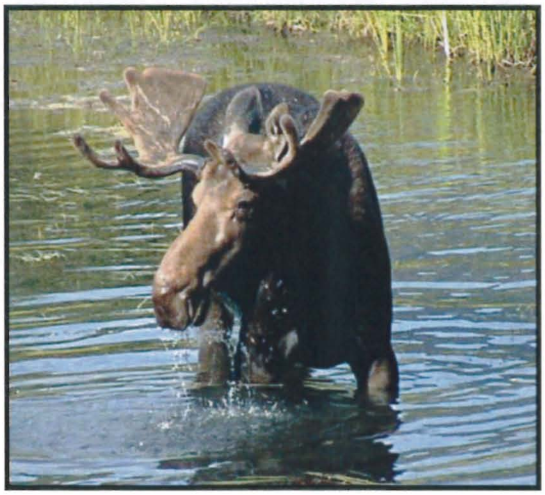
APPENDIX 39

Morrison Copper/Gold Project
Tailings Storage Facility
Wildlife Risk Assessment



August 2009

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EXECUTIVE SUMMARY

Executive Summary

This report presents the wildlife risk assessment for the proposed tailings storage facility during operations and post-closure phases of the Morrison Copper/Gold Project (the Project) for Pacific Booker Minerals Inc (PBM). The report also presents monitoring criteria for metals in wetland vegetation and aquatic invertebrates for the closure and post-closure stage of the Project.

PBM's proposed Morrison Copper/Gold Project (the Project) is 65 km northeast of Smithers and 35 km north of the village of Granisle in north-central British Columbia. The Project is on the east side of Morrison Lake on Crown land and falls within the traditional territory of the Lake Babine Nation. Access to the Project site is by road with barge access across Babine Lake, which is 50 km south of the site. The Project is approximately 35 km north of the former Bell and Granisle copper/gold mines.

The Morrison mine will be a 30,000 tpd open pit operation with ore processed in a conventional milling plant and the copper/gold concentrate transported to the Port of Stewart for shipment to offshore smelters. Molybdenum concentrate will be trucked from the mine to a refinery location to be confirmed. The mine will produce approximately 224 Mt of tailings and 169 Mt of waste rock throughout the mine life.

The information contained in this report is intended to support a full environmental and socio-economic impact assessment of the Project.

The objectives of the wildlife risk assessment were to identify and assess heavy metals that could pose a potential health risk to wildlife valued ecosystem components that may enter the tailings storage facility during mining operations. Wildlife valued ecosystem components that enter the tailings storage facility could be exposed to heavy metals from the incidental ingestion of tailings, ingestion of water, or the ingestion of foods that have been exposed and accumulated metals from the tailings.

The metals assessed included: arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, vanadium, and zinc. These metals were assessed for the following valued ecosystem components: grizzly bear, moose, mule deer, American marten, fisher, barred owl, goldeneye, and red-winged blackbird. The risk assessment evaluated the heavy metal exposure to valued ecosystem components using the tailings and water quality model predictions during operations presented in the *Morrison Copper/Gold Project: Water Balance / Water Quality Model Report* (Rescan 2009b). The estimated exposures for each valued ecosystem component were compared to TRVs, which are benchmark concentrations used to indicate the potential for wildlife health risks. The risk assessment found no potential for wildlife health risks to occur in the tailings storage facility during mining operations or post-closure phase.

In addition to the risk assessment, monitoring criteria were also established for heavy metals in wetland vegetation and aquatic invertebrates for the closure and post-closure stage of the Project. The monitoring criteria are the predicted maximum metal concentrations that would pose no

potential health risks to wildlife that consume the wetland vegetation and aquatic invertebrates. Wildlife would not be directly exposed to whole tailings after closure. However, upon closure, wetlands and aquatic invertebrates may establish in waterbodies that may contain submerged tailings. These wetland species and aquatic invertebrates could bioaccumulate metals from the submerged tailings. Subsequently, wildlife VECs that consume wetland vegetation and aquatic invertebrates could be inadvertently exposed to heavy metals through this indirect route.

The monitoring criteria are the concentrations in wetland vegetation and aquatic invertebrates that would pose no health risk to wildlife. Upon closure and reclamation of the tailings storage facility, wetlands and invertebrate tissue should be monitored and compared to the monitoring criteria. In the event that metals concentrations are observed to approach the monitoring criteria, adaptive management would then be initiated. The adaptive management plans for wetlands and wildlife are presented in Chapter 14.

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LIST OF ACRONYMS

List of Acronyms

BC	British Columbia
BC MELP	British Columbia Ministry of Environment Lands and Parks
BC MOE	British Columbia Ministry of Environment
BW	body weights
CCME	Canadian Council of Ministers of the Environment
COPC	chemical of potential concern
Eco-SSL	ecological soil screening level
EDI	estimated daily intake
ER	exposure ratio
ET	exposure time
IR	ingestion rate
ISQG	interim sediment quality guideline
LOAEL	lowest observed adverse effect level
masl	metres above sea level
NOAEL	no observed adverse effects level
PAG	potentially acid generating
PBM	Pacific Booker Minerals Inc.
PEL	probable effects level
the Project	Morrison Copper/Gold Project
Rescan	Rescan Environmental Services Ltd.
ROPC	receptor of potential concern
TRV	toxicity reference value
TSF	tailings storage facility
UCLM	upper confidence limit of the mean
US EPA	United States Environmental Protection Agency
VECs	valued ecosystem components

1. OVERVIEW

1. Overview

Pacific Booker Minerals Inc. (PBM) is proposing the construction of a tailings storage facility (TSF) to store tailings during mining operations and closure at the proposed Morrison Copper/Gold Project (the Project). Wildlife that enters the TSF area during these stages may be exposed to metals contained in the tailings media. This report is a wildlife risk assessment, which determines whether the design and conditions that are predicted in the proposed TSF would be safe for wildlife valued ecosystem components (VECs) during the mining operations and closure stages.

This report is divided into two sections, as summarized below.

1.1 Wildlife Risk Assessment – Operations Stage

This section models the metal concentrations that would be present in the TSF soil, water, and food during operations and compares them to species-specific characteristics (e.g., body weight (BW), ingestion rates (IR) of food, soil and water, time spent in the TSF). These conditions are used to estimate the amount of metals to which animals would be exposed. Predicted exposures are compared to benchmark toxicity reference values (TRVs) and quantitative risks for wildlife are calculated.

1.2 Wildlife Risk Monitoring – Closure Stage

This section addresses the TSF area during and after the closure stage at the end of the mine life. Upon closure, the tailings in the TSF will either be capped with soil or submerged under 2.0 m of water to form a lake to prevent wildlife from direct exposure to tailings. Some areas of the lake will contain tailings that are submerged in less than 2.0 m of water; particularly along the slopes of the three tailings dams. Wetlands and other aquatic life are expected to establish along the shores of the TSF lake and/or may be constructed as part of the reclamation strategy for the Project. Although efforts will be made to prevent direct exposure to tailings in the majority of the lake, wetland vegetation and aquatic invertebrates may establish in the shallow submerged tailings at the tailing dams and uptake metals into their tissues. This would provide an indirect exposure route of metals to wildlife such as herbivores and waterfowl.

Post-closure monitoring of wetland and invertebrate tissue will be conducted within the TSF after closure to ensure the closure and reclamation efforts remain effective in the long term and/or whether adaptive management is required. This section establishes monitoring criteria, defined as the maximum heavy metal concentrations that can be present in wetland or invertebrate tissue without posing a risk to wildlife health.

2. WILDLIFE RISK ASSESSMENT – OPERATIONS STAGE

2. Wildlife Risk Assessment – Operations Stage

2.1 Introduction

This section describes the wildlife risk assessment during mining operations, during which the tailings storage facility (TSF) will contain a mixture of tailings and processing water. The assessment examines wildlife exposures through three pathways: (1) when animals enter the TSF and consume the tailings; (2) when animals consume overlying water in the TSF; and (3) when animals consume other animals that have been exposed to and taken up contaminants from the TSF.

2.2 Risk Assessment Framework

The risk assessment framework provides the basis and methodology for conducting the wildlife risk assessment. The methodology used in this assessment follows the risk assessment framework provided by the US Environmental Protection Agency (US EPA 1998).

The potential for negative wildlife and ecological health effects to arise from exposure to chemicals depends on three elements: (1) the chemicals must be present; (2) receptors (i.e., wildlife) must be present; and (3) exposure pathways must exist between the source of the chemicals and the receptors. In the absence of any one of the three elements, risk cannot occur. However, the presence of all three elements does not necessarily indicate risk. In such situations, risk assessments involve multiple steps that address the magnitude and duration of each exposure pathway, effects associated with each chemical substance, and the uncertainties/assumptions that were made during the assessment.

The overall risk process can be divided into five areas:

1. Problem Formulation: The problem formulation stage lays the foundation for the risk assessment. It describes and rationalizes which metals pose a concern, and which wildlife species would be most at risk. The problem formulation stage also provides a description and rationale for conducting the exposure assessment, toxicity assessment, and risk characterization stages. This generally includes an integration of available information on sources, stressors (chemical or physical), effects, and ecosystem and receptor characteristics that might be at risk (US EPA 1998).
2. Exposure Assessment: The exposure assessment determines the extent and magnitude to which wildlife will be exposed to heavy metals. The exposure depends on site-specific conditions that would exist at the proposed TSF and the species of wildlife that are present.
3. Toxicity Assessment: The toxicity assessment determines the exposure threshold that could pose a risk to wildlife health. The toxicity of a chemical substance depends on its inherent physical and chemical properties and is assessed independently from the conditions in the proposed TSF.
4. Risk Characterization: The risk characterization stage compares the results of the exposure assessment and toxicity assessment. It quantitatively predicts wildlife health

risks associated with metal exposure from the ingestion of soil/sediments, water, and food in the proposed TSF.

5. Uncertainty Analysis: The uncertainty analysis stage describes any data gaps and/or assumptions that were made in the risk assessment, and how these may affect the overall conclusion for the risk assessment.

2.3 Site Background and Description

The proposed TSF (Figure 2.3-1), is approximately 3 km northeast of the open pit and covers an area of approximately 575 ha (5.75 km^2). The proposed TSF is 190 metres above the proposed open pit. An initial 50 m-high starter dam will be constructed, which will be followed by a 45-m northern and 35-m western dam during mining operations as the TSF expands. The TSF will receive the tailings from the processing of 30,000 tonnes of ore per day by a conventional milling plant. An estimated total of 224 Mt of tailings will be produced throughout the mine life. The TSF will be operated as a zero discharge system. A seepage collection system will include a water return to recycle seepage and sand drainage back to the impoundment for reuse.

The TSF design is based on protecting aquatic life in Morrison Lake and Nakinilerak Lake, which are downstream of the TSF. The TSF will contain wet tailings that will settle over time to form tailings-based sediment with an overlying waterbody. This water will be recovered by a seepage collection system, which will recycle the water for repeat tailings processing. The receiving waters of any incidental seepage will meet the British Columbia (BC) water quality guidelines for the protection of freshwater aquatic life (30-day average guidelines). However, during operations the supernatant water in the TSF, which forms after the tailings settles, would not have been collected or treated.

During operations, all existing vegetation in the TSF area will be covered by the addition of new tailings, and no new vegetation will grow until closure and reclamation of the proposed Project. Tailings are composed of coarse, sandy material and have poor water retention properties, do not contain any organic nutrients, and have low or no fertility for plant growth. As mine operations progress, the TSF will consist of supernatant (water) at lower elevations where water will pool, and dried tailings at higher elevations. At the perimeter of the tailings facility, a beach will provide wildlife with access to water and sediments. Water and soil/sediments will contain elevated concentrations of heavy metals, which may pose a risk to wildlife that enter the TSF area and ingest these media.

During operations, the TSF is expected to provide poor habitat for wildlife because of a lack of vegetative forage cover and food. Although water is present for drinking in the TSF, it may not be aesthetically favourable to wildlife if the water is too saline. Terrestrial wildlife and birds may enter the TSF area occasionally and attempt to forage for food and water. However, the time spent in the TSF would not constitute a substantial proportion of the year because the environment will provide poor food and habitat with the absence of vegetative growth. It is assumed that for approximately half the year, the TSF water will be completely frozen caused by sub-zero temperatures and tailings will be covered in snow and ice, making it inaccessible for consumption.

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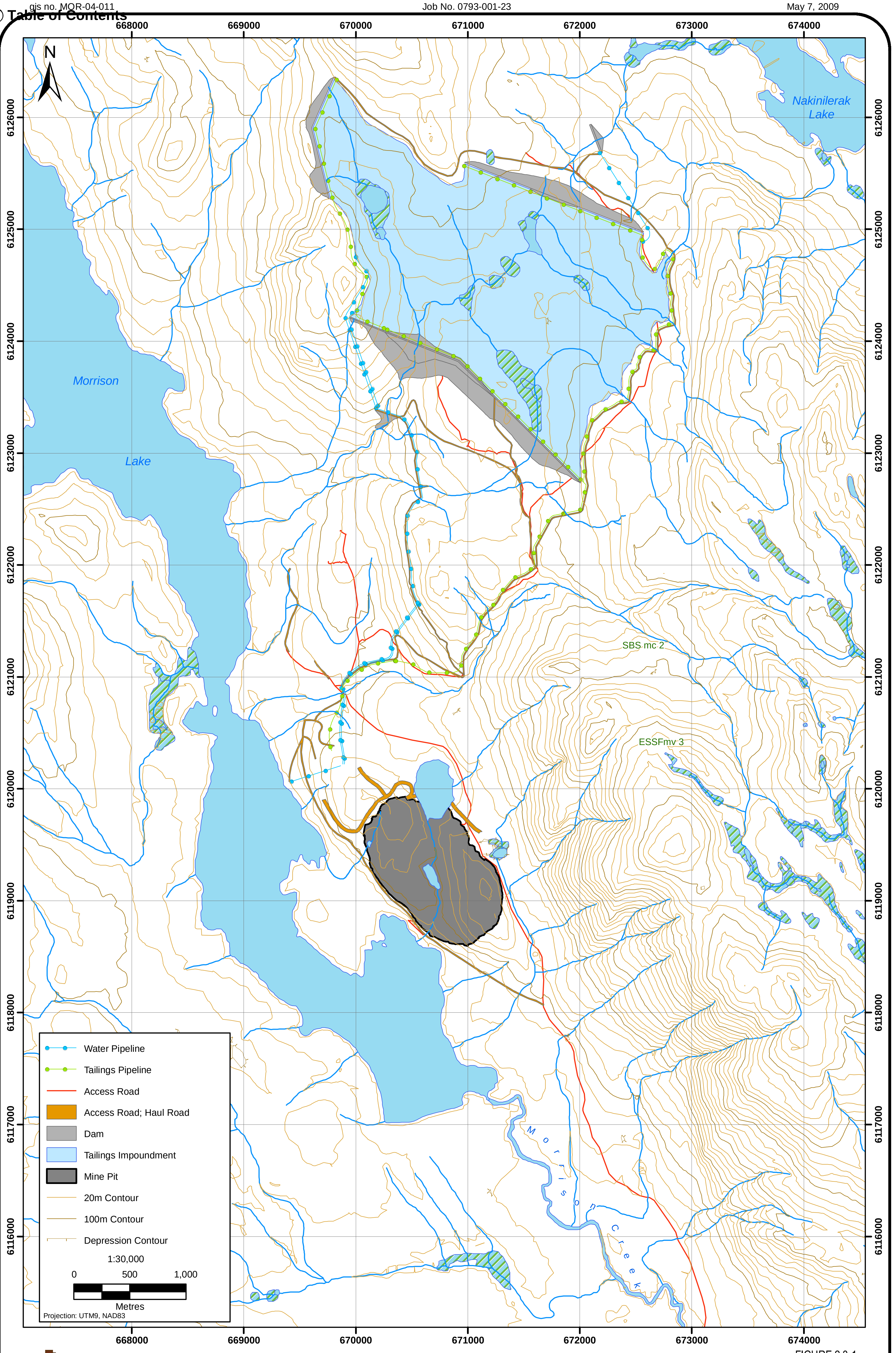

pbm

Morrison Copper/Gold Project: Proposed Tailings Storage Facility Location

FIGURE 2.3-1

Rescan

2.4 Problem Formulation

This section lays the foundation and rationale for the risk assessment. It describes the rationale for selecting metals that are chemicals of potential concern (COPCs) and wildlife species that are receptors of potential concern (ROPCs). This section also describes the exposure pathways that are relevant in this assessment.

2.4.1 Selection of Chemicals of Potential Concern

A step-wise screening process was used to select metals that are considered COPCs in the wildlife risk assessment. The three-step screening process provides a rationalization for the inclusion or exclusion of metals in the wildlife risk assessment.

The first step was to model the metal concentrations in the water and sediment in the proposed TSF. The second step was to compare the modelled concentrations with the applicable regulatory guidelines. Metals above one or more guideline were selected as potential COPCs. The third step was to screen and remove potential COPCs from the wildlife risk assessment. Potential COPCs were removed if they are essential dietary minerals with low toxicity at high doses.

2.4.1.1 Step 1: Compilation of Environmental Data

In the proposed TSF, metal concentrations in the tailings water and sediment were modelled based on ore samples collected from the proposed mine pit area. The same processing specifications were used to process ore obtained from the proposed Project area and analyzed in the laboratory. The laboratory data on the chemical characteristics of the tailings were used to model the expected metal concentrations of the water and underlying sediment in the proposed TSF, which considered various environmental parameters (e.g., weather, precipitation, pH). The *Morrison Copper/Gold Project: Water Balance / Water Quality Model Report* presents the models used to predict the tailings water and sediment metals concentrations (Rescan 2009b).

