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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APPENDIX A

TOXICITY PROFILES

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GLOSSARY AND ACRONYMS

Absolute bioavailability	Absolute bioavailability is the fraction or percentage of an administered dose that reaches systemic circulation (blood) irrespective of via the gastrointestinal tract, skin or lungs
Ah	Aryl hydrocarbon
ATSDR	Agency for Toxic Substances and Disease Registry
Bioavailability	The degree to which a substance becomes available to the target tissue after administration or exposure.
CEPA	Canadian Environmental Protection Act
COPC	Contaminants of Potential Concern
ESOD	Erythrocyte Superoxide Dismutase
FAO	Food and Agriculture Organization. An organization of the United Nations.
IARC	International Agency for Research on Cancer. An organization of the WHO.
IOC	Intake of concern
IOM	Institute of Medicine
IPCS	International Programme on Chemical Safety
IRIS	Integrated Risk Information System. A database maintained by the US EPA.
LOAEL	Lowest-observed-effects-level. A term that describes the benchmark on a threshold dose-response curve at which the lowest dose results in observed adverse health effects. May be used in place of a NOAEL where a NOAEL cannot be determined.
MAC	Maximum Allowable Concentration
MADEP	Massachusetts Department of Environmental Protection

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MOE	Ontario Ministry of the Environment
MRL	Minimal Risk Level. A term used by the ATSDR to describe an estimate of daily human exposure to a hazardous substance that is likely to be without an appreciable risk of adverse noncancer health effects over a specified route and duration of exposure.
NATO	North Atlantic Treaty Organization
NCEA	National Center for Environmental Assessment
NIOSH	National Institute for Occupational Safety and Health
NOAEL	No-observed-effects-level. A term that describes the benchmark on a threshold dose-response curve at which the highest dose does not result in adverse effects.
NRC	National Research Council
OEHHA	Office of Environmental Health Hazard Assessment
ORD	Office of Research and Development
PCB	Polychlorinated biphenyls
PCDD	Polychlorinated dibenzo-p-dioxins
PCDF	Polychlorinated dibenzofurans
PTWI	Provisional Tolerable Weekly Intake
RAF	Relative absorption factor
RDA	Recommended Dietary Allowance
REL	Reference Exposure Level is a NIOSH time-weighted average concentration for up to a 10-hour workday during a 40-hour work week.

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Relative bioavailability	A comparative fraction which predicts bioavailability in one medium or form in relation to the medium for which the TRV was derived.
RfC	Reference Concentration. The RfC is an estimate of lifetime daily exposure to a non-carcinogen in air for the general human population that appears to be without appreciable risk of deleterious effects expressed in mg chemical/kg body weight-day.
RfD	Reference Dose. The RfD is an estimate of lifetime daily exposure to a non-carcinogen for the general human population that appears to be without appreciable risk of deleterious effects expressed in mg chemical/kg body weight-day.
SF	Slope factor. The SF is a plausible upper bound estimate of the probability of a response per unit intake of a chemical over a lifetime expressed as (mg chemical/kg body weight-day)$^{-1}$ and is used to express carcinogenic effects.
STSC	Superfund Health Risk Technical Support Center
TC	Tolerable Concentration. A term used by Health Canada to describe concentrations in air that a person may be continuously exposed to over a lifetime without adverse effects. The TC is used to derive the TDI
TC_{05}	Tumorigenic concentration that will induce a 5% increase in the incidence of tumors or deaths due to tumors following exposure to that chemical in air.
TD	Tumorigenic Dose. A term used to describe a dose that will induce an increase in the incidence of tumors or deaths due to tumours as calculated from a non-threshold dose-response curve.
TD_{05}	Tumorigenic Dose that will induce a 5% increase in the incidence of tumors or deaths due to tumors.
TDI	Tolerable Daily Intake. A term used by Health Canada in place of RfD.
TEF	Toxic Equivalency Factor

GLOSSARY AND ACRONYMS

TEQ	Toxic Equivalent
TRV	Toxicity Reference Value
UF	Uncertainty Factor. A factor that is applied to NOAELs or LOAELs to yield a RfC or RfD. For example, the UF can be used to account for intra-species and inter-species extrapolations.
UL	Tolerable upper intake level. A term used by the IOM to describe the highest daily nutrient intake that will not result in adverse health effects.
Unit Risk	Units risks estimate the upper bound probability of an individual developing cancer following exposure to a particular level (usually as 1 µg/L in water or 1 µg/m^3) of a potential carcinogen. For example, if the unit risk is 1.2 x 10^{-6} µg/L then it is expected that 1.2 excess tumours are expected to occur per 1,000,000 people exposed to 1 µg of that chemical in 1 L of drinking water.
US EPA	United States Environmental Protection Agency
WHO	World Health Organization

1. INTRODUCTION

For the purpose of this assessment, toxicity reference values (TRVs) were obtained for each of the identified chemicals of potential concern (CoPC). Toxicological information was obtained, as necessary, from various sources including Health Canada, the US EPA Integrated Risk Information System (IRIS) database, the Agency for Toxic Substances and Disease Registry (ATSDR).

