to estimate human health risks.

1.0 INTRODUCTION

Jacques Whitford Limited (Jacques Whitford) was commissioned by Public Works and Government Services Canada (PWGSC) on behalf of the Department of Indian and Northern Development (DIAND) to complete a Human Health and Ecological Risk Assessment (HHERA) to evaluate the current risk associated with chemical concentrations found on-site, develop surface site specific target levels (SSTLs) and evaluate the effects of proposed remedial actions on the risk associated with the FOX-C (Ekalugad Fjord) Distant Early Warning (DEW) site (Figure 1.1). The study addresses concerns regarding exposure to potentially hazardous metals and organic chemicals in surface soil and water.

FOX-C was an intermediate DEW line site that is listed as one of the high priority sites for mitigation and remediation of environmental impacts as part of the Federal Contaminated Sites Accelerated Action Plan (FCSAAP).

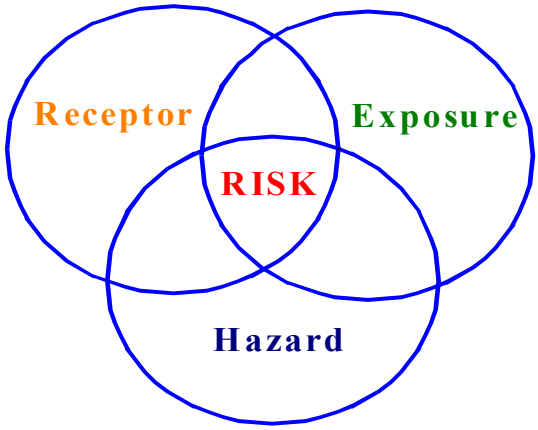
1.1 SCOPE AND OBJECTIVES

The purpose of this study was to determine concentrations of chemicals of potential concern (CoPCs) in surface soil below which no adverse health effects would be expected. These site-specific target levels (SSTLs) are to be used in preparation for reclamation work at the FOX-C DEW line site. To meet this objective, a widely accepted risk assessment framework was adopted in which potential hazards, exposure pathways, and receptors are evaluated to determine if a risk is present, as illustrated in the diagram below:

The human health and ecological risk assessment framework comprises the following major components:

Hazard Identification: Identification of the environmental hazards that may pose a health risk (e.g. chemicals).

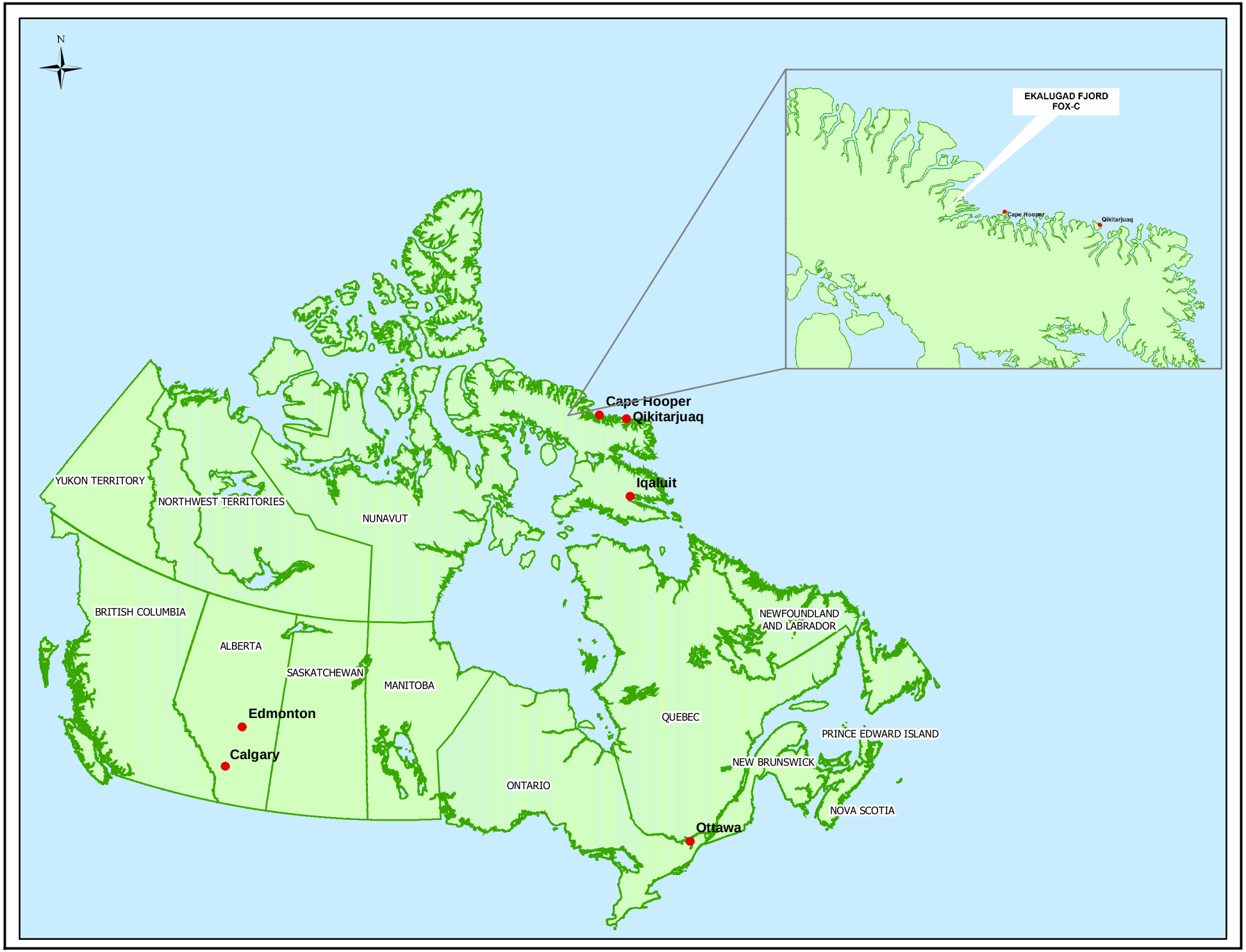
Receptor Identification: Identification of the human receptors and biota that may be exposed to the above hazard(s).



Toxicity Assessment: Identification of published, scientifically reviewed toxicity values against which exposures can be compared.

Exposure Assessment: Qualitative or quantitative evaluation of the likelihood or degree to which the receptors will be exposed to the hazard.

Risk Characterization: Qualitative or quantitative assessment of the actual health risk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EKALUGAD FJORD
FOX-C
Cape Hooper
Qikitarjuaq
Cape Hooper
Qikitarjuaq
Iqaluit
YUKON TERRITORY
NORTHWEST TERRITORIES
NUNAVUT
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND
AND LABRADOR
PRINCE EDWARD ISLAND
NEW BRUNSWICK
NOVA SCOTIA
Edmonton
Calgary
Ottawa

of each hazard to each receptor, based on the degree of exposure.

Uncertainty Assessment: Review of the uncertainty associated with the risk estimation.

SSTL Determination: The determination of concentrations at the site below which no adverse effects would be expected.

The derivation of SSTLs presented in this report follows the general methodology as outlined above. Specific tasks included:

- Review and compilation of existing data and a summary of past results;
- Qualitative risk screening to identify scenarios which are likely to present the greatest risk; and
- Quantitative risk analysis to develop SSTLs for those scenarios which are most likely to present risk.

It is important to note that this report does not evaluate potential health issues that may have occurred in the past, rather it is designed only to evaluate current and potential future exposures to chemicals in soil, based on present day conditions and assumed future post-reclamation conditions.

1.2 RATIONALE FOR SITE-SPECIFIC RISK ASSESSMENT

Generic or Tier I surface soil guidelines have been developed by the Canadian Council of Ministers of the Environment (CCME 1999). These guidelines are conservative benchmarks developed for screening purposes. If soil concentrations are less than these guidelines, then the potential for human health and ecological effects is negligible. Conversely, if soil concentrations exceed these guidelines it does not necessarily mean that unacceptable risks exist. The generic guidelines are intentionally conservative, do not take into account regional or site-specific information (e.g., background soil conditions) and are not appropriate for every site or region of the country.

With this in mind, in 1996 the CCME published two documents (CCME 1996a, b), thereby acknowledging that these guidelines are not set in stone but may be modified in some instances if supported by sound reasoning and/or by the provision of site-specific data. In fact, to proceed with remediation without developing site-specific criteria could result in disruptive remedial action that brings little or no health benefit. Deriving SSTLs specifically for Ekalugad Fjord is a more accurate way of assessing the significance of soil concentrations to human and ecological health in the area.

Soil chemical concentrations were initially evaluated using the Canadian Environmental Quality Guidelines published by the CCME in 1999.

The specific methods employed to develop the SSTLs are consistent with CCME and Health Canada protocols as referenced above, and with standard human health and ecological risk assessment methodologies.

2.0 STUDY BACKGROUND

2.1 SITE DESCRIPTION

Ekalugad Fjord is located on the northern coast of Baffin Island (68°42' N, 68°33' W), above Quarmaratalik Cove. The site was an intermediate DEW Line site (FOX-C) until 1963 (see Figure 1). The Ekalugad Fjord is situated in the Arctic Cordillera ecozone, which is characterized by rugged and partially ice covered mountainous terrain. At FOX-C, the landscape is composed mainly of Precambrian bedrock hills with lowland plains covered with extensive glacial moraine and sand outwash.

2.2 STUDY AREAS

The study area was defined as the area including and surrounding the investigated areas at FOX-C, which was divided into two distinct sites (upper and lower).

Upper Site

Infrastructure at the Upper Site includes a module train; warehouse and garage; Inuit house (dormitory); petroleum, oil, lubricant (POL) pumphouse; quonset hut; collapsed communications antenna; POL tanks; storage shed; paint shed; and four dump sites. The upper site included highest points of the DEW line site as well as middle station barrel dumps.

Lower Site

The lower site, for the purpose of the HHERA, was defined as all lower areas which include lake area, helipad area, river area and beach area. This area will most likely have the most ecological and human receptor contact and was the primary focus of the risk assessment report. The Lower Site includes a wooden hut; POL tanks; and storage shed. For the purposes of the HHERA, impacted area of the Lower Site was estimated to be 2 hectares (ha), which also includes various areas where drums have been discarded around the site. An access road connects the Lower and Upper Sites.

At the Lower Site, a glacier fed freshwater lake (approx. 40 ha) is situated northwest of the main area where site activities were carried out. The freshwater lake was used as an airstrip during the winter period.

The lake is connected to Qarmaralik Cove in the Arctic Ocean via a meandering river approximately 1 km long. The lake supports a breeding population of anadromous Arctic charr. The potentially contaminated areas associated with past operations at FOX-C lie within this overall environmental context.

2.3 PREVIOUS REPORTS

In 1994, the Environmental Sciences Group of Royal Roads Military College (RRMC) completed a report entitled "Environmental Study of Abandoned DEW Line Sites" (RRMC, 1994) in which a detailed surface soil, water, and vegetation sampling program was completed for DEW line sites across the Canadian north. Soil contamination exceeding DEW Line Clean-up Criteria (DCC) was identified at various locations throughout the FOX-C site for PCBs, copper, cadmium, lead, and zinc (RRMC 1994). Dew Line Clean-up Criteria (DCC) were

developed specifically for remediation of Department of Natural Defence Dew Line Sites. Samples analyzed for PAHs, although detectable, did not exceed criteria.

In 1998, Gartner Lee Limited with Cantox Inc. conducted an ecological risk assessment (screening level) for the FOX-C DEW Line site (GLL 1998) to determine the potential risks to ecological receptors due to onsite contamination of soils and vegetation with a variety of metals and PCBs. Results showed that concentrations of five inorganic chemicals (cadmium, copper, lead, nickel, and zinc) and PCBs in the soil and vegetation were above CCME soil quality guidelines for parkland/residential land use. However, the environmental effects were not expected to be significant because the physical characteristics of the site were such that significant numbers of wildlife were unlikely to frequent the contaminated areas for a long enough period of time to result in adverse environmental effects (GLL 1998). Hydrocarbon contamination was not assessed.

In 2003, SENES Consultants Limited completed screening-level human health risk assessment (SLRA) and ecological risk evaluation (SLERE) for FOX-C (SENES 2003). The SLRA concluded that none of the contaminants of concern (non-carcinogenic: lead and zinc; and carcinogenic: PCBs) to potential human receptor exceeded the non-carcinogenic hazard quotient value of 0.2 and the carcinogenic risk level of 1×10^{-5}; however, indicated some physical risks involving debris scattered across the site, topographical setting and disrepaired building. The SLERE determined that five inorganic chemicals (cadmium, chromium, copper, lead, and zinc) and PCBs in soil were above CCME ecologically-based guideline criteria. Samples analyzed for pesticides and PAHs, although detectable, did not exceed criteria.

The current study undertakes a quantitative human and ecological risk assessment of the FOX-C site. It is supported by new contaminants data for the site, based on a Phase III Environmental Site Assessment (Earth Tech 2004), which included analysis for hydrocarbons, as well as PAHs, PCBs, and inorganic elements in soils. A limited number of analyses for lake and river sediments, lake water and fish were collected. A restricted number of background soil samples were also collected. The ERA considers a broad range of ecological receptors and incorporates the new data, while also retaining the previously collected data for FOX-C and surrounding areas. The HHRA also evaluates both Phase II and the newly generated Phase III data supplied and described by Earth Tech (2004).

2.4 INUIT TRADITIONAL LAND USE

In their 1998 Risk Assessment, Gartner Lee and Cantox argue that due to the northern location of the FOX-C and the probable use of the site by Inuit for traditional purposes, the conventional land use categories (residential, parkland, commercial, and industrial) must be expanded to incorporate an additional land use, which they term " Traditional Land Use". The parameters of this land use were developed after consultation with residents of the Eastern Arctic, the Quikiqtaaluk Corporation and DIAND.

The current assessment adopted the Traditional Land Use for the FOX-C site, as set out by Gartner Lee and Cantox (1998). The traditional land use designation consists of Inuit families residing on the land, in tents for periods up to 3 months. It was assumed that during this period the Inuit engage in traditional hunting, fishing and gathering activities. It was also assumed that all time spent on site was in the non-snow covered months, which resulted in the most extensive exposure scenario for the human receptors. Detailed exposure values are discussed in Section 4.3, and in the Gartner Lee and Cantox risk assessment (1998).

3.0 DATA COMPILATION

3.1 SOURCES

The primary source of data for this risk assessment was supplied by Earth Tech Environmental Inc., who on behalf of PWGSC and DIAND, conducted the field investigation and sampling in August 2004. Environmental data consisted of soil, surface water and tissue samples collected from around the site. Detailed list of samples and their locations are presented by Earth Tech in their report (2004). In addition to the 2004 data collection, inorganic data was also used for vegetation and soil samples analyzed and presented by the Environmental Sciences Group at Royal Roads Military College (RRMC) in their 1994 report. Description of samples and sample locations can be found in that report (RRMC, 1994) and will not be detailed further herein.

3.2 SELECTION OF DATA

The soil and water sample data from the Phase II and Phase III sampling programs were screened for use in this risk assessment. For the purposes of the risk assessment for both human and ecological receptors, only soil samples that accurately reflect concentrations in the upper 10 to 15 cm from ground surface are relevant to potential exposures. The Phase II and Phase III data were screened on the basis of depth and any sample that did not intersect the surface and/or extended to a depth of greater than 0.3 m below ground surface (mbgs) was excluded. This was done to ensure that the data used were representative of surface soil and not heavily influenced by subsurface soil characteristics.

To verify that this screening was protective, an alternate data set was created that included all soil samples with any portion of the sample interval within the top 0.3 m of the soil profile. Exposure Point Concentrations (EPCs) calculated using this second data set were lower than the EPCs based on only the surface soil samples, confirming that the screened data set was protective of possible exposures.

All surface water samples were considered to be valid inputs for the risk assessment.

3.2.1 Phase III Data

Data supplied and described in Earth Tech's report (2004). Data was sampled and analyzed in August 2004.

3.2.2 Phase II Data

RRMC's Environmental Sciences Group presented their data in a 1994 report. All the presented data was taken as part of their 1994 sampling of the FOX-C DEW line site.

3.2.3 Division of Data

As discussed in Section 2.2, the site was sub-divided into two areas for the risk assessment based on current and likely future land uses:

- Upper site area – assumed to be residential/parkland for screening purposes and used potentially for camping on site, but for a limited amount of time due to its remote location.

- Lower site area – included beach area, river area, and lake area – assumed to be residential/parkland for screening purposes and used potentially for camping on site for extended periods of time for fishing, caribou, sea mammal hunting areas.

In order to provide area-specific estimates of risk and SQROs, the current data sets were subdivided into the two areas for the calculations of EPCs.

3.3 DESCRIPTION AND STATISTICAL ANALYSIS OF DATA

Maximum concentrations of all chemicals were screened against generic criteria guidelines for either human or ecological assessments. If a chemical exceeded a guideline and if it was measured in both the Phase II and Phase III site assessments, the Phase II data was manually appended to the existing Phase III data set for statistical analysis.

Environmental data are generally log-normally distributed resulting in a skewed data set. This data was tested and found to closely resemble log normal distribution but still mostly failed Shapiro Wilk's Test for log normal distribution confirmation. This is likely to be a result of the non-random sample selection where only known "hot spots" or areas where significant contamination is known to exist were sampled. As a result, the data has outliers, samples with very high concentrations compared to other samples analyzed on-site. Nevertheless, the data is more representative of a log normal distribution than a normal distribution, therefore, data was log transformed to calculate the appropriate exposure point concentration (EPC) – 95% upper confidence limit (UCL) of the geometric mean for the ERA.

Maximum concentrations were used for the HHRA to be protective of the fact that human receptors (especially the most sensitive – toddlers) may in fact play/use a single area where significant contamination exists. Ecological receptors will be more mobile, moving from location to location resulting in a less than maximum exposure scenario. Therefore, maximum and 95% UCL of the geometric means were derived from the existing data sets and used in the ERA.

4.0 HUMAN HEALTH RISK ASSESSMENT

4.1 RISK ASSESSMENT FRAMEWORK

To guide the conduct of the human health and ecological risk assessments, a common framework was developed (illustrated in Figure 2). The steps in this flowchart are described briefly below:

Box 1 Compare maximum concentrations to guidelines.
Maximum concentrations sampled on site were compared to generic CCME and MOE generic soil quality guidelines for residential/parkland land use or to DCC cleanup criteria.

Box 2 Maximum concentration greater than guideline?
If the maximum soil sample CoPC concentration from the data set was less than the appropriate generic guideline, either CCME or MOE, then the CoPC was not carried forward into this quantitative risk assessment.

Box 3 Determine the EPC.
To remain conservative, the maximum CoPC concentration values were adopted as the EPCs for the human health risk assessment while the 95% upper confidence limit for and were used in the quantitative risk assessments to calculate potential risks and area-wide SSTLs.

Box 4 Is the EPC greater than the background soil concentration?
Only if the EPC is greater than the background soil concentration will the CoPC be carried forward to the risk assessment process.

Box 5 Conduct quantitative risk assessment
CoPCs that exceeded guidelines and background concentrations were carried forward into the risk assessment process. The risk assessment was conducted using EPCs. This process was conducted independently for each chemical on the site and for the HHRA and the ERA separately. In this way, the chemicals subjected to ecological risk assessment were not necessarily included in the human health risk assessment.

Box 6 Do the hazard quotients in the risk assessment exceed the target hazard quotient value?
When hazard quotients (HQs) exceed the target HQ value (0.2 for HHRA, 1.0 for ERA), there may be an inherent risk on site. Therefore, SSTLs or calculated soil concentrations where risk would be considered minor, would be calculated and remedial action could be taken to obtain those concentrations on site.