For this assessment, the modelled maximum total metal concentrations in both water and in sediment were used to select the potential COPCs.

2.4.1.2 Step 2: Comparison to Regulatory Guidelines

The purpose of the second step was to identify heavy metals that may be potential COPCs. The modelled maximum metal concentration in the TSF water was compared to the Canadian Council of Ministers of the Environment (CCME) water quality guideline for the protection of aquatic life (CCME 1999) and the BC water quality guideline for the protection of aquatic life (BC MOE 2009b). For the BC water guideline, the 30-day average guideline superseded the maximum guideline, when available.

The maximum heavy metal concentration in tailings sediment was compared to the CCME sediment quality guideline for the protection of aquatic life (CCME 2002) and BC sediment quality guidelines for the protection of aquatic life (BC MOE 2009a). For the BC sediment guideline, the interim sediment quality guideline (ISQG) superseded the probable effects level (PEL) when available. This is because the PEL is indicative of potential effects, while the ISQG are concentrations below the PEL.

Table 2.4-1 presents the modelled TSF concentrations of heavy metals in the environmental media and from measured data during the baseline studies as a comparison. Total metal concentrations were compared with their respective regulatory guideline values. Metal concentrations in the tailings that were above a guideline are presented in shaded boxes and are potential COPCs for the wildlife risk assessment. The potential COPCs that exceeded the guidelines included: arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, silver, vanadium, and zinc.

Table 2.4-1
Metal Concentrations in the Tailings Storage Facility during Operations Compared to Regulatory Guidelines

	Water Guideline		Average Baseline Water[4]	TSF Water	Sediment Guideline		Average Baseline Sediment[5]	TSF Sediment
	BC	CCME			BC	CCME		
COPC	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/dry kg)	(mg/dry kg)	(mg/dry kg)	(mg/dry kg)
Aluminum	0.05[1]	0.1[2]	0.1328[2]	0.0016[1] 0.0323[2]			26833	72,150
Antimony			0.00025	0.00779			26.667	0.945
Arsenic	0.005	0.005	0.0007	0.0105	5.9	5.9	48.4	17.1
Barium			0.0340	0.0422			384	1,175
Beryllium			0.000500	0.000242			0.667	1.135
Bismuth			n/a	0.00281			26.667	0.194
Cadmium	0.00002	0.000017[3]	0.000016	0.000568	0.6	0.6	1.15	0.28
Calcium			23.99	45.90			19508	24,700
Chromium	0.001	0.0089	0.00060	0.00442			34	122
Cobalt	0.004		0.00020	0.00187			11.88	12.82
Copper	0.00004	0.002	0.0033	0.0153	35.7	35.7	373	590
Iron	1	0.3	0.251985	0.000272	20,000		34317	28,950
Lead	0.005	0.001	0.001	0.038	35	35	12.63	11.81
Lithium			0.00250	0.00178			17.39	13.75
Magnesium			5.7	13.1			5148	13,750
Manganese	0.7		0.023	0.212			1087	355
Mercury	0.00000125	0.000026	n/a	0.0000871	0.17	0.17	0.368	0.135
Molybdenum	1	0.073	0.0007	0.0288			11.57	16.15
Nickel	0.025	0.025	0.0006	0.0189	16		48.2	52.4
Potassium			1.03	8.34			3133	12,050
Selenium	0.002	0.001	0.000500	0.000683	5	5	66.67	1.35
Silver	0.00005	0.0001	0.00001	0.01260	0.5	0.5	2.667	0.979
Sodium			2	145			357	91,950
Tin			0.0003	0.0102			13.33	2.28
Titanium			0.0074	0.0566			483	2,215
Vanadium	0.006		0.015	0.224			51.81	52.05
Zinc	0.033	0.03	0.0030	0.0823	123	123	167	85.55

[1] Dissolved aluminum.
[2] Total aluminum.
[3] Cadmium guideline = $\{10^{0.86[\log(hardness)]-3.2}\}/1{,}000$. Reported guideline based on a hardness of 48.5 mg/L $CaCO_3$.
Shaded values indicate concentrations that are above the regulatory guideline.
4 Baseline water concentrations are reflective of average stream water within the Morrison Project study area. This baseline data is consistent with the baseline data summarized in the country foods baseline report.
5 Baseline sediment concentrations are reflective of the average sediment concentrations in Booker Lake and Ore Pond.

2.4.1.3 Step 3: COPC Screening

The COPC screening eliminates metals that were identified as potential COPCs, but are not representative indicators of adverse or health effects to wildlife. Many metals are required by organisms at trace amounts to maintain normal biological function. For example, calcium is the primary mineral component of bones, while iron is required for blood haemoglobin in animals. It is difficult to classify some elements as either essential or toxic. Toxicity is a property that is inherent to all chemicals and is a function of the dosage or the amount that enters the body. Trace concentrations of essential minerals are beneficial, while elevated concentrations may have no adverse effects. However, excessively elevated concentrations may have adverse effects. For the wildlife risk assessment, essential minerals that are considered not toxic at elevated concentrations in the environment were removed from the assessment.

Iron was excluded as a COPC. Iron is the second most abundant metal and the fourth most abundant element in the Earth's crust (BC MOE 2008; TOXNET 2009). Iron is ubiquitous in soils and sediment and usually exists in high concentrations relative to other trace metals. The majority of iron is tightly bound within the soil matrix and is not available for uptake into mammals or birds. Iron is an essential element and is a required component in blood cells and necessary for transporting oxygen in the body. Iron was not evaluated in the wildlife risk assessment because of its essential nature and its relative lack of toxic effects compared with other metals.

2.4.1.4 Final List of COPCs

The following 10 metals were selected as COPCs for evaluation in the wildlife risk assessment: arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, vanadium, and zinc.

2.4.2 Selection of Receptors of Potential Concern (ROPC)

Eight species were selected for the wildlife risk assessment. These included five VEC species and three avian categories. The three categories were raptors, waterfowl, and songbirds. One species from each category was selected as a representative avian ROPC. Barred owl was chosen as the raptor species because it was documented in the Project area. Goldeneye was chosen as the waterfowl species because breeding of both common and Barrow's goldeneye have been documented within the Project area. Red-winged blackbird was chosen as the representative songbird species because it has also been documented in the Project area. Rationale for the selection of ROPCs is presented in Table 2.4-2.

2.4.3 Wildlife Exposure Pathways and Conceptual Model

2.4.3.1 Wildlife Exposure Pathways

Exposure pathways are the means by which wildlife are exposed to COPCs. The significance of each pathway depends on the COPC concentration in the media and the wildlife characteristics (i.e., ingestion rate (IR), BW, exposure time (ET)).

Table 2.4-2
Receptors of Potential Concern and Rationale for Inclusion

Common Name	Species Name	Classification	Rationale for Inclusion
Grizzly Bear	*Ursus arctos*	Mammalian Omnivore	- Species of cultural significance to First Nations and economically important to local outfitters - Blue-listed in British Columbia - High value grizzly bear foraging habitat near the proposed Project and presence confirmed during baseline studies
Moose	*Alces alces*	Mammalian Herbivore	- Identified as an important food source for First Nations and local hunters - Presence confirmed during baseline studies
Mule Deer	*Odocoileus hemionus*	Mammalian Herbivore	- Identified as an important food source for First Nations and local hunters - Presence confirmed during baseline studies
American Marten	*Martes americana*	Mammalian Omnivore	- Culturally important to First Nations and economically important furbearer to trappers - Presence confirmed during baseline studies - Biological importance as an indicator species
Fisher	*Martes pennanti*	Mammalian Omnivore	- Blue-listed in British Columbia and economically important furbearer to trappers - Presence confirmed during baseline studies - Biological importance as an indicator species
Barred Owl	*Strix varia*	Avian Carnivore (Raptor)	- Presence confirmed in the Project area during baseline studies
Goldeneye	*Bucephala* spp.	Avian Insectivore (Waterfowl)	- Presence and breeding confirmed in the Project area during baseline studies
Red-winged Blackbird	*Agelaius phoeniceus*	Avian Insectivore (Songbird)	- Presence confirmed in the Project area during baseline studies

The wildlife risk assessment focused on the ingestion exposure pathways, which included ingestion of food, water, and soil (i.e. tailings). Table 2.4-3 presents a summary of the dietary and ingestion exposure pathways for each ROPC. For example, grizzly bears are mammalian omnivores with a diet consisting primarily of animal tissue (i.e.fish). Grizzly bears would be exposed to heavy metals from the ingestion of prey animals, vegetation, soil/sediments, and water. Food exposures for omnivores were assumed to consist of 15% vegetation and 85% prey tissue.

Table 2.4-3
Dietary Preference of the Receptor of Potential Concern

ROPC	Classification	Dietary Preference	Soil/Sediment Ingestion	Water Ingestion
Grizzly Bear	Mammalian Omnivore	15% vegetation and 85% prey	Evaluated for all ROPCs	Evaluated for all ROPCs
Moose	Mammalian Omnivore	100% vegetation		
Mule Deer	Mammalian Herbivore	100% vegetation		
American Marten	Mammalian Omnivore	15% vegetation and 85% prey		
Fisher	Mammalian Omnivore	15% vegetation and 85% prey		
Barred Owl	Avian Carnivore (Raptor)	100% prey		
Goldeneye	Avian Insectivore (Waterfowl)	100% insect		
Red-winged Blackbird	Avian Insectivore (Songbird)	100% insect		

Ingestion of Water

Tailings will be composed of coarse sandy material and have poor water retention properties. New tailings introduced in the TSF will be a mixture of coarse sand and processing water. The processing water will drain to the lower elevations of the TSF, forming a tailings pond. Wildlife that enter the proposed TSF may consume the water and ingest COPCs. Therefore, the water ingestion pathway was assessed for all ROPCs.

Soil and Sediments Ingestion

Wildlife may ingest soil inadvertently when ingesting vegetation, grooming, or purposely ingesting soils for mineral content (Beyer, Connor, and Gerould 1994). Herbivores and omnivores typically consume the most soil because it is trapped in plant roots while being consumed. There will be no vegetation in the TSF during operations. However, animals entering the TSF may consume water from the tailings supernatant, which includes incidental ingestion of disturbed sediments. Wildlife were assumed to have incidental sediment IRs from drinking water which would be similar to soil IRs associated with eating vegetation.

For this assessment, the modelled sediment quality was used in place of soil quality in the TSF, because the ground would be composed of tailings instead of organic soils. Soil IRs were considered soil/sediment IRs, and the chemistry of the soil/sediment was based on the modelled sediment quality. Soil/sediment ingestion was assumed for all ROPCs.

Vegetation Ingestion

The vegetation ingestion pathway for herbivores and omnivores was not included in the wildlife risk assessment. This assessment determines the risk associated with consuming environmental media in the proposed TSF. There would be no vegetation in the TSF because tailings would be continuously added to the area during mining operations. Tailings are composed of coarse, sandy material and have poor water retention properties, do not contain any organic nutrients, and have low or no fertility for plant growth. This would prevent any vegetation from growing. Animals would only consume vegetation outside of the TSF, which would not be affected by the tailings. Consumption of baseline quality vegetation was considered when predicting the metal concentrations in prey animal tissue that are consumed by carnivores and omnivores. Therefore, there would be no direct metal exposure from vegetation to herbivores that enter the TSF.

Prey Ingestion

Predatory animals could consume herbivores that have consumed water and soil from the TSF area and vegetation from the Project area. Since prey would also accumulate metals in their tissues, predatory wildlife would be exposed to these metals from consuming prey tissue. Therefore, the pathway of prey ingestion was evaluated for grizzly bear, American marten, fisher, and barred owl. The omnivores in this wildlife risk assessment are primarily carnivorous and were assumed to consume 15% vegetation and 85% prey tissue.

Prey tissue concentrations were predicted using a food chain model presented in Appendix A. The food chain model predicts tissue concentrations of metal COPCs in a representative herbivore (moose) in the Project area. The prey tissue concentrations were modelled by evaluating the consumption of soil, water, and vegetation. The soil and water is based on the modelled sediment and water concentrations in the proposed TSF. Baseline concentrations of COPCs in vegetation were used to evaluate food consumption.

Admittedly, the assessed omnivores and carnivores do not necessarily eat moose. For example, American marten, fishers, and barred owl hunt small mammals. However, moose was selected as a representative prey animal because the food chain model accounts for the relationship between the modelled animal's body size and food consumption rate. For example, a small mammal would eat less food, but food consumption relative to body size would be similar. Modelled COPC concentrations would not be substantially different between large or small prey animals because the levels primarily depend on the concentrations present in the soil, water, and food.

Insect Ingestion

Insectivores would ingest insects that are representative of the conditions outside of the proposed TSF. During operations, tailings will be continually added to the proposed TSF, which would cover any potential insect larvae, providing few feeding opportunities for avian insectivores. Therefore, the pathway of insect ingestion was not evaluated.

Dermal Contact

Direct skin contact was not considered to be a significant exposure pathway for fur- or feather-bearing receptors since fur and feathers provide effective protection of skin. Water and soil on fur or feathers is more likely to be ingested during grooming than absorbed through the skin. Grooming was considered as part of the incidental ingestion pathway for soils.

Air Inhalation

The air inhalation pathway was not evaluated because none of the metals are volatile chemicals and because inhalations of airborne particles that may be composed of metals are an insignificant pathway when compared to the soil, food, and water ingestion pathways.

2.4.3.2 Conceptual Model

Figure 2.4-1 presents the conceptual model for wildlife exposures to COPCs and illustrates the relevant ingestion pathways. The wildlife species that were included were grizzly bear, moose, mule deer, American marten, fisher, barred owl, goldeneye, and red-winged blackbird. The main pathways that were assessed included the ingestion of soil/sediment, water, and prey from the proposed TSF.

2.4.4 Assessment Endpoints and Measures of Effect

Ecosystems are diverse with many levels of organization (e.g., individuals, populations, communities, ecosystems). In ecological risk assessment, the overall goal is to ensure that the structure and function of the ecosystem is not changed to the point where populations and communities cannot be sustained. The assessment endpoints may be different depending on the type of species being evaluated. Listed species are typically protected at the individual level.

The exposure limit that is deemed acceptable (i.e., no risk to wildlife) is based on experimental data using sub-lethal endpoints. Sub-lethal endpoints may adversely affect the species as a whole, but are assessed at the individual level. For example, toxicity tests may evaluate reduced body growth of an animal as an endpoint to heavy metal exposure. Reduced growth rates may be unacceptable endpoints for species such as dominant predators, where survival and hunting may be size-dependent. Reduced growth rate may also affect intraspecies competition and the ability to obtain mates for reproduction. Thus, the endpoint may not be lethal to the individual, but could have substantial effects on the species as a whole.

Protection of the population means that the population of a species within the area of interest should not be affected; however, a small number of individual animals within the population may be affected. These would typically be more sensitive individuals. Unacceptable risks to populations are defined as having sufficient effects on individuals that the population viability declines.

The assessment endpoints for ROPCs in this risk assessment are:

- Moose, mule deer, American marten, fisher, goldeneye, and red-winged blackbird populations that consume water or tailings from the TSF will not be exposed to concentrations that will pose a health risk.
- Grizzly bears and barred owls that consume water, tailings, or hunt prey in the proposed TSF will not be exposed to concentrations that will pose a health risk to individual animals.

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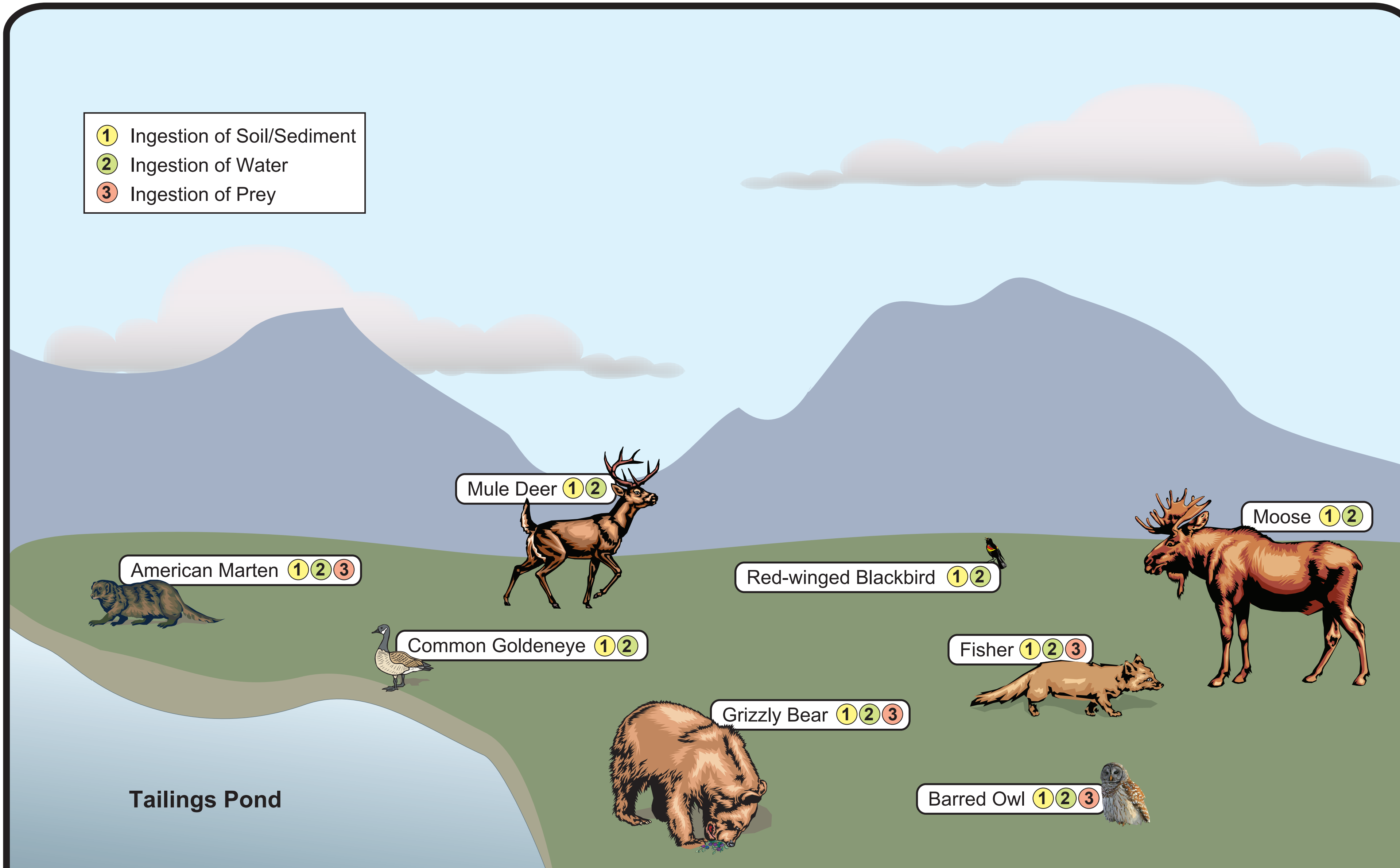

Morrison Copper/Gold Project:
Wildlife Risk Assessment Conceptual Model at Operations Stage

FIGURE 2.4-1

TRVs are safe exposure levels below which there is minimal to no risk of adverse health effects to ROPCs. To ensure the viability of wildlife receptors based on assessment endpoints, the TRV is derived from the lowest observed adverse effect level (LOAEL) or the no observed adverse effects level (NOAEL). The ratio between the estimated daily intake (EDI) and the TRV for a COPC is the exposure ratio (ER).

