Red Dog Mine
Closure and Reclamation Plan

Supporting Document H
Ecological Risks

Red Dog Mine
Closure and Reclamation Plan

Evaluation of Ecological Risk within the Ambient Air/Solid Waste Permit Boundary (Exponent, 2008)

Exponent®

Evaluation of Ecological Risk within the Ambient Air/Solid Waste Permit Boundary

Red Dog Mine, Alaska

Prepared for

Teck Cominco Alaska Incorporated
Anchorage, Alaska

Exponent®

Evaluation of Ecological Risk within the Ambient Air/Solid Waste Permit Boundary

Red Dog Mine, Alaska

Prepared for

Teck Cominco Alaska Incorporated
3105 Lakeshore Drive
Building A, Suite 101
Anchorage, AK 99517

Prepared by

Exponent
15375 SE 30th Place, Suite 250
Bellevue, WA 98007

December 2007

Doc. no. 8601997.005 5700 1207 SS07

Contents

List of Figures

Figures are presented at the end of the main text.

List of Tables

Tables are presented at the end of the main text.

Acronyms and Abbreviations

CoPC	chemical of potential concern
CSB	concentrate storage building
CSM	conceptual site model
DMTS	DeLong Mountain Regional Transportation System
LOAEL	lowest-observed-adverse-effect level
MOU	memorandum of understanding
NOAEL	no-observed-adverse-effect level
NPS	National Park Service
TRV	toxicity reference value
UCL	upper confidence level
WACH	Western Arctic Caribou Herd
XRF	x-ray fluorescence

Executive Summary

Elevated metals concentrations have been identified in tundra in areas surrounding Red Dog Mine and the DeLong Mountain Regional Transportation System (DMTS) transportation corridor, primarily as a result of fugitive dust deposition originating from operations within the mine and the DMTS. A fugitive dust risk assessment was previously conducted to assess the potential for risks to human and ecological receptors posed by exposure to metals in soil, water, sediments, and biota in areas surrounding the DMTS and outside of the Red Dog Mine ambient air/solid waste permit boundary (Exponent 2007a,b).

The objective of this study was to assess the potential for adverse effects to ecological receptors (e.g., wildlife and plants) from metals exposure under both current conditions and predicted post-closure conditions, in facility areas and in the surrounding tundra environment within the mine ambient air/solid waste permit boundary. This evaluation was conducted in support of the closure planning process, as part of the state solid-waste permitting program.

Potentially complete exposure pathways exist for both terrestrial and aquatic communities within the mine permit boundary. Primary exposure pathways for terrestrial wildlife (such as herbivorous, invertivorous, and carnivorous birds and mammals) include the consumption of plant material or prey and the incidental ingestion of soil, sediment, or water within active facility areas (e.g., pits, waste rock piles, and mine water bodies) and in the surrounding tundra environment. For terrestrial plants, the primary pathways of exposure are uptake of metals from soil, and the uptake of metals deposited onto plant surfaces as fugitive dust. The exposure pathway for fish is incomplete in the mine water bodies, as fish are not present in the tailings impoundment, and will not be present in the future Aqqaluk Pit lake. Aquatic biota including periphyton, invertebrates, and fish are monitored regularly in several streams within the mine area as part of the National Pollutant Discharge Elimination System (NPDES) permit requirements, therefore the aquatic pathway was not further studied in this evaluation.

The assessment endpoints for ecological receptors include survival, growth, and reproduction of various bird and mammal populations. Measurement endpoints were the range of modeled dietary exposures of seven wildlife receptors selected for the evaluation (caribou, ptarmigan, fox, teal, muskrat, shrew, and vole).

Food-web models were developed for the selected wildlife receptors to estimate daily dietary exposures to metals of concern, which are cadmium, lead, and zinc. A variety of current and post-closure scenarios were examined for each receptor. The scenarios evaluated can be generally classified as “near facilities” (more conservative) and “all areas” (more realistic). Measured and predicted values in food, soil, sediment, and surface water were used as inputs in food web models. The metals concentrations in prey media (such as lichen, moss, willow/birch, sedge, invertebrates, and small mammals) were estimated based on existing data sets collected for use in the DMTS risk assessment (Exponent 2007a). Post-closure concentrations in soil and other exposure media were estimated by applying a 2.5 multiplier to current condition concentrations. This selected multiplier was based on the conservative assumption that there is a linear progression in concentration change over time.

Results of this evaluation indicated that population-level effects are unlikely for the caribou, fox, teal, and muskrat under either current conditions or post-closure conditions. Results did indicate a potential for adverse effects to individual ptarmigan, tundra shrew, and tundra vole under both current and post-closure conditions. However, the predicted effects, if occurring, are unlikely to translate into regional population-level effects, given the limited spatial extent of the mine area where adverse effects could occur.

Tundra vegetation communities, although not directly assessed in this study, have been previously found to exhibit localized effects in the vicinity of the mine facilities (Teck Cominco 2005, 2006, 2007). At this point, it is uncertain what degree of change might be expected over time in vegetation communities throughout the broader area within the permit boundary. Additional studies of vegetation communities within the permit boundary are in progress, including a spatial evaluation of effects, assessment of effects mechanisms, and evaluation of possible measures to mitigate effects (Teck Cominco 2006, 2007). As part of this program, some re-growth of moss has been observed in affected areas, perhaps as a result of reductions in fugitive dust deposition over the past several years (Clark 2006, pers. comm.). This work is being conducted under the terms of an MOU between Teck Cominco and DEC (DEC 2005). Regular reports on this work are being submitted to DEC and are posted on the DEC Division of Air Quality website for Red Dog Mine (www.dec.state.ak.us/air/reddog.htm). The ecological significance of potential vegetation effects over the long term may be better assessed in the future based on the results of these ongoing studies.

There are many uncertainties in this evaluation, particularly with respect to predicting future conditions. However, each time an uncertainty was encountered in the evaluation, a conservative assumption was made to ensure that the results of the analysis were conservative, or protective. Using more realistic assumptions in the models reduces or, in many cases, eliminates predicted risk to wildlife receptors.

1 Introduction

Elevated metals concentrations have been identified in tundra in areas surrounding the DeLong Mountain Regional Transportation System (DMTS[1]) and Red Dog Mine, primarily as a result of the deposition of fugitive dust[2] originating from active facilities and roads.

A detailed risk assessment was previously conducted to estimate the magnitude and likelihood of possible risks to human and ecological receptors in areas surrounding the DMTS corridor, and in areas outside the mine boundary (Exponent 2007a). However, the DMTS risk assessment only examined areas surrounding the DMTS and outside the ambient air/solid waste permit boundary at the mine, and did not examine areas within the boundary.

This document evaluates the ecological risks arising from metals in tundra and facility area environments within the Red Dog Mine ambient air/solid waste permit boundary (hereafter referred to as the permit boundary). Risk is evaluated under current conditions and under conditions following closure of the mine and reclamation of the mine facility area. The objective is to provide information needed in evaluating closure options within the mine closure planning process. Although the predictive nature of this evaluation is beyond the scope of a typical risk assessment, and relies heavily on the work documented in the DMTS risk assessment (Exponent 2007a), the evaluation generally follows EPA guidelines for risk assessment as described in the *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (ERAGS, EPA 540-R-97-006, OSWER Directive #9285.7-25, June 1997; U.S. EPA 1997) and in the *Framework for Metals Risk Assessment* (U.S. EPA 2007). Given the scope and limitations of this effort, the work presented herein is referred to as a “risk evaluation” rather than a “risk assessment.”

1.1 Document Organization

This document is organized into the following sections:

- Section 1, Introduction
- Section 2, Site Overview and Environmental Setting
- Section 3, Problem Formulation
- Section 4, Exposure Characterization

---

[1] In this document, “the DMTS” is used to refer to the entire transportation corridor from the mine to the deepwater ships, including the road, the port facilities, and the barges.

[2] “Fugitive dust” is defined herein as any dust or particulate matter emitted to the ambient air from operational activities. Along the DMTS corridor, fugitive dust may originate from ore concentrate, road dust, or a combination of both. Near the mine, fugitive dust may originate from various sources within the mine, including blasting in the pit, ore stockpiles, waste rock dumps, tailings pond sediments (historically), and road dust from truck traffic, which may also include some ore concentrate dust.

- Section 5, Toxicity Assessment
- Section 6, Risk Characterization
- Section 7, Uncertainty Analysis
- Section 8, Interpretation of Ecological Significance
- Section 9, Conclusions
- Section 10, References.

Appendices include:

- Appendix A, Food-Web Model Tables—Current Conditions
- Appendix B, Food-Web Model Tables—Post-Closure Conditions
- Appendix C, Data Tables
- Appendix D, Chronology of Dust Control Improvements to the Mine Operation.

2 Site Overview and Environmental Setting

The Red Dog Mine in the western end of the Brooks Range of Northern Alaska is located approximately 50 miles east of the Chukchi Sea in the foothills of the DeLong Mountains (Figure 1). The mine site is bounded to the north and east by rugged ridges of the DeLong Mountains. To the west and southwest, the mountains give way to more gently sloping terrain. The topography immediately surrounding the mine site is moderately sloped with broad stream valleys. Elevations in the mine area range from 780 to 1,500 ft above sea level (SRK 2007).

SRK (2007) describes the soils in the vicinity of the site as highly variable, depending on slope, aspect, and geological conditions. In general, slopes of the rolling hills have mineral silty soils with some sphagnum peat, while steeper areas exhibit talus slopes. River terraces are characterized by sandy, silty soil overlying cobbles. Floodplains are composed of sand and gravel. Upland drainage channels have sphagnum peat and mineral soil types, while moraine knolls have mineral rocky soils. Lake basins tend to have mineral to organic silty soils. Permafrost has developed to a depth of several hundred feet, and permafrost features such as patterned ground and thaw lakes are found throughout the region. The active layer (seasonal thaw) ranges in depth from 20 to 40 in. in vegetated areas, and up to 10 ft on exposed rocky hillsides (SRK 2007).

Base metal mineralization occurs naturally throughout much of the western Brooks Range (Figures 2 and 3), and strongly elevated zinc, lead, and silver concentrations (reflecting the mineralization) have been identified in many areas (DEC et al. 2002). The mine is located on land owned by the NANA Regional Corporation (see Figure 1). The previously completed DMTS risk assessment focused geographically on the DMTS corridor extending from the Red Dog Mine to the port, including the road, the port facilities, outlying tundra areas, and the marine environment at the port, as well as the area outside of the ambient air/solid waste permit boundary around the mine. This evaluation studies the area within the permit boundary (shown in Figure 4), consisting of approximately 33 square miles.

The Red Dog Mine commenced operations in 1989. Ore containing lead sulfide and zinc sulfide is mined and milled to produce lead and zinc concentrates in powder form. Facilities and features within the permit boundary are illustrated in Figure 4. The concentrates are hauled year-round from the concentrate storage building (CSB) at the mine via the DMTS road to CSBs at the port, where they are stored for later loading onto ships during the summer months.

Moss studies conducted in 2000 and 2001 by the National Park Service (NPS) (Ford and Hasselbach 2001; Hasselbach et al. 2005) reported elevated concentrations of metals in tundra along the DMTS road and near the port, apparently resulting from fugitive dust from these facilities. A fugitive dust study completed for Teck Cominco in 2001 (Exponent 2002a) provided an initial characterization of the nature and extent of fugitive dust releases from the DMTS corridor. The data from that study provided an understanding of baseline conditions from which to monitor the performance of new transport and handling equipment and dust management practices. A fugitive dust background document was published in the spring of 2002, providing an overview of local observations and concerns, local and regional background information, Red Dog Mine operations, regulatory history, environmental data, nature and extent of fugitive dust, a preliminary conceptual site model (CSM) for the risk assessment, and review of regulatory and decision-making frameworks for addressing the fugitive dust issue (DEC et al. 2002).

Additional characterization at the port site was completed in 2002 (Exponent 2003a; Teck Cominco 2003). Sampling programs designed to support the DMTS risk assessment were conducted in 2003 and 2004 to obtain data for additional analytes in multiple environments and media. These programs, which provided data also used in this ecological risk evaluation, are described in Exponent (2003b, 2004), and in Appendices A through G to the DMTS risk assessment (Exponent 2007a).

The nature and extent of dust deposition was evaluated in these prior studies, and described in the associated documents, particularly the 2001 fugitive dust data report (Exponent 2002a) and the fugitive dust background document (DEC et al. 2002). More recently, characterization work has been conducted within the permit boundary, as summarized in Teck Cominco (2005) and illustrated in Figure 5. Some key observations from these studies are summarized below:

- Metals concentrations vary along the length of the road corridor, with the highest concentrations near the port and the mine, as a result of the tracking of concentrate on trucks and tires that occurred historically with haul trucks exiting the CSB at the mine and the truck unloading building at the port.
- Moss tissue concentration data collected during various sampling efforts by NPS and Teck Cominco, when presented together (Figure 6), effectively illustrate the primary source areas and deposition patterns in the vicinity of the DMTS corridor and mine. The moss tissue metal concentration patterns illustrate how the prevailing wind patterns originating from the southeast to northeast result in greatest deposition to the north and west of the DMTS road, and to the west of the active mine areas.
- Within the permit boundary area (shown in Figure 5, and more closely in the inset of Figure 6), metals concentrations in tundra decrease with distance away from facility sources, including the pit, mill facilities, tailings pond, and waste rock piles. Concentrations in the tundra environment are highest to the west of the facility areas, which is the prevailing downwind direction from the dust sources in the active areas of the mine.

Over the years, Teck Cominco has made many improvements to reduce fugitive dust emissions. Broadly, these include improvements to engineering controls and enclosures around ore crushing, milling, concentrate storage, and loading at the mine, as well as concentrate trucking, conveyance, barge loading, and shiploading facilities at the port. In addition to physical dust control improvements, procedural improvements have also been made. A chronology of improvements for dust control within the mine permit boundary is summarized in Appendix D.

3 Problem Formulation

As part of the closure planning process, the objectives of this focused evaluation are to assess ecological risks for the area within the permit boundary (including tundra areas, streams, tailings pond, and other facility areas within the boundary), both for current conditions and for conditions after mine closure (i.e., "post-closure" conditions). More specifically, the question to be addressed by this evaluation is as follows:

- What are the potential risks to ecological receptors (e.g., wildlife and plants) from metals exposure under both current conditions and predicted post-closure conditions, in active areas and surrounding tundra areas within the permit boundary?

Addressing this question involves evaluating exposure concentrations in active areas (e.g., waste rock piles, pits and pit walls, the tailings pond and other possible mine water bodies, etc.) and in outlying tundra areas within the permit boundary that have experienced, and will continue to experience, deposition of metals-bearing dust from operational activities. In this document the active areas within the permit boundary are referred to as the "mine area" or "facility areas," and the areas outside the facility areas are referred to as "outlying areas" or "tundra areas." "Mine water bodies" refers to the man-made water bodies associated with the mine, including the tailings pond, and possible future pit lakes.

3.1 Conceptual Site Model

A CSM is a planning tool used to identify chemical sources (metals in this case), complete exposure pathways, and potential receptors on which to focus the risk evaluation. The CSM describes the network of relationships between sources of metals at the site and the receptors that may be exposed to those metals through pathways (e.g., ingestion of food or water). The CSM examines the range of potential exposure pathways and identifies those that are present and may be important for ecological receptors, and eliminates those pathways that are incomplete, and therefore, do not pose a risk.

The CSM developed for the area within the permit boundary (Figure 7) describes possible sources of exposure to metals within the facility areas and in surrounding terrestrial and aquatic ecosystems, and the pathways by which receptors may be exposed to those metals. The CSM was developed based on site history, conditions, and the results of available sample analyses.

All potential sources of metals exposure were considered in this evaluation, both under current conditions as well as conditions after closure and reclamation. Sources of metals exposure within the permit boundary are primarily the active mine operational areas, including the mill buildings, roads, pits (including future Aqqaluk and Qanaiyaq pits), waste rock piles, main dam, tailings beaches, borrow pits, and stockpiles, and the mine water bodies (the tailings pond that currently exists within the mine boundary, and the Aqqaluk Pit lake that will be present after the mine closes in 2031). Other sources of metals exposure include both tundra and streams in outlying areas, with metals concentrations resulting from dust deposition in these areas.

Tundra areas receive dust deposition originating from the operational areas, including metals-bearing dust from point sources, as well as fugitive dust from distributed sources. Dust can come from multiple material types, such as ore, waste rock, tailings, road construction materials, and ore concentrates. The different dust sources have varying characteristics associated with material type. The dust deposition in the surrounding tundra environment is a mixture of dust from these multiple sources and material types.

A variety of terrestrial and aquatic environments within the permit boundary are potential habitat for ecological receptors. In addition to the active mine facility areas, significant and largely undisturbed tundra areas surround the facilities. For this evaluation, the permit boundary area (approximately 21,000 acres, or 33 square miles) was divided into subareas, as illustrated in Figure 8, and the characteristics of these areas were defined. The outlying tundra areas were roughly defined based on concentration patterns observed in grid-based sampling that had been conducted in the area (Figure 5). On Figure 8, four tundra areas are labeled Tundra Area 1 (59 acres), Tundra Area 2 (122 acres), Tundra Area 3 (1,587 acres) and Tundra Area 4 (17,770 acres); the latter is the largest and farthest outlying from the facilities. Tundra Areas 1, 2, and 3 surround the facilities in relatively close proximity.

Exposure to small-home-range receptors (i.e., shrews and voles) at Tundra Area 1 was not evaluated in this assessment because the area does not provide viable small mammal habitat, as it is immediately adjacent to mill facilities, and is largely devoid of live vegetation. This area will be addressed as part of the mine closure and reclamation process. Exposure to small mammal receptors in Tundra Areas 2, 3, and 4 was evaluated. Exposures of larger-home-range receptors was evaluated across all four tundra areas as well as facility areas.

3.2 Complete Exposure Pathways

An exposure pathway is the course a chemical (metals, in this case) takes from a source to an exposed ecological receptor. Exposure pathways consist of the following four elements: 1) a source; 2) a mechanism of release, retention, or transport to a given medium (e.g., air, water, soil); 3) a point of contact with the medium (i.e., exposure point); and 4) a route of exposure at the point of contact (e.g., incidental ingestion, dermal contact). If any of these elements is missing, the pathway is considered incomplete (i.e., it does not present a means of exposure). Only those exposure pathways judged to be potentially complete are considered to be of concern for ecological receptors. Additionally, exposure to naturally occurring metals likely occurs throughout the area, both beyond and within the area of the permit boundary, through the pathways described above. Exposure of receptors to metals in facility areas and to metals in outlying tundra areas affected by dust represents an incremental exposure above the exposure to naturally-occurring metals.

Potential pathways by which ecological receptors may be exposed to metals associated with the Red Dog Mine exist for both terrestrial and aquatic ecological receptors within the permit boundary, as illustrated in the CSM (Figure 7). Potential exposure environments within the permit boundary include tundra and facility areas, streams, and mine water bodies. The mine water bodies include the tailings impoundment that currently exists within the mine boundary, and the Aqqaluk Pit lake that will be present after the mine closes in 2031 (Figure 8). The CSM identifies routes by which receptors are potentially exposed to chemicals of potential concern (CoPCs), but makes no conclusions regarding potential risks associated with the exposure pathways.

Primary exposure pathways are those expected to contribute most to total exposure, while secondary exposure pathways are not expected to substantially increase exposure. Primary exposure pathways for terrestrial wildlife (e.g., herbivorous, invertivorous, and carnivorous birds and mammals) include the consumption of plant material or prey and the incidental ingestion of soil, sediment, or water within facility areas (e.g., pits, waste rock piles, and mine water bodies) and in the surrounding tundra areas. Secondary exposure pathways for terrestrial wildlife include dermal contact with and ingestion of surface water and inhalation of soil particles. In most situations, dermal contact and inhalation are less important sources of metals exposure in wildlife than are food and incidental soil ingestion (Newman et al. 2003; U.S. EPA 2007). The external epithelium, an effective barrier to inorganic metals, minimizes the dermal uptake of metals in higher organisms (Drexler et al. 2003). In general, inhalation of particles is assumed to be insignificant compared to other exposure routes for metals and is typically not addressed in ecological risk assessments (Newman et al. 2003). Therefore dermal contact is not considered a pathway for terrestrial wildlife, and inhalation is generally considered a secondary pathway.

For terrestrial plants, the primary pathways of exposure are contact with, and uptake of, metals incorporated into soil and the uptake of metals deposited onto plant surfaces as fugitive dust (Figure 7). Soil fauna are primarily exposed to metals through direct contact with and uptake of the soil and via ingestion of food in soil.

For aquatic plants, the primary pathways are direct uptake of sediment and surface water, and contact with surface water. Primary exposure pathways for aquatic receptors, such as fish and aquatic invertebrates in the mine water bodies (e.g., tailings pond or pit lake) or streams, include the ingestion or uptake of surface water, consumption of plant material or prey (if present), incidental ingestion of sediment during foraging, and direct contact with surface water (Figure 7). Secondary exposure pathways for aquatic receptors include contact with sediment. Some aquatic receptors may also be exposed through the uptake of metals from sediments.

The pathway for fish is incomplete in the mine water bodies (i.e., tailings impoundment and future Aqqaluk Pit lake) because fish are not present in the tailings impoundment, and will not be present in the future Aqqaluk Pit lake, given highly mineralized conditions and low pH.

3.3 Assessment Endpoints

The assessment endpoints for the ecological risk evaluation are summarized in Table 1. Assessment endpoints include any likely adverse ecological effects on receptors for which exposure pathways are complete. They represent important environmental values and could be adversely affected by exposure to metals in the environments within the permit boundary (U.S.

EPA 1997). The assessment endpoints were adapted from those defined in the DMTS ecological risk assessment (Exponent 2007a).

Five assessment endpoints were evaluated in the terrestrial tundra environment:

- Structure and function of terrestrial plant communities
- Survival, growth, and reproduction of terrestrial avian herbivore populations
- Survival, growth, and reproduction of terrestrial mammalian herbivore populations
- Survival, growth, and reproduction of terrestrial mammalian invertivore populations
- Survival, growth, and reproduction of terrestrial mammalian carnivore populations.

Two assessment endpoints were evaluated in the stream environment:

- Survival, growth, and reproduction of stream avian herbivore populations
- Survival, growth, and reproduction of stream mammalian herbivore populations.

Two assessment endpoints are evaluated in the mine water body environments (i.e., tailings pond, possible future pit lake):

- Survival, growth, and reproduction of aquatic avian herbivore populations
- Survival, growth, and reproduction of aquatic mammalian herbivore populations

3.4 Measurement Endpoints

The measurement endpoints for the ecological risk evaluation are summarized in Table 1. Measurement endpoints are defined as measurable ecological characteristics related to valued characteristics chosen as the assessment endpoints, and are measures of biological effects, such as mortality, reproduction, or growth (U.S. EPA 1997). The measurement endpoints provide the actual parameters used to evaluate attainment of each assessment endpoint. For assessment endpoints such as the survival, growth, and reproduction of various bird and mammal populations, the measurement endpoints are the range of modeled dietary exposures of each representative receptor to CoPCs (based on measured and predicted CoPC concentrations in food, soil, sediment, and surface water) as compared to toxicity reference values (TRVs) derived from the literature. To assess the structure and function of the terrestrial plant community assessment endpoint, the measurement endpoints included the comparison of measured CoPC concentrations in moss with literature-based effects levels.

3.5 Ecological Receptors Evaluated

This section describes the ecological receptors selected to represent functional and/or taxonomic groups identified as assessment endpoints, such as terrestrial mammalian invertivores or aquatic avian herbivores, in the quantitative wildlife exposure assessment. The following seven wildlife receptors were selected for use in the evaluation:

- Willow ptarmigan (terrestrial avian herbivore)
- Tundra vole (terrestrial mammalian herbivore)
- Caribou (terrestrial mammalian herbivore)
- Tundra shrew (terrestrial mammalian invertivore)
- Arctic fox (terrestrial mammalian carnivore)
- Green-winged teal (stream and pond avian herbivore)
- Muskrat (stream and pond mammalian herbivore).

These specific receptors are listed in Table 1 and were selected for two reasons:

1. To include receptors for which potential risk was identified in DMTS risk assessment
2. To evaluate representative receptors from different trophic levels or ecological guilds relevant to the terrestrial and aquatic environments within the permit boundary, including herbivores, invertivores, and carnivores in terrestrial and aquatic environments. Although not every possible trophic category is represented by these selected receptors, those most relevant or most likely to be affected have been included.

In the terrestrial environment, the caribou was selected as a large-home-range herbivore, the ptarmigan as a small- to medium-home-range herbivore, the fox as a medium-home-range carnivore, and the vole and shrew as small-home-range herbivores and invertivores, respectively. The teal was selected as a representative aquatic herbivore, and the muskrat as an aquatic herbivore that spends some time in the terrestrial environment as well.

The following wildlife receptors were evaluated in the DMTS risk assessment (Exponent 2007a), but were not evaluated in this assessment, as explained below:

- Moose (terrestrial and stream mammalian herbivore)
- Lapland longspur (terrestrial avian invertivore)
- Snowy owl (terrestrial avian carnivore)

- Common snipe (terrestrial and stream invertivore)
- Brant (coastal lagoon avian herbivore)
- Black-bellied plover (coastal lagoon avian invertivore).

The brant and black-bellied plover were not included in this assessment because they were receptors for the coastal environment. The moose, longspur, snowy owl, and snipe were not included because the potential for effects was found to be low in the DMTS risk assessment. In addition, piscivorous receptors were not included because they were screened out in the screening assessment in the DMTS risk assessment, and thus similarly have a low likelihood of effects.

Potential risks to aquatic biota in streams are not evaluated further in this document. Pre- and post-mining surveys have indicated limited aquatic life in Red Dog Creek as a result of naturally high concentrations of cadmium, lead, zinc, aluminum, and other metals, as well as naturally low pH (U.S. EPA 2006). As a result of effective water management and treatment practices, aquatic productivity has increased in the main stem Red Dog Creek relative to pre-mining conditions, and fish barriers have been constructed to block passage of fish up the Middle Fork, which leads to the point of discharge for the mine (U.S. EPA 2006). If mine discharges were to be discontinued, aquatic productivity in the stream would decrease (U.S. EPA 2006). As part of the National Pollutant Discharge Elimination System permit requirements, periphyton (measured as chlorophyll-a), taxa richness and abundance of aquatic invertebrates, and fish presence and use are monitored in several creeks, including the Middle Fork of Red Dog Creek (Ott and Morris 2006; www.dnr.state.ak.us/habitat/reddog.htm).

