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**Roberts Bay Mine and Ida Bay Deposit**

**Human Health and Ecological Risk Assessment**

**FINAL Report**

Prepared for:

**Public Works Government Services Canada**
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# Executive Summary

UMA Engineering Ltd. was subcontracted by EBA Engineering Ltd. to complete the Human Health and Ecological Risk Assessment (HHERA) for the Roberts and Ida Bay abandoned mines in Nunavut. The project was commissioned by Public Works Government Services Canada on behalf of Department of Indian Affairs and Northern Development (DIAND). The assessment of the ecological and human health risks forms one component of an overall final remediation plan. The former Roberts Bay silver mine is located along the northern coast of Nunavut, separated from Queen Victoria Island and Cambridge Bay by Melville Sound, Kent Peninsula and Dease Strait. The associated Ida Bay silver mine is approximately 8 km north of the Roberts Bay mine along the coast of Melville Sound. Remnants of the mine workings, including mill, tailings pond, garage, fuel storage were all left at the Roberts Bay site. Other than exploration trenches, the mine adit, waste rock and a small camp, the Ida Bay site was devoid of major infrastructure. Several previous and concurrent environmental investigation have been completed at these site. The findings from these studies indicated the potential contaminants of concern were both petroleum hydrocarbons (PHC) and trace metals. Following a comprehensive data compilation and screening process, a final list of contaminants of concern was generated which included the PHCs and a narrowed selection of trace metals. The screening utilized CCME human health and ecological guidelines and background concentrations, where available. Waste rock was not considered a true soil and therefore not compared to a CCME soil quality guidelines and not used to generate an exposure point concentration in the soil media. Nevertheless, samples of the fine fraction of the waste rock and tailing material were considered soil. Screening analytical data from the water media included adits, tailings pond, isolated standing water, a former drinking water lake, the main discharge stream and Roberts Lake. Vegetation samples from the Roberts Bay site were collected and trace element concentrations quantified to increase the certainty in the wildlife exposure assessment.

The human health risk conceptual exposure scenario included a local Inuit family visiting the site annually for at least one month at a time. The family was assumed to camp in the vicinity of the site and subsist primarily on Arctic Char and lake trout harvested from Roberts Lake, with periodic meals of trapped Arctic hare. Drinking water was assumed to be obtained from either the discharging stream or Roberts Lake. Direct exposure to the fine fraction of waste rock and tailing was assumed (e.g. incidental ingestion and dermal contact). Ingestion of caribou meat over the entire year and over an entire lifetime was included. Because of the relatively large grain size and absence of dwellings, inhalation of metal laden dust and PHC vapours were not included. A toddler and adult receptor were evaluated for non-cancer and cancer endpoints. The chemicals of concern evaluated in the human health risk assessment were arsenic (cancerous endpoint), lead and selenium.

The ecological receptors of concern included both terrestrial and aquatic based animals. In the terrestrial setting the receptors included the herbaceous mammals: tundra vole, Arctic hare and caribou. The gyrfalcon was included as the terrestrial predator, assumed to prey exclusively upon the abundant voles. In the aquatic environment, the receptors of concern included the algae, invertebrates, fish and Pacific loon, assumed to subsist off fish in Roberts Lake.

The estimated exposure point concentrations in each of the media (soil, water, sediment, vegetation and food) were based upon the upper 95$^{th}$ percentile calculated from the extensive database compiled in Appendix B. Exposure point concentrations in mammals (voles, hare and caribou) were estimated using the latest model guidance from US EPA. Exposure point concentration in fish were obtained from baseline data collected as part of the neighbouring Doris North Project. The wildlife exposure model incorporated as much ecological reality as possible, including variation in exposure due to larger home ranges in relation to the sites and seasonal use factors for the loon and gyrfalcon.

Estimated daily doses for animals and humans alike were compared against the most recent, and scientifically sound, toxicity reference values (TRVs) available. These TRVs are considered to be "safe" daily doses that are unlikely to cause adverse health effects. For the generic aquatic receptors (e.g. algae, invertebrates and fish) the exposure point concentrations were compared directly against the appropriate CCME aquatic life guideline. Incremental lifetime risks greater than 1 in $10^{-5}$ are considered excessive when compared to natural background chances of contracting cancer.

For the human exposure scenario, all non-cancerous hazard quotient were at least three orders of magnitude below one. In terms of cancer risks related to exposure to the arsenic at the sites, the probability was estimated at 1 in $10^{-6}$, which is less than the accepted background chance. Essentially, the PHC and trace metals at Roberts Bay mine and Ida Bay deposit do not represent a chemical hazard to periodic visitors to the site. Regardless, remedial strategies should considers mitigating the human exposure to fine waste rock/ tailings and isolated standing water.

In contrast, the small mammalian receptors, represented with the tundra vole, are anticipated to be exposed to PHC at 10 times their safe daily limit. Furthermore, the exposures to silver, copper, vanadium and zinc are predicted to be greater than 5 times the safe limit at both Ida and Roberts Bay. Arsenic exposure to the small mammals is expected to just exceed the safe limit at both locations. With current conditions, the Arctic hare is predicted to be exposed to 2 times it's safe limit of silver at Roberts Bay alone. The caribou, with their large home ranges, are not anticipated to be adversely affected from the periodic exposure to these sites. Similarly, the secondary avian consumers are unlikely to be exposed to potentially harmful concentrations of contaminants of concern.

In the aquatic environment at Roberts Bay, the data suggests that both silver and copper concentrations are elevated in bodies of water on the site, and in the local stream at the point of discharge to Roberts Lake. There is uncertainty surrounding the validity of the silver concentrations because the method detection limits are set too close to the CCME guideline. Nevertheless, copper discharging to Roberts Lake is elevated relative to other regional data. The remedial action plan must consider mitigating any acid generating material and ensuring fine waste rock material is isolated from surface water run - off channels. Deposition of waste rock off shore of Ida Bay has resulted in lead concentrations in the sediment close to toxicological thresholds for sensitive benthic organisms. Remedial action within the ocean may trigger Habitat Alteration or Destruction (HADD), and could require the Department of Fisheries and Oceans authorization. Depending on the findings from additional leachate testing, undertaken by Earth Tech, remedial action may not be warranted.

In order to assist with the remedial planning for the waste rock and tailings, the risk assessment herein provided soil based site-specific remedial objectives (SSROs), based on back calculations using the exposure to the most sensitive receptor, the tundra vole. Soil is considered to be synonymous with the fine fraction of waste rock. This process successfully assigned SSROs to both silver and arsenic. Vanadium was assigned a remedial objective equivalent to it's CCME guideline. Due to the oral exposure associated with vegetation, assignment of soil based SSROs for zinc and copper were problematic. Therefore, the objective for these required elements was modified. Rather than establishing a fixed "safe" dose for the vole and back calculating the soil concentration, the ratio between soil : vegetation contribution in the oral dose was fixed at 50:50. This presumes that exposure to the direct soil would be more detrimental than exposure to naturally occurring trace elements in vegetation.

Based on the calculated SSROs, trace metal concentrations in the fine fraction of waste rock below the mill assay building and garage are requiring remedial action. Additionally, the tailings material, and possibly the waste rock in the vicinity of the barrel storage, must be considered potentially harmful. The PHC affected soils are 10 times the safe limits for small mammals and are expected to be addressed in the remedial plan with or without the application of SSROs. Several remedial options are available for biodegrading organic compounds.

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# 1.0 Introduction



UMA Engineering Ltd. was subcontracted by EBA Engineering Ltd. to complete the Human Health and Ecological Risk Assessment for the Roberts and Ida Bay abandoned mines in Nunavut. The project was commissioned by Public Works Government Services Canada on behalf of Department of Indian Affairs and Northern Development (DIAND). The assessment of the ecological and human health risks forms one component of an overall final remediation plan.

## 1.1 Rationale for Risk Assessment

Early reconnaissance and environmental reports on these former mine sites provided only limited information on chemical hazards to humans and ecological receptors. Under the Federal Contaminated Sites Accelerated Action Plan (FCSAAP), a screening level risk assessment (SLRA) was completed in 2003 (Senes, 2004). The findings were based upon the limited site characterization data and relied on mathematical models to estimate contaminant concentrations in various environmental media. Additionally, the screening level risk assessment lacked a quantitative risk assessment for important ecological receptors. The SLRA process lead to the conclusion that greater risk certainty would be obtained by completing a comprehensive site-specific human health and ecological risk assessment (HHERA).

Generic environmental guidelines, such as those published under the auspices of Canadian Council of Ministers of the Environment (CCME, 2002), are inherently conservative and do not take into account unique exposure scenarios and biophysical site-specific conditions. Not every site will fall under the generic assumptions built into the CCME environmental guidelines. Realizing this, CCME published protocols to facilitate the derivation of site-specific guidelines (CCME, 1996). The risk assessment provides the scientific rigour to support the establishment of site-specific environmental criteria. The risk assessment process allows remedial activities to be focused in locations, and on those specific contaminants anticipated to pose health risks to the receptors.

### 1.1.1 Technical Guidance

The technical guidance for the HHERA has been drawn from various Canadian and United States documents including Health Canada, US EPA, CCME publications and the Ontario Ministry of the Environment (Ontario MOE). In addition to these federal /provincial documents, there are several books published on the topic which provide valuable guidelines and framework for conducting and documenting the ecological risk assessments component (Suter et. al., 2000).

## 1.2 Scope and Objectives

Based on the original terms of reference, the objectives for the HHERA component were described as a) completion of a comprehensive human health risk assessment; and b) completion of a preliminary quantitative ecological risk assessment. In response to the terms of reference objectives, UMA offered the following specific scope of work:

- Review and revise any models, assessment and measurement endpoints in the previous SLRA.
- Ensure suitable available field data is incorporated into all calculations.
- Produce quantitative estimates of risk in the form of site-specific criteria.
- Provide professional opinions regarding the acceptability of identified risks and suggest components that should be focused on during remedial planning.

To accomplish this scope of work and integrated approach to the HHERA was adopted (Section 1.4).

### 1.3 Project Team

The HHERA was only one component of an overall remediation program commissioned by PWGSC in 2005. The project team consisted of:

| | |
|---|---|
| AMEC Earth & Environmental | Reclamation conceptual closure plan, waste rock characterization, survey |
| Earth Tech Environmental | Environmental site assessment components |
| EBA Engineering Consultants Ltd. | Subcontracted by Earth Tech for ground geophysical work |
| UMA Engineering Ltd. | Subcontracted by EBA for the HHERA |

The HHERA will draw upon each of these main investigation components. The conceptual closure plan, especially the handling of the waste rock, influences the exposure scenario for this risk assessment. The degree of mobilization of metals from the waste rock will change the risk characterization of the site over time. This risk assessment was based on the soil, sediment and water quality data collected in previous studies and by Earth Tech during the August 2005 field work.

### 1.4 Integrated Human Health and Ecological Risk Assessment

The goal of a environmental risk assessment is to help managers make effective and prioritized decisions that have the greatest potential to improve human health outcomes or ecosystem health. Environmental risk assessment (ERA) is useful only to the extent that it guides informed risk management decisions. Risk assessment is also intended to be a transparent decision-making tool, with clearly documented assumptions.

Environmental risk assessment is often divided into two components, although there is considerable overlap between these:

- Human Health Risk Assessment (HHRA), and
- Ecological Risk Assessment (EcoRA).

This report examines both the risks to humans potentially visiting the site and other non-human members of the ecosystem (e.g. wildlife) – which we refer to as "ecological receptors".

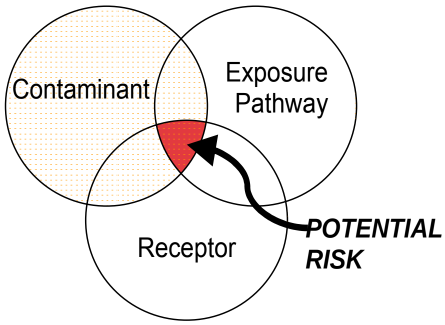
The human health risk assessment evaluates the possible effects of contaminated soil and water to humans, through both direct and indirect exposure. The ecological risk assessment includes an evaluation of possible risks to terrestrial and aquatic organisms.

The plausibility of risks is directly influenced by three major components (Figure 1):

- Sources of potential risks (i.e. contaminants),
- Humans or ecological receptors about which we are concerned, and
- Environmental pathways that potentially connect the receptors to contaminants (exposure pathways).

The pathways not only link source to receptor, they also modify the degree of potential exposure, since most stressors or hazards tend to change in magnitude over space and/or time.

**Figure 1: Components of Environmental Risk**




***For there to be a human health or ecological risk, there must exist a source, a potentially exposed group, and the environmental pathway(s) connecting them.***

A first step in conducting an environmental risk assessment is to compile a list of potential risk scenarios that are plausible; i.e. those situations for which there is a viable source, exposure pathway and receptor. This further allows the exclusion from further assessment of those situations where environmental risks would be precluded.

It is important to note that:

- Sometimes, we cannot unequivocally rule out the possibility of risks by virtue of the absence of one of its major components (source, pathway, receptor), and
- The presence of a risk does not necessarily mean that the risk is unacceptable (i.e. high enough to be a cause for concern).

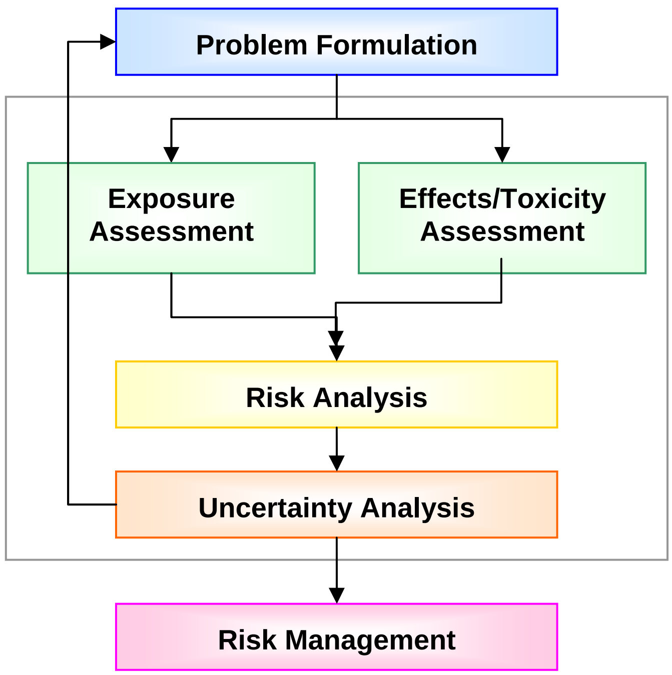
Figure 1 provides a schematic of the typical risk assessment framework used in Canada by both CCME and Ontario Ministry of Environment. This framework was developed by the United States Environmental Protection Agency (USEPA), and is the same for both ecological and human health risk assessment.

The overall risk assessment process can be divided into five areas:

- Problem Formulation – Identifying the contaminants/stressor of concern and humans or other important organisms that are potentially at risk. Develop conceptual models – essentially a blue print for conducting the risk assessment;
- Exposure Assessment – Assessing the extent to which humans or the valued ecological receptors might be exposed to contaminants/stressors;
- Effects/Toxicity Assessment – Assessing through reference to the toxicology literature, or the measurement of toxicological responses, the thresholds of exposure that can lead to negative effects;
- Risk Characterization – Combining the exposure and effects assessment to make quantitative risk estimates. The interpretation also requires an evaluation of sources of uncertainty, and dependence of conclusions on the underlying assumptions;
- Uncertainty Analysis – A formal evaluation of the degree of certainty about the various assumptions used, the adequacy of the conceptual models, and the data used in the risk

assessment. The risk assessor evaluates the dependence of conclusions about risks on various components of the risk assessment, and may conduct a sensitivity analysis around critical drivers of the risk estimates produced.

**Figure 2: The Risk Assessment Framework**




The problem formulation stage of the risk assessment is the beginning of an often cyclic process to define the "conceptual model" for assessing risk. This can be a powerful tool for building consensus. If the major stakeholders can agree on the important features of perceived or potential risk, then this increases the likelihood that the subsequent assessment of risk(s) will be broadly accepted as well.

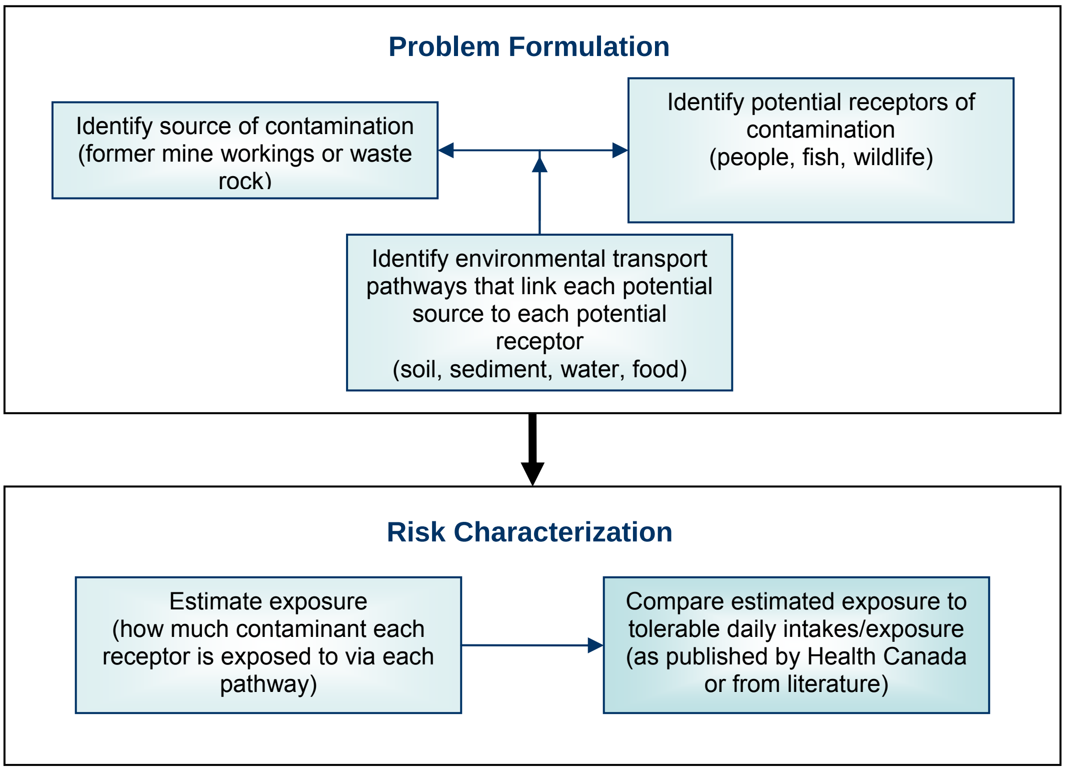
The stressor(s) of concern (often contaminants of concern) arise from the human activity or disturbance that stimulated the interest in possible environmental risks in the first place. For problem formulation, a list of contaminants of concern is derived en route to the more detailed examination of contaminant risks.

The stakeholders may collectively define those aspects of the biosphere (ecological receptors and highly exposed or potentially exposed humans) that merit consideration for evaluation of risks. The ecological receptors are chosen based on perceptions of their value to humans, as having an important role in the overall functioning of the ecosystem (e.g. – a valued ecosystem component, VEC), as being rare or endangered, as being good indicators of possible risks to other valued organisms, or a combination of these.

Once the contaminants of concern (C of C) and receptors are defined, then possible interconnections between the two (exposure pathways) are examined. Those situations where a C of C qualitatively has the potential to affect a prioritized ecological receptor or human by a viable exposure pathway are included within a formalized conceptual model. The model should exhibit predefined assessment and measurement endpoints that are credible based on current scientific understanding and are pragmatic.

Steps in risk assessment are summarized in Figure 3:

**Figure 3: Details of the Framework – Defining the Problem to be Addressed**




This study involves the collection of data on the site-specific conditions as well as background conditions for comparison. It uses models and scientific evaluations to make predictions about potential risks from exposure to contaminants in the environment. The study also includes an uncertainty analysis: in other words – what we know, what we don't, and how our confidence in the overall evaluation (or lack thereof) should be used to ensure that human and environmental health is adequately protected.

# 2.0 Problem Formulation 2.0

## 2.1 Site Description

The former Roberts Bay silver mine is located along the northern coast of Nunavut, separated from Queen Victoria Island and Cambridge Bay by Melville Sound, Kent Peninsula and Dease Strait (Figure 4). The associated Ida Bay silver mine is approximately 8 km north of the Roberts Bay mine along the coast of Melville Sound. The land mass immediately south of Queen Maud Gulf is designated as protected bird sanctuary known as the Queen Maud Gulf Migratory Bird Sanctuary.

### 2.1.1 Historical Perspective

The following historical chronology has been paraphrased from Rescan, 2004.

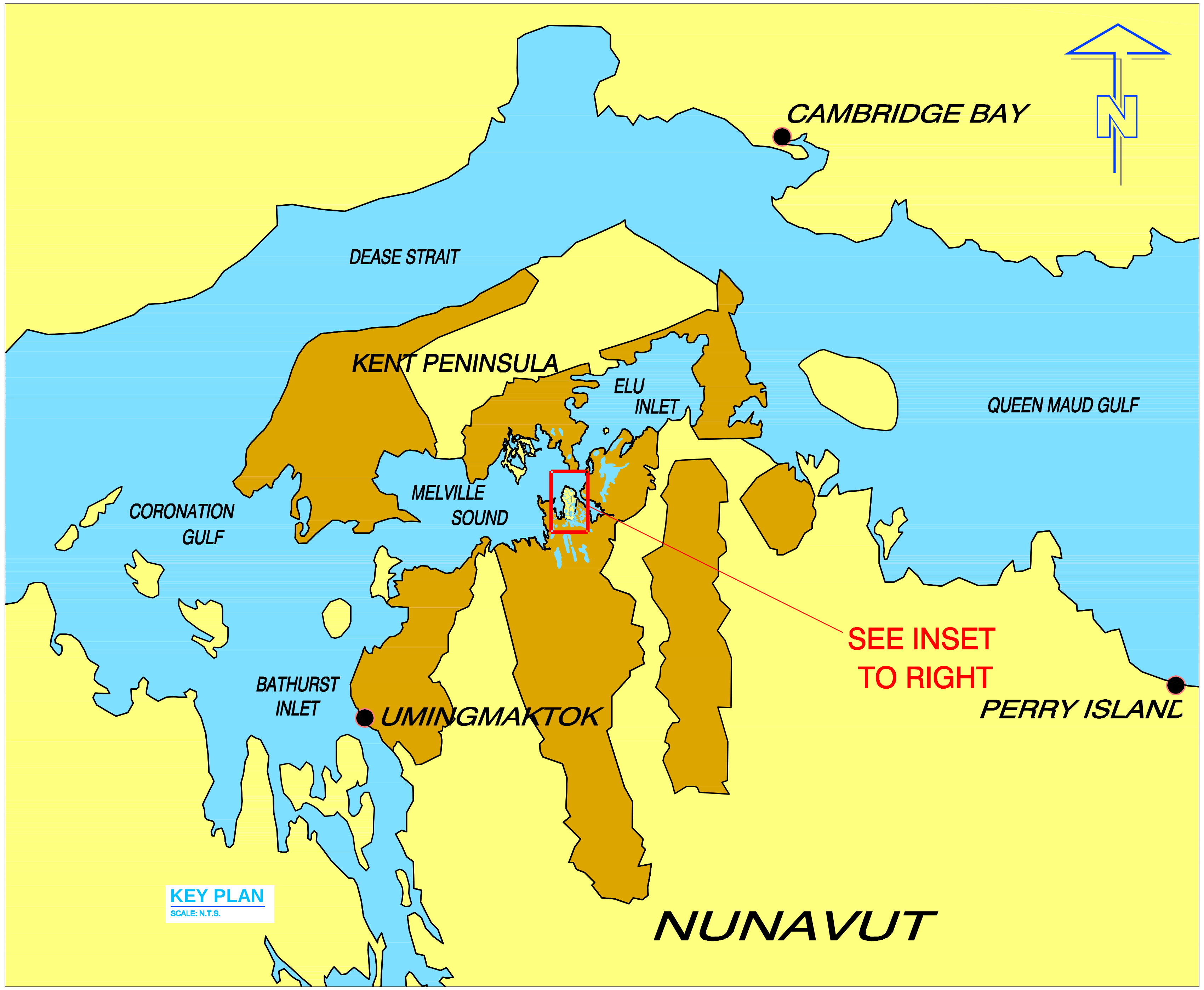
- The lands were first staked by the Roberts Mining Company Ltd. in 1964;
- Exploration of the Ida and Roberts Bay silver showings were conducted by the Hope Bay Silver Syndicate from 1967 until 1972;
- Mobilization of mining equipment to Ida Bay was initiated by Hope Bay Mines Ltd. (formerly Hope Bay Mining Co.) in 1973;
- Mining at Ida Bay included driving a 600 ft. decline yielding over 10,000 oz. of high grade silver. That same year, a 400 ft. decline excavated into the Roberts Bay deposit produced 10 tons of hand sorted ore grading 4,863 oz/ton;
- In 1974 Hope Bay Mines Ltd. entered into a joint venture with Van Silver Explorations Ltd. and Reako Explorations to upgrade the Roberts Bay mine;
- A small 50-75 ton/day mill was constructed at the Roberts Bay site yielding a total of 74,500 oz. of silver until operations ceased in 1975;
- Further exploration continued at the leases throughout the 1980s and 1990s, but in 1997 the Roberts Mining Lease was surrendered and the area covered by the lease was open for staking;
- In 1998 the ground was restaked as the ORO 5 claim.

Remnants of the mine workings, including mill, tailings pond, garage, fuel storage were all left at the Roberts Bay site. Other than exploration trenches, the mine adit, waste rock and a small camp, the Ida Bay site was devoid of major infrastructure.

The spatial scope of this HHERA is limited to the immediate areas surrounding the Roberts and Ida Bay mines, plus the potential risks associated with down gradient drainage to Roberts Lake and Melville Sound. In order to maintain a consistent nomenclature for describing spatial features and infrastructure, Earth Tech and UMA have agreed on the following identifiers. At Roberts Bay, the areas are described as background (ridge east of the mine), muskeg (down gradient of mine), barrel storage, camp, camp dump (Rescan “landfill”), garage, mill assay and fuel storage. The Ida Bay site is not separated into different areas, but samples are readily identified with the prefix “Ida”.

### 2.1.2 Geological and Geomorphic Features

These former silver mines are located on the northern tip of the late Archean aged Hope Bay Volcanic Belt within the Slave Structural Province. The rocks in this belt are dominantly mafic to felsic lavas and tuffs, namely basalts and andesites that have undergone metamorphism. From the air, the Hope Bay Volcanic Belt is readily recognizable by the conspicuous volcanic ridges forming long narrow low-lying drainage basins with a northerly flow.





**NOTICE:**
**THE BASE PLAN FOR THIS DRAWING WAS TAKEN FROM AMEC DRAWING NUMBER: ALS050052-SITE**

**LEGEND**

- INUIT OWNED LANDS
- NUNAVUT LAND
- MINE SITE AREA
- EXISTING TRAIL (ROUGH, QUAD ONLY)

**Public Works Government Services**
**Roberts Bay**
**Human Health and Ecological Risk Assessment**

## SITE LOCATION

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**Figure 4**

The Roberts Bay mine workings and tailing pond are located atop one of these volcanic outcrops. In the low-lying areas, the bedrock is covered by surficial deposits primarily comprised of sand dominated glacial till with an overlying marine clay and silts (Ryder, 1992 and EBA, 1996). The marine clay and silt was deposited after the retreat of the Wisconsin aged ice sheet and prior to the isostatic rebound of the land mass. Numerous raised beaches along the coastal areas of Kent Peninsula and Cambridge Bay provide further evidence of this variation in relative sea level.

Continuous ground permafrost in the Artic influences the geomorphic and hydrogeologic characteristics of the landscape. Permanently frozen ground at relatively shallow depths ensures that groundwaters remain close to the surface. Essentially, groundwater in the Artic is only present in the thawed “active layer” and typically expressed on the surface in low lying saturated areas. As part of the baseline data collection for the environmental impact assessment of the neighbouring Dorris North Project (Miramar Hope Bay Ltd.), Golder Associates Ltd. (2001) completed a study of ground temperatures using thermistor strings installed in boreholes. The conclusions were that the permafrost was located approximately 2 – 2.5 m below ground and that the thickness of the permanently frozen subsurface was 563 m. Based on the proximity to the Roberts and Ida Bay mines, the Dorris North data provide reasonable estimates of the permafrost conditions at the site.

### 2.1.3 Biophysical Attributes

#### Terrestrial Ecoregions

The Hope Bay Volcanic Belt is situated within the Southern Artic Ecozone, characterized by a vegetative transition from southern taiga forest to northern treeless Artic tundra. Harsh climatic conditions contribute to slow, restricted plant growth. There are subtle variations in plant distribution, abundance and size based on sensitivities to microclimatic conditions. In areas with sufficient soil profiles, low scrubs such as willow, birch and Labrador tea form vast scrublands. In exposed bedrock areas, these scrublands give way to mats of lichen, mosses and ground hugging scrubs. According to the nationally accepted ecosystem classification system, Hubert & Associates (2002) described three ecosystem units that can generally be applied to the Hope Bay Volcanic Belt. The classification system is based upon characteristics of landforms, climate, soil and water. The three general classes are: a) ocean shoreline associations comprised mainly of salt tolerant vegetation such as alkali grass and Lyme grass; b) lacustrine, fluvial and fine marine substrate associations dominated by dwarf birch, willow, cotton grass Labrador tea, blueberry and flood tolerant grasses and sedge; and c) rock outcrop and coarse substrate associations dominated by dry land sedge, lichen and scrubs, Labrador tea, blueberry and Artic heather. The low lying grassy areas identified as ‘muskeg’ down gradient of the Roberts Bay mine fall within the moisture tolerant, fine substrate association. The majority of the area within the immediate vicinity of the Roberts Bay mine fall within the dryer, coarse substrate, bedrock outcrop associations. The Ida Bay mine would fall under the ocean shoreline association.

#### Aquatic Resources

Surface runoff originating in the main area of mine workings at Roberts Bay will drain into the low lying area immediately south, which develops into a creek, eventually discharging to Roberts Lake. Surface runoff draining off the west flank of the main volcanic ridge, including the tailing pond, infiltrates into the shallow soils in the low lying area west of the mine, or forms small isolated pools. In contrast, the Ida Bay audit and associated waste rock lie immediately adjacent to the ocean (Melville Sound). The marine habitat in the vicinity of Ida Bay is too shallow for float plane, or any type of marine vessel access.

The plausible aquatic resources of Melville Sound and Roberts Lake will be inferred from the baseline compilation (1995 – 2000) for the Doris North Project (RL&L /Golder, 2002). The marine mammal baseline data was compiled in Hurbert & Associates (2002).

The marine mammal aerial survey data compiled by Hurbert & Associates (2002) indicates that ringed seals are the dominant marine mammal within the coastal inlets surrounding Kent Peninsula. Other marine mammals, including the primary predator of the ringed seals, the polar bear, are rare in this region. The RL&L/Golder (2002) aquatic baseline studies included 3 marine benthos samples in the summer of 1997 and 1998 within Roberts Bay. The sample program included a shallow (<1.5 m), moderate (7 - 9 m) and deep (>15 m) habitat. Polychaeta (marine worms) were a dominate factor in all but the shallowest habitat. The shallow habitat was dominated, in terms of total numbers, by Nematoda (up to 80%) and Bivalvia (*Macoma inquinata*). In the moderate depth habitat, the marine scud *Pontoporeiu femorata* accounted for 33% of total numbers of organisms. There was a trend toward increasing overall benthic abundance with increasing depth. The deepest habitat was dominated by Polycheata, Nematoda and Cumacea.

The baseline data available on the freshwater lakes and streams is comprehensive, but does not specifically include Roberts Lake. The aquatic resource potential of Roberts Lake will be inferred from that described in neighbouring lakes, which include Little Roberts Lake and the outflow stream draining into Roberts Bay.

Lakes in the region fall into a mesotrophic to oligotrophic category with low concentrations of available nutrients. The limnological data collected in support of the Doris North Project are typical of other lakes in the Slave Province (Puznicki, 1996a). The primary producers (peripyton and phytoplankton) in Little Roberts Lake and the outflow are dominated by the blue green cyanophyta *Oscillatoria spp*. The diatom *Diatoma elongatum* contributed up to 25% to the total cells/$cm^2$ in the periphyic samples from the outflow in August 1997. Primary producers are dominated by the cyanophyta algae throughout all the lakes in the region. This fact suggests that cyanophyta possess an adaptive advantage which allows them to flourish in the nutrient poor northern lakes. This is likely related to the fact that cyanophyta are capable of fixing atmospheric nitrogen, rather than being reliant of dissolved available nitrogen (Wetzel, 1983 and R.L&L/Golder,2002). The secondary producers include the zooplankton in pelagic habitat and the benthic invertebrates in the lake substrate and stream beds. The numbers of zooplankton in the lakes of the Hope Bay region are dominated by Rotifera, Cladocera and Cyclopodia with little variation among the various lakes. The benthic communities in these lakes, including Little Roberts Lake, are dominated by Chironomidae (midges), Nematoda (roundworm), Bivalvia (clams), Oligochaeta (brittle worm) and Malacostraca (fairy shrimp, tadpole shrimp, isopods). In Little Roberts Lake, Chironomidae accounted for over 75% of the total numbers with up to 22% contribution from the mollusc *Pisidium* spp in the summer of 1997. *Pisidium* spp are particularly sensitive to acidification in lentic environments.

The drift organisms captured in the outflow streams are comprised of both benthic lentic invertebrates and pelagic zooplankton. The numbers of drift organisms are dominated by Chironomidae (midges), Simuliidae (black flies), Ostracoda (seed shrimp) and Cladocera (water fleas). Differences in relative abundance in the various outflows can largely be ascribed to differences in physical characteristics of the streams. In July of 1996 the drift from Little Roberts Lake was dominated by the midges, while in August 1997 the cladoceran *Holopedium gibberum* dominated the total numbers. Stream benthic macro invertebrates are important components of the aquatic food chain. Similar to the lotic drift sampling, the lotic benthic samples are dominated in numbers by the Chironomidae and Simuliidae. Little Roberts Lake outflow was on of the least productive streams (based on total abundance) perhaps because of marine influences. Other than the midge and black flies, the Little Roberts Lake outflow showed relatively high numbers of the Plecoptera (stoneflies) and Coelenterata (freshwater Cnidaria – hydra).

The aquatic assessment conducted between 1995 and 2000 resulted in over 1500 fish captured in gill nets and beach seines. In order of abundance, the captured species include cisco (36%), lake whitefish (34%), lake trout (28%), Arctic char (2%), least cisco (<1%) and broad whitefish (<1%). Ninespine stickleback were also present in most lakes and appeared to be favoured prey for lake trout. Fish populations in Little Roberts Lake were different from all other lakes because of the direct passage to Roberts Bay. The diadromous species (Arctic char and broad whitefish) are found in Little Roberts Lake. The arctic char use Little Roberts Lake and the outflow of Roberts Lake during their migration and over wintering in Roberts Lake. Younger char aged between 1-4 years (smolts) use Roberts Lake and Little Roberts Lake as rearing grounds. The average fork length of these smolts is roughly 330 mm which translates into approximately 220 grams. The older char that migrate into Roberts Bay and Melville Sound for summer feeding gain significant weight. Lesser numbers of these older aged char were captured in Little Roberts Lake. The maximum fork length was 900 mm with a weight of > 9,000 grams. These larger char would be harvested by Inuit and other recreational fishermen. Based on the analysis of stomach contents, the char in Little Roberts Lake appear to be feeding on tadpole shrimp. Lake trout are also present in Little Roberts Lake, and presumably Roberts Lake. The mean weight for lake trout ranges between 500 and 2000 grams. The lake trout captured in Little Roberts Lake fall into the smaller range. Nevertheless, recreational fishermen are likely to encounter more lake trout then char. The lake whitefish and cisco are both much too small to be considered as a recreational source. These smaller species may be prey items for piscevorois avians (heron) and mammals (mink). The grizzly bear will also hunt for fish, especially larger char migrating up the Little Roberts and Roberts Lake outflows.