For wildlife health risk assessments, an ER threshold of 0.5 is considered the acceptable threshold value. This value was selected because it assumes that up to 50% of the heavy metal intake that ROPCs experience would come from the TSF. The other 50% of heavy metal exposure could come from water, soil, food ingestion outside of the TSF, and from exposure routes that were not considered (e.g., dermal, inhalation).

2.5 Exposure Assessment

2.5.1 Introduction

The amount of COPCs that wildlife receptors are exposed to from the ingestion pathway depends on:

- the concentration of COPCs in the environmental media (i.e., soil/sediments and water);
- the concentration of COPCs that have been accumulated in lower food chain species (i.e., prey);
- the wildlife receptor characteristics (i.e., IRs, BW, ET).

These factors are considered when calculating the EDI of COPCs from each ingestion pathway. The following sections describe the COPC concentrations in the TSF, the wildlife exposure characteristics and the EDI for each ROPC.

2.5.2 COPC Concentrations

Table 2.5-1 presents the maximum COPC concentrations in prey tissue, soil, and water that were modelled based on the TSF conditions. A food chain model was used to calculate COPC concentrations in prey tissue (Appendix A). The model predicts prey tissue concentrations of metals from the prey's ingestion of tailings water, tailings soil/sediments, and baseline vegetation.

2.5.3 Wildlife Exposure Characteristics

The wildlife exposure characteristics are species-specific parameters describing their natural characteristics. These parameters include the BW, ET (i.e., time spent in the TSF area), and the IRs for soil, water, and food. These parameters must be known to determine the EDI of COPCs from the diet. The following sections describe the relevant wildlife exposure characteristics required to calculate the EDI.

Body Weight

The BWs for each ROPC were the average weight of males and females of a species. When available, regional BWs that were representative of the Project area were used.

Table 2.5-1
COPC Concentrations in the Proposed Tailings Storage Facility

COPC	95% UCLM Modelled Prey in TSF (C_{prey}) (mg/kg ww)	Modelled Tailings Concentration in TSF (C_{soil}) (mg/dry kg)	Modelled Water Concentrations in TSF (C_{water}) (mg/L)
Arsenic	5.85E-03	1.71E+01	1.05E-02
Cadmium	1.25E-04	2.80E-01	5.68E-04
Chromium	1.70E-01	1.22E+02	4.42E-03
Copper	8.64E-01	5.91E+02	1.53E-02
Lead	1.13E-03	1.18E+01	3.80E-02
Mercury	4.03E-04	1.35E-01	8.71E-05
Nickel	5.15E-02	5.24E+01	1.89E-02
Silver	1.38E-03	9.79E-01	1.26E-02
Vanadium	3.47E-02	5.21E+01	2.24E-01
Zinc	4.61E+00	8.56E+01	8.23E-02

The average BW of grizzly bears from the BC interior was 158 kg. The average BW is on the lower range of grizzly bear weights, with coastal grizzly bears having the largest average weight (Schwartz, Miller, and Haroldson 2003). The difference in average weights is due to the diet of coastal grizzly bears, which contain a larger proportion of spawning salmon that are high in fat content. The average moose and mule deer BWs were 395 kg and 59 kg, respectively (BC MELP 2000a, 2000b). American marten and fisher had average BWs of 0.5 kg and 2.75 kg, respectively (Powell, Scanlon, and Fuller 1997).

For avian species, barred owls were based on live and museum specimen weights for an average of 0.7 kg (Mazur and James 2000). Goldeneye average BW, of 0.8 kg, was based on the Barrow's goldeneye (Eadie, Savard, and Mallory 2000). The average red-winged blackbird weight was 0.06 kg (Yasukawa and Searcy 1995).

Ingestion Rate

Ingestion of food and water largely depends on an organism's BW. Larger animals would ingest more food and water, based on total food intake. However, food intake per unit BW increases with smaller body sizes. Metabolic rates of smaller animals are higher than larger ones belonging to the same general category (i.e., based on categories such as mammals/avians or herbivores/carnivores). Total food IR (i.e., total of vegetation, soil, and prey ingestion) was calculated following US EPA guidance for estimating wildlife exposure factors (US EPA 1993).

IRs were calculated based on the animal class, defined by the following formulas:

$$\textbf{Mammalian Ingestion Rate (kg dry weight/day)} = 0.0687 \times (\textbf{Body Weight})^{0.822}$$

$$\textbf{Non-passerine Bird Ingestion Rate (kg dry weight/day)} = 0.64 \times (\textbf{Body Weight})^{0.651}$$

$$\textbf{Passerine Bird Ingestion Rate (kg dry weight/day)} = 0.398 \times (\textbf{Body Weight})^{0.85}$$

BWs for mammals were in kilograms and grams for birds. The IR for each ROPC was calculated as dry weight ingestions and converted to wet weights for food. These IRs were corrected for wet weight concentrations, assuming a 74%, 70%, and 72% moisture content in foods for herbivores, carnivores, and omnivores, respectively. The moisture content in foods was based on the average moisture content of vegetation tissue samples collected during baseline studies. The total wet weight IRs were calculated for vegetation and prey although vegetation ingestion was not assessed because there would be no vegetation in the TSF during operations.

Calculations for soil IRs (IR_{soil}) followed US EPA guidance (1993). The soil IR (kg-dw/day) for herbivorous mammals was based on jackrabbit soil IRs of 6.8% of the total food IR. For example, the total soil IR for moose was 6.8% of the dry weight food ingestion of 9.4 kg-dw/day, or 0.64 kg-dw/day of soil. Soil IR for omnivores was based on red fox IRs, and was 2.8% of the total IR. Soil IR for birds was less than 2% of the total IR.

Water IRs (IR_{water}) were calculated based on US EPA guidance (1993). Water IRs were based on BWs (in kilograms) and independent of food IRs. The water IRs were calculated as:

$$\textbf{Mammalian Water Ingestion Rate (L/day)} = \textbf{0.099 x (Body Weight)}^{0.9}$$

$$\textbf{Avian Water Ingestion Rate (L/day)} = \textbf{0.059 x (Body Weight)}^{0.67}$$

Exposure Time

ET is the fraction of the year that ROPCs would be active within the TSF area of 575 hectares and directly exposed to tailings water and soil/sediment. It is calculated by multiplying the fraction of active weeks in the year with the fraction of the TSF within the ROPC home range. For ROPCs with home ranges smaller than the TSF area (i.e., goldeneye, red-winged blackbird), the entire home range would be within the TSF and the ratio of TSF to home range would be 1.0. The formula for calculating the ET is:

$$\textbf{Exposure Time (unitless)} = \frac{\textbf{Active Weeks}}{\textbf{Weeks per year (52)}} \times \frac{\textbf{TSF Area (575 ha)}}{\textbf{Home Range of ROPC}}$$

For grizzly bears, the home range of 20,400 ha was the average of male and female home ranges from a population in the BC interior (Schwartz, Miller, and Haroldson 2003). Grizzly bears were assumed to be attracted to water sources such as the tailings water and be active in the TSF for up to 6 weeks of the year resulting in an ET of 0.003. For moose, the non-migratory home range of 4,220 ha was used (Demarchi 2003). Moose were assumed to be active in the area for the entire year (52 weeks) because during winter months, they may attempt to forage for grass and lichens beneath the snow although none would be present. Consequently, they may be exposed to TSF media throughout the winter months resulting in an ET of 0.134. For mule deer, the summer home range of 1,070 ha was used because the habitat in the Project area including the TSF would not be suitable for winter use (D'Eon and Serrouya 2005). Mule deer would be active in the area for approximately 16 weeks based on the summer home range occupancy (D'Eon and Serrouya 2005) resulting in an ET of 0.165. For American marten, the home range of 520 ha is approximately the same size as the TSF (Powell, Scanlon, and Fuller 1997). American marten are active for half of the year in the TSF area (26 weeks). During the winter, standing water sources would freeze, requiring the American marten to seek other water sources. Prey would constitute most of its diet rather than vegetation. The resulting ET would be 0.50. For fisher, the home range size was 2,650 ha (Powell, Scanlon, and Fuller 1997) and they are active for the entire year resulting in an ET of 0.217.

For avian species, barred owl's home range was based on their territory size of 540 ha. During the winter, snow cover would provide poor hunting areas and water sources. Therefore, barred owl was assumed to be active in the area for half of the year during non-ice cover periods. The resulting ET was 0.50. Goldeneye and red-winged blackbird home range was based on average brood territory size of 0.9 ha and 0.2 ha, respectively. Thus the entire home range of goldeneye and red-winged blackbird would be within the TSF, and would be active between April to August (20 weeks). The resulting exposure fraction for both species would be 0.385.

Summary of Wildlife Characteristics

IRs, ET, and BWs of each ROPC are presented in Table 2.5-2. The following section describes the rationale for the values reported for each ROPC.

Table 2.5-2
Morrison Copper/Gold Project: Wildlife Exposure Characteristics

ROPC	Body Weight (BW) (kg)	Total Food Ingestion Rate (kg-dw/day)	Total Food Ingestion Rate (kg-ww/day)	Vegetation Ingestion Rate (kg-ww/day)	Prey Ingestion Rate (IR_{prey}) (kg-ww/day)	Soil Ingestion Rate (IR_{soil}) (kg-dw/day)	Water Ingestion Rate (IR_{water}) (L/day)	Exposure Time (ET) (unitless)
Grizzly Bear	158	4.4	15.7	2.3	13.3	0.12	9.43	0.003
Moose	395	9.4	36.0	35.4	N/A	0.64	21.51	0.134
Mule Deer	59	2.0	7.5	7.4	N/A	0.13	3.89	0.165
American Marten	0.5	0.04	0.14	0.021	0.117	0.0011	0.05	0.50
Fisher	2.75	0.16	0.56	0.084	0.475	0.0044	0.25	0.217
Barred Owl	0.7	0.046	0.152	N/A	0.151	0.0009	0.05	0.50
Goldeneye	0.8	0.050	0.177	N/A	N/A	0.0010	0.05	0.385
Red-winged Blackbird	0.06	0.013	0.0461	N/A	N/A	0.0003	0.01	0.385

dw = dry weight.
ww = wet weight.
N/A = not assessed.

2.5.4 Estimated Daily Intake

2.5.4.1 Methodology

The EDI is the amount of each COPC that a receptor is exposed to per unit BW from the assessed exposure pathways. The calculation for each exposure pathway is described by Sample et al. (1996). Three wildlife exposure pathways were assessed (i.e., water, soil, and prey). The total EDI (EDI_{total}) is the sum of the individual EDIs from each exposure pathway. Table 2.5-3 presents the EDI formula for each ingestion exposure pathway.

Table 2.5-3
Wildlife Estimated Daily Intake Equations

Total COPC Ingestion (EDI_{total})	**(EDI_{total})**	**=**	**$EDI_{water} + EDI_{soil} + EDI_{prey}$**
Water Ingestion (EDI_{water})	**EDI_{water}**	**=**	**$\frac{IR_{water} \times C_{water} \times ET}{BW}$**
	EDI_{water}	=	Estimated Daily Exposure of COPC from water ingestion (mg/kg-day)
	IR_{water}	=	Ingestion rate of water from the tailings storage facility (L/day)
	C_{water}	=	Concentration of COPC in water (mg/L)
	ET	=	Exposure time of ROPC to the tailings storage facility area (unitless)
	BW	=	Body weight of ROPC (kg)
Soil Ingestion (EDI_{soil})	**EDI_{soil}**	**=**	**$\frac{IR_{soil} \times C_{soil} \times ET}{BW}$**
	EDI_{soil}	=	Estimated Daily Exposure of COPC from soilingestion (mg/kg-day)
	IR_{soil}	=	Ingestion rate of soil from the tailings storage facility (kg-dw/day)
	C_{soil}	=	Concentration of COPC in soil (mg/kg-dw)
	ET	=	Exposure time of ROPC to the tailings storage facility area (unitless)
	BW	=	Body weight of ROPC (kg)
Prey Ingestion (EDI_{prey})	**EDI_{prey}**	**=**	**$\frac{IR_{prey} \times C_{prey} \times ET}{BW}$**
	EDI_{prey}	=	Estimated Daily Exposure of COPC from prey ingestion (mg/kg-day)
	IR_{prey}	=	Ingestion rate of prey from the tailings storage facility (kg-ww/day)
	C_{prey}	=	Concentration of COPC in prey (mg/kg-ww)
	ET	=	Exposure time of ROPC to the tailings storage facility area (unitless)
	BW	=	Body weight of ROPC (kg)

2.5.4.2 Results

Table 2.5-4 presents the total EDI of each COPC calculated by combining intakes from each exposure pathway in the proposed TSF. Appendix B provides a sample calculation of the EDI of vanadium by the red winged blackbird in the proposed TSF. Appendix C presents summary tables of the receptor-specific EDIs for each of the three exposure pathways in the proposed TSF.

Table 2.5-4
Total Estimated Daily Intake of COPCs in the Tailings Storage Facility (mg/kg-day)

	EDI_{total}							
Metal	Grizzly Bear	Moose	Mule Deer	American Marten	Fisher	Barred Owl	Goldeneye	Red Wing Blackbird
Arsenic	4.23E-05	3.79E-03	6.33E-03	2.00E-02	6.36E-03	1.20E-02	8.48E-03	3.36E-02
Cadmium	7.71E-07	6.49E-05	1.08E-04	3.51E-04	1.13E-04	2.14E-04	1.48E-04	5.75E-04
Chromium	3.22E-04	2.66E-02	4.45E-02	1.55E-01	4.89E-02	9.71E-02	5.89E-02	2.35E-01
Copper	1.57E-03	1.28E-01	2.15E-01	7.51E-01	2.38E-01	4.73E-01	2.85E-01	1.14E+00
Lead	3.40E-05	2.84E-03	4.71E-03	1.50E-02	4.89E-03	9.07E-03	6.60E-03	2.52E-02
Mercury	4.25E-07	2.99E-05	5.00E-05	2.00E-04	6.37E-05	1.33E-04	6.71E-05	2.65E-04
Nickel	1.36E-04	1.15E-02	1.93E-02	6.46E-02	2.05E-02	3.99E-02	2.57E-02	1.02E-01
Silver	4.83E-06	3.04E-04	4.93E-04	1.87E-03	6.40E-04	1.23E-03	7.74E-04	2.69E-03
Vanadium	1.67E-04	1.29E-02	2.14E-02	7.25E-02	2.38E-02	4.52E-02	3.04E-02	1.15E-01
Zinc	1.37E-03	1.92E-02	3.20E-02	6.38E-01	2.04E-01	5.55E-01	4.32E-02	1.70E-01

2.6 Toxicity Assessment

2.6.1 Introduction

The toxicity assessment provides the basis for evaluating what is considered an acceptable COPC exposure (i.e., no risk to wildlife health) and what is potentially unacceptable exposure (i.e., potential risk to wildlife and/or ecological health). TRVs are benchmark values that set the basis for defining the acceptable exposure limits in this assessment.

TRVs used in the wildlife risk assessment are based on laboratory toxicity studies. Ideally toxicity tests are conducted on the same species evaluated in the wildlife risk assessment, but this is rarely possible. Most often, toxicity studies conducted using rats, mice, mallard ducks, or other captive species provide dose-response information that can be extrapolated and applied to wildlife receptors. TRVs for the wildlife risk assessment were primarily obtained from the US EPA's Ecological Soil Screening Level (Eco-SSL) documents and from Sample et al. (1996).