Plant communities may also be affected within the permit boundary. Some adverse effects on the vegetation community have been observed in the vicinity of the mine facility areas, such as absence or mortality of mosses, lichens, and liverworts, and leaf loss on some evergreen shrubs (Teck Cominco 2005, 2006, 2007). It is unclear what degree of change might be expected over time in vegetation communities throughout the area within the permit boundary as a whole. Under the terms of a recent memorandum of understanding (MOU) (DEC 2005), studies of vegetation communities currently in progress within the permit boundary include a spatial evaluation of effects, assessment of effects mechanisms, and evaluation of possible measures to mitigate effects (Teck Cominco 2006, 2007). Regular reports on this work are being submitted to DEC and are posted on the DEC Division of Air Quality website for Red Dog Mine (www.dec.state.ak.us/air/reddog.htm).

The structure and function of tundra soil fauna communities were not evaluated quantitatively in this assessment. Ecological screening benchmarks for soil are typically much lower for plants than for soil fauna. Therefore, it is anticipated that if there were adverse effects resulting from the presence of incremental metals concentrations in tundra habitats, these effects would be observed in plant communities before effects on soil fauna would be observed. For this reason, it is assumed that evaluation and monitoring of the terrestrial plant community will be protective of soil fauna.

4 Exposure Characterization

Receptor-specific food-web models were developed to estimate daily dietary exposures to CoPCs for selected receptors that may feed at the site. This approach allows for a direct comparison of exposure rates with measures of toxicity and is consistent with EPA's wildlife exposure guidance (U.S. EPA 1993; 61 Fed. Reg. 47552). Exposure variables in food-web models include receptor-specific parameters such as body weight; food, water, and sediment or soil ingestion rates; dietary composition; and fractional intake, as well as site-specific CoPC concentrations in dietary components and inert media (U.S. EPA 1997).

The food-web model estimates dietary exposure as a body-weight-normalized total daily dose for each receptor species. The general structure of the food-web exposure model is described by the following equation:

$$IR_{chemical} = \frac{\sum_i \left(C_i \times M_i \times A_i \times F_i\right)}{W}$$

where:

- $IR_{chemical}$ = total ingestion rate of chemical from all dietary components (mg dry weight/kg body weight/day)
- C_i = concentration of the chemical in a given dietary component or inert medium (mg/kg dry weight)
- M_i = rate of ingestion of dietary component or inert medium (kg dry weight/day)
- A_i = relative gastrointestinal absorption efficiency for the chemical in a given dietary component or inert medium (fraction)
- F_i = fraction of the daily intake of a given dietary component or inert medium derived from the site (unitless area-use factor)
- W = body weight of receptor species (kg).

The term $IR_{chemical}$ can be expanded to specify each ingestion medium, which includes one or more primary food items, drinking water, and incidentally ingested sediment or soil:

$$IR_{chemical} = [\Sigma\ (C_{food} \times M_{food} \times A_{food} \times F_{food}) + (C_{water} \times M_{water} \times A_{water} \times F_{water}) + (C_{sediment/soil} \times M_{sediment/soil} \times A_{sediment/soil} \times F_{sediment/soil})]/W$$

The model provides an estimated total dietary exposure to chemicals resulting from consumption of food and the incidental ingestion of soil or sediment on a mg chemical/kg body-weight-day basis.

For all the receptors modeled, the screening-level exposure calculation assumed that the entire diet comes from the study area ($F_i = 1$), and that 100 percent of the chemical ingested in food is absorbed ($A_i = 1$). These conservative assumptions represented a worst-case exposure scenario; thus, using these values resulted in protective exposure estimates that were appropriate for a screening-level assessment. Water ingestion was not included in the exposure analysis, but because chemical concentrations in water are low, exposure via water would be minimal compared to exposure via food and soil/sediment ingestion, and results are not affected by omission of this pathway.

4.1 CoPCs Evaluated

A large number of CoPCs were evaluated in the DMTS risk assessment, including aluminum, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, fluoride, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, tin, vanadium, and zinc (Exponent 2007a). Cadmium, lead, and zinc concentrations in tundra soil and moss were measured within the permit boundary and compared to the measured concentrations from the DMTS area. The maximum concentrations for the CoPCs in tundra soil and moss were similar to or lower than concentrations in the DMTS dataset (Table 2), and therefore the screening assessment conducted as part of the DMTS risk assessment is considered applicable and relevant to the area within the permit boundary.[3] Of the CoPCs evaluated in the DMTS risk assessment, the primary CoPCs for which potential ecological risks were identified were cadmium, lead, and zinc. Thus, these three metals were the CoPCs evaluated in this study, for the area within the permit boundary.

4.2 Exposure Scenarios

A variety of exposure scenarios were evaluated for the various receptors for both current and post-closure conditions within the permit boundary as well as in reference areas. The fox, ptarmigan, vole, shrew, and muskrat were assumed to reside year-round within the permit boundary. The teal is assumed to be present within the permit boundary for 4 months and at the reference area for the remaining 8 months. The caribou was assessed using two different time-use scenarios. For the overwintering scenario, caribou are assumed to be present at the facility for 5 consecutive months, and are assumed to migrate elsewhere for the remaining 7 months of the year. In the resident scenario, caribou are assumed to be present on the site for 8 consecutive months and at the reference area for the remaining 4 months of the year.

The scenarios evaluated for each receptor depend in part on the receptor's home-range size and the amount of time assumed to be present at the facility. The scenarios are described below and are summarized in Table 3:

- All Areas/All Water Scenario. In this scenario, ptarmigan, teal, and muskrat were assumed to range over all terrestrial areas within the permit boundary. Exposure concentrations in each exposure area within the permit boundary (Figure 8) are weighted by the fraction of the overall area. This scenario also assumes that the receptors use all water sources within the permit boundary,

[3] Maximum media concentrations were used in the DMTS screening assessment.

with exposure concentrations from each water source weighted by its fraction of the overall area. The water sources include the streams (associated with the area of outlying Tundra Area 4) and the tailings impoundment.

- All Areas/All Water Overwintering Scenario. This scenario is used to evaluate exposure for the caribou. This scenario is similar to the All-Areas/All Water Scenario, except that caribou are assumed to be present on the site for 5 months, and for the remaining 7 months of the year they are assumed to migrate elsewhere.

- All Areas/All Water Resident Scenario. This scenario is also used to evaluate exposure for the caribou. This scenario is similar to the All Areas/All Water Scenario, except that caribou are assumed to be present on the site for 8 months, and for the remaining 4 months of the year they are assumed to spend time at the reference area. (Note that the reference area used for this assessment is the same as that used for the DMTS risk assessment, and is located just south of the mine as shown on Figure 1.)

- Near-Facilities Scenario. This scenario is used to evaluate ptarmigan, fox, teal, and muskrat exposure, assuming that these receptors are restricted to areas within and near the facilities (i.e., assuming a more limited home-range). In this scenario, Tundra Area 4 and the stream water source are excluded. The water source is assumed to be the tailings impoundment.

- Tundra Area Scenario. Small mammals (i.e., tundra vole and tundra shrew), as small-home-range receptors, were assumed to be restricted to limited areas within each of the tundra areas where they may live. The assumed water source for the small mammals is the streams (although in reality they likely get water from their food and from within the tundra). The terrestrial habitats included in this scenario include Tundra Areas 1, 2, 3, and 4.

Additional scenarios are included for evaluation of possible variations to receptor exposures under post-closure conditions. These additional scenarios are described below, and are also summarized in Table 3:

- All Areas/50 Percent Impoundment Scenario. This scenario is used to evaluate ptarmigan, fox, teal, and muskrat exposure, assuming that these receptors are exposed to all terrestrial areas within the permit boundary, with exposure concentrations in each area weighted by its fraction of the overall area. In this scenario, usage of the tailings impoundment is set at 50 percent. The other 50 percent of water usage is assumed to consist of streams and Aqqaluk Pit Lake with adjusted area-based percentages.

- Near-Facilities/Impoundment and Pit Lake Scenario. This scenario is used to evaluate ptarmigan, fox, teal, and muskrat exposure, assuming that these receptors are restricted to areas within and near the facilities (i.e., assuming a more limited home-range). In this scenario, Tundra Area 4 and the stream water source are excluded, and the receptors are instead assumed to use the tailings impoundment and Aqqaluk Pit Lake with adjusted area-based percentages.

- Near-Facilities/Pit Lake Scenario. This scenario is used to evaluate a worst-case exposure for ptarmigan under post-closure conditions, assuming that the ptarmigan is restricted to areas within and near the facilities, and to consume water only from the future Aqqaluk Pit Lake.
- Near-Facilities/50 Percent Pit Lake Scenario. This scenario is used to evaluate a worst-case exposure for teal under post-closure conditions, assuming that the teal is constrained to areas within and near the facilities, with 50 percent use of the tailings impoundment water and 50 percent use of the future Aqqaluk Pit Lake.

4.3 Exposure Concentrations

This section describes existing and predicted exposure concentration datasets, and how the datasets were prepared for various media so that both current and post-closure conditions could be evaluated.

4.3.1 Current Conditions

The first objective of this focused risk evaluation is to assess ecological risks under current conditions that represent metals concentrations in tundra and facility areas resulting from operations from the start of the mine (1989) to the present. The data used to evaluate the potential risk of adverse effects to receptors as a result of current conditions are discussed below and summarized in Table 4.

4.3.1.1 Soil Concentrations—Tundra Areas

A grid dataset was available that includes lead, zinc, and cadmium data collected during an x-ray fluorescence (XRF) sampling program in the tundra areas (Teck Cominco 2005). XRF data were used in this evaluation without adjustment, because the concentrations have typically been higher on average than analytical laboratory values, lending a conservative element to the analysis (Exponent 2002b, 2003c). Figure 5 shows the distribution of lead concentrations in samples collected during that effort. The XRF dataset was used to calculate 95-percent upper confidence level (UCL) on the mean lead, zinc, and cadmium concentrations in each of the four tundra exposure areas illustrated in Figure 8. These tundra soil metals concentrations are shown in Table 4.

4.3.1.2 Soil Concentrations—Facility Areas

Soil concentrations in facility areas (including waste rock) for current conditions were estimated from various sources, as indicated in the footnotes in Table 4. Appendix C provides data tables from which values in Table 4 were obtained.

4.3.1.3 Water Concentrations

Water concentrations were used in the risk evaluation to represent the drinking water component of the diet for the wildlife receptors. Water concentrations for current conditions in the areas within the permit boundary are included in Table 4. These tables were assembled from water quality data collected for streams from 1998 through to the present. The tailings impoundment water data were assembled from 2003 and 2005 reclaim water quality data. Appendix C provides data tables from which values in Table 4 were obtained.

4.3.1.4 Other Exposure Media

Other exposure media that were also considered in the evaluation included the following: lichen, moss, willow/birch, sedge (blades, seeds, whole plant), invertebrates, and small mammals. The concentrations in these media are provided in Table 4 and were estimated based on existing datasets collected for use in the DMTS risk assessment (Exponent 2007a). The DMTS datasets were used to establish predictive relationships between each of these media and tundra soil. The concentrations in exposure media within the permit boundary were then estimated by applying the predictive relationships established between the DMTS exposure media and DMTS tundra soil to the existing tundra soil dataset in the area within the permit boundary (Figure 5). In cases where predictive correlation relationships could not be established, 95-percent UCL on the mean values for the DMTS risk assessment media datasets were used instead. The methods used to prepare these data are described in further detail in the following section.

4.3.1.5 Preparation of Exposure Media Data for the Evaluation

Statistical analyses of metals concentrations were used to predict concentrations in multiple media for use in the ecological risk evaluation within the permit boundary. Predictive relationships were developed to estimate concentrations of lead, zinc, and cadmium in lichen, willow, sedge (blades, seeds, and whole plant), moss, invertebrates, and mammal tissue. The predictive relationships were then used to predict concentrations within the various media based on the concentrations in tundra soil.

Initial analyses evaluated the correlation between concentrations of each DMTS metal measured in tundra soil with lichen, willow, sedge (blades only), moss, invertebrates, and mammal tissue concentrations collected at the same locations (Table 5). Sedge seeds and whole plants were not collocated with any tundra soil samples. Aluminum, antimony, barium, and thallium in DMTS tundra soil were measured in only a subset of tundra soil samples; these were the samples used to develop the correlations with lead, zinc, and cadmium concentrations in DMTS tundra soil (Table 5). (Note: Although lead, zinc, and cadmium were the three metals of interest for this evaluation, aluminum, antimony, barium, and thallium concentrations were also used to develop the best predictive relationships for the various media; therefore, correlations with aluminum, antimony, barium, and thallium are also included in Table 5.) If multiple analytical results were available for a given tissue medium but only a single tundra soil sample was available, the tundra soil concentration was paired with each of the other media sample results to prepare the dataset for analysis. The Spearman rank correlation method was used to avoid needing to make assumptions regarding concentration distributions across all media and metals. The strongest and most significant correlations were used to establish the best predictive relationship for each of the media. Table 5 summarizes the correlation estimates with DMTS tundra soil for all media and lists the best predictive relationship for each. Only significant correlations ($P < 0.05$) were included in selecting the best prediction relationships. If tundra soil did not provide a significant correlation, relationships among other media (i.e., biota tissue) were evaluated.

Simple linear regression was used to quantify the predictive relationships. The best predictor based on the correlation analysis was regressed against the metal and media to be predicted. All concentrations were $\log_{10}$ transformed prior to the regression analysis, and residual plots and probability plots were evaluated to confirm that the underlying assumptions of the regression method were met by using the $\log_{10}$ transformation. All model outputs, including model fit statistics and coefficient estimates, are provided directly from the fit of each relationship (i.e., from fitting a linear model to the $\log_{10}$ transformed variables). A summary of the significant predictive relationships among tundra soil and various biota tissue media is provided in Table 6. Where reliable, predictive relationships were achieved between tundra soil and other media, those are presented. In some cases where predictive relationships were not established with tundra soil, relationships were established among tissue media, as indicated in Table 6.

The regression models in Table 6 were used (where needed) to predict concentrations for each metal in each medium based on the mean and 95 percent UCL concentrations in tundra soil. The predictive relationships for aluminum, antimony, barium, and thallium concentrations in tundra soil were used to prepare a complete tundra soil dataset by calculating concentrations for needed metals that had not been measured at the station locations within the permit boundary. EPA's ProUCL software was used to calculate summary statistics and the recommended UCL for each dataset. The prepared tundra soil dataset, combining measured and predicted values, is summarized in Table 7. Table 8 provides summary statistics, including UCL concentrations, for the most representative measured concentrations in all biota tissue media, either from data collected at stations within the permit boundary (e.g., moss), or from the datasets previously collected for the DMTS risk assessment. A complete dataset for biota tissue concentrations was then prepared by using: 1) the available measured data within the permit boundary, 2) predicted values where significant predictive relationships were available, and 3) where predictive relationships were not suitable, the most representative of the available measured biota data. These are summarized in Table 8. The complete prepared dataset (mean and UCL values) is shown in Table 9, which indicates the source of the values, whether from measurements or predictions. This table summarizes the best estimates of concentrations in all tissue media for use in the ecological risk evaluation.

Concentrations were predicted only for media where the relationship based on tundra soil was significant ($P<0.05$) and explained greater than 50 percent of the variability ($R^2 >50\%$). The best predictive relationships for several metal and media combinations had R^2 values less than 50 percent; these were not used for prediction, as noted in Table 6.

4.3.2 Post-Closure Conditions

Post-closure concentrations in soil and other exposure media were estimated by applying a 2.5 multiplier to current condition concentrations (described below and in Section 7.1.2). The

2.5 multiplier is based on the assumption that there is a linear progression in media concentration change over time. From the time the mine opened in 1989 to the present (year 2006) is equivalent to 17 years, and the mine is expected to be operational until 2031, representing 42 years of operations. Therefore, 42 years of forecasted operations divided by 17 years of actual operations yields an approximate factor of 2.5. Inherent in this assumption is the idea that the areas surrounding Red Dog Mine began with baseline CoPC concentrations of zero. In reality, this assumption ignores any background concentrations present before mine operations began in 1989. Also, concentration increases associated with mine operations in surrounding areas are not likely to occur on a strictly linear basis (that is, recent and planned fugitive dust control measures result in reduced emissions compared to the early years of operations); therefore, the 2.5 multiplier provides a conservative estimate for predicted post-closure conditions. Further discussion on the conservative nature of this assumption is provided in Section 7.1.2. Concentrations used in the post-closure scenario evaluation are described below and summarized in Table 10.

4.3.2.1 Soil Concentrations—Tundra Areas

Soil concentrations that were measured in Tundra Areas 1–4 and used for the current conditions evaluation were also used for the post-closure evaluation after multiplying them by a factor of 2.5 to estimate future concentrations. Post-closure tundra area soil concentrations are presented in Table 10.

4.3.2.2 Soil Concentrations—Facility Areas

Soil concentrations in facility areas for post-closure conditions (e.g., concentrations for waste rock, cover materials, and road surfaces) were estimated from various sources, as indicated in the footnotes in Table 10. Appendix C provides data tables from which values in Table 10 were obtained. It was assumed that Kivalina shale would be used as cover material over all facility areas that are to be covered as part of closure and reclamation. In contrast to the soil concentrations in tundra areas described above, the metals concentrations in these materials were not multiplied by the factor of 2.5 because the unadjusted concentrations represent the nature of the material to be present and/or stockpiled and used as cover material on the surface of these areas.

4.3.2.3 Water Concentrations

Water bodies evaluated for post-closure conditions included the streams associated with Tundra Area 4, the tailings impoundment, and the Aqqaluk Pit lake. The stream water concentrations that were used in the model are equivalent to those used in the current conditions evaluation, based on stream data available from stations within the permit boundary. The mine tailings impoundment and Aqqaluk Pit lake data were modeled by SRK (2004) and SRK (2006a), respectively, and reflect a more conservative “dirty pond” scenario, rather than the likely objective of a “clean pond” scenario. All water concentrations used in the post-closure evaluation are included in Table 10, and supporting data are provided in Appendix C tables.

4.3.2.4 Other Exposure Media

Other exposure media that were used in the post-closure evaluation included the following: lichen, moss, willow/birch, sedge (blades, seeds, whole plant), invertebrates, and small mammals. The concentrations that were developed and used for the current conditions analysis from predictive relationships based on the DMTS risk assessment were multiplied by a factor of 2.5 (as described above) to conservatively estimate future concentrations. All predicted media concentrations used in the post-closure evaluation are included in Table 10.

5 Toxicity Assessment

Food-web exposure models were developed to estimate site-specific daily doses of CoPCs for selected receptors. The potential for adverse effects to wildlife populations was evaluated by comparison of exposures with toxicity effects thresholds using the hazard quotient approach. The ratio of an exposure estimate to an ecotoxicity value, such as a TRV, is known as a hazard quotient (U.S. EPA 1997). Hazard quotients developed as single-point exposure and effects comparisons are useful for identifying potential low- or high-risk situations (63 Fed Reg. 26845–26924).

The hazard quotient is computed as follows:

$$HQ = \frac{IR_{chemical}}{TRV}$$

where:

HQ = hazard quotient (unitless)

$IR_{chemical}$ = total ingestion rate of the chemical (mg/kg body weight-day)

TRV = toxicity reference value (mg/kg body weight-day).

For each food-web model exposure scenario evaluated, the daily dietary exposure to a CoPC was compared against the no-observed-adverse-effect level (NOAEL) and lowest-observed-adverse-effect level (LOAEL) TRVs (Table 11). For migratory receptors that spend only a portion of the year at the site, hazard quotients for the site and reference areas were weighted by residence time at the site (time use, reported in Table 12) and summed to derive a quotient that reflected year-round chemical exposure.

The focus of the toxicity assessment is on receptor and chemical combinations for which hazard quotients indicate the potential for adverse ecological effects (i.e., hazard quotients greater than 1.0). The majority of receptor and chemical combinations evaluated had NOAEL-based hazard quotients below 1.0, indicating a low likelihood of adverse ecological effects.

NOAEL and LOAEL hazard quotient results for each receptor, all analytes, and all scenarios evaluated (described above in Section 4.2 and summarized in Table 3) are presented in Table 13 for current conditions and Table 14 for post-closure conditions. Tables of the food web model calculations for each receptor in each of the scenarios are provided in Appendix A for current conditions and Appendix B for post-closure conditions.

6 Risk Characterization

In this section, the hazard quotients calculated in the toxicity assessment are evaluated and interpreted to characterize the ecological risks to assessment endpoints (survival, growth, and reproduction of wildlife populations). The daily dietary exposure estimates for wildlife receptors were compared against 1) no-effects levels (NOAEL TRVs), and 2) thresholds at which significant adverse effects to test organisms were observed in laboratory studies (LOAEL TRVs). Exposure estimates that are below the NOAEL TRV identify conditions under which adverse ecological effects are unlikely to occur to bird or mammal populations.

Exposure estimates greater than the NOAEL TRV, but less than the LOAEL TRV, indicate that individuals are ingesting chemicals in excess of a toxicity threshold and may exhibit adverse effects similar to those observed in the test organisms. In these cases, risk cannot definitively be concluded to be negligible, because the true effect threshold is not exactly known, only that it lies somewhere between the NOAEL and LOAEL. Furthermore, because the endpoints measure organism-level responses, there is considerable uncertainty regarding how these effects, if occurring, would translate to population-level demographics.

For CoPCs where hazard quotients are greater than 1.0 in comparison to both the NOAEL and LOAEL TRVs, adverse effects could occur in wildlife receptors, and could affect population-level parameters (e.g., survivorship, productivity, population abundance). However, if a hazard quotient is less than or equal to hazard quotients for the same receptor-CoPC exposure scenario in the reference area, then it can be concluded that the site poses no incremental risk over background exposures in that case.

The results of the risk characterization are presented in Tables 13 and 14, and are discussed in the following sections.

6.1 Caribou

6.1.1 Current Conditions

In the current conditions evaluations, caribou were evaluated under two scenarios. The first scenario (All Areas/All Water Overwintering) assumes that caribou are present within the permit boundary area for 5 months, while the second scenario (All Areas/All Water Resident) assumes the caribou are present onsite for 8 months of the year. For both scenarios, the NOAEL and LOAEL hazard quotients for lead, cadmium, and zinc did not exceed 1.0 for caribou foraging within the permit boundary area. The only exception is lead, with a hazard quotient of 1.1 in the Resident Scenario (Table 13). The results indicate that adverse effects to caribou foraging within the permit boundary from cadmium, lead, and zinc are unlikely, considering that caribou are unlikely to spend 8 months of the year within the permit boundary.

6.1.2 Post-Closure Conditions

Hazard quotients for cadmium and zinc were less than 1.0 for caribou foraging within the permit boundary under both the All Areas/All Water Overwintering and Resident scenarios in the post-closure scenario, indicating that no effects are predicted from exposure to these CoPCs (Table 14). Exposure levels exceeded the NOAEL TRV but not the LOAEL TRV for lead in both the overwintering and resident scenarios. Based on these results, effects from lead exposure appear unlikely because the LOAEL TRV was not exceeded, but cannot be ruled out since the NOAEL TRV was exceeded.

6.2 Ptarmigan

Ptarmigan were evaluated under two scenarios for current conditions, and four scenarios for post-closure conditions. The results for both evaluations are described below.

6.2.1 Current Conditions

In the All Areas/All Water Scenario, ptarmigan were assumed to range over all terrestrial areas within the permit boundary and to use the streams and tailings impoundment as water sources (see Section 4.2 and Table 3). In the Near Facilities Scenario, ptarmigan were assumed to use only the Tundra Areas 1, 2, and 3 and the water source was the tailings impoundment. Hazard quotients for cadmium were less than 1.0 for ptarmigan in the All Areas/All Water scenario. Although cadmium exposure slightly exceeded the NOAEL TRV in the Near Facilities scenario for current conditions (hazard quotient = 1.02), the LOAEL TRV was not exceeded (Table 13). The hazard quotient for zinc was less than 1.0 in the All Areas/All Water scenario, but was 1.4 in the Near Facilities scenario. Although potential effects from zinc cannot be ruled out, the slight exceedance in the near facilities scenario is based on a NOAEL TRV only, because no zinc LOAEL is available. Lead exposure estimates exceeded the NOAEL and LOAEL TRVs in both exposure scenarios, indicating the possibility of effects, although the LOAEL exceedance is small in the all areas scenario.

6.2.2 Post-Closure Conditions

Under post closure conditions, hazard quotients for lead were elevated under each of the exposure scenarios evaluated, indicating the possibility of effects from lead (Table 14). The highest exceedances occurred in the two near facilities scenarios. Cadmium hazard quotients slightly exceeded 1.0 when compared to NOAEL TRVs, but not LOAEL TRVs. Zinc hazard quotients slightly exceeded 1.0 in all scenarios when compared to NOAEL TRVs, but LOAEL TRVs were not available for zinc. Thus, while effects from cadmium and zinc cannot be ruled out, they are less likely than the potential for effects from lead.

6.3 Fox

6.3.1 Current Conditions

Hazard quotients for cadmium and zinc were below 1.0 in both the All Areas/All Water and Near Facilities scenarios under current conditions, indicating that no effects are predicted in arctic fox (Table 13). The NOAEL and LOAEL hazard quotients for lead was below 1.0 in the All Areas/All Water Scenario. In the Near Facilities Scenario, the NOAEL hazard quotient was slightly greater than 1.0 (1.01) but the LOAEL hazard quotient was less than 1.0, suggesting potential for risk if fox use only Tundra Areas 1, 2, and 3, and only drink water from the tailings impoundment. In the more realistic All Areas/All Water Scenario, there is no potential for adverse effects, and therefore, it is unlikely that lead, zinc, and cadmium pose a risk to fox that utilize the area within the permit boundary.

