APPENDIX 6G

EVALUATION OF EXPOSURE POTENTIAL FROM ORE DUSTING

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EVALUATION OF EXPOSURE POTENTIAL FROM ORE DUSTING EVENTS IN SELECTED VECS: CARIBOU AND BLUEBERRY

Baffinland Iron Mines Corporation

FINAL REPORT

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EVALUATION OF EXPOSURE POTENTIAL FROM ORE DUSTING EVENTS IN SELECTED VECS: CARIBOU AND BLUEBERRY

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EVALUATION OF EXPOSURE POTENTIAL FROM ORE DUSTING EVENTS IN SELECTED VECS: CARIBOU AND BLUEBERRY

1.0 INTRODUCTION

Mining projects generate ore and waste products that have the potential to be released to the environment, through the discharge of effluents as well as air emissions. The Mary River Project will mine a high-grade iron oxide ore that is relatively low in trace metals when compared to many ores that are mined. As such, the potential for contaminants to be released in dust emissions and effluent in meaningful quantities is expected to be low.

NIRB (2009) directed Baffinland to evaluate and consider the following issues:

1. *"Potential impacts to vegetation of cultural or practical value to Inuit"*

Inuit harvest a number of plant species, as documented by Outcrop (2010), including berries and root tubers. Some of the plants identified are traditionally used, but berries (mainly blueberries and to a lesser extent crowberries) are the most widely harvested. As such, this assessment focuses on blueberries as a key plant species harvested by Inuit. The most likely pathway by which blueberries would encounter facility emissions is through dust deposition generated from the mining, transportation, crushing, screening, and stockpiling of ore.

Therefore, the focused question for the current report is:

Will ore dust deposition from the Project result in levels of metals in blueberries that are harmful for human consumption?

The second question requested by the NIRB (2009) is:

2. "*Evaluation of the potential for contaminants to be released to the environment as a result of the Project and be taken up by VEC species"*

The VEC species assessed by Baffinland that are important to Inuit include caribou and a number of marine mammals (ringed-seal, walrus, beluga whale, narwhal, polar bears). The current report focuses on the main terrestrial VEC, caribou. The focused question for this study is:

Will ore dust deposition from the Project result in levels of metals in caribou tissue that are harmful for human consumption, or harmful for the health of the caribou?

This report presents a high-level qualitative evaluation of these two focused questions based on ore chemistry data, exposure potential and metals toxicological considerations. This report only considers dusts released to areas outside the active operations of the Project (referred to as

Potential Development Areas, or PDA). To be more specific, the areas assessed in this report are those which would incur dust deposition rates of ≤180 $g/m^2/yr$, since the vast majority of lands with dust deposition rates higher than this, are located inside the PDAs of the various Project components.

Since the vast majority of dusts generated from the Project are expected to be related to the mining, transportation, crushing, screening, and stockpiling of ore, the chemical composition of the dust considered in this report is specifically associated with ore. No other Project emissions are considered in this report such as emissions from waste management activities, burning of fuels for power generation, vehicles and equipment, waste rock handling, *etc*. Since ore is composed only of naturally occurring metals and metalloids (hereafter collectively referred to as metals), this study only considered such substances.

This report provides a brief overview of fate and transport pathways of dusts generated by the Project to the environment (Section 2.0); a desk-top calculation of possible future levels of metals in soils as a result of dust deposition outside the PDA, based on two estimated dust deposition scenarios (Section 3.0); an assessment of caribou exposures to trace metals in dusts on soils and vegetation (Section 4.0); an assessment of human exposures to trace metals in dusts related to local food consumption of caribou and blueberry (Section 5.0), and Conclusions (Section 6). References cited are provided in Section 7.0.

2.0 FATE AND TRANSPORT PATHWAYS RELATED TO ORE DUST DEPOSITION IN TERRESTRIAL AREAS

The Project has the potential to generate dusts related to the open pit mining operation at Mary's River, as well as the operations related to ore transport via truck (Tote Road), and stockpiling of materials in Milne Port for shipment, and the operations related to transport via rail and stockpiling at a second port (Steensby Port). The vast majority of these dusts are expected to be generated from the mining, transportation, crushing, screening, and stockpiling of ore (Cook, 2010 pers. comm.). The ore is largely composed of iron, silica, and aluminum, but does contain a number of trace metal contaminants as well. Metals are naturally occurring in the environment, and are obviously present within the Project area, as the proposed operation is a mine. Dusts released during Project activities will contain metals, and these metals will not degrade in the environment, once released.

Dust deposition studies have been conducted by RWDI (2010) to predict the levels of dust that will occur within the active footprint of the mining area (the PDA), as well as in near-field areas outside of the PDA at each of the three main operational areas (Mary's River, Milne Port and Steensby Port). Larger particles of dusts will tend to settle out within the PDA but some dusts of smaller particle size will be transported into the local study area, outside of the footprint of the mine, and the port areas (see Figures 13, 26, 26a and 39; November 29 and 30th versions; RWDI, 2010).

Based on the dust deposition predictions provided by RWDI (2010), dusts are expected to settle in areas outside of the PDA for each of the 3 operational area of the Project. Dusts released from operational activities will be transported by air and will deposit on local soils and vegetation. The metals present in the dust will add to naturally occurring metals in soils, and have the potential of being taken up into vegetation through root uptake. In addition, dusts will also deposit directly on vegetation. Some foliar uptake may occur but this is likely limited. Direct ingestion of dusts on vegetation is possible for both humans and caribou, particularly in light of the limited precipitation rates in the region. Based on this, caribou and humans have a potential to be exposed to dusts via consumption of food sources within areas outside of the PDAs of the Project.

3.0 PREDICTIONS OF INCREMENTAL TRACE METAL CONTRIBUTIONS TO AREA SOILS AS A RESULT OF DUSTING EVENTS

3.1 Approach to Predicting Future Soil Concentrations

The approach taken to estimate future incremental soil concentrations of metals utilized dust deposition estimates (expressed as mg TSP/m^2/year) for areas surrounding the PDA (based on isopleths of dust deposition rates provided by RWDI, 2010, in g/m^2/year), ore metals chemistry data collected by Knight-Piésold, and equations developed by the U.S. EPA (2005) for calculating soil loading rates and bulk soil concentrations from atmospheric dust deposition rates. Future soil concentrations were estimated under two dust deposition scenarios: 180 g TSP/m^2/year (which corresponds to locations outside the PDA and major Project operational areas that would incur the greatest dust deposition), and 60 g TSP/m^2/year (which corresponds to larger spatial areas near Project operational areas that would experience a lower rate of dust deposition). Given that ore is considered the largest potential source of metals associated with the Project, it was assumed that all deposited TSP was comprised entirely of ore dust.

To calculate soil metals loading rates and concentrations that would occur from the deposition of ore dust, it was necessary to apportion the deposited dust (which was provided by RWDI, 2010 as non-specific total suspended particulate matter, or TSP) so that it was representative of the metals concentrations that were measured in ore samples. This was accomplished by calculating the ratio of the concentration of each metal of interest in ore to the average total metals concentration across all ore samples (*e.g.*, µg Fe per g ore divided by the average concentration of all metals (µg) per g ore). To ensure a conservative estimate of the metals content of deposited ore dust, maximum measured individual metals concentrations were used. These maxima were determined from ore chemistry data (analyzed using ICP-MS) collected by Knight-Piésold in 2006 and 2007 (N=21). Maxima were used as the detection frequency and reported detection limits of several metals displayed high variability across the ore samples. To confirm that these maximum metals concentrations in ore were representative and conservative, comparisons were made against a much larger dataset of ore chemistry data collected by AMEC (N=6794, but included both ore and non-ore bearing rock samples). These data were collected for different purposes, therefore, the larger dataset could not be pooled with the Knight-Piésold data as ore and non-ore samples are not clearly identified in this dataset at this time, and the list of target analytes, as well as the analytical method (ICP-OES) are slightly different from those used to generate the Knight-Piésold ore chemistry data. For the majority of metals, the maximum ore metals concentrations that were used to estimate future soil concentrations were considerably higher than central tendency metals concentrations in the larger dataset (such as means, medians), and were similar to upper percentiles calculated from this dataset. As such, the maximum ore metals concentrations used in this current evaluation are considered adequately representative of the ore that will be mined.

Not all metals analyzed in the ore samples underwent the estimation of future soil concentrations. Several metals were excluded from consideration prior to this process (*i.e.*, mercury, bismuth, calcium, lithium, potassium, magnesium, sodium, titanium yttrium, and sulphur). Rationale for the exclusion of these substances is provided in the following bullets.

- Mercury was not present at measurable concentrations in any ore sample from the Knight-Piésold dataset. Mercury was not a target analyte in the larger AMEC ore and rock chemistry dataset. As mercury is also present at low concentrations in baseline soils, any potential future incremental additions of mercury to soil from ore dust deposition would be insignificant.

- Bismuth was present at measurable concentrations in roughly half of the ore samples collected by Knight-Piésold, and was not detected above the RDL in any of the 6794 ore and rock samples that were considered from the AMEC dataset. Bismuth is widely considered to be of low concern in regards to both animal and human health (NAS, 2005). Due to its low solubility, bismuth compounds are very poorly absorbed in the gastrointestinal tract of humans and animals. In rats and humans, greater than 99% of an oral dose of a variety of bismuth compounds was excreted in the feces unchanged (Dresow *et al*., 1992; Slikkerveer *et al*., 1995). NAS (2005) also notes that bismuth does not bioaccumulate in terrestrial food chains or food webs, and that bismuth toxicity is likely only in situations where pharmaceutical preparations containing this substance are chronically administered at high doses.