The US EPA values for TRVs were based on the NOAEL for sub-lethal toxicity test endpoints such as growth and reproduction effects. The TRVs from Sample et al. were based on the LOAEL for sub-lethal effects. In studies where mortality was the endpoint or where a LOAEL was not identified, the NOAEL was selected. The TRV values used were from the US EPA's Eco-SSL when available. For metals where TRVs were not provided by the US EPA, TRV values from Sample et al. were used.

Table 2.6-1 presents a summary of the TRVs for all COPCs. The following section provides the rationale that was used to establish the TRVs.

Table 2.6-1
Summary of Toxicity Reference Values

Metal	Toxicity Reference Value (mg/kg-day) Mammals	Avian	Source
Arsenic	1.04	2.24	(US EPA 2005a)
Cadmium	0.77	1.47	(US EPA 2005b)
Chromium	2.4	2.66	(US EPA 2005c)
Copper	5.6	4.05	(US EPA 2006a)
Lead	4.7	1.63	(US EPA 2005d)
Mercury	1	0.9	(Sample, Opresko, and G. W. Suter II 1996)
Nickel	1.7	6.71	(US EPA 2007a)
Silver	6.02	2.02	(US EPA 2006b)
Vanadium	4.16	0.344	(US EPA 2005e)
Zinc	75.4	66.1	(US EPA 2007b)

2.6.2 Toxicity Reference Values

2.6.2.1 Arsenic

The US EPA's Eco-SSL document provides TRVs for arsenic for both mammalian and avian ecological receptors (US EPA 2005a). These values were selected for this assessment.

For the mammalian TRV, the NOAEL values for growth and reproduction were used to calculate a geometric mean NOAEL. This was conducted by screening a total of 138 papers for sub-lethal endpoints. 55 papers were found to fit these criteria for growth and reproduction. This result was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance. The geometric mean of the NOAEL values for growth and reproduction was 2.47 mg/kg-day. However, this value was higher than the lowest bounded LOAEL for reproduction, growth, or survival results. Therefore, the TRV was set at 1.04 mg/kg-day, which is the highest bounded NOAEL lower than the lowest bounded LOAEL for reproduction, growth, or survival. The results were based on tests with primarily rats (*Rattus norvegicus*) and mice (*Mus musculus*), but also included dogs (*Canis familiaris*) and goats (*Capra hircus* and *Ovis aries*).

For the avian TRV, there were five reviewed papers with 16 results among biochemical, behavioural, pathology, reproduction, growth, and survival effects. The NOAEL values for growth and reproduction were used to calculate a geometric mean NOAEL. This result was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance. The geometric mean of the NOAEL values for growth and reproduction could not be calculated as only two values were available. The TRV was set at 2.24 mg/kg-day, which is the lowest NOAEL value for reproduction, growth, or survival. The results were based on tests with primarily chickens (*Gallus domesticus*) and mallard ducks (*Anas platyrhynchos*).

2.6.2.2 Cadmium

The US EPA's Eco-SSL document provides TRVs for cadmium for both mammalian and avian ecological receptors (US EPA 2005b). These TRVs were selected for this assessment.

For the mammalian TRV, there were 145 papers with 304 results for sub-lethal and lethal endpoints. The NOAEL results for growth and reproduction were used to calculate a geometric mean NOAEL. This geometric mean was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to the Eco-SSL guidance. The geometric mean of the NOAEL values for reproduction and growth was 1.86 mg/kg-day. However, this value was higher than the lowest bounded LOAEL for reproduction, growth, or mortality results. Therefore, the TRV was set at the highest bounded NOAEL below the lowest bounded LOAEL for reproduction, growth, or survival, which was equal to 0.770 mg/kg-day.

For the avian TRV, there were 93 results for biochemical, behaviour, physiology, pathology, reproduction, growth, and survival effects that were used to derive the TRV. The NOAEL results for growth and reproduction were used to calculate a geometric mean. This result was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance. The geometric mean of the NOAEL values for reproduction and growth was 1.47 mg/kg-day. This value was lower than the lowest bounded LOAEL for reproduction, growth, or survival. Therefore, the TRV was set at the geometric mean of NOAEL values for reproduction and growth, which was 1.47 mg/kg-day. The results were based on tests conducted on a number of avian species.

2.6.2.3 Chromium

The US EPA's Eco-SSL document provides TRVs for chromium for both mammalian and avian ecological receptors (US EPA 2005c). These values were selected for this assessment.

For the mammalian TRV, there were 33 results for sub-lethal and lethal endpoints used to derive the TRV for trivalent chromium. There were 71 results for hexavalent chromium. The NOAEL results for growth and reproduction were used to calculate a geometric mean NOAEL. This mean NOAEL was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance.

For trivalent chromium, the geometric mean of the NOAEL values for reproduction and growth was 2.40 mg/kg-day. There were no bounded LOAEL values for reproduction, growth, or mortality results for comparison. Therefore, this value based on NOAELs was used as the TRV.

For hexavalent chromium, a geometric mean of the NOAEL values for reproduction and growth was calculated at 9.24 mg/kg-day. The geometric mean was lower than the lowest bounded

LOAEL value for reproduction, growth, and survival results. Therefore, the TRV was equal to the geometric mean of NOAELs. For this assessment the lower, more conservative value of the two chromium species (2.40 mg/kg-day) was selected as the TRV.

For the avian TRV, there were 28 results for trivalent chromium for sub-lethal and lethal effects that were used to derive the TRV. The NOAEL results for growth and reproduction were used to calculate a geometric mean NOAEL. This mean NOAEL was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance. The geometric mean of the NOAEL values for reproduction and growth was 2.66 mg mg/kg-day. This value was lower than the lowest bounded LOAEL for reproduction, growth, or survival. Therefore, the TRV was set at this geometric mean based on the NOAELs. Geometric mean data originated primarily from toxicological studies with chickens (*Gallus domesticus*). A TRV was not derived for hexavalent chromium as there were not enough study results to meet the minimum data requirements required by the US EPA to derive a TRV.

2.6.2.4 Copper

The US EPA's Eco-SSL document provides TRVs for copper for both mammalian and avian ecological receptors (US EPA 2006a). These TRVs were selected for this assessment.

For the mammalian TRV, there were 278 results for sub-lethal and lethal endpoints that were used to derive the TRV. The NOAEL results for growth and reproduction were used to calculate a geometric mean NOAEL. This geometric mean was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to the Eco-SSL guidance. The geometric mean of the NOAEL values for reproduction and growth was 25 mg/kg-day. However, this value was higher than the lowest bounded LOAEL for reproduction, growth, or mortality results. Therefore, the TRV was set as the highest bounded NOAEL below the lowest bounded LOAEL for reproduction, growth, or survival, which was equal to 5.60 mg/kg-day.

For the avian TRV, there were 393 results for biochemical, behaviour, physiology, pathology, reproduction, growth, and survival effects used to derive the TRV. The NOAEL results for growth and reproduction were used to calculate a geometric mean. This result was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance. The geometric mean of the NOAEL values for reproduction and growth was 18.5 mg/kg-day. However, this value was higher than the lowest bounded LOAEL for reproduction, growth, or survival. Therefore, the TRV was set at the highest bounded NOAEL lower than the lowest bounded LOAEL for reproduction, growth, or survival, which was equal to 4.05 mg/kg-day. The results were based on tests conducted primarily with chickens (*Gallus domesticus*).

2.6.2.5 Lead

The US EPA's Eco-SSL document provides TRVs for lead for both mammalian and avian ecological receptors (US EPA 2005d). These TRVs were selected for this assessment.

For the mammalian TRV, there were 219 papers with 343 results for sub-lethal and lethal endpoints that were used to derive the TRV. The NOAEL results for growth and reproduction were used to calculate a geometric mean NOAEL. This mean NOAEL was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance. The geometric mean of the NOAEL values for reproduction and growth was 40.7 mg/kg-day. However, this value was higher than the lowest bounded LOAEL for reproduction, growth, or mortality results. Therefore, the TRV was set as the highest bounded NOAEL below the lowest bounded LOAEL for reproduction, growth, or survival, which was 4.70 mg/kg-day.

For the avian TRV, there were 106 results for sub-lethal and lethal endpoints used to derive the TRV. The NOAEL results for growth and reproduction were used to calculate a geometric mean NOAEL. This mean NOAEL was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance. The geometric mean of the NOAEL values for reproduction and growth was 10.9 mg/kg-day. However, this value was higher than the lowest bounded LOAEL for reproduction, growth, or survival. Therefore, the TRV was set as the highest bounded NOAEL, lower than the lowest bounded LOAEL for reproduction, growth, or survival, which was 1.63 mg/kg-day.

2.6.2.6 Mercury

The avian and mammalian TRVs for mercury were based on data compiled by Sample et al. (1996).

The mammalian TRV selected was 1.0 mg/kg-day. This TRV represents the NOAEL that was reported for reproductive effects (fertility and kit survival) in mink that were exposed to mercuric chloride for 6 months (Aulerich, Ringer, and Iwamoto 1974). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction). A LOAEL was not reported for this study.

The avian TRV selected was 0.9 mg/kg-day. This TRV represents the LOAEL reported for effects on reproduction in Japanese quail that were exposed to mercuric chloride in food for 1 year (Hill and Schaffner 1976). Exposure was considered chronic because it occurred for 1 year that included critical life stages (reproduction).

2.6.2.7 Nickel

The US EPA's Eco-SSL document provides TRVs for nickel for both mammalian and avian ecological receptors (US EPA 2007a). These values were selected for this assessment.

For the mammalian TRV, there were 119 results for sub-lethal and lethal endpoints that were used to derive the TRV. The NOAEL results for growth and reproduction were used to calculate a geometric mean NOAEL. This geometric mean was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to the Eco-SSL guidance. The geometric mean of the NOAEL values for reproduction and growth was 7.70 mg/kg-day. However, this value was higher than the lowest bounded LOAEL for reproduction, growth, or mortality results. Therefore, the TRV selected was equal to the highest bounded NOAEL below the lowest bounded LOAEL for reproduction, growth, or survival, which is equal to 1.70 mg/kg-day.

For the avian TRV, there were 28 results for sub-lethal and lethal effects used to derive the TRV. The NOAEL results for growth and reproduction were used to calculate a geometric mean. This result was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance. The geometric mean of the NOAEL values for reproduction and growth was 6.71 mg/kg-day. This value is lower than the lowest bounded LOAEL for reproduction, growth, or survival. Therefore, the TRV was equal to the geometric mean of the NOAEL values for reproduction and growth, which is 6.71 mg/kg-day. Geometric mean data were primarily from toxicological studies with chickens (*Gallus domesticus*).

2.6.2.8 Silver

The US EPA's Eco-SSL document provides TRVs for silver for both mammalian and avian ecological receptors (US EPA 2006b). These values were selected for this assessment.

For the mammalian TRV, there were 13 papers with 15 results for sub-lethal and lethal endpoints that were used to derive the TRV. The NOAEL results for growth and reproduction were not used to calculate a geometric mean NOAEL because there were only three NOAEL values available. The mammalian TRV for silver was set as the lowest LOAEL for reproduction or growth divided by an uncertainty factor of 10, which resulted in a TRV of 6.02 mg/kg-day.

For the avian TRV, there were 22 results for sub-lethal and lethal endpoints used to derive the TRV. The NOAEL results for growth and reproduction were used to calculate a geometric mean NOAEL. This mean NOAEL was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance. There were only three NOAEL values within the growth and reproduction effect groups. Thus, a geometric mean could not be calculated. In addition, there was only one NOAEL for reproduction or growth. However, there were three LOAEL values within the growth and reproduction effect groups. The avian TRV for silver was set as the lowest LOAEL for reproduction or growth divided by an uncertainty factor 10, which was 2.02 mg/kg-day.

2.6.2.9 Vanadium

The US EPA's Eco-SSL document provides TRVs for vanadium for both mammalian and avian ecological receptors (US EPA 2005e). These values were selected for this assessment.

For the mammalian TRV, there were 48 papers, with 101 results for sub-lethal and lethal endpoints to derive the TRV. The NOAEL values for growth and reproduction were used to calculate a geometric mean NOAEL. This result was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance. The geometric mean of the NOAEL values for growth and reproduction was 5.92 mg/kg-day. However, this geometric mean NOAEL was higher than the lowest bounded LOAEL for growth, reproduction, or survival. The TRV was set at 4.16 mg/kg-day, which was the highest bounded NOAEL lower than the lowest bounded LOAEL for reproduction, growth, or survival.

For the avian TRV, there were 36 reviewed papers, with 132 results for sub-lethal and lethal effects used to derive the TRV. The NOAEL values for growth and reproduction were used to calculate a geometric mean NOAEL. This result was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL guidance. A geometric mean of the NOAEL values for growth and reproduction was calculated at 1.19 mg/kg-day. However, this geometric mean NOAEL was higher than the lowest bounded LOAEL for growth, reproduction, or survival. The TRV was set as 0.344 mg/kg-day, which was the highest bounded NOAEL lower than the lowest bounded LOAEL for reproduction, growth, or survival. The results were based on tests with primarily chickens (*Gallus domesticus*).

2.6.2.10 Zinc

The US EPA's Eco-SSL document provides TRVs for vanadium for both mammalian and avian ecological receptors (US EPA 2007b). These values were selected for this assessment.

For the mammalian TRV, there were 190 results for sub-lethal and lethal endpoints used to derive the TRV. The NOAEL results for growth and reproduction were used to calculate a geometric mean NOAEL. This geometric mean was examined in relation to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to the Eco-SSL guidance. A geometric mean of the NOAEL values for reproduction and growth was calculated at 75.4 mg/kg-day. This value was lower than the lowest bounded LOAEL for reproduction, growth, or mortality results. Therefore, the TRV was set as the geometric mean of the NOAEL values for reproduction and growth, which was 75.4 mg/kg-day.

For the avian TRV, there were 168 results for sub-lethal and lethal endpoints used to derive the TRV. The NOAEL results for growth and reproduction were used to calculate a geometric mean. This result was examined in relationship to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV according to procedures in the Eco-SSL. A geometric mean of the NOAEL values for reproduction and growth was calculated at 66.1 mg/kg-day. This value was lower than the lowest bounded LOAEL for reproduction, growth, or survival. Therefore, the TRV was set as the geometric mean of NOAEL values within the reproduction and growth effect groups, which was 66.1 mg/kg-day. The results were based on tests with primarily chickens (*Gallus domesticus*).

2.7 Risk Characterization

2.7.1 Introduction

Using the results of the exposure assessment and toxicity assessment, potential ROPC health risks from exposure to metals in the TSF were quantified. The following section presents the methodology for risk characterization and the results.

2.7.2 Methodology

Results from the exposure assessment (EDI_{total}) and toxicity assessment (TRVs) were compared to determine of there would be a potential for wildlife health risks. Risk estimates are defined as ERs, which is the ratio of the total EDI and the TRV for each COPC. The ER was calculated using the following formula:

$$\text{Exposure Ratio (ER) (unitless)} = \frac{\text{Total Estimated Daily Intake } (EDI_{total})}{\text{Toxicity Reference Value (TRV)}}$$

For wildlife risk characterization, an ER of 1.0 is typically an acceptable risk threshold when all potential exposure routes are considered. The TRV values are derived from toxicity tests at concentrations where there are no observed adverse effects. If the ER value reaches 1.0 (i.e., the EDI_{total} equals the TRV), it does not imply that there would be risk; but that the EDI_{total} is at the maximum concentration that has been shown to elicit no effects. Cumulative ER values above 1.0 may pose a potential risk, as this maximum threshold of NOAEL is exceeded. However, this also depends on how much higher the LOAEL is compared to this threshold.

For this assessment, an ER value of 0.5 is considered an acceptable risk threshold. This is because this assessment does not consider all potential metal exposure routes. For example, it is assumed that wildlife will spend only a fraction of the year in the TSF area, and will ingest soil, water, and food outside of the TSF area. Other exposure pathways such as inhalation of dust and dermal exposure were not considered. The ER value of 0.5 assumes that up to 50% of the metal intake results from ingesting media and food from the TSF. An additional exposure amount of up to 50% may safely occur outside of the TSF, and still remain within the ER of 1.0.

ERs that are less than 0.5 represent exposures that do not pose a health risk to wildlife ROPCs. Notably, an ER value greater than 0.5 does not necessarily indicate that adverse health effects will occur as there were several levels of conservatism associated with the EDIs. For instance, it was assumed that all water and soil in the TSF would contain concentrations representative of the maximum modelled concentrations. It was also assumed that wildlife would consume soil/sediments in the proposed TSF despite the TSF containing no vegetation or preferred habitat. Thus, an ER value of greater than 0.5 is not conclusive evidence that a wildlife health risk will exists.

2.7.3 Results

2.7.3.1 Exposure Ratios in the Tailings Storage Facility

Table 2.7-1 presents the ERs for each wildlife species and each COPC. All ERs were below the risk threshold of 0.5, indicating that there would be no unacceptable risk to the ROPCs. The highest ER was 0.3331 due to vanadium exposure by the red wing blackbird. Vanadium tended to have the highest ER values among avian ROPCs because the TRV for vanadium is low relative to other COPCs. Most other ER values were well below 0.01, indicating no risk to wildlife based on the scenario assessed.