TRVs are values used to describe maximum acceptable doses of chemicals that will not result in the development of adverse health effects. TRVs can be used to describe non-carcinogenic and carcinogenic effects and can express effects in different terms based on magnitude of the dose, length of exposure and route of exposure.

1.1 Non-Carcinogenic TRVs

Non-carcinogenic chemicals exhibit threshold effects following exposure. Threshold effects are defined by the observation of adverse effects at a given dose or concentration. Given these threshold effects, two measures of interest can describe the dose-response curve: the no-adverse-effects-level (NOAEL) and lowest-adverse-effects-level (LOAEL). The NOAEL is the benchmark at which the highest dose does not result in observed adverse effects. The LOAEL may be used when a NOAEL is not available and is the lowest dose at which adverse effects are observed.

The reference dose (RfD) is used for the assessment of non-carcinogenic endpoints. The 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 chemical/kg body weight/day (*e.g.*, mg/kg-day). The RfD is derived from either the NOAEL or the LOAEL determined in a laboratory study. Uncertainty factors (UF) are applied to the NOAEL or LOAEL to account for interspecies variability and intraspecies variability (*e.g.*, sensitive sub-populations). Additionally, uncertainty factors are applied to extrapolate from subchronic exposure to chronic exposure or where there is a paucity of data available for a chemical (*e.g.*, no data regarding effects on reproduction).

Other regulatory agencies have substituted the term RfD to be reflective of objectives and toxicological endpoints. Health Canada replaces the term RfD with tolerable daily intake (TDI), also expressed in mg/kg-day. Health Canada also uses a tolerable concentration (TC) to express concentrations in air that a person can be continuously exposed to over their lifetime without adverse effects. The Institute of Medicine (IOM) uses the tolerable upper intake level (UL) expressed as mg chemical/day to describe the highest daily nutrient intake that will not result in

adverse health effects. The ATSDR uses a minimal risk level (MRL) similar to the IOM's UL, that estimates daily human exposure to a substance that, over a specified duration, will not cause an appreciable risk of adverse effects.

The reference concentration (RfC) is also used as a non-carcinogenic endpoint specific to inhalation exposure. The RfC is typically reported as a concentration in air which can be converted to a RfD for inhaled dose expressed as mg/kg-day.

1.2 Carcinogenic TRVs

Carcinogenic chemicals exhibit non-threshold effects following exposure. Non-threshold effects are defined by the observation of adverse effects regardless of concentration and length of exposure. Primarily, two TRVs are used to describe carcinogenic effects: the slope factor and unit risk.

A slope factor (SF) is used for assessment of carcinogenic effects of a chemical. The SF is a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime, expressed as $(mg/kg\ body\ weight/day)^{-1}$. 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.

Unit risks are used to estimate an upper bound probability of an individual developing cancer as a result of exposure to a particular level (usually as 1 µg/L in water, or 1 $\mu g/m^3$ in air) of a potential carcinogen. Unit risks are calculated by dividing the SF by body weight and multiplying that product by the inhalation or drinking rate as applicable.

Health Canada uses tumorigenic doses and concentrations for substances that are considered to have non-threshold or carcinogenic effects. The potency is expressed as a dose or concentration that will induce a 5% increase in the incidence of tumours or deaths due to tumours as calculated from a dose-response curve. The TRVs that defined the 5% increased are tumorigenic concentration 05 (TC_{05}) primarily used as a benchmark for exposure to a certain chemical in air or tumorigenic dose 05 (TD_{05}).

1.3 Bioavailability

The definition of bioavailability varies with the source and context in which the term is used. The simplest and broadest definition of bioavailability describes the extent or rate that a chemical enters a receptor or is made available at the target site (*e.g.,* blood). The importance of bioavailability in risk assessment is illustrated by comparison TRVs as toxicity measures that are

usually defined by laboratory studies. The fraction of a dose which is absorbed during an animal study may differ from the fraction that is available to a receptor in the environment due to several factors including weathering.