Terrestrial Wildlife Resources

The terrestrial wildlife resources of the Hope Bay Volcanic Belt have been characterized as part of the comprehensive environmental impact assessment of the neighbouring Dorris North Project (Miramar Hope Bay Ltd.). Baseline wildlife information, intended to support the mineral extraction within this area of Nunavut, has been collected by various consultant since 1994. Prior to this, peer reviewed papers and government supported research has been published on the subject. UMA reviewed the Hurbert and Associates Ltd, November 2002 synopsis of data to prepare this brief overview. The objective of this overview is twofold: i) to provide a general understanding of the wildlife use of the area; and ii) to identify potential relevant species to include in the ecological risk assessment.

Although the majority of the published reports focus on the higher profile avian and mammalian species (e.g. raptors and caribou), the Hope Bay area is known to support a full complement of arctic and sub-arctic mammalian and avian species. Most importantly, none of the species observed or reported to be present in the area are listed as “endangered” in Nunavut. For mammals, species in nine different families have been observed. These include shrews (Scoricidae), hares (Leporidae), squirrels (Sciuridae), voles and lemmings (Arvicolidae), weasels (Mustelidae), wolves and foxes (Canidae), deer/caribou (Cervidae), muskox (Bovidae) and bears (Ursidae). Many of these mammals have much larger home territories relative to the study area (e.g. bears, foxes, wolverines, wolves, muskox) or are migratory over very wide areas (e.g. caribou). Although these large mammalian species are likely to be valued to the local Inuit populations, their larger home territory limits their usefulness in determining ecological risk from residual contaminants at Roberts and Ida Bay mines. The more prolific smaller mammals, such as red-backed or tundra vole, brown or collarded lemming are more likely candidates to include in the ecological risk assessment. These smaller mammals would be exposed for greater portions of their lifespan. These mammals play and important role in the northern ecosystem and were the most abundant in field trapping programs conducted in support of the Doris North Project. They are reportedly an important prey item for falcons, hawks, eagles, owls, pomarine jaegers, foxes, weasels and infrequently wolves and grizzly bears. The populations of the species belonging to the family Arvicolidae, known as microtine rodents, cycle over a 3-4 year period with population shifts of 10 - 100 fold differences. Predator abundance will also vary with the cycles of these microtine rodents.

The bird inventories summarized by Hurbert & Associates (2002) tabulated 65 different avian species including waterfowl, raptors, ptarmigan, shorebirds, gulls and jaegers, owls, sparrows, longspurs and a finch. Most of the avians tabulated are migratory breeding species, but a few are resident (ptarmigan, gyrfalcons, ravens, redpoll finch and snowy owl). None of the species tabulated are categorized as "endangered" or are identified with special status in Nunavut. Based on ground census of breeding birds, the Lapland longspurs, savannah sparrows, redpoll finch, treed sparrow and horned larks are the most abundant species found. The density of scrub cover accounted for more than 70% of the spatial distribution of these breeding songbirds. The aerial surveys of nesting waterfowl conducted between 1996 and 1998 determined that the geese, both Canada and white-fronted species, represented 75% to 99% of all waterfowl observed. The loon and merganser were infrequently observed on the lakes in the Hope Bay area. An aerial survey in 1998 produced low density estimates (0.35 birds/ $km^2$) for ground dwelling ptarmigan. These surveys were not repeated in following years. Ptarmigan are well camouflaged on the tundra and may be present at higher densities than estimated by this technique.

Due to the topographic elevation provided by the volcanic ridges in the Hope Bay Volcanic Belt, the area has long been known to be important habitat for nesting raptors (Ferguson, 1987). From 1995 through to 2001 raptor nesting in the Hope Bay area has been evaluated, typically by helicopter surveys. The data indicate that a 400 $km^2$ area encompassing Doris, Patch and Windy Lakes supports approximately 50% of the raptor nesting in the overall area. The most abundant raptors are the peregrine falcons, rough-legged hawks and golden eagles. Hubert & Associates (2002) noted that non of these raptors are considered endangered in Nunavut. Nevertheless, it is acknowledged that peregrine falcons are listed in the federal Species at Risk Act (SARA). Productivity of these raptors was tracked based of the number of young or eggs per nest. When compared to earlier reproductive data (Poole and Bromley, 1988), the productivity among all raptors through 1996 to 2000 remained relatively constant at roughly 1.2 to 2.8 young or eggs per nest, In 2001 an unprecedented reproductive failure occurred for all raptors and the author noted that this failure was also observed at the Jericho diamond mine site 330 km southwest of the Hope Bay area. Furthermore, the raptor productivity remained relatively low in 2002 despite the fact that this was an especially productive year in the lemming cycle. Hurbert & Associates (2002) speculate that harsh weather condition in late May and early June in 2001 contributed to the raptor productivity declines. A similar cold spring with delayed ice break-up on the lakes occurred in 2002. Dietary exposure to excess contaminants from the Roberts and Ida Bay mines may contribute to reproductive impairment of these raptors. Therefore, inclusion of a raptor predator in the ecological risk scenario is logical.

### 2.1.4 Inuit Land Use

In the summer months, access to the Roberts Bay mine is only possible by fixed wing air craft equipped with pontoon floats, helicopter, or via boat into Melville Sound/Roberts Bay and over land travel. In the winter, access is possible via snow mobile and sled. The closest community is located along the eastern coast of Bathurst Inlet and is known as Umingmaktok. In the traditional language this name means "where the musk oxen are many". While musk oxen were occasionally hunted, the main sustenance for these people was, and still is, the caribou. Cambridge Bay, considered a larger centre, is located approximately 115 km northeast. In order to better understand the possible "traditional land use" the archaeological compilation report prepared for the Doris North Project (Points West Heritage Consulting Ltd., June 2002) was reviewed. In the early to mid 1900's the local Inuit would have followed a much more nomadic life style. Northern communities are much more concentrated today; nevertheless, up to 58% of the population in major centres and over 75% of the population in smaller northern communities participate in traditional hunting and fishing activities (R. Hornal & Associates Ltd., Jan. 2003). The Points West, June 2002 report outlined how the natural food resource cycles dictated the hunting and fishing habits of the Inuit. These natural cycles are likely still followed today. During the winter (December through until May) the focus would be on seal hunting on the ice. During early spring and before ice break-up on the lakes, the focus would shift to ice fishing on inland freshwater lakes. Caribou hunting would stretch from spring through until fall, but hunters preferred to hunt caribou between August and November. This was because these animals would contain more fat deposits and thicker coats. Incidental hunting for small terrestrial game, including ptarmigan and Arctic hare would also occur through the summer. In late summer the focus would be on netting the migrating char as they return from the ocean toward their over wintering habitats in the inland lakes.

The generic traditional land use scenario described by Gartner Lee and Cantox (1998) has been previously used in a risk assessment problem formulation for a remote DEW line site (Jacques, 2004). This scenario involves a temporary residence (camp) on the affected site during the summer months for hunting and fishing purposes. While the Roberts Bay / Ida Bay area may not be desirable for caribou hunting, it is plausible that the sites could be occupied in late summer primarily for char fishing. The screening level risk assessment conducted for the Roberts Bay mine (SENES, 2004) involved a similar scenario. Adult and child receptors annually visiting the site for a three month duration (camping) would consume water from the immediate area (i.e. tailing pond /adit) and obtain small terrestrial game for food (hare and ptarmigan). Incidental soil ingestion and dermal contact were also considered. The SENES Inuit land use scenario did not consider consumption of Arctic char, or any fish species from Roberts Lake. The Golder, 2005 risk assessment in support of the proposed Doris North Project assumed that local hunting families would spend up to 30 days at a time in the area hunting for wild game (caribou and Arctic hare). The 30 day duration appears short compared with the other scenarios, but is based on public consultation with the local Inuit and considered herein as a suitable time frame. While in the area these hunting families are assumed to eat fish from local lakes and ingest water from the local lakes or stream discharges.

## 2.2 Previous Environmental Investigations

Several previous site reconnaissance and environmental assessment reports have been prepared for the Roberts Bay and Ida Bay mine sites. UMA has received and reviewed the following reports:

Vista Engineering, 1996. Abandon Mine Assessments Hope Bay Mine

> Assessment of articles, waste and infrastructure left abandon at the mine site. Limited environmental assessment involved. No data carried forward into this current risk assessment.

Rescan Environmental Services Ltd., September 2003. Preliminary Assessment of Roberts Bay and Ida Bay Abandon Mine Sites.

> This report described the site reconnaissance findings and estimated volumes of waste rock. The report also included analytical data on the total and leachable metals from ten waste rock and tailings samples. Acid base accounting data was also collected from the ten samples. The waste rock/ tailings analytical data was carried forward into this risk assessment.

Rescan Environmental Services Ltd., February 2004. Phase I/II Environmental Site Assessment Roberts Bay Silver Mine and Ida Bay silver Deposit, Nunavut.

> This report supplemented the previous report with laboratory analytical data for soil, water and potentially hazardous material. The soil samples were collected with a shovel to depths of 0.6 m and the main area of focus was the former fuel bladders with additional samples collected at the mill, camp and garage. Other than a single background lake sample, the seven (7) water samples collected were from various standing bodies of water including the tailing pond and

audits from both Ida and Roberts Bay mine. This analytical data on the soil and water has been carried forward into this risk assessment.

SENES Consultants Limited. October 2004. Draft Report on Human Health Screening Level Risk Assessment for Roberts Bay Silver Mine and Ida Bay Silver Deposit.

A conservative screening risk assessment evaluating both the adult and child receptor. The exposure scenario assumed annual visits to the site for three month durations during the summer (camping/hunting). Furthermore, the receptors were assumed to consume drinking water from the immediate area (i.e. highest values from Rescan, 2004) and subside off small terrestrial game from the site (hare and ptarmigan). Incidental soil ingestion and dermal contact were also considered along with vapour inhalation. The assessment included twelve (12) metals, xylene, and petroleum hydrocarbon fractions F1 and F2. The hazard quotients from this conservative assessment ranged between < 0.005 to as high as 0.49. For carcinogenic compounds the risk level for arsenic exposure was slightly higher than an acceptable background of $1.0 \times 10^{-5}$. This risk was primarily due to ingestion of contaminated water from the site.

SENES Consultants Limited. October 2004. Draft Report on Ecological Risk Evaluation for Roberts Bay Mine, Level 1 Custodial Input Section.

This ecological risk evaluation is a check list procedure to quickly evaluate the potential for ecological risks at a site. Numerical scores are applied against various categories, such as habitat sensitivity and degree of chemical hazard. The higher the score the more likely a true ecological risk may be present. The following summarizes the findings from this check list evaluation.

- Habitat sensitivity – this category was assigned a **14** mainly because of the involvement of freshwater habitat and a sensitive Arctic ecosystem. Uncertainty about the presence of endangered or protected species was acknowledged.
- Chemical hazards – overall this category was given the maximum possible score of **25**. Several metals and hydrocarbon compounds exceed applicable CCME environmental criteria in the soils and standing surface waters on the site.
- Scale of Impact – considering the chemical hazards were identified in localized areas throughout the mine area, and the entire disturbance area of the mine itself is relatively small, this category was assigned a low **5** out of a possible 25.
- Operable Pathways – Exposure – based on the water, soil and food chain routes of exposure, a maximum score of **25** was assigned to this category.

### 2.3 Supplemental 2005 Environmental Investigations

To fill in the data gaps and prepare the final site reclamation plan, further investigations were conducted in 2005. As identified in Section 1.3, the overall assessment of the Roberts Bay and Ida Bay abandon mines involved multiple consultants.

| | |
|---|---|
| AMEC Earth & Environmental | Reclamation conceptual closure plan, waste rock characterization, survey |

| | |
|---|---|
| Earth Tech Environmental | Environmental site assessment and waste inventory components |
| EBA Engineering Consultants Ltd. | Subcontracted by Earth Tech for ground geophysical work |

The collection of soil, sediment and water samples to supplement the existing data on chemical hazards was the responsibility of Earth Tech Environmental. All the chemical data collected under the Earth Tech program was shared with UMA for inclusion in this HHERA. The field methodological approaches used, and details of the individual sampling locations are described within the Earth Tech report. AMEC prepared the base Auto CADD site drawings herein and shared the results of water sampling at various mine structures. Extensive waste rock and tailing samples were collected by AMEC for acid base accounting (ABA) characterization as part of the 2005 work program. Rather than collate this data and provide interpretations, the reader is referred to the AMEC report.

## 2.4 Data Compilation: Screening for Chemicals of Concern

### 2.4.1 Applicable Screening Guidelines

The analytical data collated from each of the above noted environmental reports were tabulated based on the media – waste rock/tailings, soil, water, sediment and vegetation. The total and leachable metal analysis from the waste rock and tailings was deliberately excluded from the screening process because waste rock does not fall under a soil media. The waste rock analytical data will be qualitatively discussed based on comparison against various acid base accounting parameters, rather than soil and water environmental guidelines. Within each remaining environmental media, the chemical results have been compared against the applicable Canadian Council of Ministers of the Environment (CCME) human health and ecological guidelines. In the soil media the basis for the CCME guideline is not always straightforward. Table 1 tabulated the important soil quality guidelines used within this HHERA. The table clarifies the basis of the guideline, and associated land use or soil type. The consolidated soil quality data is available in Table B1 in Appendix B. The original analytical reports reside with the source reports for this data (Rescan, 2004 and recent Earth Tech data).

**Table 1**
**Source of Applicable Soil Screening Guidelines**

| CLASS/ Compounds | Receptor Category | Source | Soil Type or Land Use | Basis of Guideline |
|---|---|---|---|---|
| Hydrocarbons | | | | |
| BTEX | Eco | CCME, 2004 | Coarse | Contact with invert/plants |
| BTEX | Human | CCME, 2004 | Coarse | Protection of potable groundwater |
| Aliphatics (F1 – F4) | Eco | CCME, 2000 | Coarse | Contact with invert/plants |
| Naphthalene | Eco | CCME, 1999 | Res/Park | Provisional eco-contact |
| Benzo[a]pyrene | Eco | CCME, 1999 | Park/Res | Interim guideline (CCME, 1991) |
| Benzo[a]pyrene | Human | CCME, 1999 | Park/Res | Protection of potable groundwater |
| Remaining PAHs | both | CCME, 1999 | Park/Res | Interim guideline (CCME, 1991) |
| Organic Bioaccumulative | | | | |
| total PCB | Eco | CCME, 1999 | All | Protection of tertiary consumers |
| total DDT | Eco | CCME, 1999 | All | Protection of secondary consumers |

| Table 1 - Cont.<br>Source of Applicable Soil Screening Guidelines | | | | |
|---|---|---|---|---|
| CLASS/ Compounds | Receptor Category | Source | Soil Type or Land Use | Basis of Guideline |
| | | | | (birds) |
| Metals | | | | |
| Arsenic | both | CCME, 1997 | Park/Res | Contact with invert/plants & human ingestion↾ |
| Barium | both | CCME, 1991 | Park/Res | Interim guideline |
| Cadmium | both | CCME, 1999 | Park/Res | Contact with invert/plants & human ingestion |
| Chromium | both | CCME, 1997 | Park/Res | Contact with invert/plants & human ingestion |
| Copper | Both | CCME, 1999 | Park/Res | Contact with invert/plants & human ingestion |
| Lead | Both | CCME, 1999 | Park/Res | Contact with invert/plants & human ingestion |
| Mercury | Both | CCME, 1999 | Park/Res | Contact with invert/plants & human ingestion |
| Nickel | Eco only | CCME, 1999 | Park/Res | Contact with invert/plants |
| Selenium | Both | CCME, 2002 | Park/Res | Contact with invert/plants & human ingestion |
| Thallium | Both | CCME, 1999 | Park/Res | Contact with invert/plants & human ingestion |
| Vanadium | Eco only | CCME, 1999 | Park/Res | Contact with invert/plants |
| Zinc | Eco only | CCME, 1999 | Park/Res | Contact with invert/plants |

BTEX = benzene, toluene, ethyl benzene and xylene. ↾ - arsenic human health guideline based on acceptable risk of $10^{-5}$

In the water media, the human screening guidelines are based on the Health Canada's Canadian Drinking Water Quality Guidelines, updated in April 2004. The ecologically based guidelines are taken from CCME (1999) Canadian Water Quality Guidelines for the Protection of Aquatic Life with updated values incorporated in 2002 (nitrate). In order to bring site-specific data into the risk assessment, the freshwater guideline for cadmium, copper, lead and nickel have been adjusted according to the geometric mean water hardness concentration from all Roberts Bay mine water data. The freshwater guideline for aluminum has been adjusted according to the geometric mean total organic carbon, as a surrogate for dissolved organic carbon. The water quality data has been compiled into Table B2, Appendix B. The original analytical reports reside with the source reports for this data (Rescan, 2004 and Earth Tech).

The sediment samples collected in Roberts Lake and offshore of Ida Bay (Melville Sound) have been compared against the CCME (1999) Canadian Sediment Quality Guidelines for Protection of Aquatic Life. The guidelines provide two categories, called interim sediment quality guidelines "ISQG" and probable effects levels "PEL" and are established for marine and freshwater environments. There were no samples exceeding PEL; therefore, the summary tables have only included the ISQGs for the marine and freshwater environments. These guidelines are based on protection of benthic invertebrates. The sediment quality data has been compiled into Table B3, Appendix B. The original analytical reports reside with the source report (Earth Tech).

The vegetation tissue metal concentrations have been collected to help quantify the accumulation of metals surrounding the Roberts Bay mine. The vegetation is assumed to provide a source of food to the local small mammals. As such, the US EPA food benchmarks established for the prairie vole have been used as a comparison tool. The original analytical report for the vegetation samples is attached in Appendix C.

The specific locations of the Earth Tech 2005 soil, sediment and water samples and the UMA 2005 vegetation samples have been identified in the detailed site plans for Roberts Bay mine (Figure 5) and Ida Bay (Figure 6).

Concentrations that are identified as less than method detection limits in the data tables located in Appendix B have been converted to half their respective detection limits to facilitate the calculation of geometric means and upper 95$^{th}$ percentiles. While there was no specific Canadian FCSAAP guidance on how to deal with non-detections, the US EPA and Suter et a., (2000) discuss this issues. The US EPA conventions is to apply the MDL during screening risk assessments and ½ MDL for more definitive risk assessments. Suter et al., (2000) discusses the option of applying more rigorous statistical approaches – such as a software algorithm to estimate the complete parametric distribution based on a limited sample. Regardless of whether or not ½ MDL or the MDL is used in the upper 95$^{th}$ percentile exposure estimate, the list of included chemicals of concern and overall conclusions concerning risk are unchanged.

### 2.4.2 Data QA/QC and Uncertainty

Generally, the quality of the soil, sediment and vegetation analytical data was acceptable. Method detection limits (MDLs) have remained low enough compared to the applicable CCME guidelines and they have not changed substantially between the Rescan 2003 data and the Earth Tech 2005 data. In the water media, the MDLs have changed between the two sets of data and, infrequently, they were too high to be useful in comparison with conservative CCME freshwater aquatic guidelines. For example, the MDLs for cadmium, selenium and silver are either above or very close to their respective CCME guidelines. This deficiency introduces uncertainty into the risk assessment, but does not jeopardize the overall conclusions. Additionally, it is noted in the 2005 data that the dissolved results for silver and selenium are actually higher that the total results.

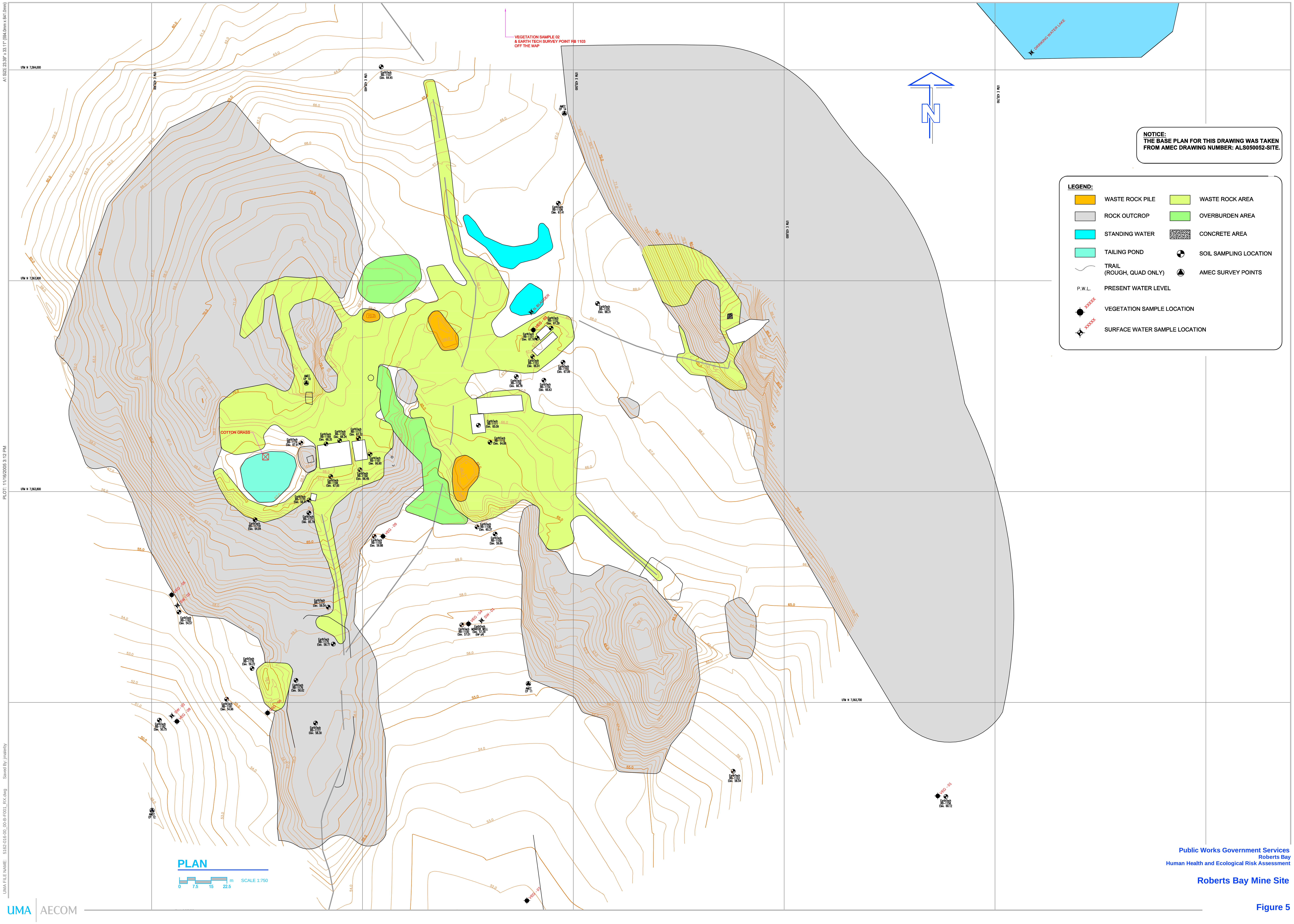
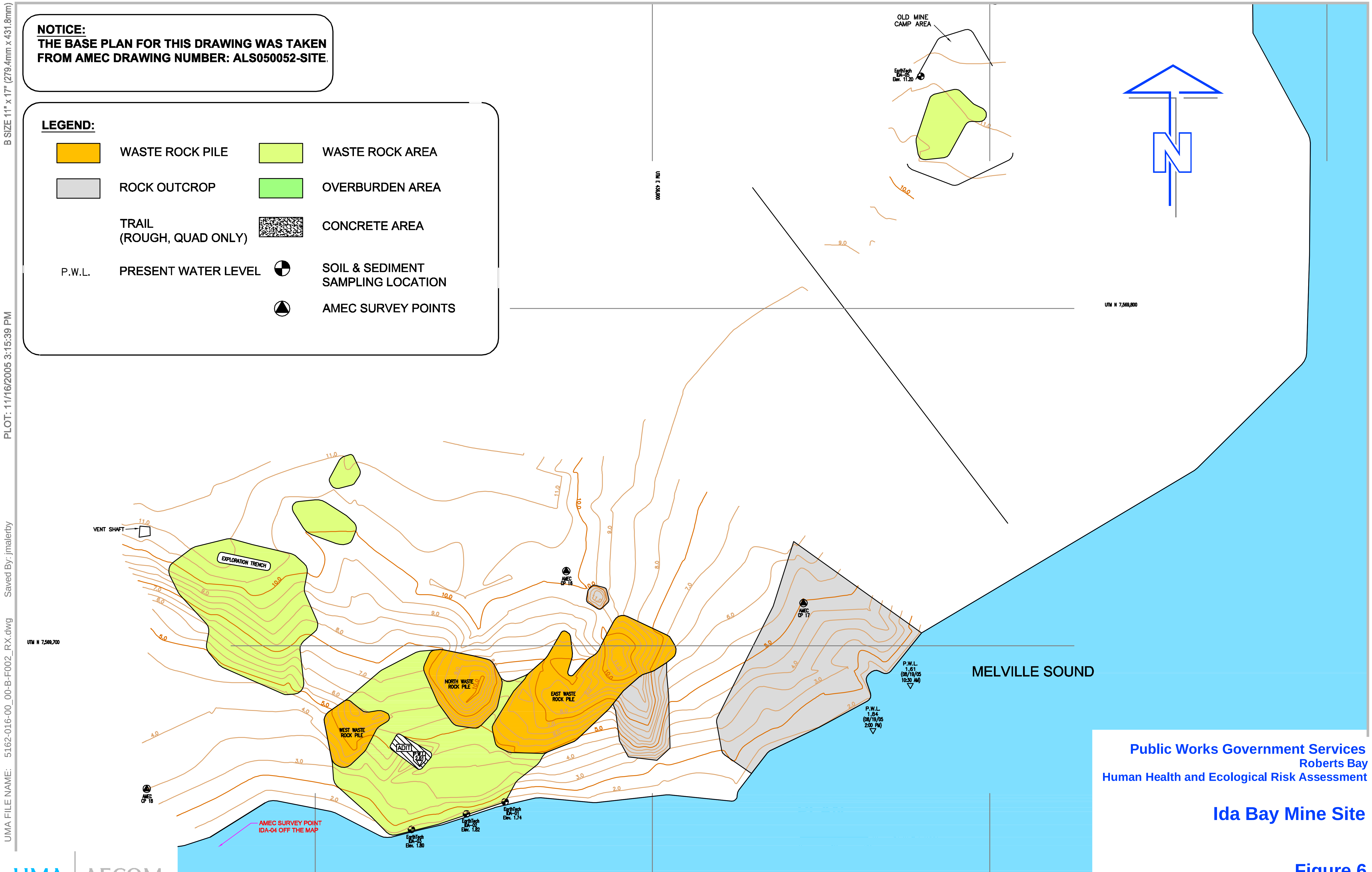

VEGETATION SAMPLE 02
& EARTH TECH SURVEY POINT RB 1103
OFF THE MAP
DRINKING WATER LAKE
N
NOTICE:
THE BASE PLAN FOR THIS DRAWING WAS TAKEN FROM AMEC DRAWING NUMBER: ALS050052-SITE.
LEGEND:
WASTE ROCK PILE
WASTE ROCK AREA
ROCK OUTCROP
OVERBURDEN AREA
STANDING WATER
CONCRETE AREA
TAILING POND
SOIL SAMPLING LOCATION
TRAIL (ROUGH, QUAD ONLY)
AMEC SURVEY POINTS
P.W.L.
PRESENT WATER LEVEL
VEGETATION SAMPLE LOCATION
SURFACE WATER SAMPLE LOCATION
COTTON GRASS
PLAN
SCALE 1:750
0 7.5 15 22.5 m
Public Works Government Services
Roberts Bay
Human Health and Ecological Risk Assessment
Roberts Bay Mine Site
UMA AECOM

Figure 5




**Public Works Government Services**
**Roberts Bay**
**Human Health and Ecological Risk Assessment**

## Ida Bay Mine Site

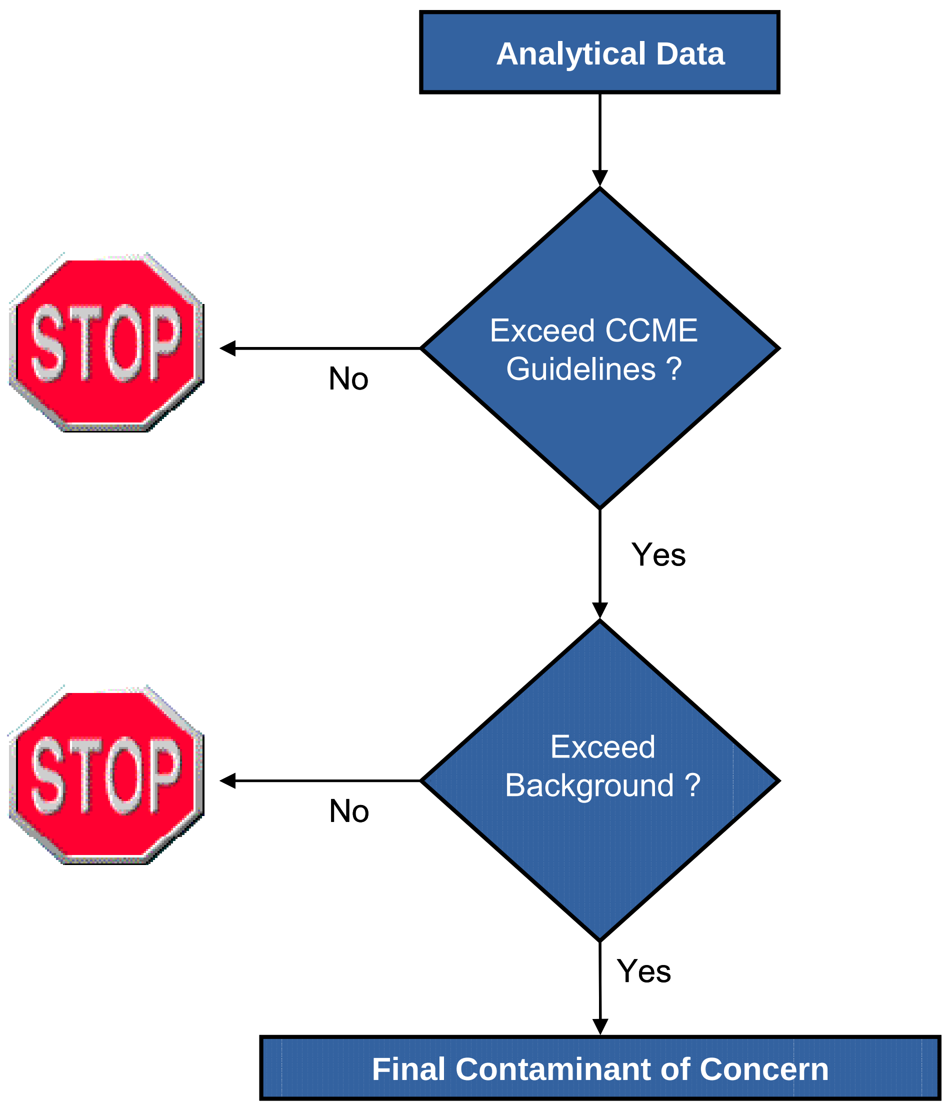
UMA | AECOM

**Figure 6**

### 2.4.3 Screening Process

The process undertaken to screen potential chemicals of concern into the risk assessment is portrayed in Figure 7. The results from the screening process are summarized for the soil, sediment and water media in Tables 2, 3 and 4, respectively. After consideration for regional background conditions and professional opinion, the final list of contaminants of concern are summarized at the end of Section 2.4. All regional background concentrations, in the aquatic media, have been obtained from RL&L/ Golder (2002).

**Figure 7: Screening Process for Identifying Potential Chemicals of Concern**



UMA | AECOM

| Table 2<br>Soil Screening Table for Roberts Bay Human Health and Ecological Risk Assessment | | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | No. of Samples | No. Exceeding CCME Ecological Guideline | No. Exceeding CCME Human Health Guideline | Average Soil Background (µg/g) | 95th Percentile (µg/g) | Geometric Mean (µg/g) | Areas where concentrations exceed: |
| **Metals** | | | | | | | |
| Arsenic | 50 | 17 | 12 | 1.3 | 168.5 | 6.2 | barrel storage, garbage mill assay building (highest) |
| Barium | 50 | 8 | n/a | 70.5 | 1136 | 122 | barrel storage, garage, mill assay building |
| Chromium | 50 | 17 | 0 | 27.8 | 105.4 | 26.2 | garage associated with PHC, mill assay building, barrel storage |
| Copper | 50 | 22 | 0 | 20.5 | 239 | 37 | garage associated with PHC, mill assay building, barrel storage |
| Lead | 50 | 8 | 14 | 7.75 | 399.3 | 29.3 | highest from mill assay building, barrel storage and garage |
| Nickel | 50 | 17 | n/a | 16 | 162 | 25 | highest from mill assay building, barrel storage and garage |
| Selenium | 50 | 3 | 0 | 0.1 | 0.9 | 0.1 | mill assay building and garage (waste oil) |
| Vanadium | 50 | 1 | n/a | 38.5 | 105 | 40 | garage - associated with waste oil? |
| Zinc | 50 | 10 | n/a | 45 | 358 | 81 | highest from mill assay building, barrel storage and garage |
| **Hydrocarbons** | | | | | | | |
| F1-VPH (C6-C10) | 56 | 4 | n/a | nil | 245.5 | 7.7 | fuel bladder area |
| F2-EPH (C10-C16) | 56 | 15 | n/a | nil | 14150.0 | 32.5 | fuel bladder, mill assay building, garage |
| F3-EPH (C16-C34) | 56 | 18 | n/a | nil | 8535.0 | 132.6 | fuel bladder, garage, mill assay building |
| F4-EPH (C34-C50) | 56 | 3 | n/a | nil | 2285.0 | 23.9 | garage - waste oil? |

The complete collated dataset is tabulated in Table B1, Appendix B

UMA | AECOM

**Table 3**

**Sediment Screening Table for Roberts Bay Human Health and Ecological Risk Assessment**

| Parameter | No. of Samples | No. Exceeding CCME ISQG | No. Exceeding CCME PEL | Geometric Mean (µg/g) | 95th Percentile (µg/g) | Regional Lake Maximum (µg/g) | Little Roberts Lake Average (µg/g) | Pelvic Lake Average (µg/g) | Patch Lake Average (µg/g) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| **Metals** | | | | | | | | | | |
| Arsenic | 10 | 3 | 0 | 3.3 | 9.0 | 44 | 2.06 | 3.25 | 6.32 | Within regional background |
| Chromium | 10 | 7 | 0 | 45.4 | 67.2 | 132 | 62.9 | 74 | 99.3 | Within regional background |
| Copper | 10 | 4 | 0 | 25 | 35 | 64 | 23.3 | 32 | 35 | Within regional background |
| Lead | 10 | 1 | 0 | 9.4 | 38.2 | 14 | 6.52 | 9 | 10.8 | Elevated at Ida-1 only |

**Table 4**

**Water Screening Table for Roberts Bay Human Health and Ecological Risk Assessment**

| Parameter | No. of Samples | No. Exceeding CCME Drinking Water Guidelines | No. Exceeding CCME Aquatic Life Guidelines | Geometric Mean (mg/L) | 95th Percentile (mg/L) | Average Maximum Regional Lake (mg/L) | Average Median Regional Lake (mg/L) | Environments where concentrations exceed: |
|---|---|---|---|---|---|---|---|---|
| **Metals (total)** | | | | | | | | |
| Aluminum | 21 | n/a | 9 | 0.059 | 0.390 | 0.2877 | 0.1527 | Regional lakes, stream and standing water |
| Arsenic | 21 | 1 | 4 | 0.0017 | 0.020 | 0.0021 | 0.0009 | N bladder & tailing pond |
| Cadmium | 21 | 0 | 6 | 0.00016 | 0.0010 | 0.0001 | 0.0001 | Standing water bodies and Rescan 2003 background lake |
| Copper | 21 | 0 | 16 | 0.00484 | 0.0120 | 0.0027 | 0.0015 | Little Roberts and Roberts Lake drainage, stream, standing water |
| Iron | 21 | 9 | 9 | 0.1827 | 2.380 | 0.2700 | 0.1987 | Regional Lake, Roberts Lake, stream, standing water |
| Lead | 21 | 1 | 3 | 0.00062 | 0.0078 | 0.0032 | 0.0010 | tailing pond only |
| Manganese | 15 | 3 | n/a | 0.0139 | 0.1804 | 0.0187 | 0.0123 | standing water near fuel bladder and Robert |
| Selenium | 14 | 1 | 6 | 0.00072 | 0.0093 | 0.0018 | 0.0008 | Regional lakes, Roberts Lake, standing water (N. Bladder) |
| Silver | 21 | n/a | 4 | 0.00014 | 0.0005 | 0.0001 | 0.00002 | Rescan 2003 background lake, tailing pond and Ida adit |
| Sodium | 8 | 1 | n/a | 22 | 377 | 0.271 | 0.0268 | standing water (N. Bladder) |
| Zinc | 21 | 0 | 2 | 0.0060 | 0.0360 | 0.0043 | 0.0025 | Roberts Lake mine adit only |
| **Metals (dissolved)** | | | | | | | | |
| Aluminum | 8 | n/a | 0 | 0.0303 | 0.0685 | 0.0597 | 0.0492 | Regional lake maximum exceeds |
| Copper | 8 | 0 | 5 | 0.0020 | 0.0042 | 0.0017 | 0.0014 | Roberts Lake, stream, standing water |
| Iron | 8 | 1 | 1 | 0.0499 | 1.1915 | 0.0750 | 0.0627 | N. Bladder only |
| Selenium | 8 | 1 | 2 | 0.0010 | 0.0119 | 0.0007 | 0.0005 | Regional Lake stream, standing water (N. Bladder) |
| Silver | 8 | n/a | 4 | 0.0002 | 0.0005 | 0.0001 | 0.00004 | stream and standing water |

Within the fine waste rock "soil media", the concentrations of arsenic and lead in the immediate foot print of the Roberts Bay mine workings and associated facilities frequently exceed the CCME soil quality guidelines for protection of human health ($SQG_{HH}$) in residential parkland settings. Although the early analytical record suffers from high method detection limits, the tailing material also contains lead and possibly other elements that exceed $SQG_{HH}$. Herein, the tailing material will be assumed to be equivalent to the fine fraction of waste rock. These $SQG_{HH}$ for arsenic and lead are based primarily on the incidental ingestion of soil. No other soil contaminant has been screened into the human health risk component since no other CCME $SQG_{HH}$ were identified in Table 2. Soil metal concentrations, in general, are high at the mill assay building, barrel storage area, tailings and garage. Additional trace metals exceeding the CCME soil quality ecological guidelines include barium, chromium, copper, nickel and zinc (Table 2). Selenium concentrations were slightly above CCME ecological guidelines in two samples from the mill assay building and one from the garage (likely associated with waste oil). The one sample from the garage also contains vanadium in excess of the applicable CCME ecological guideline.