6.3.2 Post-Closure Conditions

With the exception of the Near Facilities/50% Impoundment/Pit Lake scenario, all hazard quotients for cadmium, lead, and zinc were below 1.0 for the arctic fox under post-closure conditions (Table 14). Even when exposure is assumed to occur entirely in the Near Facilities area with all water intake derived from impoundment water, the lead hazard quotient based on a NOAEL TRV was only 1.1; and all other hazard quotients were below 1.0 for this scenario. Thus, effects in arctic fox are unlikely to occur under post-closure conditions.

6.4 Teal

6.4.1 Current Conditions

No effects are predicted in green winged teal in the All Areas/All Water scenario under current conditions because all hazard quotients were less than 1.0 (Table 13). In the Near Facilities Scenario, predicted exposure levels for lead exceeded the NOAEL and LOAEL TRVs, suggesting potential risk if teal use solely Tundra Areas 1, 2, and 3, and drink water only from the tailings impoundment. In the more realistic All Areas/All Water scenario, the potential for risk associated with lead is unlikely.

6.4.2 Post-Closure Conditions

No effects are predicted for the green winged teal for the All Areas scenarios under post-closure conditions (Table 14). In addition, no effects are predicted from cadmium and zinc in the Near Facilities scenarios. However, possible effects from lead cannot be ruled out in the Near Facilities scenarios because lead hazard quotients were slightly elevated (above 3.0 for the NOAEL TRVs and above 1.0 for the LOAEL TRVs) in Near Facilities scenarios that assume intake of either impoundment water only or 50 percent pit lake water and 50 percent impoundment water.

6.5 Muskrat

6.5.1 Current Conditions

No adverse effects are predicted for muskrat in the All Areas scenario under current conditions because hazard quotients for cadmium, lead, and zinc did not exceed 1.0 (Table 13). In the Near Facilities scenario, effects cannot be ruled out because predicted lead exposure levels slightly exceeded the NOAEL TRV but not the LOAEL TRV; however, in the Near Facilities area the muskrat is assumed to use only Tundra Areas 1, 2, and 3, and use the tailings impoundment as the sole water source. In the more realistic All Areas scenario, adverse effects are not predicted, and therefore it is unlikely that muskrat will experience adverse effects from lead under current conditions.

6.5.2 Post-Closure Conditions

No effects are predicted for the muskrat under post-closure conditions for both the All Areas/All Water and the All Areas/50% Impoundment scenarios because hazard quotients for cadmium, lead, and zinc were all less than 1.0 (Table 14). In the Near Facilities scenario, effects from lead cannot be ruled out because the predicted lead hazard quotient based on the NOAEL TRV was 2.0. This exposure scenario, however, is not realistic because muskrat would not find appropriate habitat and food sources in the tailing impoundment and would be unlikely to survive there. As a result, it is unlikely that the muskrat will experience adverse effects from lead or cadmium exposure under post-closure conditions.

6.6 Shrew

Although tundra shrew exposure to CoPCs was modeled for Tundra Area 1 and potential effects were predicted, Tundra Area 1 is not a viable small mammal habitat, as it is immediately adjacent to mill facilities and is largely devoid of live vegetation habitat. As a result, the following sections describe results for Tundra Areas 2, 3, and 4, under current and post-closure conditions.

6.6.1 Current Conditions

Although predicted exposure to cadmium, lead, and zinc did not suggest exceedance of LOAEL TRVs in Tundra Areas 2, 3, and 4, exposure estimates exceeded NOAEL TRVs in each of those areas (Table 13). Therefore, possible adverse effects to shrew from cadmium, lead, and zinc cannot be ruled out under current conditions in the Tundra Areas.

6.6.2 Post-Closure Conditions

Predicted exposure of shrew in Tundra Areas 2, 3 and 4 exceeded the NOAEL TRVs for cadmium, lead, and zinc. Cadmium did not exceed the LOAEL TRVs for shrew, but lead and zinc did exceed the LOAEL TRVs. As a result, there is a possibility of adverse effects to shrew under post-closure conditions (Table 14).

6.7 Vole

Although tundra vole exposure to CoPCs was modeled for Tundra Area 1 and potential effects were predicted, Tundra Area 1 is not a viable small mammal habitat, as it is immediately adjacent to mill facilities and is largely devoid of live vegetation habitat. As a result, the following sections describe results for Tundra Areas 2, 3, and 4 only, under current and post-closure conditions. Overall, exposure estimates for voles were lower than for shrews.

6.7.1 Current Conditions

Hazard quotients for cadmium and zinc were less than 1.0 in Tundra Areas 2, 3 and 4 under all current conditions scenarios (Table 13). However, effects to vole from lead cannot be ruled out because exposure estimates exceeded the NOAEL TRV, but not the LOAEL TRV, for all three tundra areas.

6.7.2 Post-Closure Conditions

Predicted exposure of vole to lead and zinc in Tundra Areas 2 and 3 exceeded both NOAEL and LOAEL TRVs under-post closure conditions (Table 14). Thus, potential adverse effects are possible under the predicted post-closure conditions. Cadmium exposure in these areas was less than the LOAEL TRV but not the NOAEL TRV, so the potential for effects cannot be ruled out. Similarly, in Tundra Area 4, effects from cadmium, lead, and zinc cannot be ruled out, as exposure estimates were lower than the LOAEL TRV but higher than the NOAEL TRV.

7 Uncertainty Analysis

There are a number of inherent uncertainties associated with any risk assessment. For example, uncertainties can exist with regard to the characterization of CoPC concentrations in site media and biota (including predicted values), input parameter assumptions associated with food web models, time and area usage by receptors, and overall significance of predicted effects on receptor populations. This section presents an evaluation of the most important sources of uncertainty and the effects of these uncertainties on conclusions about the extent and magnitude of risks. A summary of the major areas of uncertainty in the evaluation is provided in Table 15, along with a qualitative estimation of the effect of each assumption on the results.

7.1 Uncertainty Related to Media Concentration Estimation

This section discusses the uncertainties associated with the preparation of input data for various media used in the food web models. The discussion is presented for current conditions and post-closure conditions.

7.1.1 Current Concentrations

To conduct this assessment, CoPC concentrations for soil, water, and other media (i.e., lichen, moss, willow/birch, sedges, invertebrates, and small mammals) were needed. However, data were not available for all CoPCs in all media and exposure areas. Therefore, predictive relationships were established using the existing DMTS risk assessment data (Exponent 2007a). These relationships were used in combination with available measured data to prepare a complete dataset, as described in Section 4.3.1. The use of predictive statistical relationships to estimate CoPC concentrations in the absence of measured concentrations introduced uncertainty into the exposure estimates. Lead, cadmium, and the 95 percent UCL for zinc from Tundra Area 2 and lead from Tundra Area 3 are outside the range for which the predictive relationships were established. Predictions made outside the range for which the relationship was developed assume that the same relationship between the two media continues to hold for higher concentrations. The approach used to prepare the complete dataset may have resulted in overestimation of exposure concentrations in some cases, and underestimation in others. Although the occurrence of overestimation or underestimation is unknown, the use of 95 percent UCL values in the analysis adds an element of conservatism.

In some cases, predictive relationships could not be developed. In those cases, mean and 95 percent UCL on the mean concentrations for these media were calculated directly from measured concentrations available from the DMTS risk assessment dataset. For some media (soil and water), concentrations from other locations or for other material types were used as conservative surrogates because the values were not available for a given material type. Since water ingestion is such a minor component of total dietary exposure, the uncertainty associated with water data is not likely to affect risk conclusions. By using data from other locations, uncertainty was introduced into the exposure estimates. In some cases, this may have resulted in an overestimation of exposure, because metals concentrations in media sampled near the CSBs at the port site were likely higher than those in tundra areas within the permit boundary.

The XRF sampling grid data from which the datasets were developed were largely focused in areas relatively near the active facilities (Figure 5), leaving much of the outlying portion of Tundra Area 4 (Figure 8) unsampled. The sample stations within Tundra Area 4, although relatively close to the operational areas, were taken to represent concentrations throughout Tundra Area 4. This likely introduced a conservative bias to all of the media concentrations assigned to Tundra Area 4 for the food web modeling.

There is some uncertainty associated with use of results below method detection limits to calculate exposures; a reported undetected value indicates that the true concentration of the analyte is somewhere between zero and the limit of detection. All analyses with results reported as undetected were represented as one-half the detection limit, which may have underestimated or overestimated true concentrations, but selecting a measure of central tendency is not likely to greatly bias results in one direction or the other.

Also, all plant samples collected were unwashed prior to analysis; therefore, measured CoPC concentrations reflect both the internal tissue concentrations and concentrations in dust, soil, or sediment particles adhering to plant tissues. Because plants were assumed to be a dietary item in the food web models for all the receptors except the tundra shrew and fox, inclusion of incidental soil or sediment ingestion as separate pathways in these exposure models may have resulted in a duplicative and thus conservative (high) estimate of exposure to these media for herbivorous wildlife.

Concentrations from facility-area road surfaces and other areas within the facility were compiled from various sources as footnoted in Tables 4 and 10. The concentrations used for these areas and material types were for the most part 95 percent UCL on the mean concentrations, with a few exceptions: 1) in the case of stream water data, a 95 percent UCL was used on median concentrations compiled by SRK for stream stations within the permit boundary (Hockley 2006a, pers. comm.); and 2) for the tailings impoundment, mean values were used for water quality under current conditions, as indicated in Appendix C data tables. Where data were not available for a particular CoPC for a given material type, an appropriate surrogate value was used, as noted in Tables 4 through 10. These substitutions add an element of uncertainty to the analysis, and likely result in overestimated exposure estimates.

7.1.2 Post-Closure Concentrations

All uncertainties discussed above for current concentrations are also generally applicable for post-closure concentrations. Also, within facility areas, it was assumed that Kivalina shale would be used as cover material in all areas to be covered during mine closure and reclamation. This assumption likely results in conservatively high metals concentrations used for cover material in some areas. In addition, tailings pond water quality estimates predicted for a “dirty pond” scenario were used in the assessment rather than the likely target of a “clean pond” water quality scenario, adding an element of conservatism to the analysis.

In tundra areas, post-closure concentrations in tundra soil and biota tissue exposure media were estimated by applying a 2.5 multiplier to current condition concentrations (initially described above in Section 4.3.2). The 2.5 multiplier is based on the assumption that there is a linear progression in concentration changes over time. Inherent in this assumption is the idea that the areas surrounding Red Dog Mine began at baseline CoPC concentrations of zero. In reality, this assumption ignores the elevated concentrations present before mine operations began in 1989. Also, concentration increases associated with mine operations in surrounding areas are not likely to occur on a strictly linear basis; therefore, the 2.5 multiplier results in a conservative estimate for predicted post-closure conditions.

The assumption that was used to predict future media concentrations is best illustrated in the conceptual model shown in Figure 9, where future media concentrations are assumed to increase steadily over time, resulting in a 2.5-fold increase in concentrations at the time of mine closure. In comparison, this conceptual model hypothesizes that the largest increases in concentrations in soil, non-vascular plants (e.g., mosses, lichens), and vascular plants (e.g., willow, sedge) likely occurred between the time the mine opened in 1989 and 1998, during the period of construction and rapid changes associated with initial startup and operational upgrades. As a result of major dust control improvements that took place throughout the history of mine operations (see Appendix D for a list of these improvements), and ongoing dust control improvements that will occur until the mine closes in 2031, the concentrations in soil and plants are not expected to increase at a rate anywhere near the linear rate assumed for the purposes of the food web modeling.

During the remaining years that the mine will be in operation, concentrations in media may stabilize, and could even decline in non-vascular plants (such as mosses) due to ongoing dust control improvements. During the first decade after the mine closes, concentrations in plants, particularly non-vascular plants, such as mosses and lichens, are expected to decline significantly, and tundra soil concentrations may also decline gradually, as additional organic matter decays and accumulates through senescence (Figure 9). Based on the comparison made in this conceptual model, the 2.5-fold increase in concentration appears to represents a conservative means for predicting post-closure media concentrations.

Another reason that the multiplier approach for estimating future concentrations likely adds significant overestimation is because the concentration of metals in dust on plant surfaces is not likely to be significantly different in the future than it is currently. The concentration of dust on the surface of plants likely has reached a state of near equilibrium, given rates of dust deposition and weathering of dust from the plant surfaces as a result of wind, rain, and snow events. Since the plant tissue concentrations used in this analysis were total concentrations of metals both in and on plant tissue samples, and the multiplier was applied to these total concentrations, the future concentrations are likely overestimated as a result of the factor also being applied to the external (i.e., dust) portion of the plant tissue concentration. Food web models based on these overestimated plant concentrations would also overestimate wildlife exposure.

Current conditions data that were used for stream water quality in tundra areas were not modified to represent post-closure conditions. It is uncertain whether stream water quality might change over time, and if so, to what degree. However, the results of this assessment were not driven by stream water quality (see daily exposure estimates in the food web model tables in

Appendices A and B). Therefore, the uncertainty in future stream water quality was not a significant factor in this assessment.

7.2 Uncertainty Related to the Wildlife Assessment

The risk characterization for wildlife is based on an individual-based model intended to predict the response of a population of wildlife receptors as the result of the presence of a number of CoPCs in a particular location, at a particular concentration, at a particular time. Through the development of multiple risk scenarios, the risk characterization takes into account the distribution of CoPCs at the site and combines this information with estimated values for key life-history parameters of the receptors and predicted physiological responses to CoPC exposure to provide a measure of the likelihood that the conditions, as understood, will affect receptor population demography. However, a risk assessment provides only a model of reality. Because of limited information on receptor ecology and toxicology, models must generalize conditions, assume events and responses, and disregard factors and conditions based on the presumption that such factors are inconsequential. Best professional judgment is applied to ensure that while the models do not significantly underestimate the potential risks, they do not become so conservative as to render the results meaningless.

The specific uncertainties associated with the risk evaluation for wildlife are identified and discussed in the following sections. The approach to evaluating uncertainties in this study is based on the approach taken in the DMTS risk assessment (Exponent 2007a), including the input parameters such as body masses, intake rates, and diet composition for the receptors previously approved by DEC in the work plan for that assessment (Exponent 2004). Below is a detailed discussion on specific sources of potential uncertainty that have been identified in the food-web exposure models.

7.2.1 Wildlife Exposure Estimates

Uncertainty is inherent in all the assumptions used to estimate the exposure of receptors to CoPCs within the permit boundary area. However, these assumptions are as ecologically accurate and realistic as possible. Where uncertainty was identified, values were selected that would tend to maximize exposure or effect and therefore would be conservative in the estimation of risk.

Exposure estimates for wildlife receptors were based on a model that incorporated site-specific data on CoPC concentrations in food and environmental media with assumptions about the life history characteristics of the receptor species. The food-web exposure analyses were deterministic and incorporated concentrations and receptor-specific exposure parameters. Almost all of these values have associated probability distributions; however, selection of determinate values for the exposure and effects characterizations was based on the best available information on the average individual. In the absence of site-specific information on model input parameters information was obtained from literature sources.

7.2.2 Body Masses

The application of single determinate values for exposure parameters introduces a level of error to the exposure estimates, because the parameters are not constant to an individual all of the time, nor are they constant across individuals within a population. Body mass estimates were based on values reported in the scientific literature, with a focus on mean female body masses from Alaska or other northern regions. Female body masses are used because most of the endpoints used to establish NOAELs or LOAELs relate to reproductive parameters. Therefore, female exposure to CoPCs is important when predicting the likelihood of population effects.

7.2.3 Diet Composition

The diet composition for each receptor was approximated using best professional judgment based on information found in the literature. Since receptors were selected to represent feeding guilds (e.g., tundra shrew for terrestrial mammalian invertivores), their modeled diets emphasized primary food sources (e.g., invertebrates for tundra shrew). Use of multiple feeding guilds minimizes the likelihood that risk for any particular guild is underestimated. For example, insect matter constitutes a minor proportion of the vole diet. If insects have higher CoPC concentrations than plant matter, then omitting this component of the diet could underestimate risk for herbivorous small mammals that eat some animal tissue. However, the risk estimates for shrews would be protective of these receptors, because one of the assumptions of the shrew food web model is that they consume 100 percent invertebrates (Table 12). The most appropriate tissue data were used to represent food concentrations in the models. Diets were simplified for the purpose of the assessment, and because exposure estimates were determinate, they did not capture the temporal and individual variability in receptors' diets. Therefore, the simplification of receptors' diets introduced some uncertainty into the risk calculations, and could either result in over- or underestimation of risk.

7.2.4 Bioavailability

Gastrointestinal absorption of metals was assumed to be 100 percent in the risk models. In reality, however, all of the CoPCs evaluated in this study are elemental, are natural constituents of the soil matrix, and would have varying degrees (but less than 100 percent) of absorption if ingested by a receptor. For example, the relative bioavailability of lead in Red Dog ore (i.e., bioavailability of lead in Red Dog ore relative to soluble lead acetate), as determined from the National Toxicology Program rat study data reported by Arnold and Middaugh (2001) ranged from 13.6 to 27 percent, with a mean of 19.4 percent. In the absence of site-specific data on bioavailability, the risk model assumed that the form of the metal present in the environment was absorbed with the same efficiency as the form used in the laboratory study from which the TRV was derived.

To address some of the uncertainty associated with assuming 100 percent bioavailability for lead, an additional analysis of current conditions using more site-specific assumptions is provided (Table 16). The food web model results presented in Table 16 are based on mean concentrations rather than 95 percent UCL on the mean values, and a lead bioavailability of 19.4 percent, the mean relative bioavailability value from Arnold and Middaugh (2001). These modifications result in decreased hazard quotients in all scenarios (including the more conservative Near Facilities scenario) for caribou, fox, teal, and muskrat to less than 1.0. For ptarmigan, the modified assumptions still result in NOAEL and LOAEL exceedances for lead, although not for cadmium. Aside from ptarmigan, the only two receptors for which estimated exposures exceed NOAEL TRVs (but not LOAEL TRVs) are vole and shrew. The results of these more site-specific modifications to the food web models are clearly more favorable. However, risk cannot definitively be concluded to be negligible to vole and shrew, because the true effect threshold is not exactly known, only that it lies somewhere between the NOAEL and LOAEL. Similarly, risk cannot be concluded to be negligible to ptarmigan because estimated exposures with the modified assumptions still result in exceedances of both the NOAEL and LOAEL for lead.

7.2.5 Toxicity Reference Values

Availability of toxicity data and suitability for use at a given site vary on a case-by-case basis. The selection of TRVs used in this assessment was based on an evaluation of the technical quality and ecological relevance of the study from which the values were taken. Modeled exposures were compared directly with the best available NOAEL and LOAEL TRVs derived from the literature. However, metals are naturally occurring constituents in the environment and vary in concentrations across geographic regions (U.S. EPA 2007). High background levels of cadmium, lead, and zinc within the vicinity of the mine may have resulted in local adaptations in plants and animals to soils that are naturally high in certain metals. This would represent a conservative bias to the TRVs that were selected based on laboratory studies and receptors not representative of the region. Furthermore, some metals, such as zinc, are classified as essential metals that are necessary for the normal development of plants and animals. As a result, there may be some difficulty relating to distinguishing between recommended dietary requirements of essential elements and toxicity threshold values (U.S. EPA 2007). Additional uncertainty is introduced from TRVs because the toxicokinetics and toxicodynamics of metals depend on the metal, the form of the metal or metal compound, and the organism's ability to regulate and/or store the metal (U.S. EPA 2007). This could result in either an over- or underestimation of risk.

7.2.6 Time and Area Use

Because the caribou and many of the avian receptors selected for this evaluation are migratory, it would have been unrealistic to assume that they were exposed to CoPCs within the permit boundary for the entire year. Therefore, the assessment standardized the exposure rates over an annual cycle and apportioned exposure concentrations from the site based on the proportion of time receptors are assumed to spend in that habitat. The selection of residence times for birds was generally not site-specific, but rather based on the typical times of the year that the specific receptor is most likely to arrive at and depart from Cape Thompson, Alaska. In cases where a range of values was available, the period that maximized their residency at the site was selected, thus maximizing exposure to site CoPCs. For the purposes of this assessment, the teal is assumed to be present within the permit boundary for 4 months and at the reference area for the remaining 8 months of the year. It is extremely unlikely that a teal would spend 4 months at the site, and in fact, it is questionable whether the teal would spend any time at the site (see

Section 7.2.6.1 below for further discussion). Therefore, this assumption most likely results in an overestimation of risk to teal.

The caribou was assessed assuming two different scenarios. For the overwintering scenario, caribou are assumed to be present at the facility for 5 consecutive months and to migrate elsewhere for the remaining 7 months of the year. In the resident scenario, caribou are assumed to be present on the site for 8 consecutive months and at the reference area for the remaining 4 months of the year. In most years, the majority of caribou in the Western Arctic Caribou Herd (WACH) migrates to river drainages south of the site in autumn and does not over-winter in and around the mine. These animals would be exposed to CoPC concentrations at the site for short durations rather than the 5 months assumed in the over-wintering scenario or the 8 months assumed in the resident scenario. Migratory caribou may be present on the site for as little as 1 week, and their short exposure to site-related CoPCs would not translate into adverse effects. Therefore, the uncertainty associated with the time-use estimate used in the exposure model represents an overestimation of site exposure for the majority of caribou in the WACH. However, the time use estimate of 5 months is a conservative assumption appropriate for the very small proportion of the herd that potentially over-winter at the site. In addition, the area within the permit boundary is likely less attractive than surrounding areas as habitat to wildlife species. Thus, even if caribou were to over-winter or reside in the area for many months, they would be unlikely to spend the entire time within the permit boundary. This last point also applies to other large-home-range animals such as teal and fox, and even to medium-home-range animals such as ptarmigan.

The following sections provide further discussion on uncertainties associated with the potential usage of mine water bodies by waterfowl (e.g., teal) and by muskrat.

7.2.6.1 Uncertainty Related to Birds Utilizing Mine Water Bodies During Migration

Migrating birds typically need to make stops for food, water, and rest. As a result, ponds and other water bodies (including mine tailings ponds or pit lakes) are attractive to birds, especially during migrations, and particularly in arid areas such as the Great Basin of the western United States (Henny et al. 1994). Although there are cases where acute effects have been observed among birds using contaminated water bodies, it is unknown what kind of population effects potentially contaminated sites along an arid migration route can have on bird populations. This section reviews available studies and information, and evaluates the potential for exposure and acute effects to birds that may use water bodies within the permit boundary.

As reported in Beyer et al. (2004), there have been some instances reported of waterfowl poisoning from mining wastes containing zinc, lead, and cadmium in the Tri-State Mining District (Oklahoma, Kansas, and Missouri). Henny et al. (1994) mentioned that susceptibility of wildlife exposed to mine water varies among species and depends on a variety of factors, such as proximity to alternative water sources and degree of dehydration. Stubblefield (1997) reported that snow geese that were fasted and dehydrated were more sensitive in terms of measured blood chemistry parameters to acidic mining pit water collected from the Berkeley Pit in Butte, Montana than birds that were not dehydrated. Stubblefield (1997) also reported that exposure to clean water following exposure to acidic water reversed symptoms.

Some studies have indicated that birds may exhibit taste aversion to contaminated water. For example, Isanhart et al. (2005) conducted a laboratory study with mallards that were fasted and dehydrated for 24 hours to simulate migratory conditions and were offered either synthetic acid metalliferous water (treatment) or clean water (control). The researchers found that some of the mallards exhibited aversion to the treatment water, and switched to clean water if available. Similarly, Heinz and Sanderson (1990) found that mallards avoid foods mixed with selenium after associating the diet with illness. Therefore, evidence exists to suggest that birds might be able to identify and avoid contaminated water bodies. Read (1999) has suggested that in arid regions of Australia, waterfowl use of toxic water bodies would decrease if nearby clean water bodies were made more attractive to nomadic individuals by protecting sites from human disturbance, providing areas for roosting, or using decoy ducks to encourage birds to use clean water bodies.

Potential risk encountered by birds migrating through arid regions with few available water bodies in heavily mined areas is not similar to the situation at the Red Dog study area. This is because the Red Dog study area landscape has abundant water bodies such as ponds and broad stream valleys, including the Wulik, Kivalina, and Noatak Rivers. Also, great densities of migrating birds do not congregate in the region of the Red Dog study area because it is not located along a major migration flyway system (Bellrose 1976; Elphick 1995; Kessel and Gibson 1978). In Alaska, the major bird migration staging/stopover posts include St. Paul Island (in the Bering Sea), the Copper River Delta (South-Central Alaska), and the Aleutian Islands (in the Northern Pacific Ocean) (Elphick 1995). In the vicinity of Red Dog, migrating birds are likely to follow the coastal plain 50 miles away from the mine, rather than traveling over the mountains that surround the mine.

The Red Dog study area could serve as potential breeding habitat for waterfowl such as green winged teal. Green winged teal are dabbling ducks that are abundant breeders in river deltas and forested wetlands of Canada and Alaska (Kessel and Gibson 1978). High-density breeding areas consist of wooded ponds of deciduous parklands, boreal forests, arctic deltas, and often include wetland or woodlands next to a marsh or pond, such as beaver ponds (Johnson 1995; Armstrong 1990). Tundra ponds surrounded by dense emergent vegetation are common in the vicinity of the Red Dog study area.

Risk of exposure for migrant birds using tailings ponds in arid regions is a phenomenon not applicable to the Red Dog study area because migrating waterfowl do not use the Red Dog study area as a migration stopover, and because the Red Dog study area is not located in an arid region. Acute effects are therefore unlikely for birds that breed in the Red Dog study area.

7.2.6.2 Uncertainty Related to Muskrat Utilizing Mine Water Bodies

The highest populations of muskrats are in the broad flood plains and deltas of major rivers and in marshy areas dotted with small lakes. Although muskrat occur throughout the mainland of Alaska, they are not found on some islands in southeast Alaska, on the Alaska Peninsula west of Ugashik Lakes, and north of the Brooks Range (Earnest 1994). Muskrat harvesting is typically concentrated in the Yukon Flats in Eastern Alaska, Minto Flats, Northway-Tetlin Flats, the Yukon Kuskokwim Delta, and the northernmost Selawik-Kobuk-Noatak area (Earnest 1994). No areas north of the Selawik-Kobuk-Noatak area are noted as high-concentration harvest areas.