Table 2.7-1
Wildlife Exposure Ratios

	Exposure Ratio							
Metal	**Grizzly Bear**	**Moose**	**Mule Deer**	**American Marten**	**Fisher**	**Barred Owl**	**Goldeneye**	**Red Wing Blackbird**
Arsenic	4.07E-05	3.64E-03	6.09E-03	1.93E-02	6.12E-03	5.36E-03	3.79E-03	1.50E-02
Cadmium	1.00E-06	8.43E-05	1.40E-04	4.56E-04	1.47E-04	1.45E-04	1.01E-04	3.91E-04
Chromium	1.34E-04	1.11E-02	1.85E-02	6.44E-02	2.04E-02	3.65E-02	2.21E-02	8.85E-02
Copper	2.80E-04	2.29E-02	3.84E-02	1.34E-01	4.24E-02	1.17E-01	7.03E-02	2.81E-01
Lead	7.23E-06	6.05E-04	1.00E-03	3.20E-03	1.04E-03	5.56E-03	4.05E-03	1.54E-02
Mercury	4.25E-07	2.99E-05	5.00E-05	2.00E-04	6.37E-05	1.48E-04	7.45E-05	2.95E-04
Nickel	7.99E-05	6.77E-03	1.13E-02	3.80E-02	1.21E-02	5.95E-03	3.83E-03	1.52E-02
Silver	8.03E-07	5.06E-05	8.19E-05	3.10E-04	1.06E-04	6.08E-04	3.83E-04	1.33E-03
Vanadium	4.03E-05	3.11E-03	5.13E-03	1.74E-02	5.72E-03	1.31E-01	8.85E-02	3.33E-01
Zinc	1.82E-05	2.54E-04	4.24E-04	8.46E-03	2.71E-03	8.40E-03	6.53E-04	2.57E-03

2.7.3.2 Discussion

The wildlife risk assessment predicted no unacceptable risks to ROPCs from ingestion of COPCs in the TSF. This section presents a brief summary of the ERs calculated for each ROPC.

Grizzly Bear

For grizzly bear, the ER values for all heavy metals were well below the threshold ER of 0.5. The grizzly bear had the lowest ER values among all ROPCs, resulting from lower rates of soil ingestion (relative to herbivores), smaller surface area to volume ratio and low exposure time because grizzly bear home range is large relative to the TSF area. The highest ER was less than 0.001 from the exposure to copper. The main exposure of copper to the grizzly bear was from soil ingestion (Appendix C). Water ingestion constituted relatively minor intakes of COPCs.

Moose

For moose, the ER values for all heavy metals were well below the threshold ER of 0.5. The highest ER value was 0.0229 from copper exposure. Copper exposure was primarily from soil ingestion. Soil consumption is normally associated with vegetation consumption. However, because no vegetation is predicted to grow in the TSF, it is likely that the soil/sediment consumption intakes are overestimated for moose and other herbivores.

Mule Deer

All ER values for mule deer were below the threshold ER of 0.5. Moose and mule deer have similar wildlife characteristics since they are both mammalian herbivores. Therefore, the highest ER was also from copper exposure, which was 0.0384. This ER is also likely to be overestimated because the calculations assumed that the soil was ingested in association with vegetation ingestion.

American Marten

All ER values for American marten were below the threshold ER of 0.5. American marten had the highest ER value among all mammalian ROPCs. The highest marten ER values were 0.134 for copper. The main exposure route for copper was from the ingestion of prey meat and soil. Relative to other mammalian omnivores that were assessed, American marten is the smallest in size. Smaller animals tend to have larger metabolic rates, requiring higher ingestion rates of food per unit body mass. This leads in a higher COPC exposure per unit body mass through food ingestion pathways for smaller animals compared with larger ones. For example, the wildlife characteristics (Table 2.5-2) show that American marten consume 23% of their body weight daily as prey meat, while fishers consume 17.3% and grizzly bears 8.4% as wet weight ingestions. Therefore, smaller omnivorous mammals have higher COPC exposure rates per unit body mass than larger mammals.

American marten also has a high ET in the TSF area because its home range is small relative to the TSF. American marten that live near the TSF may spend up to half of the year in the TSF area. In comparison, the area of the TSF is less than 10% of the home range of a grizzly bear.

Fisher

The ER values for fisher were below the threshold ER of 0.5. Fisher is in the same class as grizzly bear and American marten (i.e., omnivorous mammals) and has the same formulas for calculating ingestion rates for soil, water, and prey for their wildlife characteristics. Differences in the ER between omnivorous mammals are primarily the result of the differences in home range and exposure time in the TSF. The highest ER value for fishers was 0.0424 for copper. The primary source of copper would be through the ingestion of soil.

Barred Owl

The ER values for barred owl were below the threshold ER of 0.5. Barred owls are carnivores and have low soil ingestion rate per unit body mass. The highest ER for barred owl was 0.131 for vanadium, followed by 0.117 for copper. The primary exposure route for vanadium was from soil. The TRV for vanadium in avians is substantially lower than in mammals, resulting in vanadium being the highest ER in birds.

Goldeneye

The ER values for goldeneye were below the threshold ER of 0.5. The highest ER was 0.0885 for vanadium exposure, followed by 0.0703 for copper. The main exposure to vanadium and copper was from soil/sediment ingestion. Incidental soil/sediment ingestion would normally result from searching for aquatic invertebrates for food because this species is a waterfowl. However, there would be no invertebrates living in the water or sediments during operations, therefore the soil/sediment ingestion rates are likely overestimated.

Red-winged Blackbird

The ER values for red-winged blackbirds were below the threshold ER of 0.5. The highest ER values were 0.333 for vanadium and 0.281 for copper. Red-winged blackbirds are passerine birds that feed on terrestrial and flying insects and have limited contact with water compared to goldeneye. The main exposure route to vanadium was from soil/sediment ingestion. Incidental soil/sediment ingestion would occur when red-winged blackbirds forage for insects in the tailings. Water exposure was substantially lower.

2.8 Uncertainty

2.8.1 Introduction

The process of assessing wildlife risks from exposure to environmental media in the TSF involves multiple steps. Inherent in each step of the assessment are uncertainties and assumptions that ultimately affect the final risk assessment. Uncertainties may exist in numerous areas, including the accuracy of the modelled water and soil/sediment concentrations in the proposed TSF, the potential COPCs that were selected based on the modelled TSF conditions, wildlife exposure characteristics, and the derivation of TRVs. When these uncertainties existed, a conservative approach applied when appropriate to overestimate rather than underestimate the potential risk.

2.8.2 Modelled Environmental Media in the TSF

The modelled concentrations of water and soil/sediment in the TSF were the maximum concentrations that are predicted to exist at anytime during the operations phase of the Project. Environmental factors such as heavy precipitation and snowmelt would dilute trace metal concentrations in the TSF. Therefore, the maximum concentrations are not representative of what wildlife would generally be exposed to at most times of the year. Average environmental media concentrations were not modelled for the TSF. Overall, the use of the maximum concentrations is considered a conservative approach.

2.8.3 Contaminants of Potential Concern

2.8.3.1 COPC Selection Based on Water Quality Guidelines

The selection of COPCs was based on a comparison of the modelled water and sediment concentrations with provincial and federal guidelines designed to protect aquatic life. These aquatic guidelines used are not necessarily applicable because the wildlife risk assessment considers only terrestrial or avian wildlife species and not aquatic species. Guidelines based on adverse effects to aquatic life were used in the absence of provincial or federal water guidelines designed for terrestrial wildlife. The application of aquatic regulatory guidelines for comparison only determines which heavy metals were selected for evaluation and does not affect determination of exposure or risk. The use of aquatic guidelines is conservative because aquatic organisms are generally more sensitive than terrestrial organisms to metals in the water. Aquatic organisms are continuously exposed to metals in the water while terrestrial wildlife is exposed only when drinking water.

2.8.4 Bioavailability

Bioavailability is the proportion of the exposed contaminant that is absorbed by an organism. Wildlife that ingests soil, sediment, and water will absorb some of the ingested COPCs, while the remaining amount is excreted. Bioavailability of COPCs depends on various factors such as the speciation of the compound (i.e., organic, inorganic, ionic, neutral, soluble, insoluble). Trace metals in soils and sediments may be strongly bound to organic matter, clays, or to each other (e.g., iron), thus reducing the metal bioavailability. Insoluble precipitates are generally less bioavailable than the dissolved fraction.

For all COPCs, it was assumed that 100% of ingested metals were bioavailable. The assumption of 100% bioavailability is conservative because organisms absorb a fraction of the amount they are exposed to, and excrete the unabsorbed portion. The amount differs between each metal and metal species. For example, metallo-organics such as methylmercury is readily absorbed, while inorganic mercury is absorbed relatively poorly.

2.8.5 Wildlife Exposure Characteristics

The wildlife exposure characteristics that were used to estimate COPC exposure had a number of uncertainties that may substantially overestimate the actual exposure that would occur in the TSF.

2.8.5.1 Body Weight

The average BWs reported for each wildlife species was based on local literature when available. For example, male grizzly bears have a wide range of average BW ranging from 145 to 357 kg in North America (Schwartz, Miller, and Haroldson 2003). The difference in average BWs is based on the geographical area, where coastal grizzly bears have access to fat-rich salmon and are the heaviest. Grizzly bears near the Project area are not coastal and a larger proportion of the diet consists vegetation. Bears consuming principally vegetative diets are smaller, which increases the proportion of food ingested relative to BW (Schwartz, Miller, and Haroldson 2003). This increases the EDI relative to grizzly bears with larger BWs.

Details on other species were not as geographically accurate. BWs for moose, mule deer, American marten, fisher, and red-winged blackbird were based on average weights that were independent of geographical location. Barred owl and goldeneye were based on individuals in captivity and museum samples. Captive individuals may not be the same in BW because of different environmental conditions. It was assumed that captive animals were representative of wild animals.

The impact of BW on the overall assessment is minor for most mammalian species because the exposure to COPCs from ingestion pathways is proportional to the BW. Potential uncertainties to the overall assessment would be greater when the BW is small, based on the food IR formulas presented in Section 2.5.2.2. The proportion of food ingestion relative to BW increases with smaller animal species. Therefore, food intake for small animals such as the American marten, barred owl, goldeneye, and red-winged blackbird constitutes a larger proportion of their BW daily. Underestimating the average weight of small animals can substantially affect the overall assessment. However, there were no conservative assumptions to be made regarding the BW and IR. The reported values for BW and IR are considered the most accurate estimates.

2.8.5.2 Ingestion Rates

The IRs that were used for food, soil, and water were based on guidance on estimating wildlife exposure characteristics provided by the US EPA (1993). The guidance does not account for conditions that are specific to the TSF. For example, mammals and birds do not intentionally consume soil for nutrition. The bulk of soil ingestion is incidental, resulting from the consumption of vegetation and the accompanying soil associated with roots. Therefore, mammals that are herbivorous have the highest soil IRs. For birds, passerine species such as the red-winged blackbird ingest a larger proportion of their BW as food, soil, and water, relative to non-passerine birds based on the formula used in Section 2.5.2.2.

The wildlife risk assessment assumes that soil IRs would not change for animals in the TSF area. However, there would be no vegetation and accompanying soil for herbivores to consume. Thus, incidental ingestion of soils by ROPCs would be reduced in the TSF. Therefore, the soil IRs that would occur in the TSF area were likely overestimated for all ROPCs

The effect of overestimating soil IRs may be substantial for herbivores and passerine birds because concentrations of trace metals in soil are generally several magnitudes higher than water. This may have resulted in overestimating the EDI of all COPCs from the soil/sediment ingestion route.

2.8.5.3 Exposure Time

The ET that animals would spend in the TSF was based on the home range of the animal and estimation of the fraction of the year that the ROPCs would be exposed to the TSF area. The home ranges for each ROPC were based on literature data. The fraction of the year animals would be exposed to the TSF media was based on best professional judgment by Rescan wildlife biologists and on the proposed conditions that would exist in the TSF (i.e., size of the TSF and climate). The *Morrison Copper/Gold Project: Meteorological and Air Quality Baseline Report* that was conducted from 2006 to 2008 showed that there was a snow depth ranging from 26 to 98 cm in the area encompassing the TSF between the months of October to April (7 months inclusive), while the average air temperature was below zero from October to May (8 months inclusive; Rescan 2009a). During the year when temperatures are sub-zero, the water and sediment in the TSF would be frozen and animals would not be exposed to this media from drinking water. During the months with snow cover, the exposed tailings along the shore of the TSF adjacent to the water would be covered and unavailable for animals to consume.

As a conservative estimate, it was assumed that ice and snow conditions lasted for half of the year, or 26 out of 52 weeks in a warm year. Animals could be exposed to the TSF media for the remaining half of the year, although some ROPCs such as moose normally forage for food beneath the snow in the winter and are assumed to be exposed to the TSF for the entire year. Year-round exposure was assumed in modelling for moose. It was also assumed that the ROPCs would spend equal amounts of time in all sections of their home range. However, most species do not spend equal amounts of time throughout their home range.

The conditions in the TSF may act as attractants and deterrents. For example, the tailings pond may act as an attractant to terrestrial animals and birds as a source of water and as a deterrent because there is no vegetation for potential habitat. Ungulates such as moose and mule deer may be attracted to the soils as a potential salt lick if the soils are salty. Herbivores and omnivores may also be deterred from the area because there would be poor habitat and food resources and no protective cover from predators. Man-made structures such as bare ground (i.e., roads) and the TSF have reduced insect density such as mosquitoes. Wildlife may be attracted to these areas to avoid insect harassment (Mueller and Gunn 1996). Overall, there is uncertainty in the amount of time that the ROPCs will spend at the TSF. However, the amount of time assumed for each ROPC is considered to have been overestimated rather then underestimated, because of the lack of vegetation and suitable forage materials in the TSF even though tailings water is readily accessible. The wildlife management plan proposes to monitor the amount of time that the ROPCs spend in the TSF area to verify the assumption made in this wildlife risk assessment.

2.8.6 Modelled Tissue Concentrations (Prey)

Metal concentrations in moose tissue were predicted using an uptake model. All models have uncertainties, including the food chain model used in this assessment. The food chain model calculations and resulting prey tissue concentrations of COPCs are presented in Appendix A. The main uncertainty in the model was the biotransfer factors used, which determines how much of the ingested COPCs are retained in the tissues or excreted out of the body. Biotransfer factors were provided for domesticated animals used for food (i.e., cows, chickens). Biotransfer factors for cows were used for moose because they were the closest related animal (large mammalian herbivore).

Other uncertainties associated with the predicted animal tissue concentrations include the following:

- Tissue concentrations were estimated based on a limited sample size of vegetation, which may not be representative of the overall vegetation concentrations over the Project area.
- Soil/sediment and water concentrations in the TSF were also modelled rather than using empirical measurements. The conditions at the proposed TSF currently do not exist because there is no mine.
- Moose diets were assumed to comprise the plant species collected, which were berries, and may not be representative of the actual foods that these animals eat.

2.8.7 Toxicity Reference Values

There is uncertainty associated with the application of TRV values in risk assessments for multiple chemicals. TRVs are derived for individual COPCs. However, it is recognized that water, soil, and food contain multiple chemicals and that interactions of these chemicals are not considered. Interactions between chemicals may cause antagonistic, additive, synergistic, or potentiating effects. The scientific understanding of the mechanisms causing these interactions is moderate, but there is no scientifically accepted and practical method of assessing the interactions of all the COPCs considered for this assessment. Therefore, interaction effects were not considered when comparing exposures with TRVs. This could mean that risk to wildlife is higher than calculated, should two or more COPCs interact in a synergistic manner. However, because most ER values were well below 1% of maximum threshold for exposure, it is very unlikely that interactions could cause effects to wildlife.

The use of generic TRVs also presents an uncertainty associated with this assessment. Although the TRVs are presented for each metal, a metal can exist as multiple species, each possessing unique physical and chemical characteristics. These characteristics define the ability of a chemical substance to be absorbed, excreted, and its potential to cause adverse biological effects or interactions.

2.8.8 Exposure Ratio

The ER used to determine if there would be potential risk to ROPCs is 0.5. An ER value of 1.0 would be used when assessing the EDI of all exposure routes (including non-ingestion pathways). This adjustment assumes that ROPCs obtain 50% of their exposure to COPCs from ingestion pathways. The remaining 50% is assumed to come from exposures that were not assessed (i.e., dermal absorption, inhalation), or from the ingestion of foods outside of the TSF area after closure.

It is extremely unlikely that any wildlife would receive anywhere near their full 50% exposure through other exposure routes (dermal, inhalation) away from the TSF, because metals are not prevalent in nearby streams and lakes (to be absorbed through skin) or in the air (to be inhaled). Most of the time, wildlife are not immersed in water, and feathers and thick skin act to prevent any trace levels of metals from entering biota through dermal layers.

2.9 Conclusion

The wildlife risk assessment predicted that no unacceptable risks to wildlife health at the individual level and population level would occur in the TSF during operations. This prediction is based on the ER values that were all below 0.5 for all COPCs and ROPCs.

Overall, the main contributor to metal exposure was soil and sediment ingestion. Prey ingestion was the secondary contributor in most cases and water exposure was the least significant of the three exposure routes.

Because prey and soil/sediment consumption were the main contributors to heavy metal ingestion, any monitoring and adaptive management plans should address the uncertainties that affect these two pathways. The key considerations are:

1. **Water and Soil/Sediment Quality**: The soil/sediment quality used for the wildlife risk assessment was ore samples that were subjected to the same processing procedures that will be used during operations. Laboratory analysis of the tailings and supernatant water that were produced was entered into a computer model that simulated environmental conditions that would exist in the TSF during operations (i.e., precipitation, temperature, pH). Modelled data represents the best estimate of the conditions that would exist in the TSF before its actual construction. However, at operations, a more detailed evaluation including the sampling of existing TSF water and sediments would provide empirical data over modelled data.
2. **Wildlife Characteristics—Dietary intake**: An issue to consider is whether the prey intake rates for omnivores and carnivores are accurate for the wildlife species assessed. A formula was used to calculate the prey IRs as a function of BW. If prey animals do not enter the TSF area, there may be no exposure of COPCs to prey animals and no hunting opportunities for omnivores and carnivores while in the TSF. Monitoring of ROPC consumption of prey, soil, and water in the TSF is proposed in the wildlife management plan.