Soil hydrocarbons (F1 through F4) concentrations in the area of the former fuel bladders and surface stained locations in the mill assay building and garage also exceed CCME Canada-Wide Standards designed for the protection of soil plants and invertebrates.

The marine sediment sample identified as Ida 1 contains lead above CCME marine interim sediment quality guidelines (ISQG). Additionally, all four marine sediment samples, including the background sample, contain copper in excess of the CCME marine ISQG. The copper concentrations in these marine sediments are similar to the freshwater sediments collected in Roberts Lake. The sediment copper concentrations cannot be attributed to the historical mining operation; rather, the concentrations reflect the natural background. Concentrations of chromium and less frequently, arsenic, in Roberts Lake sediment naturally exceed their representative CCME freshwater ISQGs. The regional database and background Roberts Lake sample reflect these natural concentrations.

In the aquatic environment, the selection of appropriate chemicals of concern is complicated by the fact that trace elements are ubiquitous in the environment and the method detection limits (MDLs) for cadmium and silver were too high to be useful in comparison to their respective aquatic life guidelines. Nevertheless, the record of trace elements exceeding their respective CCME guidelines is summarized as follows:

- Primary elements of concerns – copper, selenium and silver exceed their respective CCME freshwater guidelines in both total and dissolved form. Concentrations in standing bodies of water, and in the discharging stream were elevated above the concentrations found in Patch, Pelvic and Little Roberts Lake. Silver was the primary precious metal mined at the site and copper concentrations in the extracts from the waste rock (Rescan 2003) were elevated. Although selenium is not a major element is the waste rock extracts, the concentration in the standing water north of the fuel bladders exceeded the CCME drinking water guideline.

- Secondary elements of concern – total lead, cadmium, arsenic and zinc were found in excess of their respective CCME freshwater guidelines in the standing water within the tailing pond and adits. These elements were not found in excess of their applicable freshwater guidelines in any other surface ponds, discharge stream or receiving waters. Lead and arsenic are major contributing elements in the waste rock metal extract analysis, but the zinc and cadmium were rarely, if ever, detected in the Rescan (2003) analysis. The data indicates that migration of these elements in the aqueous media is limited, and exposure to the water in the adits and tailing pond may be controlled, or eliminated in the remedial plan for the site.

- Tertiary elements of concern – aluminum, iron, manganese and sodium were present above their respective CCME guidelines in various bodies of water, especially small isolated ponds. The isolated pond north of the fuel bladders contains elevated concentrations of iron, manganese and sodium. Total aluminum and iron were found in regional lakes and the Roberts Lake background site at concentrations in excess of their applicable CCME guidelines. These earth elements are not inherently toxic. The CCME iron, manganese and sodium drinking water guidelines are related to aesthetic objectives, rather than health based concerns. As such, these elements will not be included in the human health risk assessment.

The preliminary list of potential chemicals of concern to be included in the Human Health Risk Assessment are:

- Arsenic (soil exposure)
- Lead (soil exposure)
- Selenium (water ingestion)

The preliminary list of potential chemicals of concern to be included in the Ecological Risk Assessment are:

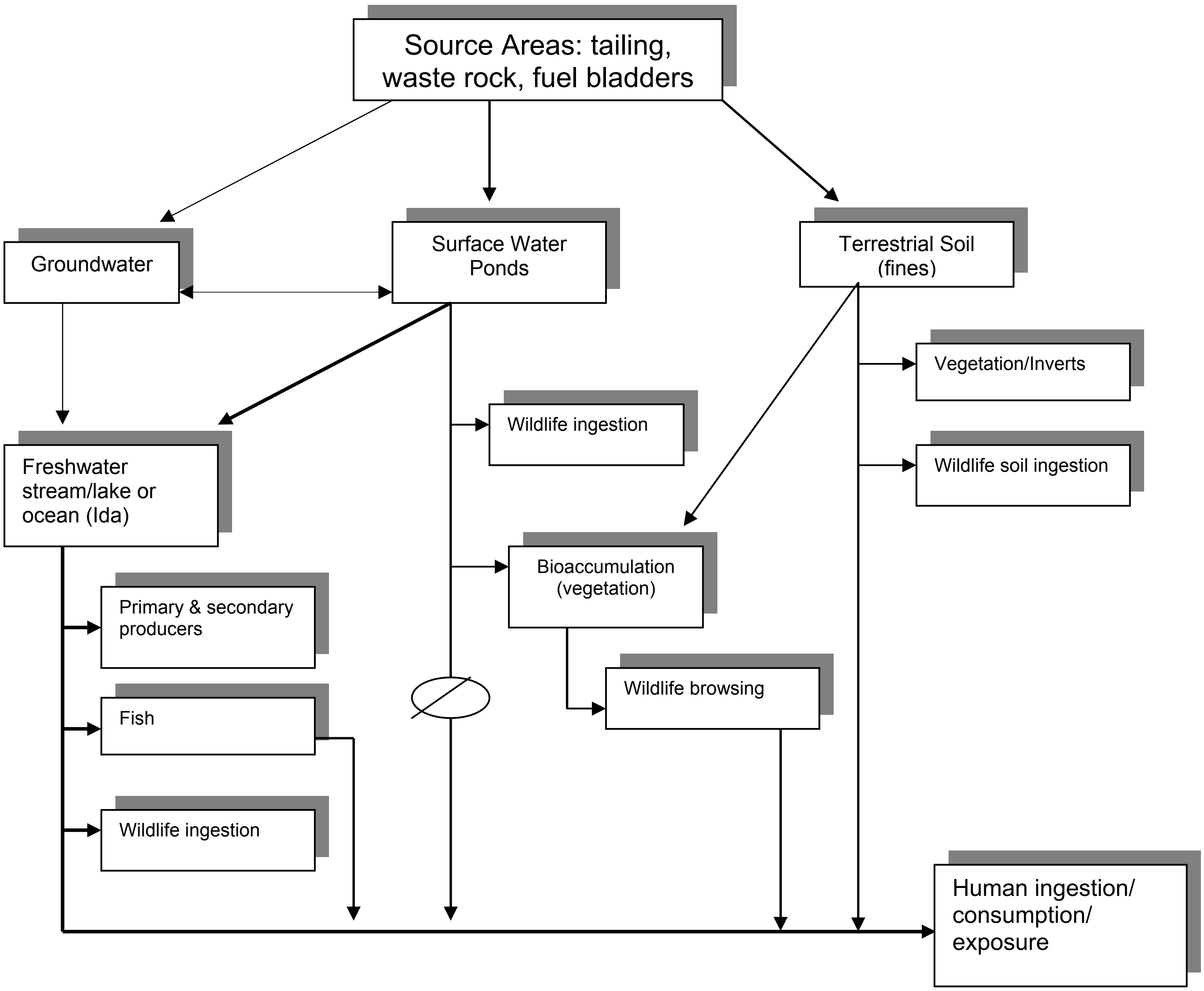
- Petroleum Hydrocarbons CCME F1 through F4 (soil contact)
- Arsenic (soil contact)
- Barium (soil exposure)
- Cadmium (water exposure)
- Chromium (soil contact)
- Copper (water and soil )
- Lead (soil contact)
- Nickel (soil contact)
- Selenium (water and soil)
- Silver (water)
- Vanadium (soil contact)
- Zinc (soil contact)

This list of potential chemicals of concern can be refined down further, depending on the completeness of the exposure pathways. Exposure pathways will be changed, depending on the actions taken during the remedial work on the site. The conceptual model portrays these exposure pathways in greater detail.

## 2.5 Preliminary Human Health and Ecological Conceptual Model

Figure 8 depicts the preliminary conceptual model with the all viable exposure pathways indicated. The conceptual model is modified from that presented in the earlier screening level assessment. The main difference is that the conceptual model herein will not consider exposure via inhalation. The local human receptor will be exposed to the contaminants of concern via ingestion of game, fish, surface water and incidental ingestion and dermal contact with soil. The break in the exposure pathway between the isolated pond water and human ingestion indicates that this pathway is expected to be eliminated through either remedial action or risk management. Additionally, humans visiting the site are not expected to use small isolated pockets of water for drinking water. The ecological risk assessment will consider receptors in the aquatic and terrestrial environments and will consider tertiary levels in the food chain. Specific details will be described with Sections 3.0 (Human Health) and 4.0 (Ecological).

**Figure 8: Preliminary Conceptual Model: Roberts Bay Mine**




**Aquatic Based Receptors**:

- Algae and Invertebrates
- Fish
- Pacific Loon (fish -> piscivore)

**Terrestrial Based Receptors**:

- Tundra vole (soil/water - - veg - ->herbivore)
- Arctic hare (soil/water - - > veg - -.>herbivore)
- Caribou (soil/water - - > veg - - > herbivore)
- Gyrfalcon (voles - - > predator)

# 3.0 Human Health Risk Assessment 3.0

### 3.1 Exposure Assessment

There are no communities near the Roberts Bay or Ida Bay sites. The closest community is Umingmaktok, which is approximately 70 km southwest of the sites. Industrial activities are proposed in the area (Doris North Project) and local Inuit will likely carry out traditional hunting and fishing in the area. The human exposure scenario will combine aspects of the conservative approaches taken in Jacques (2004) and SENES (2004) with the more realistic assumptions in Golder (2005). The following scenario will be evaluated in the human health risk assessment:

- Adult and child receptors residing on the site annually for periods of 30 days during the summer/fall
- Traditional land use activities include trapping Arctic hare, hunting caribou and fishing for Arctic char
- Drinking water will be collected from the discharging stream and/or Roberts Lake, but not from mine workings or standing bodies of water
- The family will primarily subsist off arctic char and lake trout caught in Roberts Lake for 30 days of the year with trapped Arctic hare providing only two of the thirty meals;
- Ingestion of caribou meat will be assumed for the other 335 days of the year;
- Incidental soil ingestion and dermal contact will be included and the toddler receptor will be assumed to be in contact with the soil twice as frequently as the adult
- No inhalation pathway will be assessed.

UMA recognizes that local community members will likely harvest Arctic char and dry the meat for year round consumption. However, more productive char runs are available closer to the two communities of Cambridge Bay and Umingmaktok. Therefore consumption of char and other fish from Roberts Lake would only occur during visits to the site.

Additionally, exposure through the inhalation of particulates has not been included in this HHRA. The affected area at Roberts Bay mine and Ida Bay deposit do not include extensive areas of fine grained material. The majority of the affected material is a relatively coarse grained material associated with waste rock or tailings.

#### 3.1.1 Exposure Estimate Equations

The generalized human health exposure equations are taken from Health Canada, September 2004. The equations were designed for preliminary quantitative human health risk assessments at federal contaminated sites. The human health exposure will be calculated based on the upper 95$^{th}$ percentile of each of the contaminant concentrations in the various media. Concentrations in food items will be obtained from baseline fish tissue data collected in support of the Doris North Project (RL&L/Golder Associates Ltd., November 2002). Concentrations in game meat will have to be estimated through published, or site-specific calculated bioconcentration factors.

**INGESTION OF CONTAMINATED DRINKING WATER**

$$\text{Dose (mg/kg/day)} = \frac{C_W \times IR_S \times AF_{GIT} \times D_1 \times D_2 \times D_3}{BW \times LE}$$ *Equation 1.0*

Where:

| | |
|---|---|
| $C_W$ | = concentration of contaminant in drinking water (mg/L) |
| $IR_S$ | = receptor water intake rate (L/d) |
| $AF_{GIT}$ | = absorption factor from the gastrointestinal tract (unitless) |
| $D_1$ | = days per week exposed/7 days |
| $D_2$ | = weeks per year exposed/52 weeks |
| $D_3$ | = total years exposed to site (to be employed for assessment of carcinogens only |
| BW | = body weight (kg) |
| LE | = life expectancy (yr) (to be employed for assessment of carcinogens only) |

**INGESTION OF CONTAMINATED PRODUCE, FISH, GAME OR OTHER FOOD**

$$\text{Dose(mg/kg/day)} = \frac{[\sum [C_{FoodI} \times IR_{Food i} \times RAF_{GUT} \times D_i]] \times D_2}{BW \times 365 \times LE}$$ *Equation 2.0*

Where:

| | |
|---|---|
| $C_{FoodI}$ | = concentration of contaminant in food I (mg/kg) |
| $IR_{Food}i$ | = receptor ingestion rate for food i (kg/d) |
| $RAF_{GITi}$ | = relative absorption factor from the gastrointestinal tract for contaminant *i* (unitless) |
| $D_i$ | = days per year in which game / fish are eaten (days/ 365 days) |
| $D_2$ | = total years exposed to site (to be employed for assessment of carcinogens only) |
| BW | = body weight (kg) |
| 365 | = total days per year (d/yr) |
| LE | = life expectancy (yr) (to be employed for assessment of carcinogens only) |

**DERMAL CONTACT WITH CONTAMINATED SOIL**

$$\text{Dose (mg/kg/day)} = \frac{(C_S \times SA_H \times SL_H) \times AF_{Skin} \times EF \times D_1 \times D_2 \times D_3}{BW \times LE}$$ *Equation 3.0*

Where:

| | |
|---|---|
| $C_S$ | = concentration of contaminant in soil (mg/kg) |
| $SA_H$ | = skin surface area exposed (cm2) |
| $SL_H$ | = soil loading to exposed skin (kg/cm2-event) |
| $AF_{Skin}$ | = dermal absorption factor (unitless) |
| EF | = exposure frequency (events/d) |
| $D_1$ | = days per week exposed/7 days |
| $D_2$ | = weeks per year exposed/52 weeks |
| $D_3$ | = total years exposed to site (to be employed for assessment of carcinogens only) |
| BW | = body weight (kg) |
| LE | = life expectancy (yr) (to be employed for assessment of carcinogens only) |

**INADVERTENT INGESTION OF CONTAMINATED SOIL**

$$\text{Dose (mg/kg/day)} = \frac{C_S \times IR_S \times AF_{GIT} \times D_1 \times D_2 \times D_3}{BW \times LE}$$

*Equation 4.0*

Where:

$C_s$ = concentration of contaminant in soil (mg/kg)
$IR_s$ = receptor soil ingestion rate (kg/d)
$AF_{GIT}$ = absorption factor from the gastrointestinal tract (unitless)
$D_1$ = days per week exposed/7 days
$D_2$ = weeks per year exposed/52 weeks
$D_3$ = total years exposed to site (to be employed for assessment of carcinogens only)
BW = body weight (kg)
LE = life expectancy (yr) (to be employed for assessment of carcinogens only)

### 3.1.2 Receptor Characteristics

The receptor specific input parameters were based on guidance provided by Health Canada (September 2004). Although the Health Canada (September 2004) publication provides parameter estimates for infants, toddlers, child, teen, adult and construction worker, this risk assessment calculated risk quotients for the toddler and adult receptors only. The toddler provided a worst case for incidental soil ingestion and the adult has the highest food ingestion rates and cancer risks can be estimated. Site-specific modifications were made to account for the infrequent duration of exposure and Inuit specific food ingestion rates for game and fish. The receptor parameters are summarized in Table 5 and the exposure duration parameters are tabulated in Table 6. Chemical specific parameters related to bioavailability are presented in Table 7.

**Table 5**
**Human Receptor Characteristics**

| Parameters | Toddler | Adult | Source |
|---|---|---|---|
| Age | 7 mo. – 4 yr | > 20 yr | Health Canada, 1994 |
| Body weight BW (kg) | 16.5 | 70.7 | Richardson, 1997 |
| Soil ingestion rate (g/day) | 0.08 | 0.02 | Richardson, 1997 |
| Water ingestion rate (L/d) | 0.6 | 1.5 | Richardson, 1997 |
| Game ingestion rate (g/day) | 85 | 270 | Richardson, 1997 |
| †Fish ingestion rate (g/day) | 95 | 220 | Richardson, 1997 |
| Skin surface areas ($cm^2$) | | | Richardson, 1997 |
| Hands | 430 | 890 | |
| Arms | 890 | 2500 | |
| Legs | 1690 | 5720 | |
| Soil loading to exposed skin (g/cm2/event) | | | Kissel et al., 1996, 1998 |
| Hands | $1 \times 10^{-4}$ | $1 \times 10^{-4}$ | |
| Other surfaces | $1 \times 10^{-5}$ | $1 \times 10^{-5}$ | |

†- maximum fish ingestion rates from studies of N.W.T. native population range between 60 – 100 grams per day (Chan and Solomon, 2005). Richardson's rates are likely over estimates, nevertheless they are used herein.

**Table 6**
**Human Exposure Duration Parameters (Site-Specific to Roberts Bay)**

| Parameters | Toddler | Adult | Source |
|---|---|---|---|
| D1 – days per week exposed | 7 days | 7 days | Site-Specific |
| D2 – weeks per year exposed | 4 weeks | 4 weeks | Site-Specific |
| † D3 – total years camping at site | na | 45 yr | Site-Specific |
| † Life expectancy (years) | na | 75 yrs | Health Canada, 2004 |
| EF – exposure frequency per day (dermal contact ) | 2 | 1 | Health Canada, 2004 & Site-Specific |

† - used for calculation of incremental lifetime cancer risk (ILCR). Health Canada recommends an exposure frequency for dermal contact of once per day for toddler and adults. Because we are modelling a camping scenario, UMA has increased the toddler EF to twice per day.

**Table 7**
**Human Health Chemical Specific Bioavailability Parameters**

| Parameters | AFGIT (water) | AFGUT (soil) | †AFskin | RAFGUT (food) | †BTF |
|---|---|---|---|---|---|
| Arsenic | 100% | 100% | 0.03 | 100% | 0.002 |
| Lead | 100% | 100% | 0.006 | 100% | 0.0004 |
| Selenium | 100% | 100% | 0.002 | 100% | 0.1 |

† dermal absorption factor ($AF_{skin}$) from Health Canada, September 2004 (Table 6). † Biotransfer factors (BTFs) from individual references in RAIS, 2005.

Tissue concentration data is not available for the game (Arctic hare and caribou). In order to quantify the chemical exposure related to the ingestion of game, the tissue concentration for these food items are estimated using the food ingestion component of the wildlife exposure model (Section 4.0) multiplied by the biotransfer factors (BTFs) identified in Table 7. Guidance on this approach is available on the Risk Assessment Information System (RAIS, 2005).

$$C_{tissue} = BTF \times (FIR \times C_{food} + WIR \times C_{water}) \qquad \textit{Equation 5.0}$$

Where:
$C_{tissue}$ = concentration of contaminant in game meat (µg/g)
FIR = game food ingestion rate (mg/kg bw/d)
WIR = water ingestion rate (L/kg bw/d)
$C_{food}$ = concentration of contaminant in vegetation (µg/g)
$C_{water}$ = concentration of contaminant in water – geometric mean (mg/L)

The site-specific concentrations for all media are summarized in Table 8.

**Table 8**
**Input Concentrations for Human Health Contaminants of Concern**

| C of C | (b) Water 95th % mg/L | Soil 95th % mg/kg | Vegetation 95th % µg/g | (a) max fish tissue µg/g | (c) caribou tissue µg/g | (c) hare tissue µg/g |
|---|---|---|---|---|---|---|
| Arsenic | 0.0034 | 168.5 | 0.5 | 0.42 | 0.0003 | 0.0007 |
| Lead | 0.0047 | 399.3 | 2.65 | 0.13 | 0.0002 | 0.0004 |
| Selenium | 0.0026 | 0.9 | 0.1 | 1.50 | 0.0005 | 0.0011 |

(a) Fish tissue concentrations calculated as the average maximum from baseline data in Patch, Pelvic and Little Roberts Lakes (RL&L/Golder, 2002).

(b) The water concentrations are calculated as the upper 95% of the maximum total concentrations from the three regional lakes (RL&L/Golder, 2002), Rescan (2003) background lake, Earth Tech (2005) total concentrations from Roberts Lake and the main discharge stream. The calculated 95th percentile is based on setting non-detects to the MDL, rather than ½ MDL.

(c) caribou and hare tissue concentrations calculated based on food + water ingestion dose estimates multiplied by biotransfer factors published in RAIS, 2005.

### 3.2 Toxicity Assessment: Selection of Toxicity Reference Values

Exposure to metals is conventionally assessed against toxicity benchmarks. Toxicity is the potential of a chemical to cause some type of damage, either permanent or temporary, to the structure or functioning of any part of the body. The toxicity depends on the amount of the chemical taken into the body (generally termed the intake or dose) and the length of time a person is exposed. Every chemical has a specific dose and duration of exposure that is necessary to produce a toxic effect in humans. Toxicity assessments generally involve the evaluation of scientific studies, based either on laboratory animal tests or on workplace exposure investigations, by a number of experienced scientists in a wide range of scientific disciplines in order to determine the maximum dose that a human can be exposed to without having an adverse health effect. Levels that are likely to result in no appreciable risks or measurable adverse effects are known as exposure limits.

Exposure limits are derived for two different classes of chemicals: non-carcinogens and carcinogens. For non-carcinogens, scientists generally agree that there is a level (threshold) below which no adverse effects would be measurable or expected to occur. These exposure limits are generally called reference doses (RfDs), tolerable daily intakes (TDIs) or acceptable daily intakes (ADIs) and are generally derived by regulatory agencies such as Health Canada and the United States Environmental Protection Agency (U.S. EPA). These exposure limits are usually expressed as the quantity of a chemical per unit body weight per unit time (mg/(kg body weight d)). For carcinogenic chemicals which act on the functions of genetic material and cell reproduction it is assumed that any exposure will cause some risk of developing cancer. Exposure limits for carcinogens are generally expressed as slope factors in units of risk per mg/(kg body weight day$^{-1}$). The risk of incurring cancer is estimated by multiplying the estimated exposure or dose by the slope factor.

Exposure limits often take into consideration sensitive individuals in the public using the most sensitive endpoint. Additionally, these factors involve the incorporation of "safety factors" by regulatory agencies to provide additional protection for members of the public. As discussed above, there are several regulatory sources that report exposure limits. Some of the most used sources are Health Canada, U.S. EPA

Integrated Risk Information System (IRIS) database; U.S. EPA health assessment reports (HEAST), U.S. EPA National Center for Environmental Assessment (NCEA), the World Health Organization (WHO) and the Agency for Toxic Substances and Disease Registry (ATSDR). Given that this assessment is within a Canadian jurisdiction, exposure limits provided by Health Canada were selected for evaluation of the health impacts on people. The Toxicology Evaluation Section of the Health Products and Food Branch of Health Canada has published Tolerable Daily Intakes for a number of trace elements found in foodstuff. These values were selected for use in this assessment as the major pathways of exposure to people involve the consumption of traditional foodstuffs. In addition, the U.S. EPA IRIS database is another major source for exposure limits and these values are also provided in this report. Toxicological benchmarks from both Health Canada and the U.S. EPA are summarized in Table 9. As seen from the table, arsenic has both carcinogenic and non-carcinogenic properties. The table also provides a biological endpoint or health effect for which each of these numbers is based.

**Table 9**

**Human Health Toxicity Reference Values and Cancer Slope Factors**

| C of C | (c) Health Canada Tolerable Daily Intake (mg/ kg day$^{-1}$) | (c) Health Canada Oral Slope Factor (risk/mg/kg day$^{-1}$) | (c) Health Canada Oral DW Slope Factor (risk/mg/kg day$^{-1}$) | (b)US EPA Reference dose (RfC) (mg/ kg day$^{-1}$) | Health Effect |
|---|---|---|---|---|---|
| Arsenic | 0.002 (a) | 2.8 | 1.7 | 0.0003 | Skin cancer (dermal and oral) Hyperpigmentation, keratosis and vascular complications (non-cancer) |
| Lead | 0.0036 | | | | Safe blood levels in children (< 10 µg/dL) |
| Selenium | | | | 0.005 | Clinical selenoisis |

(a) Health Canada food directorate. DW = drinking water slope factor (b) US EPA Integrated Research Information System) IRIS, available online at http://www.epa.gov/iris/. (c) Health Canada, 1996.

## 3.3 Risk Characterization

### 3.3.1 Non-Cancer Effects

For many non-carcinogenic effects, protective biological mechanisms must be overcome before an adverse effect is manifested from exposure to the contaminant. This is known as a "threshold" concept. A reference dose (RfD) is the value most often used in the evaluation of non-carcinogenic effects. Reference doses are discussed above.

For non-carcinogenic contaminants, the hazard quotient (HQ) is defined as follows (Health Canada, September 2004):

$$HQ = \frac{D_o}{RfD_o} + \frac{D_d}{RfD_d} \qquad \text{Equation 6.0}$$

Where:

| | | |
|---|---|---|
| $D_o$ | = | Dose due to oral (ingestion of water, soil and dietary items) exposure (mg/(kg d)) |
| $D_d$ | = | Dose due to dermal exposure (mg/(kg d)) |
| $RfD_o$ | = | Reference Dose for oral exposure (mg/(kg d)) |
| $RfD_d$ | = | Reference Dose for dermal exposure (mg/(kg d)) (assumed equal to $RfD_o$) |

For contaminants with non-carcinogenic effects, the predicted doses would be compared to the RfD or Tolerable Daily Intake (TDI) to derive a HQ for each chemical of concern. In general the exceedance of a reference dose does not mean that an effect will occur, but rather, that there is an increased risk of an adverse effect. In preliminary quantitative risk assessments, Health Canada suggests that 20% of the dose, or a hazard quotient of 0.2, is considered to be acceptable exposure. The remaining 80% "allowable" exposure is assumed to results from a multitude of sources, including food. Because this HHRA incorporated multiple exposure pathways, including partial background exposure, an HQ value of 50% was considered an appropriate point of comparison. This was based entirely on professional judgement.

The assessment discussed above was based on the upper 95$^{th}$ percentile measured, or modelled, concentrations in the various environmental media. In the soil media, the upper 95$^{th}$ percentile actually represents the fine material associated with the waste rock foundations within close proximity of the former tailing pond, mill, assay lab and garage. Even with this conservative model, the non-carcinogenic hazard quotients (HQs) are two to three orders of magnitude below acceptable limits (Table 10).

**Table 10**

**Estimated Hazard Quotients for Adult and Toddler Receptors**

| Chemical of Concern | Receptor | Upper 95$^{th}$ % HQ |
|---|---|---|
| Arsenic | Adult camper | $6.3 \times 10^{-4}$ |
| | Toddler camper | $2.0 \times 10^{-3}$ |
| Lead | Adult camper | $1.6 \times 10^{-4}$ |
| | Toddler camper | $4.7 \times 10^{-4}$ |
| Selenium | Adult camper | $2.1 \times 10^{-4}$ |
| | Toddler camper | $2.2 \times 10^{-4}$ |

### 3.3.2 Cancer Effects

The calculation of incremental lifetime cancer risk is shown in Equation 7.0 (Health Canada September 2004). Oral dose includes ingestion of drinking water, soil and game. The results of the assessment of carcinogenic lifetime risk is presented in Table 11.

$$Risk = (D_o \times SF_o + D_d \times SF_d) \times \frac{ED}{L}$$ *Equation 7.0*

Where:

| | | |
|---|---|---|
| *Risk* | = | risk of cancer effects {-} |
| $D_o$ | = | dose - oral pathway {mg/kg d)] |
| $D_d$ | = | dose – dermal pathway {mg/kg d)] |
| $SF_o$ | = | Slope Factor – oral pathway $\{(mg/(kg\ d))^{-1}\}$ (see Table 9) |
| $SF_d$ | = | Slope Factor – dermal pathway $\{(mg/(kg\ d))^{-1}\}$ (assumed to equal $SF_o$) |
| *ED* | = | exposure duration {yr} (see Table 6). |
| *L* | = | lifetime {yr} (assumed to be 75 for adult) |

Because slope factors have not been specifically developed for dermal contact, oral slope factors are assumed to be a reasonable surrogate for the dermal exposure.

**Table 11**
**Estimated Incremental Lifetime Cancer Risk Due to Exposure to Arsenic**

| Receptor | Based on upper 95$^{th}$ % |
|---|---|
| Adult camper | $2.6 \times 10^{-6}$ |

Health Canada (2003) states that cancer risks below $1 \times 10^{-5}$ are deemed to be "essentially negligible." For this assessment the potential incremental lifetime cancer risk due to the exposure to arsenic is $2.6 \times 10^{-6}$. This estimate is below the Health Canada acceptable level and is therefore not expected to be a concern. The risk levels associated with the carcinogenic effects (skin lesions) of background exposure (across Canada) to arsenic range from $7 \times 10^{-4}$ to $1 \times 10^{-3}$ for an adult. The estimated risk to arsenic at Roberts and Ida Bay is lower than a general Canadian background because the model does not account for lifetime background exposures in other food items and community drinking water. Despite this lack of background exposure, significant incremental risk for skin tumours, or other forms of cancer related to exposure to arsenic at Roberts and Ida Bay mines is considered to be negligible.

### 3.4 Human Health RA Uncertainty Analysis

Uncertainty arises from a lack of available knowledge and the inherently random natural variability called "stochasticity". Many aspects of uncertainty, whether originating from knowledge gaps or natural stochasticity, can be defined by probability distributions functions (PDFs). A quantitative probabilistic risk assessment would assign PDFs to key parameters in both the exposure and effect assessments and would result in a "forecasted" probabilistic endpoint, such as the probability of adverse effects on the assessment endpoint species. Probabilistic risk assessments linked with decision tree analysis can be powerful tools assisting decision makers on remedial actions. This uncertainty analysis is not intended as a quantitative assessment (*i.e.* assigning probability distribution functions to uncertain parameters), but rather a qualitative acknowledgement of the uncertainties present in the Human Health Risk Assessment (HHRA).

The sources of uncertainty in this HHRA are discussed in the following sections.

### 3.4.1 Analytical Uncertainty

Water, soil, plant and fish tissue concentrations of the various potential chemicals of concern are all sources of uncertain variability. A significant proportion of the analytical data presented herein was obtained from historical reports and regional data collected in support of the Doris North Project. The field collection methods and analysis techniques may not be comparable, especially from historical data dating back to the mid 1990's.

An important uncertainty in this assessment is associated with estimates of concentrations of contaminants in game using biotransfer factors (BTFs). Clearly, these contribute to uncertainties in the estimates of exposure. Transfer factors are highly dependent on the form of a contaminant (e.g. dissolved in water, bound in an inorganic complex). It is unlikely the form of the contaminants at Roberts and Ida Bay are similar to the conditions present in the derivation of biotransfer factors. The use of the BTF assumes that the wildlife species is receiving a steady intake of the contaminants and that an equilibrium condition has developed between the concentrations in the food/ water and in the game tissue. This is a conservative assumption.

### 3.4.2 Exposure Uncertainty

The characteristics of game, fish and water consumption of community members likely to visit Roberts and Ida Bay were based on conservative assumptions for behaviour and human characteristics obtained from Richardson,1997. Recently published (Chan and Solomon, 2005) fish consumption rates for a variety of Northern communities are lower than those stated in Richardson, 1997. The simplified consumption scenarios used in the HHRA are not reflective of real consumption patterns and are not designed to assess overall community health risks. The scenarios are used to identify increased health risk specifically related to potential exposure to Roberts Bay and Ida Bay.

### 3.4.3 Toxicity Uncertainty

Another area of uncertainty is the use of a single value for toxicity. Slope factors are selected to be very protective. The slope factor for arsenic used in the human health assessment represents risk from upper bound ($95^{th}$ percentile) dose-response estimates. Reference doses for non-carcinogenic contaminants represent an exposure day-after-day for a lifetime. The use of an upper bound for the toxicity values ensures that the risk to humans is not underestimated. No adjustments were made for bioavailability, and this would tend to overestimate the exposure.

Another area of uncertainty in the risk assessment is the effect of multiple contaminants. When dealing with toxic chemicals, there is potential interaction with other chemicals that may be found at the same location. Synergism, potentiation, antagonism or additivity of toxic effects may occur in the environment. A quantitative assessment of these interactions is outside the scope of this study and, in any event, would be constrained, as there is not an adequate base of toxicological evidence to quantify these interactions. This may result in an underestimate of the risk for some contaminants. However, additivity or synergistic effects are considered important primarily for suites of contaminants that have a shared mode of toxicological action and/or site of activity. Since this is not the case for the trace elements examined within the HHRA , neglecting interactive effects provides a reasonable estimate of risk.

In summary, considering all these uncertainties, it is likely that the risks calculated in this assessment are overestimates of actual exposures at these remote sites.

# 4.0 Ecological Risk Assessment 4.0

### 4.1 Selection of Ecological Receptors

The assessment and measurement endpoints for the ecological risk assessment (EcoRA) are explicitly defined in Table 12. Because it is not practical, or possible to evaluate all possible aquatic and wildlife receptors, a limited number of representative receptors were chosen. The EcoRA addresses ecologically and socio-economically important receptors in the aquatic and terrestrial environments. These wildlife receptors were discussed in Section 2.1. This list of wildlife receptors captures different consumer levels within the food chain and captures wildlife that subsist on both terrestrial based and aquatic based food.