Additionally, part of the Red Dog study area is located on the Brooks Range, near the northern limits for muskrat habitat. The major concentrations of muskrat in Alaska do not appear to be in the vicinity of the Red Dog study area, and muskrat have not been observed within the permit boundary. However, if muskrat were to occur within the permit boundary, they would be less likely to use mine tailings pond or pit lake water bodies because these water bodies do not provide appropriate habitat and food sources, whereas other surrounding water bodies do.

8 Interpretation of Ecological Significance

In the previous sections, results of ecological risk calculations were presented and their uncertainties discussed. This section further interprets the results to determine whether there is a potential for ecological impacts.

Considerations Regarding Toxicity Reference Values. Exposure estimates that are below the NOAEL TRV identify conditions under which adverse ecological effects are unlikely to occur to bird or mammal populations, because members of those populations are exposed to CoPC levels known through observation to cause no significant effects in test organisms. Thus, for CoPCs where hazard quotients are less than 1.0 in comparison to the NOAEL, it is very unlikely that adverse effects would occur at the population level for wildlife receptors.

Exposure estimates greater than the NOAEL TRV, but less than the LOAEL TRV, indicate that individuals are ingesting metals in excess of a no-effects threshold and thus may exhibit adverse effects similar to those observed in the test organisms. In these cases, potential for adverse effects cannot definitively be concluded to be negligible, because the true effect threshold is not exactly known, only that it lies somewhere between the NOAEL and LOAEL. However, because the endpoints measure organism-level responses, there is considerable uncertainty regarding how these effects, if occurring, would translate to population-level demographics.

Considerations Regarding Area Usage Assumptions and Available Habitat Within the Mine Permit Boundary. The current and post-closure evaluations involved a variety of different scenarios, as described in Section 4.2 (Exposure Scenarios). The scenarios can be separated into two discrete groups, with the more realistic scenarios classified under the All Areas scenarios and the more conservative scenarios classified as Near Facilities scenarios. The All Areas scenarios consisted of a larger habitat area including all mine facility and tundra areas within the permit boundary, while the Near Facilities scenarios considered only areas near the mine facility and excluded outlying tundra areas (Tundra Area 4) and streams (Figure 8). Within each of these two categories, various scenarios were analyzed, making different assumptions about water body usage by the receptors. Of these two groups, the Near Facilities scenarios were much more conservative because the areas near the facilities do not provide ideal habitat conditions for the receptors selected. For example, Tundra Area 1, which is a terrestrial area used to characterize risk for the tundra vole and tundra shrew, is mostly not viable small mammal habitat, as it is immediately adjacent to mill facilities and is largely devoid of live vegetation. This area will be addressed as part of the mine closure and reclamation process. Similarly, the tailings impoundment and pit lake do not provide appropriate habitat and food sources for aquatic mammals such as the muskrat. Therefore, although areas near the facilities are not likely to be as desirable for the ecological receptors, exposure within these areas is emphasized in the conservative worst-case exposure scenarios.

Discussion of Results for Caribou. Caribou could potentially spend time seasonally within the permit boundary, and the caribou was therefore evaluated using two different scenarios. The first scenario assumes caribou overwinter for a period of 5 months within the permit boundary, while the other scenario assumes that caribou are present within the permit boundary for a period of 8 months as residents. The less time the caribou are assumed to spend within the permit boundary, the lower the exposure estimate. Nevertheless, these scenarios represent worst-case scenarios, and under current conditions, there are no expected adverse effects to caribou from lead, zinc, or cadmium in the Overwintering scenario; for the Resident scenario, the NOAEL hazard quotient for lead was 1.1, indicating slight potential for adverse effects. The same was true for post-closure conditions, such that lead exceeded the NOAEL TRV but not the LOAEL TRV; this occurred for both the Overwintering and Resident scenarios. Both scenarios are conservative because caribou can move over extremely large areas to find suitable foraging habitat, and for them to overwinter or reside solely within the permit boundary for 5 to 8 months is a conservative assumption. Therefore, under both current and predicted future conditions, no adverse effects are predicted for caribou within the permit boundary from zinc and cadmium, and it is unlikely that there would be potential adverse effects to the caribou from lead given the conservative assumptions associated with the analyses.

In addition, it is unlikely that any individual-level growth effects, if occurring, would lead to population-level effects because of the very small proportion (<0.02 percent) of the total WACH, estimated at 430,000 individuals (DFG 2003), that could possibly overwinter within the permit boundary. For example, the greatest numbers of caribou would likely arrive in the vicinity of the mine during the fall migration, when caribou of the WACH are known to cross the DMTS road on their way to winter ranges in river drainages south of the site (Hemming 1987, 1988, 1989, 1990, 1991; Pollard 1994a,b). Intra-year differences in occurrence can be pronounced because caribou migration routes can vary annually (DFG 2003). Although caribou may have a clumped distribution during the winter, these low densities indicate that it is very unlikely that more than, at most, a few hundred individuals of the WACH would be present near the DMTS during the winter, and likely even fewer would be present within the permit boundary itself for any extended period of time. Fewer caribou are expected at the site during the spring and summer than during the fall migration because the site is outside of the summer range and calving grounds (DFG 2003).

Discussion of Results for Fox, Teal, and Muskrat. Under current conditions, population-level effects are unlikely for the fox, teal, and muskrat because exposures for these receptors did not exceed NOAEL or LOAEL TRVs for lead, zinc, and cadmium in the outlying tundra areas, and only slightly exceeded NOAEL TRVs in more conservative Near Facilities scenarios. Results were similar for these receptors under post-closure conditions, with no TRVs exceeded for lead, zinc, or cadmium in the outlying tundra areas. Although the NOAEL TRV was exceeded for lead for fox and muskrat only in the tailings impoundment scenario, the LOAEL TRV was not exceeded for these receptors. The teal NOAEL and LOAEL TRVs for lead were slightly exceeded, although only in the Near Facilities scenarios. In the All Areas scenarios, these receptors do not exceed LOAEL TRVs for lead, zinc, or cadmium. The results suggest that if the receptors use the habitat more likely to provide foraging potential and protection, the potential for adverse effects is very low. Considering the conservative nature of the analysis, including that of the future concentration predictions and the area usage assumptions, population-level effects are considered unlikely for fox, teal, and muskrat under current and post-closure conditions.

Discussion of Results for Ptarmigan. The food web model results for terrestrial avian herbivores (i.e., willow ptarmigan) suggest that adverse effects (reproductive effects), particularly from lead, could occur in individuals foraging near the mine facility under both current and post-closure conditions. The prediction of potential risk to ptarmigan could be a result of conservative assumptions used in the evaluation, as described in the uncertainty analysis in Section 7, particularly the discussion of uncertainty pertaining to bioavailability (Section 7.2.4). Regardless, there is uncertainty as to whether predicted effects to individual herbivorous birds inhabiting areas within the permit boundary would actually produce detectable population-level changes. The implicit assumption in the assessment is that the result is based on the responses of individuals. The hazard quotient approach presumes that an exposure level associated with individual effects is absolutely consistent (i.e., lacking in natural variability) and is likely to cause demographic effects on a wild population, although this may not actually occur. Also, effects, if occurring, are unlikely to translate into regional population-level effects, given the limited spatial extent of the permit boundary where adverse effects could occur, and the abundance of ptarmigan throughout the region. Therefore, although there is uncertainty associated with these assumptions, the conservative nature of the selection of input parameters for individual exposure scenarios should result in a conservative assessment with respect to the potential for population-level effects.

Discussion of Results for Small Mammals. Herbivorous small mammals (i.e., tundra vole) inhabiting Tundra Areas 2–4 within the permit boundary showed potential for adverse effects from exposure to lead, zinc, and cadmium, with potential for adverse effects the highest near the facility areas at Tundra Area 2 and lowest furthest away at Tundra Area 4. Similarly, invertivorous small mammals (i.e., tundra shrew) also showed the potential for adverse effects from exposure to lead, zinc, and cadmium in the tundra areas decreasing along the same gradient away from facilities. However, as described in the uncertainty section discussion on bioavailability (Section 7.2.2), if mean concentrations (rather than 95 percent UCL on the mean concentrations) and site-specific bioavailability of lead are used to evaluate current conditions, hazard quotients decrease such that there are no exceedances of 1.0 based on LOAEL TRVs. The only exceedances of 1.0 were based on NOAEL TRVs.

Under post-closure conditions, food web model results also indicate the potential for adverse effects to these small-home-range receptors (i.e., the small mammal shrew and vole). These adverse effects to individuals, if occurring, could produce detectable higher-level responses, such as decreased population abundance within these localized areas. Regardless, possible effects on individuals within the permit boundary are unlikely to translate into regional population-level effects, given the limited spatial extent within the permit boundary where adverse effects could occur.

Summary of Ecological Significance for Wildlife Receptors. Overall, adverse effects are not expected for receptors in outlying tundra areas within the permit boundary under current conditions, with the possible exception of the ptarmigan. There is a possibility of adverse effects to ptarmigan and to small mammals in near-facilities tundra areas under current conditions. Similarly, under post-closure conditions the potential for adverse effects was predicted for tundra shrew, tundra vole, and ptarmigan. The potential for adverse effects would most likely occur at tundra areas nearest the facility, and would decrease with increasing distance from the facility. Effects to caribou, fox, teal, and muskrat appear to be unlikely under current and post-closure conditions.

Evaluation of Vegetation Effects. Vegetation effects have been observed in the vicinity of the mine facilities, such as absence or mortality of mosses, lichens, and liverworts, and leaf loss on some evergreen shrubs (Teck Cominco 2005, 2006, 2007); however, there is uncertainty as to what degree of change might be expected over time in vegetation communities throughout the broader area within the permit boundary. Additional studies of vegetation communities within the permit boundary are in progress, including a spatial evaluation of effects, assessment of effects mechanisms, and evaluation of possible measures to mitigate effects (Teck Cominco 2006, 2007). As part of this program, some re-growth of moss has been observed in affected areas, perhaps as a result of reductions in fugitive dust deposition over the past several years (Clark 2006, pers. comm.). This work is being conducted under the terms of a recent MOU (DEC 2005). Regular reports on this work are being submitted to DEC and are posted on the DEC Division of Air Quality website for Red Dog Mine (www.dec.state.ak.us/air/reddog.htm). The ecological significance of potential vegetation effects over the long term may be better assessed in the future based on the results of these ongoing studies.

9 Conclusions

The objective of this evaluation was to assess the potential for adverse effects to ecological receptors (e.g., wildlife and plants) from metals exposure under both current conditions and predicted future (post-closure) conditions, within active areas and surrounding tundra areas within the mine permit boundary.

To evaluate the potential for ecological effects, multiple scenarios for current and post-closure conditions were developed and evaluated using food web models for the animal receptors. Based on multiple scenarios, results indicate that caribou, fox, teal, and muskrat are unlikely to experience adverse effects from exposure to lead, zinc, and cadmium under either current conditions or post-closure conditions. However, results did indicate a potential for adverse effects to ptarmigan and small mammals under both current and post-closure conditions (Table 17).

Specifically, the evaluation for ptarmigan, tundra vole, and tundra shrew indicated that these wildlife receptors may experience effects as a result of lead, zinc, and cadmium exposure. Adverse effects, particularly from lead, could occur for ptarmigan that forage near the mine facilities and more broadly in the areas within the permit boundary under both current and post-closure conditions. Results for the tundra vole and tundra shrew also indicate potential for adverse effects from lead, zinc, and cadmium under both current and post-closure conditions. However, the predicted effects, if occurring, are unlikely to translate into regional population-level effects, given the limited spatial extent of the mine area where adverse effects could occur.

Tundra vegetation communities, although not directly assessed in this study, have been previously found to exhibit localized effects in the vicinity of the mine facilities (Teck Cominco 2005, 2006, 2007). At this point, it is uncertain what degree of change might be expected over time in vegetation communities throughout the broader area within the permit boundary. Additional studies of vegetation communities within the permit boundary are in progress, including a spatial evaluation of effects, assessment of effects mechanisms, and evaluation of possible measures to mitigate effects (Teck Cominco 2006, 2007). As part of this program, some re-growth of moss has been observed in affected areas, perhaps as a result of reductions in fugitive dust deposition over the past several years (Clark 2006, pers. comm.). This work is being conducted under the terms of an MOU between Teck Cominco and DEC (DEC 2005). Regular reports on this work are being submitted to DEC and are posted on the DEC Division of Air Quality website for Red Dog Mine (www.dec.state.ak.us/air/reddog.htm). The ecological significance of potential vegetation effects over the long term may be better assessed in the future based on the results of these ongoing studies.

There are many uncertainties in this evaluation, particularly with respect to predicting future conditions. However, each time an uncertainty was encountered in the evaluation, a conservative assumption was made to ensure that the results of the analysis were conservative, or protective. Using more realistic assumptions in the models reduces or, in many cases, eliminates predicted risk to wildlife receptors.

10 References

Aitchison, C.W. 1987. Review of winter trophic relations of soricine shrews. Mamm. Rev. 17(1):1–24.

Andreev, A.V. 1991. Winter adaptations in the willow ptarmigan. Arctic 44(2):106–114.

Anthony, R.M. 1997. Home ranges and movements of arctic fox (*Alopex lagopus*) in western Alaska. Arctic 50(2):147–157.

Anthony, R.M., N.L. Barten, and P.E. Seiser. 2000. Foods of Arctic foxes (*Alopex lagopus*) during winter and spring in western Alaska. J. Mammal. 81(3):820–828.

Armstrong, R.H. 1990. Guide to the Birds of Alaska. Alaska Northwest Books: Bothell, Washington.

Arnold, S., and J.P. Middaugh. 2001. Bioavailability of Red Dog Mine lead ore. Assessment of Battelle study: Evaluation of lead ore in Fischer 344 rats, submitted to the National Toxicology Program, June 1993. www.doerun.com/ENGLISH/html/leadinforeddog.htm.

Azar, A., H.J. Trochimowicz, and M.E. Maxfield. 1973. Review of lead studies in animals carried out at Haskell laboratory-two-year feeding study and response to hemorrhage study. pp. 199–210. In: Environmental Health Aspects of Lead. D. Barth, A. Berlin, R. Engel, et al. (eds). Commission of the European Communities, Luxembourg.

Bee, J.W., and E.R. Hall. 1956. Mammals of northern Alaska. University of Kansas Publishing, Museum of Natural History. ~297 pp.

Bellrose, F.C. 1976. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, PA.

Bergman, C.M., and C.J. Krebs. 1993. Diet overlap of collared lemmings and tundra voles at Pearce Point, Northwest Territories. Can. J. Zool. 71:1703–1709.

Beyer, W.N., E.E. Connor, and S. Gerould. 1994. Estimates of soil ingestion by wildlife. J. Wildl. Manage. 58(2):375–382.

Beyer, W.N., J. Spann, and D. Day. 1999. Metal and sediment ingestion by dabbling ducks. Sci. Total Environ. 231:235–239.

Beyer, W.N., J. Dalgarn, S. Dudding, J.B. French, R. Mateo, J. Miesner, L. Sileo, and J. Spann. 2004. Zinc and lead poisoning in wild birds in the tri-state mining district (Oklahoma, Kansas, and Missouri). Arch. Environ. Contam. Toxicol. 48:108–117.

Boertje, R.D. 1990. Diet quality and intake requirements of adult female caribou of the Denali herd, Alaska. J. Appl. Ecol. 27:420–434.

Buckner, C.H. 1964. Metabolism, food capacity, and feeding behavior in four species of shrews. Can. J. Zool. 42:259–279.

Campbell, K.L., G.L. Weseen, and R.A. MacArthur. 1998. Seasonal changes in water flux, forage intake, and assimilated energy of free-ranging muskrats. J. Wildl. Manage. 62(1):292–299.

Clark, J. 2006. Personal communication (conversation on September 24, 2006, with S. Shock, Exponent, Bellevue, WA, regarding vegetation studies being undertaken in the Red Dog Mine area). Teck Cominco, Red Dog Mine, Alaska.

DEC. 2005. Memorandum of understanding between the State of Alaska, Department of Environmental Conservation and Teck Cominco Alaska Incorporated. Effective September 21, 2005. Available at: http://www.dec.state.ak.us/air/doc/RD_Mine_MOU_Cominco_Fugitive_Dust_9-05.pdf. Accessed March 15, 2007. State of Alaska, Department of Environmental Conservation.

DEC, Teck Cominco, and Exponent. 2002. Draft fugitive dust background document, DeLong Mountain Regional Transportation System, Alaska. Alaska Department of Environmental Conservation, Anchorage, AK; Teck Cominco Alaska Incorporated, Anchorage, AK; and Exponent, Bellevue, WA.

DFG. 2003. Caribou management of survey-inventory activities, 1 July 2000–30 June 2002. C. Healy (ed). Alaska Department of Fish and Game, Juneau, AK.

Drewien, R.C. 1967. Ecological relationships of breeding waterfowl to prairie potholes. P.R. Rep. W-756R-8. South Dakota Department of Game, Fish, and Parks, Pierre, SD. (Not seen, as cited in Granholm 2003.)

Drexler, J., N. Fisher, G. Henningsen, R. Lanno, J. McGeer, and K. Sappington. 2003. Issue paper on the bioavailability and bioaccumulation of metals. Draft. Submitted to U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC. ERG, Lexington, MA.

Dunning Jr., J.B. 1993. CRC handbook of avian body masses. CRC Press.

Earnest, J. 1994. Muskrat. Alaska Department of Fish and Game Wildlife Notebook Series. www.adfg.state.ak.us/pubs/notebook/furbear/muskrat.php. Last accessed May 6, 2006.

Edens, F.W., E. Benton, S.J. Bursian, and G.W. Morgan. 1976. Effect of dietary lead on reproductive performance in Japanese quail, *Coturnix coturnix japonica*. Toxicol. Appl. Pharmacol. 38:307–314.

Elphick, J. 1995. The atlas of bird migration. Random House, New York.

Exponent. 2002a. Fugitive dust data report, DeLong Mountain Regional Transportation System, Alaska. Draft. Prepared for Teck Cominco Alaska Incorporated, Anchorage, AK. Exponent, Bellevue, WA.

Exponent. 2002b. Supplemental road sampling and surface material removal verification report. Prepared for Teck Cominco Alaska Incorporated, Anchorage, AK. Exponent, Bellevue, WA.

Exponent. 2003a. DMTS fugitive dust risk assessment work plan. Draft report. Prepared for Teck Cominco Alaska Incorporated, Anchorage, AK. Exponent, Bellevue, WA.

Exponent. 2003b. Phase I field sampling and analysis plan for the DMTS fugitive dust risk assessment. Prepared for Teck Cominco Alaska Incorporated, Anchorage, AK. Exponent, Bellevue, WA.

Exponent. 2003c. Port site characterization data report. Prepared for Teck Cominco Alaska Inc., Anchorage, AK. Exponent, Bellevue, WA.

Exponent. 2004. Draft DMTS fugitive dust risk assessment work plan. Prepared for Teck Cominco Alaska Inc., Anchorage, AK. Exponent, Bellevue, WA.

Exponent. 2007a. DMTS fugitive dust risk assessment. Prepared for Teck Cominco Alaska Incorporated, Anchorage, AK. Exponent, Bellevue, WA. November.

Exponent. 2007b. Fact sheet, risk assessment of metals in dust from Red Dog. Available at: http://www.dec.state.ak.us/spar/csp/docs/reddog/rafinal/fin_ra_factsh.pdf. Prepared for Teck Cominco Alaska Incorporated. Exponent, Bellevue, WA. 15 pp.

Ford, S., and L. Hasselbach. 2001. Heavy metals in mosses and soils on six transects along the Red Dog Mine haul road, Alaska. NPS/AR/NRTR-2001/38. National Park Service, Western Arctic National Parklands.

Fuller, W.A. 1951. Measurements and weights of northern muskrats. J. Mammal. 32(3):360–362.

Granholm. 2003. Green-winged teal (*Anas crecca*): Distribution, abundance, and seasonality. California Wildlife Habitat Relationship System. www.dfg.ca.gov/whdab/B077.html. Accessed February 25, 2003. California Department of Fish and Game, California Interagency Wildlife task group.

Hannon, S.J. and G. Dobush. 1997. Pairing status of male willow ptarmigan: Is poygyny costly to males? Anim. Behav. 53:369-380.

Hannon, S.J., P.K. Eason, and K. Martin. 1998. Willow ptarmigan (*Lagopus lagopus*). In: The Birds of North America, No. 369. A. Poole and F. Gill (eds). The Birds of North America, Inc., Philadelphia, PA.

Hanson, W.C., F.W. Whicker, and J.F. Lipscomb. 1975. Lichen forest ingestion rates of free-roaming caribou estimated with fallout cesium-137. pp. 71–79. In: Proc. First Int. Reindeer and Caribou Symposium, 9–11 August 1972, University of Alaska, Fairbanks, Alaska. J.R. Luick, P.C. Lent, D.R. Klein, and R.G. White (eds). Biological Papers of the University of Alaska.

Harbke, D. 2006a. Personal communication (e-mail transmittals dated February 8, 2006, to S. Shock, Exponent, Bellevue, WA, regarding XRF soil data with Excel files of data attached). Teck Cominco Alaska Incorporated, Anchorage, AK.

Harbke, D. 2006b. Personal communication (e-mail transmittal dated October 25, 2006, to S. Shock, Exponent, Bellevue, WA, regarding laboratory soil data with Excel file of data attached). Teck Cominco Alaska Incorporated, Anchorage, AK.

Hasselbach, L., J.M. Ver Hoef, J. Ford, P. Neitlich, E. Crecelius, S. Berryman, B. Wolk, and T. Bohle. 2005. Spatial patterns of cadmium and lead deposition on and adjacent to National Park Service lands in the vicinity of Red Dog Mine, Alaska. Sci. Tot. Environ. 348:211–230.

Hawes, M.L. 1977. Home range, territoriality, and ecological separation in sympathetic shrews, *Sorex vagrans* and *Sorex obscurus*. J. Mammal. 58(3):354–367.

Heinz, G.H., and C.J. Sanderson. 1990. Avoidance of selenium-treated food by mallards. Environ. Toxicol. Chem. 9:1155–1158.

Hemming, J.E. 1987. Annual caribou monitoring report. Prepared for NANA Regional Corporation. Dames & Moore, Anchorage, AK.

Hemming, J.E. 1988. Caribou monitoring report. Prepared for NANA Regional Corporation. Dames & Moore, Anchorage, AK.

Hemming, J.E. 1989. Annual caribou monitoring report. Prepared for NANA Regional Corporation. Dames & Moore, Anchorage, AK.

Hemming, J.E. 1990. Annual caribou monitoring report. Prepared for NANA Regional Corporation. Dames & Moore, Anchorage, AK.

Hemming, J.E. 1991. Annual caribou monitoring report. Prepared for NANA Regional Corporation. Dames & Moore, Anchorage, AK.

Henny, C.J., R.J. Hallock, and E.F. Hill. 1994. Cyanide and migratory birds at gold mines in Nevada, USA. Ecotoxicology 3:45–58.

Hockley, D. 2006a. Personal communication (e-mail to S. Shock, Exponent, Bellevue, WA, dated February 8, 2006, regarding draft Table 3.6.3: Summary of water quality monitoring data (1998–2004) from the Environmental Information Document for the Aqqaluk Zone Expansion report). SRK Consulting, Vancouver, BC.

Hockley, D. 2006b. Personal communication (data provided to S. Shock, Exponent, Bellevue, WA, at a meeting held on March 6, 2006, in Bellevue, WA, regarding tailings pond water quality data [originally provided to SRK Consulting by Teck Cominco Alaska Incorporated]). SRK Consulting, Vancouver, BC.

Hoefler. 2000. Supplemental submission for the February 1998 application for an amendment to AQC permit to operate No. 9632-AA001 for Red Dog Port, Red Dog, Alaska. Prepared for Teck Cominco Alaska Incorporated, Anchorage, AK.

Hughes, J.H., and E.L. Young, Jr. 1982. Autumn foods of dabbling ducks in southeastern Alaska. J. Wildl. Manage. 46(1):259–263.

Isanhart, J., R. MacRae, C. Roberts, and M. Hooper. 2005. Avian consumption and use of acid metalliferous water: Toxicological assessments of exposure, effects and susceptibility. Society of Environmental Toxicology and Chemistry, November 17, 2005, Baltimore, MD.

Jackson, N., S.W. Gibson, and M.H. Stevenson. 1986. Effects of short-and long-term feeding of zinc oxide-supplemented diets on the mature, female domestic fowl with special reference to tissue mineral content. Brit. J. Nutr. 55:333–349.

Johnson, K. 1995. Green-winged teal (*Anas crecca*). In: The Birds of North America, No. 193. A. Poole and F. Gill (eds). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, DC.

Kessel, B., and D.D. Gibson. 1978. Status and distribution of Alaska birds. Allen Press, Lawrence, KS.

Lambin, X., C.J. Krebs, and B. Scott. 1992. Spacing system of the tundra vole (*Microtus oeconomus*) during the breeding season in Canada's western Arctic. Can. J. Zool. 70:2068–2072.

Lent, P.C. 1966. The caribou of northwestern Alaska. pp. 481–517. In: Environment of the Cape Thompson Region, Alaska. N.J. Wilimovsky and J.N. Wolfe (eds). U.S. Atomic Energy Commission, Division of Technical Information, Oak Ridge, TN.

Martell, A.M., and A.M. Pearson. 1978. The small mammals of the Mackenzie Delta Region, Northwest Territories, Canada. Arctic 31(4):475–488.

Miller, D.R. 1976. Biology of the Kaminuriak population of barren-ground caribou. Part 3: Taiga winter range relationships and diet. Canadian Wildlife Services Report Series Number 36.

Nagy, K.A., I.A. Girard, and T.K. Brown. 1999. Energetics of free-ranging mammals, reptiles, and birds. Annu. Rev. Nutr. 19:247–277.