- Lithium was present at measurable concentrations in only two of the ore samples from the Knight-Piésold dataset (2/21 or 9.5%). Lithium was not a target analyte in the larger AMEC ore and rock chemistry dataset. Lithium is widely considered to be of low concern in regards to both animal and human health, and may be a beneficial or even essential element in higher animals (NAS, 2005). While lithium is of high solubility and can be readily absorbed in vertebrate gastrointestinal tracts, its uptake is strongly influenced by interactions with sodium, potassium and magnesium (NAS, 2005; Aral and Vecchio-Sadus, 2008). In a recent review, Aral and Vecchio-Sadus (2008) concluded that lithium is not expected to bioaccumulate to any significant extent, and its human and environmental toxicity are low. Uptake of lithium by plants is highly variable and species-specific, but tends to be highest in acidic soils (Aral and Vecchio-Sadus, 2008). Based on limited baseline soil pH data that was collected within the various Project study areas, soil pH is in the neutral range, suggesting limited potential for vegetation uptake of lithium.

- Titanium was present at measurable, albeit low concentrations in only five of the ore samples from the Knight-Piésold dataset (5/21 or 24%). While it was measurable above the RDL in roughly 70% of the samples from the larger AMEC ore and rock chemistry dataset, concentrations were low and near RDL values for the vast majority of samples. Titanium is considered to be of low concern in regards to both animal and human health, and may have beneficial functions in animals and plants (NAS, 2005). While little is known about the metabolism of titanium, it is generally believed that most titanium, especially that from soil contamination, is poorly absorbed in the gastrointestinal tracts of vertebrates (NAS, 2005). It is considered that titanium is essentially nontoxic in the amounts and forms that would likely be ingested under typical environmental and dietary exposure conditions (NAS, 2005).

- Yttrium was present at measurable concentrations in all ore samples from the Knight-Piésold dataset, but at low concentrations relative to the major ore constituents. Yttrium was not a target analyte in the larger AMEC ore and rock chemistry dataset. As is the most for most elements classified as "rare earths", yttrium is considered to be of low concern in regards to both animal and human health (NAS, 2005). It has been suggested that yttrium may have beneficial effects in animals and humans (Horovitz, 1993). While information is limited, it is generally believed that rare earth elements are poorly absorbed in vertebrate gastrointestinal tracts, and that uptake is dependent on interactions with calcium (as most rare earths occur as divalent cations in biological tissues) (NAS, 2005). In general, it is considered that rare earth elements are relatively nontoxic to animals (NAS, 2005), and consequently, would be expected to be of low to negligible toxicity in humans.

- Calcium, Potassium, Magnesium, Sodium, and Sulfur were excluded on the basis that these elements are well established as essential macronutrients that are required for all organisms. As such, their uptake, metabolism and excretion are physiologically regulated such that exceptionally high or extreme exposures would be necessary to overwhelm internal compensatory or homeostatic mechanisms, and result in toxicity. The expected limited exposure to these elements in soil, vegetation or ore dust does not represent a situation of extreme exposure.

Following estimation of the metals content of deposited ore dust, soil metals loading rates were determined using the following equation (as per U.S. EPA, 2005): Ds = Dtot / (Zs x Bd).

Where,

Ds	=	Deposition (or loading) to soil; mg metal/kg soil/yr
Dtot	=	Atmospheric dust deposition rate; mg/m^2/year (provided by RWDI, 2010 as g/m^2/year and converted to mg/m^2/year)
Zs	=	Soil mixing zone; assumed 0.02 m as per U.S. EPA (2005) default recommendations
Bd	=	Soil bulk density; assumed 1500 kg/m^3 as per U.S. EPA (2005) default recommendations

Following calculation of soil metals loading rates, incremental bulk soil metals concentrations were determined using the following equation (also from U.S. EPA, 2005): Cs = Ds x tD. It was conservatively assumed that there are no metals losses from soil, once deposited.

Where,

Cs = Incremental bulk soil concentration; mg metal/kg soil
Ds = Deposition to soil; mg metal/kg soil/yr
tD = Time period for deposition; assumed 21 years as per Project description

The calculated incremental metals soil concentrations were then added to the 90th percentile[1] of the baseline soil metals concentrations data (N=56; data provided by Knight Piésold), for each metal of interest. Baseline soils sampling occurred over the regional study area, and represents a broad characterization of pre-mine metals levels in local surface soils.

Table 3-1 presents a summary of the calculation steps described above for the metals of interest, up to the estimation of the incremental soil metal concentrations. Tables 3-2 and 3-3 present the baseline, incremental and total (baseline + increment) soil metals concentrations, for the two ore dust deposition rate scenarios that were considered.

[1] A number of regulatory agencies prefer or endorse the use of the 90th percentile for soil background or baseline concentration statistics.

Table 3-1 Summary of Ore Dust Metal Ratios, Soil Loading Rates and Incremental Soil Concentrations for Metals of Interest

Metal	Maximum Measured Ore Concentration (μg/g ore)	Metal Ratios (Maximum Measured Ore Concentration : Average Total Element Mass (for all elements analyzed in ore)	Estimated Loading to Soil (Ds; mg/kg/yr) at Deposition Rate of 180 g/m^2/year	Predicted Incremental Soil Concentration (μg/g soil) at Deposition Rate of 180 g/m^2/year	Estimated Loading to Soil (Ds; mg/kg/yr) at Deposition Rate of 60 g/m^2/year	Predicted Incremental Soil Concentration (μg/g soil) at Deposition Rate of 60 g/m^2/year
Silver (Ag)	8.9	1.52E-05	0.091	1.9	0.030	0.64
Aluminum (Al)	68000	0.116	698	14700	233	4890
Arsenic (As)	830	0.0014	8.5	180	2.8	60
Barium (Ba)	58	9.93E-05	0.596	12.5	0.199	4.17
Beryllium (Be)	2.4	4.1E-06	0.025	0.52	0.0082	0.17
Cadmium (Cd)	8.5	1.5E-05	0.087	1.8	0.029	0.61
Cobalt (Co)	71	0.000122	0.729	15.35	0.243	5.10
Chromium (Cr)	430	0.000736	4.42	92.7	1.47	30.9
Copper (Cu)	260	0.000445	2.67	56.1	0.890	18.7
Iron (Fe)	720000	1.23	7390	155000	2460	51800
Lithium (Li)	11	1.9E-05	0.11	2.4	0.038	0.79
Manganese (Mn)	28600	0.0489	294	6170	97.9	2060
Molybdenum (Mo)	233	0.000399	2.39	50.2	0.798	16.7
Nickel (Ni)	270	0.000462	2.77	58.2	0.924	19.4
Lead (Pb)	75	0.000128	0.770	16.2	0.257	5.39
Antimony (Sb)	22	3.77E-05	0.226	4.74	0.0753	1.58
Selenium (Se)	11	1.9E-05	0.11	2.4	0.038	0.79
Tin (Sn)	3.4	5.8E-06	0.035	0.73	0.012	0.24
Strontium (Sr)	33	5.65E-05	0.339	7.12	0.113	2.37
Thallium (Tl)	0.3	5.1E-07	0.0031	0.065	0.0010	0.022

Metal	Maximum Measured Ore Concentration (µg/g ore)	Metal Ratios (Maximum Measured Ore Concentration : Average Total Element Mass (for all elements analyzed in ore)	Estimated Loading to Soil (Ds; mg/kg/yr) at Deposition Rate of 180 g/m^2/year	Predicted Incremental Soil Concentration (µg/g soil) at Deposition Rate of 180 g/m^2/year	Estimated Loading to Soil (Ds; mg/kg/yr) at Deposition Rate of 60 g/m^2/year	Predicted Incremental Soil Concentration (µg/g soil) at Deposition Rate of 60 g/m^2/year
Uranium (U)	2.7	4.62E-06	0.0277	0.582	0.00924	0.194
Vanadium (V)	150	0.000257	1.54	32.3	0.513	10.8
Zinc (Zn)	220	0.000377	2.26	47.4	0.753	15.8

Notes:
The average total element mass (for all elements analyzed) was 584,302 µg/g ore.

Table 3-2 provides a summary of the 90th percentile baseline soil concentrations, the predicted incremental soil concentration from ore dust deposition (for a dust deposition rate of 180 g/m^2/year for 21 years of Project operations), and the total future estimated soil concentration (baseline + incremental), for each metal of interest. Baseline soil data was provided by Knight Piésold, and summary statistics are presented in Appendix A.