There are two specific types of bioavailability that are applicable to risk assessment: absolute and relative bioavailability. Absolute bioavailability is the fraction or percentage of an administered dose that reaches systemic circulation (blood) irrespective of via the gastrointestinal tract, skin or lungs. Relative bioavailability is the absolute bioavailability in one medium divided by the absolute bioavailability of the chemical under the conditions used to derive the TRV. Therefore, the relative bioavailability is a comparative fraction which predicts bioavailability in one medium or form in relation to the medium for which the TRV was derived. Relative bioavailability can be expressed as a relative absorption fraction (RAF).

In the following toxicity profiles, both absolute and relative bioavailabilities have been provided, where applicable, with the relative bioavailability selected for use in the assessment.

2. BERYLLIUM

According to the ATSDR (2002), beryllium is a hard, grayish metal naturally found in mineral rocks, coal, soil, and volcanic dust. Beryllium compounds are commercially mined, and the beryllium is purified for use in nuclear weapons and reactors, aircraft and space vehicle structures, instruments, x-ray machines, and mirrors. Beryllium ores are used to make speciality ceramics for electrical and high-technology applications. Beryllium alloys are used in automobiles, computers, sports equipment (golf clubs and bicycle frames), and dental bridges.

2.1 Assessment of Carcinogenicity

The Department of Health and Human Services (DHHS) and the International Agency for Research on Cancer (IARC) have determined that beryllium is a human carcinogen. The U.S. EPA has determined that beryllium is a probable human carcinogen.

2.2 Susceptible Populations

There are no studies on the health effects of children exposed to beryllium. It is likely that the health effects seen in children exposed to beryllium will be similar to the effects seen in adults. We do not know whether children differ from adults in their susceptibility to beryllium (ATSDR, 2002).

It is not known if exposure to beryllium will result in birth defects or other developmental effects in people: the studies on developmental effects in animals are not conclusive.

2.3 Selection of Toxicity Values

2.3.1 Non-Cancer Oral Toxicity Reference Values

The oral reference dose (RfD) for beryllium published by the US EPA (1998) is 0.002 mg/kg-d. The US EPA oral RfD is based on a long-term study of dogs fed diets containing beryllium by Morgareidge et al (1976). The oral RfD is based on the development of intestinal lesions. A BMD_{10} (the lower 95% confidence limit on the dose from the maximum likelihood estimate [MLE] of a 10% relative change) of 0.46 mg/kg-day (MLE = 1.4 mg/kg-day) was derived for the lesions and used for further quantitation in this assessment in the US EPA's assessment. (U.S. EPA, 1995). An uncertainty factor of 300 was applied: 10 for extrapolation for interspecies differences, 10 for consideration of intraspecies variation, and 3 for database deficiencies. The USEPA has low to medium confidence in this RfD.

An oral RfD of 0.002 mg/kg-day has been adopted in this assessment based on the US EPA's recommended oral RfD.

2.3.2 Cancer Oral Toxicity Reference Values

The lack of suitable positive carcinogenic data precludes the derivation of an oral SF or unit risk for beryllium.

2.3.3 Non-Cancer Inhalation Toxicity Reference Values

The inhalation reference concentration (RfC) for beryllium published by the US EPA (1998) is 2E-2 $\mu g/m^3$. The RfC is based on beryllium sensitization and progression to chronic beryllium disease (CBD) identified in the co-principal studies by Kreiss *et al.* (1996) and Eisenbud *et al.* (1949). The Kreiss *et al.* (1996) occupational exposure study identified a lowest observed adverse effects level (LOAEL) for beryllium sensitization in workers exposed to 0.55 $\mu g/m^3$ (median of average concentrations). The Eisenbud *et al.* (1949) study, using relatively insensitive screening methods, suggests a no observed adverse effects level (NOAEL) of 0.01-0.1 $\mu g/m^3$ in community residents living near a beryllium plant. The LOAEL from the *Kreiss et al.* study was used for the operational derivation of the RfC because the screening method used in the Eisenbud *et al.* (1949) study was less sensitive than the method used in the Kreiss *et al.* (1996) study.

Because individuals developing beryllium sensitization and CBD are the most sensitive subpopulation, an uncertainty factor of 1 was used to account for human variability. An uncertainty factor of 1 was also used to adjust for the less-than-chronic exposure duration of the Kreiss et al. (1996) study; use of this uncertainty factor is supported by the evidence that the occurrence of CBD does not appear to be related to exposure duration. A database uncertainty factor of 3 was used to account for the poor quality of exposure monitoring in the co-principal studies and other epidemiology studies that assessed the incidence of beryllium sensitization and CBD among exposed workers and community residents. The US EPA has medium confidence in this RfD.

An RfD of 4.47E-6 mg/kg-d was then calculated based on the US EPA RfC, by dividing by an adult body weight of 70.7 kg and multiplying by an adult inhalation rate of 15.8 m^3/d, which was then used in this assessment.