3. **Wildlife Characteristics—ET**: Wildlife species may be attracted or deterred from entering the TSF area during operations. One assumption in this wildlife risk assessment is that wildlife will use all areas within their home range equally. The ET was calculated as the proportion of the TSF area relative to the wildlife species' home range. The ET estimation also considers that half of the year experiences sub-zero temperatures, where water cannot be accessed and tailings are covered in snow. However, during the times that the TSF is accessible, it was assumed that wildlife would use the area for the same amount of time as the natural habitat surrounding the TSF. This may not be a realistic assumption if the animal is attracted or deterred from entering the TSF. Monitoring of ROPC use of the TSF is proposed in the wildlife management plan.

3. WILDLIFE RISK MONITORING – CLOSURE STAGE

3. Wildlife Risk Monitoring – Closure Stage

3.1 Introduction

Mine closure and reclamation procedures at the Project will incorporate techniques to minimize surficial disturbance and progressively reclaim areas affected by mining during the operations stage. As part of the closure procedures, all whole and fine tailings within the TSF will either be capped with fresh soil or submerged in water to prevent dust generation and reduce the exposure potential to wildlife.

Efforts will be made to segregate mine tailings from direct exposure to wildlife. Wetland vegetation and aquatic invertebrates will establish over time in some aquatic sections of the closed TSF. Along the TSF dams, the tailings will be submerged in shallow water (<2.0 m). In these areas, wetland vegetation would be rooted directly in the tailings. Aquatic invertebrates will inhabit and directly interact with the submerged tailings. Therefore, wetlands and invertebrates may uptake and bioaccumulate metals in their tissues. Wildlife that consumes wetland vegetation and invertebrates may be indirectly exposed to these heavy metals.

Post-closure monitoring of wetland and invertebrate tissue will be conducted at closure within the TSF to ensure the closure and reclamation efforts remain effective in the long term and or any requirements for adaptive management. This section of the wildlife risk assessment establishes the recommended monitoring criteria, defined as the maximum metal concentrations that can be present in wetland or invertebrate tissue before there may be a potential risk to wildlife health.

The previous Section 2 assessed wildlife risk by using modelled metal concentrations in soil/sediment, water, and food to calculate the EDI_{total} of each heavy metal. The EDI_{total} was compared to TRVs to calculate the ER (i.e., ER <0.5 = no risk). This section establishes monitoring criteria using the same risk assessment methodology in Section 2, but applied in reverse. By taking the maximum allowable ER (i.e., ER = 0.5), and the post-closure metal concentrations of soil/sediments and water, it is possible to calculate the maximum allowable heavy metal concentration in food (i.e., wetland and invertebrate tissue) required to achieve an ER of 0.5.

Monitoring is preferred rather than modelling chemical concentrations in biota because it is difficult to predict or model future metal concentrations in plants and animals accurately. Factors such as bioaccumulation, absorption, and excretion rates and species-specific variability are some factors that cannot be easily accounted for by modelling. Monitoring integrates all of these factors and provides the actual resultant concentrations in tissues. It is stressed that the monitoring criteria presented here are not developed as “pollute-up-to” values, rather they are a maximum threshold whereby monitoring and adaptive management plans can be initiated, if the concentrations are observed to approach these values.

3.2 Site Background and Description

Upon closure and reclamation of the mine area, the TSF will be closed as a lake by submerging the whole tailings with water with a minimum tailings depth of 2.0 m around most of the lake perimeter, and a maximum depth of 10 m near the lake centre. The lake will have three dams to contain the water: the larger starter dam and two smaller dams. Along these dams will be the only areas of the lake where tailings will be submerged in less than 2.0 m of water. The lake area will be approximately 466 ha (4.66 km^2).

Figure 3.2-1 presents a schematic cross-section of the lake at the dams. Upon closure, the dam will be comprised of compact glacial till (Zone A), surrounded by loose and compact coarse tailings (Zone C and D, respectively). Whole tailings up to a distance of 100 m from Zone A will be capped with an average of 1.0 m of glacial till which is non-potentially acid generating (non-PAG). An overlying 0.3 m layer of soil will cover the entire beach. Coarse rock will be placed at the edge of the non-PAG glacial till at the water interface to prevent erosion.

Terrestrial vegetation will grow above the water level but will not establish roots that could reach the whole tailings. Terrestrial vegetation is will be grasses and low-lying shrubs. The roots of these plants do not penetrate beyond the 0.3 m layer of soil. Deep-rooting plants such as trees will be discouraged from growing along the dam banks and may be removed. There would be no potential for terrestrial vegetation to uptake COPCs from the whole tailings that are capped.

Wetland vegetation is expected to establish in the submerged whole tailings at depths of less than 2.0 m. At depths of more than 2.0 m, sunlight intensity may not sustain plant growth. Wetland vegetation would be rooted directly in the whole tailings, which could uptake COPCs from the roots into plant tissues. Wildlife that enter the lake could consume wetland vegetation and be indirectly exposed to COPCs from their diet. Affected wildlife would primarily be large herbivores such as moose and mule deer. Omnivores such as grizzly bears, American marten, and fisher would be at considerably less risk because only a small proportion of their diet consists of vegetation and smaller mammals may have poorer access to deeper rooting wetland vegetation.

Water-borne invertebrates (e.g., zooplankton) and benthic-dwelling invertebrates will also establish in the water column and whole tailings, respectively. Aquatic invertebrates will be naturally introduced to the lake from nearby watercourses through drift, migration, and flying adult ovipositioning. Benthic-dwelling invertebrates could accumulate COPCs from direct exposure to whole tailings, and all aquatic invertebrates could accumulate COPCs from the water. Invertebrates would be present throughout the entire lake and may indirectly expose wildlife to COPCs, particularly waterfowl and passerine birds that eat mainly aquatic invertebrates such as emerging adult insects (i.e., mosquitoes, blackflies, midgeflies, fishflies, etc.).

Lake water would be directly exposed to tailings sediment, but water quality is expected to reach a steady state after several years. Inflows from upstream watercourses would provide a continuous turnover of lake water, while substances in the water column would gradually settle to the lake bottom. Lake water levels may vary seasonally throughout the year, but would not cause any substantial turbulence that could disturb the benthos.

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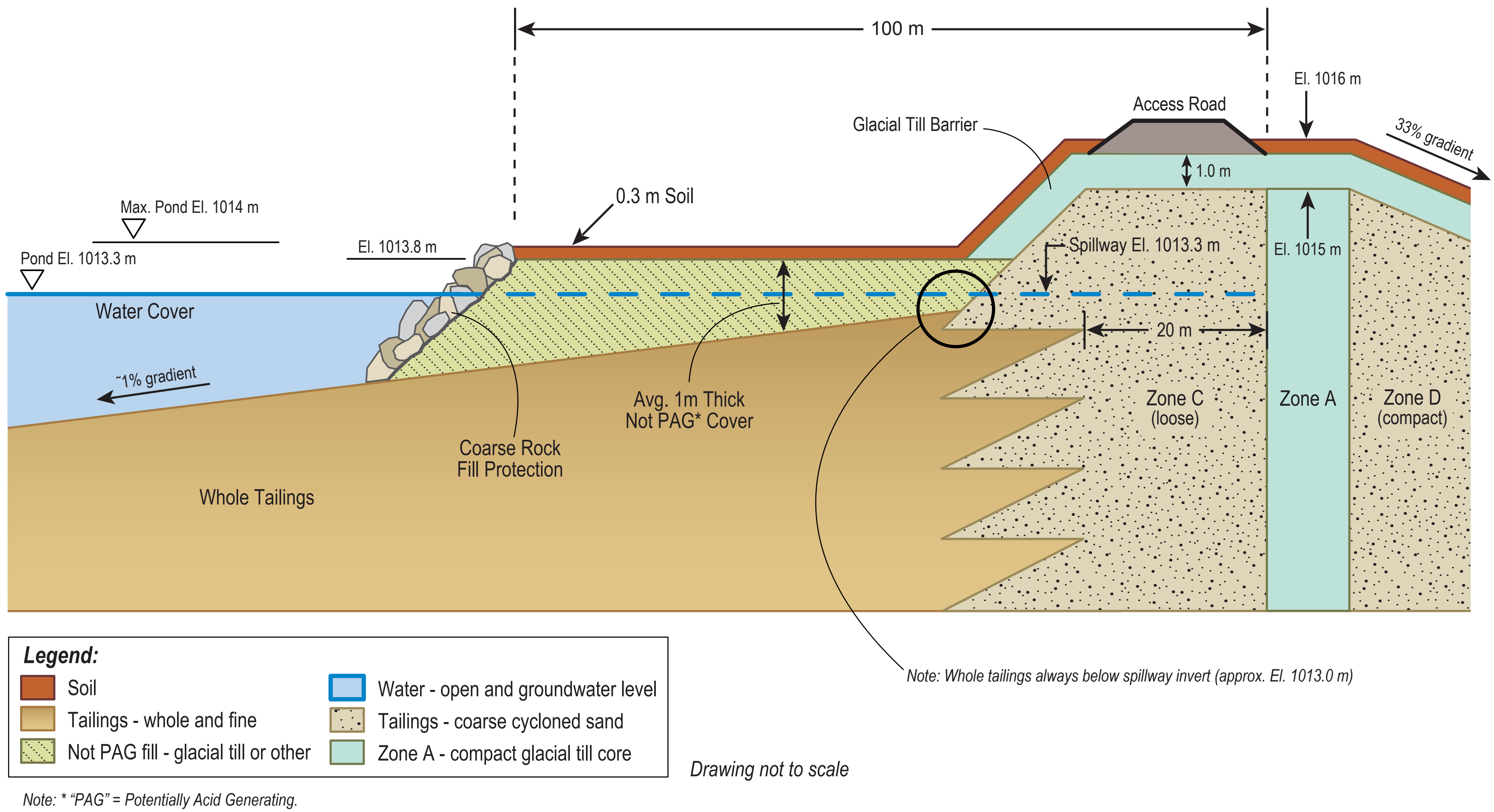

FIGURE 3.2-1

Morrison Copper/Gold Project: Schematic Cross-Section of the Tailings Storage Facility Beach at the Main Dam

Along the lake shores where dams are not present, there would be minimal to no impact to wetland vegetation from whole tailings. All wetland vegetation that establishes outside of the dam area would be rooted in natural soils, which are reflective of baseline conditions. Whole tailings would be present at lake depths below 2.0 m throughout the entire lake area except at the 3 dams.

3.3 Selection of Chemicals of Potential Concern

The COPCs included in this risk monitoring plan (Section 3) are the same metals evaluated in Section 2 (wildlife risk assessment). The COPCs were selected based on water and sediment concentrations of COPCs predicted for the TSF during operations. Post-closure concentrations in water are expected to reach a steady state several years post-closure. The quality of the submerged tailings may improve over time; however, such attenuation (if any) cannot be predicted (Rescan 2009b). The COPCs include: arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, vanadium, and zinc.

3.4 Selection of Receptors of Potential Concern

The ROPCs are the VECs that are herbivorous or consume primarily aquatic invertebrates for their diet. These species could be exposed to heavy metals from the ingestion of wetland vegetation and aquatic/sediment dwelling invertebrates. The ROPCs that were selected are: moose, mule deer, and goldeneye. Moose and mule deer could enter the lake and consume wetland vegetation when available. Goldeneyes are waterfowl that consume aquatic invertebrates for their diet.

Omnivores (i.e., grizzly bear, American marten, and fisher) were excluded because vegetation constitutes a substantially smaller proportion of their diet compared to herbivores. Barred owl are excluded because they are carnivorous and do not consume vegetation or aquatic invertebrates. Omnivores and carnivores were also excluded because prey meat would be similar to baseline concentrations since the tailings on land will be capped beneath at least 1.0 m of non-PAG glacial till and 0.3 metres of soil. Red-winged blackbirds are excluded because their main diet consists of terrestrial or flying insects and they do not eat invertebrates that are in their aquatic lifestage. If the monitoring results of the wetlands and benthos are safe for moose, mule deer, and goldeneye, then the results would also be safe for other VECs, which consume substantially less wetland vegetation and fewer invertebrates.

3.5 Wildlife Exposure Pathways and Conceptual Model

3.5.1 Wildlife Exposure Pathways

Wildlife exposure pathways are the routes that may expose wildlife to metals. For the purpose of this monitoring stage, only ingestion exposure pathways for soil, water, and food (i.e., invertebrates and vegetation) are considered. The following section describes each exposure pathway.

3.5.1.1 Soil Ingestion

All wildlife may ingest soil inadvertently when eating terrestrial vegetation or grooming. Some animals also intentionally ingest soils for its mineral content (Beyer, Connor, and Gerould 1994).

Herbivores generally consume a greater quantity of soil relative to carnivores because of the association of soils with plant roots. In the closure stage and post-closure of the TSF, terrestrial vegetation would establish and could be consumed by herbivore ROPCs. Soils associated in plant roots would also be ingested. These soils would be similar to baseline soil quality because a 0.3 m capping layer of soil will be added on top of a 1.0 m layer of glacial till to separate the underlying whole tailings.

The soils ingested would be representative of baseline soil quality. Surface soil (i.e., 0 to 20 cm depth) samples were collected during baseline studies and are used as a reference for the existing baseline conditions in the Project area. The laboratory analytical data is presented in the *Morrison Copper/Gold Project: Physiography, Surficial Materials, and Soils Baseline* (Rescan 2008). In summarizing the baseline conditions, the 95% upper confidence limit of the mean (95% UCLM) was calculated for each metal in the soil. All 95% UCLMs were calculated using the US EPA approved and recommended software ProUCL version 4.0 (US EPA 2007c). Soil ingestion was evaluated for all ROPCs.

3.5.1.2 Water Ingestion

Upon closure of the mine, the TSF will require approximately 3 years to fill with water, prior to it being piped to the Pit. Once the water levels have reached a steady state, wetlands may establish along the banks of the TSF dam. Predicted water quality 3 years post-closure was used as the ingestion concentration all ROPCs. These concentrations are presented in Table 3.5-1.

Table 3.5-1
COPC Concentration in the Tailings Storage Facility Post-closure

Parameter	Water (mg/L)
Arsenic	0.0105
Cadmium	0.000568
Chromium	0.00442
Copper	0.0153
Lead	0.0380
Mercury	0.0000871
Nickel	0.0132
Silver	0.0126
Vanadium	0.224
Zinc	0.0823

3.5.1.3 Wetland Vegetation Ingestion

Wetland vegetation may grow along the slope of the submerged whole tailings down to a depth of 2.0 m below the water surface. Wetland vegetation may uptake heavy metals in the sediments through their roots. Aquatic vegetation can also uptake and accumulate heavy metals in dissolved form through submerged leaves (Kamal et al. 2004; Keskinkan et al. 2004). The metal concentrations in aquatic plant tissues are typically proportional to the sediments they are rooted in (Jackson 1998). Different tissues are also shown to accumulate metals at varying rates. Heavy metal concentrations in aquatic plant tissue generally followed the corresponding order: roots to rhizomes to leaf to flower to stem to seed (Sawidis et al. 1995). This order may reflect the primary site of metal absorption (i.e., roots and rhizomes), and the distribution of metals to periphery structures (i.e., leaf, stem) and the lowest concentrations in structures developed at later life stage of development (i.e., seeds).

Animals that consume wetland vegetation may be exposed to elevated COPC concentrations in plant tissues if wetland vegetation establishes roots in the submerged whole tailings. The degree of bioaccumulation cannot be determined with any accuracy because it is based on various physical/chemical/ biological conditions in the environment (i.e., water pH, hardness, plant species). The magnitude of bioaccumulation will affect how much vegetation ROPCs can consume before unacceptable risks to wildlife health may occur. Monitoring criteria for COPC concentrations in wetland vegetation tissues can be established based on the known EDI of ROPCs from all other potential exposure pathways.

3.5.1.4 Aquatic and Benthic Invertebrate Ingestion

Aquatic invertebrates will likely establish in the water and sediment of the TSF after closure. All freshwater aquatic invertebrates accumulate metals and ions in their tissues to concentrations greater than the surrounding water (Dallinger and Rainbow 1993). Many of these metals are essential for life at high concentrations (i.e., calcium), while others are required at trace levels but harmful at elevated levels (i.e., copper, zinc). Some serve no biological role and are harmful at elevated levels (i.e., mercury).

Benthic invertebrates generally have higher bioaccumulation factors for metals than pelagic invertebrates that live primarily in the water column. Sediments are environmental sinks for metals, which form precipitates that sink to the benthos or adsorb to organic matter in the sediments. Pore water in sediments also contains higher metal concentrations than surface water. Invertebrates that live in the sediments or feed on other sediment-dwelling organisms may thus accumulate metals at a faster rate than invertebrates dwelling in the water column, which has lower metal concentrations.

Wildlife that consume invertebrates that have come into contact with submerged tailings sediment and its associated pore water may be exposed indirectly to heavy metals through their diet. The degree of bioaccumulation cannot be determined based on the environmental concentrations of heavy metals. However, monitoring criteria for metal concentrations in aquatic invertebrate tissues can be established based on the known EDI from all other potential exposure pathways.