Table 3-2 Future Predicted Soil Concentrations at 180 g/m^2/yr Dust Deposition Rate

Element	Baseline 90th%ile Soil Concentration; mg/kg	Predicted Incremental Soil Concentration; mg/kg	Total Future Predicted Soil Concentration after 21 Years of Operations; mg/kg
Silver (Ag)	0.2	2	2.2
Aluminum (Al)	9760	14700	24460
Arsenic (As)	1.3	180	181.3
Barium (Ba)	65.0	12.5	77.5
Beryllium (Be)	0.50	0.52	1.02
Cadmium (Cd)	0.3	2	2.3
Cobalt (Co)	7.20	15.3	22.5
Chromium (Cr)	29.1	92.7	121.8
Copper (Cu)	40.2	56.1	96.3
Iron (Fe)	23800	155000	178800
Manganese (Mn)	214	6170	6384
Molybdenum (Mo)	2.93	50.2	53.13
Nickel (Ni)	21.7	58.2	79.9
Lead (Pb)	21.1	16.2	37.3
Antimony (Sb)	<2[a]	4.74	6.74[b]
Selenium (Se)	0.59	2.4	2.99
Tin (Sn)	2	1	3
Strontium (Sr)	23.9	7.12	31.02
Thallium (Tl)	0.26	0.065	0.325
Uranium (U)	5.59	0.582	6.172
Vanadium (V)	42.0	32.3	74.3
Zinc (Zn)	61.9	47.4	109.3

Notes:

a. assumed RDL; value was not reported

b. For total future concentration, the predicted increment was added to the detection limit (RDL)

Table 3-3 provides a summary of the 90th percentile baseline soil concentrations, the predicted incremental soil concentration from ore dust deposition (for a dust deposition rate of 60 g/m^2/year for 21 years of Project operations), and the total future estimated soil concentration (baseline + incremental), for each metal of interest.

Table 3-3 Future Predicted Soil Concentrations at 60 g/m^2/yr Dust Deposition Rate

Element	Baseline 90th%ile Soil Concentration; mg/kg	Predicted Incremental Soil Concentration; mg/kg	Total Future Predicted Soil Concentration after 21 Years of Operations; mg/kg
Silver (Ag)	0.2	0.6	0.8
Aluminum (Al)	9760	4890	14650
Arsenic (As)	1.3	60	61.3
Barium (Ba)	65.0	4.17	69.17
Beryllium (Be)	0.50	0.17	0.67
Cadmium (Cd)	0.3	0.6	0.9
Cobalt (Co)	7.20	5.10	12.3
Chromium (Cr)	29.1	30.9	60.0
Copper (Cu)	40.2	18.7	58.9
Iron (Fe)	23800	51800	75600
Manganese (Mn)	214	2060	2274
Molybdenum (Mo)	2.93	16.7	19.6
Nickel (Ni)	21.7	19.4	41.1
Lead (Pb)	21.1	5.39	26.49
Antimony (Sb)	<2[a]	1.58	3.58
Selenium (Se)	0.59	0.79	1.38
Tin (Sn)	2	0.2	2.2
Strontium (Sr)	23.9	2.37	26.27
Thallium (Tl)	0.26	0.022	0.282
Uranium (U)	5.59	0.194	5.784
Vanadium (V)	42.0	10.8	52.8
Zinc (Zn)	61.9	15.8	77.7

Notes:

a. assumed RDL; value was not reported

4.0 ASSESSMENT OF CARIBOU EXPOSURES TO TRACE METALS IN ORE DUSTS ON SOILS AND VEGETATION

This section of the report addresses the question:

- *"Will ore dust deposition from the project result in levels of metals that are harmful for the health of the caribou?"*

4.1 Background

A Terrestrial Wildlife Impact Assessment has been conducted by EDI (2010) on possible Project-related impacts to the North Baffin Island caribou. Based on surveys and information gathered by EDI (2010), caribou currently occur at low densities in the Project area, and their abundance is cyclical (roughly a 70 year cycle of abundance). EDI (2010) concluded that even though their current abundance is low, there is evidence that caribou are present throughout the entire region and currently use habitat in most of the Project area. Habitat analyses suggest that the probability of occurrence of caribou is relatively equal in many areas throughout the Project area (EDI, 2010). Caribou feed primarily on lichens, but also eat sedges, cottongrass, blueberries, willows, flowers and leaves of forbs (EDI, 2010).

A screening level assessment of caribou exposures to metals in ore dusts is presented in Section 4.2. Section 4.3 provides an evaluation of potential caribou exposure to key metals of interest. Conclusions are presented in Section 4.4.

4.2 Screening Level Assessment - Caribou

4.2.1 Comparison to Environmental Health-Based Soil Quality Guidelines

Total future soil concentrations (predicted increment + 90th percentile baseline) for both dust deposition scenarios (180 g/m^2/yr and 60 g/m^2/yr) were compared to both ecological health-based soil quality guidelines (*e.g.*, CCME, 2007; U.S. EPA EcoSSLs) and the maximum measured baseline soil concentrations. The soil quality guidelines used in these comparisons are derived by Canadian or U.S. regulatory agencies, and are widely used across North America for determining whether or not chemicals present in soils merit further study. Where possible, the soil quality guidelines used in the caribou screening level assessment are for an agricultural land use classification (agricultural land use guidelines are the most conservative, relative to guidelines derived for all other land uses), and were based on soil and food ingestion pathways. These pathway-specific guideline values are developed to be generally protective of mammalian ecological receptors. It is recognized however that the toxicity information used to develop these soil quality guidelines may not consider Arctic species and environmental conditions; therefore, there is some uncertainty in the application of these values. Since no Arctic-specific soil quality guidelines exist though, the soil quality guidelines used in this evaluation are considered to be reasonable benchmarks for determining which metals require further assessment in relation to potential caribou exposures.

In addition to soil quality guideline comparisons, it is also important to consider the naturally occurring metals levels in the existing environment (*i.e.*, baseline conditions). The available baseline dataset for metals levels in soils is relatively small given the size of the Project areas (N = 52), but does provide an indication of existing natural metals soil concentration ranges within the region (see Appendix A). The baseline soil chemistry data provides an additional benchmark of comparison to identify which metals could become significantly elevated in local soils as a result of ore dust deposition.

Where predicted future metals soil concentrations (baseline + increment) are below the applicable agricultural land use soil quality guidelines, and within the range of measured baseline soil concentrations (which is the same as being less than the maximum baseline soil concentrations), there is a reasonably high degree of confidence that caribou health will not be adversely affected. If predicted future metals soil concentrations (baseline + increment) are greater than both the applicable soil quality guideline and the maximum baseline soil concentration, caribou are not necessarily at risk, but, further evaluation is indicated (See Section 4.3). In situations where no soil quality guideline is available for a particular metal, the predicted future soil concentration was compared to the maximum baseline soil concentration. Exceedances of future soil concentrations above the baseline maxima were considered to require further evaluation.

Table 4-1 presents the soil quality guideline and maximum baseline concentration comparisons for both the 180 g/m^2/year and 60 g/m^2/year dust deposition scenarios.

Table 4-1 Comparison of Total Predicted Future Soil Metals Concentrations after 21 Years of Operations to Environmental Soil Quality Benchmarks and Baseline Soil Concentration Maxima

Chemical	Environmental Soil Quality Benchmark (mg/kg)	Maximum Baseline soil Concentration; mg/kg	Total Future Soil Concentration (Increment + 90th%ile Baseline); mg/kg	
			180 g/m^2/yr Scenario	60 g/m^2/yr Scenario
Aluminum	Soil pH <5.5[a]	21400	24,460	14,650
Antimony	0.27[b]	2[g]	6.74	3.6
Arsenic	380[c]	12.6	181	61.3
Barium	2,000[b]	111	77.5	69.2
Beryllium	21[b]	2.4	1.0	0.67
Cadmium	3.8[c]	1.0	2.3	0.9
Cobalt	230[b]	18.5	22.5	12.3
Chromium	34[b]	65.6	122	60.0
Copper	300[c]	283	96.3	58.9
Iron	Soil pH <5 or >8[d]	40900	178,800	75,600
Lead	70[c]	66.5	37.3	26.5
Manganese	4,000[b]	388	6,384	2,274
Molybdenum	6.9[e]	57.6	53.1	19.6
Nickel	355[c]	45.2	79.9	41.1
Selenium	4.5[c]	1.3	3.0	1.4
Silver	14[b]	0.2	2.2	0.8
Strontium	NGA	109	31.0	26.3
Tin	5[f]	6.0	3	2.2
Thallium	1[c]	0.65	0.33	0.28
Uranium	33[c]	36.5	6.2	5.8
Vanadium	280[b]	81.6	74.3	52.8
Zinc	640[c]	188	109	77.7

Notes:
Shading indicates exceedance over both the soil quality guideline and maximum baseline soil concentration.

a. U.S. EPA (2003a) reports that total or available aluminum in soils is not a suitable or reliable predictor of toxicity and bioaccumulation , and recommends that aluminum be carried forward for further evaluation as at sites where the soil pH is <5.5. This is because aluminum solubility and speciation (which determine uptake into biota) are pH-dependent processes. Aluminum bioavailability and toxicity to all ecological receptors is associated only with soluble forms. Insoluble aluminum compounds such as aluminum oxides are considerably less toxic relative to soluble forms (such as aluminum chloride, nitrate, acetate, and sulfate). Based on limited baseline soil pH data that was collected within the various Project study areas, soil pH is in the neutral range (6-7.5). Thus, aluminum does not merit further study.

b. U.S. EPA EcoSSLs (http://www.epa.gov/ecotox/ecossl/index.html); selected benchmarks are the mammalian EcoSSL.

c. CCME, 2007. Update 7.1. Canadian Soil Quality Guidelines (Environmental Soil Quality Guidelines; Agricultural land use categories); selected values are the soil and food ingestion guideline.

d. U.S. EPA (2003b) reports that identifying a specific benchmark for iron in soils is difficult since iron's bioavailability to plants and resulting toxicity are dependent upon site-specific soil conditions such as pH, Eh, and moisture. The U.S. EPA recommends that the site-specific measured pH and Eh (collected in the field) be used to determine the expected valence state of iron and associated chemical compounds, and the resulting bioavailability and toxicity in the environmental setting. In well-aerated soils between pH 5 and 8, the iron demand of plants is higher than the amount available. Thus, plants have evolved various mechanisms to enhance iron uptake. Under these soil conditions, iron is not expected to be toxic to plants.