Neal, T.J. 1968. A comparison of two muskrat populations. Iowa State J. Sci. 43:193–210. (not seen, as cited in U.S. EPA 1993)

Newman, M.C., G.L. Diamond, C. Menzie, J. Moya, and J. Nriagu. 2003. Issue paper on metal exposure assessment. Draft. Submitted to U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC. ERG, Lexington, MA.

Ondreicka, R., E. Ginter, and J. Kortus. 1966. Chronic toxicity of aluminium in rats and mice and its effects on phosphorus metabolism. Brit. J. Ind. Med. 23:305–312.

Ott, A.G., and W.A. Morris. 2007. Aquatic biomonitoring at Red Dog Mine, 2006. National Pollution Discharge Elimination System Permit # AK-003865-2. Technical Report No. 07-03. Alaska Department of Natural Resources, Office of Habitat Management and Permitting.

Pattee, O.H. 1984. Eggshell thickness and reproduction in American kestrels exposed to chronic dietary lead. Arch. Environ. Contam. Toxicol. 13:29–34.

Pollard, R.H. 1994a. 1993 annual caribou monitoring report. Prepared for NANA Regional Corporation. LGL Alaska Research Associates, Inc., Anchorage, AK.

Pollard, R.H. 1994b. 1994 annual caribou monitoring report. Prepared for NANA Regional Corporation. LGL Alaska Research Associates, Inc., Anchorage, AK.

Read, J.L. 1999. A strategy for minimizing waterfowl deaths on toxic waterbodies. J. Appl. Ecol. 36:345–350.

Schlicker, S.A., and D.H. Cox. 1968. Maternal dietary zinc, and development and zinc, iron, and copper content of the rat fetus. J. Nutr. 95:287–294.

Scotter, G. 1967. The winter diet of barren-ground caribou in northern Canada. Can. Field-Nat. 81:33–39.

Silva, M., and J.A. Downing. 1995. Handbook of mammalian body masses. CRC Press, Boca Raton, FL. 359 pp.

SRK. 2003. Red Dog Mine, consolidation of studies on geochemical characterization of waste rock and tailings. Draft. Prepared for Teck Cominco Alaska Inc, Anchorage, AK. Steffen Robertson and Kirsten (Canada) Inc., Vancouver, BC.

SRK. 2004. Water and load balance. Memo prepared for Teck Cominco Alaska Inc., File #1CT006.03, Task 310. October 20, 2004.

SRK. 2006a. Estimates of post-closure water quality in the flooded Aqqaluk Pit. File Memo provided in Appendix E of Red Dog Closure Options, Volume II–Mine Area (SRK 2006c), initially prepared January 19, 2006, updated April 20, 2006.

SRK. 2006b. Red Dog Mine closure options. Volume I–Tailings. Prepared for Teck Cominco Alaska, Inc., Anchorage, AK. SRK Consulting (Canada) Inc., Vancouver, BC.

SRK. 2006c. Red Dog Mine closure options. Volume II–Mine area. Prepared for Teck Cominco Alaska, Inc., Anchorage, AK. SRK Consulting (Canada) Inc., Vancouver, BC.

SRK. 2007. Environmental information document for the Aqqaluk Extension. Prepared for Teck Cominco Alaska Incorporated, Anchorage, AK. SRK Consulting (Canada) Inc., Vancouver, BC.

Stahl, J.L., J.L. Greger, and M.E. Cook. 1990. Breeding-hen and progeny performance when hens are fed excessive dietary zinc. Poult. Sci. 69:259–263.

Stubblefield, W. 1997. Evaluation of the toxic properties of acid mine drainage water to snow geese. SETAC 18th annual meeting, November 16–20, 1997, San Francisco, CA.

Sutou, S., K. Yamamoto, H. Sendota, and M. Sugiyama. 1980. Toxicity, fertility, teratogenicity, and dominant lethal tests in rats administered cadmium subchronically. II. Fertility, teratogenicity, and dominant lethal tests. Ecotoxicol. Environ. Saf. 4:51–56.

Teck Cominco. 2002. Map provided by Teck Cominco Alaska Incorporated, Anchorage, AK.

Teck Cominco. 2003. 2003 port site supplemental characterization data report, DeLong Mountains Regional Transportation System, Alaska. Prepared by Teck Cominco Alaska, Inc., Anchorage, Alaska. Unpublished report.

Teck Cominco. 2004. Map provided by Teck Cominco Alaska Incorporated. Anchorage, AK.

Teck Cominco. 2005. Summary of mine related fugitive dust studies. Red Dog mine site. March 14, 2005. Teck Cominco Alaska Incorporated. Anchorage, AK.

Teck Cominco. 2006. Tundra vegetation impact study. Slides 34–36. In: 2006 Semi-Annual Fugitive Dust MOU Report presentation. www.dec.state.ak.us/air/doc/RD_Mine_Semi-Annual_MOU_Rpt_10-06_WEB.pdf. Accessed March 15, 2007. Teck Cominco, Red Dog Operations.

Teck Cominco. 2007. Red Dog Fugitive Dust Update No. 7–4th Quarter 2006. Prepared for Alaska Department of Environmental Conservation, Anchorage, AK. www.dec.state.ak.us/air/doc/RD_FDltr_4qtr06.pdf. Accessed March 15, 2007. Teck Cominco Alaska Incorporated, Anchorage, AK.

U.S. EPA. 1993. Wildlife exposure factors handbook. Volume II: Food ingestion factors. EPA/600/P-95/002Fb. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

U.S. EPA. 1997. Ecological risk assessment guidance for Superfund: Process for designing and conducting ecological risk assessments. Interim Final. U.S. Environmental Protection Agency, Environmental Response Team, Edison, NJ.U.S. EPA. 2002. Calculating upper confidence limits for exposure point concentrations at hazardous waste sites. OSWER 9285.6-10. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC.

U.S. EPA. 2006. Red Dog Mine use attainability analysis. www.epa.gov/waterscience/standards/uaa/pdf/cs_reddog.pdf.

U.S. EPA. 2007. Framework for metals risk assessment. EPA 120/R-07/001. Office of the Science Advisor, Risk Assessment Forum, U.S. Environmental Protection Agency, Washington, DC.

West, G.C., R.B. Weeden, L. Irving, and L.J. Peyton. 1970. Geographic variation in body size and weight of willow ptarmigan. Arctic 23:240–253.

White, D.H., and M.T. Finley. 1978. Uptake and retention of dietary cadmium in mallard ducks. Environ. Res. 17:53–59.

Williamson, F.S.L., M.C. Thompson, and J.Q. Hines. 1966. Avifaunal investigations. pp. 437–480. In: Environment of the Cape Thompson Region, Alaska. N.J. Wilimovsky and J.N. Wolfe (eds). U.S. Atomic Energy Commission, Division of Technical Information, Oak Ridge, TN.

Yudin, B.S. 1962. Ecology of shrews (genus *Sorex*) in western Siberia. Akademiya Nauk S.S.S.R., Siberian Section, Trudy, Institut Biologii 8:33–34. (not seen, as cited in Aitchison 1987 and Buckner 1964)

Figures

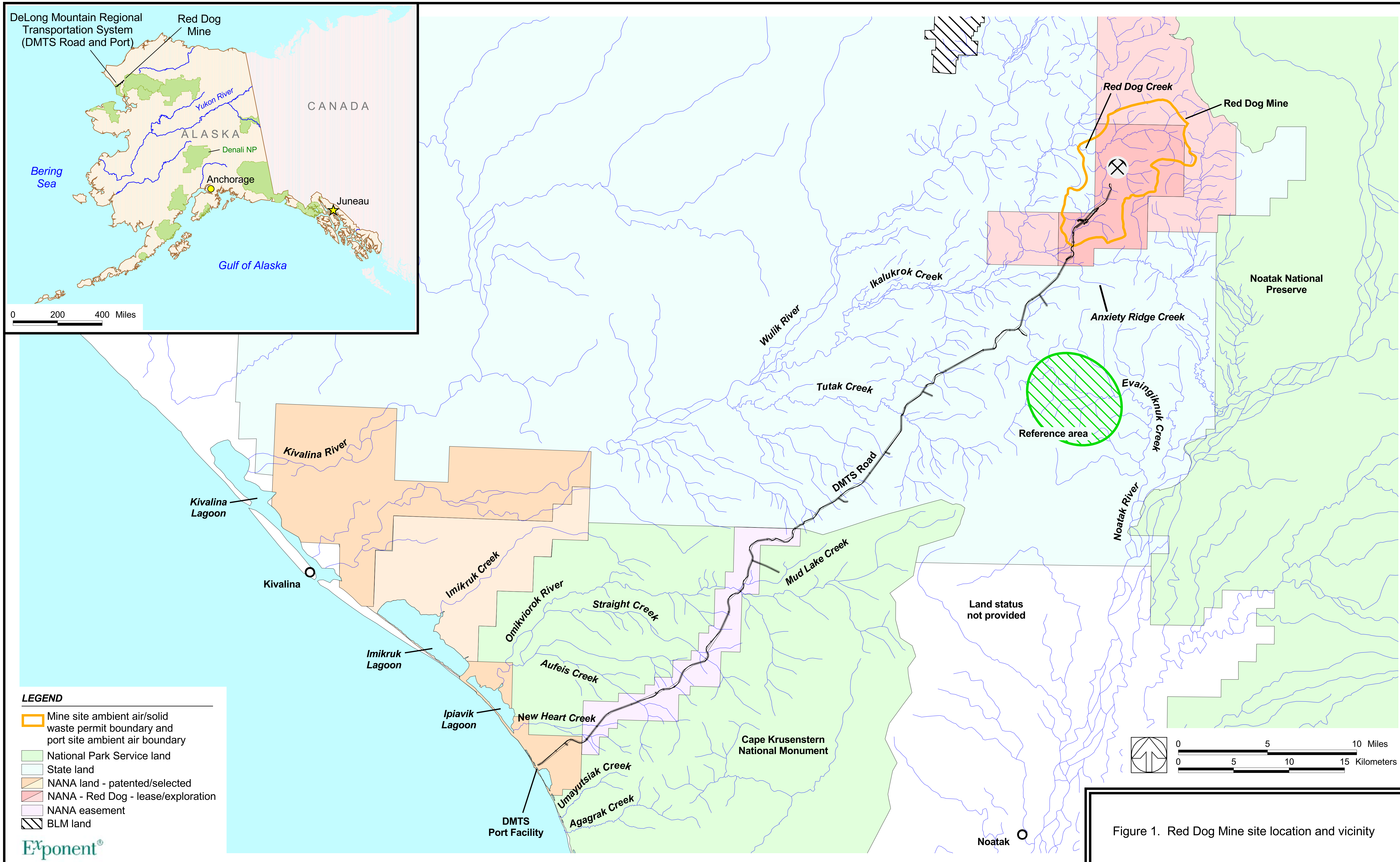
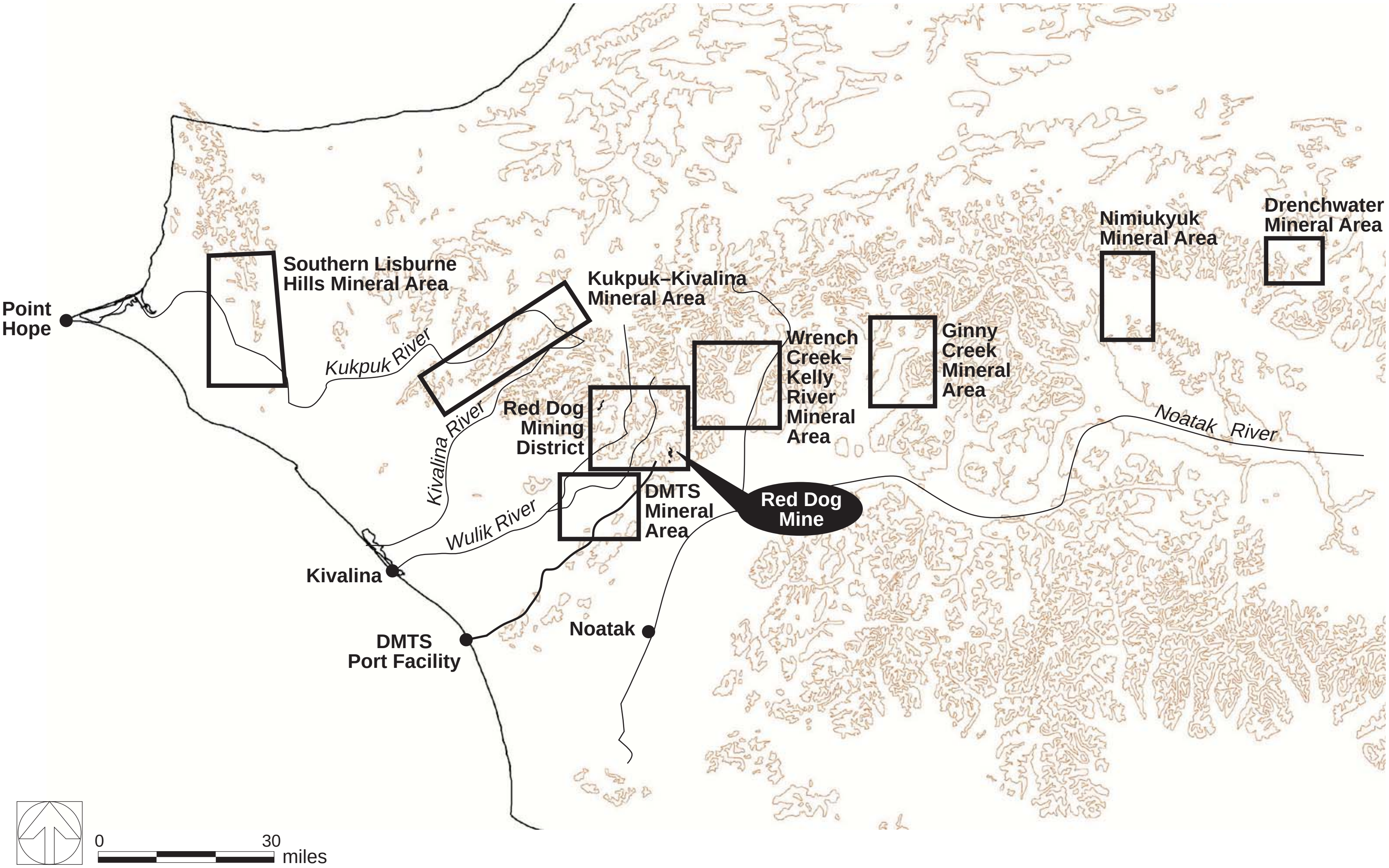


Figure 1. Red Dog Mine site location and vicinity

8601997.001 5700 | Oct 31, 2006 | Fig 1 zoom to site view | Fig 1 site location layout | j:\red_dog\projects\mine_closure_prj1.apr



Source: Adapted from Teck Cominco (2002)

Figure 2. Areas of zinc, lead, and barite mineralization in the western Brooks Range, Alaska

8601997.001 5700 10/31/06 WA

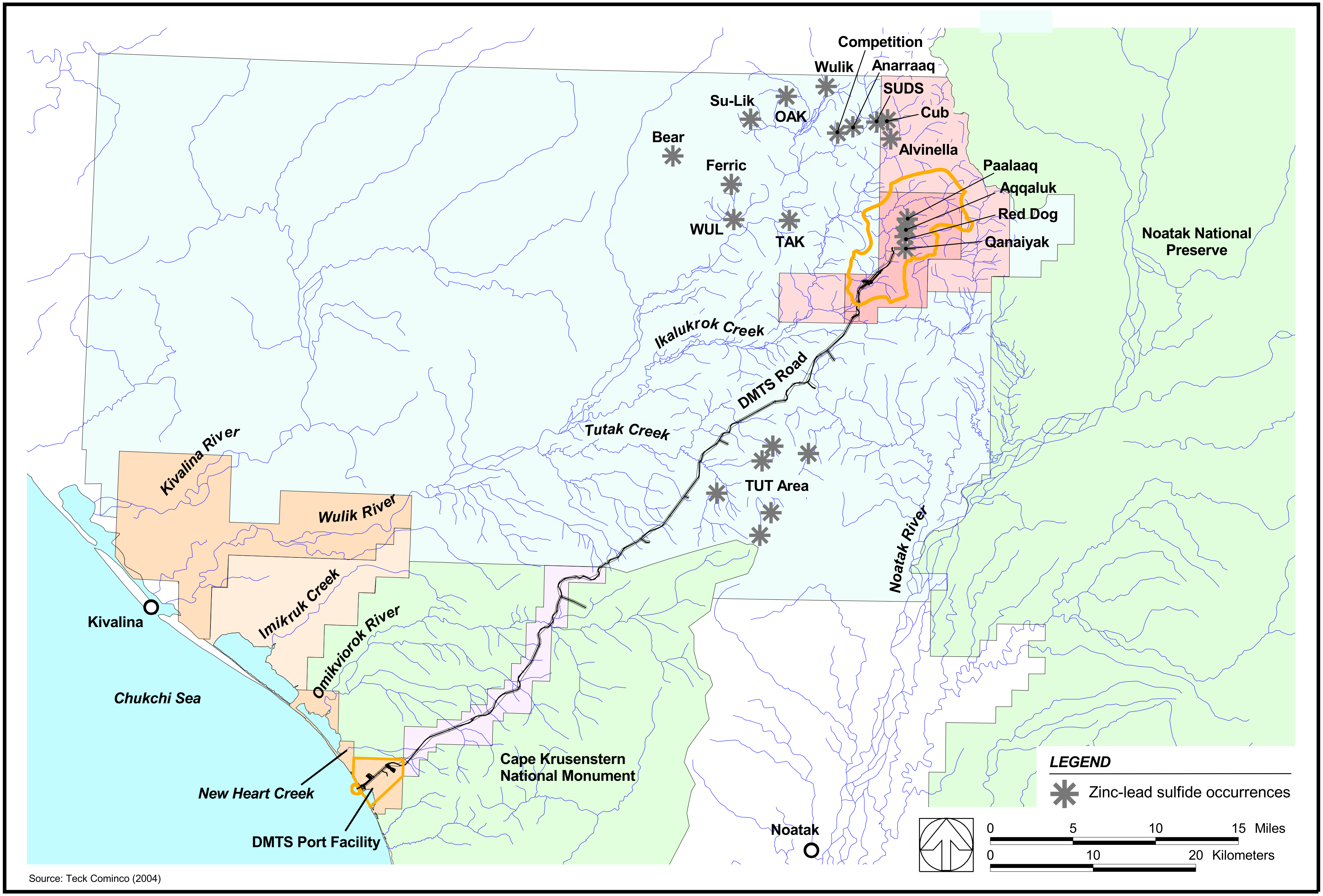


Figure 3. Mineralization map for the Red Dog mining district

Exponent®

8601997.001 5700 | Aug 09, 2007 | Fig 3 mineralization view | Fig 3 mineralization layout | j:\red_dog\projects\mine_closure_prj1.apr

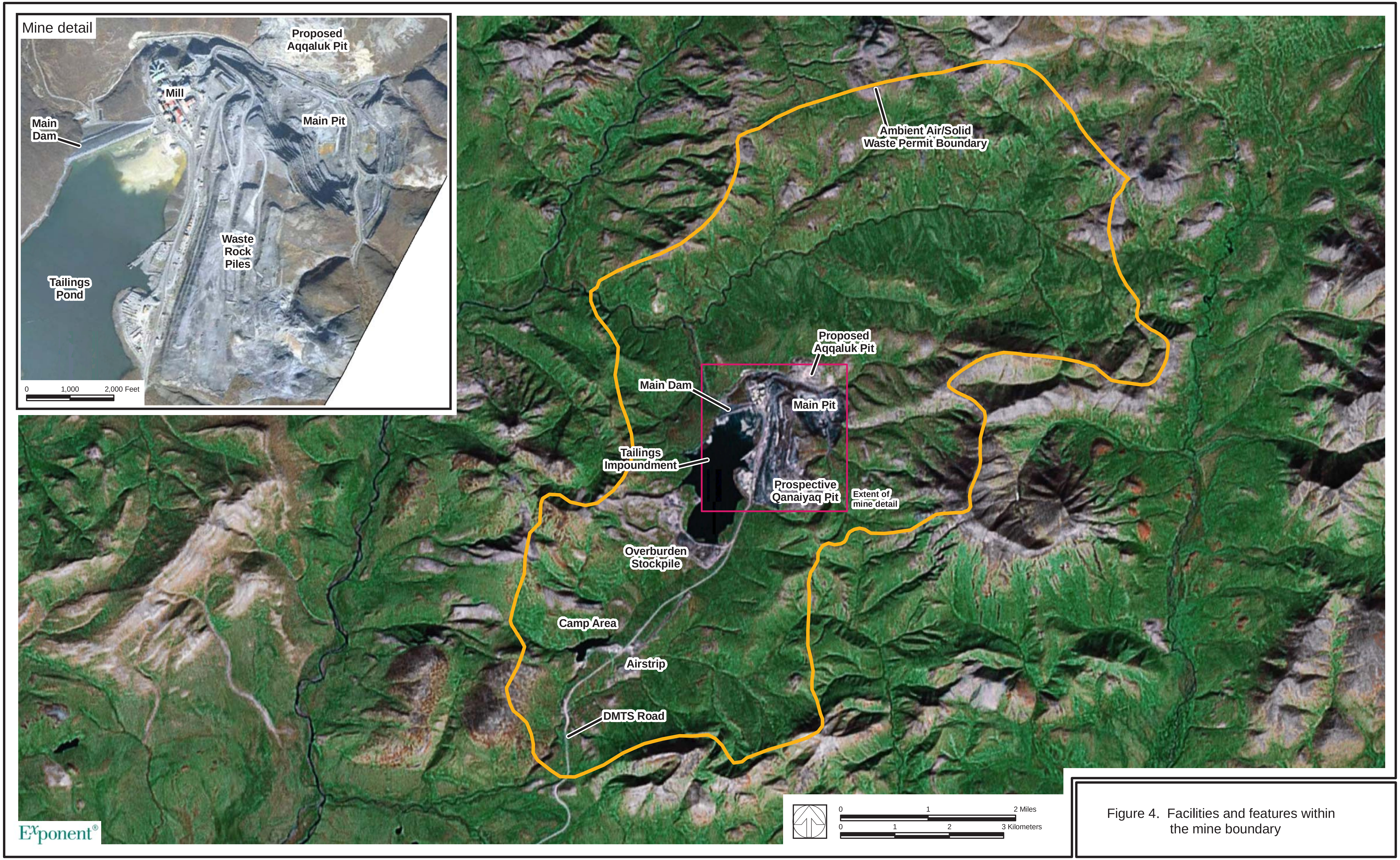
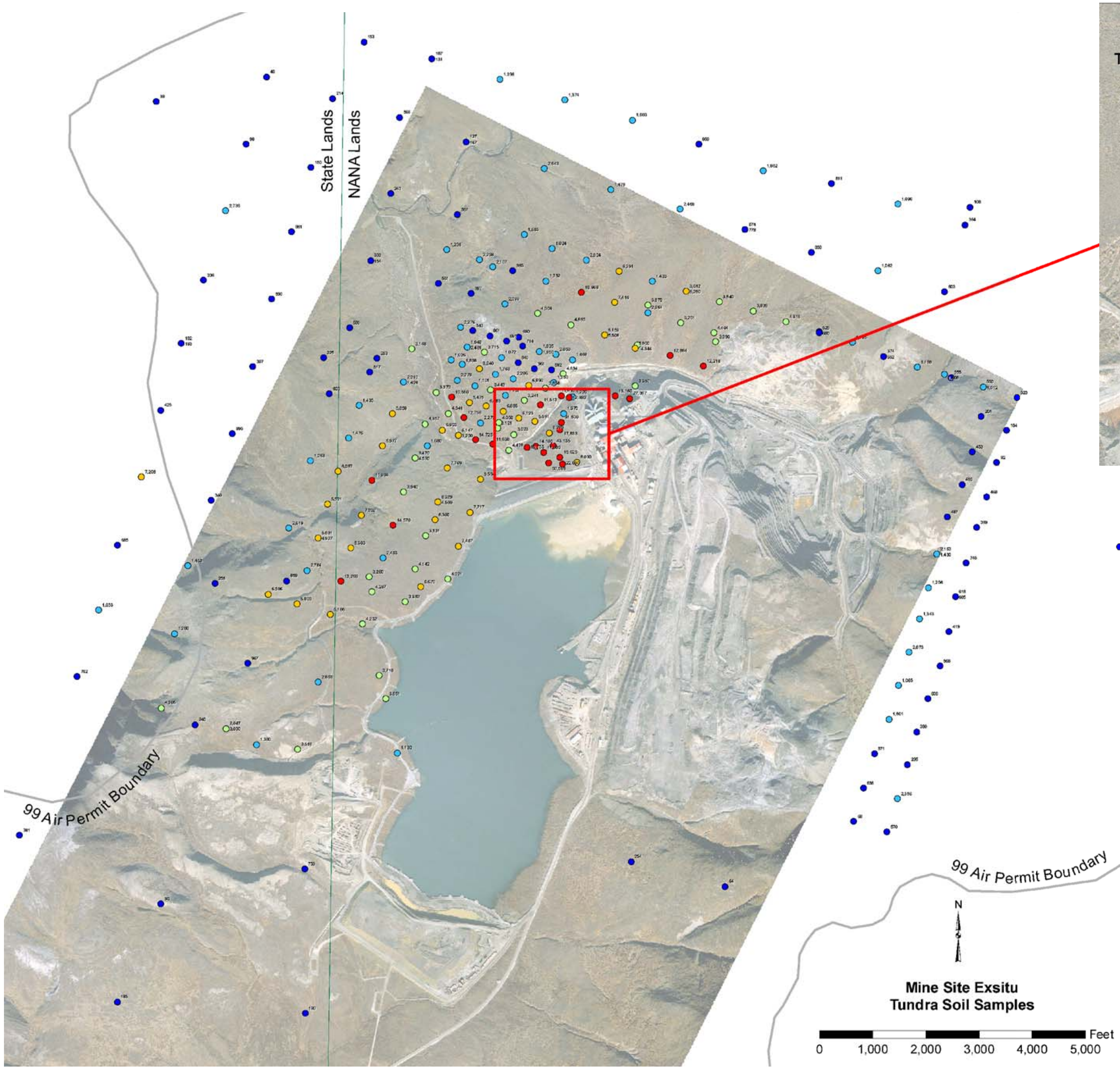
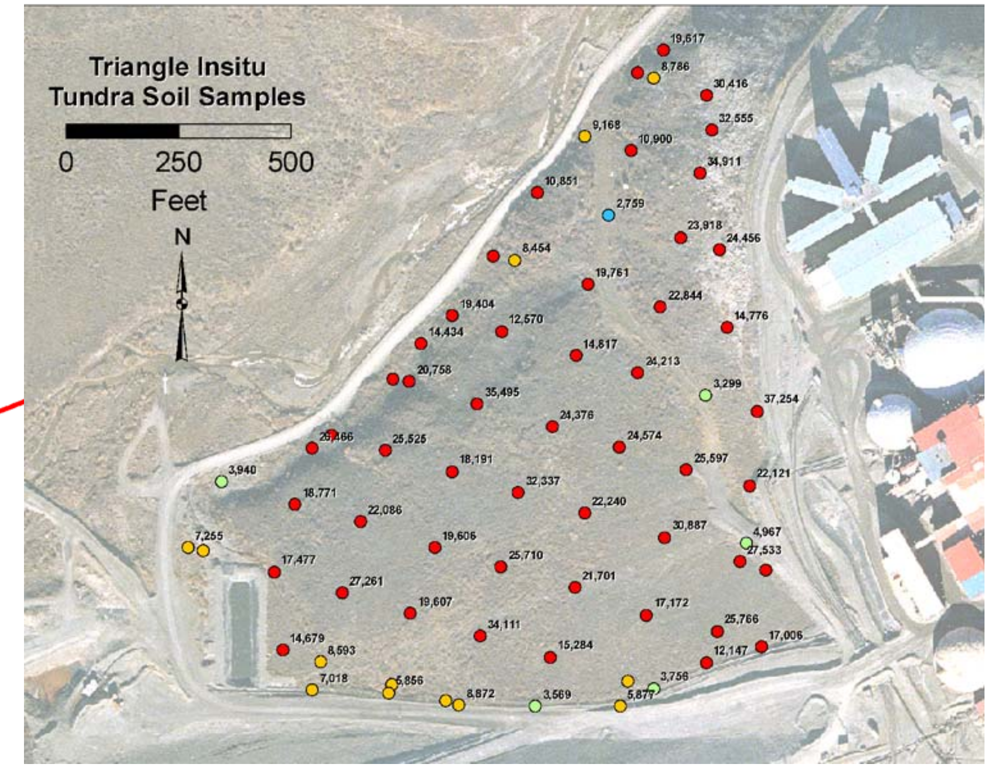