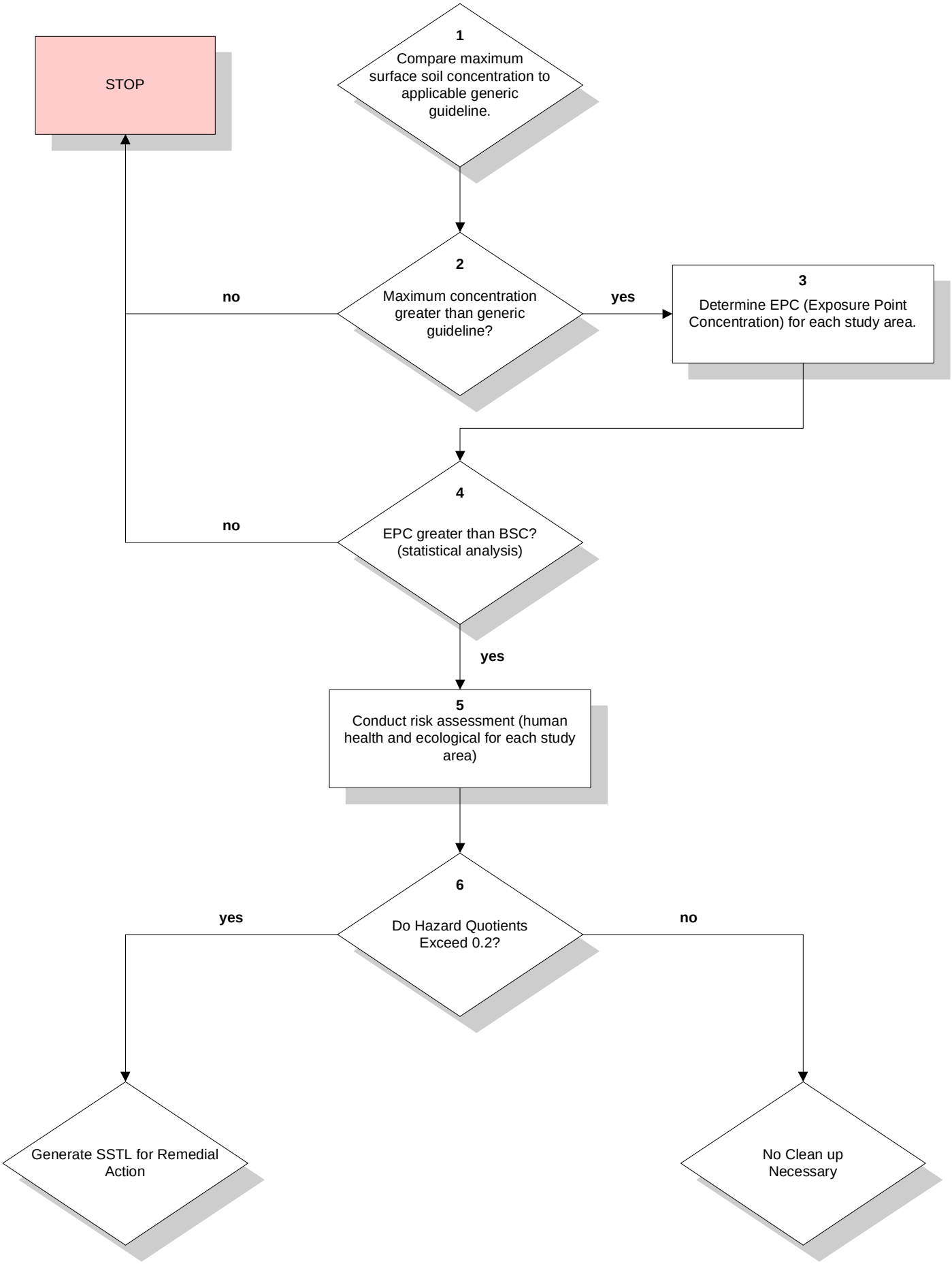


Figure 4 Risk Assessment Framework

4.2 RISK SCREENING

The screening of CoPC maximum concentrations against generic CCME and the Ontario Ministry of the Environment (MOE) guidelines and standards was undertaken by Earth Tech in the 2004 Phase III Site Assessment. The CoPCs identified include metals, benzene, toluene, ethylbenzene, xylene (BTEX), total petroleum hydrocarbon (TPH) and polycyclic aromatic hydrocarbon (PAH) parameters from Earth Tech's report (Earth Tech 2004).

Generic CCME and MOE soil quality guidelines may be based on either ecological or human health protection and provide a protective initial screening of the site data. For the human health risk assessment, the remaining CoPCs are then screened specifically against human health based generic guidelines. Because the HHRA includes an exposure scenario for Inuit camping at the site, residential/parkland values have been adopted for the screening. In order of preference, these guidelines are taken from CCME (2002), OMOE (1996), or the US EPA (2003). The maximum CoPC values were also screened against the Defense Construction Canada (DCC) DEW Line Soil Clean-up Criteria, to provide a comparison to criteria used on DND DEW Lines sites.

4.2.1 Hazard Identification

The results of the human health screening for the upper site and the lower site are presented in Tables 1 and 2, respectively, and are discussed in the following sections.

4.2.1.1 Upper Site

Soils

As indicated in Table 1, and based upon the human health screening described in Box 5 of Figure 1, the maximum soil concentrations of antimony, arsenic, barium, boron, cadmium, chromium, cobalt, mercury, molybdenum, nickel, selenium, silver, vanadium, tin and zinc at FOX-C's upper site are less than their corresponding human health-based soil quality guidelines. Therefore, these metals were not considered further in the HHRA.

The maximum concentration of beryllium in soils was greater than the MOE human health based criterion and thus it was carried forward as a CoPC in the HHRA. Likewise, the maximum concentration of lead in soils was greater than the CCME human health based criterion and it, too, was carried forward. Although the maximum concentration of copper in soils was less than both the CCME and MOE health based criteria, it exceeded the DCC DEW Line cleanup criteria, and so was carried forward into the HHRA.

Table 1 Human Health Soil Screening for FOX-C Upper Site

Top Site Soils CoPCs	Phase III Max Conc. (mg/kg)	Phase II Max[a] Conc. (mg/kg)	No. of Samples	CCME Human Health (mg/kg)	MOE Human Health (mg/kg)	Other Human Health (mg/kg)	DCC Criteria Tier I (mg/kg)	DCC Criteria Tier II (mg/kg)	No. of Samples Exceeding Guidelines	% of Samples Exceeding Guidelines
Inorganics										
Antimony	5.60		29		13					
Arsenic	2.60	5.10	29	12	13			30		
Barium	411		29	500	3700					
Beryllium	**0.780**		29		**0.37**				**4**	13.8
Boron	0.500		29			7000 [d]				
Cadmium	4.30	11.0	72	14	14			5		
Chromium	82.2	116	72	220				250		
Cobalt	7.53	19.3	29		2700			50		
Copper	**381**	**278**	72	1100	1100			**100**	**4**	5.56
Lead	**946**	**1060**	72	**140**			200	500	**5**	6.94
Mercury	0.100		29	6.6	13			2		
Molybdenum	1.60		29		170					
Nickel	34.7	41.0	29		310			100		
Selenium	0.300		29		320					
Silver	1.89		29		98					
Tin	17.8		29			50b				
Vanadium	42.3		29		470					
Zinc	931	1410	72		16000			500		
Organics										
Benzene	0.0200	BD	56		35					
Toluene	0.0400	BD	56	0.8	6100					
Ethylbenzene	0.0200	BD	56		2300					
Total Xylenes	0.230	BD	56	5	61000					
F1 (C_6 - C_{10})	113	BD	56	15000						

Top Site Soils CoPCs	Phase III Max Conc. (mg/kg)	Phase II Max[a] Conc. (mg/kg)	No. of Samples	CCME Human Health (mg/kg)	MOE Human Health (mg/kg)	Other Human Health (mg/kg)	DCC Criteria Tier I (mg/kg)	DCC Criteria Tier II (mg/kg)	No. of Samples Exceeding Guidelines	% of Samples Exceeding Guidelines
F2 (>C_{10} - C_{16})	**8810**	BD	56	**8000**					**2**	3.57
F3 (>C_{16} - C_{34})	**31900**	BD	56	**18000**					**4**	7.14
F4 (>C_{34} - C_{50})	**57300**	BD	56	**25000**					**3**	5.36
Total PCBs	**2.20**	c	41			1.3[b]	1	5		
Acenaphthene	0.0700	0.0200	13		1400					
Acenaphthylene	0.610	0.00840	13		1000					
Anthracene	0.0800	0.0470	13		5300					
Benzo(a)anthracene	0.100	0.0330	13			120[e]				
Benzo(a)pyrene	0.0900	BD	13	0.7						
Benzo(b)fluoranthene	0.100	0.190	13			12[e]				
Benzo(k)fluoranthene	0.0700	BD	13			12[e]				
Benzo(g,h,i)perylene	0.260	0.180	13			120[e]				
Chrysene	0.630	0.820	13	1.5		12[e]				
Dibenzo(a,h) anthracene	BD	0.00710	13			1.2[e]				
Fluoranthene	0.300	0.220	13		910					
Fluorene	0.840	0.540	13		910					
Indeno(1,2,3-c,d)pyrene	0.140	BD	13		12					
Naphthalene	0.630	0.0910	13		1300					
Phenanthrene	6.54	1.70	13			120[e]				
Pyrene	0.160	0.290	13		680					

a - 1994 Reimer et al.
b - interim CCME guideline 1991
c - data from Phase III not usable for comparison due to differences in analytical determination
d - U.S. EPA Region III Risk Based Concentration (RBC) Table, 2003.
e - OMOE 1996. Table B Soil Remediation Criteria - Non-Potable Groundwater Situation, Coarse Textured Soils, Residential Parkland, Human health based criteria.
Shaded boxes - criteria used to screen for risk assessment.

Although the maximum concentration of the TPH F1 fraction in soils was below the Canada Wide Standard (CWS) criterion, the maximum concentrations of the F2, F3 and F4 fractions were greater than their CWS criteria, and were carried forward as CoPCs in the HHRA.

Maximum soil concentrations of BTEX and PAH and were all less than their respective human health based criteria, and were therefore not carried forward. Total Aroclor polychlorinated biphenyls (PCBs) were higher than the interim CCME guideline criteria and since PCBs are of special concern to human health in the Arctic, were carried forward in the HHRA

The soil CoPCs from the upper site carried into the HHRA included:

- *beryllium;*
- *copper;*
- *lead;*
- *PCBs;*
- *TPH F2 fraction;*
- *TPH F3 fraction; and*
- *TPH F4 fraction*

Surface Water

There was no potable surface water present at the upper site. It was thus assumed that lake water from the lower site would be used as drinking water for receptors at the upper site, as it was the nearest fresh water source. Data from surface water samples are presented and discussed below.

4.2.1.2 Lower Site

Soils

As indicated in Table 2, the maximum soil concentrations of antimony, arsenic, barium, boron, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, vanadium, tin and zinc at the lower site were less than their corresponding human health-based soil quality guidelines. Therefore, these metals were not considered further in the HHRA.

The maximum concentration of beryllium in soils was greater than the MOE human health based criterion and thus was carried forward as a CoPC in the HHRA.

Maximum soil concentrations of BTEX and PCB parameters were all less than their respective human health based criteria, and were therefore not carried forward in the HHRA.

Although the maximum concentration of the TPH F1, F2, and F4 fractions in soils were below the CWS criteria, the maximum concentration of the TPH F3 fraction was greater than its CWS criterion, thus was carried forward as a CoPC in the HHRA.

It should be noted that because there was no evidence of burned petroleum products at the lower site (unlike at the upper site), and was not considered necessary to analyse lower site soils for PAHs.

The soil CoPCs from the upper site carried into the HHRA included:

- *beryllium; and,*
- *TPH F3 fraction.*

Table 2 Human Health Soil Screening for FOX-C Lower Site

Soils CoPCs	Phase III Maximum (mg/kg)	Phase II Maximum[a] (mg/kg)	No. of Samples	CCME Human Health (mg/kg)	MOE[e] Human Health (mg/kg)	Other Human Health (mg/kg)	DCC Criteria Tier I (mg/kg)	DCC Criteria Tier II (mg/kg)	No. of Samples Exceeding Guidelines	% of Samples Exceeding Guidelines
Inorganics										
Antimony	3.50		10		13					
Arsenic	4.30	2.50	10	12	13			30		
Barium	141		10	500	3700					
Beryllium	**0.580**		10		**0.37**				8	80
Boron	1.30		10			7000[d]				
Cadmium	0.100	1.3	10	14	14			5		
Chromium (total)	82.8	93	10	220				250		
Hexavalent Chromium	0.200		10							
Cobalt	9.77	13.0	10		2700			50		
Copper	32.0	30	10	1100	1100			100		
Lead	10.9	25	10	140			200	500		
Molybdenum	1.10		10		170					
Nickel	35.2	32.0	10		310			100		
Tin	2.70		10			50b				
Vanadium	72.2		10		470					
Zinc	83.3	74	10		16000			500		
Organics										
Benzene	BD	BD	20		35					
Toluene	0.0200	BD	20	0.8	6100					
Ethylbenzene	0.280	BD	20		2300					
Total Xylenes	4.31	BD	20	5	61000					
F1 (C_6 - C_{10})	179	BD	20	15000						
F2 (>C_{10} - C_{16})	2890	BD	20	8000						

Soils CoPCs	Phase III Maximum (mg/kg)	Phase II Maximum[a] (mg/kg)	No. of Samples	CCME Human Health (mg/kg)	MOE[e] Human Health (mg/kg)	Other Human Health (mg/kg)	DCC Criteria Tier I (mg/kg)	DCC Criteria Tier II (mg/kg)	No. of Samples Exceeding Guidelines	% of Samples Exceeding Guidelines
F3 (>C_{16} - C_{34})	**18100**	BD	20	**18000**					1	5
F4 (>C_{34} - C_{50})	11500	BD	20	25000						
Total PCBs	ND	c	20				1	5		

a - 1994 Reimer et al.

b - interim CCME guideline 1991

c - data from Phase III not usable for comparison due to differences in analytical determination

d - U.S. EPA Region III Risk Based Concentration (RBC) Table, 2003.

e - OMOE 1996. Table B Soil Remediation Criteria - Non-Potable Groundwater Situation, Coarse Textured Soils, Residential Parkland, Human health based criteria.

Shaded boxes - criteria used to screen for risk assessment.

bd – below detection limit

Surface Water

Surface water samples were taken from the lake at the lower site. Table 3 presents the results of the screening for all parameters that were above the analysis detection limits. A full table of results is available in the Phase III Site assessment (Earth Tech, 2004). None of the maximum CoPC concentrations were greater than available drinking water guideline criteria. A number of parameters, including lithium, sulphur, strontium, titanium, toluene, xylenes and TPH F1 fraction do not have published health based drinking water criteria, and so no benchmark against which to evaluate the concentrations found in the surface water. Because neither the CCME, MOE or US EPA has derived drinking water criteria for these parameters, they are assumed to have a low inherent toxicity and not to pose a risk to human health. Additionally, the concentrations are deemed to be sufficiently low that surface water is not considered a contaminated medium, and was not carried forward into the HHRA.

However, where parameters were identified as CoPCs based on soil concentrations and were also detected in surface water, surface water was treated as an additional source medium and surface water ingestion and dermal contact were included in the total dose for that parameter.

Table 3 Human Health Surface Water Screening

Surface Water CoPCs	Phase III Max	Screening Criteria				
		CCME [1]			EPA[3]	
		Human Health [1]		MOE[2] Drinking Water		
		MAC (ug/L)	IMAC (ug/L)		Drinking Water	Other
Inorganics						
Aluminum	**358**					50
Antimony	0.200	6		6		
Barium	31.0	1000		1000		
Boron	6.00			5000		
Cadmium	0.0300		5	5		
Chromium (total)	1.10	50		50		
Copper	4.00			23		1000
Iron (dissolved)	1090					300
Lead	1.00	10		10		
Lithium	2.00					
Manganese	41.0				1600	
Nickel	12.6			100		
Silicon	3970					
Sulphur	3020					
Strontium	17.0					
Titanium	38.4					
Vanadium	0.800			200		
Zinc	56.0			1100		5000
Organics						
Toluene	1.00					
Xylenes	3.00					
F1	13.0			1000		

1. CCME. 1999. Community Water Supplies. Updated 2002.
2. MOE. 2004. Soil, Groundwater and Sediment Standards for Use under Part XV.1 of the Environmental Protection Act. Table 2 – Full Depth Generic Site Condition Standards in a Potable Groundwater Condition.
3. EPA. 2004. 2004 Edition of the Drinking Water Standards and Health Advisories.

4.2.2 Wild Game and Fish

Additional exposure to CoPCs from the site could occur through ingestion of contaminated wild game and fish. Because FOX-C is a site that may be used as a recreation area for Inuit visitors, and would serve as a base for hunting and fishing activities, wild game and fish meat were considered as a further source of CoPCs.

While concentrations of CoPCs can be, and have been measured in water, soils and plants, it is necessary to estimate the concentrations of CoPCs occurring in the meat of other biological components. The process by which the uptake of CoPCs from soil to plants, and from soil to animals, are estimated is explained in detail in Section 5.4.2.

4.2.2.1 Wild Game

Because wild game is not restricted to either the upper or lower sites, uptakes were calculated based on the proportion of time spent at each site based on the area of their range. A composite CoPC meat concentration was then calculated for two wild game species, the caribou and the Arctic hare. While CoPCs have been identified based on maximum soil concentrations for each of the upper and lower sites, the CoPCs concentrations in caribou and hare meat reflect their use of both sites. However, CoPCs were not screened in for the HHRA based on caribou or hare meat concentration; the exposure via wild game is only assessed for CoPCs previously identified for the site.

Table 4 summarizes the calculated concentrations of CoPCs in caribou meat, while Table 5 presents a summary of the CoPC concentrations in Arctic hare. The results of detailed calculations are provided in Tables 20 and 21, respectively.

Table 4 Summary of Modeled CoPC Concentration in Caribou Meat

CoPC	Concentration in Caribou Meat (mg/kg)
Beryllium	1.08E-04
Copper	6.73E-01
Lead	7.28E-03
TPH F2 Fraction	8.68E-02
TPH F3 Fraction	1.53E-01
TPH F4 Fraction	2.29E-02
PCBs	2.35E-02

Table 5 Summary of Modeled CoPC Concentration in Arctic Hare Meat

CoPC	Concentration in Arctic Hare Meat (mg/kg)
Beryllium	1.08E-04
Copper	3.82E+00
Lead	9.86E-01
TPH F2 Fraction	8.68E-02
TPH F3Fraction	1.52E-01
TPH F4 Fraction	2.29E-02
PCBs	2.30E-02

4.2.2.2 Arctic Charr

Although surface water was not carried forward a contaminated medium, and PCB levels were below guidelines for both soils and water, the bioaccumulation of PCBs in fish is of particular concern throughout the Canadian north.

Due to this particular concern, fish samples were taken from the lake at the lower site and the samples were analyzed to determine the levels of PCBs in their flesh.

Because of the particular concern regarding the intake of PCBs from the fish, PCBs in fish flesh were carried forward into the HHRA, and the risk associated with ingestion was assessed. However, it should be noted that PCBs were also carried forward as CoPCs based on soil and surface water concentrations, which were greater than CCME and MOE guidelines. It should be noted that a confirmatory input of PCBs into the fish environment will be through global transport of PCBs to the Arctic environment.

As with surface water, where parameters were identified as CoPCs based on soil concentrations and were also detected in fish flesh, fish was treated as an additional source medium and fish ingestion was included in the total dose for that parameter.

Table 6 presents the maximum measured CoPC and PCB concentrations in Arctic Charr flesh. All fish analysis data can be found in the Earth Tech report (2004).

Table 6 Summary of CoPC and PBC Concentrations in Arctic Charr

CoPC	Concentration in Arctic Charr (mg/kg)
PCBs	**0.0026**
Beryllium	nd
Copper	0.46
Lead	0.028
F2 TPH Fraction	na
F3 TPH Fraction	na
F4 TPH Fraction	na

nd – non detect
na – not analysed for.

4.2.3 Receptor Identification

Existing and intended land use is an important factor in evaluating the potential exposures and estimating risk. This risk assessment was directed toward the following potential end use of the land:

- Intermittent use of the general area for recreational and hunting purposes.

Therefore the potential human "receptors", or people who may be most affected by the potential hazards are people hunting on the land. For the purposes of this assessment, the human receptor is characterized as an adult or child with no extreme sensitivities. Carcinogenic and non-carcinogenic chemicals are evaluated differently as illustrated below:

	RESIDENTIAL EXPOSURE
NON-CARCINOGENIC CHEMICALS (oral/dermal)	Most sensitive receptor modelled as a toddler aged six months to four years old.
CARCINOGENIC CHEMICAL (inhalation)	Receptor assumed to visit the site yearly from birth to 75 years lifetime. Exposures averaged over five age groups: (0 to 6 months) + (6 months to 4 yrs) + (5 to 11 yrs) + (12 to 19 yrs) + (20 to 75yrs).

The above assumptions regarding receptors are the most protective approaches for the intended land uses. Important characteristics of the receptors (including body weight, soil ingestion rate, *etc.*) considered in the analysis are presented Section 4.3.