The main concern from an ecological risk perspective is not the direct chemical toxicity of iron, but the effect of iron as a mediator in the geochemistry of other (potentially toxic) metals. Soil pH in baseline soils was in the pH 6 – 7.5 range, and therefore is slightly acidic to neutral. This indicates that iron would not likely be of concern to terrestrial plants. However, since the U.S. EPA iron guideline does not explicitly consider mammalian health, and the predicted future iron soil concentration in both dust deposition scenarios exceeds the baseline soil concentration range, iron was considered to merit further evaluation.

e. MOE, 2009. Terrestrial protection value for mammals and birds; Agricultural land use (based on LOEL for short-tailed shrew).

f. AENV, 2009. While this value is an agricultural land use soil contact (plants and invertebrates) guideline, rather than a soil food and ingestion pathway-specific guideline, it is considered adequately conservative given that no soil and food ingestion-based guidelines exist for tin.

g. Antimony was not analyzed in baseline soil samples. Therefore the maximum soil concentration was assumed to be equal to a typical detection limit for antimony of 2 mg/kg.

Based on the comparisons presented in Table 4-1, the key metals of interest in the 180 $g/m^2/yr$ scenario are: antimony, chromium, iron and manganese. The key metals of interest in the 60 $g/m^2/yr$ scenario are: antimony and iron. These metals are evaluated further in Section 4.3.

4.2.2 Bioaccumulation Check

Metals are found naturally in the environment, and occur in virtually all environmental media, irrespective of anthropogenic sources. As such, numerous metals are present at measurable concentrations in baseline soil and vegetation samples (see Appendix A).

As a check mechanism for the identification of the metals of interest in the current evaluation, the bioaccumulation and/or biomagnification potential of each metal of interest was reviewed, in order to identify those metals with the potential to bioaccumulate in terrestrial organisms and/or biomagnify within terrestrial food webs, such that there could be significant transfer of the metals from soil and plants to higher trophic levels. If a substance does not bioaccumulate to any significant degree within terrestrial organisms, it will not biomagnify in higher trophic levels. For some metals where the literature indicates a moderate or high potential for bioaccumulation, the nutrient status of that metal is important to consider. A number of metals are essential macro or micronutrients and organisms physiologically regulate the uptake, metabolism and excretion of these substances. While these substances may be actively absorbed from environmental media to concentrations in tissues and organs that can substantially exceed the media concentrations, it does not necessarily mean that the concentrations of such substances will increase further in the food chain.

In Appendix B, information on the bioaccumulation and/or biomagnification potential of each metal of interest was obtained from a general literature review of major regulatory agency toxicology review documents (*i.e.*, ATSDR toxicological profiles, and/or World Health Organization Environmental Health Criteria monographs or Concise International Chemical Assessment Documents). In addition, a limited selection of primary scientific literature and other regulatory review documents were also considered. The outcomes of these general reviews for each metal in Table 4-1 are provided in Appendix B.

Based on the information presented in Appendix B, cadmium, lead, selenium and thallium were identified as having a moderate or high potential to bioaccumulate in terrestrial biota. None of these metals are expected to biomagnify.

Examination of the soil concentration increments for cadmium, lead, selenium and thallium (which could be added to baseline soil concentrations as a result of ore dust deposition; See Tables 3-1 and 3-2), relative to the applicable soil quality guidelines and maximum baseline soil concentrations (presented in Table 4-1), suggests that lead and thallium do not merit further consideration. The predicted future soil levels of these two metals are below agricultural land use soil quality guidelines, and are within the baseline concentration ranges.

While the predicted future soil concentration of selenium and cadmium slightly exceed their maximum baseline soil concentrations, they do not exceed conservative agricultural land use soil quality guidelines (Table 4-1). As such, future soil concentrations of these metals are not considered to pose an ecological health concern for caribou. As indicated in Appendix B, cadmium has the potential to bioaccumulate in the terrestrial food chain, but the main concerns are largely restricted to organs, such as the liver and kidneys (rather than muscle tissue), and cadmium is generally poorly absorbed from the intestinal tract (Sileo and Beyer, 1985; Vos *et al*, 1990). This issue has been identified previously in northern caribou herds (INAC, 2003), where elevated cadmium concentrations have been measured in caribou liver and kidneys. However, despite the accumulation of cadmium in caribou organs, there are no indications that this issue is adversely affecting caribou health. Rather, this is considered to be primarily a human health exposure issue related to the consumption of caribou organ meats, and therefore is discussed further in Section 5.3.

An important factor which has not been considered in the bioaccumulation check is the potential bioavailability of the metals within the ore dust in the environment, once released. The form of metal present in the environment is a major factor influencing metals accumulation in species and dietary items (Chapman, 2008). Bioavailability refers to the extent and rate to which a chemical can be absorbed into the systemic circulation of an organism, and potentially produce an adverse effect (Hrudey *et al*., 1996; Kelly *et al.*, 2002). There is a large volume of research that has been conducted which indicates that when metals in soils are ingested, only a fraction of the metal is available for absorption (as opposed to 100% of the metal). The available fraction varies depending upon the specific form of the metal present, the soil characteristics, as well as the gut characteristics of the organism ingesting the soils.

4.3 Further Evaluation of Metals of Interest - Caribou

As previously noted in Section 4.2, the key metals of interest in the 180 $g/m^2/yr$ scenario are: antimony, chromium, iron and manganese. The key metals of interest in the 60 $g/m^2/yr$ scenario are: antimony and iron. These metals are discussed in the following bullets.

- Accumulation Potential in Food Sources for Caribou:

  Based on a limited search of the scientific literature, antimony, chromium, iron and manganese would not be expected to significantly accumulate within terrestrial caribou food sources (See Appendix B). However, as none of the literature reviewed specifically focused on lichen, or other arctic vegetation species that caribou eat, there is some uncertainty in this statement. Baseline vegetation sampling clearly shows that many metals are present naturally in vegetation sampled from local study areas (see Appendix A). While the accumulation potential for antimony, chromium, iron and manganese in caribou food items is expected to be low overall, there is a high degree of uncertainty in this statement, due to the unique environmental conditions in the arctic.

- Exposure Potential based on Considerations of Spatial Areas Affected by Ore Dust Deposition versus Areas used by Caribou:

  Based on the isopleth diagrams provided by RWDI (2010), the size of the areas potentially influenced by dust deposition rates of 180 $g/m^2/yr$ (outside the PDAs) are very limited and are directly adjacent to the active operational areas at Mary River and Milne Inlet. No areas outside the PDA at Steensby Port are predicted to incur dust deposition rates that are higher than 180 $g/m^2/yr$ (RWDI, 2010). Areas which would incur dust deposition rates of 60 $g/m^2/yr$ outside the PDAs are most predominant at the active mine site in Mary River, followed by Milne Inlet, where this rate of dust deposition affects very limited areas that are close to the PDA (RWDI, 2010). No areas outside of the PDA at Steensby Port are predicted to incur dust deposition rates that are higher than 60 $g/m^2/yr$. Therefore, based on this information, the size of areas affected by the higher dust loadings (180 $g/m^2/yr$) are relatively small and are limited to areas in close proximity to two of the operational areas (Mary River and Milne Inlet, and to a lesser extent, the trucking stockpile north to Camp Lake). Areas affected by the more moderate dust loadings (60 g/m^2 /yr) are limited to areas within the PDAs, with the possible exception of Milne Inlet, which has a small area to the south > 60 g/m^2 /yr and Mary River, where dust plumes will extend in the south west (area of about 10 km^2), east of the mine (area of about 4 km^2) and westerly directions (area of about 12 km^2).

  Caribou are known to be present throughout the region (EDI, 2010), and therefore could incur exposure to dusts and soils through the consumption of vegetation containing metals, incidental ingestion of soils, and ingestion of dusts present on vegetation surfaces. Individual caribou movement ranges vary from 12,062 Ha to 149,181 Ha within the caribou regional study area; with a large caribou movement area range of 1,030,880 Ha recorded that transcends the regional study area boundary (Figure 13; Appendix 6F; EDI, 2010).

Based on the limited size of the areas affected by deposition rates of 180 g/m^2/year, and the fact that these areas, and areas exhibiting higher dust deposition rates, are largely within the active PDAs, the likelihood of significant metals exposures to caribou is considered to be low, particularly in light of their movement through the study area. The size of the areas that are projected to experience lower dust deposition rates (60 g/m^2/yr) are larger, and therefore caribou would be expected to spend a larger of portion of their time in these areas. Caribou metal exposure levels in these areas, however, would be considerably lower than those in areas closer to the PDAs.