Figure 4. Facilities and features within the mine boundary



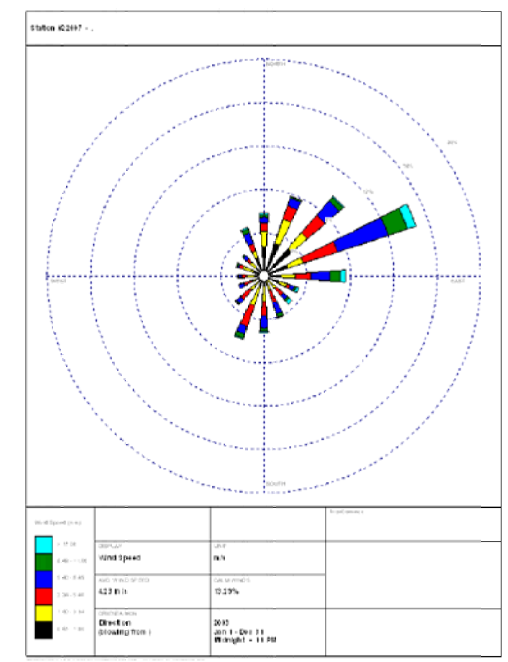


Teck Cominco Alaska
Red Dog Mine Site
Alaska

2003 & 2004 Tundra Soil Samples

Lead ppm

- <1000
- 1001 - 3000
- 3001 - 5000
- 5001 - 10000
- >10001



Source: Teck Cominco (2005)

Exponent®

Figure 5. Lead concentrations in mine soil samples

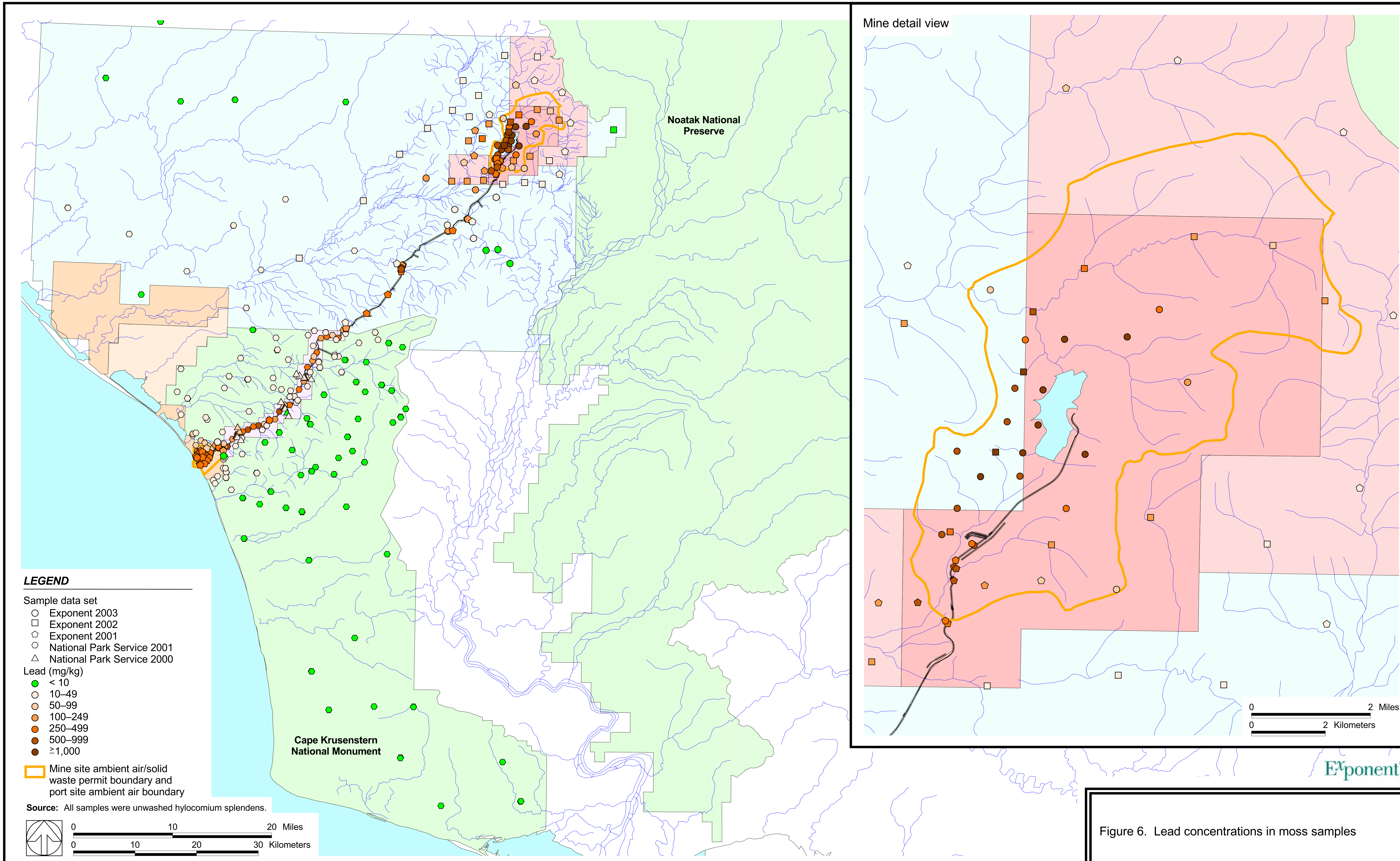


Figure 6. Lead concentrations in moss samples

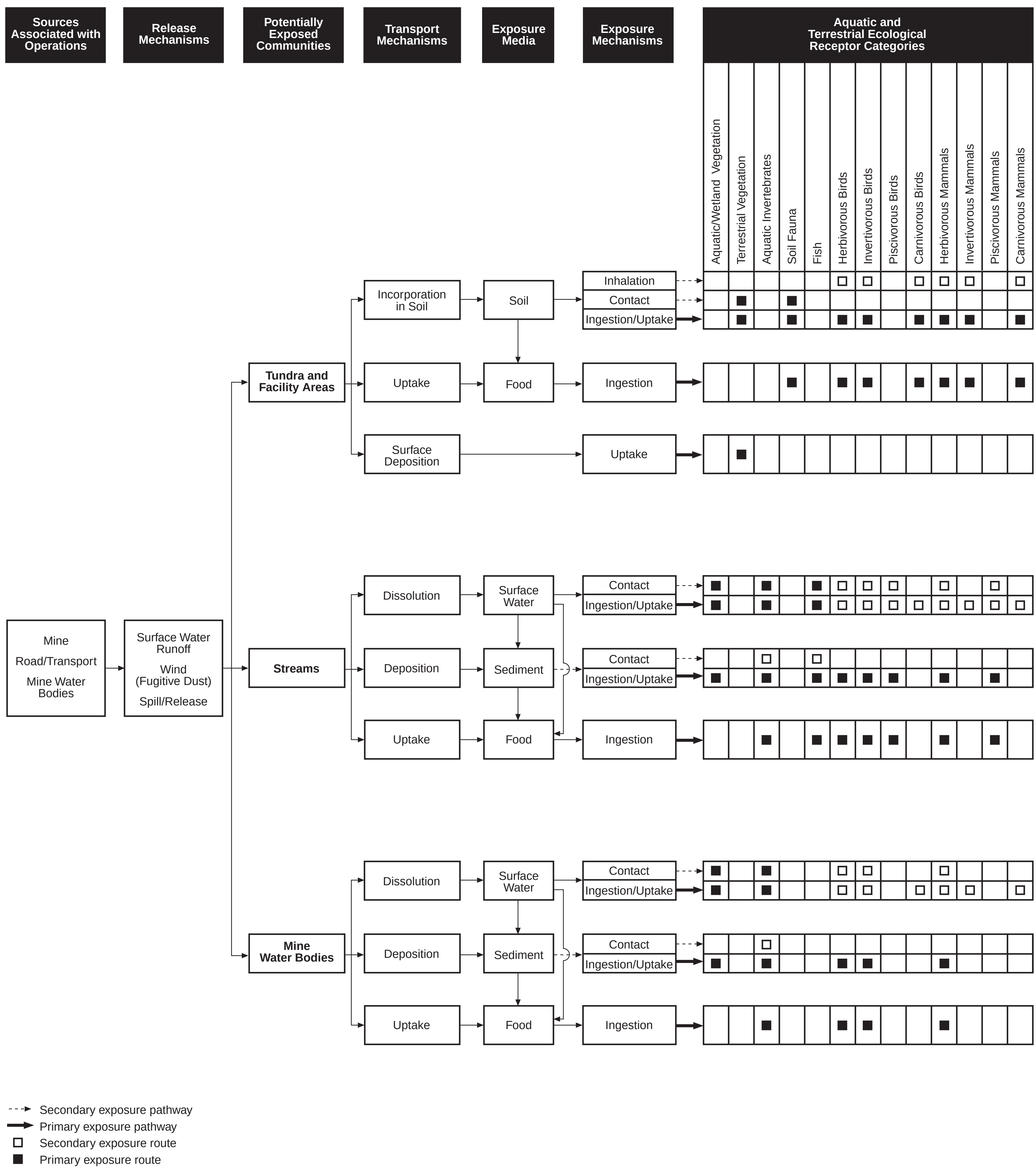


Figure 7. Conceptual site model

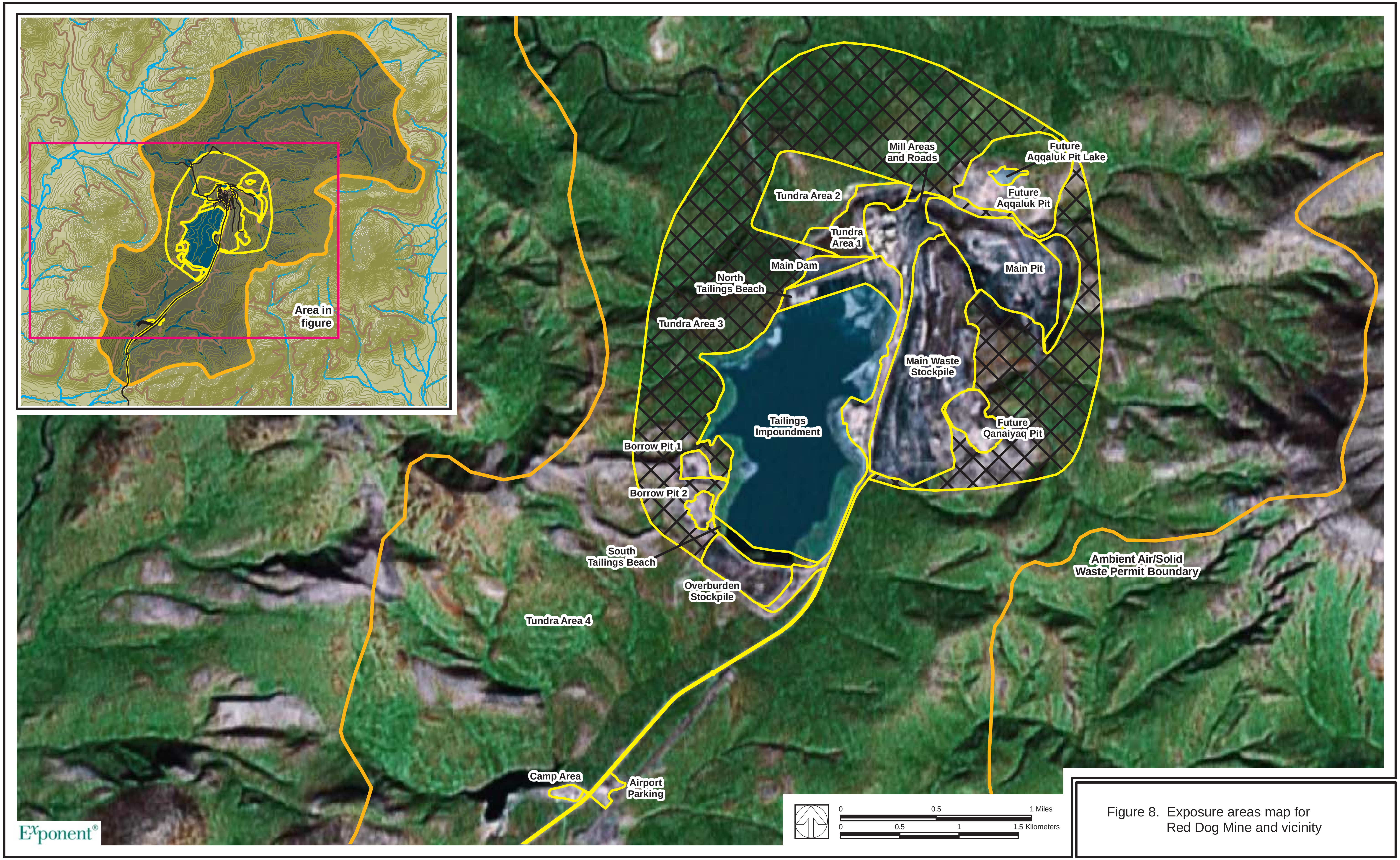


Figure 8. Exposure areas map for Red Dog Mine and vicinity

8601997.001 5700 | October 31, 2006 | J:\Red_Dog\projects\mine closure prj5.mxd

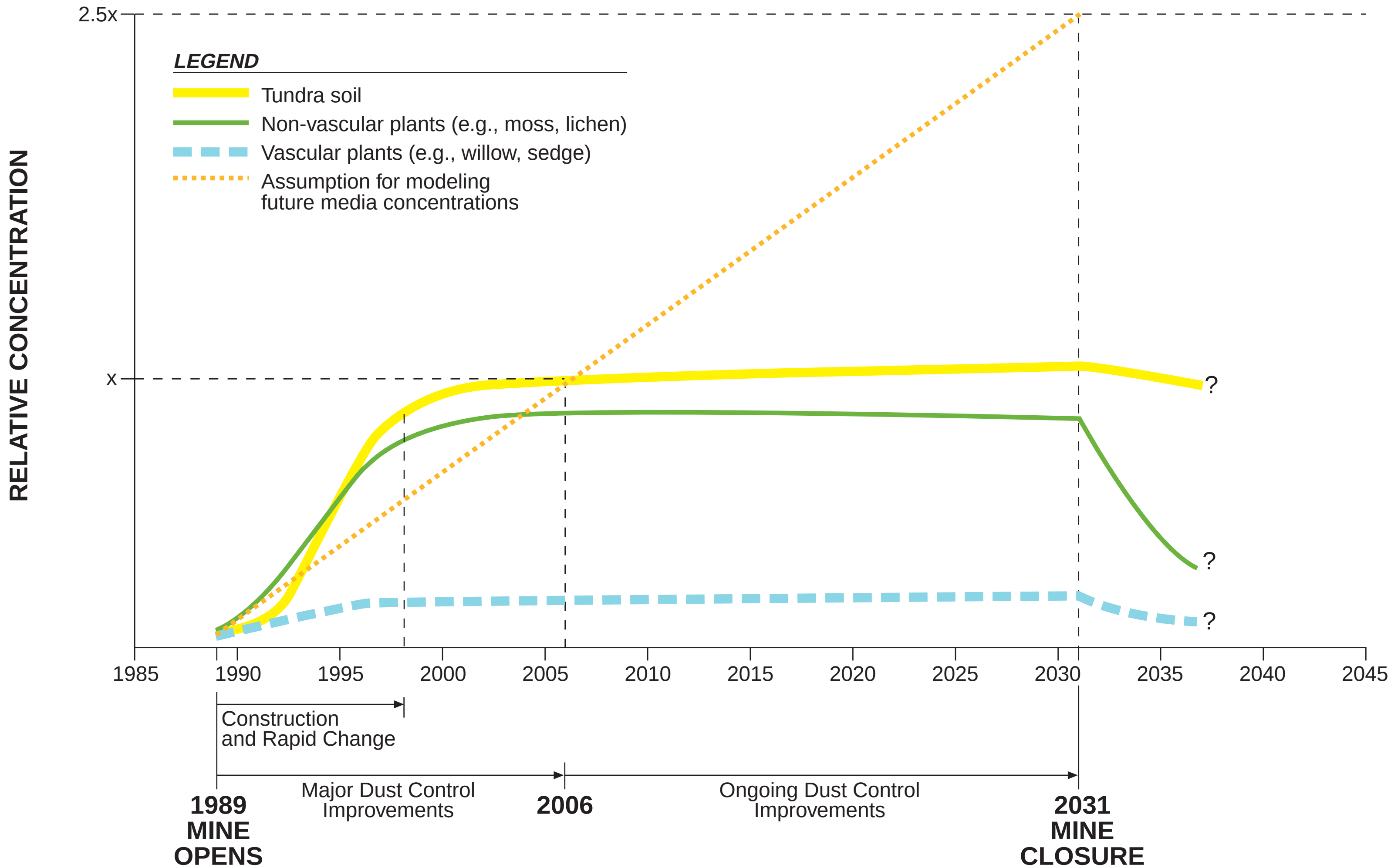


Figure 9. Conceptual model of concentration changes in tundra media over time

8601997.001 5700 12/06/07 WA

Tables

Table 1. Assessment endpoints, representative receptors, and measurement endpoints

Environment	Assessment Endpoint	Representative Receptor[a]	Measurement Endpoint
Tundra	Structure and function of terrestrial plant communities	Terrestrial plant communities	Comparison of measured CoPC concentrations in moss with literature-based effects levels.
Tundra	Structure and function of tundra soil fauna communities	Tundra soil fauna communities	Not directly assessed, evaluated through terrestrial plant community analysis
Tundra	Survival, growth, and reproduction of terrestrial avian herbivore populations	Willow ptarmigan	Range of modeled total dietary exposures (based on measured CoPC concentrations in food, soil, and surface water) relative to avian TRVs
Tundra	Survival, growth, and reproduction of terrestrial mammalian herbivore populations	Tundra vole; caribou	Range of modeled total dietary exposures (based on measured CoPC concentrations in food, soil, and surface water) relative to mammalian TRVs
Tundra	Survival, growth, and reproduction of terrestrial mammalian invertivore populations	Tundra shrew	Range of modeled total dietary exposures (based on measured CoPC concentrations in food, soil, and surface water) relative to mammalian TRVs
Tundra	Survival, growth, and reproduction of terrestrial mammalian carnivore populations	Arctic fox	Range of modeled total dietary exposures (based on measured CoPC concentrations in food, soil, and surface water) relative to mammalian TRVs
Streams	Survival, growth, and reproduction of stream avian herbivore populations	Green-winged teal	Range of modeled total dietary exposures (based on measured CoPC concentrations in food, sediment, and surface water) relative to avian TRVs
Streams	Survival, growth, and reproduction of stream mammalian herbivore populations	Muskrat	Range of modeled total dietary exposures (based on measured CoPC concentrations in food, sediment, and surface water) relative to mammalian TRVs
Mine waterbodies[b]	Survival, growth, and reproduction of tundra pond avian herbivore populations	Green-winged teal	Range of modeled total dietary exposures (based on measured CoPC concentrations in food, sediment, and surface water) relative to avian TRVs
Mine waterbodies[b]	Survival, growth, and reproduction of tundra pond mammalian herbivore populations	Muskrat	Range of modeled total dietary exposures (based on measured CoPC concentrations in food, sediment, and surface water) relative to mammalian TRVs

Note: CoPC - chemical of potential concern
TRV - toxicity reference value

The focused list in this table is adapted from Exponent (2007a). See discussion in Section 3.1.4 of this document.

[a] Receptors evaluated in the risk assessment.

[b] Tailings pond and pit lake (post-closure).

Table 2. Comparison of tundra soil and moss concentrations within the mine permit boundary to those around the DMTS

	N	Min	Max	Arithmetic Mean
Tundra Soil Concentrations				
Cadmium				
Tundra Area 2	47	1.0	348	51.8
Tundra Area 3	96	1.0	196	37.4
Tundra Area 4	72	1.1	80.0	25.3
DMTS port area	238	0.44	438	16.0
DMTS whole area	231	0.53	438	15.6
Lead				
Tundra Area 2	47	340	14,700	4,030
Tundra Area 3	96	169	19,000	3,980
Tundra Area 4	72	23.0	2,740	596
DMTS port area	238	8.62	16,000	800
DMTS whole area	271	11.4	16,000	675
Zinc				
Tundra Area 2	47	1,510	49,200	9,111
Tundra Area 3	96	220	32,800	7,809
Tundra Area 4	72	164	6,720	1,909
DMTS port area	238	15	82,700	3,000
DMTS whole area	271	15	82,700	2,181
Moss Concentrations				
Cadmium				
Tundra Area 3	6	14.0	29.6	23.4
Tundra Area 4	11	1.6	33.5	11.5
DMTS port area	27	0.502	14.0	48.4
DMTS whole area	49	0.502	48.4	11.0
Lead				
Tundra Area 3	6	564.0	1,590	1,139
Tundra Area 4	11	54.2	1,750	578
DMTS port area	27	9.5	1,720	480
DMTS whole area	49	9.5	1,720	380
Zinc				
Tundra Area 3	6	2140	5,340	3,623
Tundra Area 4	11	163	3,960	1,359
DMTS port area	27	59.2	8,120	2,110
DMTS whole area	49	59	8,120	1,510

Note: All concentrations reported in mg/kg.

"DMTS whole area" refers to measured samples from the entire DMTS data set.

Tundra Areas 2, 3, and 4 are exposure areas within the mine permit boundary defined in Figure 8.

Table 3. Exposure scenarios evaluated in the assessment

Receptor	Current Conditions	Post-Closure Conditions
Caribou	• All areas/all water, overwintering[a] • All areas/all water, resident[b]	• All areas/all water, overwintering[a] • All areas/all water, resident[b]
Willow ptarmigan	• All areas/all water • Near facilities, 100 percent impoundment water	• All areas/all water • All areas, 50 percent impoundment water • Near facilities, impoundment and pit lake water • Near facilities, pit lake water only
Arctic fox	• All areas/all water • Near facilities, 100 percent impoundment water	• All areas/all water • All areas, 50 percent impoundment water • Near facilities, impoundment and pit lake water
Green-winged teal	• All areas/all water • Near facilities, 100 percent impoundment water	• All areas/all water • All areas, 50 percent impoundment water • Near facilities, impoundment and pit lake water • Near facilities, 50 percent pit lake water
Muskrat	• All areas/all water • Near facilities, 100 percent impoundment water	• All areas/all water • All areas, 50 percent impoundment water • Near facilities, impoundment and pit lake water
Tundra shrew	• Tundra Areas 2, 3, 4; stream water only	• Tundra Areas 2, 3, 4; stream water only
Tundra vole	• Tundra Areas 2, 3, 4; stream water only	• Tundra Areas 2, 3, 4; stream water only

Note: "All areas" indicates that the receptor is assumed to be exposed in all areas within the permit boundary, with exposure concentrations in each area weighted by its fraction of the overall area.

"All water" indicates that the receptor is assumed to be exposed in all water sources within the permit boundary, with exposure concentrations from each water source weighted by its fraction of the overall area. Streams are associated with the area of Tundra Area 4 (the outlying tundra areas).

"Near facilities" indicates that the receptor's modeled exposure is constrained to areas within and near facilities (i.e., excluding the outlying area and stream water sources in Tundra Area 4).

[a] Five months within the permit boundary, 7 months migrating.

[b] Eight months within the permit boundary, 4 months in reference area.