4.2.4 Exposure Pathway Assessment

The exposure assessment evaluated the likelihood that the potential hazards would come into contact with the potential receptors. The likelihood of exposure as determined through consideration of the properties of individual hazards that control chemical mobility, and the various pathways through which the hazard could move to contact the receptor, or through which the receptor could move to contact with the hazard. The exposure analysis also considers the possible mechanisms through which a hazard could be introduced to a human receptor (i.e., ingestion, dermal contact, inhalation).

4.2.5 Potential Transport Pathways

The principal pathways through which environmental hazards can typically contact a receptor include:

- direct contact (with soil, dust, liquid product phase hazards, or water);
- transport of liquid product phase contaminants;
- transport in groundwater;
- transport in surface water;
- air borne transport (as dust); and
- transport as a vapour.

4.2.6 Potential Exposure Mechanisms

The mechanisms by which receptors typically become exposed to hazards include:

- inhalation;
- ingestion;
- dermal contact; and
- uptake by plants/animals.

4.2.7 Human Receptor Exposure Scenarios

The exposure scenarios which have been considered for human receptors include:

- ingestion/dermal contact with soil;
- inhalation/ingestion/dermal contact with dust;

- ingestion of vegetation or garden produce grown in contaminated soil or irrigated with contaminated groundwater;
- ingestion of wild game (e.g., Caribou, hares) caught by hunting on the land in the FOX-C site area;
- ingestion/dermal contact with surface water;
- ingestion/dermal contact with groundwater; or
- inhalation of vapours.

Jacques Whitford evaluated the likelihood that the identified human receptors could be exposed to the identified hazards through the various exposure scenarios using a qualitative method. The likelihood of exposure is considered and evaluated in terms of the following series of definitions, presented in Table 7.

The relevant exposure pathways are summarized in Table 8. Table 8 includes the qualitative evaluation of each pathway and a justification for the likelihood of exposure assigned. The likelihood of exposure includes consideration of the duration and frequency of exposure to each potential hazard and to the relative concentrations to which the receptor is likely to be exposed. Those hazard-exposure-receptor combinations considered to have the highest likelihood to contribute a health risk are carried forward for further quantitative analysis.

Table 7 Exposure Definitions

Likelihood of Exposure	Definition
Very Unlikely	Level of exposure that could result in adverse effects is not expected.
Unlikely	Level of exposure that could result in adverse effects would probably not occur.
Possible	Level of exposure that could result in adverse effects might be expected.
Likely	Level of exposure that could result in adverse effects is expected. Exceedance of this exposure level might be expected.

Table 8 Potential Exposure Scenarios – Inuit Visitor

Exposure Pathway Description	Likelihood of Exposure	Carried Forward for Quantitative Analysis	Justification
Ingestion of soil	Likely	Yes	Surface soil samples collected during the soil sampling program 2004 were impacted by beryllium, copper, lead, and petroleum hydrocarbons exceeding human health screening guidelines, as described in Section 4.2.1.
Dermal contact with soil			
Inhalation of soil particles			
Inhalation of soil vapours	Unlikely	No	Neither the inorganic CoPCs nor the TPH F2 to F4 fractions found on site were considered volatile, therefore the inhalation of vapours pathway was considered negligible.
Ingestion of sediment	Unlikely	No	There is little likelihood that receptors would come into direct contact with sediment considering the cold water temperatures.
Dermal contact with sediment			
Inhalation of sediment particles/vapours			
Ingestion of surface water	Unlikely	Yes	Surface water was not considered a source medium for contaminants, however where CoPCs were identified in soil, and were detected in the surface water, surface water was considered an additional exposure pathway.
Dermal contact with surface water			
Inhalation of surface water vapours	Unlikely	No	No volatile CoPCs were identified in surface water, therefore vapour inhalation was not considered a valid pathway.
Ingestion of ground water	Very Unlikely	No	Groundwater was not used as a source for either drinking or showering and therefore was not considered a valid pathway.
Dermal contact with ground water			
Inhalation of ground water particles/vapours			
Ingestion of vegetation	Very Unlikely	No	Due to the climate, significant harvest of vegetation was not expected.
Ingestion of wild game	Likely	Yes	Visiting Inuit receptors were expected to hunt and consume wild game on the site.
Ingestion of wild fish	Likely	Yes	Visiting Inuit receptors were expected to catch and consume fish from the site.

4.2.8 Qualitative Risk Assessment

Based on the qualitative risk screening presented above, the conceptual model (Figure 2) that formed the basis for the calculation of potential risk:

Traditional Use of Upper Site Scenario

- A toddler aged six months to four years is exposed to surface soil contaminated with non-carcinogenic lead, beryllium, copper, PCBs and TPH F2, F3 and F4 fractions by inadvertent ingestion / dermal contact / dust inhalation, ingestion of wild game (caribou and hare) and fish, and by ingestion and dermal contact with surface water.
- A person visits the site yearly from birth to 75 years of age and is exposed to carcinogenic beryllium by dust inhalation and total PCBs by inadvertent ingestion / dermal contact / dust inhalation, ingestion of wild game (caribou and Arctic hare) and Arctic charr, and by ingestion and dermal contact with surface water throughout their lifetime.

Traditional Use of Lower Site Scenario

- A toddler aged six months to four years is exposed to surface soil contaminated with non-carcinogenic beryllium and the TPH F3 fraction by inadvertent ingestion / dermal contact / dust inhalation, ingestion of wild game (caribou and hare) and fish, and by ingestion and dermal contact with surface water.
- A person visits the site yearly from birth to 75 years of age and is exposed to carcinogenic beryllium by dust inhalation, throughout their lifetime.

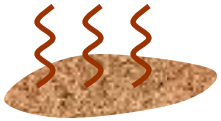
Figure 2 Site Conceptual Model

Fox C - Ekalugad Fjord

Soil Ingestion

Soil Contact

Dermal Contact



Dust Resuspension

Drinking Water

Caribou

Arctic Charr

Arctic Hare

Food Chain

Receptors

4.3 RECEPTOR CHARACTERISTICS

As discussed in Section 4.2.3, it is important that the most protective assumptions are made about the potential receptors. For the assessment of risk for beryllium, copper, lead, and the TPH F2, F3 and F4 fractions for exposure to the upper site the most sensitive receptor was a toddler aged 6 months to 4 years old. Similarly, for the assessment of risk for beryllium and the TPH F3 fraction for exposure to the lower site, the most sensitive receptor was a toddler aged 6 months to 4 years old. In addition, a composite receptor was included in the assessment to examine the carcinogenic effects of beryllium, and total PCBs. A reasonable maximum exposure approach is adopted for a traditional land use of the sites in which it was assumed that the toddler will be at the upper site for 24 hours per day, 14 days per year, while a toddler will be present at the lower site for a conservative 90 days per year. It was also conservatively assumed that the human receptor was exposed to the most highly contaminated soil present on each particular site. This is a very conservative assumption since most contaminated spots are localized to small areas and the receptor would likely wander off those areas at least part of the time while on site. Nevertheless, for this HHRA and to be protective of human health, maximum exposure concentrations were assumed.

Receptor characteristics for the toddler are presented in Table 9 below:

Table 9 Summary of Receptor Characteristics

Characteristics		Values		Source
		Visitor Toddler	Visitor Composite	
Averaging Times and Constant Values				
AT_c	Averaging time – cancer (yrs)	n/a	75	Equal to exposure duration
AT_{nc}	Averaging time – non-cancer (yrs)	4.5	n/a	Equal to exposure duration
ED	Exposure duration (yrs)	4.5	75	CCME (2001)
EF_{upper}	Exposure Frequency – Upper Site (d)	14	14	Based on professional judgement and the size and location of the site.
EF_{lower}	Exposure Frequency – Lower Site (d)	90	90	Based on assumptions proposed in Gartner Lee Inc. (1998)
ET_{ing}	Exposure time – soil ingestion (hrs/d)	24	24	Based on full-time exposure to the site.
ET_{derm}	Exposure time – soil dermal contact (hrs/d)	24	24	Based on full-time exposure to the site.
ET_{inh}	Exposure time – soil particulate inhalation (hrs/d)	24	24	Based on full-time exposure to the site.
BW	Body weight (kg)	16.5	62.3	HC (2003)
Ingestion of Surface Soil				
IR_{soil}	Ingestion rate of surface soil (mg/hr)	3.33	0.98	HC (2003)

Characteristics		Values		Source
		Visitor Toddler	Visitor Composite	
Dermal Contact with surface Soil				
SA_{body}	Exposed surface area - body (cm^2)	2580	7385	Richardson (1997)
Sa_{hand}	Exposed surface area - hand (cm^2)	430	821	Richardson (1997)
SAF_{body}	Soil adherence factor – body (mg/cm^2-d)	0.01	0.01	HC (2003)
SAF_{hand}	Soil adherence factor – hand (mg/cm^2-d)	0.10	0.10	HC (2003)
Inhalation of Soil Particles				
IR_{air}	Inhalation rate (m^3/hr)	0.39	0.63	Richardson (1997)
Ingestion of Surface Water				
IR_{water}	Ingestion of surface water (L/d)	0.6	1.32	Richardson (1997)
Dermal Contact with Surface Water				
SA_{water}	Exposed surface area dermal water (cm^2)	430	821	Richardson (1997)
Ingestion of Wild Game				
IR_{game}	Ingestion rate of wild game (mg/d)	85000	233433	Richardson (1997)
F_{site}	Fraction of wild game that is from site (unitless)	1.00	1.00	Conservative site specific assumption
$F_{caribou}$	Fraction of wild game that is caribou (unitless)	0.90	0.90	Assumed based on professional judgement.
F_{hare}	Fraction of wild game that is hare (unitless)	0.10	0.10	Assumed based on professional judgement.
IR_{fish}	Ingestion rate of fish (mg/d)	95000	204233	Richardson (1997)
F_{site}	Fraction of fish that is from site (unitless)	1.00	1.00	Conservative site specific assumption

For non-threshold chemicals (carcinogens), in which any level of exposure is considered to have a potential for adverse health effects, exposures are not calculated within specific age groups (e.g., toddler) but are averaged over a lifetime. In accordance with the reasonable maximum exposure approach, it was assumed that a public visitor to the site grows up in Nunavut from birth to 75 years old. For the purposes of the risk characterization calculations, exposures are averaged over five age groups: (0 to 0.5 years) + (0.5 to 4 years) + (5 to 11 years) + (12 to 19 years) + (20 to 75 years). Receptor characteristics for each age group are presented in Table 10.

Table 10 Summary of Receptor Characteristics for Each Age Group

Characteristic	Receptor Values						Source
	Infant	Toddler	Child	Teen	Adult	Composite	
Age	0 – 6 mo.	7 mo. – 4 yr	5 – 11 yr	12 – 19 yr	20 - 75 yr	over 75 year lifetime	HC, 1994
AT (years)	0.5	4.5	7	8	56	75	
BW (kg)	8.2	16.5	32.9	59.7	70.7	62.33	HC(2003)
IR_{soil} (mg/h)	0.83	3.33	0.83	0.83	0.83	0.98	HC (2003)
IR_{air} (m^3/hr)	0.0875	0.4	0.6	0.7	0.7	0.6	Richardson, 1996
IR_{water} (L/d)	0.3	0.6	0.8	1	1.5	1.319	Richardson, 1997
SA_{hand} (cm^2)	320	430	590	800	890	821	Richardson, 1997
SA_{body} (cm^2)	1780	3010	5140	8000	9110	8206	Richardson, 1997
IR_{fish} (mg/d)	0	95	170	200	220	204.23	Richardson, 1997
IR_{game} (mg/d)	0	85	125	175	270	233.43	Richardson, 1997

Note:
All characteristic acronyms described in Table 9.

4.4 TOXICITY ASSESSMENT

The potential hazards associated with exposures to non-carcinogenic (threshold) substances are assessed differently than the potential risks associated with exposures to carcinogenic (non-threshold) substances. For threshold substances, it is assumed that there is a dose (or concentration) of the chemical of potential concern that does not produce any adverse effect. A Tolerable Daily Intake (TDI) is an estimate of a chemical intake that is unlikely to cause an increased incidence of deleterious health effects during a lifetime of exposure. TDIs are specifically developed to be protective for chronic exposure to a chemical. For the purposes of deriving site-specific threshold levels, a chronic daily intake (CDI) is calculated for the exposed individual and compared to the TDI. If CDI/TDI >0.2, then there is the potential for adverse health effects and further assessment would be required.

For contaminants for which the critical effect is assumed to have no threshold (i.e., carcinogens), it is assumed that there is some probability of harm to human health at any level of exposure (CCME, 1996). There is a linear dose-response relationship that converts estimated daily intakes averaged over a lifetime of exposure directly to an incremental risk of an individual developing cancer. For the purposes of deriving site-specific soil quality guidelines, Health Canada considers that a single increased case of cancer in an exposed population of 100,000 merits action (Health Canada, 2003). As such, a target risk (TR) of one in one hundred thousand or 10-5 is used in this risk assessment for carcinogenic effects.

4.5 SELECTION OF TOXICITY REFERENCE VALUES (TRVS)

An essential part of the risk assessment is the identification of appropriate toxicity reference values. This is typically done by a literature review of published toxicological assessments.

Toxicity values have been established by several agencies including Health Canada, the United States Environmental Protection Agency (US EPA), as well as others. Preference has been given to Health Canada toxicity reference values (TRVs) as per Federal Guidance (HC, 2003). In the event that a Health Canada TRV does not exist the most scientifically up to date toxicity values upon which to evaluate health risks were utilized.

Summaries of the toxicity values selected for inclusion in the risk assessment are provided in Table 11 and 12, and detailed rationales for each of the toxicity values are provided in Appendix B.

Table 11 Selected Cancer Toxicity Values

CoPC	Route of Exposure	Exposure Limit (mg/kg-d) $^{-1}$	Toxicological Basis	Source Agency
Inorganics				
Beryllium	Ingestion	na	na	na
	Inhalation	10.7	Lung cancer	Calculated based on US EPA, 1998
Organics				
PCB's	Ingestion	2.0	liver hepatocellular adenomas, carcinomas, and cholangiomas	US EPA, 1997
	Inhalation	0.4	Not Specified	US EPA, 1997

Table 12 Selected Non-Carcinogenic Toxicity Values

CoPC		Route of Exposure	Exposure Limit (mg/kg-d)	Toxicological Basis	Source Agency
Inorganics					
Beryllium		Ingestion	0.002	Small Intestinal Lesion s	US EPA, 1998
		Inhalation	4.74E-6	Beryllium sensitization and progression to CBD	US EPA, 1998
Copper		Ingestion	0.03	Not Specified	CCME, 1999
		Inhalation	na	na	na
Lead		Ingestion	0.00357	Blood levels in young children	Health Canada, 1996
		Inhalation	na	na	na
Organics					
PCBs		Ingestion	0.001	Not Specified	Health Canada, 2003
		Inhalation	na	na	na
Petroleum Hydrocarbons CWS Fractions					
F2	Aliph>C10-C12	Ingestion	0.1	Hepatic and hematological changes	CCME, 2000
		Inhalation	na	na	na
	Aliph>C12-C16	Ingestion	0.1	Hepatic and hematological changes	CCME, 2000
		Inhalation	na	na	na
	Arom>C10-C12	Ingestion	0.04	Decreased body weight	CCME, 2000
		Inhalation	na	na	na
	Arom>C12-C16	Ingestion	0.04	Decreased body weight	CCME, 2000
		Inhalation	na	na	na
F3	Aliph>C16-C21	Ingestion	2	Hepatic granuloma	CCME, 2000
		Inhalation	na	na	na
	Aliph>C21-C34	Ingestion	2	Hepatic granuloma	CCME, 2000
		Inhalation	na	na	na
	Arom>C16-C21	Ingestion	0.03	Nephrotoxicity	CCME, 2000
		Inhalation	na	na	na
	Arom>C21-C34	Ingestion	0.03	Nephrotoxicity	CCME, 2000
		Inhalation	na	na	na
F4	Aliph>C34-C50	Ingestion	20	Hepatic granuloma	CCME, 2000
		Inhalation	na	na	na
	Arom>C34-C50	Ingestion	0.03	Nephrotoxicity	CCME, 2000
		Inhalation	na	na	na

Na – not available: when no separate inhalation TRV is available, the inhalation dose is summed with the dermal/ingestion doses and compared to the oral TRV.

4.5.1 Bioavailability

Bioavailability refers to "the fraction of the total amount of material in contact with a body portal-of-entry (lung, gut, skin) that enters the blood". Relative bioavailability is the amount of a substance entering the blood via a particular route of exposure (e.g., gastrointestinal) relative to the study used to derive the TRV. These factors were then applied in the risk assessment to more realistically represent the portion of contaminants held in soil that are available. For instance, a relative bioavailability factor of 0.5 indicates that 50% of the administered (e.g., ingested) chemical is absorbed into the bloodstream compared to the absorption in the TRV study. Relative bioavailability via ingestion and inhalation routes of exposure are conservatively assumed to be a factor of 1.0. Table 13 provides the bioavailability factors used in this assessment.

Table 13 Selected Relative Bioavailability Factors

CoPC		Oral	Dermal	Inhalation
Beryllium		1	0.03	1
Copper		1	0.1	1
Lead		1	0.06	1
Total PCBs		1	0.1	1
Petroleum Hydrocarbon CWS Fractions	F2	1	0.2	1
	F3	1	0.2	1
	F4	1	0.2	1

Detailed rationale supporting the selection of each of the values recommended for use in this assessment is provided in Appendix B.

4.5.2 Non-Carcinogens

The potential health effects associated with non-carcinogenic chemicals are assessed differently than those for carcinogenic chemicals. Non-carcinogenic chemicals are generally considered to act through a threshold mechanism where it is assumed that there is a dose (or concentration) that does not produce any adverse effect. As the dose or concentration increases to the point where the body can no longer process or excrete the chemical, an adverse effect may occur. This point is termed the threshold and is different for every chemical.

Approach and Methodology

For risk characterization of non-carcinogenic CoPCs individual hazard quotients (HQs) were derived for each of the CoPCs. The estimated daily intakes (EDIs) for the CoPCs in this assessment were not available and thus can not be subtracted from the TDI.

$$HQ = \frac{CDI}{TDI}$$

where:

CDI Chronic Daily Intake
= sum of all site-specific intake pathways
= soil/dust ingestion + soil/dust dermal contact + soil particulate/dust inhalation

TDI Tolerable Daily Intake

A target HQ of 0.2 was used for CoPCs as this risk assessment has not addressed all potential pathways of exposure, including background exposure from items such as supermarket foods.

Using a HQ benchmark of 0.2 permits 80% of a person's CoPC intake to come from non-site related exposures. If the HQ is less than 0.2 then the intake of CoPCs from site exposure does not exceed the tolerable level and no adverse health effects are expected.

4.5.3 Results for Upper Site Non-Carcinogens

HQs for beryllium, copper, lead, PCBs and TPH F2, F3, F4 fractions, which were derived using the maximum concentration as EPC, are presented in Table 14.

In the recreational use of the upper FOX-C site scenario the total exposure risks from maximum beryllium, copper, lead, PCBs and TPH F2, F3, F4 concentrations on the site was below 0.2, thus exposure to the site results in negligible potential risk to receptors.

Table 14 Hazard Quotients for Non-Carcinogenic CoPCs at Upper Site

CoPC	EPC (mg/kg)	Total HQ	Target HQ	Exceeds Target HQ?
Beryllium	0.78	8.8E-5	2.0E-1	No
Copper	381	3.8E-2	2.0E-1	No
Lead	1060	6.3E-2	2.0E-1	No
Total PCBs	2.2	5.7E-4	2.0E-1	No
TPH F2 Fraction	8800	2.5E-2	2.0E-1	No
TPH F3 Fraction	31900	4.9E-2	2.0E-1	No
TPH F4 Fraction	57300	8.4E-2	2.0E-1	No

Figures 4 to 10 illustrate the relative contributions of the individual pathways assessed to the total HQ. The HQ from each pathway is presented in Appendix C.