3.5.1.5 Conceptual Model

Figure 3.5-1 presents the conceptual model for the wildlife exposure pathways to heavy metals. The three wildlife species considered are moose, mule deer, and goldeneye. All wildlife species ingest soil and water. Herbivores also ingest wetland vegetation that grows in the whole tailings, while waterfowl ingest aquatic invertebrates that are in direct contact with water and submerged whole tailings.

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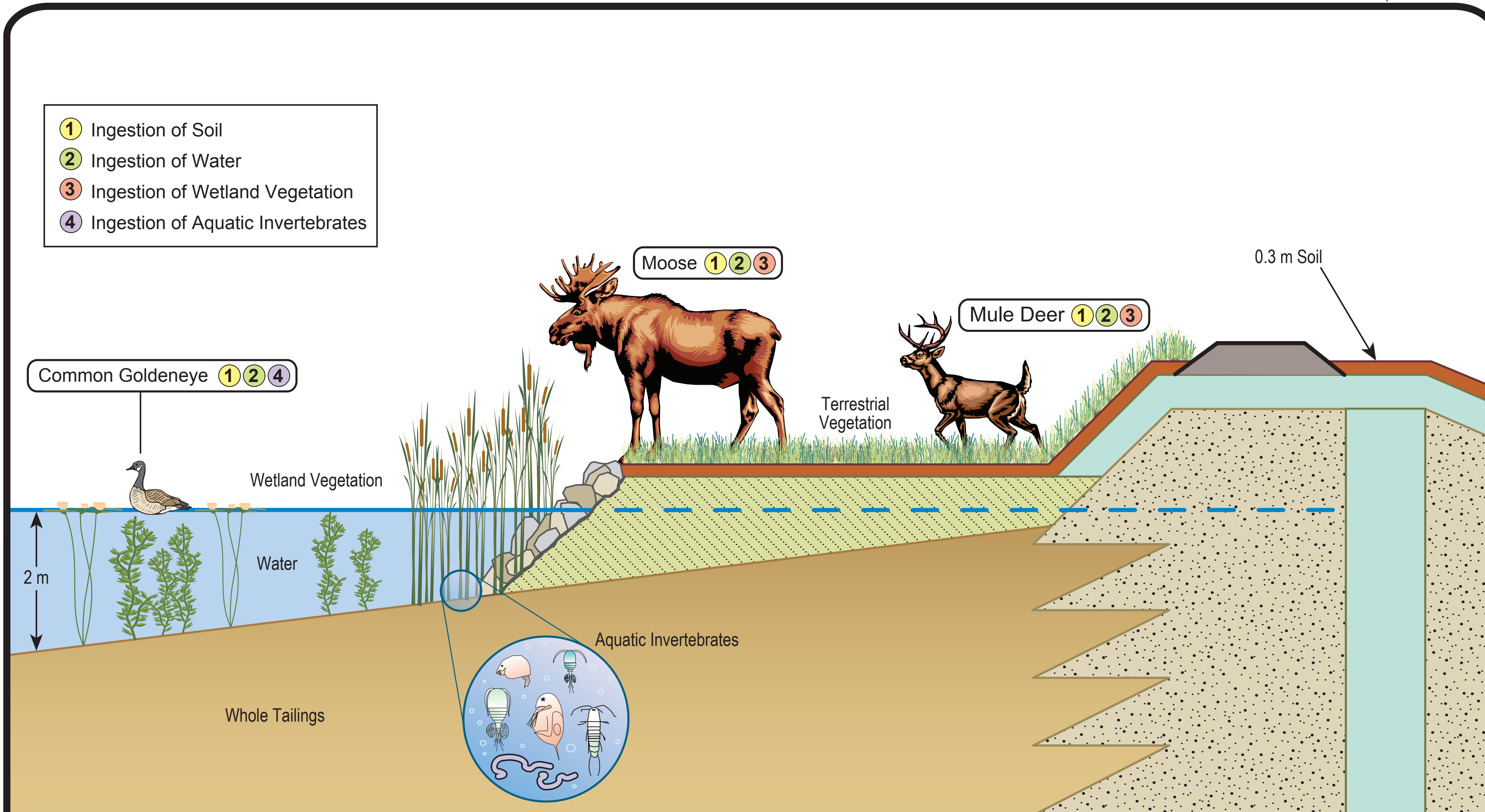

Drawing not to scale

Morrison Copper/Gold Project: Wildlife Risk Monitoring Conceptual Model at Closure Stage

FIGURE 3.5-1

Terrestrial vegetation with shallow penetrating roots such as grasses and shrubs would establish at levels above the lake water level. This vegetation would grow in soils that are not affected by the underlying whole tailings. Terrestrial vegetation concentrations of COPCs would be similar to existing baseline levels. Only wetland vegetation would have roots anchoring in the whole tailings, which could uptake metals.

3.6 Methodology in Establishing Monitoring Criteria

Establishing maximum allowable COPC concentrations in wetland vegetation and aquatic invertebrates for monitoring involves the same methodology used in the wildlife risk assessment of Section 2. However, the methodology for Section 3 is applied in reverse order. The first step determines the total EDI (EDI_{total}) that would be considered a potential risk to wildlife health. The second step determines the EDI from soil and water exposure pathways (i.e., EDI_{soil} and EDI_{water}). The final step determines how much additional COPC exposure is required before wildlife is exposed to COPC levels that may be a possible risk to health. The following section describes each step in detail.

3.6.1 Monitoring Endpoints for Wildlife Effects

When the EDI_{total} exceeds a threshold, there may be potential for adverse health effects to ROPCs. To determine the threshold EDI_{total}, TRVs were used as a benchmark. TRVs are safe exposures below which there is minimal risk of adverse health effects to ROPCs. The ratio between EDI_{total} and the TRV is the ER. For wildlife health risk assessment presented in Section 2, an ER less than 0.5 was considered the acceptable threshold value and is represented as:

$$\frac{EDI_{total}}{TRV} < 0.5 \text{ (ER), No unacceptable risk to wildlife health}$$

For example, the mammalian TRV for arsenic is 1.04 mg/kg-day. For mammalian species to be considered at no unacceptable risk of adverse effects from arsenic exposure, the EDI_{total} must be below 0.52 mg/kg-day to achieve a ER below 0.5.

Table 3.6-1 presents a summary table of the TRVs for each heavy metal for mammals and avians, and the resulting maximum EDI_{total} to achieve an ER <0.5. The rationale for the TRVs used was presented in Section 2.6.2.

3.6.1.1 Estimated Daily Intakes

Wildlife are exposed to metals from the ingestion of soil, water, and food (i.e., vegetation and invertebrates) as described previously. The exposure pathways from water, soil, and food consumption contribute to the EDI_{total} of heavy metals. Therefore, the EDI_{total} can be calculated as the sum of all ingestion exposure routes for herbivores or waterfowl based on the following formula:

$$EDI_{total} = EDI_{water} + EDI_{soil} + EDI_{veg}$$

or

$$EDI_{total} = EDI_{water} + EDI_{soil} + EDI_{invert}$$

Where the individual exposure routes can be calculated as:

$$EDI_{media} = \frac{C_{media} \times IR_{media} \times ET}{BW}$$

Where,

EDI_{media}	=	EDI of a COPC from ingesting water, soil, or food (mg/kg-day)
C_{media}	=	Concentration of COPC in the water, soil, or food (mg/L or mg/kg-dw or mg/kg-ww)
IR_{media}	=	Ingestion rate of water, soil, or food (L/day or kg-dw/day or kg-ww/day)
ET	=	Exposure time – fraction of the year spent at the site (unitless)
BW	=	Body weight of the wildlife species (kg)

Table 3.6-1
TRVs and Maximum Acceptable EDI for ER <0.5

	TRV (mg/kg-day)		Maximum Acceptable EDI_{total} (mg/kg-day)	
Metal	**Mammals**	**Avian**	**Mammals**	**Avian**
Arsenic	1.04	2.24	0.52	1.12
Cadmium	0.77	1.47	0.385	0.735
Chromium	2.4	2.66	1.2	1.33
Copper	5.6	4.05	2.8	2.025
Lead	4.7	1.63	2.35	0.815
Mercury	1	0.9	0.5	0.45
Nickel	1.7	6.71	0.85	3.355
Silver	6.02	2.02	3.01	1.01
Vanadium	4.16	0.344	2.08	0.172
Zinc	75.4	66.1	37.7	33.05

Table 3.6-2 presents a summary of the EDI_{soil} and EDI_{water} for moose, mule deer, and goldeneye, derived from measured baseline C_{soil} and C_{water} concentrations. The IR, ET, and BW used were described previously in Section 2.

3.6.1.2 Monitoring Criteria in Wetland Vegetation and Aquatic Invertebrates

The monitoring criteria for COPCs in wetland vegetation and aquatic invertebrates can be determined based on the values for EDI_{total}, EDI_{soil}, and EDI_{water}. The sum of all EDIs cannot exceed the EDI_{total} in order to achieve an ER below 0.5. Therefore, the EDI_{veg} for moose and mule deer and EDI_{invert} for goldeneye can be determined based on the following formula:

$$EDI_{invert} = EDI_{total} - EDI_{water} - EDI_{soil}$$

or

$$EDI_{veg} = EDI_{total} - EDI_{water} - EDI_{soil}$$

The resulting EDI_{invert} or EDI_{veg} value can be used to calculate C_{invert} or C_{veg} for each monitored species, based on the following formula:

$$C_{invert} = \frac{BW \times EDI_{invert}}{IR_{invert} \times ET} \quad \text{or} \quad C_{veg} = \frac{BW \times EDI_{veg}}{IR_{veg} \times ET}$$

The values for C_{veg} and C_{invert} are the maximum allowable concentrations of COPCs that would be used in future post-closure monitoring of wetland vegetation and aquatic invertebrate tissue.

Table 3.6-2
Estimated Daily Exposure of COPCs from Exposure Pathways (mg/kg-day)

	Moose		Mule Deer		Goldeneye	
Metal	EDI_{water}	EDI_{soil}	EDI_{water}	EDI_{soil}	EDI_{water}	EDI_{soil}
Arsenic	7.68E-05	3.71E-03	1.15E-04	6.22E-03	2.53E-04	8.23E-03
Cadmium	4.14E-06	6.08E-05	6.18E-06	1.02E-04	1.37E-05	1.35E-04
Chromium	3.22E-05	2.65E-02	4.80E-05	4.44E-02	1.06E-04	5.88E-02
Copper	1.12E-04	1.28E-01	1.67E-04	2.15E-01	3.69E-04	2.84E-01
Lead	2.77E-04	2.56E-03	4.13E-04	4.29E-03	9.14E-04	5.68E-03
Mercury	6.36E-07	2.93E-05	9.47E-07	4.91E-05	2.10E-06	6.50E-05
Nickel	1.38E-04	1.14E-02	2.06E-04	1.91E-02	4.55E-04	2.52E-02
Silver	9.19E-05	2.13E-04	1.37E-04	3.56E-04	3.03E-04	4.71E-04
Vanadium	1.64E-03	1.13E-02	2.44E-03	1.89E-02	5.39E-03	2.50E-02
Zinc	6.01E-04	1.86E-02	8.96E-04	3.11E-02	1.98E-03	4.12E-02

3.7 Monitoring Criteria Results

3.7.1 Wetland Vegetation Monitoring

Table 3.7-1 presents a table of the maximum allowable heavy metal concentrations in wetland vegetation as dry weight concentrations. If the concentrations approach these levels, additional mitigation may be required to reduce the exposure of wildlife to wetland vegetation (Chapter 14).

3.7.2 Aquatic/Benthic Invertebrate Monitoring

Table 3.7-2 presents the maximum allowable COPC concentrations in aquatic and benthic invertebrates as dry weight concentrations. When concentrations are above this level, the ER of 0.5 will be exceeded. In most cases, metal concentrations in invertebrates are much lower than those allowable for vegetation. Additional mitigation may be required to reduce the exposure of wildlife to aquatic/benthic invertebrates if the monitored concentrations are shown to approach these concentrations (Chapter 14). The animal species that would be at risk would be goldeneye.

Table 3.7-1
Maximum Allowable Concentration of COPCs in Wetland Vegetation

Metal	Maximum Allowable Concentration (mg/kg-dw)
Arsenic	91.8
Cadmium	68.8
Chromium	206.6
Copper	462.2
Lead	419.3
Mercury	89.4
Nickel	148.5
Silver	538.1
Vanadium	368.1
Zinc	6734.6

Table 3.7-2
Maximum Allowable Concentration of COPCs in Aquatic/Benthic Invertebrates

Metal	Maximum Allowable Concentration (mg/kg-dw)
Arsenic	46.2
Cadmium	30.5
Chromium	52.8
Copper	72.3
Lead	33.6
Mercury	18.7
Nickel	138.4
Silver	41.9
Vanadium	5.9
Zinc	1371.7

3.8 Uncertainty

3.8.1 Introduction

To determine the maximum COPC concentrations for monitoring the closure stage of the TSF, assumptions are made that affect the level of certainty with the monitoring concentrations that were established. Uncertainties may exist in numerous areas, including the conditions at the TSF upon closure, the wildlife exposure pathways considered, and the wildlife exposure characteristics. When these uncertainties existed, a conservative approach was taken when appropriate to overestimate the potential risk.

3.8.2 Tailings Storage Facility Conditions at Closure

There are several uncertainties regarding the conditions that are expected to be present at the TSF at closure. For example, it is assumed that the concentration of metals in the water would gradually attenuate approximately 3 years after closure. There would be upstream watercourses that would flow into the TSF, and gradually fill it approximately 3 years after closure. Once the TSF fills with water, excess will spill into the pit and the water in the TSF will gradually turnover.

Another uncertainty associated with the TSF is the assumption that wetland vegetation will not grow beyond a depth of 2.0 m. The wetland vegetation that would establish outside of the TSF dams will be rooted in natural soils and sediments. Whole tailings will only be present at a submerged depth of at least 2.0 m in these areas. If wetland vegetation grows beyond a depth of 2.0 m, there is the potential that this vegetation will be affected directly by tailings throughout the entire TSF lake. The depth extent of wetland vegetation growth should be established before closure to ensure that only vegetation at the lake dams are rooted directly in the tailings.

3.8.3 Wildlife Exposure Characteristics

The wildlife exposure characteristics that were used to estimate COPC exposure had a number of uncertainties that may substantially overestimate the actual exposure that would occur in the TSF at closure. These uncertainties included the estimation of ROPC BW and food IRs, and use of aquatic guidelines as TRVs. These were discussed previously in Section 2.5.2.2.

3.8.3.1 Exposure Time

The ET is the fraction of the year that wildlife would be affected by the relevant exposure pathways. In Section 2.5.2.2, the ET was established by comparing the TSF area (575 ha at operations) with the home range of each animal and the active period during the year. The ET for goldeneye would be similar to the operations stage because aquatic invertebrates could establish throughout the entire lake and sediments. The lake in the TSF at closure is slightly smaller (466 ha) compared to the entire TSF at operations, but the same ET value was used to determine invertebrate monitoring concentrations to be conservative.

For moose and mule deer, the ET values would be based on the lake area that wetland vegetation could establish along the dam areas. The total dam area where wetlands are rooted in whole tailings is approximately 78 ha, with a total lake area of 466 ha. However, wetlands would also establish outside of the dam area, which are rooted in natural soils but exposed to the same water. The predicted wetland area that would be directly affected by rooting in whole tailings is small. However, it is uncertain if wetlands growing adjacent to the dam area would be similar or substantially different in their COPC concentrations. As a conservative approach, it was assumed that all wetlands that could grow in the post-closure lake would be affected by whole tailings. This assumption overestimates the ET that moose and mule deer would be ingesting wetland vegetation. It is also conservative because it assumes all of the vegetation ingested by herbivores while in the TSF is wetland vegetation. Terrestrial vegetation will also establish on land that would experience no effect from tailings.

3.8.3.2 Exposure Ratio

The maximum acceptable concentration of COPCs in wetlands and invertebrates was established based on an ER of 0.5. Normally, an ER value of 1.0 would be used when assessing the EDI of all exposure routes (including non-ingestion pathways). This adjustment assumes that ROPCs obtain 50% of their exposure to COPCs from ingestion pathways. The remaining 50% is assumed to come from exposures that were not assessed (i.e., dermal absorption, inhalation), or from the ingestion of foods outside of the TSF area after closure. It is very likely that this remaining 50% of exposure would not occur since baseline concentrations in environmental media will be lower than that predicted for the TSF and the TSF concentrations do not pose a threat to wildlife. Therefore, media (soil, water) outside the TSF cannot pose a threat to wildlife.

3.9 Conclusion

The risk monitoring criteria are COPC concentrations in wetland vegetation and aquatic invertebrates, which if exceeded, could pose a risk to ROPC health. The predicted concentrations are based on the assumption that the water and soil ingested by ROPCs are reflective of current baseline conditions and that only wetland vegetation and aquatic invertebrates are affected by submerged tailings. Consequently, water and sediment concentrations of COPCs should be monitored to confirm this assumption during post-closure. If COPC concentrations in the soil and water are substantially higher than baseline, their monitoring criteria in wetland vegetation and aquatic invertebrates would be lower than the concentrations currently predicted.

After closure and reclamation procedures are completed, the surface environment is expected to return to baseline conditions after several years. Tailings from the TSF will be capped with soil or submerged in water to prevent wildlife from being directly exposed to the tailings. Wetland vegetation and aquatic invertebrates will eventually establish at beaches along the lake dam. These organisms will uptake COPCs from the submerged tailings. If the concentrations of COPCs substantially bioaccumulates in wetland vegetation and aquatic invertebrates, terrestrial wildlife that consume these as part of their diet may experience high COPC exposure. Based on the estimated daily exposure from the consumption of known media, maximum allowable concentrations of COPCs were established in vegetation and invertebrates. These concentrations (in dry weight) are the monitoring criteria in vegetation and invertebrate tissue, which should not be exceeded after closure and reclamation, without additional wildlife monitoring being conducted.