**Table 12**
**EcoRA Receptors, Assessment and Measurements Endpoints**

| Receptors | Assessment Endpoint | Measurement Endpoint |
|---|---|---|
| Red backed or tundra vole | Ensure no chronic adverse impacts on individuals browsing within affected areas. | Wildlife ingestion models with comparison to a toxicological benchmark dose and calculation of tissue residues. |
| Bathurst caribou and Arctic hare (included to calculate tissue concentrations for Human Health RA) | Ensure no chronic adverse impacts on individual caribou and hare possibly visiting the area. | Wildlife ingestion models with comparison to a toxicological benchmark dose and calculation of tissue residues. |
| Gyrfalcon (prey upon abundant voles) | Ensure no chronic adverse impacts on individuals preying upon resident voles. | Wildlife ingestion models with comparison to a toxicological benchmark dose. |
| Pacific loon (included as fish eating avian) | Ensure no chronic adverse impacts on individuals preying upon resident fish. | Wildlife ingestion models with comparison to a toxicological benchmark dose . |
| Aquatic life – Arctic char | Protection of all aquatic life community including periphyton, invertebrates and fish. | Screening monitoring data against chronic benchmarks. |

## 4.2 Exposure Assessment

Wildlife Exposure Model

The wildlife ingestion model estimates the average daily dose over the life time of the animal and takes the following form (Suter et al. 2000):

$$E_j = SUF \times \frac{A}{HR} \sum_{i=1}^{m} P_i \times AE_i \left( I_i \times C_{ij} \right)$$ *Equation 8.0*

Where

| | | |
|---|---|---|
| $E_j$ | = | oral exposure to contaminant (j) (mg/kg/day) |
| *m* | = | number of ingested media (i) (e.g. food, water soil) |
| $I_j$ | = | ingestion rate for media (i) (kg/kg body weight or L/kg body weight) - in US EPA, 1993 |
| $P_i$ | = | proportion of media (i) consumed (unitless) – in US EPA, 1993 or assumed |
| $C_{ij}$ | = | concentration of contaminant (j) in media (i) (mg/kg or mg/L) |
| *A* | = | area contaminated material (ha) |
| *HR* | = | home range of assessment species (ha) – in US EPA, 1993 |
| *SUF* | = | seasonal use factor - percent time spent feeding at site |
| $AE_i$ | = | assimilation efficiency – assume 100% for preliminary quantitative ERA |

Food and water consumption rates were estimated based on formula that link metabolic requirements to body weights (bw). The equations for food and water rates were developed by Nagy (1987) and Calder and Braun (1983), respectively. The general form of the equations are as follows:

$$I_{ff} = \frac{coeff\,(BW)^{\exp} \times 1/(1 - WC)}{BW}$$

*Equation 9.0*

$$I_w = \frac{coeff\,(BW)^{\exp}}{BW}$$

*Equation 10.0*

Where

| | | |
|---|---|---|
| $I_{ff}$ | = | total fresh food ingestion rate (kg food wet weight/ kg body weight/day) |
| $I_w$ | = | water ingestion rate (L/ kg body weight/day) |
| *BW* | = | body weight (kg) |
| coeff | = | slope coefficient - specific to avian and mammalian feeding guild |
| exp | = | exponent - specific to avian and mammalian feeding guild |
| *WC* | = | percent water content of food item (Sample et al., 1997) |
| | | *Fish = 80%* |
| | | *Small mammals = 68%* |
| | | *Vegetation: Dicotes (leaves) = 85%; Berries = 77%; Seeds = 10%; dry grass = 7%; use* ***50%*** |

The physiological parameter assumptions for each of the ecological receptors are presented in Table 13 and the point estimates for the various exposure media are presented in Table 14.

| Table 13<br>Wildlife Receptor Exposure Parameters | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wildlife Receptor | (f)Body weight | Water ingestion rate ($I_w$) | Trophic group | Food ingestion rate ($I_{ff}$) | Soil ingestion rate % of food rate | HR (ha) | SUF (% ) |
| Tundra vole | 0.05 kg | 0.133 | herbivore | 0.22 | 2.4% (a) | 0.01(c) | 100 |
| Arctic hare | 5.5 kg | 0.083 | herbivore | 0.11 | 6.3% (b) | 9.6 (d) | 100 |
| Caribou | 110 kg | 0.062 | herbivore | 0.05 | 1.5% (a) | > 500 (e) | 5 |
| Gyrfalcon | 0.8 kg | 0.063 | carnivore | 0.20 | nil | na | 30 |
| Pacific loon | 4 kg | 0.037 | piscivore | 0.18 | nil | na | 30 |

(a) Beyer et al., 1994 (b) Authur & Gates, 1988 using the jackrabbit as a surrogate (c) US EPA, 1993 – using smallest home range from surrogate prairie and meadow voles (d) calculated based on McNabb, 1963 – cited in Sample et al., 1997 (e) estimated from literature and Doris North Project EIA supporting documents. "na" – not applicable – falcon and loon are assumed to ingest voles and fish caught exclusively at the site and Roberts Lake, respectively. (f) body weights obtained from online searches and a variety of sources: Silva & Downing (1995) – hare & vole; Hurbert & Associates (2002) caribou and Ehrlich et al. (1988) – gyrfalcon and loon.

| Table 14<br>Input Concentrations for Ecological Contaminants of Concern | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C of C | (a)Site Water Geomean mg/L | (a)Site Water $95^{th}$ % mg/L | (b)Soil $95^{th}$ % mg/kg | (b)Soil Geomean mg/kg | Vegetation $95^{th}$ % µg/g | Sediment $95^{th}$ % µg/g | max fish tissue µg/g | (d)vole tissue µg/g |
| Arsenic | 0.0017 | 0.020 | 168.5 | 0.5 | 3.2 | 9.0 | 0.42 | 1.2 |
| Barium | 0.0278 | 0.160 | 1136 | 122 | 69.2 | 128 | 1.44 | 70 |
| Cadmium | 0.0002 | 0.0010 | 5.3 | 0.5 | 1.05 | 0.25 | 0.05 | 0.6 |
| Chromium | 0.0016 | 0.007 | 105.4 | 26.2 | 7.0 | 67.2 | 1.44 | 9.3 |
| Copper | 0.0048 | 0.012 | 239 | 37 | 7.92 | 35 | 1.43 | 26 |
| Lead | 0.0047 | 0.0078 | 399.3 | 2.65 | 9.52 | 38.2 | 0.13 | 12 |
| Nickel | 0.0139 | 0.0124 | 162 | 25 | 4.28 | 34 | 2.42 | 8.4 |
| Selenium | 0.0007 | 0.0093 | 0.9 | 0.1 | 0.1 | 0.4 | 1.50 | 0.6 |
| Silver | 0.0001 | 0.0005 | 708.6 | 8.4 | 0.05 | 3.0 | 0.29 | 1.7 |
| Vanadium | 0.0009 | 0.0030 | 105 | 40 | 2.59 | 68 | na | 1.4 |
| Zinc | 0.006 | 0.036 | 358 | 81 | 229.6 | 86 | 15.07 | 135 |
| (c)PHC F1 | na | nd | 245 | nil | na | na | na | na |
| (c)PHC F2 | na | nd | 14150 | nil | na | na | na | na |
| (c)PHC F3 | na | na | 8535 | nil | na | na | na | na |
| (c)PHC F4 | na | na | 2285 | nil | na | na | na | na |

(a) wildlife water ingestion is based on geometric mean, with the exception of tundra vole, which is modeled on the upper $95^{th}$ %. The water statistical $95^{th}$ % includes tailing pond, adits and standing water at the fuel bladder. (b) Area of affected soil (upper $95^{th}$ %) will be limited to the footprint of "waste rock" identified in Figures 5 and 6 equivalent to 1.5 ha (Roberts) and 0.5 ha (Ida). (c) Area of petroleum hydrocarbon affected soil limited to 0.07 ha around the fuel bladder, garage and mill. (d) Estimated based on upper $95^{th}$% soil concentration and recommended bioaccumulation approaches provided in Sample et al., 1998.

na – not available; nil – assumed background concentration as zero; nd – not detected

### 4.3 Selection of Wildlife Toxicity Reference Values (TRVs)

Detailed toxicological information on the species of interest, for the contaminants of interest, is rarely available. As a result, toxicity reference values (TRVs) are often estimated using published information on the toxicity of a substance to a laboratory animal. Potential differences in sensitivities of different species, the prediction of chronic (long-term) toxicity from acute or sub-chronic toxicity studies, and the prediction of more sensitive effects endpoints (e.g. reproduction or immune response capabilities) from less sensitive endpoints such as mortality is typically handled by including an safety factor (SF) or uncertainty factor (UF). Sample et al., 1996 recommended “body weight scaling” when extrapolating a threshold dose across species since a toxic effect in a large species can be achieved at a relatively smaller dose in comparison with the same effect in smaller species. This practice of “allometric scaling” is not without its controversies. Empirical studies of differences in species sensitivity have tended to indicate that variability in sensitivity based on body size is obscured by other forms of variability. As a result, allometric scaling was not used to adjust the toxicity reference values within this Eco RA..

For the selected contaminants of concern (C of Cs) there were four sources of information on wildlife TRVs, all of which have been referenced in Table 15. If available, TRVs were first selected from the most recent US EPA, 2003 interim Eco SSL reports. The development of the Eco SSL values involves critical review, screening out and ranking of numerous literature toxicity values prior to inclusion in the statistically derivation of the final Eco SSL. The final metadata is graphically portrayed in “species sensitivity distributions” for a variety of biological endpoints and the selected TRV is typically based on a statistically derived no observable adverse effect level (NOAEL) for growth. No uncertainty factors are applied to these TRVs. Approximately half of the TRVs in Table 15 have been obtained from US EPA Region 9, 2002. These values represent low level chronic thresholds derived from laboratory studies, often with uncertainty factors applied. The vanadium avian and mammalian TRVs have been obtained from Sample et al., 1996 and are based upon 1) a chronic study evaluating reproductive parameters (mammalian); and 2) a NOAEL in a chronic mallard duck study (avian).

For the hydrocarbon TRVs, UMA cites the Scientific supporting document CCME 2000 which used the lowest observable adverse effects level (LOAEL) cited in Stober 1962 for livestock ingesting crude oil. The LOAEL was 2.1 g fresh crude/kg body weight/day. An uncertainty factor of 0.1 was applied to reach the daily threshold effects dose (DTED) of 210 mg/kg bw/day. From this DTED, values were derived for the individual CCME subfractions. Table 1.3 in AENV September 2001 lists the DTED values for the protection of livestock/wildlife. Although these DTEDs were designed for deer and cattle, the individual TRVs are applied herein without allometric scaling.

**Table 15**
**Summary of Wildlife TRVs Used in the Eco- RA**

| C of C | Avian "A" (mg/kg bw day$^{-1}$) | Mammalian "M" (mg/kg bw day$^{-1}$) | Derivation approach | Reference |
|---|---|---|---|---|
| Arsenic | 2.24 | 1.04 | SSD – metadata analysis | US EPA Eco-SSL, 2005 |
| Barium | 20.8 | 51.8 | A – subchronic NOAEL for chicks with UF of 0.1.<br>M – SSD metadata analysis | A- US EPA, Region 9, 2002<br>M- US EPA Eco-SSL, 2005 |
| Cadmium | 1.47 | 0.770 | SSD – metadata analysis | US EPA Eco-SSL, 2005 |
| Chromium | 2.66 | 2.40 | SSD – metadata analysis | US EPA Eco-SSL, 2005 |
| Copper | 4.7 | 0.685 | A – subchronic NOAEL for chicks with UF of 0.1.<br>M – subchronic NOAEL on mink with UF of 0.1. | US EPA, Region 9, 2002 |
| Lead | 1.63 | 4.70 | SSD – metadata analysis | US EPA Eco-SSL, 2005 |
| Nickel | 65 | 8 | A-subchronic NOAEL for Coturnix quail with UF of 0.1<br>M-chronic NOAEL for rat without any UF | US EPA, Region 9, 2002 |
| Selenium | 0.5 | 0.058 | A-chronic NOAEL for mallard without any UF<br>M-chronic LOAEL for mouse mortality with UF of 0.1 | US EPA, Region 9, 2002 |
| Silver | 178 | 0.375 | A-chronic NOAEL for mallard with UF of 0.1<br>M-chronic LOAEL for hypoactivity in mouse with UF of 0.1 | US EPA, Region 9, 2002 |
| Vanadium | 11.4 | 0.21 | A-chronic NOAEL on mallard without UF applied<br>M-chronic LOAEL on rats with UF of 0.1. | Sample et al., 1996 |
| Zinc | 130.9 | 10.4 | A-chronic NOAEL for leghorn hen & rooster without any UF<br>M-subchronic NOAEL for mouse with UF of 0.1 | US EPA, Region 9, 2002 |
| PHC F1 | na | 9.74 | Daily threshold effects dose (DETD) based on studies dosing crude oil to cattle (Stober, 1962) | CCME CWS PHC, 2000 and AENV, September 2001 |
| PHC F2 | | 8.95 | | |
| PHC F3 | | 14.5 | | |
| PHC F4 | | 9.64 | | |

na – not available. NOAEL = no observable adverse effects level. LOAEL = lowest observable adverse effects level
UF= uncertainty factor.

## 4.4 Risk Characterization

### 4.4.1 Results from Wildlife Ingestion Models

To express a potential for biological effect from exposure to the assessment C of Cs, the simple ratio of *Ej*/TRV, called the hazard quotient is used. Because the individual hydrocarbon fractions act on biological tissue in a similar "mode of action", the cumulative hazard quotient is a better expression of potential adverse effects. The formula takes the following general form:

$$HQ_{PHC} = \sum \frac{Ej}{DTED} \leq 1.0$$

*Equation 11.0*

Table 16 presents the calculated hazard quotients for the various ecological wildlife receptors and individual C of Cs.

**Table 16**
**Estimated Wildlife Hazard Quotients for Roberts Bay and Ida Bay**

| C of C | Ecological Receptors | | | | | |
|---|---|---|---|---|---|---|
| | Tundra vole | Arctic hare (Roberts) | Arctic hare (Ida) | Caribou | Gyrfalcon | Pacific loon |
| Arsenic | **1.43** | 0.24 | 0.08 | < 0.001 | 0.03 | 0.01 |
| Barium | 0.40 | 0.05 | 0.02 | < 0.001 | 0.20 | 0.004 |
| Cadmium | 0.34 | 0.03 | 0.01 | < 0.001 | 0.02 | 0.002 |
| Chromium | 0.86 | 0.10 | 0.03 | < 0.001 | 0.21 | 0.029 |
| Copper | **4.19** | 0.61 | 0.20 | < 0.001 | 0.33 | 0.016 |
| Lead | 0.84 | 0.13 | 0.04 | < 0.001 | 0.43 | 0.004 |
| Nickel | 0.21 | 0.03 | 0.01 | < 0.001 | 0.008 | 0.002 |
| Selenium | 0.48 | 0.05 | 0.02 | < 0.001 | 0.07 | 0.16 |
| Silver | **8.57** | **2.18** | 0.73 | < 0.001 | 0.001 | 0 |
| Vanadium | **5.05** | 0.80 | 0.27 | < 0.001 | 0.007 | 0 |
| Zinc | **5.14** | 0.44 | 0.15 | < 0.001 | 0.06 | 0.006 |
| PHC (all) | **10.8** | 0.13 | na | < 0.001 | na | na |

HQ calculations for Arctic hare vary depending of the assumed affected area: Roberts Bay – 1.5 ha identified as "waste rock" in Figure 5 (modeled on upper $95^{th}$ % of soil trace elements concentration). Ida Bay – 0.5 ha identified as "waste rock" in Figure 6 (modeled on upper $95^{th}$ % of soil trace element concentration). Tundra vole calculations assume the receptor lives entirely within the affected areas; therefore, HQ estimates are identical for both Ida and Roberts Bays. Bold and shaded HQ values represent potential daily exposure in excess of safe toxicological benchmarks. na = not assessed.

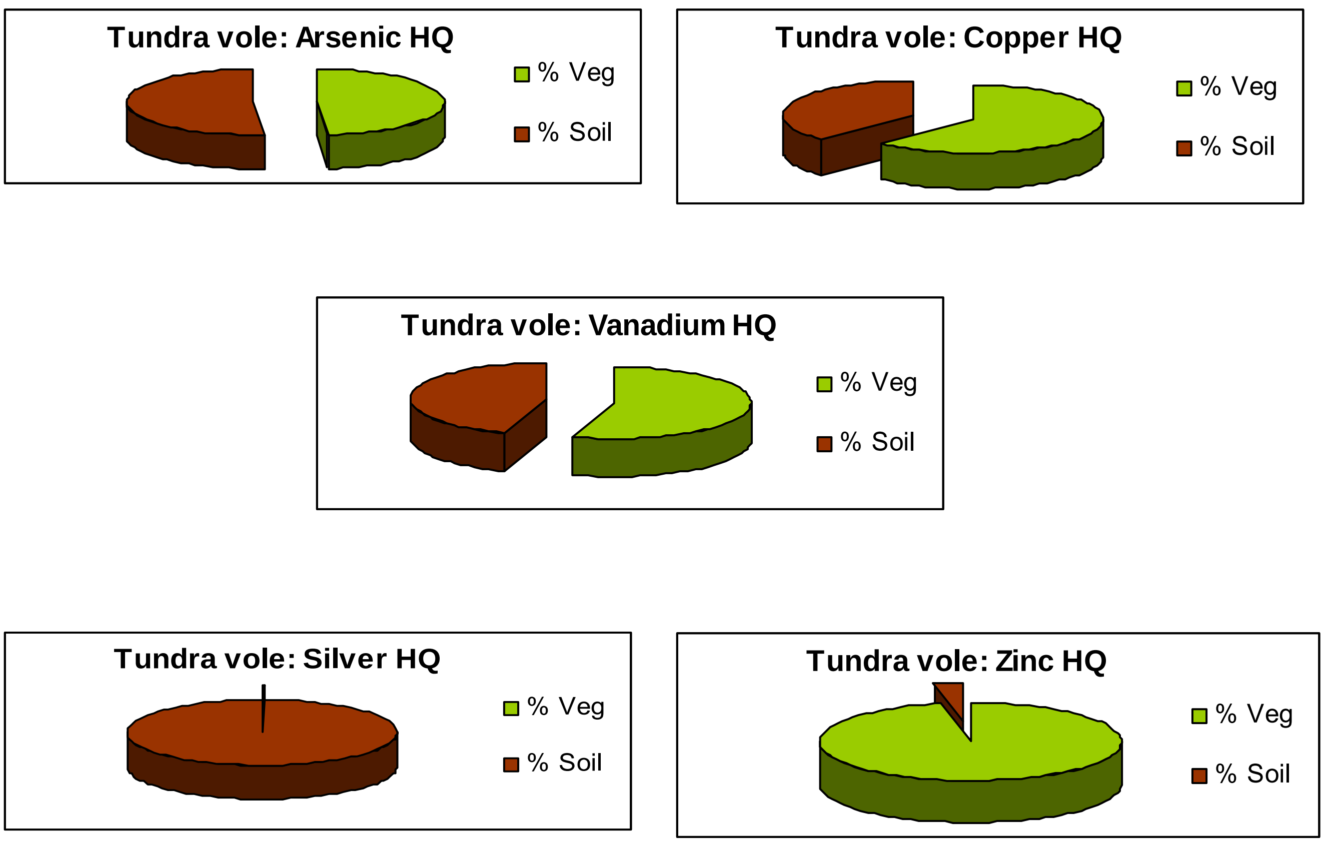
Small mammals with small ranges may be at risk, particularly at Roberts Bay. Large ungulates, avian predators and piscevorois species are likely not at risk at either site.

Evaluating the percent contribution of the various routes of exposure helps in the interpretation of the hazard quotients (HQ). In all cases the contribution from ingestion of water is negligible. For the petroleum hydrocarbons, the HQ is entirely attributed to ingestion of soil and the predicted HQ is ten times the safe exposure limit. For the various trace elements, exposure via food (vegetation) versus soil helps to determine whether or not elevated trace metals in soil are actually a risk to terrestrial mammals.

The following pie graphs (Figure 9) illustrate the relative percentage of the HQ for the trace elements of concern, modeled with the tundra vole. Similar proportions are observed with the Arctic hare (i.e. 100% of silver HQ attributed to soil exposure).

In the case of zinc, close to 100% of the dose is attributed to the ingestion of vegetation. It is important to point out that the upper $95^{th}$ % input concentration for zinc is strongly influenced by the willow leaves collected below the tailing pond and within a drainage ditch in the muskeg area (Veg-04). For arsenic and copper, the higher $95^{th}$ % concentrations are influenced by the cotton grass sampled on the margins of the tailing pond. Vanadium in the vegetation is observed at the highest concentrations in crowberry directly below the mill and cotton grass adjacent to the tailing pond. The risks from elevated trace elements within the fine fraction of waste rock (i.e. soil) is most pronounced with silver and to a lesser extent, arsenic, copper and vanadium.

**Figure 9: Proportion of Estimated Hazard Quotient Attributed to Vegetation and Soil**




Although the potentially harmful exposure to trace elements via ingestion of vegetation cannot be ruled out, the gastrointestinal absorption of zinc, and other trace elements, will not be as efficient as experienced in the laboratory studies for which the TRVs are based. Typically, the laboratory animals are dosed with an ionic salt form of the elements within their diet or water.

*Microtus* species, such as the tundra vole, prefer habitat with good grass cover, or riparian areas with low shrubbery, for development of their narrow runways (Johnson and Johnson, 1982). Exposure to the high metal concentrations in the fines of the waste rock and tailings areas would only be a periodic occurrence.

### 4.4.2 Establishing Site-Specific Remedial Objectives (SSRO) for Soil/Waste Rock Fines

Based on exposure to the most sensitive terrestrial receptor (tundra vole), soil site-specific remedial objectives (SSROs) were established. The SSROs have been back-calculated based on rearrangement of Equation 8. Rather than calculating an estimated daily dose based on observed site conditions, UMA calculated what the soil concentration of the C of Cs would be if the $HQ_{vole}$ were set at 0.5. For the PHCs this methodology was modified slightly, such that a cumulative $HQ_{vole}$ would not exceed 1. To achieve this, the HQs for the individual PHC fraction were reduced to 0.3 (F4) or 0.35 (F3 and F2).

Estimation of the soil based SSRO is simple in cases where the ingestion of vegetation contributes negligible amounts to the $HQ_{vole}$ (e.g. silver/PHC), but can be complicated in cases where vegetation contributes the majority of the dose (e.g. zinc/copper). The following protocols were followed to establish the trace element SSROs:

For non-essential trace metals (arsenic/silver/vanadium)

- the ultimate goal was to set individual trace element $HQ_{vole}$ to ≤ 0.5
- trace element concentrations in vegetation were fixed at the geometric mean (background)
- soil concentrations were adjusted to achieve the goal of $HQ_{vole}$ ≤ 0.5 and
- where the re-calculated SSRO was well below a reasonable background and CCME guidelines, the soil concentration was fixed at the respective CCME SQG and an $HQ_{vole}$ re-calculated.

For essential trace metals (zinc / copper)

- in this case the objective was to limit the soil exposure to less than 50% of the overall daily dose and re-calculate the allowable soil concentration and resultant HQvole.

Those C of C that originally produced $HQ_{vole}$ less than 1 are not likely to be the remedial “drivers” on the Roberts Bay and Ida Bay sites. Therefore, no attempt was made to recalculate soil site-specific remedial objectives for these compounds. The compounds in this category are: barium, cadmium, chromium, lead, nickel and selenium. For the remaining C of C, Table 17 summarizes the results of the calculations and presents the soil site-specific remedial objectives (SSROs).

**Table 17**
**Recommended Site-Specific Soil / Waste Rock Fines Remedial Objectives**

| C of C | SSRO mg/kg | CCME mg/kg | $HQ_{vole}$ | % from vegetation |
|---|---|---|---|---|
| Arsenic | 105 | | 0.5 | 8% |
| Copper | 176 | | **2.33** | 50% |
| Silver | 39 | | 0.5 | 5% |
| Vanadium | | 130 | **2.98** | 6% |
| Zinc | >2000 | | **1.92** | 50% |
| PHC F1 | 245 | | 0.13 | 0% |
| PHC F2 | 700 | | 0.35 | 0% |
| PHC F3 | 1135 | | 0.35 | 0% |
| PHC F4 | 647 | | 0.30 | 0% |

The goal of $HQ_{vole}$ ≤ 0.5 cannot be achieved for copper and zinc because of the contribution in the diet from vegetation. The protection objective for these required trace elements is to limit the contribution to soil exposure to less than 50%. This presumes that exposure to these essential trace elements in soil is more detrimental than the exposure from vegetation. The re-calculated HQs for copper and zinc still exceed 1, but are unlikely to represent true risks. Vertebrates and invertebrates posses biochemical mechanisms which allow them to absorb, sequester and excrete essential trace elements such as copper and zinc.

The goal of $HQ_{vole} \leq 0.5$ for vanadium resulted in a soil concentration which was below the natural background and an order of magnitude below the respective CCME $SQG_{Eco}$. Although the resulting vanadium $HQ_{vole}$ exceed 1, it is recommended that the remedial objective for this trace element be set at the CCME SQG, which is based on the lower 25$^{th}$ percentile of the ecotoxicological effect data distribution compiled in CCME, 1999b.

UMA understands that the limited areas with PHC contamination are going to be targeted for remedial action. Since the volumes of PHC affect soil are limited, it is not anticipated that SSROs will be required. Furthermore, these SSRO values for the petroleum hydrocarbons are not meant to replace the Canada-wide standards. The Canada-wide standards for fractions F2, F3 and F4 are based on ecotoxicological data on plants and invertebrates. These SSRO are based on protection of a small terrestrial mammal.

### 4.4.3 Evaluation of Risk to Aquatic Resources

The concentrations of trace elements in the various aquatic environments have been summarized into Table 18.

**Table 18**
**Summary of Trace Element Concentrations in Water (Roberts Bay Mine)**

| C of C | units | CCME AL | (a)Waste rock acid extractable (geomean) | (b)Waste rock water extractable (geomean) | Tailing and adit water (geomean) | Roberts standing water (geomean) | Discharge stream (total) | Discharge stream (dissolved) |
|---|---|---|---|---|---|---|---|---|
| Arsenic | µg/L | 5 | **24.9** | **9.7** | **5.4** | 1 | 0.5 | 0.5 |
| Barium | µg/L | -- | 84.2 | 83.5 | 46.6 | 64.5 | 20.4 | 16.3 |
| Cadmium | µg/L | 0.4* | <0.05 | <0.2 | 0.3 | <0.05 | <0.2 | <0.1 |
| Chromium | µg/L | 8.9 | **< 10** | <1 | 3.8 | 1.2 | <0.8 | 0.5 |
| Copper | µg/L | 3* | 1.6 | 0.7 | **9.4** | **3.2** | **4** | **3.3** |
| Lead | µg/L | 7 | 0.2 | <1 | 1.9 | 0.4 | <0.1 | <0.1 |
| Nickel | µg/L | 150* | 0.6 | <0.9 | 4.7 | 0.4 | 1.7 | 1.3 |
| Selenium | µg/L | 1 | <1 | <1 | 0.9 | 0.6 | 0.8 | **1.1** |
| Silver | µg/L | 0.1 | **0.2** | **<0.25** | **0.1** | **0.1** | **<0.4** | **0.5** |
| Vanadium | µg/L | -- | <30 | 2.4 | 1.1 | 0.5 | 0.4 | 0.1 |
| Zinc | µg/L | 30 | <20 | <5 | 12 | 4.4 | <4 | 3 |

* hardness adjusted values reflected - assume receiving environment varies ~ 50 mg/L total hardness. Bold / shaded values exceed CCME guidelines. (a) from Rescan, 2003. (b) from AMEC, 2005 – BC MEM shake flash method.

Based on the summary of trace element concentrations within the waste rock extracts, mine workings, isolated ponds and discharge stream, it appears that the concentrations of copper and silver, at the point of discharge, exceed the generic CCME aquatic life standards. The relative difference between the method detection limits for selenium and silver and their respective guidelines introduces uncertainty into the assessment of risks to the aquatic environment. Nevertheless, the expected continuous discharge of low levels of silver and copper above CCME freshwater guidelines warrants further examination.

Furthermore, this assessment represents the state of the site as of 2005 and, depending on the potential for acid drainage to intensify, dissolved metal ions may actually increase in the discharging stream over the long term.

In the US the National Ambient Water Quality Criteria (NAWQC) for copper and silver allow for water hardness adjustments. In Canada, the CCME aquatic life guidelines for copper adopted the same adjustment methodology, but silver is set at 0.1 μg/L, regardless of pH or hardness. Assuming the hardness of the receiving environment fluctuates around 50 mg/L, the US NAWQC for copper (chronic continuous) and silver (maximum) would be 5 and 1 μg/L, respectively. Furthermore, dissolved and particulate organics in the water column are known to bind to ionic copper, reducing the biological availability of the toxic element. As part of the Doris North Project, the deposition of tailings into Tail Lake is predicted to increase the concentration of ambient copper above the CCME guidelines. In response to this problem, Golder Associates, 2004 was commissioned to develop site-specific water quality value (WQV) for copper based on the biotic ligand model (BLM). The WQV is based upon the dissolved ionic species, rather than total extractable copper. The copper WQV recommended for the Tail – Doris Lakes was 4.1 μg/L.

This assessment of risk uses the concentrations at the point of discharge to compare against generic water quality guidelines and ignores the fact that the low concentrations of copper and silver will be diluted once entering Roberts Lake. Once in the lake there are two major sinks within which the trace elements will reside: biological tissue and sediment. The data on fish tissue is not specifically from Roberts Lake and therefore, cannot be used to determine biological accumulations in Roberts Lake. On the other hand, sediment samples located just off shore from the stream discharge are not found to contain elevated silver or copper. Based on the current data, and in the absence of long term acid generating predictions, the continuous discharges of dissolved copper and silver do not appear to have caused any obvious adverse impacts to the discharging environment. Nevertheless, any remediation activity that mitigates the dissolution of silver and copper from mineralized waste rock will help to reduce the concentrations of these elements discharging to the aquatic environment.

In the preliminary screening of the sediment quality, it was established that all but a single sample with elevated lead off shore of Ida Bay were within the regional background for the area. According to a review of various sediment toxicological benchmarks (Jones et al., 1997), the concentration of lead, 49 μg/g, falls within a grey area between a probable, or sever effects range > 250 μg/g and a no effects, or low effects range ~ 30 - 35 μg/g. Depending on the results of the pending BC MEM shaker flash analysis on this sediment sample, remedial action may not be warranted. Furthermore, remedial action within the ocean could trigger Habitat Alteration or Destruction (HADD) and could require Department of Fisheries and Oceans authorization.

## 4.5 Eco RA Uncertainty Analysis

### 4.5.1 Analytical Uncertainty

Water, soil, plant and fish tissue concentrations of the various potential chemicals of concern are all sources of uncertainty. A significant proportion of the analytical data presented herein was obtained from historical reports and regional data collected in support of the Doris North Project. The field collection methods and analysis techniques may not be comparable, especially from historical data dating back to the mid 1990's.

Of particular concern for this ecological risk assessment is the method detection limits for trace elements in water. As previously mentioned, the MDLs for selenium, silver and cadmium are often higher than the respective CCME freshwater guidelines. This introduces uncertainty into the aquatic components of the ecological risk assessment. The presence of dissolved copper and silver in the discharge stream is a plausible scenario considering the site was a former silver mine with abundant chalcopyrite mineralization. The uncertainty resulting from the variable detection limits can be addressed during future water monitoring on the site, which must use low-level detection limits for trace elements.

#### 4.5.2 Exposure Uncertainty

Significant uncertainty enters into the ecological risk assessment in the modelling of exposure to the endpoint wildlife species. When estimating wildlife ingestion of a contaminated media, uncertainty arises surrounding the areal extent of feeding ranges, temporal extent of feeding behaviour, credibility of predicted ingestion rates, proportion of the diet consisting of soil and the bioavailability of the C of C within the soil/vegetation. In addition to these aspects, there will be natural variation in physiological characteristics, such as body weights and metabolism.

The selected model to predict dietary intake is subject to its own inherent uncertainty. The ingestion model has not attempted to account for realistic gastrointestinal absorption. Consequently, assimilation efficiency (*AE*) was assumed to be 1, or 100%. Furthermore, the model did not account for excretion of assimilated C of Cs, which increases the inherent conservative nature of the model. Despite the uncertainties surrounding the physiological input parameters for the individual receptors, the exposures are likely over-estimates based on the use of an upper 95% percentiles for the various media concentrations.

#### 4.5.3 Toxicity Uncertainty

Toxicity data for the specific species and contaminants of interest were not readily available. By necessity, therefore, TRVs were extrapolated from laboratory studies on other species, and this introduces uncertainty. The US EPA Eco-SSL, 2005 wildlife TRVs chosen explicitly account for uncertainty associated with species sensitivity differences through the application of statistical distributions and selection of the threshold from the lower end of the distribution. Earlier TRVs adopted from US EPA Region 9, 2002 account for differences in inter-species variability and LOAEL to NOAEL extrapolations with the application of uncertainty factors.

While it may appear conservative to assume 100% oral bioavailability in the exposure assessment, it is important to point out that the toxicological studies on which the various TRVs have been based are primarily based on oral exposures. Where the largest differentiation occurs is the form of the dose. In the real world, herbivores ingest plant material and incidental soil which naturally contains trace elements. In contrast, most of the laboratory studies ensure bioavailability by administering the dose in spiked drinking water, or pure ionic form in the animals food.

# 5.0 Summary and Recommendations 5.0

This discussion is an overall summary of the findings from this human health and ecological risk assessment. The findings of this integrated risk assessment are summarized based on a weight of evidence approach that evaluates the following:

- frequency of analytical detection and confidence in results;
- whether or not the chemical is present at concentrations above background;
- whether or not there are sensitive receptors present, or likely to be present;
- whether or not a plausible route of exposure exists;
- whether or not predicted hazard quotients (*HQ*) exceed 1, or incremental lifetime cancer risks are greater than 1 in $10^{-5}$; and
- whether or not adverse long-term effects are likely for the assessment endpoint species (i.e. population effects).

## 5.1 Human Health RA

The human health component of the risk assessment incorporated what is deemed to be a realistic exposure scenario in which a local family may visit the site annually for a period of 30 days. The family was assumed to subsist off the aquatic resources within Roberts Lake and periodically trap Arctic hare for consumption. Drinking water was assumed to be obtained from the discharge stream or Roberts Lake, but not from any standing water, tailing pond or the adit. The visitors were assumed to accidentally ingest fine grained soils and be exposed to these soils through dermal contact. This human exposure scenario presumes some limited risk management or remediation that effectively eliminates exposure to standing bodies of water.

The assessment of human health risks concluded that there would be negligible risk associated with periodic exposure to the Roberts Bay or Ida Bay sites. Although there were no excessive risks predicted, two sources of contaminants stand out as the highest sources of risk: 1) standing bodies of water, including flooded adits and tailing pond; and 2) the fine fraction of waste rock/tailings with elevated arsenic and or lead. The remedial plan should consider mitigation of these two sources, by blocking access (water) or eliminating altogether (burial of fine waste rock). Burial locations for fine waste rock or tailing material must be carefully considered to avoid creating an increased concentration of trace metals in the discharging stream.

## 5.2 Ecological RA

From an ecological perspective, the localized soil petroleum hydrocarbon impacts stand out as an area of concern to small herbaceous mammals. If left on the surface, vegetative regrowth may also be hampered in these petroleum hydrocarbon impacted areas. Considering the relatively small quantities of impacted soil, it is recommended that these soils be remediated. Based on the surface water analytical record, there is no evidence that hydrocarbons, as currently situated, are being mobilized off site. Remedial actions should consider all available options including in-situ techniques.