Figure 4 Relative Contributions to the Upper Site Beryllium Total HQ

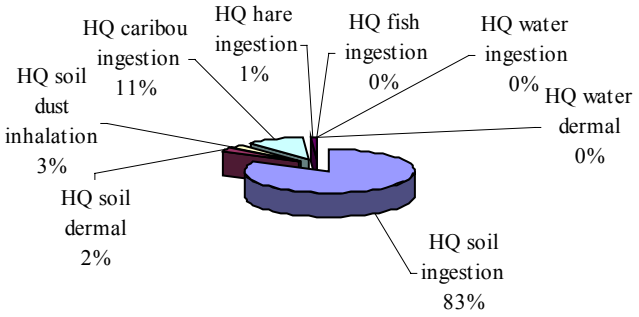


Figure 5 Relative Contributions to the Upper Site Copper Total HQ

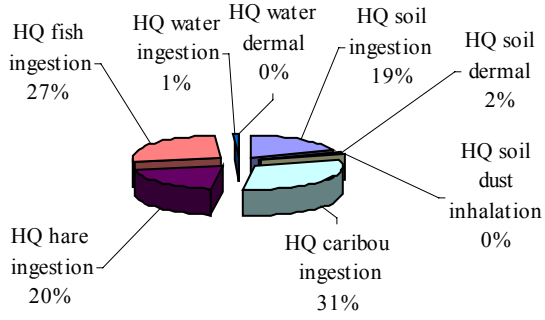


Figure 6 Relative Contributions to the Upper Site Lead Total HQ

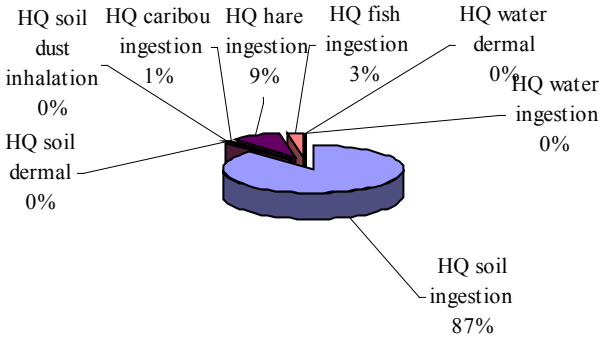


Figure 7 Relative Contributions to the Upper Site F2 TPH Fraction Total HQ

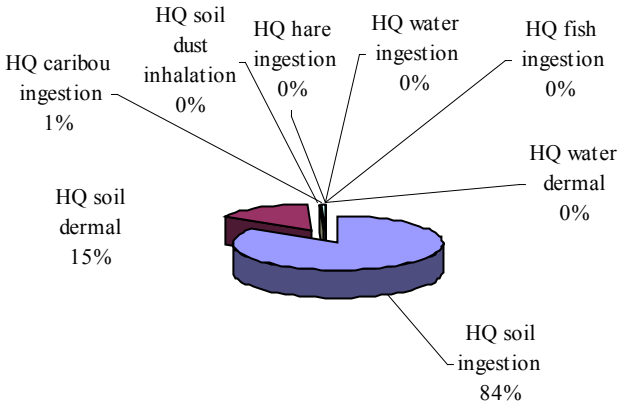


Figure 8 Relative Contributions to the Upper Site F3 TPH Fraction Total HQ

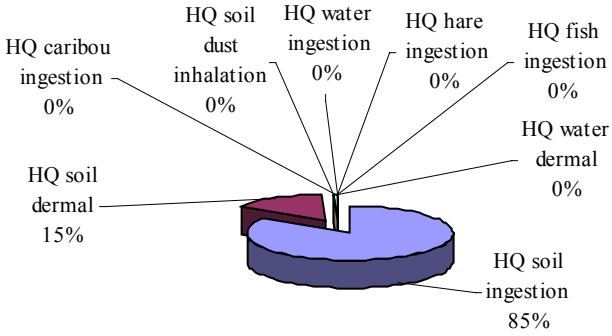


Figure 9 Relative Contributions to the Upper Site F4 TPH Fraction Total HQ

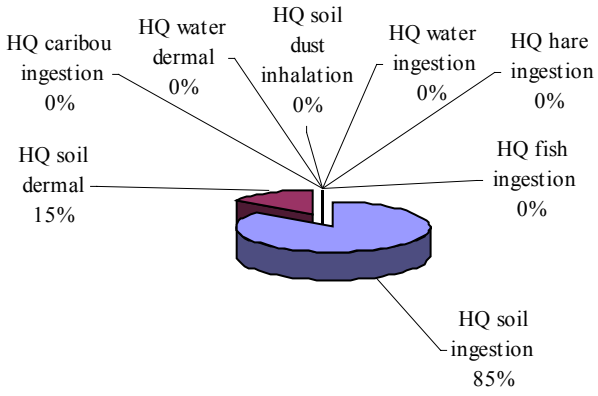
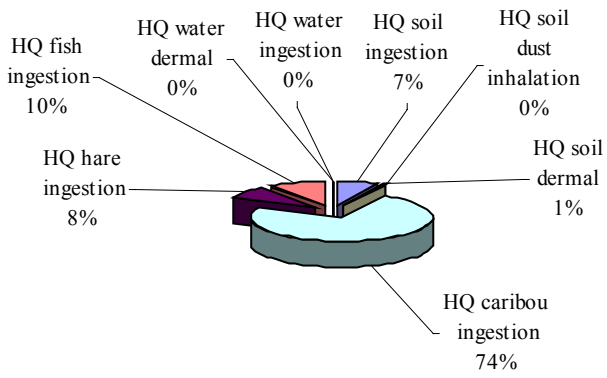


Figure 10 Relative Contributions to the Upper Site PCB Total HQ



4.5.4 Results for Lower Site Non-Carcinogens

HQs for beryllium and the TPH F3 fraction, were derived using the maximum concentration as EPC, are presented in Table 15.

In the Traditional Land Use of the lower FOX-C site scenario the total exposure risk from the maximum beryllium and TPH F3 Fraction concentrations on the site were below 0.2, thus CoPC exposure from the site results in negligible potential risk to receptors.

Table 15 Hazard Quotients for Non-Carcinogenic CoPCs at Lower Site

CoPC	EPC (mg/kg)	Total HQ	Target HQ	Exceeds Target HQ?
Beryllium	0.58	6.9E-4	2.0E-1	No
TPH F3 Fraction	18000	1.8E-1	2.0E-1	No

It must be noted that this assessment was based on an EPC equal to the maximum concentration found on the site, and the conservative assumption that the receptor would spend 90 days on the site, and the HQ is therefore very conservative and is likely an over-estimate of the risk. Figures 11 and 12 illustrate the relative contributions of the individual pathways assessed to the total HQ. The HQs from each pathway is presented in Appendix C.

Figure 11 Relative Contributions to the Lower Site Beryllium Total HQ

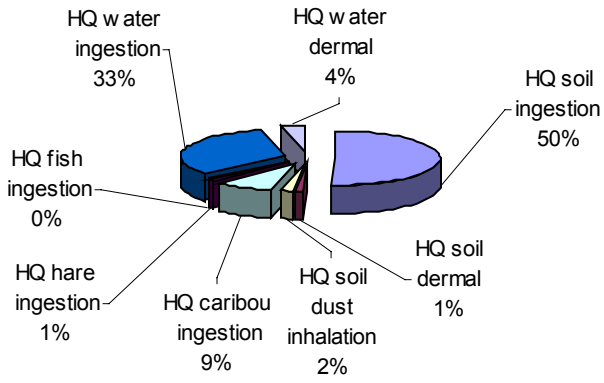
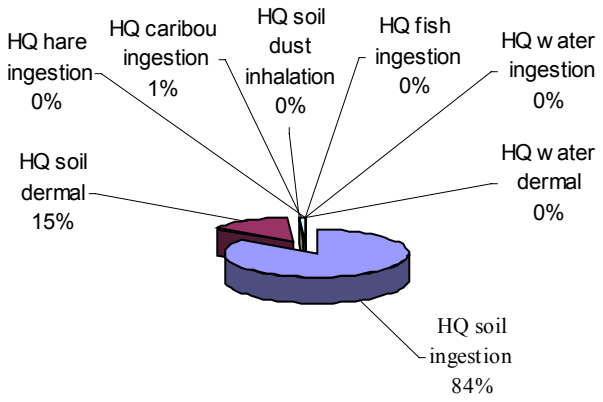


Figure 12 Relative Contributions to the Lower Site F3 TPH Fraction Total HQ



4.5.5 Results for Lower Site Ingestion of PCBs in Wild Game

Because of concerns regarding the bio-accumulation of PCBs in wild game in the Canadian north, the risk posed by ingestion PCBs in Arctic charr, caribou and hare from the site was assessed.

The HQs for PCB ingestion of Arctic charr, were derived using the maximum measured concentration of PCBs in fish. The HQs for the ingestion of caribou and hare were calculated based on PCB concentration modelled using soil-plant-animal uptake factors, as discussed in Section 5.4.2. The HQs for PCB ingestion via wild game are presented in Table 16.

Table 16 Hazard Quotients for PCB in Wild Game

CoPC	EPC (mg/kg)	HQ	Target HQ	Exceeds Target HQ?
Caribou				
PCB	0.0024	0.0042	0.2	No
Hare				
PCB	0.0024	0.00046	0.2	No
Arctic Charr				
PCB	0.0026	0.00057	0.2	No
Total Land Foods				
PCB	--	0.00523	0.2	No

The HQs for ingestion of PCBs in Arctic charr, caribou and hare from the site were all less than 0.2. Additionally, the total PCB exposure from the site is less than 0.2, indicating that exposure from wild game from the site resulted in a negligible potential risk to receptors.

4.5.6 Carcinogens

As previously discussed, the characterization of potential hazards associated with carcinogenic and non-carcinogenic exposures were assessed separately, based on the differences in the way these two types of chemicals may produce effects in the body. Beryllium has both carcinogenic and non-carcinogenic potential, therefore was assessed as both for this HHRA.

Approach and Methodology

In determining the incremental increase in lifetime cancer risk associated with exposure to beryllium, the estimated dose is compared to the established cancer slope factors as shown below:

$$IELCR = LADD*CSF$$

where:

IELCR	Incremental Excess Lifetime Cancer Risk
LADD	Lifetime Averaged Daily Dose (mg/kg-day)
CSF	Cancer Slope Factor ([mg/kg-day] $^{-1}$)

The Incremental Excess Lifetime Cancer Risk (IELCR) estimates the incremental probability that a person will develop cancer as a result of a lifetime of exposure to the site. This incremental lifetime cancer risk is over and above the probability of developing cancer due to ambient exposures. The characterization of potential IELCR was undertaken using a target risk benchmark established by Health Canada of 1 in 100,000 (theoretically one additional cancer per 100,000 population). Calculation of the Lifetime Average Daily Dose (LADD) is based on methods presented by US EPA (1989), CCME (1996), and OMOE (1996). Details of the equations and parameter values used in the analysis are provided in Appendix C.

In general, exposure pathways and intake values were consistent with those used for the development of the non-carcinogenic HQs but were averaged over a lifetime of exposure rather than being specific to one age group.

Results of the risk characterization are presented in Sections 4.5.7 and 4.5.8.

4.5.7 Results for Upper Site Carcinogens

IELCRs have been derived for beryllium and Total PCBs at the upper site, and are presented in Table 17.

The IELCRs of the composite visitor engaging in traditional land use on the upper site was less than the acceptable benchmark of $1x10^{-5}$. Therefore, exposure to beryllium and total PCB concentrations in soil at the upper site the site pose a negligible potential risk to human receptors.

Table 17 Incremental Excess Lifetime Cancer Risks for Carcinogenic CoPCs at Upper Site

CoPC	EPC (mg/kg)	Total IELCR	Target IELCR	Exceeds Target IELCR?
Beryllium	7.8E-01	5.6E-11	1.00E-5	No
Total PCBs	2.20E+00	7.89E-6	1.00E-5	No

Because only an inhalation carcinogenic TRV is available for beryllium, only the inhalation pathway was assessed, and the entire increased lifetime cancer risk can be attributed to the inhalation of soil particles.

4.5.8 Results for Lower Site Carcinogens

An IELCR was derived for beryllium inhalation at the lower site, and is presented in Table 18.

The IELCRs of the composite visitor engaging in traditional land use on the lower site were less than the acceptable benchmark of 1 x 10^{-5}. Therefore, exposure to beryllium concentrations in soil at the lower site of the site pose a negligible potential risk to human receptors.

Table 18 Incremental Excess Lifetime Cancer Risks for Carcinogenic CoPCs at Lower Site

CoPC	EPC (mg/kg)	Total IELCR	Target IELCR	Exceeds Target IELCR?
Beryllium	5.8E-1	2.68E-10	1.00E-5	No

Because only a carcinogenic TRV is available for beryllium, only the inhalation pathway was assessed, and the entire IELCR can be attributed to the inhalation of soil particles.

4.5.9 Summary of Site Risk

The HQs for exposure to all non-carcinogenic CoPCs during traditional land uses at both the upper and lower FOX-C sites were less than 0.2, indicating that CoPCs pose a negligible risk to human health at the site.

The IELCRs for exposure to all carcinogenic CoPCs during Traditional Land Uses at both the upper and lower FOX-C sites were less than 1 x 10^{-5}, indicating that CoPCs pose a negligible cancer risk at the site.

This assessment has incorporated a number of very conservative assumptions, including exposure times for traditional land use of the upper site for 14 days and of the lower site for 90 days, and the use of the maximum concentrations found on the site as the EPC. However, even with such conservative assumptions, the result of the risk assessment is that the CoPCs on site do not pose a risk to human receptors.

4.6 HUMAN HEALTH SITE SPECIFIC TARGET LEVELS

Human health site-specific target levels (SSTLs) are developed based on the exposure characteristics of the user of the site. The SSTL values represent concentrations above, which adverse health effects are possible and further action may be required. These values could be used during any future site assessment activities at the site, only if land use has not changed from those scenarios modeled in this human health risk assessment. However, in this case, none of the maximum CoPC concentrations resulted in a HQ greater than 0.2, and therefore there is a negligible risk to receptors on site. Because the current maximum concentrations do not pose a risk to the human receptor, the derivation of SSTLs is unnecessary and remediation or risk management plans are not required.

4.7 UNCERTAINTY ANALYSIS

Risk estimates normally include an element of uncertainty, and generally these uncertainties are addressed by incorporating conservative assumptions in the analysis. As a result, risk assessments tend to overstate the actual risk. Although many factors are considered in preparation of a risk analysis, the results are generally only sensitive to very few of these factors. The uncertainty analysis is included to demonstrate that assumptions used are

conservative, or that the analysis result is not sensitive to the key assumptions.

A risk assessment containing a high degree of confidence will be based on:

- conditions where the problem is defined with a high level of certainty based on data and physical observations;
- an acceptable and reasonable level of conservatism in assumptions that will ensure that risks are overstated; or
- an appreciation of the bounds and limitations of the final solution.

The exposure assessment performed as part of this assessment was based on:

- available data to describe existing surface soil conditions and CoPC distributions;
- sound conservative assumptions for certain parameters, as required; and
- well-understood and generally accepted methods for risk prediction.

4.7.1 Uncertainties in Toxicological Information

There is a very limited amount of toxicological information on the effects associated with human exposures to low levels of chemicals in the environment. What human information is available is generally based on epidemiological studies of occupationally exposed workers. These studies are generally limited in scope and provide results that may not be applicable to chronic or continuous exposures to low levels of chemicals. Because human toxicological information is limited, reference doses and cancer potency estimates for many compounds are based on the results of dose-response assessment studies using animals.

The use of experimental animal data to estimate potential biological effects in humans introduces uncertainties into the evaluation of potential human health effects. These estimations require that a number of assumptions be made:

- The toxicological effect reported in animals is relevant and could occur in humans.
- The assumption that extrapolation from high-dose studies to low-dose environmental exposures adequately represents the shape of the dose-response curve in the low-dose exposure range.
- Short-term exposures used in animal studies can be extrapolated to chronic or long-term exposures in humans.
- The uptake of a compound from a test vehicle (drinking water, food, etc.) in animals will be the same as the uptake of the chemical from environmental media (soil, sediment, air-borne particulate matter) in humans.
- The pharmacokinetic processes that occur in the test animals also occur in humans.

There are clearly a number of uncertainties associated with extrapolating from experimental animal data to humans. To address these weaknesses, regulatory agencies, such as the Health Canada and the US EPA, incorporate a large number of conservative assumptions to try and account for the uncertainties associated with this process. The uncertainties are accounted for by the use of Uncertainty Factors that are used to lower the reference dose well below the level at which adverse health effects have been reported

in the test species. Uncertainty factors are generally applied by factors of 10 and are used to account for the following types of uncertainties:

- Variation within the population (protection of sensitive members of the population).
- Differences between humans and the test species.
- Differences in using short or medium-term studies to estimate the health effects associated with long-term or chronic exposures.
- Limitations in the available toxicological information.

The magnitude of the uncertainty factors applied by the various regulatory agencies provides an indication of the level of confidence that should be placed in the reference value. Uncertainty factors typically range between 100 and 10,000, although some can be lower than 10. The latter values are found for a few chemicals where sound and substantial human toxicological information is available to enable the setting of toxicological end-point solely on the basis of human epidemiological information.

The application of uncertainty factors is intended to introduce a high degree of conservatism into the risk assessment process and to ensure, as far as possible, that limited exposures that exceed the reference concentrations will not result in adverse human health effects. Because risk assessments that use these regulatory limits incorporate the conservatism used in the development of the toxicological information, the results can generally be viewed as being extremely conservative.

4.7.2 Summation of Hazards for a Single Compound

For some CoPCs, the toxicity values for inhalation and oral exposures are based on different biological end-points. In this case, the summation of exposures or hazard indices is not a sound toxicological practice and will not provide adequate assessments of either the inhalation or ingestion hazard. Therefore, it is necessary to assess the biological end-points separately. The estimate of overall risk would be based on the greater of the two risks. Inhalation and ingestion exposure hazard have been assessed independently and the greater of the two hazards selected as the representative hazard.

However, for the CoPCs considered in this risk assessment the biological end-point is the same for both routes of exposure, estimates of hazard were based on estimates of total exposure.

4.7.3 Summation of Hazards of Multiple Compounds

The summation of hazards between compounds that do not have the same biological end-point or mechanism of action has little practical meaning.

The summation of hazard indices across compounds is only supportable when the individual compounds affect the same target organ and have similar mechanisms of action. In these cases, the summation of hazard indices may provide a better estimate of total risk than evaluations based on exposures to single chemicals. For this risk assessment, the toxicity

values for the metals assessed are based on different biological end-points, hence, hazard indices have not been summed to provide an estimate of the overall hazard associated with these exposures.

4.7.4 Modeling Assumptions

Table 19 contains a summary of the assumptions used in this risk analysis, provides an evaluation for each assumption and an opinion as to whether the assumption is acceptable.