Table 4. Media concentrations for food web models (current conditions)

Area Name	Area Description	Closure Conditions	Area Inclusion[a]	Change Factor[b]	Surface Area (ft^2)	Area Fractions (percent)	Soil Concentration (mg/kg) Water Concentration (mg/L) Cadmium	Lead	Zinc
Soil Exposure Areas - Disturbed Areas									
Main Pit	Main pit west of RD Ck diversion	Main Waste surrogate	1	1	7,132,284	0.80	97.1 [c]	25,307 [c]	13,618 [c]
Main Pit - Upper	East of Red Dog Creek diversion	Main Waste surrogate	1	1	1,607,004	0.18	97.1 [c]	25,307 [c]	13,618 [c]
Aqqaluk Pit		Main Waste surrogate	1	1	5,963,224	0.67	97.1 [c]	25,307 [c]	13,618 [c]
Main Waste & Oxide Stockpiles		Main Waste data	1	1	13,156,071	1.5	97.1 [c]	25,307 [c]	13,618 [c]
Qanaiyaq Pit		Main Waste surrogate	1	1	1,809,653	0.20	97.1 [c]	25,307 [c]	13,618 [c]
Tailings Beaches	Beach areas	Tailings data	1	1	3,333,714	0.37	341 [c]	26,000 [d]	55,500 [d]
Main Dam	Assume Siksikpuk		1	1	746,130	0.08	64.3 [c]	20,497 [c]	10,116 [c]
Overburden Stockpile	Kivalina shales		1	1	2,343,465	0.26	38.6 [c]	4,030 [c]	3,086 [c]
Facility Areas & Roads	Mill, roads, airport pkg and camp	Use current road data	1	1	6,845,314	0.76	33.2 [e]	2,491 [e]	6,985 [e]
Borrow Pits	Assume Siksikpuk		1	1	1,101,147	0.12	64.3 [c]	20,497 [c]	10,116 [c]
Soil Exposure Areas - Undisturbed Areas									
Tundra Area 1	Triangle and north slope near PAC		1	1	2,583,048	0.29	65.3	23,563	14,176
Tundra Area 2	Near triangle and impoundment		1	1	5,324,691	0.59	65.2	5,012	11,182
Tundra Area 3	Surrounding Area 2 and facility		1	1	69,153,193	7.7	42.9	4,614	8,875
Tundra Area 4	Outlying tundra		1	1	774,106,016	86.5	33.3	722	2,260
Area-Weighted Soil Concentrations			Included Area:		895,204,954	**Soil**	**37.7**	**2,086**	**3,488**
Water Exposure Areas									
Streams	Mine area stream data		1	1	774,106,016	96.7	0.010 [f]	0.132 [f]	1.33 [f]
Tailings Impoundment	Main tailings pond	2005 reclaim water	1	1	26,174,354	3.3	5.4 [g]	2.2 [g]	416 [g]
Weighted Water Concentration			Included Area:		800,280,370	**Water**	**0.2**	**0.2**	**15**
Lichen Exposure Areas									
Tundra Area 1			1	1	2,583,048	0.30	9.4	325	1,016
Tundra Area 2			1	1	5,324,691	0.63	9.4	307	1,015
Tundra Area 3			1	1	69,153,193	8.1	7.5	275	849
Tundra Area 4			1	1	774,106,016	90.9	6.5	227	763
Area-Weighted Lichen Concentrations			Included Area:		851,166,949	**Lichen**	**6.6**	**232**	**772**
Willow/Birch Exposure Areas									
Tundra Area 1			1	1	2,583,048	0.30	4.2	5.0	238
Tundra Area 2			1	1	5,324,691	0.63	4.2	5.0	238
Tundra Area 3			1	1	69,153,193	8.1	4.2	5.0	238
Tundra Area 4			1	1	774,106,016	90.9	4.2	5.0	238
Area-Weighted Willow/Birch Concentrations			Included Area:		851,166,949	**Willow/Birch**	**4.2**	**5.0**	**238**
Sedge Blade Exposure Areas									
Tundra Area 1			1	1	2,583,048	0.30	0.30	5.1	91.2
Tundra Area 2			1	1	5,324,691	0.63	0.30	5.1	91.2
Tundra Area 3			1	1	69,153,193	8.1	0.30	5.1	91.2
Tundra Area 4			1	1	774,106,016	90.9	0.30	5.1	91.2
Area-Weighted Sedge blades Concentrations			Included Area:		851,166,949	**Sedge blades**	**0.30**	**5.1**	**91.2**

Table 4. (cont.)

Area Name	Area Description	Closure Conditions	Area Inclusion[a]	Change Factor[b]	Surface Area (ft^2)	Area Fractions (percent)	Soil Concentration (mg/kg) Water Concentration (mg/L) Cadmium	Lead	Zinc
Invertebrate Exposure Areas									
Tundra Area 1			1	1	2,583,048	0.30	7.8	24.8	373
Tundra Area 2			1	1	5,324,691	0.63	7.8	23.0	373
Tundra Area 3			1	1	69,153,193	8.1	7.8	20.0	373
Tundra Area 4			1	1	774,106,016	90.9	7.8	15.6	373
Area-Weighted Invertebrate Concentrations			Included Area:		851,166,949	**Invertebrate**	**7.8**	**16.0**	**373**
Mammal Exposure Areas									
Tundra Area 1			1	1	2,583,048	0.30	0.41	13.7	146
Tundra Area 2			1	1	5,324,691	0.63	0.41	13.7	146
Tundra Area 3			1	1	69,153,193	8.1	0.41	13.7	141
Tundra Area 4			1	1	774,106,016	90.9	0.41	13.7	137
Area-Weighted Mammal Concentrations			Included Area:		851,166,949	**Mammal**	**0.41**	**13.7**	**138**
Sedge Seeds Exposure Areas									
Tundra Area 1			1	1	2,583,048	0.30	0.13	0.0036	60.8
Tundra Area 2			1	1	5,324,691	0.63	0.13	0.0036	60.8
Tundra Area 3			1	1	69,153,193	8.1	0.13	0.0036	60.8
Tundra Area 4			1	1	774,106,016	90.9	0.13	0.0036	60.8
Area-Weighted Sedge Seeds Concentrations			Included Area:		851,166,949	**Sedge Seeds**	**0.13**	**0.0036**	**60.8**
Sedge Whole Plants Exposure Areas									
Tundra Area 1			1	1	2,583,048	0.30	1.1	29.8	165
Tundra Area 2			1	1	5,324,691	0.63	1.1	29.8	165
Tundra Area 3			1	1	69,153,193	8.1	1.1	29.8	165
Tundra Area 4			1	1	774,106,016	90.9	1.1	29.8	165
Area-Weighted Sedge Whole Plant Concentrations			Included Area:		851,166,949	**Sedge Whole**	**1.1**	**29.8**	**165**
Moss Exposure Areas									
Tundra Area 1			1	1	2,583,048	0.30	148	1,283	24,892
Tundra Area 2			1	1	5,324,691	0.63	51.9	1,192	8,763
Tundra Area 3			1	1	69,153,193	8.1	49.1	1,040	8,287
Tundra Area 4			1	1	774,106,016	90.9	14.0	816	2,373
Area-Weighted Moss Concentrations			Included Area:		851,166,949	**Moss**	**17.5**	**838**	**2,961**

[a] A flag used to indicate the inclusion of an area in calculation of area-weighted concentrations.

[b] A multiplier used to modify media concentrations.

[c] SRK (2003).

[d] SRK (2006b).

[e] Harbke (2006a,b).

[f] Hockley (2006a).

[g] Hockley (2006b).

Table 5. Summary of significant Spearman rank correlations between metals in tundra soil and metals in other biota tissue media

Media	Metal	Correlation with Soil Metals: Antimony	Barium	Cadmium	Lead	Thallium	Zinc	Strongest Correlation	Related to
Tundra Soil (N=51)									
	Aluminum[a]	ns	ns	ns	ns	0.846	ns	0.846	Thallium
	Antimony	--	0.585	0.866	0.826	0.749	0.811	0.866	Cadmium
	Barium	0.585	--	0.691	0.746	0.808	0.721	0.808	Thallium
	Thallium	0.749	0.808	0.840	0.852	--	0.780	0.852	Lead
Moss (N=12)									
	Aluminum	0.673	0.813	0.757	0.846	0.708	0.768	0.846	Lead
	Antimony	0.823	0.725	0.739	0.772	0.816	0.712	0.823	Antimony
	Barium	ns	0.900	ns	ns	0.774	ns	0.900	Barium
	Cadmium	0.823	0.774	0.837	0.877	0.865	0.804	0.877	Lead
	Lead	0.851	0.746	0.809	0.835	0.837	0.772	0.851	Antimony
	Thallium	0.725	0.865	ns	0.660	0.886	ns	0.886	Thallium
	Zinc	0.900	0.697	0.914	0.930	0.767	0.912	0.930	Lead
Lichen (N=18)									
	Aluminum	0.538	0.741	ns	0.605	0.665	0.615	0.741	Barium
	Antimony	0.700	0.692	0.826	0.812	0.775	0.775	0.826	Cadmium
	Barium	0.570	0.918	0.501	0.619	0.809	0.592	0.918	Barium
	Cadmium	0.733	0.527	0.786	0.705	0.759	0.633	0.786	Cadmium
	Lead	0.751	0.520	0.720	0.668	0.662	0.644	0.751	Antimony
	Thallium	ns	0.684	ns	ns	0.514	ns	0.684	Barium
	Zinc	0.673	ns	0.692	0.640	0.640	0.620	0.692	Cadmium
Willow (N=20)									
	Aluminum	ns	0.492	0.501	0.588	ns	0.648	0.648	Zinc
	Antimony	ns	ns	ns	ns	ns	ns	0.800	Aluminum (willow)
	Barium	ns	ns	ns	ns	ns	ns	0.879	Aluminum (invertebrates)
	Cadmium	ns	ns	ns	ns	ns	ns	0.722	Barium (sedge blades)
	Lead	ns	ns	0.627	0.653	ns	0.642	0.653	Lead
	Thallium	ns	ns	0.610	0.661	0.603	0.576	0.661	Lead
	Zinc	ns	ns	ns	ns	ns	ns	0.813	Aluminum (invertebrates)
Sedge, blades (N=23)									
	Aluminum	0.531	0.483	0.546	0.662	ns	0.666	0.666	Zinc
	Antimony	ns	ns	ns	ns	ns	ns	0.631	Antimony (willow)
	Barium	0.492	0.723	0.448	0.594	0.695	0.552	0.723	Barium
	Cadmium	0.554	0.452	0.547	0.576	0.637	0.489	0.637	Thallium
	Lead	ns	ns	ns	ns	ns	ns	0.950	Cadmium (sedge,whole)
	Thallium	ns	ns	ns	ns	ns	ns	0.912	Lead (sedge,whole)
	Zinc	ns	ns	ns	ns	ns	ns	0.933	Lead (sedge,whole)
Invertebrates (N=17)									
	Aluminum	0.665	0.571	0.645	0.651	0.531	0.657	0.665	Antimony
	Antimony	0.846	ns	0.836	0.770	0.611	0.738	0.846	Antimony
	Barium	0.581	0.857	0.545	0.652	0.695	0.680	0.857	Barium
	Cadmium	ns	0.582	ns	ns	0.646	ns	0.646	Thallium
	Lead	0.792	ns	0.746	0.678	0.531	0.666	0.792	Antimony
	Thallium	0.819	0.620	0.627	0.657	0.669	0.637	0.819	Antimony
	Zinc	ns	ns	ns	ns	ns	ns	0.608	Zinc (lichen)
Mammals (N=19)									
	Aluminum	0.790	0.743	0.777	0.729	0.786	0.736	0.790	Antimony
	Antimony	0.767	0.747	0.665	0.751	0.597	0.730	0.767	Antimony
	Barium	ns	0.623	ns	ns	0.493	ns	0.623	Barium
	Cadmium	0.725	0.694	0.662	0.628	0.628	0.634	0.725	Antimony
	Lead	0.531	ns	0.536	ns	ns	ns	0.536	Cadmium
	Thallium	0.591	0.583	0.488	0.552	ns	0.529	0.591	Antimony
	Zinc	0.736	0.681	0.777	0.702	0.682	0.702	0.777	Cadmium

Note: Sedge whole plant and seed samples are collocated with no other media. No predictive relationship was possible.

-- - correlation with itself, estimate is 1
ns - not significant (*P* > 0.05)

[a] Relationship based on mine, road, and port area survey data from the DMTS assessment (Exponent 2007a).

Table 6. Significant regression models for strongest relationships based on Spearman rank correlations

	Data Used	N	Model Fit *P*-value	Model Fit R-square	Intercept	Slope	Resid.SE	Predictive Relationship Used?[a]	
Predict Tundra Soil									
Aluminum	Thallium, tundra soil[b]	13	0.0003	70.3%	3.6693	0.6218	0.2531	Yes	
Antimony	Cadmium, tundra soil	51	<0.0001	71.8%	-0.2835	0.5487	0.1887	Yes	
Barium	Thallium, tundra soil	51	<0.0001	59.7%	3.4852	0.8159	0.3500	Yes	
Thallium	Lead, tundra soil	51	<0.0001	73.3%	-2.2310	0.6787	0.2700	Yes	
Predict Moss									
Aluminum	Lead, tundra soil	12	0.0061	54.6%	1.9357	0.5434	0.3662	Yes	
Antimony	Antimony, tundra soil	12	0.0002	77.6%	-0.0747	0.9454	0.2172	Yes	
Barium	Barium, tundra soil	12	0.0000	84.4%	-0.4904	1.1653	0.2861	Yes	
Cadmium	Lead, tundra soil	12	0.0000	83.6%	-0.8193	0.6784	0.2216	Yes	
Lead	Antimony, tundra soil	12	0.0000	87.0%	2.1980	1.2411	0.2054	Yes	
Thallium	Thallium, tundra soil	12	0.0001	80.0%	0.0222	1.0249	0.2625	Yes	
Zinc	Lead, tundra soil	12	0.0000	90.3%	1.4337	0.6745	0.1638	Yes	
Predict Lichen									
Aluminum	Barium, tundra soil	18	0.0034	42.4%	1.5029	0.4349	0.3506	No	1
Antimony	Cadmium, tundra soil	18	<0.0001	74.4%	-0.3741	0.4046	0.1365	Yes	
Barium	Barium, tundra soil	18	<0.0001	70.6%	0.6601	0.6537	0.2920	Yes	
Cadmium	Cadmium, tundra soil	18	<0.0001	83.4%	-0.0223	0.5426	0.1392	Yes	
Lead	Antimony, tundra soil	18	<0.0001	70.0%	1.7887	0.9847	0.1900	Yes	
Thallium	Barium, tundra soil	18	0.0102	34.7%	-1.9765	0.2757	0.2619	No	1
Zinc	Cadmium, tundra soil	18	<0.0001	69.4%	2.2206	0.4259	0.1627	Yes	
Predict Willow									
Aluminum	Zinc, tundra soil	20	0.0143	29.0%	-0.0599	0.4540	0.4197	No	1
Antimony	Aluminum, willow	20	0.0017	43.1%	-1.9208	0.5553	0.3182	No	1,2
Barium	Aluminum, invertebrates	12	0.0005	72.1%	0.0918	0.7981	0.1946	No	2
Cadmium	Barium, sedge blades	20	0.0009	47.0%	-1.7924	1.2589	0.3079	No	1,2
Lead	Lead, tundra soil	20	0.0072	33.8%	-0.7091	0.3778	0.3743	No	1
Thallium	Lead, tundra soil	20	0.0016	43.5%	-3.3429	0.3965	0.3193	No	1
Zinc	Aluminum, invertebrates	12	0.0100	50.1%	1.5560	0.4600	0.1796	No	2
Predict Sedge Blades									
Aluminum	Zinc, tundra soil	23	0.0056	31.2%	0.0764	0.3884	0.3734	No	1
Antimony	Antimony, willow	21	0.0189	25.8%	-0.6012	0.4811	0.3260	No	1,2
Barium	Barium, tundra soil	23	0.0001	51.3%	1.0208	0.2428	0.1790	Yes	
Cadmium	Thallium, tundra soil	23	0.0011	40.6%	-0.6839	0.4972	0.3298	No	1
Lead	Cadmium, tundra soil	23	0.0010	40.8%	-0.3094	0.6797	0.4174	No	1
Thallium	Lead, willow	21	0.0086	31.1%	-2.4736	0.6284	0.4185	No	1,2
Zinc	Zinc, invertebrates	15	0.0128	39.0%	-0.3611	0.8751	0.1530	No	1,2
Predict Invertebrate									
Aluminum	Antimony, tundra soil	17	0.0018	48.7%	1.5566	1.0339	0.3140	No	1
Antimony	Antimony, tundra soil	17	0.0000	71.4%	-1.7650	1.4530	0.2723	Yes	
Barium	Barium, tundra soil	17	0.0000	72.7%	0.0833	0.4453	0.2449	Yes	
Cadmium	Thallium, tundra soil	17	0.0359	26.2%	0.8741	0.4498	0.3741	No	1
Lead	Antimony, tundra soil	17	0.0002	61.2%	0.4384	1.2711	0.2994	Yes	
Thallium	Antimony, tundra soil	17	0.0003	59.7%	-2.0650	1.0152	0.2468	Yes	
Zinc	Zinc, lichen	16	0.0318	28.9%	1.6275	0.3193	0.1457	No	1,2
Predict Mammal									
Aluminum	Antimony, tundra soil	19	0.0002	67.2%	1.9887	1.1961	0.3612	Yes	
Antimony	Antimony, tundra soil	19	0.0004	52.7%	-1.7887	0.6155	0.2516	Yes	
Barium	Barium, tundra soil	19	0.0129	31.2%	1.1912	0.1673	0.1930	No	1
Cadmium	Antimony, tundra soil	19	0.0036	40.1%	-0.7941	0.5805	0.3067	No	1
Lead	Cadmium, tundra soil	19	0.0055	37.3%	0.5749	0.3449	0.3350	No	1
Zinc	Cadmium, tundra soil	19	0.0000	64.3%	2.0031	0.0880	0.0491	Yes	

Note: Sedge whole plant and seed samples are collocated with no other media. No analysis was conducted.

[a] Where the predictive relationship is not used, measured data were used. See Table 7 for specifics.
1 - Relationship explains less than 50 percent of the variability, therefore not used for predicting media concentrations.
2 - No significant relationship to tundra soil, therefore not used for predicting media concentrations (see Table 3).

[b] Relationship based on mine, road, and port area survey data from the DMTS assessment (Exponent 2007a).

Table 7. Prepared dataset of tundra soil concentrations

	N	Min	Max	Arithmetic Mean	Geometric Mean	UCL	UCL Method
Cadmium							
Tundra Area 1	20	8.0	131	53.4	44.4	65.3	Normal
Tundra Area 2	47	1.0	348	51.8	33.9	65.2	Gamma
Tundra Area 3	96	1.0	196	37.4	26.9	42.9	Gamma
Tundra Area 4	72	1.1	80.0	25.3	18.3	33.3	Non-parametric
Lead							
Tundra Area 1	20	1,370	50,600	16,363	11,068	23,563	Gamma
Tundra Area 2	47	340	14,700	4,030	2,744	5,012	Gamma
Tundra Area 3	96	169	19,000	3,980	2,707	4,614	Gamma
Tundra Area 4	72	23.0	2,740	596	369	722	Gamma
Zinc							
Tundra Area 1	20	1,910	30,600	10,509	8,085	14,176	Gamma
Tundra Area 2	47	1,510	49,200	9,111	6,504	11,182	Gamma
Tundra Area 3	96	220	32,800	7,809	5,871	8,875	Gamma
Tundra Area 4	72	164	6,720	1,909	1,322	2,260	Gamma

Note: All concentrations reported in mg/kg.

Tundra area statistics from mine grid data in Teck Cominco (2005).

UCL - 95 percent upper confidence limit on the mean, recommended by ProUCL software

Table 8. Statistical summary of representative measured metals concentrations in biota tissue media

Metal	Location of Samples	N	Min	Max	Arithmetic Mean	Geometric Mean	UCL	UCL Method
Moss								
Cadmium	Tundra Area 3	6	14.00	29.6	23.4	22.6	28	Normal
Cadmium	Tundra Area 4	11	1.6	33.5	11.5	8.2	17	Normal
Lead	Tundra Area 3	6	564.0	1,590	1138.8	1,069	1,468	Normal
Lead	Tundra Area 4	11	54.2	1,750	578	376	862	Normal
Zinc	Tundra Area 3	6	2140	5,340	3,623	3,430	4,650	Normal
Zinc	Tundra Area 4	11	163	3,960	1,359	943	1,992	Normal
Lichen								
Cadmium	DMTS near mine	11	1.3	19.1	5.5	4.0	9.0	Gamma
Lead	DMTS near mine	11	46.1	1,530	316	175	690	Lognormal
Zinc	DMTS near mine	11	141	2,740	682	458	1,446	Lognormal
Willow								
Cadmium	DMTS near mine	8	1.8	4.9	3.3	3.1	4.2	Normal
Lead	DMTS near mine	8	0.37	6.9	1.6	1.0	5.0	Lognormal
Zinc	DMTS near mine	8	79.8	330	182	166	238	Normal
Sedge, blades								
Cadmium	DMTS near mine	9	0.038	0.40	0.21	0.16	0.30	Normal
Lead	DMTS near mine	9	0.30	8.0	2.4	1.4	5.1	Gamma
Zinc	DMTS near mine	9	33.0	166	65.3	58.6	91.2	Gamma
Sedge, seeds								
Cadmium	DMTS whole area	8	0.043	0.14	0.098	0.089	0.13	Normal
Lead	DMTS whole area	8	0.28	2.6	1.0	0.8	1.5	Normal
Zinc	DMTS whole area	8	55.3	65.0	58.9	58.8	60.8	Normal
Sedge, whole plants								
Cadmium	DMTS whole area	9	0.034	1.7	0.51	0.29	1.1	Gamma
Lead	DMTS whole area	9	0.76	48.1	13.0	6.8	29.8	Gamma
Zinc	DMTS whole area	9	40.5	351	100	78	165	Gamma
Invertebrates								
Cadmium	DMTS whole area	17	0.38	19.9	5.2	3.6	7.8	Gamma
Lead	DMTS whole area	17	0.45	24.1	6.3	3.7	10.1	Gamma
Zinc	DMTS whole area	17	143	602	311	287	373	Gamma
Mammals								
Cadmium	DMTS whole area	19	0.034	1.0	0.28	0.20	0.41	Gamma

Note: All concentrations are reported in mg/kg.

Tundra Areas 3 and 4 are exposure areas within the mine permit boundary defined in Figure 8.

"DMTS near mine" refers to data from the DMTS dataset collected in the mine vicinity outside the mine permit boundary.

"DMTS whole area" refers to measured samples from the entire DMTS dataset.