In the general footprint of the Roberts Bay Mine and Ida Bay deposit, the concentrations of arsenic, silver, copper, vanadium and zinc in soil and vegetation are shown to be a potential health concern to small herbaceous mammals. Overall, the area of impacted “soil” is actually limited to the fine fraction of waste rock or tailings material. Nevertheless, the concentrations of selected trace elements in the vegetation downgradient of sources (tailing pond and mill assay building) may also be causing a health concern to the resident voles, or other small mammals.

Based on the limited impact area relative to home range, larger herbaceous mammals such as the Arctic hare and caribou are not anticipated to experience the same level of exposure. In fact the exposure to caribou is insignificant.

As for the avian receptors, the gyrfalcon preying upon the voles is estimated to ingest approximately 40% and 30% of its safe daily dose of lead and copper within each season. The piscevorois loon fairs much better with HQs ranging from a high of 0.16 (16%) for selenium to zero for trace elements that are simply not detected in fish tissue (e.g. silver).

Similar to the recommendation arising from the findings of the Human Health RA, risks to the terrestrial ecological receptors suggest that the fine fraction of waste rock, and likely the tailings, are the primary source of potentially harmful trace metals. Reclamation activities should consider mitigating the direct soil contact pathway and the remedial objectives presented in Table 17 can help guide this work. The soil quality table (Table B1) in Appendix B highlights in red those location in which arsenic, silver and copper exceed their respective SSROs. Arsenic exceedances of the SSRO are limited to the mill assay building and vicinity. Soil silver and copper concentrations exceed their respective SSROs in the vicinity of the mill assay building and garage. Infrequently, exceedances of the silver SSRO are observed in other locations, such as a Rescan sample taken in the camp dump and the Earth Tech Ida Bay background location. The tailing material contains vanadium in excess of the CCME SQG and should be considered a potentially harmful source of trace metals. Although elevated trace metals are apparent at the barrel storage area, the recommended trace metal SSROs are not exceeded. Therefore, the remedial activities should focus on two worst case areas: 1) tailings, and 2) waste rock foundations below the garage and mill assay areas. If feasible, the waste rock below the barrel storage area could also be treated similar to the mill assay and garage. The trace metals in the vicinity of the camp dump, muskeg and Ida Bay are not considered to pose significant ecological risks.

The exposure prediction to the small mammals are conservative. It is unlikely that the degree of exposure and inherent toxicity of the hydrocarbons and trace elements at Roberts Bay mine and Ida Bay would be sufficient to cause adverse population effects on any given species or guild.

The assessment of risks to the important aquatic resources has concluded that generic environmental standards at the point of discharge are currently exceeded for copper and silver. This does not mean that toxic concentrations are discharging into Roberts Lake. Nevertheless, any remedial activities must consider mitigating this continuous exposure potential and must also consider mitigating long term acid drainage potential. Risk management may be required to monitor the trend in trace element concentrations in the discharging stream. Alternately, more in depth scientific studies could be commissioned to evaluate the fate and potential effects of the silver and copper. Site-specific copper discharges may be linked to the on-going work for the Doris North Project.

For the elevated sediment lead concentrations associated with the waste rock in the shallow shores off Ida Bay, the recommendation is to wait for the pending BC MEM shaker flask analysis on this sample. If the analysis shows very little potential for the lead to be bioavailable, disruptive remedial action within the ocean may not be warranted. The reader is referred to the Earth Tech report for the BC MEM shaker flask analysis.

# 6.0 Closure

6.0

The work described in this report was conducted in accordance with the Contract for Environmental Consulting Services between EBA Engineering Consulting Ltd. and UMA Engineering Ltd. The work was conducted under a standing offer agreement between EBA Engineering Consultants Ltd. and Public Works Government Services Canada (PWGSC). The report disclaimer statement appears on the cover of this document.

This report has been prepared for the exclusive use of PWGSC. The work was conducted in accordance with the agreed scope of work approved verbally and in writing by Jared Buchko of PWGSC, and generally accepted practices. No other warranty, expressed or implied, is made.

Should you have any questions, please contact either of the undersigned at (250) 475-6355 at your convenience.

Respectfully submitted,

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# Appendix A

# Roberts Bay Photo Plates
# August 2005

Plate 1: Pan shot from within the fuel bladder looking east to west.

Plate 2: Pan shot from audit looking east to west and capturing the mill and garage.

Plate 3: Pan shot from atop the ridge at the mill looking north to south east (tailings pond).

Plate 4: Example of Willow vegetation collected (Species A) *Salix glauca* or *S. planifolia*.

Plate 5: Example of Bearberry vegetation collected (Species B) *Arctostaphylus sp.*

Plate 6: Example of typical small mammalian receptor on edge of tailing pond.

Plate 7: Mill assay building – location with highest soil trace metals.

Plate 8: Tailing pond with crusher and cotton grass growing on margin.

Plate 9: Fuel bladder with crushed waste rock around margin.

Plate 10: Drainage ditch below Mill building with accumulated insulation from dump.

Plate 11: Accumulation of run-off water below the tailing pond (SW-02 and VEG-05).

Plate 12: Roberts Bay mine surface water point of discharge to Roberts Lake.

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# Appendix B

# Summary Tables
# Roberts Bay and Ida Bay
# Analytical Record

**TABLE B1: ROBERTS BAY HHERA**
**Analytical Soil Data**

| Analytical Parameter | Units | Applicable Ecological Guideline | Applicable Human Health Guideline | ET-1157 | ET-1158 | ET-1100 | ET-1101 | ET-1108 | ET-1109 | IDA AUDIT | IDA BACK | IDA 05 | IDA 06 | ET-1169 | ET-1170 | ET-1070 duplicate | ET-1171 | ET-1171 duplicate | ET-1171B | ET-1172 | RBSM-Camp-1 | RBSM-Landfill-1 | ET-1175 | ET-1176 | ET-1177 | ET-1178 | ET-1179 | ET-1180 | ET-1181 | ET-1182 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 8/20/2005 | 8/20/2005 | 8/19/2005 | 8/19/2005 | 8/19/2005 | 8/19/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2003 | 8/20/2003 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 |
| | | | | background | background | muskeg | muskeg | muskeg | muskeg | IDA soils | IDA soils | IDA soils | IDA soils | barrel storage area | barrel storage area | barrel storage area | barrel storage area | barrel storage area | barrel storage area | barrel storage area | camp dump | camp dump | camp dump | camp dump | camp dump | camp dump | camp dump | camp dump | camp dump | camp dump |
| **Hydrocarbons** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F1 - VPH ($C_6$-$C_{10}$) | ug/g | 130 | | | | <5 | <5 | <5 | <5 | <5 | <5 | | | <5 | <5 | | <5 | | | | -- | -- | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| F2 - EPH (C10-C16) | ug/g | 450 | | | | <5 | 12 | <5 | <5 | <5 | <5 | | | <5 | <5 | | <5 | | | | -- | -- | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| F3 - EPH (C16-C34) | ug/g | 400 | | | | <5 | 2500 | 45 | 15 | 46 | <5 | | | 19 | 9 | | <5 | | | | -- | -- | 87 | 7 | 27 | 49 | 13 | <5 | 7 | 100 |
| F4 - EPH (C34-C50) | ug/g | 2800 | | | | <5 | 970 | 42 | 11 | <5 | <5 | | | <5 | <5 | | <5 | | | | -- | -- | 55 | <5 | 11 | 14 | 12 | 6 | <5 | 7 |
| F4 - GHH (silica gel) | ug/g | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Benzene | ug/g | 62 | 0.03 c | | | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | | | <0.005 | <0.005 | | <0.005 | | | | <0.05 | <0.05 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Toluene | ug/g | 150 | 0.37 c | | | <0.01 | 0.02 | 0.01 | 0.01 | <0.01 | <0.01 | | | <0.01 | <0.01 | | <0.01 | | | | <0.1 | <0.1 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 |
| Ethylbenzene | ug/g | 55 | 0.082 c | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | | | <0.01 | <0.01 | | <0.01 | | | | <0.1 | <0.1 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Total Xylenes | ug/g | 95 | 11 c | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | | | <0.01 | <0.01 | | <0.01 | | | | <0.3 | <0.3 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Total Petroleum Hydrocarbons | ug/g | | | | | <5 | 3500 | 87 | 26 | 46 | <5 | | | 19 | 9 | | <5 | | | | <20 | <20 | 140 | 7 | 38 | 63 | 25 | 6 | 7 | 110 |
| **PCB/ DDT** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PCB (total) | ug/g | 1.3 | | | | <0.05 | | | | | | | | | | | | | | | -- | -- | | | | | <0.05 | | <0.05 | |
| DDT + metab | ug/g | 0.7 | | | | | | | | | | | | | | | | | | | | | <0.005 | <0.005 | | | <0.005 | | | |
| **Salinity - Buffering** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| pH | | 6 to 8 | | | | | | | | | | | | 7.4 | | | | | | | | | | | | | | | | |
| Conductivity | dS/m | 2 | | | | | | | | | | | | 0.91 | | | | | | | | | | | | | | | | |
| Acid Nuetralizing Cap.(CaCO3) | % | | | | | | | | | | | | | 11 | | | | | | | | | | | | | | | | |
| Chloride - S. Paste | mg/L | | | | | | | | | | | | | 50 | | | | | | | | | | | | | | | | |
| Sulphate - S. Paste | mg/L | | | | | | | | | | | | | 321 | | | | | | | | | | | | | | | | |
| SAR | ratio | 5 | | | | | | | | | | | | 1.9 | | | | | | | | | | | | | | | | |
| **Polycyclic Aromatic Hydrocarbons** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Benzo(a)anthracene | ug/g | 1 | | | | <0.01 | <0.01 | | | <0.01 | <0.01 | | | | | | | | | | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Benzo(k)fluoranthene | ug/g | 1 | | | | <0.01 | <0.01 | | | <0.01 | <0.01 | | | | | | | | | | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Benzo(b+j)fluoranthe | ug/g | 1 | | | | <0.01 | <0.01 | | | <0.01 | <0.01 | | | | | | | | | | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Benzo(a)pyrene | ug/g | 0.7 | 0.7 c | | | <0.01 | <0.01 | | | <0.01 | <0.01 | | | | | | | | | | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Quinoline | ug/g | | | | | <0.01 | <0.01 | | | <0.01 | <0.01 | | | | | | | | | | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Dibenz(a,h)anthracene | ug/g | 1 | | | | <0.01 | <0.01 | | | <0.01 | <0.01 | | | | | | | | | | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Indeno(1,2,3-cd)pyrene | ug/g | 1 | | | | <0.01 | <0.01 | | | <0.01 | <0.01 | | | | | | | | | | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Napthalene | ug/g | 0.6 | | | | <0.01 | <0.01 | | | <0.01 | <0.01 | | | | | | | | | | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Phenanthrene | ug/g | 5 | | | | <0.01 | <0.01 | | | <0.01 | <0.01 | | | | | | | | | | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Pyrene | ug/g | 10 | | | | <0.01 | <0.01 | | | <0.01 | <0.01 | | | | | | | | | | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| B[a]P equivalents | ug/g | | 0.7 c | | | <0.01 | <0.01 | | | <0.01 | <0.01 | | | | | | | | | | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Metals (total)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aluminum | ug/g | | | | | | | | | | | | | | | | | | | | 25300 | 6000 | | | | | | | | |
| Arsenic | ug/g | 17 | 31 | 2.1 | 0.5 | 0.8 | 3 | 6.9 | 3.1 | 1.9 | 1 | 0.5 | 0.3 | 14 | 29.2 | 31.4 | 50.7 | 50.8 | 39.8 | 1.2 | 17.2 | 2.8 | 16.4 | 1.2 | 0.8 | 1 | 1.7 | 0.8 | 0.5 | 1.3 |
| Barium | ug/g | 500 | 500 | 104 | 37 | 13 | 200 | 18 | 118 | 59 | 37 | 38 | 23 | 669 | 847 | 587 | 1790 | 1720 | 1240 | 21 | 119 | 56 | 546 | 31 | 39 | 45 | 33 | 29 | 20 | 85 |
| Beryllium | ug/g | | | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Cadmium | ug/g | 10 | 14 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 1.1 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 0.7 | 0.8 | 0.8 | <0.5 | 1.1 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Chromium | ug/g | 64 | 220 | 45 | 10.6 | 7.2 | 73.5 | 6.5 | 48.5 | 21 | 11 | 5.1 | 7.9 | 28.8 | 28.1 | 29.4 | 93.6 | 95.3 | 78 | 4.8 | 166 | 24 | 55.9 | 13.2 | 11.5 | 14.1 | 10.1 | 8.1 | 5 | 36.8 |
| Cobalt | ug/g | | | 13 | 8 | 4 | 15 | 5 | 12 | 17 | 5 | 3 | 4 | 11 | 11 | 11 | 23 | 23 | 19 | 4 | 24 | 6 | 33 | 6 | 7 | 7 | 6 | 5 | 5 | 10 |
| Copper | ug/g | 63 | 1100 | 32 | 9 | 2 | 63 | 3 | 21 | 93 | 16 | 4 | 11 | 33 | 38 | 38 | 93 | 90 | 81 | 5 | 90 | 21 | 177 | 16 | 24 | 16 | 16 | 14 | 11 | 42 |
| Cyanide (free) | ug/g | | | | | | | | | | | | | | | | | | | | -- | -- | | | | | | | | |
| Iron | ug/g | | | | | | | | | | | | | | | | | | | | 58400 | 14700 | | | | | | | | |
| Lead | ug/g | 300 | 140 | 13 | <5 | 8 | 11 | <5 | 8 | 173 | 8 | 36 | <5 | 61 | 78 | 56 | 307 | 349 | 341 | <5 | 74 | 7 | 237 | <5 | <5 | 7 | 13 | <5 | 6 | 7 |
| Manganese | ug/g | | | | | | | | | | | | | | | | | | | | 1220 | 197 | | | | | | | | |
| Mercury | ug/g | 12 | 6.6 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.09 | <0.05 | 0.15 | <0.05 | <0.05 | <0.05 | | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Molybdenum | ug/g | | | <1 | <1 | <1 | 2 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 11 | 2 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Nickel | ug/g | 50 | | 24 | 8 | 5 | 34 | 6 | 25 | 20 | 9 | 4 | 6 | 29 | 47 | 62 | 110 | 101 | 86 | 6 | 89 | 16 | 44 | 12 | 11 | 12 | 10 | 7 | 8 | 21 |
| Selenium | ug/g | 1 | 28 | <0.2 | <0.2 | <0.2 | 0.2 | <0.2 | <0.2 | 0.3 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | | | 0.7 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Silver | ug/g | | | 16 | 8 | <1 | <1 | <1 | <1 | 9 | 45 | 27 | 22 | 3 | 5 | 28 | 2 | 32 | 21 | 7 | 63 | 3 | 9 | 4 | <1 | <1 | <1 | <1 | <1 | 47 |
| Strontium | ug/g | | | | | | | | | | | | | | | | | | | | 22 | 13 | | | | | | | | |
| Thallium | ug/g | 1.4 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Tin | ug/g | | | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | | | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Uranium | ug/g | | | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | | | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 |
| Vanadium | ug/g | 130 | | 54 | 23 | 17 | 82 | 16 | 51 | 56 | 22 | 13 | 18 | 43 | 42 | 38 | 110 | 111 | 92 | 15 | 93 | 28 | 104 | 23 | 27 | 29 | 24 | 25 | 21 | 47 |
| Zinc | ug/g | 200 | | 60 | 30 | 20 | 100 | 20 | 60 | 370 | 30 | 30 | 30 | 100 | 100 | 90 | 310 | 330 | 310 | 30 | 138 | 42 | 160 | 30 | 40 | 40 | 40 | 30 | 30 | 60 |

All Guidelines Taken from CCME,1999 "c" - guideline defined by protection of potable groundwater



UMA | AECOM

**TABLE B1: ROBERTS BAY HHERA**
**Analytical Soil Data**

| Analytical Parameter | Units | Applicable Ecological Guideline | Applicable Human Heath Guideline | RBSM-Gar-1A | RBSM-Gar-1B | RBSM-Gar-2A | RBSM-Gar-2B | ET-1111 | ET-1112 | ET-1113 | Rescan Sample 1 | Rescan Sample 2 | RBSM-Mill-1 | ET-1159 | ET-1160 | ET-1161 | ET-1162 | ET-1162B | ET-1163 | ET-1164 | ET-1165 | ET-1166 | ET-1167 | ET-1168 | ET-1068 duplicate | ET-1173 | ET-1174 | RBSM-TF-1A | RBSM-TF-1C | RBSM-TF-2B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 8/20/2003 | 8/20/2003 | 8/20/2003 | 8/20/2003 | 8/19/2005 | 8/19/2005 | 8/19/2005 | | | 8/20/2003 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/20/2005 | 8/19/2003 | 8/19/2003 | 8/19/2003 |
| | | | | garage | garage | garage | garage | garage | garage | garage | tailings surface | tailings below surface | millAssay buildings | millAssay buildings | millAssay buildings | millAssay buildings | millAssay buildings | millAssay buildings | millAssay buildings | millAssay buildings | millAssay buildings | millAssay buildings | millAssay buildings | millAssay buildings | millAssay buildings | millAssay buildings | millAssay buildings | fuel area | fuel area | fuel area |
| **Hydrocarbons** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F1 - VPH ($C_6$-$C_{10}$) | ug/g | 130 | | <20 | <20 | <20 | <20 | <5 | <5 | <5 | | | <20 | <5 | <5 | <5 | <5 | | <5 | 36 | <5 | <5 | | | | | | 60 | 60 | 60 |
| F2 - EPH (C10-C16) | ug/g | 450 | | <10 | 470 | 30 | 70 | 730 | <5 | <5 | | | 740 | 6 | <5 | <5 | 1700 | | <5 | 5300 | <5 | <5 | | | | | | 20000 | 1300 | 4700 |
| F3 - EPH (C16-C34) | ug/g | 400 | | 1800 | 2500 | 5300 | 4400 | 8500 | 19000 | 36 | | | 1600 | 210 | <5 | 45 | 4400 | | 40 | 8200 | 120 | 24 | | | | | | 8600 | 180 | 1600 |
| F4 - EPH (C34-C50) | ug/g | 2800 | | 4800 | 740 | 490 | 410 | 5900 | 4300 | 23 | | | 50 | 110 | <5 | 7 | 80 | | 10 | 1200 | 40 | 21 | | | | | | <10 | <10 | 30 |
| F4 - GHH (silica gel) | ug/g | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Benzene | ug/g | 62 | 0.03 c | <0.05 | <0.05 | <0.05 | <0.05 | <0.005 | <0.005 | <0.005 | | | <0.05 | <0.005 | <0.005 | <0.005 | <0.005 | | <0.005 | <0.005 | <0.005 | <0.005 | | | | | | <0.1 | <0.1 | <0.1 |
| Toluene | ug/g | 150 | 0.37 c | <0.1 | <0.1 | <0.1 | <0.1 | 0.01 | 0.01 | <0.01 | | | <0.1 | <0.01 | <0.01 | <0.01 | <0.01 | | <0.01 | <0.01 | <0.01 | <0.01 | | | | | | <0.2 | 0.4 | <0.2 |
| Ethylbenzene | ug/g | 55 | 0.082 c | <0.1 | <0.1 | <0.1 | <0.1 | <0.01 | <0.01 | <0.01 | | | <0.1 | <0.01 | <0.01 | <0.01 | <0.01 | | <0.01 | <0.01 | <0.01 | <0.01 | | | | | | <0.2 | <0.2 | <0.2 |
| Total Xylenes | ug/g | 95 | 11 c | <0.3 | <0.3 | <0.3 | <0.3 | <0.01 | <0.01 | <0.01 | | | <0.3 | <0.01 | <0.01 | <0.01 | <0.01 | | <0.01 | 0.02 | <0.01 | <0.01 | | | | | | <0.6 | 5.7 | <0.6 |
| Total Petroleum Hydrocarbons | ug/g | | | -- | -- | -- | -- | 15000 | 23000 | 59 | | | -- | 330 | <5 | 52 | 6200 | | 50 | 15000 | 160 | 45 | | | | | | | | |
| **PCB/ DDT** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PCB (total) | ug/g | 1.3 | | <0.1 | <0.1 | <0.1 | <0.1 | <0.05 | | | | | <0.1 | | | | | | <0.05 | <0.05 | <0.05* | <0.05 | | | | | | <0.1 | -- | -- |
| DDT + metab | ug/g | 0.7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Salinity - Buffering** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| pH | | 6 to 8 | | | | | | | | | | | | | | | 8.2 | | | | | | | 7.8 | | | | | | |
| Conductivity | dS/m | 2 | | | | | | | | | | | | | | | 0.25 | | | | | | | 0.54 | | | | | | |
| Acid Nuetralizing Cap.(CaCO3) | % | | | | | | | | | | | | | | | | 19 | | | | | | | 16 | | | | | | |
| Chloride - S. Paste | mg/L | | | | | | | | | | | | | | | | <20 | | | | | | | <20 | | | | | | |
| Sulphate - S. Paste | mg/L | | | | | | | | | | | | | | | | 28 | | | | | | | 188 | | | | | | |
| SAR | ratio | 5 | | | | | | | | | | | | | | | 0.4 | | | | | | | 0.3 | | | | | | |
| **Polycyclic Aromatic Hydrocarbons** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Benzo(a)anthracene | ug/g | 1 | | | | | | <0.01 | | | | | | | | | | | <0.01 | <0.1 | | <0.01 | | | | | | | | |
| Benzo(k)fluoranthene | ug/g | 1 | | | | | | <0.01 | | | | | | | | | | | <0.01 | <0.1 | | <0.01 | | | | | | | | |
| Benzo(b+j)fluoranthe | ug/g | 1 | | | | | | <0.01 | | | | | | | | | | | <0.01 | <0.1 | | <0.01 | | | | | | | | |
| Benzo(a)pyrene | ug/g | 0.7 | 0.7 c | | | | | <0.01 | | | | | | | | | | | <0.01 | <0.1 | | <0.01 | | | | | | | | |
| Quinoline | ug/g | | | | | | | <0.01 | | | | | | | | | | | <0.01 | <0.1 | | <0.01 | | | | | | | | |
| Dibenz(a,h)anthracene | ug/g | 1 | | | | | | <0.01 | | | | | | | | | | | <0.01 | <0.1 | | <0.01 | | | | | | | | |
| Indeno(1,2,3-cd)pyrene | ug/g | 1 | | | | | | <0.01 | | | | | | | | | | | <0.01 | <0.1 | | <0.01 | | | | | | | | |
| Napthalene | ug/g | 0.6 | | | | | | <0.01 | | | | | | | | | | | <0.01 | <0.1 | | <0.01 | | | | | | | | |
| Phenanthrene | ug/g | 5 | | | | | | <0.01 | | | | | | | | | | | <0.01 | <0.1 | | <0.01 | | | | | | | | |
| Pyrene | ug/g | 10 | | | | | | 0.01 | | | | | | | | | | | <0.01 | <0.1 | | <0.01 | | | | | | | | |
| B[a]P equivalents | ug/g | | 0.7 c | | | | | <0.01 | | | | | | | | | | | <0.01 | <0.1 | | <0.01 | | | | | | | | |
| **Metals (total)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aluminum | ug/g | | | 19800 | 24400 | 12800 | 14500 | | | | 35300 | 33000 | 19100 | | | | | | | | | | | | | | | 6300 | | |
| Arsenic | ug/g | 17 | 31 | 33.1 | 16.9 | 6.1 | 10.1 | 43.5 | 11.4 | 16.9 | <100 | <100 | 35.6 | 9.5 | 1.6 | 2.9 | 42.1 | 25 | 219 | 9.7 | 244 | 15.2 | 19.1 | 379 | 521 | 1.4 | 19.4 | 1.9 | | |
| Barium | ug/g | 500 | 500 | 138 | 152 | 455 | 406 | 401 | 474 | 1010 | 1530 | 940 | 33 | 492 | 59 | 92 | 51 | 34 | 772 | 1190 | 804 | 254 | 581 | 402 | 352 | 17 | 46 | 85 | | |
| Beryllium | ug/g | | | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <0.5 | <0.5 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | | |
| Cadmium | ug/g | 10 | 14 | 4.3 | 6.9 | <0.5 | <0.5 | 4.1 | 1.4 | 3.4 | <2 | <2 | 5.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 4.8 | 2.3 | 9.1 | <0.5 | 1.6 | 4.9 | 7.5 | <0.5 | <0.5 | 0.6 | | |
| Chromium | ug/g | 64 | 220 | 101 | 136 | 106 | 74 | 68.4 | 27.3 | 93.6 | 118 | 80 | 104 | 35.4 | 10.6 | 6.4 | 10.5 | 54.6 | 94.8 | 12.1 | 69.1 | 22.6 | 71.1 | 67.4 | 67.8 | 8 | 7.8 | 20 | | |
| Cobalt | ug/g | | | 60 | 81 | 15 | 14 | 84 | 19 | 37 | 24 | 24 | 25 | 12 | 5 | 4 | 7 | 28 | 30 | 7 | 43 | 12 | 30 | 99 | 138 | 6 | 6 | 5 | | |
| Copper | ug/g | 63 | 1100 | 152 | 426 | 84 | 112 | 134 | 64 | 203 | 86 | 53 | 108 | 66 | 12 | 13 | 35 | 63 | 254 | 29 | 200 | 46 | 100 | 652 | 979 | 6 | 16 | 29 | | |
| Cyanide (free) | ug/g | | | <0.1 | <0.1 | <0.1 | <0.1 | | | | | | <0.1 | | | | | | | | | | | | | | | <0.1 | | |
| Iron | ug/g | | | 50000 | 64600 | 49000 | 57600 | | | | 44300 | 42000 | 19700 | | | | | | | | | | | | | | | 10500 | | |
| Lead | ug/g | 300 | 140 | 420 | 110 | 28 | 42 | 280 | 26 | 170 | 304 | 87 | 156 | 60 | 13 | 108 | 351 | 30 | 261 | 22 | 812 | 34 | 69 | 2750 | 4670 | <5 | 5 | 4 | | |
| Manganese | ug/g | | | 820 | 932 | 1120 | 1200 | | | | 1110 | 901 | 1030 | | | | | | | | | | | | | | | 245 | | |
| Mercury | ug/g | 12 | 6.6 | | | | | 0.58 | 0.09 | 1.06 | | | | <0.05 | <0.05 | <0.05 | 0.31 | <0.05 | 1.29 | <0.05 | 1.75 | 0.06 | 0.06 | 6.13 | 10.3 | <0.05 | <0.05 | | | |
| Molybdenum | ug/g | | | 4 | 5 | 11 | 10 | 3 | 1 | 2 | <4 | <4 | 2 | <1 | <1 | <1 | <1 | 5 | 7 | <1 | 3 | <1 | 1 | 6 | 8 | <1 | <1 | 1 | | |
| Nickel | ug/g | 50 | | 94 | 105 | 51 | 35 | 108 | 22 | 88 | 94 | 172 | 76 | 32 | 10 | 8 | 26 | 51 | 184 | 13 | 226 | 48 | 62 | 360 | 444 | 8 | 8 | 13 | | |
| Selenium | ug/g | 1 | 28 | | | | | 1.3 | <0.2 | <0.2 | <50 | <50 | | 0.6 | <0.2 | <0.2 | <0.2 | <0.2 | 0.2 | <0.2 | 0.9 | <0.2 | <0.2 | 2.6 | 4.4 | <0.2 | <0.2 | | | |
| Silver | ug/g | | | 117 | 50 | 2 | 2 | 201 | 4 | 946 | <2 | 10 | 35 | 3 | 4 | 2 | 105 | <1 | 661 | 17 | 729 | 140 | 9 | 2920 | 8030 | 8 | 3 | <1 | | |
| Strontium | ug/g | | | 19 | 17 | 20 | 20 | | | | | | 32 | | | | | | | | | | | | | | | 52 | | |
| Thallium | ug/g | 1.4 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <50 | <50 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | | |
| Tin | ug/g | | | | | | | <5 | <5 | <5 | <10 | <10 | | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | | | |
| Uranium | ug/g | | | | | | | <40 | <40 | <40 | | | | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | <40 | | | |
| Vanadium | ug/g | 130 | | 83 | 69 | 33 | 33 | 94 | 50 | 136 | 152 | 128 | 78 | 50 | 17 | 14 | 22 | 79 | 79 | 26 | 80 | 40 | 100 | 106 | 100 | 20 | 22 | 25 | | |
| Zinc | ug/g | 200 | | 329 | 142 | 74 | 120 | 330 | 180 | 190 | 282 | 89 | 172 | 110 | 30 | 30 | 50 | 140 | 300 | 160 | 370 | 60 | 140 | 780 | 1140 | 40 | 30 | 57 | | |

All Guidelines Taken from CCME,1999 "c" - guideline defined by protection of potable groundwater



UMA AECOM

**TABLE B1: ROBERTS BAY HHERA**
**Analytical Soil Data**

| Analytical Parameter | Units | Applicable Ecological Guideline | Applicable Human Health Guideline | RBSM-TF-3A | RBSM-TF-3B | RBSM-TF-4B | RBSM-TF-5B | RBSM-TF-5D | RBSM-TF-6B | RBSM-TF-7A | RBSM-TF-7B | RBSM-TF-8A | RBSM-TF-8A dup | ET-1151 A | ET-1152 A | ET-1152 B | ET-1153 A | ET-1153 B | ET-1154 A | ET-1155 A | ET-1156 A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 8/19/2003 | 8/19/2003 | 8/19/2003 | 8/19/2003 | 8/19/2003 | 8/20/2003 | 8/20/2003 | 8/20/2003 | 8/20/2003 | 8/20/2003 | 8/19/2005 | 8/19/2005 | 8/20/2005 | 8/19/2005 | 8/20/2005 | 8/19/2005 | 8/19/2005 | 8/20/2005 |
| | | | | fuel area | fuel area | fuel area | fuel area | fuel area | fuel area | fuel area | fuel area | fuel area | fuel area | fuel area | fuel area | fuel area | fuel area | fuel area | fuel area | fuel area | fuel area |
| **Hydrocarbons** | | | | | | | | | | | | | | | | | | | | | |
| F1 - VPH ($C_6$-$C_{10}$) | ug/g | 130 | | <20 | <20 | <20 | 80 | 60 | <20 | <20 | <20 | <20 | <20 | 360 | 200 | 97 | 740 | 330 | <5 | <5 | <5 |
| F2 - EPH (C10-C16) | ug/g | 450 | | 290 | 710 | <10 | 11000 | 430 | <10 | 20 | 30 | <10 | <10 | 7000 | 42000 | 3200 | 20000 | 7400 | 49 | <5 | <5 |
| F3 - EPH (C16-C34) | ug/g | 400 | | 200 | 250 | <10 | 2100 | 80 | 60 | 30 | 60 | <10 | <10 | 1400 | 13000 | 910 | 8200 | 3100 | 360 | 33 | 8 |
| F4 - EPH (C34-C50) | ug/g | 2800 | | <10 | <10 | <10 | 40 | <10 | <10 | <10 | <10 | <10 | <10 | 19 | 430 | 13 | 630 | 79 | 130 | 27 | <5 |
| F4 - GHH (silica gel) | ug/g | | | | | | | | | | | | | | | | | | | | |
| Benzene | ug/g | 62 | 0.03 c | <0.05 | <0.05 | <0.05 | <0.1 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.005 | <0.03 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Toluene | ug/g | 150 | 0.37 c | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.01 | <0.06 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Ethylbenzene | ug/g | 55 | 0.082 c | <0.1 | <0.1 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.03 | <0.06 | <0.01 | 0.07 | 0.03 | <0.01 | <0.01 | <0.01 |
| Total Xylenes | ug/g | 95 | 11 c | <0.3 | <0.3 | <0.3 | 16.9 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | 1.7 | 0.14 | 0.09 | 0.27 | 2.5 | <0.01 | <0.01 | <0.01 |
| Total Petroleum Hydrocarbons | ug/g | | | | | | | | | | | | | 8800 | 56000 | 4200 | 30000 | 11000 | 540 | 90 | 8 |
| **PCB/ DDT** | | | | | | | | | | | | | | | | | | | | | |
| PCB (total) | ug/g | 1.3 | | -- | -- | -- | -- | -- | -- | -- | -- | -- | | | <0.2 | | <0.05 | | | | |
| DDT + metab | ug/g | 0.7 | | | | | | | | | | | | | | | | | | | |
| **Salinity - Buffering** | | | | | | | | | | | | | | | | | | | | | |
| pH | | 6 to 8 | | | | | | | | | | | | | | | | | | | |
| Conductivity | dS/m | 2 | | | | | | | | | | | | | | | | | | | |
| Acid Nuetralizing Cap.(CaCO3) | % | | | | | | | | | | | | | | | | | | | | |
| Chloride - S. Paste | mg/L | | | | | | | | | | | | | | | | | | | | |
| Sulphate - S. Paste | mg/L | | | | | | | | | | | | | | | | | | | | |
| SAR | ratio | 5 | | | | | | | | | | | | | | | | | | | |
| **Polycyclic Aromatic Hydrocarbons** | | | | | | | | | | | | | | | | | | | | | |
| Benzo(a)anthracene | ug/g | 1 | | | | | | | | | | | | | <0.3 | | <1 | | | | |
| Benzo(k)fluoranthene | ug/g | 1 | | | | | | | | | | | | | <0.3 | | <1 | | | | |
| Benzo(b+j)fluoranthe | ug/g | 1 | | | | | | | | | | | | | <0.3 | | <1 | | | | |
| Benzo(a)pyrene | ug/g | 0.7 | 0.7 c | | | | | | | | | | | | <0.3 | | <1 | | | | |
| Quinoline | ug/g | | | | | | | | | | | | | | <0.3 | | <1 | | | | |
| Dibenz(a,h)anthracene | ug/g | 1 | | | | | | | | | | | | | <0.3 | | <1 | | | | |
| Indeno(1,2,3-cd)pyrene | ug/g | 1 | | | | | | | | | | | | | <0.3 | | <1 | | | | |
| Napthalene | ug/g | 0.6 | | | | | | | | | | | | | <0.3 | | <1 | | | | |
| Phenanthrene | ug/g | 5 | | | | | | | | | | | | | <0.3 | | 2 | | | | |
| Pyrene | ug/g | 10 | | | | | | | | | | | | | 0.3 | | <1 | | | | |
| B[a]P equivalents | ug/g | | 0.7 c | | | | | | | | | | | | <0.3 | | <1 | | | | |
| **Metals (total)** | | | | | | | | | | | | | | | | | | | | | |
| Aluminum | ug/g | | | | | | | | | | | | | | | | | | | | |
| Arsenic | ug/g | 17 | 31 | | | | | | | | | | | | | | | | | | |
| Barium | ug/g | 500 | 500 | | | | | | | | | | | | | | | | | | |
| Beryllium | ug/g | | | | | | | | | | | | | | | | | | | | |
| Cadmium | ug/g | 10 | 14 | | | | | | | | | | | | | | | | | | |
| Chromium | ug/g | 64 | 220 | | | | | | | | | | | | | | | | | | |
| Cobalt | ug/g | | | | | | | | | | | | | | | | | | | | |
| Copper | ug/g | 63 | 1100 | | | | | | | | | | | | | | | | | | |
| Cyanide (free) | ug/g | | | | | | | | | | | | | | | | | | | | |
| Iron | ug/g | | | | | | | | | | | | | | | | | | | | |
| Lead | ug/g | 300 | 140 | | | | | | | | | | | | | | | | | | |
| Manganese | ug/g | | | | | | | | | | | | | | | | | | | | |
| Mercury | ug/g | 12 | 6.6 | | | | | | | | | | | | | | | | | | |
| Molybdenum | ug/g | | | | | | | | | | | | | | | | | | | | |
| Nickel | ug/g | 50 | | | | | | | | | | | | | | | | | | | |
| Selenium | ug/g | 1 | 28 | | | | | | | | | | | | | | | | | | |
| Silver | ug/g | | | | | | | | | | | | | | | | | | | | |
| Strontium | ug/g | | | | | | | | | | | | | | | | | | | | |
| Thallium | ug/g | 1.4 | 1 | | | | | | | | | | | | | | | | | | |
| Tin | ug/g | | | | | | | | | | | | | | | | | | | | |
| Uranium | ug/g | | | | | | | | | | | | | | | | | | | | |
| Vanadium | ug/g | 130 | | | | | | | | | | | | | | | | | | | |
| Zinc | ug/g | 200 | | | | | | | | | | | | | | | | | | | |