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An explanation of the acronyms used throughout this reference list can be found in the *List of Acronyms*.

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APPENDIX A
FOOD CHAIN MODEL FOR PREY IN THE TAILINGS STORAGE FACILITY

Appendix A
Food Chain Model for Prey (Moose) in the TSF

1. Introduction

Prey (moose) tissue concentrations of heavy metals were estimated based on a food chain model. The model used the predicted metal concentrations in the tailings sediment (soil) and tailings water that would exist during mining operations and the baseline metal concentrations in vegetation. Wildlife characteristics for moose body weight, ingestion rates are described in the main report. Metal-specific biotransfer factors (BTFs), which is the proportion of the ingested metal that is absorbed into the body, is described in this appendix.

2. Methods

The following equation was used to predict the wet weight animal tissue concentrations:

$$C_{prey}\ (\text{mg/kg-ww}) = C_{msoil} + C_{mveg} + C_{mwater}$$

Where:
C_{msoil} = Concentration in meat from the animal's exposure to metals in soil from the TSF.
C_{mveg} = Concentration in meat from the animal's exposure to metals in vegetation from outside the TSF area.
C_{mwater} = Concentration in meat from the animal's exposure to metals in water from the TSF.

The terrestrial wildlife uptake equation used to obtain the concentrations in meat from exposure to soil, vegetation and water are presented in Table A-1.

Table A-1
Terrestrial Wildlife Uptake Equations

Pathway	Equation and Parameters
Soil ingestion	C_{msoil} = BTF_{COPC} (day/kg) x C_{soil} (mg/kg-dw) x IR_{soil} (kg-dw/day) x fw
Vegetation ingestion	C_{mveg} = BTF_{COPC} x C_{veg} (mg/kg-ww) x IR_{veg} (kg-ww/day) x fw
Water ingestion	C_{mwater} = BTF_{COPC} x C_{water} (mg/L) x IR_{water} (L/day)

BTF = Biotransfer factor for a heavy metal COPC
IR = Ingestion rate
C = Concentration of metal in media
fw = Fraction of daily consumption of soils and vegetation from site = 1

2.1 Metal Concentrations in Environmental Media

Prey animals in this assessment are large herbivorous mammals (moose), which drink water and consume soils from the TSF. Water and soil/sediment concentrations were predicted using a computer model to simulate the conditions that would exist in the TSF during operations.

Vegetation is not expected to grow in the TSF area, and any food ingestion would occur outside of the TSF. Baseline metal concentrations in vegetation was used to simulate this.

Table A-2 presents the heavy metal concentrations in the environmental media that prey animals would be exposed to. The modelled data represents the maximum levels that would exist in the TSF during operations. The vegetation concentrations are the 95% upper limit of the mean (95% UCLM) concentrations that were collected during baseline vegetation studies. The 95% UCLMs were calculated using ProUCL 4.0 software.

Table A-2
Summary of Maximum and 95% UCLM Metal Concentrations in Surface Water, Soil, and Plant Tissue

COPC	TSF Water (C_{water}) (mg/L)	TSF Soil/Sediment (C_{soil}) (mg/kg-dw)	95% UCLM Base Plant Tissue (C_{veg}) (mg/kg-ww)
Arsenic	1.05E-02	1.71E+01	9.93E-03
Cadmium	5.68E-04	2.80E-01	2.61E-02
Chromium	4.42E-03	1.22E+02	5.00E-02
Copper	1.53E-02	5.91E+02	7.15E-01
Lead	3.80E-02	1.18E+01	1.00E-02
Mercury	8.71E-05	1.35E-01	1.82E-03
Nickel	1.89E-02	5.24E+01	2.15E-01
Silver	1.26E-02	9.79E-01	N/A
Vanadium	2.24E-01	5.21E+01	5.00E-02
Zinc	8.23E-02	8.56E+01	3.19E+00

N/A = not available. Silver was not measured in plant tissue during baseline studies.

2.2 Terrestrial Wildlife Characteristics

Table A-3 presents the species specific characteristics that were used to predict meat concentrations. It was assumed that moose and grouse spend all year eating and drinking from within the Project area.

Table A-3
Terrestrial Wildlife Characteristics

Prey	Body Weight (BW) (kg)	Food Ingestion Rate (kg-ww/day)	Vegetation Ingestion Rate (IR_{veg}) (kg-ww/day)	Soil/Sediment Ingestion Rate (IR_{soil}) (kg-dw/day)	Water Ingestion Rate (IR_{water}) (L/day)
Moose	361	9.95	9.8	0.15	25

2.3 Biotransfer Factors

The tissue uptake calculations were based on metal specific biotransfer factors (BTF). No data on moose BTFs were available; therefore beef BTF, the closest related mammal, was used.

BTFs are conversion values to distinguish between the amount of metal which is ingested and the fraction which is subsequently absorbed into the body. Table A-4 presents the BTF values to calculate predicted wildlife tissue concentrations of metals. All BTFs were obtained from the Risk Assessment Information System (RAIS) online database (RAIS 2009).

Table A-4
Biotransfer Factors Used to Predict Metal Uptake into Prey (Moose) Tissue

COPC	BTF_{COPC} (day/kg-ww)
Arsenic	0.002
Cadmium	0.0004
Chromium	0.009
Copper	0.009
Lead	0.0004
Mercury	0.01
Nickel	0.005
Silver	0.003
Vanadium	0.0025
Zinc	0.1

2.4 Sample Calculation and Results

Table A-5 provides a sample calculation of the zinc concentrations in moose tissue. Table A-6 shows the summarized data for metal concentration in moose prey tissue as a result from water, soil and vegetation transfer. The results for C_{prey} are presented in the report as Table 1.5-1.

Table A-5
Sample Calculation of Zinc Concentration in Prey (Moose) Tissue from Exposure to Surface Waters, Soil, and Vegetation

C_{prey} = C_{msoil} + C_{mveg} + C_{mwater}

and:

C_{msoil} = BTF_{zinc} x C_{soil} x IR_{soil} x fw

C_{mveg} = BTF_{zinc} x C_{veg} x IR_{veg} x fw

C_{mwater} = BTF_{zinc} x C_{water} x IR_{water}

Where:

C_{prey} = Concentration of COPC (zinc) in meat tissue from soil, vegetation and water consumption

C_{msoil} = Concentration of COPC (zinc) in meat tissue from soil consumption

C_{mveg} = Concentration of COPC (zinc) in meat tissue from vegetation consumption

C_{mwater} = Concentration of COPC (zinc) in meat tissue from water consumption

BTF = Bio-transfer factor for COPC from food consumption to tissues

C = Concentration of metal in media

IR = Ingestion rate of media

F_w = Fraction of the food from the TSF area = 1

Calculation:

C_{msoil} = 0.1 day/kg-ww x 86.0 mg/kg-dw x 0.15 kg-dw/day x 1 = 1.28 mg/kg-ww

C_{mveg} = 0.1 day/kg-ww x 3.19 mg/kg-ww x 9.8 kg-ww/day x 1 = 3.12 mg/kg-ww

C_{mwater} = 0.1 day/kg-ww x 0.0823 mg/L x 25.0 L/day = 0.21 mg/kg-ww

C_{prey} = 1.28 mg/kg-ww + 3.12 mg/kg-ww + 0.21 mg/kg-ww

= **4.61 mg/kg-ww**

Table A-6
Estimated Concentrations in Moose Meat from Exposure to Surface Waters, Soil or Vegetation (mg/kg-ww)

COPC	C_{prey}	C_{msoil}	C_{mwater}	C_{mveg}
Arsenic	5.85E-03	5.13E-03	5.26E-04	1.95E-04
Cadmium	1.25E-04	1.68E-05	5.68E-06	1.02E-04
Chromium	1.70E-01	1.65E-01	9.94E-04	4.41E-03
Copper	8.64E-01	7.97E-01	3.45E-03	6.31E-02
Lead	1.13E-03	7.09E-04	3.80E-04	3.92E-05
Mercury	4.03E-04	2.03E-04	2.18E-05	1.78E-04
Nickel	5.15E-02	3.93E-02	1.65E-03	1.05E-02
Silver	1.38E-03	4.41E-04	9.44E-04	N/A
Vanadium	3.47E-02	1.95E-02	1.40E-02	1.23E-03
Zinc	4.61E+00	1.28E+00	2.06E-01	3.12E+00

$C_{prey} = C_{msoil} + C_{mwater} + C_{mveg}$
N/A = not available. Silver not assessed during baseline vegetation studies.

APPENDIX B
SAMPLE CALCULATION OF TOTAL EDI OF SELENIUM IN AMERICAN MARTEN

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Appendix B
Sample Calculation of Total EDI of Vanadium in Red Winged Blackbird

	Parameter	Value
$EDI_{total} = EDI_{water} + EDI_{soil} + EDI_{prey}$		
$EDI_{water} = \frac{IR \times C_{water} \times ET}{BW}$	IR = ingestion rate (L/day)	0.01
	C_{water} = selenium concentration in TSF water (mg/L)	0.2241
	ET = exposure time (fraction of year that animal is exposed to TSF)	0.385
$= \frac{0.01 \text{ L/day} \times 0.2241 \text{ mg/L} \times 0.385}{0.06 \text{ kg}}$	BW = body weight (kg)	0.06
$EDI_{water} = 1.44 \times 10^{-2}$ mg/kg-day		
$EDI_{soil} = \frac{IR \times C_{soil} \times ET}{BW}$	IR = ingestion rate (kg-dw/day)	0.0003
	C_{soil} = selenium concentration in TSF soil/sediments (mg/kg-dw)	52.1
	ET = exposure time (fraction of year that animal is exposed to TSF)	0.385
$= \frac{0.0003 \text{ kg-dw/day} \times 52.1 \text{ mg/kg-dw} \times 0.385}{0.06 \text{ kg}}$	BW = body weight (kg)	0.06
$EDI_{soil} = 1.002 \times 10^{-1}$ mg/kg-day		
$EDI_{prey} = \frac{IR \times C_{prey} \times ET}{BW}$	IR = ingestion rate (kg-ww/day)	0
	C_{prey} = selenium concentration in prey tissue (mg/kg-ww)	0.0347
	ET = exposure time (fraction of year that animal is exposed to TSF)	0.385
$= \frac{0 \text{ kg-ww/day} \times 0.0347 \text{ mg/kg-ww} \times 0.385}{0.06 \text{ kg}}$	BW = body weight (kg)	0.06
$EDI_{prey} = 0$ mg/kg-day		

$EDI_{total} = EDI_{water} + EDI_{soil} + EDI_{prey}$

$= (1.44 \times 10^{-2}) + (1.002 \times 10^{-1}) + (0)$ mg/kg-day

$EDI_{total} = 0.1146$ mg/kg-day

APPENDIX C
SUMMARY TABLES OF EDI FROM WATER, SOIL, AND PREY EXPOSURE PATHWAYS

Appendix C
Summary Tables of EDI from Water, Soil and Prey Exposure Pathways (mg/kg-day)

$EDI_{total} = EDI_{prey} + EDI_{soil} + EDI_{water}$

COPC	Grizzly Bear	Moose	Mule Deer	American Marten	Fisher	Barred Owl	Goldeneye	Red Wing Blackbird
Arsenic	4.23E-05	3.79E-03	6.33E-03	2.00E-02	6.36E-03	1.20E-02	8.48E-03	3.36E-02
Cadmium	7.71E-07	6.49E-05	1.08E-04	3.51E-04	1.13E-04	2.14E-04	1.48E-04	5.75E-04
Chromium	3.22E-04	2.66E-02	4.45E-02	1.55E-01	4.89E-02	9.71E-02	5.89E-02	2.35E-01
Copper	1.57E-03	1.28E-01	2.15E-01	7.51E-01	2.38E-01	4.73E-01	2.85E-01	1.14E+00
Lead	3.40E-05	2.84E-03	4.71E-03	1.50E-02	4.89E-03	9.07E-03	6.60E-03	2.52E-02
Mercury	4.25E-07	2.99E-05	5.00E-05	2.00E-04	6.37E-05	1.33E-04	6.71E-05	2.65E-04
Nickel	1.35E-04	1.15E-02	1.92E-02	6.43E-02	2.04E-02	3.97E-02	2.55E-02	1.02E-01
Silver	4.83E-06	3.04E-04	4.93E-04	1.87E-03	6.40E-04	1.23E-03	7.74E-04	2.69E-03
Vanadium	1.67E-04	1.29E-02	2.14E-02	7.25E-02	2.38E-02	4.52E-02	3.04E-02	1.15E-01
Zinc	1.37E-03	1.92E-02	3.20E-02	6.38E-01	2.04E-01	5.55E-01	4.32E-02	1.70E-01

EDI_{prey}

COPC	Grizzly Bear	Moose	Mule Deer	American Marten	Fisher	Barred Owl	Goldeneye	Red Wing Blackbird
Arsenic	1.48E-06	N/A	N/A	6.85E-04	2.19E-04	6.31E-04	N/A	N/A
Cadmium	3.15E-08	N/A	N/A	1.46E-05	4.68E-06	1.35E-05	N/A	N/A
Chromium	4.30E-05	N/A	N/A	1.99E-02	6.38E-03	1.84E-02	N/A	N/A
Copper	2.18E-04	N/A	N/A	1.01E-01	3.24E-02	9.32E-02	N/A	N/A
Lead	2.85E-07	N/A	N/A	1.32E-04	4.23E-05	1.22E-04	N/A	N/A
Mercury	1.02E-07	N/A	N/A	4.71E-05	1.51E-05	4.34E-05	N/A	N/A
Nickel	1.30E-05	N/A	N/A	6.02E-03	1.93E-03	5.55E-03	N/A	N/A
Silver	3.50E-07	N/A	N/A	1.62E-04	5.19E-05	1.49E-04	N/A	N/A
Vanadium	8.78E-06	N/A	N/A	4.07E-03	1.30E-03	3.75E-03	N/A	N/A
Zinc	1.16E-03	N/A	N/A	5.39E-01	1.73E-01	4.97E-01	N/A	N/A

EDI_{soil}

COPC	Grizzly Bear	Moose	Mule Deer	American Marten	Fisher	Barred Owl	Goldeneye	Red Wing Blackbird
Arsenic	3.90E-05	3.71E-03	6.22E-03	1.88E-02	5.94E-03	1.10E-02	8.23E-03	3.29E-02
Cadmium	6.38E-07	6.08E-05	1.02E-04	3.08E-04	9.72E-05	1.80E-04	1.35E-04	5.39E-04
Chromium	2.78E-04	2.65E-02	4.44E-02	1.34E-01	4.24E-02	7.85E-02	5.88E-02	2.35E-01
Copper	1.35E-03	1.28E-01	2.15E-01	6.50E-01	2.05E-01	3.80E-01	2.84E-01	1.14E+00
Lead	2.69E-05	2.56E-03	4.29E-03	1.30E-02	4.10E-03	7.59E-03	5.68E-03	2.27E-02
Mercury	3.08E-07	2.93E-05	4.91E-05	1.49E-04	4.69E-05	8.68E-05	6.50E-05	2.60E-04
Nickel	1.19E-04	1.14E-02	1.91E-02	5.76E-02	1.82E-02	3.37E-02	2.52E-02	1.01E-01
Silver	2.23E-06	2.13E-04	3.56E-04	1.08E-03	3.40E-04	6.29E-04	4.71E-04	1.88E-03
Vanadium	1.19E-04	1.13E-02	1.89E-02	5.73E-02	1.81E-02	3.35E-02	2.50E-02	1.00E-01
Zinc	1.95E-04	1.86E-02	3.11E-02	9.41E-02	2.97E-02	5.50E-02	4.12E-02	1.65E-01

EDI_{water}

COPC	Grizzly Bear	Moose	Mule Deer	American Marten	Fisher	Barred Owl	Goldeneye	Red Wing Blackbird
Arsenic	1.88E-06	7.68E-05	1.15E-04	5.26E-04	2.08E-04	3.76E-04	2.53E-04	6.75E-04
Cadmium	1.02E-07	4.14E-06	6.18E-06	2.84E-05	1.12E-05	2.03E-05	1.37E-05	3.64E-05
Chromium	7.91E-07	3.22E-05	4.80E-05	2.21E-04	8.71E-05	1.58E-04	1.06E-04	2.83E-04
Copper	2.75E-06	1.12E-04	1.67E-04	7.67E-04	3.02E-04	5.48E-04	3.69E-04	9.84E-04
Lead	6.80E-06	2.77E-04	4.13E-04	1.90E-03	7.49E-04	1.36E-03	9.14E-04	2.44E-03
Mercury	1.56E-08	6.36E-07	9.47E-07	4.35E-06	1.72E-06	3.11E-06	2.10E-06	5.59E-06
Nickel	2.37E-06	9.65E-05	1.44E-04	6.61E-04	2.61E-04	4.72E-04	3.18E-04	8.48E-04
Silver	2.25E-06	9.19E-05	1.37E-04	6.29E-04	2.48E-04	4.50E-04	3.03E-04	8.08E-04
Vanadium	4.01E-05	1.64E-03	2.44E-03	1.12E-02	4.42E-03	8.00E-03	5.39E-03	1.44E-02
Zinc	1.47E-05	6.01E-04	8.96E-04	4.12E-03	1.62E-03	2.94E-03	1.98E-03	5.28E-03