- Consideration of Essential Nutrients

  Manganese and iron are considered necessary for the normal development of plants and animals (US EPA, 2007). As such, these metals are highly regulated in biological organisms.

4.4 Summary/Conclusions

Based on the caribou assessment conducted herein, the following can be concluded:

- Some metals that are reported to bioaccumulate in terrestrial organisms will be released in ore dust (*e.g*., lead, thallium, selenium, cadmium). However, future soil concentrations of these particular metals are predicted to be either within baseline concentration ranges, or below agricultural land use soil quality guidelines, and therefore are unlikely to pose a significant risk to caribou.
- Based on the estimated future soil concentrations of all metals considered, some accumulation within vegetation and other terrestrial organisms tissues is anticipated to occur, but would likely be localized to areas most affected by dust loadings which are generally limited in their spatial extent.
- The metals most likely to exhibit the highest future soil concentrations (antimony, chromium, iron and manganese) are unlikely to cause adverse effects in caribou, based on the limited size of the areas affected by dust deposition relative to the home range of this species, the lower projected incremental soil concentrations in areas with moderate dusting, and essentiality of some of the metals (*i.e.,* iron, manganese).

There is a reasonable degree of confidence in this assessment.

5.0 ASSESSMENT OF HUMAN EXPOSURES TO TRACE METALS IN ORE DUSTS FROM CONSUMPTION OF BLUEBERRY AND CARIBOU

This section of the report will address the questions

- *"Will ore dust deposition from the Project result in levels of metals in blueberries that are harmful for human consumption?"*
- *"Will ore dust deposition from the project result in levels of metals in caribou tissue that are harmful for human consumption?"*

5.1 Background

Many terrestrial wildlife species are present in the study area and caribou in particular, are an important part of the Inuit culture (EDI, 2010). Caribou are an integral component of a subsistence lifestyle, and are harvested and consumed by hunters from communities surrounding the Project area. EDI (2010) summarized records dating back to the 1920s indicating harvesting of this species, and that caribou remains a key component of Inuit diet and culture to this day. The traditional use of plants has occurred in the vicinity of the proposed facility (particularly within the Steensby Inlet Port site) on an opportunistic basis, such as berry picking when staying at a hunting camp in the area (Knight Piesold, 2010a). Blueberry plants observed in the Local Study Area tend to be reasonably lush and produce large berries. Prime berry picking season is August, when the berries tend to ripen. Blueberries are found within the study area from the Milne Inlet area to the Steensby Inlet Port site and grow in abundance on sheltered slopes, but are not particularly common on Deposit 1. Blueberries are plentiful to the east of Camp Lake and are common in many other areas around the Project (Knight Piesold, 2010b). Berry picking areas were identified during the land use workshops; however, the only location identified within the Local Study Area was at the Steensby Inlet Port site (Knight Piesold, 2010a). Fresh local blueberries are only available for a short time period in late summer; however, many local residents freeze the berries for later consumption or make them into jams and jellies.

A screening level assessment of potential human exposures to metals in blueberries and caribou meat is presented in Section 5.2, with Section 5.3 providing an evaluation of exposure potential related to key metals of interest. Conclusions are presented in Section 5.4.

5.2 Screening Level Assessment

5.2.1 Comparison to Environmental Soil Quality Guidelines

Total future soil concentrations (predicted increment + 90th percentile baseline) for both dust deposition scenarios (180 g/m^2/yr and 60 g/m^2/yr) were compared to both human health-based soil quality guidelines (CCME, 2007; BC MOE, 2010; U.S. EPA Region 3, 2010) and the maximum measured baseline soil concentrations. The soil quality guidelines used in these comparisons are derived by Canadian or U.S. regulatory agencies, and are widely used across North America for determining whether or not chemicals present in soils merit further study. Where possible, the soil quality guidelines used in the human health screening level assessment are for an agricultural land use (agricultural land use guidelines are the most conservative, relative to guidelines derived for all other land uses), and were based on direct soil contact pathways (primarily soil ingestion). There is some uncertainty in the application of these guidelines though, as they were not specifically derived for arctic conditions. But, since these are national generic (and conservative) guidelines that are considered broadly protective of human health, they are considered to be reasonable benchmarks for determining which metals require further assessment in the current evaluation.

As previously described in Section 4.2, in addition to soil quality guideline comparisons, it is also important to consider the naturally occurring metals levels in the existing environment (*i.e.*, baseline conditions). The available baseline dataset for metals levels in soils, while relatively small (N = 52), provides an indication of existing natural metals soil concentration ranges within the region (see Appendix A). The baseline soil chemistry data provides an additional benchmark of comparison to identify which metals could become significantly elevated in local soils as a result of ore dust deposition.

Where predicted future metals soil concentrations (baseline + increment) are below the applicable agricultural land use soil quality guidelines, and within the range of measured baseline soil concentrations (which is the same as being less than the maximum baseline soil concentrations), there is a reasonably high degree of confidence that human health will not be adversely affected. If predicted future metals soil concentrations (baseline + increment) are greater than both the applicable soil quality guideline and the maximum baseline soil concentration, human health risks are not necessarily indicated (given the inherently conservative nature of these guidelines), but further evaluation is warranted (See Section 5.3).

Table 5-1 presents the soil quality guideline and maximum baseline concentration comparisons for both the 180 g/m^2/year and 60 g/m^2/year dust deposition scenarios.

Table 5-1 Comparison of Total Predicted Future Soil Metals Concentrations after 21 Years of Operations to Human Health–Based Soil Quality Benchmarks and Baseline Soil Concentration Maxima

Chemical	Human Health Soil Quality Benchmark (mg/kg)	Maximum Baseline Soil Concentration (mg/kg)	Total Future Soil Concentration (Increment + 90th%ile Baseline); mg/kg	
			180 g/m^2/yr Scenario	60 g/m^2/yr Scenario
Aluminum	15,400[a]	21,400	24,460	14,650
Antimony	7.8[a]	NA	6.7	3.6
Arsenic	12[b]	12.6	181	61.3
Barium	6,500[c]	111	77.5	69.2
Beryllium	32[a]	2.4	1.0	0.67
Cadmium	1.4[b]	1.0	2.3	0.9
Cobalt	4.6[a]	18.5	22.5	12.3
Chromium	220[b]	65.6	122	60.0
Copper	1,100[b]	283	96.3	58.9
Iron	11,000[a]	40,900	178,800	75,600
Lead	140[b]	66.5	37.3	26.5
Manganese	360[a]	388	6,384	2,274
Molybdenum	78[a]	57.6	53.1	19.6
Nickel	300[a]	45.2	79.9	41.1
Selenium	80[b]	1.3	3.0	1.4
Silver	78[a]	0.2	2.2	0.8
Strontium	9,400[a]	109	31.0	26.3
Tin	9,400[a]	6.0	3	2.2
Thallium	1[b]	0.65	0.33	0.28
Uranium	23[b]	36.5	6.2	5.8
Vanadium	78[a]	81.6	74.3	52.8
Zinc	10,000[c]	188	109	77.7

Notes:
Shading indicates exceedance over both the soil quality guideline and maximum baseline soil concentration.
a. U.S. EPA Region 3, 2010. Residential Soil Screening Levels (no Agricultural land use category is available from U.S. EPA). The Soil Screening Levels are adjusted (divided by 5) to equate them to target hazard quotients and/or soil allocation factors used in the derivation of CCME soil quality guidelines for the protection of human health.
b. CCME 2007. Update 7.1. Canadian Soil Quality Guidelines (Human Health Soil Quality Guidelines; Agricultural land use category).
c. BC MOE, 2010. Matrix Numerical Soil Standards (Human Health Protection, Agricultural land use category; selected values are for the intake of contaminated soil pathway.

Based on the comparisons presented in Table 5-1, the key metals of interest in the 180 g/m^2/yr scenario are: aluminum, arsenic, cadmium, cobalt, iron and manganese. The key metals of interest in the 60 g/m^2/yr scenario are: arsenic, iron and manganese. These metals are evaluated further in Section 5.3.

5.2.2 Bioaccumulation Check

As discussed in Section 4.2.2, a bioaccumulation check was conducted for all metals listed in Table 5-1, and is presented in Appendix B. Based on the information presented in Appendix B, cadmium, lead, selenium, and thallium were identified as being of potential concern with respect to bioaccumulation in terrestrial organisms, which include human food resources.

Examination of the soil concentration increments for cadmium, lead, selenium and thallium (which could be added to baseline soil concentrations as a result of ore dust deposition ; See Tables 3-1 and 3-2), relative to the applicable soil quality guidelines and maximum baseline soil concentrations (presented in Table 5-1), suggests that lead, selenium and thallium do not merit further consideration. The predicted future soil levels of these three metals are below agricultural land use soil quality guidelines, and/or are within the baseline concentration ranges.

Cadmium is the only bioaccumulative metal that merits further evaluation, on the basis of a slight exceedance of both the soil quality guideline and baseline maxima (in the 180 $g/m^2/yr$ scenario only), and its well established potential to accumulate in organ meats. This issue is discussed further in Section 5.3.

5.3 Further Evaluation of Metals of Interest - Humans

Based on the evaluation presented in Section 5.2, the metals requiring further evaluation with respect to human consumption of blueberries and caribou are: aluminum, arsenic, cadmium, cobalt, iron and manganese. The potential for exposure to humans as a result of the release of these metals is discussed in the following bullets.