Table 19 Modeling Assumptions

Risk Assessment Study Factor/Assumption	Justification	Analysis Likely to Over/Under Estimate Risk?	Acceptable assumption?
Hazard Identification			
1. Screening of CoPC against human-health based generic CCME, MOE, or US EPA guidelines.	Generic guidelines by nature are very conservative in order that they can be reliably applied to any situation, potentially with little site-specific information available. Substances present at concentrations less than generic guidelines are unlikely to be of concern.	Neutral	Yes
2. Exposure point concentrations (EPCs) based on the maximum concentrations from the site.	Maximum concentrations are used as EPCs to present the most conservative assessment of risk posed by the site, for comparison to guidelines including DEW Line cleanup criteria.	Over estimate.	Yes
Receptor Characteristics			
1. For analysis of non-carcinogenic exposure, a toddler (0.5 – 4 years old) was chosen as the receptor.	Young children are the most sensitive age group for assessing non-carcinogenic effects. Resulting risks are over protective for an adult population. This approach is in accordance with accepted practice from Health Canada and the US EPA.	Neutral for young children but will over-estimate risks to adults.	Yes
2. For analysis of potential carcinogenic effects, a lifetime average was used representing yearly exposure to the site from birth to 75 years old.	For carcinogenic chemicals this is the most protective approach. In contrast, CCME only model adult exposure (20-75 years old) and US EPA only model exposure for 25 years (0-25 years old) averaged over a lifetime, both of which are less protective approaches.	Approach likely to over-estimate the risk.	Yes
3. For the Traditional Land Use scenario, both potential receptors (toddler and lifetime) assumed to be present on the upper site 24 hours per day, 14 days per year, and on the lower site for 24 hours	These are maximum values providing a reasonable maximum exposure estimate for a toddler but likely overestimating lifetime exposure.	Neutral to over-estimate.	Yes

Risk Assessment Study Factor/Assumption	Justification	Analysis Likely to Over/Under Estimate Risk?	Acceptable assumption?
per day and 90 days per year. While on the site they are assumed to be hunting and fishing on the site.			
Toxicological Information			
1. Most current toxicity information available from Health Canada, US EPA Integrated Risk Information (IRIS) database.	This approach is in accordance with standard practice and provides the most recent scientific basis for toxicity values.	Neutral	Yes
2. Potential antagonistic/additive/ synergistic effects of chemical mixtures were not quantitatively assessed.	The summation of hazards between compounds that do not have the same biological end-point or mechanism of action has little practical meaning. Summation of hazard indices across compounds is only supportable when the individual compounds affect the same target organ and have similar mechanisms of action.	Neutral	Yes
Risk Characterization			
1. Exposure was modeled for three potential exposure pathways: soil/dust ingestion, dermal contact, and inhalation; wild game ingestion; and drinking water ingestion and dermal contact.	CCME base the generic guidelines on only soil ingestion. Therefore, this multi-pathway approach is more protective.	Neutral	Yes
2. Default CCME soil ingestion rate of 80 mg/day adopted.	CCME employed a soil ingestion rate of 80 mg/day for toddlers when they developed the 1999 soil quality guidelines. In Nunavut, climate considerations mean that outdoor exposure to soil likely only occurs over a limited period of time each year. During the winter months, residents may still be exposed to soil-derived household dust. For hunting exposure,	Neutral	Yes

Risk Assessment Study Factor/Assumption	Justification	Analysis Likely to Over/Under Estimate Risk?	Acceptable assumption?
	no soil exposure is expected during winter months.		
3. Assessment of the current nutritional health status of local receptors was not included in the scope of work.	Inuit peoples of the Canadian Arctic can have different nutritional status to southern populations due to dietary differences. Micronutrient deficiency (e.g., Ca, Fe, Vitamin D) has been reported and may affect the absorption of other chemicals into the body (e.g., increased absorption of lead). However, quantitative data is not available to determine the scope or magnitude of this effect and no quantitative information is available on the current health status of Arctic Bay residents who generally have a mixed diet of supermarket foods and country foods. Assessment of current health status, past exposures, and lifestyle factors (e.g., smoking) are beyond the scope of this risk assessment, which is a forward-looking process that considers current and future exposures based on post-reclamation site conditions. However, it should be noted that the dietary intakes of lead were not adjusted for relative bioavailability compared to the toxicity study, which was based on metabolic studies in infants. Absorption of lead is known to be higher in infants and young children and the TDI was extended by Health Canada to older age groups, where lead absorption is significantly lower, to protect other sensitive population groups. Therefore, a factor of safety is built into the TDI that would protect	Neutral	Yes

Risk Assessment Study Factor/Assumption	Justification	Analysis Likely to Over/Under Estimate Risk?	Acceptable assumption?
	against some level of increased lead absorption sue to dietary deficiencies.		
4. Target risk for IELCR set at 1 in 100,000 (10^{-5}).	This is the value adopted by CCME for "acceptable" target risk. Health Canada uses target risks in the range of 10^{-5} to 10^{-6}. The CCME soil quality guidelines correspond to IELCRs of approximately 10^{-5} to 10^{-6}.	Neutral	Yes
5. Target Hazard Quotient for evaluating CoPC exposure = 0.2.	CCME guidelines assume that guidelines may also have to be established for other contaminated media at a site (e.g., water) and therefore only apportion 20% of the allowable daily intake to soil exposure.	Neutral	Yes

5.0 ECOLOGICAL RISK ASSESSMENT

The following sections present the results of an ecological risk assessment (ERA), which evaluated the potential for adverse effects to non-domesticated fauna, based on current conditions and habitats at the FOX-C DEW line site (FOX-C) located on the Ekalugad Fjord, Baffin Island (Figure 1.1).

Ecological risk assessment is a process that evaluates the likelihood that adverse environmental effects may occur, or are occurring, because of exposure to one or more stressors (Suter 1993). The potential hazards, or chemicals of potential concern (CoPCs), identified within the study area are chemical substances in environmental media (soil, water and terrestrial vegetation) from sources associated with past operations at the FOX-C site. Therefore, the purpose of this ERA was to provide a qualitative and quantitative analysis of the likelihood and potential magnitude of adverse environmental effects to Valued Environmental Components (VECs), which are ecological receptors (mammals and birds) present, or potentially present, in the study area.

Objectives

This ERA has been conducted according to principles laid out in Canadian guidance documents (CCME 1996, 1997). The objectives of the ERA are to:

- Qualitatively characterize the potential ecological receptors that have been observed or could be present in terrestrial habitats on or adjacent to the site.

- Assess potential exposures of ecological receptors to CoPCs in various environmental media within terrestrial habitats under current conditions.

- Quantify the risks associated with exposures of ecological receptors to CoPCs in various environmental media under current conditions.

- If unacceptable risk is identified, determine acceptable concentrations of contaminants (site specific target levels, or SSTLs) that would allow re-establishment of the habitat and would not pose ongoing risks.

This ERA used a general framework similar in concept to the approach used for the human health risk assessment, but is distinctive in its emphasis in three areas.

- The ecological risk assessment does not consider effect on individuals of a single species, rather, it is concerned with potential effects at population, community, or ecosystem levels. In order to achieve this goal, the toxicity reference values that are used to evaluate whether ecological exposures may lead to effects are based on Lowest Observed Adverse Effect Level (LOAEL) data from the ecotoxicological literature, with a focus on sublethal reproductive or developmental endpoints.

- There is no single set of ecological values or resources to be protected that can be generally applied to every site, so the selection of VECs and exposure pathways for the ERA is site-specific.

- If appropriate, the ecological risk assessment can consider non-chemical, as well as chemical, stressors.

5.1 ECOLOGICAL RISK ASSESSMENT FRAMEWORK

Conceptually, the ecological risk assessment consists of three main steps:

- **Problem Definition** - This is a review of available physical and biological data for the site and receptor habitats that may be affected by releases of chemicals to environmental media. This step i) identifies potential ecological receptors (i.e., biological communities, populations, individuals, or habitats potentially at risk); ii) determines contaminants of concern and other stressors for ecological receptors; iii) identifies potential exposure pathways; and iv) determines appropriate assessment and measurement endpoints for the ecological risk assessment. Each of these elements is integrated into a conceptual model that is specific to the site.

- **Analysis (Exposure and Effects Assessments)** - This includes estimation of exposure of the ecological receptors to the CoPCs, and identification of exposure-response standards based on the concentrations of these chemicals in various environmental media.

- **Risk Characterization** - This is a description of the nature and magnitude of potential ecological risks, which is achieved by comparing exposure estimates for various media, exposure-response standards for the ecological receptors, and results of the site-specific surveys and bioassays. Exposure may be based directly on the concentration of a CoPC in an environmental medium, or it may be based on an estimated dose or intake rate for the CoPC. The exposure response standards can be either biological responses (such as mortality or impairment) associated with the measured or estimated concentration, or can be toxicological responses to the estimated dose (such as impaired reproduction or development). Risk characterization also includes a discussion of the uncertainties in the analysis, an evaluation of the necessity for remedial action, and may involve estimating the maximum chemical concentrations, or site-specific threshold levels (SSTLs) consistent with an acceptable level of risk.

The organization of this ERA is consistent with these elements of an ecological risk assessment.

5.2 RISK SCREENING

The ERA was concerned primarily with substances that are present in environmental media that are accessible to wildlife. Therefore, FOX-C data were screened to consider surface soils (0 to 30 cm depth) and surface waters. It should be noted that although both the HHRA and the ERA draw from the same overall

dataset, they may not be based on identical subsets from that data. The locations of soil and surface water and samples used in this study are shown in the Earth Tech Phase III report (Earth Tech, 2004). The specific sampling location identifiers are also presented in the Earth Tech Phase III report (Earth Tech, 2004). Screening for inorganic elements also included analysis of samples collected by the Environmental Sciences Group of the Royal Roads Military College in 1994 (RRMC 1994).

5.2.1 Hazard Identification

This step involved the selection of chemical substances that have potential for adversely impacting ecological receptors in habitats associated with the site. CoPCs were selected based on their concentration in soils, surface water or sediments, and their potential toxicity to ecological receptors. Identification of CoPCs was based on a comparison of site data to both toxicity-based screening criteria and (for inorganic substances) site-specific background concentrations.

An initial generic assessment of the potential for adverse effects associated with site-originated chemicals was conducted. This assessment compared the maximum detected concentration in soils with the generic CCME soil quality guidelines for the protection of ecological health (CCME 1999, 2001). For those substances for which CCME guidelines have not been developed, concentrations were screened using guidelines from the Ontario Ministry of Environment (OMOE 1997).

Tables 20 and 21 illustrate the screening of CoPCs for the Upper and Lower Sites, respectively. The tables list the maximum observed soil concentration and number of samples for each substance, and the relevant guideline. If the substance is carried forward, its Exposure Point Concentration (EPC) is calculate. The EPC is intended to be a conservative (i.e., pessimistic, but not necessarily worst-case) estimator of the average on-site concentration that wildlife may be exposed to. Where sufficient data are available (i.e., if $n \geq 5$) the EPC is estimated as the 95% upper confidence limit (UCL) of the geometric mean value. Where few data are available (i.e., $n < 5$), the EPC was assumed to be the maximum observed soil concentration from the FOX-C site-specific data. For context, the EPC is also compared (for inorganic substances) with site-specific background data and Ontario Typical Range (OTR; OMOE 1993) data for that substance, if available. The purpose of this comparison is to avoid inclusion of naturally occurring substances in the ERA that may have locally high background conditions. Finally, a decision is rendered regarding whether each substance is present at a concentration that is below a threshold for concern, or whether the concentration could potentially cause harm to one or more ecological receptors. In the former case, the substance is not of interest to the ERA. In the latter case, the substance is deemed to be a CoPC and is carried forward into the quantitative ERA.

5.2.1.1 Upper Site

For inorganic substances, as indicated in Table 20, the maximum cadmium, chromium, copper, lead, and zinc concentrations in soils were greater than the corresponding ecological health-based guidelines and were all

subsequently carried forward in the ERA. The maximum concentrations in soil for the remaining metals were less than the applicable guidelines and were not carried forward, with the exception of beryllium which was carried forward to be consistent with the human health risk assessment. The EPCs for cadmium and chromium were less than site-specific background data and typical background values (OTR data for rural parkland). These metals were carried forward in the ERA because maximum soil concentrations for each metal were greater than both the site-specific and OTR background data, and it was felt that the ERA would help to determine whether clean-up of localized hotspots would be worthwhile. Beryllium was carried forward in the ERA to be consistent with the HHRA although its EPC was less than OTR data and site-specific background data was not available. EPCs for copper, lead and zinc were less than OTR data for rural parkland but were greater than site-specific background values. Consequently, all three metals were carried forward in the assessment.

For organic compounds, as indicated in Table 20, the maximum concentrations of TPH F2, F3, and F4 fractions were greater than the corresponding ecological health-based guidelines. Because TPH and BTEX petroleum hydrocarbon products can be assumed to have similar modes of toxic action, and similar target organs, it is reasonable to sum the hazards for these substances. However, BTEX concentrations at the Upper Site were extremely low and would have a negligible contribution to the calculation of additive hazard quotient (HQ) values. As a result, only TPH F1, F2, F3, and F4 fractions were carried forward in the ERA. Total PCBs were also carried forward in order to be consistent with the human health risk assessment. No site-specific background data were available for organic CoPCs, however, typical background values for TPHs should be non-detectable (CCME 2001). Total PCBs were greater than site-specific background data and typical background values (OTR data for rural parkland) and were carried forward in the ERA.

5.2.1.2 Lower Site

For inorganic substances, as indicated in Table 21, the maximum chromium concentration in soils was greater than the corresponding ecological health-based guideline and chromium was subsequently carried forward in the ERA to be compared to background values. Although the maximum soil concentrations for the other metals were less than applicable guidelines, beryllium was carried forward in order to be consistent with the HHRA and cadmium, copper, lead, and zinc were carried forward in order to be consistent with what was assessed at the Upper Site (see Table 20). The exposure point concentration (EPC) for chromium was greater than site-specific background data and typical background values (OTR data for rural parkland) and was carried forward in the ERA. EPCs for beryllium, copper, lead, and zinc were all less than OTR values, but greater than site-specific background data, with the exception of beryllium for which no site-specific background data existed. The EPC for cadmium was less than site-specific background data and OTR values. Beryllium, cadmium, copper, lead, and zinc were carried forward in the ERA to be consistent with the HHRA (beryllium) and the Upper Site (cadmium, copper, lead, zinc).

For organic compounds, as indicated in Table 21, the maximum concentrations of TPH F2, F3 and F4 fractions were greater than the corresponding ecological health-based guidelines. Because TPH fractions can be assumed to have similar modes of toxic action, and similar target organs, it is reasonable to sum the hazards for these substances. As a result, TPH F1, F2, F3, and F4 fractions were carried forward in the ERA for comparison with typical background concentrations. No site-specific background data were available for organic CoPCs, however, typical background values for TPHs should be non-detectable (CCME 2001). Total PCBs were greater than site-specific background data and typical background values (OTR data for rural parkland) and were carried forward in the ERA.

5.2.1.3 Surface Water

To assess CoPC uptake as part of the drinking water pathway for ecological receptors, concentrations of CoPCs in surface water were assessed (Table 22). This assessment compared the maximum detected concentration in surface water samples taken at the site with the generic CCME guidelines for the protection of freshwater aquatic life (CCME 1999). The maximum concentrations for aluminum and zinc exceeded the applicable guidelines. However, zinc was previously identified in the soils screening as a CoPC, and would be carried forward in any case as part of the overall evaluation. High levels of aluminum were expected, as the lake from which these samples were taken is fed by glacial tributaries, and are high in total suspended solids. Therefore, it was assumed that the elevated aluminum concentration was due to suspended minerals of natural origin in the water. No new CoPCs were identified in the screening of surface water, although substances in the water were carried forward if they had previously been identified as CoPCs through the screening of soils data. Surface water was not carried forward in relation to aquatic receptors, since there were no exceedances that required this. However, for completeness, surface water was carried forward as a source of drinking water for terrestrial receptors. Due to the small number of water samples available, EPC values for CoPCs assessed as part of the drinking water pathway for each VEC were obtained by taking the maximum observed concentrations.

Table 20 Soil Hazard Screening Procedure for FOX-C ERA – Upper Site

Contaminant	Soil Concentration (mg/kg)		Generic Ecological Health Guidelines (mg/kg)		Carried Forward Y/N	Exposure Point Concentration (EPC)*	Background Soil Concentration (mg/kg)				Carried Forward Y/N
	Maximum Observed Soil Concentration	Number of Samples	Applicable Guideline	Exceeds Guideline Y/N			Site Specific Background (SSB)**	EPC > SSB Y/N	OTR Rural Parkland[f]	EPC > OTR Y/N	
Upper Site											
Inorganics											
Antimony	5.60	29	20.00[b]	N	N	-	-	-	-	-	N
Arsenic	5.10	29	17.00[a]	N	N	-	-	-	-	-	N
Barium	411.00	29	750.00[b]	N	N	-	-	-	-	-	N
Beryllium	0.78	29	4.00[b]	N	Y	0.29	na	n/a	1.10	N	Y
Boron	0.50	29	1.50[b]	N	N	-	-	-	-	-	N
Cadmium	11.00	29	10.00[a]	Y	Y	0.17	0.50	N	0.71	N	Y
Chromium	116.00	29	64.00[a]	Y	Y	36.38	47.91	N	58.00	N	Y
Hexavalent Chromium	na	na	na	n/a	N	-	-	-	-	-	N
Cobalt	19.30	29	40.00[b]	N	N	-	-	-	-	-	N
Copper	381.00	29	63.00[a]	Y	Y	26.00	22.87	Y	41.00	N	Y
Lead	1060.00	29	300.00[a]	Y	Y	18.65	5.00	Y	45.00	N	Y
Mercury	0.10	29	12.00[a]	N	N	-	-	-	-	-	N
Molybdenum	1.60	29	40.00[b]	N	N	-	-	-	-	-	N
Nickel	41.00	29	50.00[a]	N	N	-	-	-	-	-	N
Selenium	0.30	29	10.00[b]	N	N	-	-	-	-	-	N
Silver	1.89	29	20.00[b]	N	N	-	-	-	-	-	N
Tin	17.80	29	na	n/a	N	-	-	-	-	-	N
Vanadium	42.30	29	130.00[a]	N	N	-	-	-	-	-	N
Zinc	1400.00	29	200.00[a]	Y	Y	57.95	48.58	Y	120.00	N	Y
Organics											
Benzene	0.02	56	25.00[c]	N	N	-	-	-	-	-	N
Toluene	0.04	56	150.00[c]	N	N	-	-	-	-	-	N
Ethylbenzene	0.02	56	25.00[e]	N	N	-	-	-	-	-	N
Total Xylenes (m,p,o)	0.23	56	1.00[a]	N	N	-	-	-	-	-	N
F1 (C_6 - C_{10})	113.00	56	260.00[d]	N	Y	1.84	na	n/a	0.00	Y	Y
F2 (>C_{10} - C_{16})	8800.00	56	900.00[d]	Y	Y	212.71	na	n/a	0.00	Y	Y
F3 (>C_{16} - C_{34})	31900.00	56	800.00[d]	Y	Y	1246.55	na	n/a	0.00	Y	Y
F4 (>C_{34} - C_{50})	21000.00	56	5600.00[d]	Y	Y	254.54	na	n/a	0.00	Y	Y

Contaminant	Soil Concentration (mg/kg)		Generic Ecological Health Guidelines (mg/kg)		Carried Forward Y/N	Exposure Point Concentration (EPC)*	Background Soil Concentration (mg/kg)				Carried Forward Y/N
	Maximum Observed Soil Concentration	Number of Samples	Applicable Guideline	Exceeds Guideline Y/N			Site Specific Background (SSB)**	EPC > SSB Y/N	OTR Rural Parkland[f]	EPC > OTR Y/N	
Upper Site											
Naphthalene	0.63	13	40.00[b]	N	N	-	-	-	-	-	N
Acenaphthylene	0.61	13	na	n/a	N	-	-	-	-	-	N
Acenaphthene	0.07	13	40.00[e]	N	N	-	-	-	-	-	N
Fluorene	0.84	13	350.00[b]	N	N	-	-	-	-	-	N
Phenanthrene	6.54	13	40.00[b]	N	N	-	-	-	-	-	N
Anthracene	0.08	13	40.00[c]	N	N	-	-	-	-	-	N
Fluoranthene	0.30	13	40.00[b]	N	N	-	-	-	-	-	N
Pyrene	0.16	13	0.70[e]	N	N	-	-	-	-	-	N
Benzo(a)anthracene	0.09	13	40.00[c]	N	N	-	-	-	-	-	N
Chrysene	0.63	13	12.00[b]	N	N	-	-	-	-	-	N
Benzo(b)fluoranthene	0.10	13	na	n/a	N	-	-	-	-	-	N
Benzo(j)fluoranthene	bd	13	na	n/a	N	-	-	-	-	-	N
Benzo(k)fluoranthene	0.07	13	12.00[b]	N	N	-	-	-	-	-	N
Benzo(a)pyrene	0.09	13	0.70[a]	N	N	-	-	-	-	-	N
Indeno(1,2,3 c,d)pyrene	0.14	13	12.00[b]	N	N	-	-	-	-	-	N
Dibenzo(a,h)anthracene	bd	13	1.20[b]	N	N	-	-	-	-	-	N
Benzo(g,h,i)perylene	0.26	13	40.00[b]	N	N	-	-	-	-	-	N
Total PCBs	2.20	41	5.00[b]	N	Y	0.20	1.10E-04	Y	1.50E-02	Y	Y

[a] CCME. 1999. Canadian Environmental Quality Guidelines.

[b] OMOE. 1997. Guideline for Use at Contaminated Sites in Ontario. Appendix A.2.2: Table B Criteria Components - Coarse Textured Soil (Surface/Full Depth) - Non-Potable Groundwater Situation.

[c] Netherlands Criteria in MOE 1997.

[d] CCME. 2001. Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in Soil.

[e] screened versus more toxic compound (i.e., benzene, anthracene, benzopyrene)

[f] OMOE. 1993. Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags and Snow.

* if n>=5, then EPC = 95% UCL of the geometric mean. If n<5, then EPC = maximum observed soil concentration.