All Guidelines Taken from CCME,1999 "c" - guideline defined by protection of potable groundwater

**TABLE B2: ROBERTS BAY HHERA, Analytical Water Data**

| Analytical Parameter | Units | Guidelines | | Patch Lake | Patch Lake | Pelvic Lake | Pelvic Lake | Little Roberts Lake | Little Roberts Lake | DW Lake | Roberts Lake | R.B. Background | Stream Mouth | RBSM-4 | RBSM-1 | Roberts Tailing Pond | Roberts Tailing Pond (Sump) | RBSM-2 | North Pond 008 | N Blabber | RBSM-3 | Roberts Bay Adit | Ida-1 | Ida Bay Adit 1 | Ida Bay Adit 2 | RBSM-Gar-w-1 | RBSM-Val-1 | SW-1 | SW-2 | SW-3 | Trip blank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (2) Drinking Water | (1) Aquatic Life | 1995 to 1998 | 1995 to 1998 | 1997 & 2000 | 1997 & 2000 | 1995 to 1997 | 1995 to 1997 | 20-Aug-05 | 20-Aug-05 | 20-Aug-05 | 20-Aug-05 | 19-Aug-03 | 19-Aug-03 | Aug-05 | Aug-05 | 19-Aug-03 | Aug-05 | 20-Aug-05 | 19-Aug-03 | Aug-05 | 19-Aug-03 | Aug-05 | Aug-05 | 19-Aug-03 | 19-Aug-03 | 20-Aug-05 | 20-Aug-05 | 20-Aug-05 | 20-Aug-05 |
| | | | | Background Median | Background Maximum | Background Median | Background Maximum | Background Median | Background Maximum | drinking water lake east of Roberts Bay mine | | | stream discharging from Roberts Bay mine | background lake | tailings pond | tailing pond (AMEC) | groundwater downgradient of tailing pond (AMEC) | surface water north of fuel bladder | surface water north of fuel bladder (AMEC) | standing water north of fuel bladder | Roberts Bay Adit | AMEC | Ida Bay adit | AMEC | AMEC | standing water east of garage | muskeg valley east of camp | standing water from the downgradient muskeg area (ET 1100) | standing water below tailing pond (ET 1183) | standing water downgradient of tailing pond (ET 1182) | |
| **Routine Parameters** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Conductivity | uS/cm | | | 243 | 299 | 185 | 208 | 230 | 287 | 173 | 244 | 353 | 479 | | | | | | | | | | | | | | | 495 | | 279 | 1 |
| pH | | 6.5 to 8.5 | 6.5 to 8.5 | 7.10 | 7.82 | 7.40 | 7.65 | 7.08 | 7.50 | 7.5 | 6.9 | 6.9 | 7.7 | | | | | | | | | | | | | | | 7.9 | | 7.9 | 6.1 |
| Total Dissolved Solids | mg/L | 500 | 10% | 122 | 143 | 104 | 116 | 129 | 173 | 90 | 123 | 172 | 246 | | | | | | | | | | | | | | | 284 | | 149 | 1 |
| Total Hardness | mg/L | | | 42.0 | 46.0 | 29.7 | 30.5 | 32.4 | 42.9 | 58 | 39 | 52 | 121 | 57 | 168 | | | 855 | | | 277 | | 256 | | | -- | -- | 175 | | 111 | <1 |
| Alkalinity Total as CaCO3 | mg/L | | | 30 | 33 | 17 | 17 | 21.0 | 23.2 | 46 | 24 | 21 | 62 | | | | | | | | | | | | | | | 147 | | 70 | <5 |
| Bicarbonate (HCO3) | mg/L | | | 29 | 32 | | | | 22 | 56 | 29 | 26 | 76 | | | | | | | | | | | | | | | 180 | | 86 | <5 |
| Chloride | mg/L | 250 | | 53.5 | 54.2 | 41.0 | 47.4 | 51.0 | 59.4 | 28 | 61 | 90 | 96 | | | | | | | | | | | | | | | 39 | | 36 | 1 |
| Sodium | mg/L | 200 | | 29.7 | 30.3 | | 20.6 | | 24.2 | 11 | 29 | 44 | 48 | | | | | | | | | | | | | | | 39 | | 13 | <1 |
| Nitrate + Nitrite (N) | mg/L | 45 | 13 | 0.005 | | | | | | <0.1 | <0.1 | <0.1 | <0.1 | | | | | | | | | | | | | | | 0.5 | | <0.1 | <0.1 |
| Sulfate | mg/L | 500 | | 1 | 2 | 3 | 3 | 2.9 | 3.7 | 1.4 | 4.7 | 7.7 | 23.2 | | | | | | | | | | | | | | | 52.1 | | 17.8 | <0.5 |
| **Hydrocarbons** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total Petroleum Hydrocarbon | mg/L | | | | | | | | | | | | | <0.2 | <0.2 | | | <0.2 | | | 0.6 | | <0.1 | | | -- | -- | | | | |
| F1 - VPH ($C_6$-$C_{10}$) | mg/L | | | | | | | | | | <0.1 | <0.1 | <0.1 | | | | | | | <0.1 | | | | | | | | <0.1 | | <0.1 | <0.1 |
| F2 - EPH (C10-C16) | mg/L | | | | | | | | | | <0.05 | <0.05 | <0.05 | | | | | | | <0.05 | | | | | | | | <0.05 | | <0.05 | <0.05 |
| TOC | mg/L | | | | | | | | | 13 | 4 | 6 | | | | | | | | | | | | | | | | 7 | | 10 | |
| Benzene | mg/L | 0.005 | 0.37 | | | | | | | | <0.0005 | <0.0005 | <0.0005 | <0.5 | <0.5 | | | <0.5 | | <0.0005 | <0.5 | | <0.5 | | | <0.5 | <0.5 | <0.0005 | | <0.0005 | <0.0005 |
| Toluene | mg/L | 0.024 | 0.002 | | | | | | | | <0.0005 | <0.0005 | <0.0005 | <0.5 | <0.5 | | | <0.5 | | <0.0005 | <0.5 | | <0.5 | | | <0.5 | <0.5 | <0.0005 | | <0.0005 | <0.0005 |
| Ethylbenzene | mg/L | 0.0024 | 0.09 | | | | | | | | <0.0005 | <0.0005 | <0.0005 | <0.5 | <0.5 | | | <0.5 | | <0.0005 | <0.5 | | <0.5 | | | <0.5 | <0.5 | <0.0005 | | <0.0005 | <0.0005 |
| Total Xylenes | mg/L | 0.3 | | | | | | | | | <0.0005 | <0.0005 | <0.0005 | <1.5 | <1.5 | | | <1.5 | | <0.0005 | <1.5 | | <1.5 | | | <1.5 | <1.5 | <0.0005 | | <0.0005 | <0.0005 |
| **PCB + OC Pesticides** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total PCB | mg/L | | | | | | | | | | <0.00005 | <0.00005 | | | | | | | | | | | | | | | | <0.00005 | | <0.00005 | <0.00005 |
| p,p DDD | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| p,p DDE | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| p,p DDT | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| Aldrin | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| alpha - BHC | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| beta - BHC | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| gamma BHC | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| Quintozine | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| cis - Chlordane | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| trans - Chlordane | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| dieldrin | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| Endosulfan I | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| Endosulfan II | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| Endrin | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| Heptachlor | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| Methoxychlor | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| Mirex | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| Nonachlor | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| Oxychlordane | mg/L | | | | | | | | | | | | | | | | | | | | | | | | | | | <0.0003 | | <0.0003 | |
| **Metals (total)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aluminum | mg/L | | 0.1^^ | 0.069 | 0.182 | 0.147 | 0.338 | 0.242 | 0.343 | | 0.08 | 0.5 | 0.22 | 0.11 | 0.37 | 0.136 | <0.05 | 0.15 | <0.005 | <0.02 | 0.18 | <0.005 | 0.12 | <0.005 | 0.024 | 0.01 | 0.03 | 0.13 | 0.04 | 0.05 | <0.02 |
| Arsenic | mg/L | 0.025 | 0.005 | 0.001 | 0.002 | 0.0002 | 0.0003 | 0.0016 | 0.004 | | 0.0004 | 0.0006 | 0.0005 | <0.001 | 0.02 | 0.0282 | 0.0155 | 0.002 | 0.0196 | 0.0053 | 0.002 | 0.0037 | <0.001 | 0.0025 | 0.0025 | <0.001 | <0.001 | 0.0007 | 0.0031 | <0.0004 | <0.0004 |
| Barium | mg/L | 1 | | 0.0026 | <0.010 | 0.00632 | <0.010 | 0.0068 | <0.010 | | 0.0044 | 0.0095 | 0.0204 | <0.01 | 0.05 | 0.075 | 0.23 | 0.08 | 0.156 | 0.145 | 0.05 | 0.032 | 0.02 | 0.015 | 0.016 | 0.13 | 0.16 | 0.0404 | 0.0476 | 0.01 | <0.0002 |
| Beryllium | mg/L | | | <0.0005 | <0.005 | <0.003 | <0.005 | <0.0028 | <0.005 | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | | <0.001 | | <0.001 | <0.001 | | <0.001 | | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Boron | mg/L | 5 | | 0.022 | <0.100 | 0.059 | <0.100 | 0.093 | <0.100 | | 0.02 | 0.03 | 0.03 | <0.05 | <0.05 | 0.038 | <0.1 | <0.05 | 0.013 | <0.02 | <0.05 | 0.033 | <0.05 | 0.034 | 0.034 | 0.5 | 0.49 | 0.05 | 0.03 | <0.02 | <0.02 |
| Cadmium | mg/L | 0.005 | 0.00004* | <0.0002 | <0.0002 | <0.0001 | <0.0002 | <0.0002 | <0.0002 | | <0.0002 | <0.0002 | <0.0002 | 0.0008 | <0.0005 | <0.0001 | <0.001 | <0.0001 | <0.0001 | <0.0002 | 0.001 | 0.0007 | 0.0003 | <0.0001 | 0.0025 | 0.0001 | <0.0001 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Calcium | mg/L | | | 0.00689 | 0.00762 | 0.00369 | 0.00394 | 0.00566 | 0.00641 | | 5.4 | 5.9 | 22.4 | | | | | | | 197 | | | | | | | | 40.4 | 78.4 | 30.5 | <0.5 |
| Chromium | mg/L | 0.05 | 0.0089 | <0.001 | 0.0024 | <0.0008 | <0.001 | 0.0017 | 0.0027 | | <0.0008 | <0.0008 | <0.0008 | 0.003 | 0.005 | 0.0047 | <0.009 | 0.007 | 0.0067 | <0.0008 | 0.004 | 0.0042 | 0.003 | 0.0021 | 0.0026 | 0.007 | 0.004 | <0.0008 | <0.0008 | <0.0008 | <0.0008 |
| Cobalt | mg/L | | | <0.0001 | <0.015 | <0.0006 | <0.001 | 0.0006 | <0.001 | | <0.0002 | <0.0002 | <0.0002 | <0.0002 | 0.0005 | 0.0003 | 0.0021 | 0.0007 | 0.0004 | 0.0006 | 0.0004 | 0.0002 | 0.0002 | 0.0001 | 0.0003 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Copper | mg/L | 1 | 0.003* | 0.001 | 0.0027 | 0.0014 | 0.002 | 0.002 | 0.0034 | | 0.01 | 0.003 | 0.004 | 0.002 | 0.011 | 0.0087 | 0.122 | 0.003 | 0.0014 | 0.002 | 0.012 | 0.0115 | 0.008 | 0.0051 | 0.0061 | 0.003 | 0.002 | 0.005 | 0.005 | 0.004 | <0.001 |
| Cyanide (free) | mg/L | | | | | | | | 0 | | | | | 0.013 | 0.007 | | | 0.011 | | | 0.007 | | 0.013 | | | -- | -- | | | | |
| Iron | mg/L | 0.3 | 0.3 | 0.07 | 0.12 | 0.298 | 0.43 | 0.228 | 0.26 | | 0.089 | 0.308 | 0.329 | 0.08 | 0.46 | 0.26 | 0.26 | 2.14 | 0.46 | 3.21 | 0.3 | 0.12 | 0.1 | 0.05 | 0.08 | 0.04 | 2.38 | 0.218 | 0.06 | 0.099 | <0.005 |
| Lead | mg/L | 0.01 | 0.007* | <0.001 | <0.001 | 0.0015 | 0.005 | 0.001 | 0.004 | | 0.0004 | 0.0001 | <0.0001 | <0.001 | 0.013 | 0.0077 | 0.0078 | <0.001 | <0.0001 | 0.0004 | 0.001 | 0.0003 | 0.002 | 0.003 | 0.0048 | <0.001 | <0.001 | 0.002 | 0.0006 | <0.0001 | <0.0001 |
| Magnesium | mg/L | | | 0.00619 | 0.00696 | 0.0046 | 0.005 | 0.00561 | 0.00818 | | 5.4 | 7.9 | 11.6 | | | | | | | 91.4 | | | | | | | | 12.2 | 14.2 | 7.9 | <0.1 |
| Manganese | mg/L | 0.05 | | 0.005 | 0.008 | 0.0233 | 0.036 | 0.00851 | 0.012 | | 0.006 | 0.01 | 0.014 | 0.029 | 0.023 | | | 0.172 | | 0.2 | 0.1 | | 0.028 | | | <0.005 | 0.023 | 0.006 | 0.003 | 0.005 | <0.001 |
| Molybdenum | mg/L | | 0.073 | <0.0002 | <0.030 | 0.0006 | <0.001 | 0.0006 | <0.001 | | 0.0002 | 0.0002 | 0.0004 | <0.005 | 0.019 | 0.0216 | 0.0234 | <0.005 | <0.0005 | 0.0005 | <0.005 | 0.0017 | <0.005 | 0.0008 | 0.0008 | <0.005 | <0.005 | 0.0015 | 0.0016 | 0.0001 | <0.0001 |
| Nickel | mg/L | | 0.15* | <0.001 | <0.010 | 0.0007 | <0.001 | 0.0017 | 0.0025 | | 0.0007 | 0.0009 | 0.0017 | <0.005 | 0.006 | 0.0072 | 0.0178 | <0.005 | 0.0124 | <0.0002 | <0.005 | 0.0031 | <0.0005 | 0.0021 | 0.0029 | <0.005 | <0.005 | <0.0002 | <0.0002 | 0.0002 | <0.0002 |
| Potassium | mg/L | | | 0.00238 | 0.00326 | 0.00197 | 0.0023 | 0.00195 | 0.0025 | | 1.8 | 2.1 | 2.2 | | | | | | | 5.1 | | | | | | | | 2.1 | 1.8 | 1 | <0.1 |
| Selenium | mg/L | 0.01 | 0.001 | <0.0005 | 0.0022 | <0.0008 | <0.001 | 0.0016 | 0.0028 | | 0.0008 | 0.0011 | 0.0008 | | | <0.0008 | <0.008 | | 0.0055 | 0.0164 | | <0.0008 | | <0.0008 | <0.0008 | | | <0.0004 | <0.0004 | <0.0004 | <0.0004 |
| Silver | mg/L | | 0.0001 | <0.00001 | <0.0001 | <0.00006 | <0.0001 | <0.00006 | <0.0001 | | <0.0004 | <0.0004 | <0.0004 | 0.0002 | 0.0002 | <0.0002 | <0.002 | <0.0001 | <0.0002 | <0.0004 | <0.0001 | <0.0002 | 0.0001 | <0.0002 | <0.0002 | <0.0001 | <0.0001 | <0.0004 | <0.0004 | 0.0005 | <0.0004 |
| Sodium | mg/L | 200 | | 0.0306 | 0.0321 | 0.0229 | 0.025 | | 0.0243 | | 27 | 39 | 40 | | | | | | | 558 | | | | | | | | 33 | 12 | 14 | <1 |
| Strontium | mg/L | | | 0.0312 | 0.041 | | 0.025 | 0.0333 | 0.0378 | | 0.0373 | 0.0511 | 0.111 | 0.051 | 0.065 | | | 0.64 | | 1.04 | 0.232 | | 0.123 | | | 0.065 | 0.046 | 0.133 | 0.129 | 0.0572 | <0.0002 |
| Thallium | mg/L | | 0.0008 | <0.003 | <0.010 | | <0.100 | <0.050 | <0.100 | | <0.0001 | <0.0001 | <0.0001 | <0.001 | <0.001 | | | <0.001 | | <0.0001 | <0.001 | | <0.001 | | | <0.001 | <0.001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Tin | mg/L | | | <0.0001 | <0.300 | | <0.030 | 0.015 | <0.030 | | <0.0004 | <0.0004 | <0.0004 | | | | | | | <0.0004 | | | | | | | | <0.0004 | <0.0004 | <0.0004 | <0.0004 |
| Titanium | mg/L | | | <0.003 | <0.010 | | 0.01 | 0.008 | <0.010 | | <0.005 | 0.01 | 0.008 | <0.01 | <0.01 | | | <0.01 | | <0.005 | <0.01 | | <0.01 | | | 0.02 | 0.02 | 0.006 | <0.005 | <0.005 | <0.005 |
| Vanadium | mg/L | | | <0.001 | <0.030 | <0.016 | <0.030 | 0.0158 | <0.030 | | 0.0004 | 0.0008 | 0.0004 | <0.001 | 0.003 | | | 0.002 | | <0.0002 | 0.001 | | <0.001 | | | 0.003 | 0.001 | 0.0006 | <0.0002 | 0.0002 | <0.0002 |
| Zinc | mg/L | 5 | 0.03 | <0.005 | <0.005 | <0.003 | <0.005 | <0.005 | 0.008 | | 0.006 | <0.004 | <0.004 | <0.005 | <0.005 | 0.009 | 0.221 | <0.005 | 0.004 | 0.006 | 0.036 | 0.009 | <0.005 | 0.017 | 0.019 | <0.005 | <0.005 | 0.006 | 0.011 | 0.005 | <0.004 |

^^ - guideline value adjusted based on site-specific geometric mean TOC (surrogate for DOC). * - guideline values adjusted based on site-specific geometric mean hardness.

**TABLE B2: ROBERTS BAY HHERA, Analytical Water Data**

| Analytical Parameter | Units | Guidelines: (2) Drinking Water | Guidelines: (1) Aquatic Life | Patch Lake | Patch Lake | Pelvic Lake | Pelvic Lake | Little Roberts Lake | Little Roberts Lake | DW Lake | Roberts Lake | R.B. Background | Stream Mouth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1995 to 1998 | 1995 to 1998 | 1997 & 2000 | 1997 & 2000 | 1995 to 1997 | 1995 to 1997 | 20-Aug-05 | 20-Aug-05 | 20-Aug-05 | 20-Aug-05 |
| | | | | Background Median | Background Maximum | Background Median | Background Maximum | Background Median | Background Maximum | drinking water lake east of Roberts Bay mine | | | stream discharging from Roberts Bay mine |
| **Metals (dissolved)** | | | | | | | | | | | | | |
| Aluminum | mg/L | | 0.1^^ | 0.015 | 0.017 | | 0.116 | 0.025 | 0.046 | | <0.01 | 0.07 | 0.06 |
| Arsenic | mg/L | 0.025 | | <0.0006 | <0.001 | | <0.0001 | 0.0008 | 0.002 | | <0.0004 | <0.0004 | 0.0005 |
| Barium | mg/L | 1 | | 0.0058 | <0.010 | | <0.010 | 0.00564 | <0.010 | | 0.0025 | 0.0034 | 0.0163 |
| Beryllium | mg/L | | | <0.0028 | <0.005 | | <0.005 | <0.003 | <0.005 | | <0.0005 | <0.0005 | <0.0005 |
| Boron | mg/L | 5 | | 0.059 | <0.100 | | <0.100 | 0.084 | <0.100 | | 0.022 | 0.025 | 0.032 |
| Cadmium | mg/L | 0.005 | 0.00004* | <0.00013 | <0.0002 | | <0.0002 | <0.00013 | <0.0002 | | <0.0001 | <0.0001 | <0.0001 |
| Calcium | mg/L | | | 0.00695 | 0.00745 | | 0.00339 | 0.00424 | 0.0051 | | | | |
| Chromium | mg/L | 0.05 | 0.0089 | 0.00105 | 0.0012 | | <0.001 | <0.0006 | <0.001 | | <0.0004 | <0.0004 | 0.0005 |
| Cobalt | mg/L | | | <0.0006 | <0.001 | | <0.001 | <0.0006 | <0.001 | | <0.0001 | <0.0001 | <0.0001 |
| Copper | mg/L | 1 | 0.003* | 0.0008 | 0.001 | | 0.002 | 0.0015 | 0.002 | | 0.0035 | 0.0016 | 0.0033 |
| Iron | mg/L | 0.3 | 0.3 | <0.010 | <0.010 | | 0.16 | 0.043 | 0.06 | | 0.039 | 0.063 | 0.21 |
| Lead | mg/L | 0.01 | 0.004* | <0.00054 | <0.001 | | <0.001 | 0.00062 | <0.001 | | <0.0001 | <0.0001 | <0.0001 |
| Magnesium | mg/L | | | 0.00597 | 0.00664 | | 0.00402 | 0.00468 | 0.00732 | | | | |
| Manganese | mg/L | 0.05 | | <0.0025 | <0.005 | | 0.011 | 0.00259 | <0.005 | | 0.001 | 0.001 | 0.002 |
| Molybdenum | mg/L | | 0.073 | <0.0005 | <0.001 | | <0.001 | 0.0006 | <0.001 | | 0.0003 | 0.0003 | 0.0004 |
| Nickel | mg/L | | 0.065* | <0.0006 | <0.001 | | <0.001 | 0.0007 | <0.001 | | 0.0007 | 0.0004 | 0.0013 |
| Potassium | mg/L | | | 0.0023 | 0.0025 | | 0.00148 | 0.00172 | 0.0025 | | | | |
| Selenium | mg/L | 0.01 | 0.001 | <0.0005 | <0.0005 | | <0.0005 | 0.0009 | 0.0016 | | <0.0004 | <0.0004 | 0.0011 |
| Silver | mg/L | | 0.0001 | <0.00006 | <0.0001 | | <0.0001 | <0.00006 | <0.0001 | | <0.0002 | <0.0002 | 0.0005 |
| Sodium | mg/L | 200 | | 0.0297 | 0.0303 | | 0.0206 | | 0.0242 | | | | |
| Strontium | mg/L | | | 0.036 | 0.041 | | 0.025 | 0.0267 | 0.034 | | 0.0377 | 0.0504 | 0.11 |
| Thallium | mg/L | | 0.0008 | <0.050 | <0.100 | | <0.100 | <0.050 | <0.100 | | <0.00005 | <0.00005 | <0.00005 |
| Tin | mg/L | | | <0.015 | <0.030 | | <0.030 | 0.015 | <0.030 | | <0.0002 | <0.0002 | <0.0002 |
| Titanium | mg/L | | | <0.006 | <0.010 | | <0.010 | <0.006 | <0.010 | | 0.0003 | 0.0005 | 0.0016 |
| Vanadium | mg/L | | | <0.015 | <0.030 | | <0.030 | 0.0152 | <0.030 | | 0.0005 | 0.0005 | 0.0001 |
| Zinc | mg/L | 5 | 0.03 | <0.003 | <0.005 | | <0.005 | 0.0035 | <0.005 | | 0.005 | 0.002 | 0.003 |

| Analytical Parameter | RBSM-4 | RBSM-1 | Roberts Tailing Pond | Roberts Tailing Pond (Sump) | RBSM-2 | North Pond 008 | N Blabber | RBSM-3 | Roberts Bay Adit | Ida-1 | Ida Bay Adit 1 | Ida Bay Adit 2 | RBSM-Gar-w-1 | RBSM-Val-1 | SW-1 | SW-2 | SW-3 | Trip blank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 19-Aug-03 | 19-Aug-03 | Aug-05 | Aug-05 | 19-Aug-03 | Aug-05 | 20-Aug-05 | 19-Aug-03 | Aug-05 | 19-Aug-03 | Aug-05 | Aug-05 | 19-Aug-03 | 19-Aug-03 | 20-Aug-05 | 20-Aug-05 | 20-Aug-05 | 20-Aug-05 |
| | background lake | tailings pond | tailing pond (AMEC) | groundwater downgradient of tailing pond (AMEC) | surface water north of fuel bladder | surface water north of fuel bladder (AMEC) | standing water north of fuel bladder | Roberts Bay Adit | AMEC | Ida Bay adit | AMEC | AMEC | standing water east of garage | muskeg valley east of camp | standing water from the downgradient muskeg area (ET 1100) | standing water below tailing pond (ET 1183) | standing water downgradient of tailing pond (ET 1182) | |
| **Metals (dissolved)** | | | | | | | | | | | | | | | | | | |
| Aluminum | | | | | | | <0.01 | | | | | | | | 0.02 | <0.01 | 0.01 | <0.01 |
| Arsenic | | | | | | | 0.0041 | | | | | | | | 0.0004 | 0.0032 | <0.0004 | <0.0004 |
| Barium | | | | | | | 0.118 | | | | | | | | 0.0265 | 0.0389 | 0.0061 | <0.0001 |
| Beryllium | | | | | | | <0.0005 | | | | | | | | <0.0005 | <0.0005 | <0.0005 | <0.0005 |
| Boron | | | | | | | 0.015 | | | | | | | | 0.058 | 0.027 | 0.01 | <0.002 |
| Cadmium | | | | | | | <0.0001 | | | | | | | | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Calcium | | | | | | | | | | | | | | | | | | |
| Chromium | | | | | | | 0.0004 | | | | | | | | <0.0004 | <0.0004 | <0.0004 | 0.0004 |
| Cobalt | | | | | | | 0.0002 | | | | | | | | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Copper | | | | | | | 0.001 | | | | | | | | 0.0042 | 0.0041 | 0.003 | <0.0006 |
| Iron | | | | | | | 1.72 | | | | | | | | 0.021 | 0.011 | 0.075 | <0.005 |
| Lead | | | | | | | <0.0001 | | | | | | | | 0.0002 | <0.0001 | <0.0001 | <0.0001 |
| Magnesium | | | | | | | | | | | | | | | | | | |
| Manganese | | | | | | | 0.048 | | | | | | | | 0.001 | <0.001 | 0.001 | <0.001 |
| Molybdenum | | | | | | | 0.0005 | | | | | | | | 0.0015 | 0.0016 | 0.0004 | <0.0001 |
| Nickel | | | | | | | <0.0001 | | | | | | | | <0.0001 | 0.0003 | 0.0002 | <0.0001 |
| Potassium | | | | | | | | | | | | | | | | | | |
| Selenium | | | | | | | 0.0172 | | | | | | | | 0.0007 | 0.0006 | <0.0004 | <0.0004 |
| Silver | | | | | | | <0.0002 | | | | | | | | 0.0004 | 0.0003 | 0.0002 | <0.0002 |
| Sodium | | | | | | | | | | | | | | | | | | |
| Strontium | | | | | | | 1.03 | | | | | | | | 0.13 | 0.124 | 0.0493 | <0.0001 |
| Thallium | | | | | | | <0.00005 | | | | | | | | <0.00005 | <0.00005 | <0.00005 | <0.00005 |
| Tin | | | | | | | <0.0002 | | | | | | | | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Titanium | | | | | | | 0.0019 | | | | | | | | 0.0007 | 0.0006 | 0.0008 | <0.0003 |
| Vanadium | | | | | | | <0.0001 | | | | | | | | 0.0002 | 0.0001 | 0.0004 | 0.0003 |
| Zinc | | | | | | | 0.003 | | | | | | | | 0.006 | 0.009 | 0.006 | <0.002 |

^^ - guideline value adjusted based on site-specific geometric mean TOC (surrogate for DOC)
* - guideline values adjusted based on site-specific geometric mean hardness.

## TABLE B3: ROBERTS BAY HHERA, Analytical Sediment Data

| Analytical Parameter | Units | Ontario MOE LEL | CCME ISQG frshwater | CCME ISQG marine | Roberts Lake 01 | Roberts Lake 02 | Roberts Lake 03 | Roberts Lake 04 | Roberts Lake Med | Roberts Lake BKND | Patch Lake | Pelivic Lake | Little Roberts Lake | Roberts Bay | IDA 01 | IDA 02 | IDA 03 | IDA 04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Aug-05 | Aug-05 | Aug-05 | Aug-05 | Aug-05 | Aug-05 | 96/97 | Jul-97 | 96/97 | Aug-97 | Aug-05 | Aug-05 | Aug-05 | Aug-05 |
| | | | | | Roberts Lake | Roberts Lake | Roberts Lake | Roberts Lake | Roberts Lake | Roberts Lake | average n = 3 | single data point | average n = 3 | average marine baseline | marine sediment | marine sediment | marine sediment | background marine sediment |
| **Hydrocarbons** | | | | | | | | | | | | | | | | | | |
| F1 - VPH ($C_6$-$C_{10}$) | ug/g | | | | <5 | <5 | <5 | | <5 | <5 | | | | | <5 | <5 | | <5 |
| F2 - EPH (C10-C16) | ug/g | | | | <5 | <5 | <5 | | <5 | <5 | | | | | <5 | <5 | | <5 |
| F3 - EPH (C16-C34) | ug/g | | | | 30 | 24 | 29 | | 9 | 37 | | | | | <5 | 6 | | 18 |
| F4 - EPH (C34-C50) | ug/g | | | | 12 | 6 | 11 | | <5 | 17 | | | | | <5 | <5 | | 11 |
| F4 - GHH (silica gel) | ug/g | | | | | | | | | | | | | | | | | |
| Benzene | ug/g | | | | <0.005 | <0.005 | <0.005 | | <0.005 | <0.005 | | | | | <0.005 | <0.005 | | <0.005 |
| Toluene | ug/g | | | | 0.03 | 0.02 | 0.02 | | 0.02 | 0.01 | | | | | 0.01 | 0.01 | | 0.01 |
| Ethylbenzene | ug/g | | | | <0.01 | <0.01 | <0.01 | | <0.01 | <0.01 | | | | | <0.01 | <0.01 | | <0.01 |
| Total Xylenes | ug/g | | | | <0.01 | <0.01 | <0.01 | | <0.01 | <0.01 | | | | | <0.01 | <0.01 | | <0.01 |
| Total Petroleum Hydrocarbons | ug/g | | | | 42 | 30 | 40 | | 9 | 54 | | | | | <5 | 6 | | 29 |
| **PCB** | | | | | | | | | | | | | | | | | | |
| PCB (total) | ug/g | | 0.0341 | 0.0215 | <0.05 | <0.05 | <0.05 | | <0.05 | <0.05 | | | | | | <0.05 | | <0.05 |
| **Polycyclic Aromatic Hydrocarbons** | | | | | | | | | | | | | | | | | | |
| Benzo(a)anthracene | ug/g | *0.32* | 0.0817 | 0.0748 | | | | | <0.01 | <0.01 | | | | | | <0.01 | | <0.01 |
| Benzo(k)fluoranthene | ug/g | *0.24* | | | | | | | <0.01 | <0.01 | | | | | | <0.01 | | <0.01 |
| Benzo(b+j)fluoranthe | ug/g | | | | | | | | <0.01 | <0.01 | | | | | | <0.01 | | <0.01 |
| Benzo(a)pyrene | ug/g | *0.37* | 0.0319 | 0.0888 | | | | | <0.01 | <0.01 | | | | | | <0.01 | | <0.01 |
| Dibenz(a,h)anthracene | ug/g | *0.06* | 0.00682 | 0.00622 | | | | | <0.01 | <0.01 | | | | | | <0.01 | | <0.01 |
| Indeno(1,2,3-cd)pyrene | ug/g | *0.2* | | | | | | | <0.01 | <0.01 | | | | | | <0.01 | | <0.01 |
| Quinoline | ug/g | | | | | | | | <0.01 | <0.01 | | | | | | <0.01 | | <0.01 |
| Napthalene | ug/g | | 0.0346 | 0.0346 | | | | | <0.01 | <0.01 | | | | | | <0.01 | | <0.01 |
| Phenanthrene | ug/g | *0.56* | 0.0419 | 0.0867 | | | | | <0.01 | <0.01 | | | | | | <0.01 | | <0.01 |
| Pyrene | ug/g | *0.49* | 0.053 | 0.153 | | | | | <0.01 | <0.01 | | | | | | <0.01 | | <0.01 |
| **Metals** | | | | | | | | | | | | | | | | | | |
| Antimony | ug/g | | | | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | 0.085 | | <0.05 | | <0.2 | <0.2 | <0.2 | <0.2 |
| Arsenic | ug/g | *6* | 5.9 | 7.24 | 2.6 | 1.7 | 2.5 | 9.2 | 5.1 | 8.7 | 6.31 | 3.25 | 2 | 2.72 | 6.5 | 2 | 1.4 | 2 |
| Barium | ug/g | | | | 108 | 62 | 82 | 111 | 141 | 106 | | | | | 108 | 95 | 85 | 51 |
| Beryllium | ug/g | | | | <1 | <1 | <1 | <1 | <1 | <1 | | | | | <1 | <1 | <1 | <1 |
| Cadmium | ug/g | *0.6* | 0.6 | 0.7 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 0.12 | <0.1 | 0.05 | <0.1 | <0.5 | <0.5 | <0.5 | <0.5 |
| Chromium | ug/g | *26* | 37.3 | 52.3 | 63.2 | 29.6 | 40.3 | 57.9 | 70.4 | 59.2 | 99.3 | 74 | 64.3 | 48 | 47.9 | 33.7 | 41 | 30.8 |
| Cobalt | ug/g | *50* | | | 11 | 8 | 10 | 12 | 14 | 12 | 15.5 | 12 | 10.1 | 8 | 13 | 10 | 11 | 7 |
| Copper | ug/g | *16* | 35.7 | 18.7 | 20 | 14 | 22 | 30 | 25 | 30 | 35 | 32 | 23.3 | 19.4 | 39 | 26 | 28 | 21 |
| Lead | ug/g | *31* | 35 | 30.2 | 8 | <5 | 7 | 25 | 12 | 21 | 10.8 | 9 | 6.52 | 6.6 | 49 | 8 | 6 | <5 |
| Mercury | ug/g | *0.2* | 0.17 | 0.17 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.017 | 0.021 | 0.006 | <0.05 | <0.05 | <0.05 | <0.05 |
| Molybdenum | ug/g | | | | <1 | <1 | <1 | 3 | <1 | 4 | | | | | <1 | <1 | <1 | <1 |
| Nickel | ug/g | *16* | | | 32 | 17 | 22 | 31 | 35 | 31 | 43 | 39 | 25.2 | 21.4 | 31 | 21 | 24 | 17 |
| Selenium | ug/g | | | | <0.2 | <0.2 | <0.2 | 0.4 | <0.2 | 0.3 | 0.2 | 0.2 | 0.22 | 0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Silver | ug/g | *0.5* | | | <1 | <1 | <1 | *3* | <1 | *3* | 0.27 | <0.1 | 0.07 | <0.1 | *3* | 1 | <1 | <1 |
| Thallium | ug/g | | | | <1 | <1 | <1 | <1 | <1 | <1 | | | | | <1 | <1 | <1 | <1 |
| Tin | ug/g | | | | <5 | <5 | <5 | <5 | <5 | <5 | | | | | <5 | <5 | <5 | <5 |
| Uranium | ug/g | | | | <40 | <40 | <40 | <40 | <40 | <40 | | | | | <40 | <40 | <40 | <40 |
| Vanadium | ug/g | | | | 61 | 35 | 48 | 66 | 70 | 65 | | | | | 59 | 46 | 53 | 39 |
| Zinc | ug/g | *120* | 123 | 124 | 80 | 40 | 60 | 80 | 90 | 80 | 85.7 | 83 | 61.7 | 52.4 | 80 | 60 | 70 | 40 |

Background data taken from RL&L/Golder, 2002. ISQG = Interim Sediment Quality Guidelines. Underline values exceed either freshwater or marine ISQG.