- <u>Exposure due to Cadmium Uptake in Caribou Organ Meats:</u>

  Only cadmium was identified as meriting further study in relation to its bioaccumulation potential. As indicated in Appendix B, cadmium has the potential to accumulate in the terrestrial food chain, but its accumulation within game species is largely restricted to organ meats, such as the liver and kidneys (rather than muscle tissue), (Sileo and Beyer, 1985; Vos *et al*, 1990). This issue has been identified previously in northern caribou herds (INAC, 2003), where elevated cadmium concentrations have been measured in caribou liver and kidneys.

  Based on the caribou assessment (Section 4), exposures to caribou are expected to be low due to the relatively small area outside the various PDAs where dust deposition is predicted to be elevated, and given the large home range of the caribou. As a result of this, the likelihood of significant increases in metals loadings to caribou, and hence, to locals eating caribou meats and organs, is likely low.

- Exposure Due to Metals Uptake in or Dust Deposition on Blueberries:

  Many metals will accumulate in vegetation, as reported in Appendix A (baseline vegetation metals data). None of the literature reviewed specifically focused on blueberry plants, but the baseline data suggests that blueberry plants can take up metals from their natural soil environment. The uptake of metals from soils into any terrestrial plant depends on a number of soil properties, including soil concentrations, soil pH, redox potential, metal speciation (chemical form), interactions between other metals and other substances present in these media (such as organic carbon and various minerals which provide large surface areas for metal adsorption/desorption reactions, and vegetation characteristics (such as root depth, growing season, species etc.). While the accumulation potential for the metals of interest in blueberries is expected to be low overall, there is a high degree of uncertainty in this statement, due to the unique environmental conditions in the arctic. However, based on the location of berry picking areas relative to the PDAs, concentrations of metals in blueberries are unlikely to change significantly over the Project's operational lifetime as the main blueberry picking locations are in areas predicted to incur very low rates of dust deposition. During the land use workshops, the only area within the LSA where blueberry picking was identified as occurring was in the vicinity of the Steensby Inlet Port site (Knight Piesold, 2010a). The dust deposition in the Steensby Inland Port site outside of the PDA is less than 60 $g/m^2/yr$. In addition, blueberries and other fruits are generally washed prior to eating, further reducing potential exposures. Given the low dust deposition rates in the Steensby Port area, the likelihood of blueberries having significantly increased metals concentrations (beyond those reported in the baseline vegetation data), as a result of the Project is considered to be low.

5.4 Summary/Conclusions

- Based on the assessment conducted, it is considered unlikely that ore dust deposition from the Project would result in levels of metals in blueberries or caribou tissues that would be harmful to human health, if consumed. This conclusion is based on consideration of the areas expected to be affected by ore dust deposition, the location of blueberry harvesting areas, and the home range of caribou.

- There is a reasonable degree of confidence in this conclusion, but supplemental monitoring of baseline soils near the PDAs, as well as in primary berry picking areas near any of the PDAs, would reduce uncertainty. In addition, an understanding of baseline organ meat metals levels in the local study areas prior to commencing operations would also assist in the interpretation of future organ metals concentration data, if it were to be collected.

6.0 CONCLUSIONS

Based on the assessment conducted, the following can be concluded:

- Metals are naturally occurring in the environment and are present within existing soils and vegetation in the region. Mining activities will result in release of ore dusts in the vicinities of the Potential Development Areas (PDAs) at Mary River, Milne Inlet, and Steensby Port, as well as along transportation corridors associated with the Project.
- Dust deposition isopleths indicate that the size of the areas, outside the active PDAs, which will potentially receive significant dust deposition are limited in size, which limits the exposure potential;
- Areas estimated to receive more moderate dust loadings are larger but are generally less than 1 to 12 km^2 in size, and are largely associated with the Mary River active mine site, and, to a lesser extent, Milne Inlet.
- The bioavailability of ore dust is unknown at this time, but the mineral types and forms of metals present in the ore may serve to limit the potential for uptake into either terrestrial vegetation or animals.
- Some metals that are reported to bioaccumulate in terrestrial organisms will be released in ore dust (*i.e*., lead, thallium, selenium, cadmium). However, future soil concentrations of these particular metals are predicted to be either within baseline concentration ranges, or below agricultural land use soil quality guidelines, and therefore are unlikely to pose a significant risk to caribou.
- Based on the estimated future soil concentrations of all metals considered, some accumulation within vegetation and other terrestrial organisms tissues is anticipated to occur, but would likely be localized to areas most affected by dust loadings which are generally limited in their spatial extent.
- The metals most likely to exhibit the highest future soil concentrations (antimony, chromium, iron and manganese) are unlikely to cause adverse effects in caribou, based on the limited size of the areas affected by dust deposition relative to the home range of this species, and essentiality of some of the metals (*i.e.*, iron, manganese).
- Based on the assessment conducted, it is considered unlikely that ore dust deposition from the Project would result in levels of metals in blueberries or caribou tissues that would be harmful to human health, if consumed. This conclusion is based on consideration of the areas expected to be affected by ore dust deposition, the location of blueberry harvesting areas, and the home range of caribou.

Recommendations:

- Supplemental monitoring of baseline soils near the PDAs, as well as in primary berry picking areas near any of the PDAs, would reduce uncertainties in this assessment.
- An understanding of baseline organ meat metals levels in the local study areas prior to commencing operations would also assist in the interpretation of future organ metals concentration data, if it were to be collected.
- Limited data are available to comment on metals accumulation potential for lichens (a major food for caribou). Conducting an environmental baseline monitoring program for selected vegetation species (such as lichens) prior to commencing operations (baseline) near the various PDAs, with subsequent periodic monitoring during operations, would reduce this area of uncertainty.
- Washing of berries or other produce before consumption as part of usual food preparation activities is recommended for both store-bought and naturally harvested foods. This recommendation is not specifically related to this project, but helps to ensure that food is clean prior to eating.

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APPENDIX A

SOIL AND VEGETATION BASELINE SUMMARY STATISTICS

APPENDIX A SOIL AND VEGETATION BASELINE SUMMARY STATISTICS

Table A-1 Summary Statistics of Baseline Soil Concentrations (mg/kg)

Metals	N	Min	Max	Mean	Median	90th	95th
Aluminum (Al)	50	430	21400	4734	3240	9760	15565
Arsenic (As)	52	0.10	12.6	0.83	0.55	1.29	1.5
Barium (Ba)	52	3.7	111	32.2	25.5	65.0	89.1
Beryllium (Be)	52	<0.2	2.4	0.34	0.2	0.5	0.6
Boron (B)	50	2.0	41	6.02	4.0	8.1	12.8
Cadmium (Cd)	52	<0.10	1.0	0.16	0.1	0.29	0.535
Chromium (Cr)	52	0.90	65.6	14.43	9.0	29.09	57.6
Cobalt (Co)	52	0.80	18.5	4.24	3.3	7.2	10.8
Copper (Cu)	52	1.2	283	20.09	9.45	40.15	55.5
Iron (Fe)	50	1100	40900	10418	7400	23790	26605
Lead (Pb)	52	1.5	66.5	8.90	4.95	21.12	24.6
Manganese (Mn)	50	11.0	388	116	93.0	214.2	324.6
Mercury (Hg)	52	<0.05	0.71	0.07	0.05	0.099	0.16
Molybdenum (Mo)	52	0.10	57.6	2.39	0.40	2.93	8.48
Nickel (Ni)	52	1.40	45.2	9.70	6.35	21.73	31.2
Selenium (Se)	52	<0.20	1.3	0.32	0.20	0.59	0.95
Silver (Ag)	52	<0.20	0.2	0.20	0.20	0.2	0.2
Strontium (Sr)	52	2.0	109	13.1	7.50	23.9	42
Thallium (Tl)	52	<0.05	0.65	0.14	0.09	0.26	0.44
Tin (Sn)	52	<2.0	6.0	2.1	2.0	2	2
Uranium (U)	52	0.26	36.5	3.03	1.35	5.59	10.6
Vanadium (V)	52	1.8	81.6	19.26	14.05	42	56.1
Zinc (Zn)	52	9.0	188	37.17	28.0	61.9	101

Table A-2 Summary Statistics of Baseline Vegetation Concentrations (mg/kg) – Blueberries

Metals	N	Min	Max	Mean	Median	90th	95th
Aluminum (Al)	34	50	1530	215	105	435	510
Antimony (Sb)	34	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic (As)	34	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Cadmium (Cd)	34	<0.05	1.4	0.29	0.22	0.55	0.77
Chromium (Cr)	34	0.4	13.1	2.22	1.25	5.35	5.82
Cobalt (Co)	34	<0.1	0.6	0.22	0.2	0.4	0.4
Iron (Fe)	34	16	539	124	65.5	347	447
Lead (Pb)	34	<0.02	0.92	0.16	0.1	0.33	0.41
Manganese (Mn)	34	42.5	1080	420	373	784	934
Molybdenum (Mo)	34	0.06	2.76	0.349	0.17	0.671	1.03
Nickel (Ni)	34	0.8	7.4	2.47	1.85	4.86	6.68
Selenium (Se)	34	<0.2	0.3	0.21	0.2	0.2	0.24
Thallium (Tl)	34	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Notes:
This table includes the results for blueberries only.
Not all metals presented in table.