**SSB = 95% UCL of the geometric mean

bd - below detection limit

na - not available

n/a - not applicable

Table 21 Soil Hazard Screening Procedure for FOX-C ERA – Lower Site

Contaminant	Soil Concentration (mg/kg)		Generic Ecological Health Guidelines (mg/kg)		Carried Forward Y/N	Exposure Point Concentration (EPC)*	Background Soil Concentration (mg/kg)				Carried Forward Y/N
	Maximum Observed Soil Concentration	Number of Samples	Applicable Guideline	Exceeds Guideline Y/N			Site Specific Background (SSB)**	EPC > SSB Y/N	OTR Rural Parkland[f]	EPC > OTR Y/N	
Lower Site											
Inorganics											
Antimony	3.50	10	20.00[b]	N	N	-	-	-	-	-	N
Arsenic	4.30	10	17.00[a]	N	N	-	-	-	-	-	N
Barium	141.00	10	750.00[b]	N	N	-	-	-	-	-	N
Beryllium	0.58	10	4.00[b]	N	Y	0.54	na	n/a	1.10	N	Y
Boron	1.30	10	1.50[b]	N	N	-	-	-	-	-	N
Cadmium	1.30	10	10.00[a]	N	Y	0.08	0.50	N	0.71	N	Y
Chromium	93.00	10	64.00[a]	Y	Y	79.40	47.91	Y	58.00	Y	Y
Hexavalent Chromium	0.20	13	na	n/a	N	-	-	-	-	-	N
Cobalt	13.00	10	40.00[b]	N	N	-	-	-	-	-	N
Copper	32.00	10	63.00[a]	N	Y	30.20	22.87	Y	41.00	N	Y
Lead	25.00	10	300.00[a]	N	Y	10.80	5.00	Y	45.00	N	Y
Mercury	bd	10	12.00[a]	N	N	-	-	-	-	-	N
Molybdenum	1.10	10	40.00[b]	N	N	-	-	-	-	-	N
Nickel	35.20	10	50.00[a]	N	N	-	-	-	-	-	N
Selenium	bd	10	10.00[b]	N	N	-	-	-	-	-	N
Silver	bd	10	20.00[b]	N	N	-	-	-	-	-	N
Tin	2.70	10	na	n/a	N	-	-	-	-	-	N
Vanadium	72.20	10	130.00[a]	N	N	-	-	-	-	-	N
Zinc	83.30	10	200.00[a]	N	Y	80.20	48.58	Y	120.00	N	Y
Organics											
Benzene	bd	20	25.00[c]	N	N	-	-	-	-	-	N
Toluene	0.02	20	150.00[c]	N	N	-	-	-	-	-	N
Ethylbenzene	0.28	20	25.00[e]	N	N	-	-	-	-	-	N
Total Xylenes (m,p,o)	4.31	20	1.00[a]	N	N	-	-	-	-	-	N
F1 (C_6 - C_{10})	179.00	20	260.00[d]	N	Y	7.09	na	n/a	0.00	Y	Y
F2 (>C_{10} - C_{16})	2890.00	20	900.00[d]	Y	Y	151.58	na	n/a	0.00	Y	Y

Contaminant	Soil Concentration (mg/kg)		Generic Ecological Health Guidelines (mg/kg)		Carried Forward Y/N	Exposure Point Concentration (EPC)*	Background Soil Concentration (mg/kg)				Carried Forward Y/N
	Maximum Observed Soil Concentration	Number of Samples	Applicable Guideline	Exceeds Guideline Y/N			Site Specific Background (SSB)**	EPC > SSB Y/N	OTR Rural Parkland[f]	EPC > OTR Y/N	
Lower Site											
F3 (>C_{16} - C_{34})	18000.00	20	800.00[d]	Y	Y	306.04	na	n/a	0.00	Y	Y
F4 (>C_{34} - C_{50})	11500.00	20	5600.00[d]	Y	Y	110.92	na	n/a	0.00	Y	Y
Naphthalene	bd	2	40.00[b]	N	N	-	-	-	-	-	N
Acenaphthylene	bd	2	na	n/a	N	-	-	-	-	-	N
Acenaphthene	bd	2	40.00[e]	N	N	-	-	-	-	-	N
Fluorene	bd	2	350.00[b]	N	N	-	-	-	-	-	N
Phenanthrene	bd	2	40.00[b]	N	N	-	-	-	-	-	N
Anthracene	bd	2	40.00[c]	N	N	-	-	-	-	-	N
Fluoranthene	bd	2	40.00[b]	N	N	-	-	-	-	-	N
Pyrene	bd	2	0.70[e]	N	N	-	-	-	-	-	N
Benzo(a)anthracene	bd	2	40.00[c]	N	N	-	-	-	-	-	N
Chrysene	bd	2	12.00[b]	N	N	-	-	-	-	-	N
Benzo(b)fluoranthene	bd	2	na	n/a	N	-	-	-	-	-	N
Benzo(j)fluoranthene	bd	2	na	n/a	N	-	-	-	-	-	N
Benzo(k)fluoranthene	bd	2	12.00[b]	N	N	-	-	-	-	-	N
Benzo(a)pyrene	bd	2	0.70[a]	N	N	-	-	-	-	-	N
Indeno(1,2,3 c,d)pyrene	bd	2	12.00[b]	N	N	-	-	-	-	-	N
Dibenzo(a,h)anthracene	bd	2	1.20[b]	N	N	-	-	-	-	-	N
Benzo(g,h,i)perylene	bd	2	40.00[b]	N	N	-	-	-	-	-	N
Total PCBs	bd	3	5.00[b]	N	Y	0.05	1.10E-04	Y	1.50E-02	Y	Y

[a] CCME. 1999. Canadian Environmental Quality Guidelines.

[b] OMOE. 1997. Guideline for Use at Contaminated Sites in Ontario. Appendix A.2.2: Table B Criteria Components - Coarse Textured Soil (Surface/Full Depth) - Non-Potable Groundwater Situation.

[c] Netherlands Criteria in MOE 1997.

[d] CCME. 2001. Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in Soil.

[e] screened versus more toxic compound (i.e., benzene, anthracene, benzopyrene)

[f] OMOE. 1993. Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags and Snow.

* if n>=5, then EPC = 95% UCL of the geometric mean. If n<5, then EPC = maximum observed soil concentration.

**SSB = 95% UCL of the geometric mean

bd - below detection limit

na - not available

n/a - not applicable

Table 172 Surface Water Hazard Screening for FOX-C ERA

Contaminant	Maximum Observed Surface Water Concentration (mg/L)	Number of Samples	Guideline (mg/L)	Exceeds Guideline Y/N	Carried Forward Y/N
Inorganics					
Aluminum	0.358	2	0.005-0.1	Y	N
Antimony	0.0002	2	-	n/a	N
Arsenic	<0.0002	2	0.005	N	N
Barium	0.031	2	-	n/a	N
Beryllium	<0.0001	2	-	n/a	Y
Bismuth	<0.0005	2	-	n/a	N
Boron	0.006	2	-	n/a	N
Cadmium	0.00006	2	0.017	N	Y
Chromium	0.0011	2	-	n/a	Y
Cobalt	0.0049	2	-	n/a	N
Copper	0.004	2	0.002-0.004	N	Y
Iron	1.1	2	-	n/a	N
Lead	0.001	2	0.001-0.007	N	Y
Lithium	0.002	2	-	n/a	N
Manganese	0.041	2	-	n/a	N
Mercury	<0.0002	2	-	n/a	N
Molybdenum	<0.001	2	0.073	N	N
Nickel	0.0126	2	0.025-0.150	N	N
Selenium	<0.0002	2	0.001	N	N
Silicon	3.97	2	-	n/a	N
Silver	<0.0001	2	0.0001	N	N
Strontium	0.017	2	-	n/a	N
Sulphur	3.02	2	-	n/a	N
Thallium	<0.00005	2	0.0008	N	N
Tin	<0.001	2	-	n/a	N
Titanium	0.0384	2	-	n/a	N
Uranium	<0.0005	2	-	n/a	N
Vanadium	0.0008	2	-	n/a	N
Zinc	0.056	2	0.03	Y	Y
Organics					
Benzene	<0.001	3	0.370	N	N
Toluene	0.001	3	0.002	N	N
Ethylbenzene	<0.001	3	0.090	N	N
Total Xylenes (m,p,o)	0.003	3	-	n/a	N
F1 (C_6 - C_{10})	0.070	3	-	n/a	Y
F2 (>C_{10} - C_{16})	<0.100	3	-	n/a	Y
F3 (>C_{16} - C_{34})	<0.100	3	-	n/a	Y
F4 (>C_{34} - C_{50})	<0.100	3	-	n/a	Y
Total PCBs	<0.0001	3	0.0001	N	Y

Note: Criteria based on CCME Freshwater Aquatic Life Guidelines 1999

5.2.1.4 Lake and River Sediment

Concentrations of CoPCs in sediments at both the lake and river were assessed (Table 23). The assessment compared the maximum detected concentration in sediment samples with the generic CCME interim probable effect level (PEL) sediment quality guidelines (CCME 1999). Since no CoPCs exceeded screening guidelines, it was not necessary to carry sediments forward in the ERA as a potential source of contaminants to aquatic biota. No new CoPCs were identified in the screening of sediments.

Table 23 Lake and River Sediments Hazard Screening for FOX-C ERA

Contaminant	Maximum Observed Sediment Concentration (mg/kg)	Number of Samples	Guideline (mg/kg)	Exceeds Guideline Y/N	Carried Forward Y/N
Inorganics					
Antimony	0.8	4	-	N	N
Arsenic	2.2	4	17.0	N	N
Barium	29.4	4	-	N	N
Beryllium	0.2	4	-	N	N
Boron	0.4	4	-	N	N
Cadmium	0.1	4	3.5	N	N
Chromium	17.2	4	90.0	N	N
Cobalt	2.9	4	-	N	N
Copper	11.3	4	197.0	N	N
Lead	3.8	4	91.3	N	N
Mercury	bd	4	0.486	N	N
Molybdenum	0.5	4	-	N	N
Nickel	10.0	4	-	N	N
Selenium	bd	4	-	N	N
Silver	0.1	4	-	N	N
Thallium	bd	4	-	N	N
Tin	2.1	4	-	N	N
Vanadium	15.0	4	-	N	N
Zinc	20.3	4	315.0	N	N
Organics					
Benzene	bd	4	-	N	N
Toluene	bd	4	-	N	N
Ethylbenzene	bd	4	-	N	N
Total Xylenes (m,p,o)	bd	4	-	N	N
F1 (C_6 - C_{10})	bd	4	-	N	N
F2 (>C_{10} - C_{16})	bd	4	-	N	N

Contaminant	Maximum Observed Sediment Concentration (mg/kg)	Number of Samples	Guideline (mg/kg)	Exceeds Guideline Y/N	Carried Forward Y/N
F3 (>C_{16} - C_{34})	0.028	4	-	N	N
F4 (>C_{34} - C_{50})	0.018	4	-	N	N
Naphthalene	bd	4	0.391	N	N
Acenaphthylene	bd	4	0.128	N	N
Acenaphthene	bd	4	0.089	N	N
Fluorene	bd	4	0.144	N	N
Phenanthrene	bd	4	0.515	N	N
Anthracene	bd	4	0.245	N	N
Fluoranthene	bd	4	2.355	N	N
Pyrene	bd	4	0.875	N	N
Benzo(a)anthracene	bd	4	0.385	N	N
Chrysene	bd	4	0.862	N	N
Benzo(b)fluoranthene	bd	4	-	N	N
Benzo(j)fluoranthene	bd	4	-	N	N
Benzo(k)fluoranthene	bd	4	-	N	N
Benzo(a)pyrene	bd	4	0.782	N	N
Indeno(1,2,3-c,d)pyrene	bd	4	-	N	N
Dibenzo(a,h)anthracene	bd	4	0.135	N	N
Benzo(g,h,i)perylene	bd	4	-	N	N
Total PCBs	bd	4	0.277	N	N

Note: Criteria based on Interim CCME Freshwater Sediment Quality Guidelines, Probable Effect Levels (PELs), 1999

5.2.1.5 Summary of Hazards

Table 24 provides a summary of the CoPCs and EPCs identified in soils that were carried forward into the ERA.

Although the ERA is concerned with contaminants in soils (i.e., not surface water), drinking water was included as a potential exposure pathway.

Table 24 Summary of Hazards and Exposure Point Concentrations Used in the FOX-C ERA

CoPCs	Upper Site Soil Exposure Point Concentration (mg/kg)	Lower Site Soil Exposure Point Concentration (mg/kg)	Surface Water Exposure Point Concentration (mg/L)
Inorganics			
Beryllium	0.29	0.54	0.00005
Cadmium	0.17	0.08	0.00006
Chromium	36.38	79.40	0.0011
Copper	26.00	30.20	0.004
Lead	18.65	10.80	0.001
Zinc	57.95	80.20	0.056
Organics			
F1 (C_6 - C_{10})	1.84	7.09	0.07
F2 (>C_{10} - C_{16})	212.71	151.58	0.05
F3 (>C_{16} - C_{34})	1246.55	306.04	0.05
F4 (>C_{34} - C_{50})	254.54	110.92	0.05
Total PCBs	0.20	0.05	0.00005

Notes:

1. The selection of hazards and exposure point concentrations are illustrated in Tables 16, 17, 18, and 19.
2. If n>=5, then EPC = 95% UCL of the geometric mean. If n<5, then EPC = maximum observed soil concentration.
3. If EPC is below detection limit, EPC = half of detection limit.

5.2.2 Receptor Identification

Receptor selection was based on fundamental ecological considerations, but was also guided by observations made during a site visit, and information solicited from members of the local community. The following criteria were considered in selecting receptors for use in this ERA:

- keystone species known to be central to ecosystem function;
- exposed to surface soils, sediments, and/or freshwater at the site;
- representative of lower and higher trophic feeding levels (i.e., herbivorous and carnivorous animals);
- present on or near the site for some or most of the year;
- of significant cultural and/or economic significance; and
- possible endangered or sensitive species.

5.2.3 Valued Environmental Components (VECs)

Valued environmental components (VECs) are defined as resources or environmental features important to human populations, that have economic and/or social value, and/or have intrinsic ecological significance. These components also provide a baseline from which the impacts of development can be evaluated, including changes in management or regulatory policies.

Based on the above criteria, and using information gathered by a Jacques Whitford biologist during a site visit (Jacques Whitford 2004), the following ecological receptors were selected for the FOX-C site: collared lemming, ermine, Arctic hare, ptarmigan, Snowy Owl, Arctic fox, and caribou. The presence of each of these animals has been documented on or near the site. The receptors are briefly described below.

The Willow Ptarmigan (*Lagopus lagopus*) or Rock Ptarmigan (*L. mutus*) are small grouse-like birds, weighing approximately 0.5 kg, which live year-round throughout alpine and Arctic tundra. Ptarmigan nest on the ground soon after the snow melts. These birds are mainly herbivorous, feeding on willow buds and twigs throughout the year, and any other vegetation that might be available. Ptarmigan, especially chicks, will also feed on insects. Ptarmigan are estimated to consume approximately 0.124 kg (wet-weight) of food per day and drink 0.037 L of water, or its equivalent, per day. They are valued for their meat and hunted by local residents.

The Snowy Owl (*Nyctea scandiaca*), which weighs on average 2.05 kg, is a top predator that is found in the Canadian Arctic. By virtue of its location in the food chain, it may be susceptible to contaminants that accumulate in the tissue of its prey. Snowy Owls breed in the Arctic tundra and may make southerly migrations for the winter (as far as the northern United States), although some remain in the Arctic year-round. The diet of the Snowy Owl consists mainly of small mammals and birds (e.g., lemmings, Arctic hares, ptarmigan, seabirds). On average, Snowy Owls will consume approximately 0.093 kg of dry-weight food per day (0.290 kg

of wet-weight food per day) and will consume 0.095 L of water, or its equivalent, per day.

The collared lemming *(Dicrostonyx groenlandicus*) is a small burrowing rodent, which weighs approximately 0.04 kg and lives on the tundra throughout the high Arctic. It is the smallest of the mammals in the high Arctic and is a key species in Arctic ecosystems. The lemming is herbivorous, feeding on whatever vegetation exists within its habitat. In the winter, lemmings do not hibernate; rather, they forage in the space that forms between the snow and soil. Lemmings are an important food source for Arctic fox, Snowy Owl and other predatory species. On average, a lemming is estimated to consume 0.023 kg of wet-weight food per day and 0.009 L of water, or its equivalent, per day.

The Arctic hare (*Lepus arcticus*) is the largest hare in North America. Weighing approximately 4.3 kg, it inhabits the tundra regions of Canada from Newfoundland west to the Mackenzie Delta and north to the tip of Ellesmere Island. Immature Arctic hares are hunted by Arctic foxes, gyrfalcons, snowy owls, and ermine, however, as adults they have few enemies but wolves and people. Arctic hares are mainly herbivores and eat willow leaves, bark, shoots, other leaves, grasses, and herbs. They have also been observed to eat carrion and the meat from hunters' traps. An adult Arctic hare will consume approximately 1.149 kg of wet-weight food per day and 0.368 L of water, or its equivalent, per day.

Ermine, or short-tailed weasel *(Mustela erminea*), is one of the smaller predatory animals found on the Arctic tundra, weighing on average 0.128 kg. Ermine do not migrate, despite significant food shortages during the winter months. Ermine population densities fluctuate with prey abundance and home ranges vary from 10 to 20 ha. Home ranges of males are usually twice the size of female home ranges. Ermine play an important role in the small mammals communities in which they live. They are ferocious hunters that specialize in small mammals, preferably of rabbit size and smaller. When mammalian prey is scarce, ermine may eat (depending upon availability) birds, eggs, frogs, fish, insects, or berries. On average, an ermine will consume approximately 0.008 kg of dry-weight food per day (0.026 kg of wet-weight food per day) and will consume 0.009 L of water, or its equivalent, per day.

The Arctic fox (*Alopex lagopus*) is a relatively small canid mammal, weighing approximately 5.75 kg. Arctic fox are widely distributed throughout the Arctic. Each Arctic fox has its own home range which varies in size from 3 to 25 km^2. It is predominately carnivorous, preying mostly on lemmings, but also on ptarmigan and any other available meat (e.g., small birds and mammals, Inuit meat caches, wolf kills). During the summer, the Arctic fox will also forage on any berries that might be available. These animals consume approximately 0.933 kg of wet-weight food per day and 0.478 L of water, or its equivalent, per day. Breeding dens are built in the surface soil and may be used for many generations. The Arctic fox is highly valued for its fur.

The caribou (*Rangifer tarandus*) is representative of a large ungulate found throughout Canada's Arctic and is valued as a food source to both humans and other wildlife.

Caribou are typically migratory in nature and make seasonal migrations from the tundra to the taiga, returning north in the springtime. These migratory patterns of movement can significantly decrease the exposure of caribou to localized contamination, although near-stationary populations of caribou are also known. During calving, even migratory herds may remain at a specific location for an extended period of time.

There are three major types of caribou in Canada: barren-ground, woodland, and Peary. Barren-ground caribou are found in the vicinity of the FOX-C site. The barren-ground caribou weighs on average 117.5 kg and spends much or all of the year on the tundra from Alaska to Baffin Island. Herds may migrate up to 700 km to their calving grounds.

The caribou diet depends on seasonal availability, but lichens are the caribou's primary food source for much of the year. They will also feed on willow, herbs, mosses, flowers, grasses, and leaves of shrubs. On average, a barren-ground caribou will consume approximately 18.66 kg of wet-weight food per day and will consume 7.22 L of water, or its equivalent, per day. Caribou prefer habitats where vegetation is abundant and the ground conditions are dry.

Receptors were selected to be typical and representative of potential wildlife receptors at the site, including birds and mammals; herbivores and predators. This approach was based on the premise that if highly exposed components of the ecosystem are protected, then populations of other exposed biota will also be adequately protected. Although this approach is considered reasonable by CCME (1996a, b), it is recognized that protection of selected ecological receptors for particular endpoints (e.g., reproduction) may not always adequately protect all endpoints for all ecological receptors at the site. The choice of representative receptors was made, in part, on a trophic level approach in that they were chosen to represent lower and higher trophic levels. As a result, representative species were not chosen because of their sensitivity (information on sensitivity of Arctic receptors is lacking), but because of their ecological significance and trophic level.

Lemming, Arctic hare, and ptarmigan were chosen as representative of "highly exposed" biota for herbivore mammals and birds, as they remain in close contact with potentially contaminated soil year-round in a relatively restricted area. Caribou were selected because they are representative of a large ungulate which may use this site, and ermine, Arctic fox, and Snowy Owl were chosen to represent higher trophic levels that might be more likely to be exposed to contaminants via prey. Concentrations of CoPCs in the meat of caribou and small mammals (also considered to be representative of birds) were also estimated in the ERA, for inclusion in the HHRA. Selection of receptors was made to ensure that risk estimates for the specific receptors could be representative of other wildlife receptors at the site.