UMA | AECOM

## TABLE B4: ROBERTS BAY HHERA: Analytical Data for Browse Vegetation

| Analytical Parameter | Units | Benchmarks NOAEL | Benchmarks LOAEL | Veg 1A | Veg 2A | Veg 3A | Veg 4A | Veg 5A | Veg 6A | Veg 7A | Veg 8A | Veg 9A | Veg 1B | Veg 2B | Veg 4B | Veg 6B | Veg 8B | Veg 9B | Berry | Mushroom | 05-8911 | 05-8911 - dup |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | 18-Aug-05 | | |
| | | | | Willow sp background site (ET 1158) | Willow sp background site (ET 1157) | Willow sp. fuel area (ET 1151) | Willow sp. muskeg ditch (ET 1100) | Willow sp. water below tailing pond (ET 1183) | Willow sp. below camp dump (ET 1178 & 1181) | Willow sp. muskeg (ET 1101) | Willow sp. below tailing (ET 1182) | Willow sp. below Mill (ET 1159) | Crowberry background site (ET 1158) | Crowberry background site (ET 1157) | Crowberry muskeg ditch (ET 1100) | Crowberry below camp dump (ET 1178 & 1181) | Crowberry below tailing (ET 1182) | Crowberry below Mill (ET 1159) | Bearberry area wide collection | area wide collection | cotton grass within tailing pond (AMEC) | cotton grass within tailing pond (AMEC) |
| **Total Metals** | | | | | | | | | | | | | | | | | | | | | | |
| Aluminum | ug/g | 15.433 | 154.332 | 14 | 29 | 50 | 26 | 35 | 29 | 17 | 26 | 66 | 83 | 36 | 206 | 128 | 107 | 650 | 13 | 37 | 122 | 218 |
| Antimony | ug/g | 1 | 9.996 | <0.04 | <0.04 | <0.04 | <0.04 | 0.07 | <0.04 | <0.04 | 0.05 | <0.04 | <0.04 | <0.04 | <0.04 | 0.06 | 0.07 | 0.11 | <0.04 | <0.04 | | |
| Arsenic | ug/g | 1 | 10.07 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | 0.3 | <0.2 | <0.2 | 1.4 | <0.2 | <0.2 | 3.11 | 3.87 |
| Barium | ug/g | 79.6 | | 27.4 | 6.42 | 11.6 | 13.1 | 13.1 | 10.8 | 20 | 8.01 | 19.1 | 22.2 | 25.4 | 29.7 | 23.5 | 26.5 | 68.7 | 0.94 | 0.8 | 55.2 | 73.8 |
| Beryllium | ug/g | 9.75 | | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | | |
| Cadmium | ug/g | 14.255 | 142.554 | 0.61 | 0.67 | 0.75 | 0.51 | 0.73 | 1.68 | 0.27 | 0.57 | 0.98 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | 0.18 | 0.2 |
| Calcium | ug/g | | | 14800 | 13600 | 17400 | 20400 | 22900 | 19800 | 18200 | 11700 | 18800 | 5150 | 4620 | 4080 | 5210 | 4450 | 6400 | 100 | 180 | 6390 | 12000 |
| Chromium | ug/g | 40449 | | <0.2 | 0.2 | 0.5 | 0.2 | 0.3 | 0.2 | <0.2 | 0.3 | 0.4 | 0.4 | 0.2 | 1.6 | 0.5 | 0.6 | 4.3 | <0.2 | <0.2 | 6.99 | 7.3 |
| Cobalt | ug/g | | | 0.81 | 0.13 | 0.62 | 0.66 | 0.46 | 0.42 | 0.49 | 0.98 | 0.58 | 0.1 | <0.08 | 0.15 | 0.12 | 0.12 | 0.52 | <0.08 | <0.08 | 0.36 | 0.53 |
| Copper | ug/g | 224.8 | 295.9 | 3.92 | 3.53 | 4.19 | 3.52 | 4.3 | 3.46 | 4.05 | 3.83 | 4.76 | 4.15 | 2.96 | 2.46 | 3.32 | 3.57 | 4.86 | 0.41 | 2.27 | 9.62 | 7.73 |
| Iron | ug/g | | | 44 | 52 | 96 | 58 | 62 | 59 | 46 | 62 | 100 | 72 | 33 | 283 | 116 | 131 | 929 | 17 | 33 | 371 | 555 |
| Lead | ug/g | 118.23 | 1182.3 | <0.04 | 0.05 | 0.33 | 0.11 | 0.16 | 0.19 | 0.14 | 0.13 | 0.43 | 0.12 | 0.05 | 1.46 | 0.36 | 0.78 | 7.43 | <0.04 | 0.08 | 9.32 | 11.3 |
| Magnesium | ug/g | | | 4240 | 5140 | 3120 | 5230 | 3790 | 4590 | 5880 | 4490 | 3050 | 1300 | 1210 | 923 | 1490 | 1180 | 1550 | 61 | 155 | 862 | 1970 |
| Manganese | ug/g | 1301 | 4197 | 178 | 134 | 165 | 86.9 | 65.6 | 54.5 | 61.1 | 99.4 | 141 | 217 | 462 | 34.7 | 134 | 342 | 50.5 | 1.62 | 3.3 | 298 | 496 |
| Molybdenum | ug/g | 2.08 | 20.79 | 0.34 | 0.14 | 0.59 | 0.87 | 0.71 | 1.33 | 0.21 | 0.43 | 0.45 | 0.15 | 0.06 | 0.07 | 0.06 | <0.04 | 0.11 | <0.04 | 0.04 | 6.1 | 4.5 |
| Nickel | ug/g | 591.15 | 1182.3 | 1.22 | 2.69 | 0.86 | 0.91 | 0.99 | 0.75 | 1.92 | 0.92 | 0.89 | 0.67 | 0.41 | 1.01 | 0.72 | 0.79 | 2.99 | 0.1 | 0.18 | 4.13 | 5.62 |
| Phosphorus, Total (P) | ug/g | | | 1480 | 1540 | 1940 | 3500 | 1190 | 1710 | 1110 | 1000 | 1150 | 760 | 651 | 482 | 822 | 707 | 643 | 96 | 823 | 1440 | 1510 |
| Potassium | ug/g | | | 13900 | 12100 | 15300 | 17900 | 9760 | 15000 | 9980 | 11700 | 11300 | 4000 | 3320 | 2250 | 3180 | 3260 | 3360 | 1030 | 3800 | 12100 | 16000 |
| Selenium | ug/g | 2.956 | 4.877 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.10 | <0.10 |
| Silver | ug/g | | | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | 0.09 | | |
| Sodium | ug/g | | | 77 | 89 | 93 | 59 | 110 | 134 | 54 | 77 | 58 | 48 | 32 | 45 | 51 | 27 | 147 | <2 | 171 | 205 | 347 |
| Strontium | ug/g | 3887 | | 18.3 | 24.5 | 48.7 | 46.6 | 21.9 | 20.2 | 29.1 | 17.3 | 16.4 | 3.84 | 3.86 | 4.14 | 7.3 | 3.98 | 6.75 | 0.25 | 0.55 | | |
| Thallium | ug/g | 0.111 | 1.105 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | <0.05 | <0.05 |
| Tin | ug/g | 187.1 | 279.9 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | <0.08 | | |
| Titanium | ug/g | | | 0.78 | 2.41 | 4.42 | 1.71 | 2.57 | 2.46 | 1.95 | 2.14 | 4.4 | 4.58 | 1.95 | 14.3 | 6.11 | 6.49 | 38.4 | 1.07 | 1.68 | | |
| Vanadium | ug/g | 2.881 | 28.813 | <0.08 | <0.08 | 0.17 | 0.09 | 0.11 | 0.11 | <0.08 | 0.09 | 0.23 | 0.16 | <0.08 | 0.83 | 0.28 | 0.38 | 2.84 | <0.08 | <0.08 | 2.56 | 0.73 |
| Zinc | ug/g | 2364.6 | 4729.2 | 73.1 | 83.7 | 200 | 228 | 244 | 184 | 192 | 91.4 | 146 | 12.5 | 9.6 | 5.8 | 13.4 | 18.3 | 16.6 | 1.1 | 12.1 | 120 | 129 |

Benchmarks : From US EPA, 1996, values listed are for the meadow vole (food benchmarks). NOAEL - no observable adverse effect level. LOAEC - lowest observable adverse effect level

# Appendix C

# Final Analytical Report
# Vegetation Samples

ETL Enviro·Test
LABORATORIES
A DIVISION OF *ETL CHEMSPEC ANALYTICAL LIMITED*

## ANALYTICAL REPORT

UMA ENGINEERING
**ATTN:** CRAIG HARRIS
200 - 415 GORGE ROAD EAST
VICTORIA BC V8T 2W1

**DATE:** 02-SEP-05

**Lab Work Order #:** L309994 **Sampled By:** UMA **Date Received:** 25-AUG-05

**Project P.O. #:** EO211-023/96/004/EDM

**Project Reference:** ROBERTS BAY

**Other Information:**

**Comments:**

DOUG JOHNSON
Director of Operations, Edmonton

JESSICA MARIE WEBER
Client Service Specialist

# ENVIRO-TEST ANALYTICAL REPORT

| Sample Details/Parameters | Result | Qualifier | D.L. | Units | Extracted | Analyzed | By | Batch |
|---|---|---|---|---|---|---|---|---|
| L309994-1 VEG-1A ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Phosphorus (P) | 1480 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Titanium (Ti) | 0.78 | | 0.05 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Aluminum (Al) | 14 | | 4 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Barium (Ba) | 27.4 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Cadmium (Cd) | 0.61 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Cobalt (Co) | 0.81 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Chromium (Cr) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Copper (Cu) | 3.92 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Molybdenum (Mo) | 0.34 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Nickel (Ni) | 1.22 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Lead (Pb) | <0.04 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Antimony (Sb) | <0.04 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Strontium (Sr) | 18.3 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Vanadium (V) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Zinc (Zn) | 73.1 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 14800 | | 10 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Potassium (K) | 13900 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Magnesium (Mg) | 4240 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Sodium (Na) | 77 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Iron (Fe) | 44 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Manganese (Mn) | 178 | | 0.04 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| L309994-2 VEG-2B ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Phosphorus (P) | 651 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Titanium (Ti) | 1.95 | | 0.05 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Aluminum (Al) | 36 | | 4 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Barium (Ba) | 25.4 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Cadmium (Cd) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Cobalt (Co) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Chromium (Cr) | 0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Copper (Cu) | 2.96 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Molybdenum (Mo) | 0.06 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Nickel (Ni) | 0.41 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Lead (Pb) | 0.05 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |

# ENVIRO-TEST ANALYTICAL REPORT

| Sample Details/Parameters | Result | Qualifier | D.L. | Units | Extracted | Analyzed | By | Batch |
|---|---|---|---|---|---|---|---|---|
| L309994-2 VEG-2B ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| **Metals in Tissue** | | | | | | | | |
| Antimony (Sb) | <0.04 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Strontium (Sr) | 3.86 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Vanadium (V) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Zinc (Zn) | 9.6 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 4620 | | 10 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Potassium (K) | 3320 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Magnesium (Mg) | 1210 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Sodium (Na) | 32 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Iron (Fe) | 33 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Manganese (Mn) | 462 | | 0.04 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| L309994-3 VEG-6A ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Phosphorus (P) | 1710 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Titanium (Ti) | 2.46 | | 0.05 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Aluminum (Al) | 29 | | 4 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Barium (Ba) | 10.8 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Cadmium (Cd) | 1.68 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Cobalt (Co) | 0.42 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Chromium (Cr) | 0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Copper (Cu) | 3.46 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Molybdenum (Mo) | 1.33 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Nickel (Ni) | 0.75 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Lead (Pb) | 0.19 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Antimony (Sb) | <0.04 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Strontium (Sr) | 20.2 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Vanadium (V) | 0.11 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Zinc (Zn) | 184 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 19800 | | 10 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Potassium (K) | 15000 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Magnesium (Mg) | 4590 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Sodium (Na) | 134 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Iron (Fe) | 59 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Manganese (Mn) | 54.5 | | 0.04 | mg/kg | | 31-AUG-05 | HAS | R320056 |

# ENVIRO-TEST ANALYTICAL REPORT

| Sample Details/Parameters | Result | Qualifier | D.L. | Units | Extracted | Analyzed | By | Batch |
|---|---|---|---|---|---|---|---|---|
| L309994-4 VEG-4A ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Phosphorus (P) | 3500 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Titanium (Ti) | 1.71 | | 0.05 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Aluminum (Al) | 26 | | 4 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Barium (Ba) | 13.1 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Cadmium (Cd) | 0.51 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Cobalt (Co) | 0.66 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Chromium (Cr) | 0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Copper (Cu) | 3.52 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Molybdenum (Mo) | 0.87 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Nickel (Ni) | 0.91 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Lead (Pb) | 0.11 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Antimony (Sb) | <0.04 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Strontium (Sr) | 46.6 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Vanadium (V) | 0.09 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Zinc (Zn) | 228 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 20400 | | 10 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Potassium (K) | 17900 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Magnesium (Mg) | 5230 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Sodium (Na) | 59 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Iron (Fe) | 58 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Manganese (Mn) | 86.9 | | 0.04 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| L309994-5 VEG-2A ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Phosphorus (P) | 1540 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Titanium (Ti) | 2.41 | | 0.05 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Aluminum (Al) | 29 | | 4 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Barium (Ba) | 6.42 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Cadmium (Cd) | 0.67 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Cobalt (Co) | 1.13 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Chromium (Cr) | 0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Copper (Cu) | 3.53 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Molybdenum (Mo) | 0.14 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Nickel (Ni) | 2.69 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Lead (Pb) | 0.05 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |

# ENVIRO-TEST ANALYTICAL REPORT

| Sample Details/Parameters | Result | Qualifier | D.L. | Units | Extracted | Analyzed | By | Batch |
|---|---|---|---|---|---|---|---|---|
| L309994-5 VEG-2A ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| **Metals in Tissue** | | | | | | | | |
| Antimony (Sb) | <0.04 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Strontium (Sr) | 24.5 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Vanadium (V) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Zinc (Zn) | 83.7 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 13600 | | 10 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Potassium (K) | 12100 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Magnesium (Mg) | 5140 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Sodium (Na) | 89 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Iron (Fe) | 52 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Manganese (Mn) | 134 | | 0.04 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| L309994-6 VEG-1B ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Phosphorus (P) | 760 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Titanium (Ti) | 4.58 | | 0.05 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Aluminum (Al) | 83 | | 4 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Barium (Ba) | 22.2 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Cadmium (Cd) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Cobalt (Co) | 0.10 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Chromium (Cr) | 0.4 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Copper (Cu) | 4.15 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Molybdenum (Mo) | 0.15 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Nickel (Ni) | 0.67 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Lead (Pb) | 0.12 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Antimony (Sb) | <0.04 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Strontium (Sr) | 3.84 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Vanadium (V) | 0.16 | | 0.08 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| Zinc (Zn) | 12.5 | | 0.2 | mg/kg | | 31-AUG-05 | QLI | R320066 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 5150 | | 10 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Potassium (K) | 4000 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Magnesium (Mg) | 1300 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Sodium (Na) | 48 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Iron (Fe) | 72 | | 2 | mg/kg | | 31-AUG-05 | HAS | R320056 |
| Manganese (Mn) | 217 | | 0.04 | mg/kg | | 31-AUG-05 | HAS | R320056 |

# ENVIRO-TEST ANALYTICAL REPORT

| Sample Details/Parameters | Result | Qualifier | D.L. | Units | Extracted | Analyzed | By | Batch |
|---|---|---|---|---|---|---|---|---|
| L309994-7 VEG-3A ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Phosphorus (P) | 1940 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Titanium (Ti) | 4.42 | | 0.05 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Aluminum (Al) | 50 | | 4 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Barium (Ba) | 11.6 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cadmium (Cd) | 0.75 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cobalt (Co) | 0.62 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Chromium (Cr) | 0.5 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Copper (Cu) | 4.19 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Molybdenum (Mo) | 0.59 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Nickel (Ni) | 0.86 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Lead (Pb) | 0.33 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Antimony (Sb) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Strontium (Sr) | 48.7 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Vanadium (V) | 0.17 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Zinc (Zn) | 200 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 17400 | | 10 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Potassium (K) | 15300 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Magnesium (Mg) | 3120 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Sodium (Na) | 93 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Iron (Fe) | 96 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Manganese (Mn) | 165 | | 0.04 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| L309994-8 VEG-5A ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Phosphorus (P) | 1190 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Titanium (Ti) | 2.57 | | 0.05 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Aluminum (Al) | 35 | | 4 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Barium (Ba) | 13.1 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cadmium (Cd) | 0.73 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cobalt (Co) | 0.46 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Chromium (Cr) | 0.3 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Copper (Cu) | 4.30 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Molybdenum (Mo) | 0.71 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Nickel (Ni) | 0.99 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Lead (Pb) | 0.16 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |

# ENVIRO-TEST ANALYTICAL REPORT

| Sample Details/Parameters | Result | Qualifier | D.L. | Units | Extracted | Analyzed | By | Batch |
|---|---|---|---|---|---|---|---|---|
| L309994-8 VEG-5A ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| **Metals in Tissue** | | | | | | | | |
| Antimony (Sb) | 0.07 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Strontium (Sr) | 21.9 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Vanadium (V) | 0.11 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Zinc (Zn) | 244 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 22900 | | 10 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Potassium (K) | 9760 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Magnesium (Mg) | 3790 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Sodium (Na) | 110 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Iron (Fe) | 62 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Manganese (Mn) | 65.6 | | 0.04 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| L309994-9 VEG-6B ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Phosphorus (P) | 822 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Titanium (Ti) | 6.11 | | 0.05 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Aluminum (Al) | 128 | | 4 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Barium (Ba) | 23.5 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cadmium (Cd) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cobalt (Co) | 0.12 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Chromium (Cr) | 0.5 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Copper (Cu) | 3.32 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Molybdenum (Mo) | 0.06 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Nickel (Ni) | 0.72 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Lead (Pb) | 0.36 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Antimony (Sb) | 0.06 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Strontium (Sr) | 7.30 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Vanadium (V) | 0.28 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Zinc (Zn) | 13.4 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 5210 | | 10 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Potassium (K) | 3180 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Magnesium (Mg) | 1490 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Sodium (Na) | 51 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Iron (Fe) | 116 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Manganese (Mn) | 134 | | 0.04 | mg/kg | | 01-SEP-05 | HAS | R320538 |

# ENVIRO-TEST ANALYTICAL REPORT

| Sample Details/Parameters | Result | Qualifier | D.L. | Units | Extracted | Analyzed | By | Batch |
|---|---|---|---|---|---|---|---|---|
| L309994-10 VEG-9A ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Phosphorus (P) | 1150 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Titanium (Ti) | 4.40 | | 0.05 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Aluminum (Al) | 66 | | 4 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Barium (Ba) | 19.1 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cadmium (Cd) | 0.98 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cobalt (Co) | 0.58 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Chromium (Cr) | 0.4 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Copper (Cu) | 4.76 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Molybdenum (Mo) | 0.45 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Nickel (Ni) | 0.89 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Lead (Pb) | 0.43 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Antimony (Sb) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Strontium (Sr) | 16.4 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Vanadium (V) | 0.23 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Zinc (Zn) | 146 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 18800 | | 10 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Potassium (K) | 11300 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Magnesium (Mg) | 3050 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Sodium (Na) | 58 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Iron (Fe) | 100 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Manganese (Mn) | 141 | | 0.04 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| L309994-11 VEG-8A ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Phosphorus (P) | 1000 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Titanium (Ti) | 2.14 | | 0.05 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Aluminum (Al) | 26 | | 4 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Barium (Ba) | 8.01 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cadmium (Cd) | 0.57 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cobalt (Co) | 0.98 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Chromium (Cr) | 0.3 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Copper (Cu) | 3.83 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Molybdenum (Mo) | 0.43 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Nickel (Ni) | 0.92 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Lead (Pb) | 0.13 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |

# ENVIRO-TEST ANALYTICAL REPORT

| Sample Details/Parameters | Result | Qualifier | D.L. | Units | Extracted | Analyzed | By | Batch |
|---|---|---|---|---|---|---|---|---|
| L309994-11 VEG-8A ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| **Metals in Tissue** | | | | | | | | |
| Antimony (Sb) | 0.05 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Strontium (Sr) | 17.3 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Vanadium (V) | 0.09 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Zinc (Zn) | 91.4 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 11700 | | 10 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Potassium (K) | 11700 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Magnesium (Mg) | 4490 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Sodium (Na) | 77 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Iron (Fe) | 62 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Manganese (Mn) | 99.4 | | 0.04 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| L309994-12 VEG-4B ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | 0.3 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Phosphorus (P) | 482 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Titanium (Ti) | 14.3 | | 0.05 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Aluminum (Al) | 206 | | 4 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Barium (Ba) | 29.7 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cadmium (Cd) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cobalt (Co) | 0.15 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Chromium (Cr) | 1.6 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Copper (Cu) | 2.46 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Molybdenum (Mo) | 0.07 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Nickel (Ni) | 1.01 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Lead (Pb) | 1.46 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Antimony (Sb) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Strontium (Sr) | 4.14 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Vanadium (V) | 0.83 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Zinc (Zn) | 5.8 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 4080 | | 10 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Potassium (K) | 2250 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Magnesium (Mg) | 923 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Sodium (Na) | 45 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Iron (Fe) | 283 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Manganese (Mn) | 34.7 | | 0.04 | mg/kg | | 01-SEP-05 | HAS | R320538 |

# ENVIRO-TEST ANALYTICAL REPORT

| Sample Details/Parameters | Result | Qualifier | D.L. | Units | Extracted | Analyzed | By | Batch |
|---|---|---|---|---|---|---|---|---|
| L309994-13 VEG-8B ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Phosphorus (P) | 707 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Titanium (Ti) | 6.49 | | 0.05 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Aluminum (Al) | 107 | | 4 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Barium (Ba) | 26.5 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cadmium (Cd) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cobalt (Co) | 0.12 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Chromium (Cr) | 0.6 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Copper (Cu) | 3.57 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Molybdenum (Mo) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Nickel (Ni) | 0.79 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Lead (Pb) | 0.78 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Antimony (Sb) | 0.07 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Strontium (Sr) | 3.98 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Vanadium (V) | 0.38 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Zinc (Zn) | 18.3 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 4450 | | 10 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Potassium (K) | 3260 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Magnesium (Mg) | 1180 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Sodium (Na) | 27 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Iron (Fe) | 131 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Manganese (Mn) | 342 | | 0.04 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| L309994-14 VEG-9B ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | 1.4 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Phosphorus (P) | 643 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Titanium (Ti) | 38.4 | | 0.05 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Aluminum (Al) | 650 | | 4 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Barium (Ba) | 68.7 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cadmium (Cd) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cobalt (Co) | 0.52 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Chromium (Cr) | 4.3 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Copper (Cu) | 4.86 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Molybdenum (Mo) | 0.11 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Nickel (Ni) | 2.99 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Lead (Pb) | 7.43 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |

# ENVIRO-TEST ANALYTICAL REPORT

| Sample Details/Parameters | Result | Qualifier | D.L. | Units | Extracted | Analyzed | By | Batch |
|---|---|---|---|---|---|---|---|---|
| L309994-14 VEG-9B ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| **Metals in Tissue** | | | | | | | | |
| Antimony (Sb) | 0.11 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Strontium (Sr) | 6.75 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Vanadium (V) | 2.84 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Zinc (Zn) | 16.6 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 6400 | | 10 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Potassium (K) | 3360 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Magnesium (Mg) | 1550 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Sodium (Na) | 147 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Iron (Fe) | 929 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Manganese (Mn) | 50.5 | | 0.04 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| L309994-15 VEG-7A ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Phosphorus (P) | 1110 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Titanium (Ti) | 1.95 | | 0.05 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Aluminum (Al) | 17 | | 4 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Barium (Ba) | 20.0 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cadmium (Cd) | 0.27 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cobalt (Co) | 0.49 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Chromium (Cr) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Copper (Cu) | 4.05 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Molybdenum (Mo) | 0.21 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Nickel (Ni) | 1.92 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Lead (Pb) | 0.14 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Antimony (Sb) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Strontium (Sr) | 29.1 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Vanadium (V) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Zinc (Zn) | 192 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 18200 | | 10 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Potassium (K) | 9980 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Magnesium (Mg) | 5880 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Sodium (Na) | 54 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Iron (Fe) | 46 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Manganese (Mn) | 61.1 | | 0.04 | mg/kg | | 01-SEP-05 | HAS | R320538 |

# ENVIRO-TEST ANALYTICAL REPORT

| Sample Details/Parameters | Result | Qualifier | D.L. | Units | Extracted | Analyzed | By | Batch |
|---|---|---|---|---|---|---|---|---|
| L309994-16 BERRY-1 ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Phosphorus (P) | 96 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Titanium (Ti) | 1.07 | | 0.05 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Aluminum (Al) | 13 | | 4 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Barium (Ba) | 0.94 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cadmium (Cd) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cobalt (Co) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Chromium (Cr) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Copper (Cu) | 0.41 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Molybdenum (Mo) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Nickel (Ni) | 0.10 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Lead (Pb) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Antimony (Sb) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Strontium (Sr) | 0.25 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Vanadium (V) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Zinc (Zn) | 1.1 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 100 | | 10 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Potassium (K) | 1030 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Magnesium (Mg) | 61 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Sodium (Na) | <2 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Iron (Fe) | 17 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Manganese (Mn) | 1.62 | | 0.04 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| L309994-17 MUSHROOM-1 ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| Arsenic (As) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Phosphorus (P) | 823 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Selenium (Se) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Titanium (Ti) | 1.68 | | 0.05 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Silver (Ag) | 0.09 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Aluminum (Al) | 37 | | 4 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Barium (Ba) | 0.80 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Beryllium (Be) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cadmium (Cd) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Cobalt (Co) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Chromium (Cr) | <0.2 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Copper (Cu) | 2.27 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Molybdenum (Mo) | 0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Nickel (Ni) | 0.18 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Lead (Pb) | 0.08 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |

# ENVIRO-TEST ANALYTICAL REPORT

| Sample Details/Parameters | Result | Qualifier | D.L. | Units | Extracted | Analyzed | By | Batch |
|---|---|---|---|---|---|---|---|---|
| L309994-17 MUSHROOM-1 ROBERTS LAKE | | | | | | | | |
| Sample Date: 18-AUG-05 | | | | | | | | |
| Matrix: VEGETATION | | | | | | | | |
| **Metals in Plant Tissue** | | | | | | | | |
| **Metals in Tissue** | | | | | | | | |
| Antimony (Sb) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Tin (Sn) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Strontium (Sr) | 0.55 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Thallium (Tl) | <0.04 | | 0.04 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Vanadium (V) | <0.08 | | 0.08 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| Zinc (Zn) | 12.1 | | 0.2 | mg/kg | | 01-SEP-05 | QLI | R320512 |
| **Metals in Tissue** | | | | | | | | |
| Calcium (Ca) | 180 | | 10 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Potassium (K) | 3800 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Magnesium (Mg) | 155 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Sodium (Na) | 171 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Iron (Fe) | 33 | | 2 | mg/kg | | 01-SEP-05 | HAS | R320538 |
| Manganese (Mn) | 3.30 | | 0.04 | mg/kg | | 01-SEP-05 | HAS | R320538 |

Refer to Referenced Information for Qualifiers (if any) and Methodology.

# Reference Information

**Methods Listed (if applicable):**

| ETL Test Code | Matrix | Test Description | Preparation Method Reference(Based On) | Analytical Method Reference(Based On) |
|---|---|---|---|---|
| AS-FLORA-ED | Tissue | Arsenic (As) | EPA 200.3 | EPA 6020 |
| MET1-FLORA-ED | Tissue | Metals in Tissue | EPA 200.3 | EPA 6020 |
| MET2-FLORA-ED | Tissue | Metals in Tissue | EPA 200.3 | EPA 200.7 |
| P-FLORA-ED | Tissue | Phosphorus (P) | EPA 200.3 | EPA 200.7 |
| SE-FLORA-ED | Tissue | Selenium (Se) | EPA 200.3 | EPA 6020 |
| TI-FLORA-ED | Tissue | Titanium (Ti) | EPA 200.3 | EPA 6020 |

** Laboratory Methods employed follow in-house procedures, which are generally based on nationally or internationally accepted methodologies.

Chain of Custody numbers:

216634 216644

*The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:*

| Laboratory Definition Code | Laboratory Location | Laboratory Definition Code | Laboratory Location |
|---|---|---|---|
| ED | Enviro-Test Laboratories - Edmonton, Alberta, Canada | | |

*GLOSSARY OF REPORT TERMS*
*Surr - A surrogate is an organic compound that is similar to the target analyte(s) in chemical composition and behavior but not normally detected in enviromental samples. Prior to sample processing, samples are fortified with one or more surrogate compounds.*
*The reported surrogate recovery value provides a measure of method efficiency. The Laboratory warning units are determined under column heading D.L.*
*mg/kg (units) - unit of concentration based on mass, parts per million*
*mg/L (units) - unit of concentration based on volume, parts per million*
*< - Less than*
*D.L. - Detection Limit*
*N/A - Result not available. Refer to qualifier code and definition for explanation*

*Test results reported relate only to the samples as received by the laboratory.*
*UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.*
*UNLESS OTHERWISE STATED, SAMPLES ARE NOT CORRECTED FOR CLIENT FIELD BLANKS.*
*Although test results are generated under strict QA/QC protocols, any unsigned test reports, faxes, or emails are considered preliminary.*

*Enviro-Test Laboratories has an extensive QA/QC program where all analytical data reported is analyzed using approved referenced procedures followed by checks and reviews by senior managers and quality assurance personnel. However, since the results are obtained from chemical measurements and thus cannot be guaranteed, Enviro-Test Laboratories assumes no liability for the use or interpretation of the results.*

EnviroTest LABORATORIES

**CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM**
CANADA TOLL FREE 1-800-668-9878

COC # 216634

WWW.ENVIROTEST.COM



DATE: 8/24/05

LAB WORK ORDER #

**REPORT TO:**
COMPANY: UMA Engineering
CONTACT: Craig Harris
ADDRESS: 200-415 Gorge Road East
Victoria B.C
PHONE: 475 6355 FAX: 475 6388
CELLPHONE:

**REPORT DISTRIBUTION** ALL FINAL RESULTS WILL BE MAILED
EMAIL___ FAX___
EMAIL 1:
EMAIL 2:
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SELECT: pdf___ digital___ both___

**SERVICE REQUESTED**
- [ ] REGULAR SERVICE (DEFAULT)
- [ ] PRIORITY SERVICE (50% SURCHARGE)
- [ ] EMERGENCY SERVICE (100% SURCHARGE)

**INVOICE TO:** SAME Y (N)
COMPANY: PWGSC
CONTACT: MEGAN GAMBLE
ADDRESS: 5th Floor 10025 Jasper Ave
Edmonton
PHONE: 497-8753 FAX: 497-3976

INDICATE BOTTLES: FILTERED/PRESERVED (F/P) ▶
JOB # Roberts Bay
PO/AFE: E0211-023/96/004/EDM
LSD:
QUOTE #

**ANALYSIS REQUEST**

| SAMPLE ID | SAMPLING LOCATION | SAMPLED BY / DATE / TIME | SAMPLING METHOD | SAMPLE TYPE | METALS (CCME) | | | | | | | | | | HAZARDOUS ? | NUMBER OF CONTAINERS | HIGHLY CONTAMINATED ? | LAB SAMPLE # |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VEG-1A | Roberts Lake | Aug 18/05 UMA | Grab | Vegetation | ✓ | | | | | | | | | | | | | |
| VEG-2B | ↓ | ↓ | ↓ | ↓ | ✓ | | | | | | | | | | | | | |
| VEG-6A | ↓ | ↓ | ↓ | ↓ | ✓ | | | | | | | | | | | | | |
| VEG-4A | ↓ | ↓ | ↓ | ↓ | ✓ | | | | | | | | | | | | | |
| VEG-2A | ↓ | ↓ | ↓ | ↓ | ✓ | | | | | | | | | | | | | |
| VEG-1B | ↓ | ↓ | ↓ | ↓ | ✓ | | | | | | | | | | | | | |
| VEG-3A | ↓ | ↓ | ↓ | ↓ | ✓ | | | | | | | | | | | | | |
| VEG-5A | ↓ | ↓ | ↓ | ↓ | ✓ | | | | | | | | | | | | | |
| VEG-6B | ↓ | ↓ | ↓ | ↓ | ✓ | | | | | | | | | | | | | |
| VEG-9A | ↓ | ↓ | ↓ | ↓ | ✓ | | | | | | | | | | | | | |
| VEG-8A | ↓ | ↓ | ↓ | ↓ | ✓ | | | | | | | | | | | | | |
| VEG-4B | | | | | ✓ | | | | | | | | | | | | | |

**GUIDELINES / REGULATIONS**

**SPECIAL INSTRUCTIONS / NATURE OF HAZARDOUS MATERIAL**

**SAMPLE CONDITION**
- [ ] FROZEN
- [ ] COLD
- [ ] AMBIENT

MEAN TEMPERATURE

**Failure to complete all portions of this form may delay analysis. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the reverse of the white report copy.**

| RELINQUISHED BY: | DATE & TIME: | RECEIVED BY: | DATE & TIME: | SAMPLE CONDITION ACCEPTABLE UPON RECEIPT ? (Y/N) |
|---|---|---|---|---|
| [signature] | 8/24/05 | | lw 25-Aug-05 14:35 | |
| RELINQUISHED BY: | DATE & TIME: | RECEIVED BY: | DATE & TIME: | |

ETL **Enviro·Test** LABORATORIES

**CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM**
CANADA TOLL FREE 1-800-668-9878

WWW.ENVIROTEST.COM

**COC # 216644**



DATE:

LAB WORK ORDER #

REPORT TO: UMA / AECOM
COMPANY:
CONTACT: Craig Harris
ADDRESS: UMA Engineering Ltd. Victoria
200 - 415 Gorge Road East
PHONE: 250 475 6355 FAX: 250 475 6389
CELLPHONE:

REPORT DISTRIBUTION — ALL FINAL RESULTS WILL BE MAILED
EMAIL ✓ FAX___
EMAIL 1: craig.harris@uma.aecom.com
EMAIL 2: gordon.wolbttc@earthtech.com
DIGITAL EMAIL:
SELECT: pdf___ digital___ both ✓

**SERVICE REQUESTED**
- [ ] REGULAR SERVICE (DEFAULT)
- [ ] PRIORITY SERVICE (50% SURCHARGE)
- [ ] EMERGENCY SERVICE (100% SURCHARGE)

INVOICE TO: SAME Y / (N)
COMPANY: PWGSC
CONTACT: MEGAN GAMBLE
ADDRESS: M
PHONE: FAX:

INDICATE BOTTLES: FILTERED/PRESERVED (F/P) ▶
JOB #
PO/AFE:
LSD:
QUOTE #

**ANALYSIS REQUEST**

| SAMPLE ID | SAMPLING LOCATION | SAMPLED BY / DATE / TIME | SAMPLING METHOD | SAMPLE TYPE | METALS (COMB) | | | | | | | | | | HAZARDOUS ? | NUMBER OF CONTAINERS | HIGHLY CONTAMINATED ? | LAB SAMPLE # |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VEG - 8B | Roberts Bay | Aug/18 / UMA | GRAB | VEGETATION | ✓ | | | | | | | | | | | | | |
| VEG - 9B | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | | | | | | |
| VEG - 7A | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | | | | | | |
| Berry - 1 | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | | | | | | |
| Mushroom - 1 | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | | | | | | |

**GUIDELINES / REGULATIONS**

**SPECIAL INSTRUCTIONS / NATURE OF HAZARDOUS MATERIAL**

**SAMPLE CONDITION**
FROZEN / COLD / AMBIENT — MEAN TEMPERATURE

**Failure to complete all portions of this form may delay analysis. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the reverse of the white report copy.**

| RELINQUISHED BY: | DATE & TIME: | RECEIVED BY: | DATE & TIME: | SAMPLE CONDITION ACCEPTABLE UPON RECEIPT ? (Y/N) |
|---|---|---|---|---|
| [signature] | 8/24/08 | | | |
| RELINQUISHED BY: | DATE & TIME: | RECEIVED BY: | DATE & TIME: | |

REFER TO BACK PAGE FOR SAMPLING INFORMATION & REGIONAL LOCATIONS WHITE - REPORT COPY, PINK - FILE COPY, YELLOW - CLIENT COPY GENF04.01

9250225-03003

# Appendix D

# Wildlife Ingestion Models

**Appendix D: Roberts/Ida Bay ERA: Uptake of petroleum hydrocarbons in soil**

**Species** **Caribou**
date last modified November 4, 2005

$$E_j = SUF \times \frac{A}{HR} \sum_{i=1}^{m} P_i \times AE_i \left( I_i \times C_{ij} \right)$$

| Parameters | units | value | Description |
|---|---|---|---|
| Cf1 | mg/kg | 245 | Concentration of F1 hydrocarbons in soil (upper 95th %) |
| Cf2 | mg/kg | 14150 | Concentration of F2 hydrocarbons in soil (upper 95th %) |
| Cf3 | mg/kg | 8535 | Concentration of F3 hydrocarbons in soil (upper 95th %) |
| Cf4 | mg/kg | 2285 | Concentration of F4 hydrocarbons in soil (upper 95th %) |
| Cfood | mg/kg | 0 | Food hydrocarbon concentration |
| Cwater | mg/L | 0 | Concentration of hydrocarbons in surface water |

| | | | |
|---|---|---|---|
| Is | kg/kg bw per day | 0.0007 | Soil ingestion rate as 1.5% of food ingestion (Beyer et al., 1994) |
| I ff | kg/kg bw per day | 0.048 | Food ingestion rate (Nagy, 1987) |
| I w | L/kg bw per day | 0.062 | Water ingestion rate (Calder and Braun, 1983) |
| AE | unitless | 100% | Gut Assimilation Efficiency (Holman et al., 2002) |
| BW | kg | 110 | Body weight (US EPA, 1993 & Hurbert & Associates, 2002) |
| A | ha | 0.07 | area of PHC affected soils (estimated as area around fuel bladders) |
| HR | ha | 500 | home range assumed from Doris North Project EIA |
| A/HR | ha | 0.000 | area use factor |
| SUF | unitless | 0.05 | seasonal use factor - migratory animals |

| | | | AENV Sept 2001 DTED | |
|---|---|---|---|---|
| Ej = | 1.25E-06 | mg/kg day | 8.05 | F1 |
| Ej = | 7.21E-05 | mg/kg day | 9.05 | F2 |
| Ej = | 4.35E-05 | mg/kg day | 14.66 | F3 |
| Ej = | 1.16E-05 | mg/kg day | 9.75 | F4 |

| individual HQ | |
|---|---|
| 0.0E+00 | F1 |
| 0.0E+00 | F2 |
| 0.0E+00 | F3 |
| 0.0E+00 | F4 |

$$HQ_{PHC} = \sum \frac{Ej}{DTED} \leq 1.0$$

HQphc= **0**



UMA AECOM

**Appendix D: Roberts/Ida Bay ERA: Uptake of petroleum hydrocarbons in soil**

**Species** **Arctic hare**
date last moc November 4, 2005

$$E_j = SUF \times \frac{A}{HR} \sum_{i=1}^{m} P_i \times AE_i \left(I_i \times C_{ij}\right)$$

| Parameters | units | value | Description |
|---|---|---|---|
| Cf1 | mg/kg | 245 | Concentration of F1 hydrocarbons in soil (upper 95th %) |
| Cf2 | mg/kg | 14150 | Concentration of F2 hydrocarbons in soil (upper 95th %) |
| Cf3 | mg/kg | 8535 | Concentration of F3 hydrocarbons in soil (upper 95th %) |
| Cf4 | mg/kg | 2285 | Concentration of F4 hydrocarbons in soil (upper 95th %) |
| Cfood | mg/kg | 0 | Food hydrocarbon concentration |
| Cwater | mg/L | 0 | Concentration of hydrocarbons in surface water |
| | | | |
| Is | unitless | 0.0069 | Soil ingestion rate as 6.3% of food ingestion rate (Auther & Gates, 1 |
| I ff | kg/kg bw per day | 0.110 | Food ingestion rate (Nagy, 1987) |
| I w | L/kg bw per day | 0.083 | Water ingestion rate (Calder and Braun, 1983) |
| AE | unitless | 100% | Gut Assimilation Effciency |
| BW | kg | 5.5 | Body weight (US EPA, 1993 & Silva & Downing, 1995) |
| HR | ha | 9.0 | Home range from US EPA, 1993 |
| A | ha | 0.07 | area of PHC affected soils (estimated as area around fuel bladders) |
| A/HR | unitless | 0.01 | area use factor |
| SUF | unitless | 1 | hare active all year round and will dig for browse veg |

| | soil | | DTED - CCME CWS PHC, 2000 | |
|---|---|---|---|---|
| Ej = | 0.013191 | mg/kg day | 8.05 | F1 |
| Ej = | 0.761854 | mg/kg day | 9.05 | F2 |
| Ej = | 0.459535 | mg/kg day | 14.66 | F3 |
| Ej = | 0.123027 | mg/kg day | 9.75 | F4 |

| individual HQ | |
|---|---|
| 0.002 | F1 |
| 0.084 | F2 |
| 0.031 | F3 |
| 0.013 | F4 |

$$HQ_{PHC} = \sum \frac{Ej}{DTED} \leq 1.0$$

HQphc= **0.13**

**Appendix D: Roberts/Ida Bay ERA: Uptake of petroleum hydrocarbons in soil**

**Species** **Tundra vole**
date last moc November 4, 2005

$$E_j = SUF \times \frac{A}{HR} \sum_{i=1}^{m} P_i \times AE_i \left( I_i \times C_{ij} \right)$$

| Parameters | units | value | Description |
|---|---|---|---|
| Cf1 | mg/kg | 245 | Concentration of F1 hydrocarbons in soil (upper 95th %) |
| Cf2 | mg/kg | 14150 | Concentration of F2 hydrocarbons in soil (upper 95th %) |
| Cf3 | mg/kg | 8535 | Concentration of F3 hydrocarbons in soil (upper 95th %) |
| Cf4 | mg/kg | 2285 | Concentration of F4 hydrocarbons in soil (upper 95th %) |
| Cfood | mg/kg | 0 | Food hydrocarbon concentration |
| Cwater | mg/L | 0 | Concentration of hydrocarbons in surface water |
| | | | |
| Is | unitless | 0.0045 | Soil ingestion rate as 2% of food ingestion rate (beyers) |
| I ff | kg/kg bw per day | 0.226 | Food ingestion rate (Nagy, 1987) |
| I w | L/kg bw per day | 0.134 | Water ingestion rate (Calder and Braun, 1983) |
| AE | unitless | 100% | Gut Assimilation Effciency |
| BW | kg | 0.05 | Body weight (US EPA, 1993 & Silva & Downing, 1995) |
| A | ha | 0.07 | area of PHC affected soils (estimated as area around fuel bladders) |
| HR | ha | 0.01 | Home range US EPA, 1993 |
| A/HR | ha | 1 | area use factor |
| SUF | unitless | 1 | voles active all year round below snow cover |

DTED - CCME CWS PHC, 2000

| | soil | | DTED | |
|---|---|---|---|---|
| Ej = | 1.107125 | mg/kg day | 8.05 | F1 |
| Ej = | 63.94211 | mg/kg day | 9.05 | F2 |
| Ej = | 38.56861 | mg/kg day | 14.66 | F3 |
| Ej = | 10.32563 | mg/kg day | 9.75 | F4 |

| individual HQ | |
|---|---|
| 0.138 | F1 |
| 7.065 | F2 |
| 2.631 | F3 |
| 1.059 | F4 |

$$HQ_{PHC} = \sum \frac{Ej}{DTED} \leq 1.0$$

HQphc= **10.76**



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**Appendix D: Roberts/Ida Bay ERA: Uptake of metals in vegetation, soil and water**

**Species** **Caribou**
date last modified November 9, 2005

$$E_j = SUF \times \frac{A}{HR} \sum_{i=1}^{m} P_i \times AE_i \left( I_i \times C_{ij} \right)$$

| Parameters | units | value | Description |
|---|---|---|---|
| Ar soil | mg/kg | 168.51 | Arsenic in site soil (upper 95%) |
| Ba soil | mg/kg | 1136 | Barium in site soil (upper 95%) |
| Cd soil | mg/kg | 5.32 | Cadmium in site soil (upper 95%) |
| Cr soil | mg/kg | 105.4 | Chromium in site soil (upper 95%) |
| Cu soil | mg/kg | 239 | Copper in site soil (upper 95%) |
| Pb soil | mg/kg | 399.3 | Lead in site soil (upper 95%) |
| Ni soil | mg/kg | 162 | Nickel in site soil (upper 95%) |
| Se soil | mg/kg | 0.94 | Selenium in site soil (upper 95%) |
| Ag soil | mg/kg | 708.6 | Silver in site soil (upper 95%) |
| V soil | mg/kg | 105.40 | Vanadiam in site soil (upper 95%) |
| Zn soil | mg/kg | 358.00 | Zinc in site soil (upper 95%) |
| Ar water | mg/L | 0.0017 | Arsenic in site water (geomean) |
| Ba water | mg/L | 0.0278 | Barium in site water (geomean) |
| Cd water | mg/L | 0.0002 | Cadmium in site water (geomean) |
| Cr water | mg/L | 0.0016 | Chromium in site water (geomean) |
| Cu water | mg/L | 0.0048 | Copper in site water (geomean) |
| Pb water | mg/L | 0.0006 | Lead in site water (geomean) |
| Ni water | mg/L | 0.0014 | Nickel in site water (geomean) |
| Se water | mg/L | 0.0007 | Selenium in site water (geomean) |
| Ag water | mg/L | 0.0001 | Silver in site water (geomean) |
| V water | mg/L | 0.0009 | Vanadiam in site water (geomean) |
| Zn water | mg/L | 0.0060 | Zinc in site water (geomean) |
| Ar veg | mg/kg | 3.186 | Arsenic in site veg (upper 95%) |
| Ba veg | mg/kg | 69.21 | Barium in site veg (upper 95%) |
| Cd veg | mg/kg | 1.05 | Cadmium in site veg (upper 95%) |
| Cr veg | mg/kg | 7.021 | Chromium in site veg (upper 95%) |
| Cu veg | mg/kg | 7.92 | Copper in site veg (upper 95%) |
| Pb veg | mg/kg | 9.52 | Lead in site veg (upper 95%) |
| Ni veg | mg/kg | 4.28 | Nickel in site veg (upper 95%) |
| Se veg | mg/kg | 0.1 | Selenium in site veg (upper 95%) |
| Ag veg | mg/kg | 0.05 | Silver in site veg (upper 95%) |
| V veg | mg/kg | 2.59 | Vanadiam in site veg (upper 95%) |
| Zn veg | mg/kg | 229.6 | Zinc in site veg (upper 95%) |

| % Veg | | food | water | soil | total | | | TRVs | |
|---|---|---|---|---|---|---|---|---|---|
| | Ej = | 0.1545196 | 0.000104 | 0.12259 | **5.5443E-05** | mg/kg day | | 1.04 | Arsenic |
| | Ej = | 3.3566549 | 0.001717 | 0.826433 | **0.00083696** | mg/kg day | | 51.8 | Barium |
| | Ej = | 0.0509245 | 0.000010 | 0.00387 | **1.0961E-05** | mg/kg day | | 0.77 | Cadmium |
| | Ej = | 0.3405154 | 0.000101 | 0.076678 | **8.3459E-05** | mg/kg day | | 2.4 | Chromium |
| | Ej = | 0.3840681 | 0.000300 | 0.173653 | **0.0001116** | mg/kg day | | 0.685 | Copper |
| | Ej = | 0.4616189 | 0.000039 | 0.290488 | **0.00015043** | mg/kg day | | 4.7 | Lead |
| | Ej = | 0.2075296 | 0.000086 | 0.117708 | **6.5065E-05** | mg/kg day | | 8 | Nickel |
| | Ej = | 0.00485 | 0.000045 | 0.000684 | **1.1157E-06** | mg/kg day | | 0.058 | Selenium |
| | Ej = | 0.002425 | 0.000009 | 0.515502 | **0.00010359** | mg/kg day | | 0.375 | Silver |
| | Ej = | 0.1255169 | 0.000054 | 0.076678 | **4.045E-05** | mg/kg day | | 0.21 | Vanadiam |
| | Ej = | 11.1355 | 0.000369 | 0.260443 | **0.00227926** | mg/kg day | | 10.4 | Zinc |

| individual HQ | |
|---|---|
| **0.00000** | Arsenic |
| **0.00000** | Barium |
| **0.00000** | Cadmium |
| **0.00000** | Chromium |
| **0.00000** | Copper |
| **0.00000** | Lead |
| **0.00000** | Nickel |
| **0.00000** | Selenium |
| **0.00000** | Silver |
| **0.00000** | Vanadiam |
| **0.00000** | Zinc |

$$HQ_{metals} = \frac{E_j}{TRV} < 1.0$$

| | | | |
|---|---|---|---|
| Is | kg/kg bw per day | 0.001 | Soil ingestion rate as 1.5% of food ingestion (Beyer) |
| Pi | unitless | 100% | Fraction of browse veg. in diet |
| AEi | unitless | 100% | Gut assimilation efficiency |
| I ff | kg/kg bw per day | 0.048 | Food ingestion rate (Nagy, 1987) |
| I w | L/kg-bw per day | 0.062 | Water ingestion rate (Calder and Braun, 1983) |
| BW | kg | 110 | Body weight (US EPA, 1993 & Hurbert & Associates, 2002) |
| HR | ha | 500 | home range caribou (Doris North EIA, 2003) |
| A | ha | 2.00 | area of affected soils (assumed to be area of waste rock including Ida) |
| A/HR | unitless | 0.004 | area use factor "AUF" |
| SUF | unitless | 0.05 | seasonal use factor - migratory animals |



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## Appendix D: Roberts/Ida Bay ERA: Uptake of metals in vegetation, soil and water

**Species** **Arctic hare**
date last modified November 9, 2005

$$E_j = SUF \times \frac{A}{HR} \sum_{i=1}^{m} P_i \times AE_i \left(I_i \times C_{ij}\right)$$

| Parameters | units | value | Description |
|---|---|---|---|
| Ar soil | mg/kg | 168.51 | Arsenic in site soil (upper 95%) |
| Ba soil | mg/kg | 1136 | Barium in site soil (upper 95%) |
| Cd soil | mg/kg | 5.32 | Cadmium in site soil (upper 95%) |
| Cr soil | mg/kg | 105.4 | Chromium in site soil (upper 95%) |
| Cu soil | mg/kg | 238.7 | Copper in site soil (upper 95%) |
| Pb soil | mg/kg | 399.3 | Lead in site soil (upper 95%) |
| Ni soil | mg/kg | 161.8 | Nickel in site soil (upper 95%) |
| Se soil | mg/kg | 0.94 | Selenium in site soil (upper 95%) |
| Ag soil | mg/kg | 708.6 | Silver in site soil (upper 95%) |
| V soil | mg/kg | 105.40 | Vanadiam in site soil (upper 95%) |
| Zn soil | mg/kg | 358.00 | Zinc in site soil (upper 95%) |
| Ar water | mg/L | 0.0017 | Arsenic in site water (geomean) |
| Ba water | mg/L | 0.0278 | Barium in site water (geomean) |
| Cd water | mg/L | 0.0002 | Cadmium in site water (geomean) |
| Cr water | mg/L | 0.0016 | Chromium in site water (geomean) |
| Cu water | mg/L | 0.0048 | Copper in site water (geomean) |
| Pb water | mg/L | 0.0006 | Lead in site water (geomean) |
| Ni water | mg/L | 0.0014 | Nickel in site water (geomean) |
| Se water | mg/L | 0.0007 | Selenium in site water (geomean) |
| Ag water | mg/L | 0.0001 | Silver in site water (geomean) |
| V water | mg/L | 0.000879 | Vanadiam in site water (geomean) |
| Zn water | mg/L | 0.005964 | Zinc in site water (geomean) |
| Ar veg | mg/kg | 3.186 | Arsenic in site veg (upper 95%) |
| Ba veg | mg/kg | 69.21 | Barium in site veg (upper 95%) |
| Cd veg | mg/kg | 1.05 | Cadmium in site veg (upper 95%) |
| Cr veg | mg/kg | 7.021 | Chromium in site veg (upper 95%) |
| Cu veg | mg/kg | 7.919 | Copper in site veg (upper 95%) |
| Pb veg | mg/kg | 9.518 | Lead in site veg (upper 95%) |
| Ni veg | mg/kg | 4.279 | Nickel in site veg (upper 95%) |
| Se veg | mg/kg | 0.10 | Selenium in site veg (upper 95%) |
| Ag veg | mg/kg | 0.05 | Silver in site veg (upper 95%) |
| V veg | mg/kg | 2.588 | Vanadiam in site veg (upper 95%) |
| Zn veg | mg/kg | 229.6 | Zinc in site veg (upper 95%) |

| % Veg | food | water | soil | total | | TRVs | |
|---|---|---|---|---|---|---|---|
| 23% | 0.350078 | 0.000140 | 1.166501 | **0.252787** | mg/kg day | 1.04 | Arsenic |
| 49% | 7.6048015 | 0.002317 | 7.863899 | **2.578503** | mg/kg day | 51.8 | Barium |
| 76% | 0.1153741 | 0.000013 | 0.036827 | **0.025369** | mg/kg day | 0.77 | Cadmium |
| 51% | 0.7714682 | 0.000136 | 0.729626 | **0.250205** | mg/kg day | 2.4 | Chromium |
| 34% | 0.8701405 | 0.000404 | 1.652388 | **0.420489** | mg/kg day | 0.685 | Copper |
| 27% | 1.0458388 | 0.000052 | 2.764133 | **0.635004** | mg/kg day | 4.7 | Lead |
| 30% | 0.4701769 | 0.000116 | 1.120052 | **0.265057** | mg/kg day | 8 | Nickel |
| 63% | 0.010988 | 0.000060 | 0.006507 | **0.002926** | mg/kg day | 0.058 | Selenium |
| 0% | 0.005494 | 0.000012 | 4.905245 | **0.818459** | mg/kg day | 0.375 | Silver |
| 28% | 0.2843697 | 0.000073 | 0.729626 | **0.169011** | mg/kg day | 0.21 | Vanadiam |
| 91% | 25.22847 | 0.000498 | 2.478236 | **4.617867** | mg/kg day | 10.4 | Zinc |

| individual HQ | |
|---|---|
| **0.243** | Arsenic |
| **0.050** | Barium |
| **0.033** | Cadmium |
| **0.104** | Chromium |
| **0.614** | Copper |
| **0.135** | Lead |
| **0.033** | Nickel |
| **0.050** | Selenium |
| **2.183** | Silver |
| **0.805** | Vanadiam |
| **0.444** | Zinc |

$$HQ_{metals} = \frac{E_j}{TRV} < 1.0$$

| | | | |
|---|---|---|---|
| Is | kg/kg bw per day | 0.007 | Soil ingestion rate as 6.3% of food ingestion (Beyer) |
| Pi | unitless | 100% | Fraction of browse veg. in diet |
| AEi | unitless | 100% | Gut assimilation efficiency |
| I ff | kg/kg bw per day | 0.110 | Food ingestion rate (Nagy, 1987) |
| I w | L/kg-bw per day | 0.083 | Water ingestion rate (Calder and Braun, 1983) |
| BW | kg | 5.5 | Body weight (US EPA, 1993 & Silva & Downing, 1995) |
| HR | ha | 9.0 | home range ungulate (US EPA, 1993) |
| A | ha | 1.50 | area of affected soils (assumed to be area of waste rock including Ida) |
| A/HR | unitless | 0.17 | area use factor "AUF" |
| SUF | unitless | 1 | seasonal use factor - assumes no veg and ground frozen 5 month per yeaı |

**Appendix D: Roberts/Ida Bay ERA: Uptake of metals in vegetation, soil and water**

**Species** **Tundra vole**
date last modified November 9, 2005

$$E_j = SUF \times \frac{A}{HR} \sum_{i=1}^{m} P_i \times AE_i (I_i \times C_{ij})$$

| Parameters | units | value | Description |
|---|---|---|---|
| Ar soil | mg/kg | 168.51 | Arsenic in site soil (upper 95%) |
| Ba soil | mg/kg | 1136 | Barium in site soil (upper 95%) |
| Cd soil | mg/kg | 5.32 | Cadmium in site soil (upper 95%) |
| Cr soil | mg/kg | 105.4 | Chromium in site soil (upper 95%) |
| Cu soil | mg/kg | 238.7 | Copper in site soil (upper 95%) |
| Pb soil | mg/kg | 399.3 | Lead in site soil (upper 95%) |
| Ni soil | mg/kg | 161.8 | Nickel in site soil (upper 95%) |
| Se soil | mg/kg | 0.94 | Selenium in site soil (upper 95%) |
| Ag soil | mg/kg | 708.6 | Silver in site soil (upper 95%) |
| V soil | mg/kg | 105.40 | Vanadiam in site soil (upper 95%) |
| Zn soil | mg/kg | 358.00 | Zinc in site soil (upper 95%) |
| Ar water | mg/L | 0.0200 | Arsenic in site water (upper 95%) |
| Ba water | mg/L | 0.1600 | Barium in site water (upper 95%) |
| Cd water | mg/L | 0.0010 | Cadmium in site water (upper 95%) |
| Cr water | mg/L | 0.0070 | Chromium in site water (upper 95%) |
| Cu water | mg/L | 0.0120 | Copper in site water (upper 95%) |
| Pb water | mg/L | 0.0078 | Lead in site water (upper 95%) |
| Ni water | mg/L | 0.0124 | Nickel in site water (upper 95%) |
| Se water | mg/L | 0.0093 | Selenium in site water (upper 95%) |
| Ag water | mg/L | 0.0005 | Silver in site water (upper 95%) |
| V water | mg/L | 0.0030 | Vanadiam in site water (upper 95%) |
| Zn water | mg/L | 0.0360 | Zinc in site water (upper 95%) |
| Ar veg | mg/kg | 3.186 | Arsenic in site veg (upper 95%) |
| Ba veg | mg/kg | 69.21 | Barium in site veg (upper 95%) |
| Cd veg | mg/kg | 1.05 | Cadmium in site veg (upper 95%) |
| Cr veg | mg/kg | 7.021 | Chromium in site veg (upper 95%) |
| Cu veg | mg/kg | 7.919 | Copper in site veg (upper 95%) |
| Pb veg | mg/kg | 9.518 | Lead in site veg (upper 95%) |
| Ni veg | mg/kg | 4.279 | Nickel in site veg (upper 95%) |
| Se veg | mg/kg | 0.1 | Selenium in site veg (upper 95%) |
| Ag veg | mg/kg | 0.05 | Silver in site veg (upper 95%) |
| V veg | mg/kg | 2.588 | Vanadiam in site veg (upper 95%) |
| Zn veg | mg/kg | 229.6 | Zinc in site veg (upper 95%) |

| | % Veg | % Soil | food | water | soil | total | |
|---|---|---|---|---|---|---|---|
| Arsenic | 49% | 51% | 0.719857 | 0.002672 | 0.761476 | **1.484005** | mg/kg day |
| Barium | 75% | 25% | 15.63757 | 0.021373 | 5.133444 | **20.79239** | mg/kg day |
| Cadmium | 91% | 9% | 0.237241 | 0.000134 | 0.02404 | **0.261415** | mg/kg day |
| Chromium | 77% | 23% | 1.586352 | 0.000935 | 0.47629 | **2.063576** | mg/kg day |
| Copper | 62% | 38% | 1.789249 | 0.001603 | 1.078656 | **2.869508** | mg/kg day |
| Lead | 54% | 46% | 2.150533 | 0.001042 | 1.804387 | **3.955963** | mg/kg day |
| Nickel | 57% | 43% | 0.966814 | 0.001656 | 0.731154 | **1.699624** | mg/kg day |
| Selenium | 80% | 15% | 0.022594 | 0.001244 | 0.004248 | **0.028086** | mg/kg day |
| Silver | 0% | 100% | 0.011297 | 0.000067 | 3.202076 | **3.21344** | mg/kg day |
| Vanadiam | 55% | 45% | 0.584743 | 0.000401 | 0.47629 | **1.061433** | mg/kg day |
| Zinc | 97% | 3% | 51.87671 | 0.004809 | 1.617758 | **53.49927** | mg/kg day |

TRVs

| | |
|---|---|
| 1.04 | Arsenic |
| 51.8 | Barium |
| 0.77 | Cadmium |
| 2.4 | Chromium |
| 0.685 | Copper |
| 4.7 | Lead |
| 8 | Nickel |
| 0.058 | Selenium |
| 0.375 | Silver |
| 0.21 | Vanadiam |
| 10.4 | Zinc |

individual HQ

| | |
|---|---|
| **1.427** | Arsenic |
| **0.401** | Barium |
| **0.34** | Cadmium |
| **0.86** | Chromium |
| **4.189** | Copper |
| **0.842** | Lead |
| **0.212** | Nickel |
| **0.484** | Selenium |
| **8.569** | Silver |
| **5.054** | Vanadiam |
| **5.144** | Zinc |

$$HQ_{metals} = \frac{E_j}{TRV} < 1.0$$

| | | | |
|---|---|---|---|
| Is | kg/kg bw per day | 0.005 | Soil ingestion rate as 2% of food ingestion (Beyer) |
| Pi | unitless | 100% | Fraction of browse veg. in diet |
| AEi | unitless | 100% | Gut assimilation efficiency |
| I ff | kg/kg bw per day | 0.226 | Food ingestion rate (Nagy, 1987) |
| I w | L/kg-bw per day | 0.134 | Water ingestion rate (Calder and Braun, 1983) |
| BW | kg | 0.05 | Body weight (US EPA, 1993 & Silva & Downing, 1995) |
| HR | ha | 0.01 | home range ungulate (US EPA, 1993) |
| A | ha | 2.00 | area of affected soils (assumed to be all waste rock area including Ida) |
| A/HR | unitless | 1 | area use factor |
| SUF | unitless | 1 | seasonal use factor - assumes no veg and ground frozen 5 month per yeai |

**Appendix D: Roberts/Ida Bay ERA: Uptake of metals in vegetation, soil and water**

**Species** **Pacific loon**
date last modified November 4, 2005

$$E_j = SUF \times \sum_{i=1}^{m} P_i \times AE_i (I_i \times C_{ij})$$

| Parameters | units | value | Description |
|---|---|---|---|
| Ar water | mg/L | 0.0017 | Arsenic in site water (geomean) |
| Ba water | mg/L | 0.0278 | Barium in site water (geomean) |
| Cd water | mg/L | 0.0002 | Cadmium in site water (geomean) |
| Cr water | mg/L | 0.0016 | Chromium in site water (geomean) |
| Cu water | mg/L | 0.0048 | Copper in site water (geomean) |
| Pb water | mg/L | 0.0006 | Lead in site water (geomean) |
| Ni water | mg/L | 0.0014 | Nickel in site water (geomean) |
| Se water | mg/L | 0.0007 | Selenium in site water (geomean) |
| Ag water | mg/L | 0.0001 | Silver in site water (geomean) |
| V water | mg/L | 0.0009 | Vanadiam in site water (geomean) |
| Zn water | mg/L | 0.0060 | Zinc in site water (geomean) |
| Ar fish | mg/kg | 0.42 | Arsenic in site fish (regional max) |
| Ba fish | mg/kg | 1.44 | Barium in site fish (regional max) |
| Cd fish | mg/kg | 0.05 | Cadmium in site fish (regional max) |
| Cr fish | mg/kg | 1.44 | Chromium in site fish (regional max) |
| Cu fish | mg/kg | 1.43 | Copper in site fish (regional max) |
| Pb fish | mg/kg | 0.13 | Lead in site fish (regional max) |
| Ni fish | mg/kg | 2.42 | Nickel in site fish (regional max) |
| Se fish | mg/kg | 1.50 | Selenium in site fish (regional max) |
| Ag fish | mg/kg | 0.29 | Silver in site fish (regional max) |
| V fish | mg/kg | -- | Vanadiam in site fish (regional max) |
| Zn fish | mg/kg | 15.07 | Zinc in site fish (regional max) |

| | | | |
|---|---|---|---|
| Pi | unitless | 100% | Fraction of fish in diet |
| AEi | unitless | 100% | Gut assimilation efficiency |
| I ff | kg/kg bw per day | 0.179 | Food ingestion rate (Nagy, 1987) |
| I w | L/kg-bw per day | 0.037 | Water ingestion rate (Calder and Braun, 1983) |
| BW | kg | 4.0 | Body weight (Ehrlich et al., 1988 and online searching) |
| SUF | unitless | 0.3 | seasonal use factor - open water season only |

| | food | water | total | |
|---|---|---|---|---|
| Ej = | 0.075938 | 0.000063 | **0.0228** | mg/kg day |
| Ej = | 0.25756 | 0.001036 | **0.077579** | mg/kg day |
| Ej = | 0.008371 | 0.000006 | **0.002513** | mg/kg day |
| Ej = | 0.25756 | 0.000061 | **0.077286** | mg/kg day |
| Ej = | 0.257111 | 0.000181 | **0.077188** | mg/kg day |
| Ej = | 0.023319 | 0.000023 | **0.007003** | mg/kg day |
| Ej = | 0.4341 | 0.000052 | **0.130245** | mg/kg day |
| Ej = | 0.268622 | 0.000027 | **0.080595** | mg/kg day |
| Ej = | 0.051721 | 0.000005 | **0.015518** | mg/kg day |
| Ej = | -- | 0.000033 | **9.85E-06** | mg/kg day |
| Ej = | 2.702659 | 0.000223 | **0.810864** | mg/kg day |

| TRVs | |
|---|---|
| 2.24 | Arsenic |
| 20.8 | Barium |
| 1.47 | Cadmium |
| 2.66 | Chromium |
| 4.7 | Copper |
| 1.63 | Lead |
| 65 | Nickel |
| 0.5 | Selenium |
| 178 | Silver |
| 11.4 | Vanadiam |
| 130.9 | Zinc |

| individual HQ | |
|---|---|
| **0.01** | Arsenic |
| **0.004** | Barium |
| **0.002** | Cadmium |
| **0.029** | Chromium |
| **0.016** | Copper |
| **0.004** | Lead |
| **0.002** | Nickel |
| **0.161** | Selenium |
| **0.000** | Silver |
| **0.000** | Vanadiam |
| **0.006** | Zinc |

$$HQ_{metals} = \frac{E_j}{TRV} < 1.0$$



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**Appendix D: Roberts/Ida Bay ERA: Uptake of metals in vegetation, soil and water**

**Species** **Gyrfalcon**
date last modified November 4, 2005

$$E_j = SUF \times \sum_{i=1}^{m} P_i \times AE_i \left( I_i \times C_{ij} \right)$$

| Parameters | units | value | Description |
|---|---|---|---|
| Ar water | mg/L | 0.0017 | Arsenic in site water (geomean) |
| Ba water | mg/L | 0.0278 | Barium in site water (geomean) |
| Cd water | mg/L | 0.0002 | Cadmium in site water (geomean) |
| Cr water | mg/L | 0.0016 | Chromium in site water (geomean) |
| Cu water | mg/L | 0.0048 | Copper in site water (geomean) |
| Pb water | mg/L | 0.0006 | Lead in site water (geomean) |
| Ni water | mg/L | 0.0014 | Nickel in site water (geomean) |
| Se water | mg/L | 0.0007 | Selenium in site water (geomean) |
| Ag water | mg/L | 0.0001 | Silver in site water (geomean) |
| V water | mg/L | 0.0009 | Vanadiam in site water (geomean) |
| Zn water | mg/L | 0.0060 | Zinc in site water (geomean) |
| Ar vole | mg/kg | 1.2 | Arsenic in site vole (calculated Sample et al., 1998) |
| Ba vole | mg/kg | 70 | Barium in site vole (calculated Sample et al., 1998) |
| Cd vole | mg/kg | 0.6 | Cadmium in site vole (calculated Sample et al., 1998) |
| Cr vole | mg/kg | 9.3 | Chromium in site vole (calculated Sample et al., 1998) |
| Cu vole | mg/kg | 26 | Copper in site vole (calculated Sample et al., 1998) |
| Pb vole | mg/kg | 12 | Lead in site vole (calculated Sample et al., 1998) |
| Ni vole | mg/kg | 8.4 | Nickel in site vole (calculated Sample et al., 1998) |
| Se vole | mg/kg | 0.6 | Selenium in site vole (calculated Sample et al., 1998) |
| Ag vole | mg/kg | 1.7 | Silver in site vole (calculated Sample et al., 1998) |
| V vole | mg/kg | 1.4 | Vanadiam in site vole (calculated Sample et al., 1998) |
| Zn vole | mg/kg | 135 | Zinc in site vole (calculated Sample et al., 1998) |

| | | | |
|---|---|---|---|
| Pi | unitless | 100% | Fraction of fish in diet |
| AEi | unitless | 100% | Gut assimilation efficiency |
| I ff | kg/kg bw per day | 0.197 | Food ingestion rate (Nagy, 1987) |
| I w | L/kg-bw per day | 0.064 | Water ingestion rate (Calder and Braun, 1983) |
| BW | kg | 0.8 | Body weight (Ehrlich et al., 1988 & online searching) |
| SUF | unitless | 0.3 | seasonal use factor - open water season only |

| | food | water | total | | TRVs | |
|---|---|---|---|---|---|---|
| Ej = | 0.235926 | 0.000107 | 0.07081 | mg/kg day | 2.24 | Arsenic |
| Ej = | 13.76235 | 0.001763 | 4.129234 | mg/kg day | 20.8 | Barium |
| Ej = | 0.117963 | 0.000010 | 0.035392 | mg/kg day | 1.47 | Cadmium |
| Ej = | 1.828427 | 0.000103 | 0.548559 | mg/kg day | 2.66 | Chromium |
| Ej = | 5.11173 | 0.000307 | 1.533611 | mg/kg day | 4.7 | Copper |
| Ej = | 2.35926 | 0.000040 | 0.70779 | mg/kg day | 1.63 | Lead |
| Ej = | 1.651482 | 0.000088 | 0.495471 | mg/kg day | 65 | Nickel |
| Ej = | 0.117963 | 0.000046 | 0.035403 | mg/kg day | 0.5 | Selenium |
| Ej = | 0.334229 | 0.000009 | 0.100271 | mg/kg day | 178 | Silver |
| Ej = | 0.275247 | 0.000056 | 0.082591 | mg/kg day | 11.4 | Vanadiam |
| Ej = | 26.54168 | 0.000379 | 7.962617 | mg/kg day | 130.9 | Zinc |

individual HQ

| | |
|---|---|
| 0.032 | Arsenic |
| 0.199 | Barium |
| 0.024 | Cadmium |
| 0.206 | Chromium |
| 0.326 | Copper |
| 0.434 | Lead |
| 0.008 | Nickel |
| 0.071 | Selenium |
| 0.001 | Silver |
| 0.007 | Vanadiam |
| 0.061 | Zinc |

$$HQ_{metals} = \frac{E_j}{TRV} < 1.0$$