Table A-3 Summary Statistics of Baseline Vegetation Concentrations (mg/kg) – Lichen and Moss

Metals	N	Min	Max	Mean	Median	90th	95th
Aluminum (Al)	10	350	12600	4760	5060	7960	10280
Antimony (Sb)	10	<0.05	0.1	0.065	0.06	0.091	0.096
Arsenic (As)	10	<0.2	0.4	0.27	0.2	0.4	0.4
Cadmium (Cd)	10	<0.05	1.99	0.29	0.080	0.42	1.20
Chromium (Cr)	10	1.9	183	44.4	24.4	93.4	138
Cobalt (Co)	10	0.2	4.1	1.5	1.1	2.8	3.5
Iron (Fe)	10	165	7060	3240	3020	6910	6980
Lead (Pb)	10	0.74	10.6	4.31	3.75	8.75	9.67
Manganese (Mn)	10	15.5	128	67.3	68.8	103	115
Molybdenum (Mo)	10	0.13	11.9	2.38	0.725	5.09	8.49
Nickel (Ni)	10	1.2	99.9	23.6	12.6	49.9	74.9
Selenium (Se)	10	<0.2	0.2	0.2	0.2	0.2	0.2
Thallium (Tl)	10	<0.05	0.11	0.064	0.055	0.083	0.097

Notes:
This table includes the results for lichen and moss only.
Not all metals presented in table.

Table A-4 Summary Statistics of Baseline Vegetation Concentrations (mg/kg) – Other Vegetation

Metals	N	Min	Max	Mean	Median	90th	95th
Aluminum (Al)	96	10	6830	596	145	1570	2780
Antimony (Sb)	96	<0.05	0.88	0.068	0.05	0.085	0.12
Arsenic (As)	96	<0.2	0.4	0.203	0.2	0.2	0.2
Cadmium (Cd)	96	<0.05	16.6	0.553	0.1	0.88	1.69
Chromium (Cr)	96	0.3	157	7.80	2.3	23.2	30.9
Cobalt (Co)	96	<0.1	5.5	1.01	0.6	2.45	2.75
Iron (Fe)	96	12	4810	486	156	1530	2260
Lead (Pb)	96	<0.02	3.78	0.527	0.165	1.43	2.56
Manganese (Mn)	96	13.3	1330	148	97.0	273	408
Molybdenum (Mo)	96	0.05	49.6	1.65	0.41	2.09	6.81
Nickel (Ni)	96	0.5	84.2	5.97	2.9	15.6	18.5
Selenium (Se)	96	<0.2	0.3	0.204	0.2	0.2	0.2
Thallium (Tl)	96	<0.05	0.08	0.0508	0.05	0.05	0.05

Notes:
This table includes the results for all other vegetation not including blueberries, lichen and moss.
Not all metals presented in table.

APPENDIX B

BIOACCUMULATION CHECK MECHANISM

APPENDIX B BIOACCUMULATION CHECK MECHANISM

Terrestrial plants and animals have developed a variety of means to regulate the amount of metals in their tissues. Some metals are physiologically essential macro or micronutrients, and the uptake, metabolism and excretion of such metals are controlled by homeostatic and other compensatory mechanisms. While terrestrial organisms can take up metals from environmental media and food items, accumulation typically occurs within specific tissues or organs, rather than uniformly within the whole organism. Furthermore, many metals are rapidly eliminated following uptake, and undergo limited or no metabolism prior to elimination. Such metals do not tend to accumulate to any significant extent in tissues or organs.

While there are some metals that are well known to bioaccumulate in terrestrial organisms, most do not biomagnify to a major extent (*i.e*., increase with successively higher trophic levels). U.S. EPA (2007) notes that most bioaccumulative metals will not generally biomagnify across three or more trophic levels.

Some other important considerations when determining the potential for a metal to bioaccumulate within terrestrial ecosystems include the following.

It is well established that the uptake of metals from soil, water, and sediments into plants and other terrestrial organisms is dependent on numerous factors such as pH, redox potential, metal speciation (chemical form), and interactions between other metals and other substances present in these media (such as organic carbon and various minerals which provide large surface areas for metal adsorption/desorption reactions). Thus, the mere presence of an elevated metal concentration in an environmental medium says little about the potential of that metal to be taken up by, and accumulate within terrestrial biota.

Metals which do accumulate in vegetation and other terrestrial organisms may or may not have a direct toxic effect on consumers of these organisms, and may or may not be bioavailable for organisms occupying higher trophic levels. The potential for metal bioavailability and toxicity to a consumer is not solely dependent upon the mere presence of a metal; rather, toxicity depends on the form in which the metal is stored in tissues (U.S. EPA, 2007). For example, many organisms produce proteins (such as metallothionein) which bind metals, and many organisms can sequester such ligand-metal complexes in various compartments within cells and tissues, such that the metals have reduced bioavailability (both to the organism itself and to consumers of that organism).

As a check mechanism for the identification of the metals of interest in the current evaluation, the bioaccumulation and/or biomagnification potential of each metal of interest was reviewed, in order to identify those COPCs with the potential to bioaccumulate in terrestrial organisms and/or biomagnify within terrestrial food webs, such that there would be significant transfer of the metals from soil and plants to higher trophic levels. If a substance does not bioaccumulate to any significant degree within terrestrial organisms, it will not biomagnify in higher trophic levels. For some metals where the literature indicates a moderate or high potential for bioaccumulation, the nutrient status of that metal is important to consider. As noted above, a number of metals are essential macro or micronutrients and organisms physiologically regulate the uptake, metabolism and excretion of these substances. While these substances may be actively absorbed from environmental media to concentrations in tissues and organs that can substantially exceed the media concentrations, it does not necessarily mean that the concentrations of such substances will increase further in the tissues of predators.

It is important to consider these concepts as soil quality guidelines do not typically consider the potential biotransfer of metals from lower to higher trophic levels. Information on the bioaccumulation and/or biomagnification potential of each metal of interest was obtained primarily from major regulatory agency toxicology review documents (*i.e.*, ATSDR toxicological profiles, and/or World Health Organization Environmental Health Criteria monographs or Concise International Chemical Assessment Documents). Where necessary, selected primary scientific literature and other regulatory review documents were also reviewed.

The outcome of these reviews are summarized below in Table B-1. Some of the papers cited relate to secondary processing of ore (such as smelting). The Project will not involve secondary processing, and form of metal present in the environment will likely be less bioavailable than that released from a secondary processing facility. Metals considered to have a moderate to high potential for bioaccumulation and/or biomagnification are bolded.

Table B-1 Bioaccumulation/Biomagnification Potential for Chemicals Present in Ore Dust

Chemical	Potential for Significant Bioaccumulation or Biomagnification in Terrestrial Food Web	Comments
Aluminum	Low	ATSDR (2006) reports that aluminum does not significantly bioaccumulate. While it can accumulate in some plants it does not appear to significantly accumulate in cows' milk or beef tissue and is not expected to biomagnify in terrestrial food chains.
Antimony	Low	Studies at secondary metals processing facilities have shown the uptake of antimony from soil in grass and movement into shoots is low, with most of the uptake resulting from atmospheric deposition (Ainsworth, 1988). Tissue analysis of small mammals (*i.e.*, voles, shrews, rabbits) shows that antimony does not bioaccumulate from food. Available data suggests antimony does not biomagnify from lower to higher trophic levels in the food chain (ATSDR, 1992a).
Arsenic	Low	Arsenic does not bioaccumulate to any great extent, nor does it biomagnify in either aquatic or terrestrial food webs (*e.g.*, NRCC, 1978; Eisler, 1988a; Adams *et al.*, 1994; Eisler, 1994; Farag *et al.*, 1998).
Barium	Low	Limited data are available. While barium appears to be able to bioconcentrate and bioaccumulate in terrestrial ecosystems, mainly in plants, available barium bioaccumulation factors are low for all terrestrial receptors examined to date. Thus, there is little to no evidence of biomagnification of barium (Hope and Miller, 1996).