5.2.4 Rare, Threatened, or Endangered Species and Species of Special Concern

Three species at risk are found in the region of FOX-C (see Table 25).

Table 25 Species at Risk in the FOX-C Area

Common Name	Scientific Name	Status under *Species at Risk Act (SARA)*
Peregrine Falcon, tundrius subspecies	*Falco peregrinus*	Special Concern on Schedule 3
Wolverine, western population	*Gulo gulo*	Special Concern on Schedule 3, pending public consultation for addition to Schedule 1
Polar Bear	*Ursus maritimus*	Special Concern on Schedule 3, pending public consultation for addition to Schedule 1

These species were not chosen as representative receptors because the Snowy Owl, ermine, and Arctic fox have similar exposure pathways but have smaller home ranges and subsequently greater exposure to contaminants at the site. Therefore, if contaminant levels are below toxic thresholds for these species, it can be deduced that concentrations are also safe for the Peregrine Falcon, wolverine, and polar bear.

5.3 EXPOSURE ASSESSMENT

5.3.1 Potential Exposure Pathways

In order for chemicals to have deleterious effects, they need to gain access to the organism or receptor. The route by which this occurs is referred to as an exposure pathway, and is dependent on the nature of both the chemical and receptor. A complete exposure pathway is one that meets the following four criteria (USEPA 1989):

- a source of contaminants of concern must be present;
- release and transport mechanisms and media must be available to move the chemicals from the source to the ecological receptors;
- an opportunity must exist for the ecological receptors to contact the affected media; and
- a means must exist by which the chemical is taken up by ecological receptors, such as ingestion, inhalation, or direct contact.

The sources of the contaminants of concern for the study area were surface soil and surface water. Subsurface soils and groundwater were not considered as potential sources of contaminant exposure for wildlife. There were no direct exposure pathways for ecological receptors for either of these environmental media and transport of contaminants from these sources to surface soil, surface water and sediments was expected to be negligible.

An exposure route is the mechanism by which a receptor species might be exposed to a chemical from the source. For surface soils and terrestrial receptors, including mammals and birds, exposure to contaminants of concern may occur through the following routes:

- dermal contact with soils;
- incidental ingestion of soil (i.e., as a result of feeding or grooming);
- ingestion of plants or prey species that have accumulated chemicals from the soil; or
- inhalation of volatile contaminants migrating from the soil to ambient air.

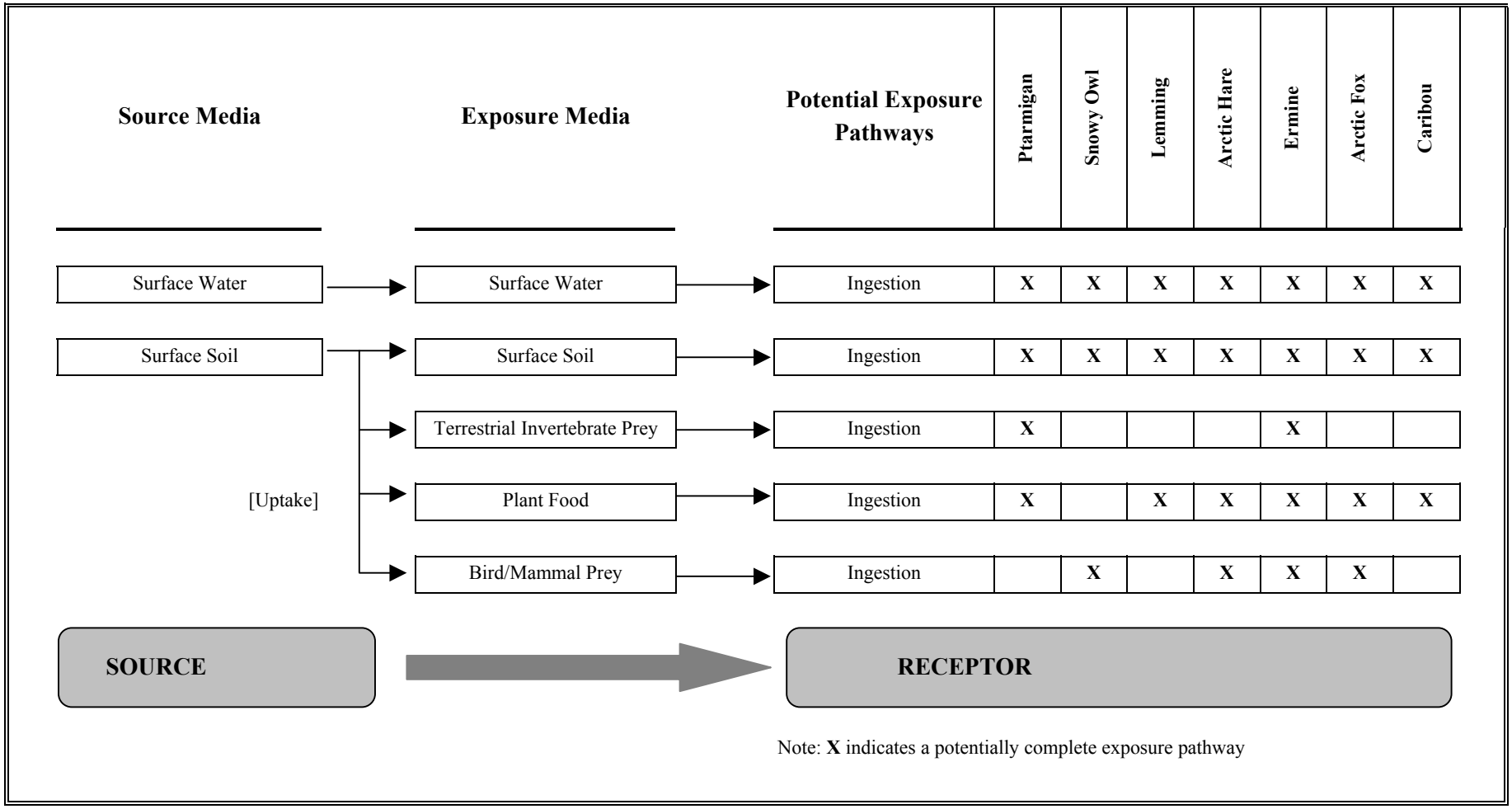
The inhalation pathway is typically of negligible importance for wildlife receptors in open air situations, and the CoPCs for the ERA typically have low or negligible vapour pressures. Therefore, inhalation has not been considered a significant exposure pathway for the ERA at FOX-C. Assessment of dermal contact with soils is included with incidental ingestion of soil.

The choice of site-specific exposure pathways is dependent on the nature of the CoPCs, their source environmental media, and nature of VECs being considered in the ecological risk assessment. These are explained, for the FOX-C site, in the following section.

5.3.2 Conceptual Site Model

A conceptual site model was developed for FOX-C and is presented in Figure 13. This figure schematically represents the interactions between the VECs and the CoPCs, via the exposure pathways identified. The relevant exposure pathways are designated by arrows leading from the contaminant source media to each VEC. The pathway is considered to be complete (i.e., functioning) for a VEC when the exposure pathway box is marked with an X. The conceptual model shows how the pathways representing soil and water ingestion, and ingestion of food items (including terrestrial plants, and small mammal prey items) have been conceptualized and implemented for each VEC.

Figure 13 Conceptual Site Model for Ecological Risk Assessment



5.3.3 Selection of Assessment and Measurement Endpoints

Assessment endpoints are explicit expressions of environmental values or characteristics to be protected at a site, and reflect societal and ecological values (Suter 1993). Societal values address the need to protect species that are endangered, threatened, of special interest, important as game or commercial species, or widely recognized as having aesthetic value. Ecological relevance refers to importance of the species to the function of the ecosystem. Therefore, evaluation of potential for adverse effects at the population level is used to infer potential for adverse effects at higher levels of organization, such as communities and ecosystems. For birds and mammals inhabiting FOX-C, assessment endpoints focus on maintenance and protection of their populations, such that contaminants in the surface water, sediment, or soil would not significantly impact either species abundance or diversity through increased mortality or decreased reproduction.

The information needed to deal directly with the assessment endpoint is difficult to generate and rarely available; thus measurement endpoints are used to bridge the gap. Measurement endpoints are measurable responses to stressors related to assessment endpoints, and are intended to provide a basis for assessing risk potential for the assessment endpoint. They may be defined in terms of an unacceptable level of impact to ecological receptors, such as a certain relative percent decrease in survival, growth or reproduction of ecological populations (Suter 1993). As part of a weight-of-evidence approach, one or more measurement endpoints may be used for each assessment endpoint. Choice of measurement endpoints for each interaction between a VEC and a contaminant of concern is typically limited by available toxicity data. Those most commonly used to quantify the survival, growth and reproduction of receptors in bioassays include the LC_{50} and LD_{50} (concentrations or doses that will be lethal to 50% of exposed organisms, over a defined period of exposure); the EC_{50} and ED_{50} (concentrations or doses that elicit a defined response or effect over a defined period of time); the Lowest Observable Adverse Effect Level (LOAEL); and the No-observable Adverse Effect Level (NOAEL). Although the dose-response relationships derived from these measurement endpoints are characteristic of test species exposed under controlled conditions, appropriate safety factors are included in order to consider the response of species in the natural environment.

The measurement endpoints for the assessment endpoints focus on whether observed concentrations of chemicals in water or soils are likely to result in doses to birds or mammals that are greater than those observed to result in increased mortality or decreased reproduction upon chronic exposure.

Therefore, the key components of this ecological risk assessment are:

- characterization of relationships between amount of a chemical present in surface water or sediments and a thresholds for adverse effects; and
- characterization of relationships between the dose resulting from the amount of a

chemical present in surface soils and a threshold dose for adverse effects.

The dose-response relationships that have been incorporated into this ERA are based upon LOAELs, in relation to survival or reproduction of birds and mammals after chronic exposure to the CoPCs. These relationships are expressed in terms of the daily ingested dose, normalized to body weight of the test organism (i.e., the reference toxicity dose or RTD value expressed as mg substance ingested / kg body weight-day). Where such data were not available, LOAEL values were estimated from other endpoints including the NOAEL, or the LD_{50} value. Standard conversion factors were implemented including division by 5 to convert an acute dose to a chronic dose; dividing by 6 to convert an LD_{50} value to a LOAEL value, or multiplication by 5 to convert a NOAEL to a LOAEL value. These conversion factors are cumulative, so an acute LD_{50} would be converted to a chronic LOAEL value by dividing by 30.

If data for the specific representative mammalian receptors was not available, a body-size scaling factor (Sample and Arenal 1999) was used for extrapolation of available data between species. The body-size scaling factor is calculated as:

$$\text{Mammal Body Weight SF} = (BWt/BWr)^{0.06}$$

where:
SF = scaling factor
BWt = mean body weight for test species
BWr = mean body weight for receptor species

If data for the specific representative avian receptors was not available, a body-size scaling factor (Sample and Arenal 1999) was used for extrapolation of available data between species. The body-size scaling factor is calculated as:

$$\text{Bird Body Weight SF} = (BWt/BWr)^{-0.20}$$

5.4 RISK CHARACTERIZATION

Risk characterization was the final step of the ecological risk assessment. It includes a quantification of the potential nature and magnitude of adverse effects that may occur to receptor species due to presence of chemicals in identified ecological habitats at the site. In this step, characterization of exposure and characterization of ecological effects for each chemical, was integrated into quantitative estimates (hazard quotients or HQ values) of the potential for adverse effects to ecological receptors.

5.4.1 Approach

For this assessment, ecological hazard quotient (HQ) values were calculated by dividing exposure (as the exposure point concentrations or total ingested dose values) derived for each receptor by their appropriate reference toxicity dose (RTD), as follows:

$$HQ = (\text{Exposure})/(\text{Reference Toxicity Dose})$$

For birds and mammals, the exposure measure is the total ingested dose (mg/kg-day) summed over all exposure pathways.

An HQ value of less than 1.0 indicates the exposure concentration is less than the threshold for adverse effects, and a low probability exists

that adverse effects might occur. Given the overall tendency to introduce conservatism (through the use of data or assumptions that are likely to overstate, rather than understate risk) into risk assessments, it is likely no adverse effect would occur. Alternatively, a HQ value of >1.0 does not automatically indicate that there is an unacceptable level of risk. In this case, the conservative approach reduces the certainty of this conclusion, and dictates a need for more careful review of both predicted exposure levels and exposure limit derivations. As a result, HQ values greater than 1.0 should be examined carefully, and further more focused investigations may be required to reduce conservatism and provide a more realistic assessment of the actual risk level. If it is ultimately determined that the HQ value is indeed greater than 1.0, then site management or remedial activities may be appropriate in order to reduce risks to ecological receptors.

5.4.2 Determination of Media to Biota Uptake Factors

The concentrations of substances evaluated in this ERA were measured empirically in water, plants, and soils from FOX-C. However, in order to complete assessment of exposure of the VECs to each substance, it is necessary to estimate concentrations of each CoPC in a variety of biological compartments. This task is accomplished generically using uptake factors (UF) that relate the concentration in various types of biota (such as invertebrates or small mammals) to concentrations in water or soil.

Substances retained in the ERA as CoPCs include TPH, phenanthrene, and selected metals. The approaches used to estimate uptake factors for each of these groups of substances, for each of the required biological food groups, are described below. The specific uptake factors used, with references as to the source of the uptake factor, can be found in the ERA model outputs located in Appendix D. Some general information on the sources of data used for media to biota accumulation factors is presented below.

Soil to Plant Uptake Factors

Soil to plant uptake factors for organic substances were generally calculated using the equation of Travis and Arms (1988):

$$\log(UFSP) = (1.588 - 0.578 \log(Kow)) \times 0.19,$$

where UFSP is the uptake factor from soil to plant (mg/kg dry plant / mg/kg dry soil), Kow is the octanol-water partition coefficient for the organic substance under consideration, and 0.19 is a conversion factor to adjust dry weight plant tissue concentrations to wet weight values.

For inorganic substances, data on plant tissue metal concentrations were collected from the site by the Environmental Sciences Group of the Royal Military College in 1994 (RRMC 1994). EPC values were calculated by taking the average value for each inorganic substance and multiplying them by a conversion factor representing the average dry solids fraction (0.40) to obtain wet-weight tissue concentrations.

Soil to Animal Uptake Factors

For organic substances, soil to animal (caribou meat) uptake factors were generally calculated using the equation of Travis and Arms (1988):

$\log(Ba_{p,s,w}) = -7.6 + \log(K_{ow})$,

where $Ba_{p,s,w}$ is the transfer factor from soil to beef (day/kg), which is assumed to also be applicable to caribou meat. These transfer factors are multiplied by the CoPC concentration in soil, feed and drinking water (mg/kg or mg/L), and by the ingestion rates of soil, feed and drinking water (kg/day or L/day) to estimate the concentration in meat (mg/kg). For the TPH substances, which are not as readily absorbed and which are more readily metabolized than the pesticide compounds that form the basis of the Travis and Arms data, a bioavailability factor (which can range from 0 to 1) is also applied.

For inorganic substances in meat, a similar approach is used for concentrations in meat, except that the transfer factors to meat (Bap,s,w) were obtained from the compilation of Baes et al. (1984).

For small animal prey items, including lemming, ptarmigan and Arctic hare, a variety of approaches and data sources were used. For organics, the approach of Travis and Arms (1988) was followed. For inorganic substances, the equations of Sample et al. (1998), which directly calculate the CoPC concentration in small mammal tissues from the soil concentration, are generally preferred. Where these equations are not available, the approach of Baes et al. (1984) was also used.

Soil to Soil Invertebrate Uptake Factors

For soil to soil invertebrate uptake factors (UPSI) for the TPH compounds, conservative default uptake factors of 0.1 were assumed. For inorganic substances, the equations of Sample et al. (1998) were preferred, although an empirical uptake factor of 0.036 was used for tin.

5.4.3 Determination of Reference Toxicity Doses

Reference toxicity doses (RTDs) for terrestrial receptors were included in the risk assessment model results for each receptor, and are presented in Appendix D. The RTD values are unique to each CoPC.

5.4.4 Risk Characterization for Avian Receptors

Tables showing the derivation of risk estimates for avian receptors can be found in Appendix D. The text below provides a synopsis of the risk estimates for each VEC. A summary of HQ values for all receptors can be found in Tables 26 and 27.

Table 26 Ecological Hazard Quotients for each VEC at the FOX-C Upper Site

CoPCs	Ptarmigan	Snowy Owl	Lemming	Arctic Hare	Ermine	Arctic Fox	Caribou
Inorganics							
Beryllium	8.83E-04	4.09E-04	3.55E-04	1.96E-04	1.64E-04	1.66E-04	2.83E-04
Cadmium	5.10E-03	5.43E-04	1.65E-02	9.75E-03	2.39E-03	1.93E-03	7.37E-03
Chromium	9.04E-01	3.50E-02	5.54E-04	3.25E-04	2.94E-05	2.90E-05	2.51E-04
Copper	3.68E-02	5.45E-03	3.74E-01	2.22E-01	5.25E-02	5.46E-02	1.69E-01
Lead	1.40E-01	1.06E-02	5.02E-02	2.96E-02	4.25E-03	4.23E-03	2.27E-02
Zinc	2.20E-01	4.06E-02	1.33E-01	7.95E-02	2.54E-02	2.44E-02	5.96E-02
Organics							
F1 (C_6 - C_{10})	2.04E-04	1.87E-05	5.30E-04	3.00E-04	9.61E-05	8.80E-05	2.55E-04
F2 (>C_{10} - C_{16})	2.03E-02	1.94E-03	2.09E-02	1.23E-02	8.30E-03	5.97E-03	1.14E-02
F3 (>C_{16} - C_{34})	3.60E-02	8.30E-03	4.64E-02	2.70E-02	2.75E-02	1.80E-02	2.89E-02
F4 (>C_{34} - C_{50})	2.11E-03	8.01E-04	3.28E-03	1.91E-03	4.05E-03	2.70E-03	2.63E-03
Total PCBs	1.43E-02	9.76E-04	5.74E-02	4.54E-02	1.29E-01	1.41E-01	2.60E-02

Table 27 Ecological Hazard Quotients for each VEC at the FOX-C Lower Site

CoPCs	Ptarmigan	Snowy Owl	Lemming	Arctic Hare	Ermine	Arctic Fox	Caribou
Inorganics							
Beryllium	1.64E-03	7.60E-04	6.59E-04	3.65E-04	3.05E-04	3.09E-04	5.27E-04
Cadmium	4.90E-03	3.83E-04	1.64E-02	9.70E-03	1.70E-03	1.45E-03	7.34E-03
Chromium	9.19E-01	6.55E-02	5.64E-04	3.31E-04	4.41E-05	4.53E-05	2.60E-04
Copper	3.69E-02	5.61E-03	3.75E-01	2.23E-01	5.39E-02	5.60E-02	1.70E-01
Lead	1.38E-01	8.07E-03	4.99E-02	2.94E-02	3.42E-03	3.44E-03	2.25E-02
Zinc	2.22E-01	4.17E-02	1.33E-01	7.97E-02	2.64E-02	2.50E-02	5.97E-02
Organics							
F1 (C_6 - C_{10})	7.26E-04	4.00E-05	1.75E-03	1.01E-03	2.59E-04	1.82E-04	8.56E-04
F2 (>C_{10} - C_{16})	1.45E-02	1.39E-03	1.49E-02	8.75E-03	5.95E-03	4.29E-03	8.14E-03
F3 (>C_{16} - C_{34})	8.86E-03	2.06E-03	1.14E-02	6.65E-03	6.81E-03	4.46E-03	7.11E-03
F4 (>C_{34} - C_{50})	9.21E-04	3.58E-04	1.45E-03	8.43E-04	1.79E-03	1.21E-03	1.16E-03
Total PCBs	1.32E-02	2.73E-04	5.68E-02	4.49E-02	1.25E-01	1.38E-01	2.54E-02

5.4.4.1 Risk Estimates for Ptarmigan

For the ptarmigan the intake pathways included surface water, soil, soil to plants, and soil to soil invertebrates. The ptarmigan feeds primarily on vegetation such as leaves, flowers, buds and twigs of willow and birch, seeds and berries, and will also consume insects, especially as chicks.