Chemical	Potential for Significant Bioaccumulation or Biomagnification in Terrestrial Food Web	Comments
Beryllium	Low	Most terrestrial plants take up beryllium from soil in small amounts, with the exception of a few species of hyperaccumulators. Uptake by plants is dependent on soil properties, particularly pH. Uptake is generally increased as soil pH decreases (since beryllium primarily occurs in as Be^{2+} compounds). Very little of the beryllium taken up by the roots is translocated to other plant parts, such as edible above ground plant tissues. Deposition onto foliar surfaces can be a more important plant uptake pathway than root uptake (WHO, 2001a; 1990, ATSDR, 2002). There is no evidence for significant biomagnification of beryllium within terrestrial food chains (WHO, 2001a; 1990, ATSDR, 2002). There is also no significant evidence for the bioaccumulation of beryllium in foods consumed by humans (ATSDR, 2002).
Cadmium	**Moderate to high**	Cadmium bioaccumulates in all levels of the terrestrial food chain (ATSDR, 2008a). Biomagnification of cadmium through the food chain may not be significant since cadmium accumulates largely in the liver and kidneys of vertebrates rather than the muscle tissue and it has low intestinal absorption (Harrison and Klaverkamp, 1990; Sileo and Beyer, 1985; Vos *et al*., 1990; Sprague, 1986). Although some data indicate increased cadmium concentrations in animals at the top of the food chain, the data available on the biomagnification of cadmium are not conclusive since comparisons among animals at different trophic levels are difficult (Beyer, 1986; Gochfeld and Burger, 1982).
Chromium	Low	In terrestrial plants, the translocation of chromium from the roots to above-ground portions of plants is generally low (ATSDR, 2008b). As such, the bioaccumulation of chromium from soil to above-ground parts of plants is considered unlikely (Petruzzelli *et al.*, 1987). It has been reported that there is no indication of biomagnification of chromium along the terrestrial food chain (ATSDR, 2008b; WHO, 2009). Van Gestel *et al*. (1993) reported low bioconcentration factors for chromium (III) in earthworms.
Cobalt	Low	The available data indicate that cobalt is not taken up to a significant degree by plants and does not biomagnify in terrestrial food chains (ATSDR, 2004a).
Copper	Low	Studies in terrestrial environments have shown no, or very little evidence of bioaccumulation and biomagnification of copper (ATSDR, 2004b). WHO (2000) notes that accumulation factors vary greatly between different organisms, but tend to be highest at lower exposure concentrations, indicating copper uptake is regulated by many organisms and does not have a linear relationship with copper media concentrations. WHO (2000) also notes that copper usually has limited bioavailability in environmental media.
Iron	Low	Iron is an essential nutrient (NAS, 2005) and its intake is

Chemical	Potential for Significant Bioaccumulation or Biomagnification in Terrestrial Food Web	Comments
		physiologically regulated. No data were identified in the literature reviewed indicating that iron would bioaccumulate or biomagnify in terrestrial systems to any significant extent.
Lead	**Moderate**	Lead has been reported to bioaccumulate in terrestrial plants and animals (Eisler, 1988b; ATSDR, 2007). However, the biomagnification of lead in terrestrial food chains does not occur (Eisler, 1988b; NAS, 2005; ATSDR, 2007).
Manganese	Low	Higher organisms tend to maintain manganese homeostasis (U.S. EPA 1984a; Folsom *et al*. 1963; Thompson *et al*. 1972). As such, the potential for biomagnification of manganese from lower to higher trophic levels is low (ATSDR, 2008c). It has been noted that the bioavailability of manganese from plant food sources can be substantially decreased by dietary components such as fiber and phytates (ATSDR, 2008c). There are conflicting reports on the biomagnification potential of manganese, and most of the available data are from studies with aquatic organisms. However, the overall potential for biomagnification of manganese from lower trophic levels to higher levels is considered to be low (ATSDR, 2008c).
Molybdenum	Low to moderate	Molybdenum is believed to be a beneficial and perhaps even an essential element for mammalian nutrition (Eisler, 1989). It has been found that molybdenum concentrations in wildlife are generally low compared to those in terrestrial plants, suggesting that bioaccumulation of molybdenum is likely not significant in terrestrial systems. However, plant uptake can be significant depending on numerous soil factors, particularly pH. Soil pH is of primary importance because molybdenum occurs in most soils as the molybdate oxyanion, and its uptake into plants increases as pH increases (due to increased desorption of molybdate from mineral surfaces, and increasing concentrations in soil porewater).
Nickel	Low to moderate	While there is evidence of uptake and accumulation of nickel in certain terrestrial plants (subject to soil properties), the available data do not suggest the biomagnification of nickel in terrestrial food chains (ATSDR, 2005a). In fact, ATSDR (2005a) notes that the lack of significant bioaccumulation of nickel in aquatic organisms, voles, and rabbits indicates that nickel is not biomagnified in the food chain. It is also well established the primary forms of nickel that occur in soil are of low oral bioavailability to mammals (ATSDR, 2005a).
Selenium	**Moderate to high**	In alkaline (pH>7.5), well-oxidized soil environments (such as those in the Project areas), selenates are the major selenium species. Because of their high solubility and low tendency to adsorb onto soil particles, selenates are mobile and are readily taken up by plants and other biota. Selenium uptake by plants is influenced by many factors including soil type, pH, colloidal content, concentration of organic material, oxidation-reduction potentials in the root-soil

Chemical	**Potential for Significant Bioaccumulation or Biomagnification in Terrestrial Food Web**	**Comments**
		environment, and total level of selenium in the soil (ATSDR, 2003). When terrestrial plants take up soluble selenate, it is converted to organic selenium compounds (such as selenomethionine and selenocysteine.). These compounds tend to bioaccumulate in consumers of plants. The fact that selenium is well established as being present at high concentrations in various plant and animal-based food items, indicates that bioaccumulation and some biomagnification in terrestrial systems does occur (ATSDR, 2003).
Silver	Low	The bioaccumulation of silver from soil has been reported to be low (Ratte, 1999). Plants grown on silver mine tailings were found to have silver mainly in the root systems, with limited translocation to above ground tissues (Ratte, 1999). In mammals, there is no substantial potential for bioaccumulation (Ratte, 1999). WHO (2002) indicate that terrestrial bioaccumulation factors reported in the literature have been low.
Strontium	Low	Bioconcentration of strontium in terrestrial plants appears to be low based on limited data. However, strontium has a strong chemical similarity to calcium, thus strontium uptake is highly dependent on calcium interactions. In general, there is limited information available on the bioavailability of strontium from environmental media (ATSDR, 2004c). A recent review by WHO (2010) reports that earthworms do not accumulate strontium in soils that are high in calcium; however, strontium accumulation may occur in acidic, calcium-deficient soils Thus, in situations of low calcium in soil and other media, strontium bioaccumulation is possible. Calcium is present at typical concentrations in baseline soil samples. Thus, it appears unlikely that Project area soils are calcium-deficient.
Tin	Low	There is some evidence that inorganic tin compounds may be bioconcentrated, but data are limited. There is no information available on the potential transfer of inorganic tin compounds from lower trophic levels to higher tophic levels (WHO, 2005; ATSDR, 2005b). ATSDR (2005b) notes that inorganic tin is not well absorbed in mammals or humans after inhalation, oral, and dermal exposure.
Thallium	**Moderate**	There are no specific data on the bioaccumulation of thallium or its potential to be transferred from lower trophic levels to higher organisms, and no data were located on the biomagnification of thallium in the food chain (ATSDR, 1992b). Thallium in soil has been reported to be readily taken up by vegetation, particularly by plants belonging to the *Brassicaceae* family (Cataldo and Wildung 1983; Scheckel *et al*., 2004; LaCoste *et al*., 2001). However, as for all metals, uptake from soil is dependent on numerous soil factors, with pH being especially important. WHO

Chemical	Potential for Significant Bioaccumulation or Biomagnification in Terrestrial Food Web	Comments
		(1996) notes that although thallium can bioconcentrate and bioaccumulate, it is not likely to biomagnify in aquatic or terrestrial food webs.
Uranium	Low	There is some evidence that cattle preferentially bioconcentrate uranium in the liver, kidney, and bone tissue, but not in muscle tissue (Lapham *et al*. 1989). Uranium present in soil is typically in the form of insoluble oxides, which have very low bioavailability (ATSDR, 1999a). Based on aquatic bioaccumulation studies and foods analyses, it appears that uranium does not biomagnify to any significant extent in terrestrial or aquatic food chains and food webs (ATSDR, 1999a).
Vanadium	Low	ATSDR (2009) notes that in the terrestrial environment, bioconcentration of vanadium is most prevalent in lower plants. Higher plants do not tend to readily bioconcentrate vanadium. Plant uptake of vanadium is dependent on speciation (whether or not vanadium species are water soluble or not), soil concentrations, soil pH, and growing conditions. In general, vanadium does not generally partition to above ground portions of plants. There are no data available regarding biomagnification of vanadium within terrestrial or aquatic food chains, but it appears to be unlikely (ATSDR, 2009). WHO (2001b) states that most organisms do not concentrate or accumulate vanadium from environmental media to a significant extent, and there is no indication of biomagnification.
Zinc	Low	Zinc does not bioconcentrate in plants nor does it biomagnify in terrestrial food chains (ATSDR, 2005c; WHO, 2001c). WHO (2001c) also states that since zinc is an essential element for nutrition and physiological function in all organisms, and its uptake is regulated, bioconcentration or bioaccumulation factors are not related to toxicity

Based on the information presented in Table B-1, the following metals are identified as having a potential to bioaccumulate in terrestrial food webs. None of these metals are expected to biomagnify though.

- Cadmium
- Lead
- Thallium
- Selenium

However, an important consideration is that many of the studies that have investigated metal bioaccumulation and biomagnification in terrestrial biota were not conducted with species or environmental conditions that occur in the high Arctic. The accumulation of certain metals in arctic wildlife (many of which are consumed as game species) has been documented for many years. For example, in caribou liver and kidney, levels of cadmium are frequently found at elevated concentrations, while lead is also commonly found in these organs at elevated concentrations (*e.g.*, Robillard *et al*., 2002; Gamberg, 2008; INAC, 2003a,b). Female caribou tend to accumulate cadmium to a greater extent than males, likely due to their higher food and energy requirements (Gamberg, 2008). Cadmium (as well as lead and selenium) have also been reported in a number of studies to bioaccumulate within various other arctic mammals, aquatic life, and birds, but the levels measured in these species appear to be well tolerated in general, by the organisms (INAC, 2003a).

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