Risks (HQ values) for the ptarmigan were less than 1 for all substances. However, a number of substances had HQ values that lay between 0.1 and 1.0. At both sites, these substances were chromium, lead, and zinc. All other substances that were assessed had HQ values that lay below 0.1. The inorganic substance having the highest HQ values was chromium at both the Upper and Lower Sites (HQ = 0.904 and 0.919, respectively). The HQ values for chromium were dominated by the plant ingestion pathway, based on measured (1994) concentrations of chromium in plant tissue from the FOX-C site. Risks due to ingestion of soil, terrestrial invertebrates, and surface water are negligible.

5.4.4.2 Risk Estimates for Snowy Owl

For the Snowy Owl the intake pathways included surface water, soil, and soil to small mammal prey. The Snowy Owl feeds mainly on small mammals.

Risks (HQ values) for the Snowy Owl were much less than 1 for all substances at both sites, which suggests that the Snowy Owl is not at risk from any of these substances at FOX-C.

5.4.5 Risk Characterization for Mammalian Receptors

Tables showing the derivation of risk estimates for mammalian receptors can be found in Appendix D. The text below provides a synopsis of the risk estimates for each VEC. A summary of HQ values for all receptors can be found in Tables 26 and 27.

5.4.5.1 Risk Estimates for Lemming

For the lemming the intake pathways include surface water, soil, and soil to plants. The lemming feeds on vegetation including grasses and shrubs, and bark and twigs of willow and birch.

Risks (HQ values) for the lemming were less than 1 for all substances. However, a number of substances had HQ values that lay between 0.1 and 1.0. At both sites, these substances were copper and lead. All other substances that were assessed had HQ values that lay below 0.1. The inorganic substance having the highest HQ value for lemming was copper at both the Upper and Lower Sites (HQ = 0.374 and 0.375, respectively).

Examination of the pathways leading to high HQ values for the copper and lead shows that the overall HQ values are dominated by risks from ingestion of terrestrial plants. Risks due to ingestion of soil and surface water are negligible.

5.4.5.2 Risk Estimates for Arctic Hare

For the Arctic hare the intake pathways included surface water, soil, soil to plants, and soil to small mammals. The Arctic hare is primarily herbivorous but will also feed on carrion.

Risks (HQ values) for the Arctic hare were less than 1 for all substances. However, copper had HQ values that lay between 0.1 and 1.0 at both the Upper and Lower Sites (HQ = 0.222 and 0.223, respectively).

Examination of the pathways leading to high HQ values for copper shows that the overall HQ values are dominated by risks from ingestion of terrestrial plants. Risks due to ingestion of soil, mammals, and surface water are negligible.

5.4.5.3 Risk Estimates for Ermine

For the ermine the intake pathways included surface water, soil, soil to small mammal, soil to soil invertebrate, and soil to plants. The ermine feeds mainly on small mammals, but also consumes some invertebrates and plant material as minor components of its diet.

Risks (HQ values) for the ermine were less than 1 for all substances. However, total PCBs had HQ values that lay between 0.1 and 1.0 at both the Upper and Lower Sites (HQ = 0.129 and 0.125, respectively).

Examination of the pathways leading to the high HQ values for PCBs is dominated by ingestion of terrestrial mammals. The risk due to ingestion of soil, terrestrial plants, terrestrial invertebrates, and surface water is negligible.

5.4.5.4 Risk Estimates for Arctic Fox

For the Arctic fox the intake pathways included surface water, soil, soil to small mammal, and soil to plants. The Arctic fox feeds mainly on small mammals, but also consumes some plant material as a minor component of its diet.

Risks (HQ values) for the Arctic fox were less than 1 for all substances. However, total PCBs had HQ values that lay between 0.1 and 1.0 at both the Upper and Lower Sites (HQ = 0.141 and 0.138, respectively).

Examination of the pathways leading to the high HQ values for Arctic fox is dominated by ingestion of terrestrial mammal prey. The risk due to ingestion of soil, terrestrial plants, and surface water is negligible.

5.4.5.5 Risk Estimates for Caribou

For the caribou, total HQs were summed across the study area (Upper and Lower Sites) to generate an overall HQ for each CoPC based on exposure to the entire DEW Line site. In addition, a further area of exposure was defined as "background" for caribou. This was done because the study area is very small in comparison with the typical home range for a caribou. Expected background concentrations for inorganic CoPCs were calculated by taking the geometric mean of all soil samples at the FOX-C site. Background concentrations for organic CoPCs in surface soil were set to zero (CCME 2001), and background concentrations in plant tissues were calculated by the model.

For caribou the intake pathways included surface water, soil, and soil to plants. The caribou feeds on vegetation, primarily lichens.

Table 28 presents the HQ for the caribou receptor. Total risks (HQ values) for caribou were much less than 1 for all substances, which suggests that caribou is not at risk from any of these substances at FOX-C.

Table 28 Ecological Hazard Quotients for Caribou

CoPC	Upper Site HQ	Weighting Factor	Lower Site HQ	Weighting Factor	Background HQ	Weighting Factor	Total HQ
Inorganics							
Beryllium	2.83E-04	0.002	5.27E-04	0.04	2.73E-04	0.958	2.83E-04
Cadmium	7.37E-03	0.002	7.34E-03	0.04	9.62E-04	0.958	1.23E-03
Chromium	2.51E-04	0.002	2.60E-04	0.04	1.44E-05	0.958	2.47E-05
Copper	1.69E-01	0.002	1.70E-01	0.04	2.29E-02	0.958	2.91E-02
Lead	2.27E-02	0.002	2.25E-02	0.04	1.25E-03	0.958	2.14E-03
Zinc	5.96E-02	0.002	5.97E-02	0.04	6.44E-03	0.958	8.68E-03
Organics							
F1 (C_6 - C_{10})	2.55E-04	0.002	8.56E-04	0.04	0.00E+00	0.958	3.48E-05
F2 (>C_{10} - C_{16})	1.14E-02	0.002	8.14E-03	0.04	0.00E+00	0.958	3.48E-04
F3 (>C_{16} - C_{34})	2.89E-02	0.002	7.11E-03	0.04	0.00E+00	0.958	3.42E-04
F4 (>C_{34} - C_{50})	2.63E-03	0.002	1.16E-03	0.04	0.00E+00	0.958	5.17E-05
Total PCBs	2.60E-02	0.002	2.54E-02	0.04	0.00E+00	0.958	1.07E-03

5.5 CONCENTRATION OF COPCS IN MEAT

Estimated concentrations of CoPCs in caribou meat are provided in Table 29. Meat concentrations were summed across the study area (Upper and Lower Sites) to generate an overall value for each CoPC based on exposure to the entire DEW Line site. In addition, a further area of exposure was defined as "background" for caribou. This was done because the study area is very small in comparison with the typical home range for a caribou. Expected background concentrations for inorganic CoPCs were calculated by taking the geometric mean of all soil samples at the FOX-C site. Background concentrations for organic CoPCs in surface soil were set to zero (CCME 2001), and background concentrations in plant tissues were calculated by the model.

Estimated concentrations of CoPCs in small mammals are provided in Table 30. Meat concentrations are provided for both the Upper and Lower Sites. Additionally, a weighted average including background meat concentrations is provided to estimate the amount of exposure to humans consuming small mammals across the landscape (to be used in the HHRA).

Table 29 Estimated Concentrations of CoPCs in Caribou Meat at FOX-C

CoCP	Upper Site Caribou Meat Conc. (mg/kg-fresh wt.)	Weighting Factor	Lower Site Caribou Meat Conc. (mg/kg-fresh wt.)	Weighting Factor	Background Caribou Meat Conc. (mg/kg-fresh wt.)	Weighting Factor	Total Caribou Meat Conc. (mg/kg-fresh wt.)
Inorganics							
Beryllium	1.08E-04	0.002	2.00E-04	0.04	1.04E-04	0.958	1.08E-04
Cadmium	5.99E-03	0.002	5.97E-03	0.04	7.78E-04	0.958	9.96E-04
Chromium	2.77E+00	0.002	2.84E+00	0.04	1.39E-01	0.958	2.52E-01
Copper	4.01E+00	0.002	4.03E+00	0.04	5.26E-01	0.958	6.73E-01
Lead	8.02E-02	0.002	7.95E-02	0.04	4.11E-03	0.958	7.28E-03
Zinc	2.82E+02	0.002	2.82E+02	0.04	3.02E+01	0.958	4.08E+01
Organics							
F1 (C_6 - C_{10})	5.45E-03	0.002	9.51E-03	0.04	0.00E+00	0.958	3.91E-04
F2 (>C_{10} - C_{16})	2.81E+00	0.002	2.03E+00	0.04	0.00E+00	0.958	8.68E-02
F3 (>C_{16} - C_{34})	1.27E+01	0.002	3.18E+00	0.04	0.00E+00	0.958	1.53E-01
F4 (>C_{34} - C_{50})	1.14E+00	0.002	5.16E-01	0.04	0.00E+00	0.958	2.29E-02
Total PCBs	5.69E-01	0.002	5.60E-01	0.04	0.00E+00	0.958	2.35E-02

Table 30 Estimated Concentrations of CoPCs in Small Mammal Meat at FOX-C

CoPC	Upper Site Small Mammal Meat Conc. (mg/kg-fresh wt.)	Weighting Factor	Lower Site Small Mammal Meat Conc. (mg/kg-fresh wt.)	Weighting Factor	Background Small Mammal Meat Conc. (mg/kg-fresh wt.)	Weighting Factor	Total Small Mammal Meat Conc. (mg/kg-fresh wt.)
Inorganics							
Beryllium	1.08E-04	0.002	2.00E-04	0.04	1.04E-04	0.958	1.08E-04
Cadmium	8.71E-02	0.002	6.17E-02	0.04	6.78E-02	0.958	6.76E-02
Chromium	1.04E+00	0.002	1.84E+00	0.04	1.02E+00	0.958	1.05E+00
Copper	3.95E+00	0.002	4.03E+00	0.04	3.81E+00	0.958	3.82E+00
Lead	1.26E+00	0.002	9.89E-01	0.04	9.85E-01	0.958	9.86E-01
Zinc	3.78E+01	0.002	3.87E+01	0.04	3.72E+01	0.958	3.73E+01
Organics							
F1 (C_6 - C_{10})	5.45E-03	0.002	9.51E-03	0.04	0.00E+00	0.958	3.91E-04
F2 (>C_{10} - C_{16})	2.81E+00	0.002	2.03E+00	0.04	0.00E+00	0.958	8.68E-02
F3 (>C_{16} - C_{34})	1.26E+01	0.002	3.17E+00	0.04	0.00E+00	0.958	1.52E-01
F4 (>C_{34} - C_{50})	1.14E+00	0.002	5.15E-01	0.04	0.00E+00	0.958	2.29E-02
Total PCBs	5.57E-01	0.002	5.48E-01	0.04	0.00E+00	0.958	2.30E-02

5.6 ECOLOGICAL SITE SPECIFIC TARGET LEVELS

Based upon the results of the ecological risk assessment, no HQ values greater than 1.0 were identified for any of the VECs. The CoPCs with HQ values between 0.1 and 1.0 were chromium, copper, lead, zinc, and total PCBs. The following VECs were identified as having the highest HQ for each of these CoPCs:

- ptarmigan at the Lower Site (chromium and zinc);
- ptarmigan at the Upper Site (lead);
- lemming at the Lower Site (copper); and
- Arctic fox at the Upper Site (total PCBs).

Consequently, site specific target levels (SSTLs) were calculated for each of these receptors. The SSTLs were calculated by setting the HQ at 1.0, and determining the corresponding surface soil EPC for that HQ, using a backward calculation. The SSTLs for each receptor are shown in Table 31.

Table 31 Site Specific Target Levels in Surface Soils at FOX-C

VEC	CoPC	Maximum Soil Conc. (mg/kg)	Surface Soil SSTL (mg/kg)
Ptarmigan	Chromium	116	320
Ptarmigan	Lead	1,060	6,000
Ptarmigan	Zinc	1,400	46,250
Lemming	Copper	381	3,375
Arctic fox	Total PCBs	2	50

SSTLs for chromium, lead, zinc, copper, and total PCBs are all well above the maximum concentrations in surface soils. These results indicate that there are no documented instances of contamination at the FOX-C site that require clean-up in order to protect ecological receptors. The overall ERA results also indicate that the existing conditions at FOX-C are not likely to result in adverse effects to exposed biota at the population level.

5.7 UNCERTAINTY ANALYSIS

Uncertainties are inherent in every aspect of the ERA process. The most effective way to decrease uncertainty is to collect site-specific data. Application of site-specific information assists in reduction of uncertainty by allowing removal of generic data that may be broadly and inaccurately applicable to a wide range of sites and cases. For FOX-C, much site-specific data has been collected, representing soils, surface water, biota, and lake sediments.

Despite incorporation of a considerable amount of site-specific data, the ERA involves many assumptions, and incorporates simplifications and uncertainty with respect to the characteristics of the receptors, exposure pathways, and CoPC concentrations in the environment. This section qualitatively discusses some significant aspects of uncertainty inherent in this risk assessment.

Data Limitations.

The quality of a risk assessment calculation often hinges on the size, extent and condition of the supporting data. In addition to making use of existing site data, a large number of samples were collected for this risk assessment, and a

significant amount of data was collected for this study, including both chemical and biological data. The time available for collection of data precluded consideration of fluctuations in measured concentrations due to daily or seasonal influences. Because some of these data sets were summarized statistically, including calculation of a conservative representative value, such as the 95% UCL as the EPC, the values presented are conservative estimators of the true concentration to which native species would be exposed.

Key limitations in the ERA included insufficient background data for inorganic substances in soils. It is possible that the concentrations of some of the substances that were carried forward as CoPCs are not elevated as a result of human activities, but reflect natural background levels. In particular, the concentrations of inorganic substances measured in plant tissue samples from the FOX-C site by RRMC (1994) are high, and suggest very high soil-to-plant concentration ratios. It is possible that additional sampling of local and background soil-plant pairs could reduce uncertainty in the model, and confirm whether concern related to high copper concentrations is real, or due to natural processes not related to former DEW line site activities.

Selection of CoPCs.

CoPCs were selected independently in each of the media evaluated in the ecological risk assessment, and the analysis was completed to include all media (water, sediment, soils, and biota exposed to these media) if the substance exceeded screening criteria for any one of these. For each of the media, there are gaps in understanding of the toxicology of CoPCs, and the physical and chemical properties of these chemicals. The approach for selecting CoPCs included comparison of each detected chemical value to values that are believed to be protective of most North American species, in most ecosystems. Because empirical data do not exist for all possible CoPCs and media, it is possible that relevant test species and sometimes even the same environmental media, have not been evaluated in the proper context for comparison.

Chemical Speciation.

The fate, food chain interactions, and toxicity of a number of inorganic and organic contaminants (including TPH and the metals evaluated here) depend to a large extent upon their chemical form, and the context in which they are ingested. As such, conservative assumptions about chemical form, bioavailability, and absorption over the gut were generally carried forward in the risk assessment, and the potential for toxicity is likely to be overstated. For example, it has been generally assumed that 100% of each ingested CoPC is absorbed from ingested soil, sediment, water, or food, and is available to the organism as a potentially toxic substance. This may be reasonable for some CoPCs, but will be highly conservative for others.

Food Chain Interactions.

Very limited "real world" data exist that allow quantification of the true relationship between a chemical in an environmental medium and chemical transfer through the food chain. Only a few classes of chemicals appear to be magnified through the food chain. These substances include methyl mercury, some PCBs,

some chlorinated pesticides (such as DDT), and some PCDD/PCDF compounds. These substances all have a tendency to partition into fatty tissue rather than water. They are also resistant to natural degradation processes by metabolic enzymes. The TPH substances and PAHs are also hydrophobic classes of chemicals present in the environment. While they are hydrophobic, they may only partially absorbed following ingestion, and may also be metabolized and/or excreted by some invertebrates and most vertebrates. For this reason, food chain magnification does not tend to occur with TPH or PAHs. The extent of food chain magnification is another uncertainty that is generally treated in a conservative manner. Additional collection and chemical analysis of tissue samples from mammalian and avian species could have further reduced uncertainties associated with these values but were beyond the scope of the ecological field program.

Wildlife Exposure Factors.

Virtually every factor incorporated into dose calculations for wildlife species possesses a site-specific component. Validity of each exposure factor is dependent on consideration of the site-specific nature of these factors. In the absence of site-specific validation, exposure factors are incorporated based on validations performed elsewhere for other cases and sometimes for other species. Considerations such as food ingestion rates, water ingestion rates, incidental soil ingestion rates, dietary composition, home range, and time spent at the site were collected from the scientific literature based on other sites and locations. It has been assumed that each receptor organism spends its entire life cycle at the FOX-C site (or in the case of the caribou, between the FOX-C sites). On the basis of this assumption, the VECs are modeled as being exposed to the 95% UCL concentration for each CoPC. Therefore, it is likely that the level of wildlife exposure has been substantially overestimated, particularly for large-bodied or migratory VECs.

Habitat Survey and VEC Selection.

This risk assessment invested significant effort into consideration of existing habitats and the species that exist within them. Both aquatic and terrestrial habitats were evaluated to identify relevant species, and to support the selection of appropriate VECs. Therefore, the VECs that were selected are known to be present, or can reasonably be expected to be present on the site. These VECs are also known to be reasonably or conservatively representative of other species that may be present on the site and exposed to CoPCs. Use of site-specific receptors decreases uncertainty since local species are considered rather than highly sensitive non-native species.

Receptor-Specific Toxicity Data.

For most of the CoPCs and VECs, toxicity data were available in some form. However, it is important to note that toxicity data are generally not available for the particular VEC species under consideration. Toxicity values are not necessarily specific to the VEC species, or to a reproductive or population-level endpoint. As a result, there is uncertainty associated with the extrapolations that are used to translate toxicity data from a test species in the laboratory, to a receptor species in the wild. The conversion factors that are used are scientifically based, and

are applied in a manner that is believed to be conservative.

In some cases, there is a lack of chemical toxicity data. Typically, when this was the case, an RTD value was obtained for a small mammal test species, and was conservatively translated into an RTD value for a bird by incorporating an additional safety factor of 5.

Measurement Endpoints from the Toxicity Data.

The paucity of toxicity data for many chemicals limited the measurement endpoints that were available. Where LOAEL values were not available, it was necessary to extrapolate from NOAEL values. Correction factors used for this extrapolation are relatively conservative and tend to under-estimate the LOAEL value. This approach is conservative, and if observed chemical concentrations are lower than the RTD values, there is little potential for observable adverse effects at the population level. This approach is more conservative than the suggestion of Suter (1993), that a 20% effect level (such as a 20% reduction in survivorship or growth of exposed biota) be treated as a conservative approximation of the threshold for regulatory concern. Therefore, use of these reference toxicity doses would overestimate the potential for significant adverse effects on species of concern, and overestimate the potential for significant ecological risks.

5.7.1 Summary of Uncertainty Analysis

As a result of the scientific investigations, literature reviews, and risk assessment guidance that have been undertaken or followed in the preparation of this ERA, it is believed that the risk assessment results present a reasonable yet conservative evaluation of the risk to ecological receptors present at the site. Where uncertainty or lack of knowledge were encountered in the development of the risk estimates, reasonable yet conservative assumptions were made, or data were selected, in order to ensure that risks were not underestimated.

6.0 EFFECTS OF PLANNED REMEDIAL ACTIONS

Specific localized areas were identified as "hot spots" where concentrations of selected CoPCs were elevated. Even though, these areas do not pose a significant human or ecological risk, they were selected to be removed for aesthetic reasons as well as to remove any remaining and obvious soil staining/contaminated areas. These areas will be excavated and removed from contact of all receptors.

6.1 NEW EXPOSURE POINT CONCENTRATIONS

With these areas being removed from contact with receptors, it is necessary to recalculate the exposure point concentrations (maximum for human health, 95% UCL for ecological risk assessment) for the identified CoPCs.

The newly calculated EPCs were compared to previous EPCs and then reinserted into the models to determine an approximate risk reduction associated with removing the targeted "hot spots".

6.2 EFFECT OF REMEDIATION ON IDENTIFIED RISKS

The consequential removal of these selected areas resulted in drops of exposure point concentrations (EPCs) for human health for the top site of 41% for PCBs, 92% for TPH F2 fraction, 90% for copper and 86% for lead. The EPC for human health represents a drop in the maximum concentrations found on site. This resulted in a subsequent drop in the calculated total hazard quotients associated with the top site of 91% for TPH F2 fraction, 19% for copper and 76% for lead. The top site contains the most contaminated soils of both the sites.

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