DMTS - DeLong Mountain Regional Transportation System
UCL - 95 percent upper confidence limit on the mean, recommended by ProUCL software

Table 9. Prepared dataset of metals concentrations for all biota tissue media within the mine tundra areas

	Moss			Lichen			Willow			Sedge, Blades			Sedge, Seeds			Sedge, Whole Plants			Invertebrates			Small Mammals		
	Mean	UCL		Mean	UCL		Mean	UCL		Mean	UCL		Mean	UCL		Mean	UCL		Mean	UCL		Mean	UCL	
Tundra Area 1																								
Cadmium	116	148	p	8.4	9.4	p	3.3	4.2	m	0.21	0.30	m	0.098	0.13	mw	0.51	1.1	mw	5.2	7.8	mw	0.28	0.41	mw
Lead	1,105	1,283	p	289	325	p	1.6	5.0	m	2.4	5.1	m	1.0	1.5	mw	13.0	29.8	mw	21.3	24.8	p	9.5	13.7	mw
Zinc	19,464	24,892	p	932	1,016	p	182	238	m	65.3	91.2	m	58.9	60.8	mw	100	165	mw	311	373	mw	143	146	p
Tundra Area 2																								
Cadmium	44.8	51.9	p	8.3	9.4	p	3.3	4.2	m	0.21	0.30	m	0.098	0.13	mw	0.51	1.1	mw	5.2	7.8	mw	0.28	0.41	mw
Lead	1,013	1,192	p	270	307	p	1.6	5.0	m	2.4	5.1	m	1.0	1.5	mw	13.0	29.8	mw	19.4	23.0	p	9.5	13.7	mw
Zinc	7,564	8,763	p	921	1,015	p	182	238	m	65.3	91.2	m	58.9	60.8	mw	100	165	mw	311	373	mw	143	146	p
Tundra Area 3																								
Cadmium	44.4	49.1	p	6.9	7.5	p	3.3	4.2	m	0.21	0.30	m	0.098	0.13	mw	0.51	1.1	mw	5.2	7.8	mw	0.28	0.41	mw
Lead	834	1,040	p	231	275	p	1.6	5.0	m	2.4	5.1	m	1.0	1.5	mw	13.0	29.8	mw	15.9	20.0	p	9.5	13.7	mw
Zinc	7,501	8,287	p	801	849	p	182	238	m	65.3	91.2	m	58.9	60.8	mw	100	165	mw	311	373	mw	139	141	p
Tundra Area 4																								
Cadmium	12.3	14.0	p	5.6	6.5	p	3.3	4.2	m	0.21	0.30	m	0.098	0.13	mw	0.51	1.1	mw	5.2	7.8	mw	0.28	0.41	mw
Lead	647	816	p	189	227	p	1.6	5.0	m	2.4	5.1	m	1.0	1.5	mw	13.0	29.8	mw	12.3	15.6	p	9.5	13.7	mw
Zinc	2,085	2,373	p	678	763	p	182	238	m	65.3	91.2	m	58.9	60.8	mw	100	165	mw	311	373	mw	134	137	p

Note: m - mean and UCL calculated from concentrations measured in mine area samples from the DMTS risk assessment
mw - mean and UCL calculated from concentrations measured in entire DMTS risk assessment areas as few or no samples were collected from the mine area
p - concentrations predicted from correlation relationship with tunda soil using the mean and UCL concentration for tundra soil
UCL - 95 percent upper confidence limit on the mean

Table 10. Media concentrations for food web models (predicted post-closure conditions)

Area Name	Area Description	Closure Conditions	Area Inclusion[a]	Change Factor[b]	Surface Area (ft^2)	Area Fractions (percent)	Soil Concentration (mg/kg) Water Concentration (mg/L) Cadmium	Lead	Zinc
Soil Exposure Areas - Disturbed Areas									
Main Pit	Main pit west of RD Ck diversion	Kivalina cover	1	1	7,132,284	0.80	38.6 [c]	4,030 [c]	3,086 [c]
Main Pit - Upper	East of Red Dog Creek diversion	Open pit walls	1	1	1,607,004	0.18	97.1 [d]	25,307 [d]	13,618 [d]
Aqqaluk Pit		Open walls w/pit lake	1	1	5,963,224	0.67	97.1 [d]	25,307 [d]	13,618 [d]
Main Waste & Oxide Stockpiles		Kivalina cover	1	1	13,156,071	1.5	38.6 [c]	4,030 [c]	3,086 [c]
Qanaiyaq Pit		bermed or fenced	1	1	1,809,653	0.20	97.1 [d]	25,307 [d]	13,618 [d]
Tailings Beaches	Beach areas	Kivalina cover	1	1	3,333,714	0.37	38.6 [c]	4,030 [c]	3,086 [c]
Main Dam		Assume Kivalina cover	1	1	746,130	0.08	64.3 [c]	20,497 [c]	10,116 [c]
Overburden Stockpile		Kivalina shales	1	1	2,343,465	0.26	38.6 [c]	4,030 [c]	3,086 [c]
Facility Areas & Roads	Mill, roads, airport pkg and camp	Use current road data	1	1	6,845,314	0.76	33.2 [e]	2,491 [e]	6,985 [e]
Borrow Pits		Kivalina cover	1	1	1,101,147	0.12	64.3 [d]	20,497 [d]	10,116 [d]
Soil Exposure Areas - Undisturbed Areas									
Tundra Area 1	Triangle and north slope near PAC		1	2.5	2,583,048	0.29	163	58,908	35,441
Tundra Area 2	Near triangle and impoundment		1	2.5	5,324,691	0.59	163	12,530	27,956
Tundra Area 3	Surrounding Area 2 and facility		1	2.5	69,153,193	7.7	107	11,534	22,187
Tundra Area 4	Outlying tundra		1	2.5	774,106,016	86.5	83.2	1,806	5,650
Area-Weighted Soil Concentrations			Included Area:		895,204,954	**Soil**	**84.2**	**3,140**	**7,175**
Water Exposure Areas									
Streams	Mine area stream data		1	1	774,106,016	96.7	0.010 [f]	0.132 [f]	1.33 [f]
Tailings Impoundment	Main tailings pond		1	1	26,174,354	3.3	6.0 [g]	1.0 [g]	316 [g]
Aqqaluk Pit Lake	Pit lake assuming no RDC input	Use this as most cons.	1	1	298,069	0.037	67.0 [h]	5.0 [h]	2,600 [h]
Weighted Water Concentration			Included Area:		800,578,439	**Water**	**0.23**	**0.162**	**12.6**
Lichen Exposure Areas									
Tundra Area 1			1	2.5	2,583,048	0.30	23.4	813	2,539
Tundra Area 2			1	2.5	5,324,691	0.63	23.4	767	2,538
Tundra Area 3			1	2.5	69,153,193	8.1	18.7	688	2,123
Tundra Area 4			1	2.5	774,106,016	90.9	16.3	568	1,906
Area-Weighted Lichen Concentrations			Included Area:		851,166,949	**Lichen**	**16.5**	**580**	**1,930**
Willow/Birch Exposure Areas									
Tundra Area 1			1	2.5	2,583,048	0.30	10.4	12.4	596
Tundra Area 2			1	2.5	5,324,691	0.63	10.4	12.4	596
Tundra Area 3			1	2.5	69,153,193	8.1	10.4	12.4	596
Tundra Area 4			1	2.5	774,106,016	90.9	10.4	12.4	596
Area-Weighted Willow/Birch Concentrations			Included Area:		851,166,949	**Willow/Birch**	**10.4**	**12.4**	**596**
Sedge Blade Exposure Areas									
Tundra Area 1			1	2.5	2,583,048	0.30	0.75	12.8	228
Tundra Area 2			1	2.5	5,324,691	0.63	0.75	12.8	228
Tundra Area 3			1	2.5	69,153,193	8.1	0.75	12.8	228
Tundra Area 4			1	2.5	774,106,016	90.9	0.75	12.8	228
Area-Weighted Sedge Blades Concentrations			Included Area:		851,166,949	**Sedge blades**	**0.75**	**12.8**	**228**

Table 10. (cont.)

Area Name	Area Description	Closure Conditions	Area Inclusion[a]	Change Factor[b]	Surface Area (ft^2)	Area Fractions (percent)	Soil Concentration (mg/kg) Water Concentration (mg/L) Cadmium	Lead	Zinc
Invertebrate Exposure Areas									
Tundra Area 1			1	2.5	2,583,048	0.30	19.4	61.9	933
Tundra Area 2			1	2.5	5,324,691	0.63	19.4	57.4	933
Tundra Area 3			1	2.5	69,153,193	8.1	19.4	49.9	933
Tundra Area 4			1	2.5	774,106,016	90.9	19.4	39.0	933
Area-Weighted Invertebrate Concentrations			Included Area:		851,166,949	**Invertebrate**	**19.4**	**40.0**	**933**
Mammal Exposure Areas									
Tundra Area 1			1	2.5	2,583,048	0.30	1.0	34.3	365
Tundra Area 2			1	2.5	5,324,691	0.63	1.0	34.3	365
Tundra Area 3			1	2.5	69,153,193	8.1	1.0	34.3	351
Tundra Area 4			1	2.5	774,106,016	90.9	1.0	34.3	344
Area-Weighted Mammal Concentrations			Included Area:		851,166,949	**Mammal**	**1.0**	**34.3**	**345**
Sedge Seeds Exposure Areas									
Tundra Area 1			1	2.5	2,583,048	0.30	0.32	0.0091	152
Tundra Area 2			1	2.5	5,324,691	0.63	0.32	0.0091	152
Tundra Area 3			1	2.5	69,153,193	8.1	0.32	0.0091	152
Tundra Area 4			1	2.5	774,106,016	90.9	0.32	0.0091	152
Area-Weighted Sedge Seeds Concentrations			Included Area:		851,166,949	**Sedge Seeds**	**0.32**	**0.0091**	**152**
Sedge Whole Plants Exposure Areas									
Tundra Area 1			1	2.5	2,583,048	0.30	2.7	74.5	414
Tundra Area 2			1	2.5	5,324,691	0.63	2.7	74.5	414
Tundra Area 3			1	2.5	69,153,193	8.1	2.7	74.5	414
Tundra Area 4			1	2.5	774,106,016	90.9	2.7	74.5	414
Area-Weighted Sedge Whole Plant Concentrations			Included Area:		851,166,949	**Sedge Whole**	**2.7**	**74.5**	**414**
Moss Exposure Areas									
Tundra Area 1			1	2.5	2,583,048	0.30	371	3,207	62,229
Tundra Area 2			1	2.5	5,324,691	0.63	130	2,981	21,908
Tundra Area 3			1	2.5	69,153,193	8.1	123	2,599	20,717
Tundra Area 4			1	2.5	774,106,016	90.9	34.9	2,040	5,932
Area-Weighted Moss Concentrations			Included Area:		851,166,949	**Moss**	**43.6**	**2,095**	**7,404**

[a] A flag used to indicate the inclusion of an area in calculation of area-weighted concentrations.

[b] A multiplier used to modify media concentrations.

[c] SRK (2003).

[d] "Main waste" waste rock data (SRK 2003) are used as a surrogate for pit walls.

[e] Harbke (2006a,b).

[f] Hockley (2006a).

[g] SRK (2004).

[h] SRK (2006a).

Table 11. Toxicity reference values for risk evaluation for wildlife receptors

	TRVs (mg/kg-day)					
	Avian			Mammalian		
CoPC	NOAEL	LOAEL	Citation	NOAEL	LOAEL	Citation
Cadmium	1.5	20	White and Finley (1978)	1.0	10	Sutou et al. (1980)
Lead	3.9	--	Pattee (1984)	11	90	Azar et al. (1973)
	--	11	Edens et al. (1976)	--	--	--
Zinc (TRV1)	130	NA	Stahl et al. (1990)	160	320	Schlicker and Cox (1968)
Zinc (TRV2)	70	120	Jackson et al. (1986)	--	--	--

Note: -- - not applicable
CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NA - not available; no suitable TRV was derived
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table 12. Food web exposure model parameters

Representative Receptor	Community	Body Weight (kg)	Food Ingestion Rate (kg/day(dry wt)	Soil/Sediment Ingestion Rate (kg/day dry wt)	Water Ingestion Rate (L/day)[a]	Diet Composition (percent)	Time Use (days)	Home Range (ha)
Terrestrial								
Willow ptarmigan	Terrestrial avian herbivores	0.53 [b]	0.060 [c]	0.0056 [d]	0.038	90% shrubs, 10% herbaceous plants [e]	365 [f]	3.93 [g]
Tundra vole	Terrestrial mammalian herbivores	0.047 [h]	0.0085 [i]	0.00020 [j]	0.0063	90% herbaceous plants, 5% moss, 5% lichen [k]	365 [f]	0.1087 [l]
Caribou	Terrestrial mammalian herbivores	107 [m]	5.0 [n]	0.34 [o]	6.6	70% lichen, 10% shrubs, 10% herbaceous plants, 10% moss [p]	150 [q]	NA
Tundra shrew	Terrestrial mammalian invertevores	0.0064 [r]	0.0021 [s]	0.00011 [t]	0.0011	100% invertebrates [u]	365 [f]	0.22 [v]
Arctic fox	Terrestrial mammalian carnivores	3.2 [w]	0.11 [x]	0.0031 [y]	0.28	100% small mammals [z]	365 [f]	407 [aa]
Freshwater Aquatic								
Green-winged teal	Freshwater aquatic avian herbivores	0.32 [bb]	0.053 [cc]	0.0010 [dd]	0.027	100% herbaceous plants [ee]	123 [ff]	243 [gg]
Muskrat	Freshwater aquatic mammalian herbivores	0.932 [hh]	0.070 [ii]	0.0014 [jj]	0.093	100% herbaceous plants [kk]	365 [f]	0.17 [ll]

[a] Based on U.S. EPA (1993) drinking water ingestion equations for all birds or all mammals.

[b] Mean female body weight from West et al. (1970).

[c] Estimated from Andreev (1991).

[d] Based on 9.3 percent soil in wild turkey diet from Beyer et al. (1994).

[e] Estimated from diets reported for Alaska in Hannon et al. (1998).

[f] Assumes receptor is present year-round at the site.

[g] Mean territory size for monogamous males (Hannon and Dobush 1997).

[h] Mean female body weight from Bee and Hall (1956).

[i] Based on Nagy et al. (1999) allometric equation for Rodentia.

[j] Based on 2.4 percent soil in meadow vole diet from Beyer et al. (1994).

[k] Estimated from summer and winter diets at Pearce Point, NWT (Bergman and Krebs 1993).

[l] Mean home range for reproductive females at Pearce Point, NWT (Lambin et al. 1992).

[m] Mean female in Alaska from Silva and Downing (1995).

[n] Based on mean value from Hanson et al. (1975).

[o] Based on 6.8 percent soil in bison diet from Beyer et al. (1994).

[p] Based on diets reported in Miller (1976), Boertje (1990), and Scotter (1967).

[q] Best professional judgment based on Lent (1966), Hemming (1987, 1988, 1989, 1991), and Pollard (1994a,b).

[r] Mean body weight from Bee and Hall (1956) and Martell and Pearson (1978).

[s] Based on measured food consumption from Buckner (1964), assuming a mid-range moisture content of 75 percent in invertebrates from U.S. EPA (1993).

[t] Best professional judgment based on Beyer et al. (1994).

[u] Based on Yudin (1962, as cited in Aitchison 1987 and Buckner 1964).

Table 12. (cont.)

[v] Mean home range for breeding females (*Sorex vagrans* and *Sorex obscurus*) in British Columbia, Canada (Hawes 1977).

[w] Mean female body weight from Anthony (1997).

[x] Based on Nagy et al. (1999) allometric equation for Carnivora.

[y] Based on 2.8 percent soil in red fox diet from Beyer et al. (1994).

[z] Simplified from Anthony et al. (2000).

[aa] Mean female home range in western Alaska (Anthony 1997).

[bb] Mean female body weight from Dunning (1993).

[cc] Based on Nagy et al. (1999) allometric equation for all birds.

[dd] Based on 1.9 percent sediment in green-winged teal diet from Beyer et al. (1999).

[ee] Estimated from autumn diet in southeastern Alaska (Hughes and Young 1982).

[ff] Based on 123 days from first to last sighting in Cape Thompson area reported by Williamson et al. (1966).

[gg] Home range for one pair in South Dakota (Drewien 1967, as cited in Granholm 2003).

[hh] Mean body weight from Fuller (1951).

[ii] Estimated from Campbell et al. (1998).

[jj] Based on minimum soil ingestion rate from Beyer et al. (1994).

[kk] Based on diets reported in U.S. EPA (1993).

[ll] Mean female home range in Iowa (Neal 1968, as cited in U.S. EPA 1993).

Table 13. Hazard quotient summary (current conditions)

Receptor/Analyte	Hazard Quotient NOAEL	Hazard Quotient LOAEL	Hazard Quotient NOAEL	Hazard Quotient LOAEL	Hazard Quotient NOAEL	Hazard Quotient LOAEL	Hazard Quotient NOAEL	Hazard Quotient LOAEL
Caribou	AA,AW-Overwintering		AA,AW-Resident				Reference Area	
Cadmium	0.19	0.019	0.31	0.031			0.0051	0.00051
Lead	0.70	0.085	1.1	0.14			0.010	0.0013
Zinc	0.13	0.064	0.21	0.11			0.0068	0.0034
Willow ptarmigan	All Areas, All Water		NF, Impoundment				Reference Area	
Cadmium	0.57	0.043	1.02	0.076			0.030	0.0022
Lead	5.9	2.1	29.6	10.5			0.032	0.011
Zinc	0.50	--	1.4	--			0.076	--
Arctic fox	All Areas, All Water		NF, Impoundment				Reference Area	
Cadmium	0.07	0.007	0.55	0.055			0.026	0.0026
Lead	0.23	0.028	1.01	0.123			0.051	0.0062
Zinc	0.06	0.030	0.33	0.16			0.026	0.013
Green-winged teal	All Areas, All Water		NF, Impoundment				Reference Area	
Cadmium	0.09	0.007	0.21	0.016			0.0039	0.00029
Lead	0.62	0.22	3.0	1.08			0.017	0.0059
Zinc	0.11	--	0.26	--			0.017	--
Muskrat	All Areas, All Water		NF, Impoundment				Reference Area	
Cadmium	0.16	0.016	0.72	0.072			0.0046	0.00046
Lead	0.49	0.060	1.7	0.21			0.0059	0.00072
Zinc	0.12	0.06	0.44	0.22			0.014	0.0072
Tundra shrew	Tundra Area 2		Tundra Area 3		Tundra Area 4		Reference Area	
Cadmium	3.6	0.36	3.2	0.32	3.1	0.31	0.31	0.031
Lead	8.5	1.0	7.8	0.95	1.6	0.19	0.025	0.0031
Zinc	1.9	1.0	1.7	0.85	0.99	0.50	0.43	0.22
Tundra vole	Tundra Area 2		Tundra Area 3		Tundra Area 4		Reference Area	
Cadmium	0.89	0.089	0.56	0.056	0.41	0.041	0.015	0.0015
Lead	3.3	0.40	3.3	0.41	1.3	0.15	0.024	0.0030
Zinc	0.95	0.47	0.65	0.32	0.31	0.16	0.042	0.021

Note: See Table 3 for scenario descriptions.

- -- - LOAEL toxicity reference value not available
- AA,AW - all areas scenario with all water sources included
- LOAEL - lowest-observed-adverse-effect level
- NF - near-facilities scenario
- NOAEL - no-observed-adverse-effect level

Table 14. Hazard quotient summary (post-closure conditions)

Receptor/Analyte	Hazard Quotient NOAEL	Hazard Quotient LOAEL	Hazard Quotient NOAEL	Hazard Quotient LOAEL	Hazard Quotient NOAEL	Hazard Quotient LOAEL	Hazard Quotient NOAEL	Hazard Quotient LOAEL	Hazard Quotient NOAEL	Hazard Quotient LOAEL
Caribou	AA,AW-Overwintering		AA,AW-Resident						Reference Area	
Cadmium	0.45	0.045	0.74	0.074					0.0051	0.00051
Lead	1.5	0.18	2.4	0.30					0.010	0.0013
Zinc	0.30	0.15	0.50	0.25					0.0068	0.0034
Willow ptarmigan	All Areas, All Water		All Areas, 50% Imp.		NF, Impoundment		NF, Pit Lake Only		Reference Area	
Cadmium	1.3	0.10	1.5	0.11	1.7	0.13	4.6	0.35	0.030	0.0022
Lead	9.1	3.2	9.1	3.2	32.3	11.5	32.4	11.5	0.032	0.011
Zinc	1.1	--	1.2	--	2.1	--	3.3	--	0.076	--
Arctic fox	All Areas, All Water		All Areas, 50% Imp.		NF, Impoundment				Reference Area	
Cadmium	0.14	0.014	0.38	0.038	0.71	0.071			0.026	0.0026
Lead	0.38	0.047	0.39	0.047	1.1	0.14			0.051	0.0062
Zinc	0.12	0.062	0.21	0.10	0.37	0.18			0.026	0.013
Green-winged teal	All Areas, All Water		All Areas, 50% Imp.		NF, Impoundment		NF, Pit Lake 50%		Reference Area	
Cadmium	0.20	0.015	0.25	0.019	0.33	0.025	0.90	0.068	0.0039	0.00029
Lead	0.96	0.34	0.97	0.34	3.3	1.2	3.3	1.2	0.017	0.0059
Zinc	0.20	--	0.24	--	0.36	--	0.61	--	0.017	--
Muskrat	All Areas, All Water		All Areas, 50% Imp.		NF, Impoundment				Reference Area	
Cadmium	0.36	0.036	0.63	0.063	1.0	0.10			0.0046	0.00046
Lead	0.94	0.11	0.94	0.12	2.1	0.26			0.0059	0.00072
Zinc	0.27	0.13	0.36	0.18	0.57	0.28			0.014	0.0072
Tundra shrew	Tundra Area 2		Tundra Area 3		Tundra Area 4				Reference Area	
Cadmium	22.6	2.3	20.2	2.0	19.1	1.9			0.31	0.031
Lead	53.1	6.5	48.7	6.0	9.9	1.2			0.025	0.0031
Zinc	12.2	6.1	10.6	5.3	6.2	3.1			0.43	0.22
Tundra vole	Tundra Area 2		Tundra Area 3		Tundra Area 4				Reference Area	
Cadmium	5.5	0.55	3.5	0.35	2.5	0.25			0.015	0.0015
Lead	20.5	2.5	20.8	2.5	7.8	0.96			0.024	0.0030
Zinc	5.9	3.0	4.0	2.0	1.9	1.0			0.042	0.021

Note: See Table 3 for scenario descriptions.

-- - LOAEL toxicity reference value not available
AA,AW - all areas scenario with all water sources included
LOAEL - lowest-observed-adverse-effect level
NF - near-facilities scenario
NOAEL - no-observed-adverse-effect level

Table 15. Summary of uncertainties in the evaluation of ecological risk

Assumption/Parameter	Effect of Assumption/Parameter: Possibly Leads to Underestimation of Risks	Leads to Neither Under- nor Over-Estimation of Risks	Likely Leads to Overestimation of Risks	Likely Leads to Overestimation of Risks by Up to 10 times	Unknown Effect
Current Media Concentration Estimation					
Soil, water, lichen, moss, plants, invertebrates and small mammals from DMTS data statistical relationships			X		
Plant samples unwashed prior to analysis			X		
Post-Closure Media Concentration Estimation					
Cover material assumed Kivalina shale for all cover areas			X		
Tailings pond water quality based on modeled "dirty pond" water quality rather than targeted "clean pond" water quality			X		
Tundra soil and biota tissue estimated using conservative multiplier of 2.5 times greater than current concentrations			X		
Current conditions data for stream water quality in tundra areas used without multiplier[a]	X				
Body Mass					
Based on literature values for mean female body weights, male body weight excluded			X		
Diet Composition					
Emphasizes primary food sources					X
Dietary Intake Rates of Food, Water and Sediment or Soil					
Food			X		
Water			X		
Soil			X		
Sediment			X		
Bioavailability					
Assumed 100% bioavailability				X	
Toxicity Reference Values					
Based on literature values from studies using soluble forms of metals			X		
Allometric scaling not applied		X			
Assumed individual effects can be extrapolated to populations			X		
Time and Area Usage					
Assumed high values for receptor residence time and usage of areas at the site				X	

[a] The modeling results were not driven by stream water quality (see daily exposure estimates in the food web model tables in Appendices A and B). Therefore, the uncertainty in future stream water quality was not a significant factor in this evaluation.

Table 16. Hazard quotient summary—current conditions using realistic assumptions[a]

Receptor/ Analyte	Hazard Quotient NOAEL	Hazard Quotient LOAEL	Hazard Quotient NOAEL	Hazard Quotient LOAEL	Hazard Quotient NOAEL	Hazard Quotient LOAEL	Hazard Quotient NOAEL	Hazard Quotient LOAEL
Caribou	AA,AW-Overwintering		AA,AW-Resident				Reference Area	
Cadmium	0.15	0.015	0.25	0.025			0.0051	0.00051
Lead	0.38	0.047	0.63	0.08			0.010	0.0013
Zinc	0.11	0.053	0.18	0.09			0.0068	0.0034
Willow ptarmigan	All Areas, All Water		NF, Impoundment				Reference Area	
Cadmium	0.45	0.033	0.86	0.064			0.030	0.0022
Lead	0.87	0.31	3.9	1.4			0.032	0.011
Zinc	0.40	--	1.1	--			0.076	--
Arctic fox	All Areas, All Water		NF, Impoundment				Reference Area	
Cadmium	0.054	0.005	0.54	0.054			0.026	0.0026
Lead	0.056	0.007	0.17	0.021			0.051	0.0062
Zinc	0.054	0.027	0.31	0.16			0.026	0.013
Green-winged teal	All Areas, All Water		NF, Impoundment				Reference Area	
Cadmium	0.072	0.005	0.19	0.014			0.0039	0.00029
Lead	0.12	0.044	0.45	0.16			0.017	0.0059
Zinc	0.096	--	0.24	--			0.017	--
Muskrat	All Areas, All Water		NF, Impoundment				Reference Area	
Cadmium	0.10	0.010	0.65	0.065			0.0046	0.00046
Lead	0.13	0.016	0.30	0.037			0.0059	0.00072
Zinc	0.083	0.042	0.39	0.20			0.014	0.0072
Tundra shrew	Tundra Area 2		Tundra Area 3		Tundra Area 4		Reference Area	
Cadmium	2.6	0.26	2.3	0.23	2.1	0.21	0.31	0.031
Lead	1.8	0.22	1.7	0.20	0.54	0.066	0.025	0.0031
Zinc	1.6	0.80	1.5	0.73	0.83	0.41	0.43	0.22
Tundra vole	Tundra Area 2		Tundra Area 3		Tundra Area 4		Reference Area	
Cadmium	0.74	0.074	0.47	0.047	0.30	0.030	0.015	0.0015
Lead	1.4	0.17	1.5	0.18	0.71	0.087	0.024	0.0030
Zinc	0.79	0.40	0.53	0.26	0.23	0.12	0.042	0.021

Note: See Table 3 for scenario descriptions.

-- - LOAEL toxicity reference value not available
AA,AW - all areas scenario with all water sources included
LOAEL - lowest-observed-adverse-effect level
NF - near-facilities scenario
NOAEL - no-observed-adverse-effect level

[a] The hazard quotients presented in this table reflect those using mean values for tundra area media concentrations rather than 95% UCL on the mean values, and reflect the use of mean relative bioavailability for lead of 19.4 percent.

Table 17. Summary of potentially significant ecological effects

	Potential for Effects	
Receptor	Current Conditions	Post-Closure Conditions
Caribou	--	--
Arctic fox	--	--
Green-winged teal	--	--
Muskrat	--	--
Ptarmigan	yes	yes
Tundra vole	yes	yes
Tundra shrew	yes	yes
Vegetation	yes	yes

Note: -- very low or no likelihood of adverse effects

See Section 8, *Interpretation of Ecological Significance*, for discussion.

Appendix A

Food-Web Model Tables—Current Conditions

Table A-1. Food-web model exposure results for overwintering caribou

Analyte	Concentration: Water (µg/L)	Concentration: Soil/ Sediment (mg/kg dw)	Concentration: Herb. Plant (mg/kg dw)	Concentration: Shrub (mg/kg dw)	Concentration: Lichen (mg/kg dw)	Concentration: Moss (mg/kg dw)	Daily Exposure: Water (mg/day)	Daily Exposure: Soil/ Sediment (mg/day)	Daily Exposure: Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV: NOAEL (mg/kg-day)	TRV: LOAEL (mg/kg-day)	Hazard Quotient: NOAEL Hazard Quotient	Hazard Quotient: LOAEL Hazard Quotient
Aluminum	388	3,774	1,341	25.7	1,820	4,211	2.6	1,283	9,159	10,445	97.6	1.9	19	21	2.1
Barium	25.2	8,011	232	82.4	532	1,661	0.167	2,724	2,848	5,572	52.1	5.1	20	4.2	1.07
Cadmium	186	37.7	1.10	4.18	6.61	17.5	1.2	12.8	34.5	48.5	0.454	1.0	10	0.19	0.019
Lead	200	2,086	29.8	4.97	232	838	1.32	709	1,248	1,959	18.3	11	90	0.68	0.084
Zinc	14,893	3,488	165	238	772	2,961	99	1,186	4,384	5,669	53.0	160	320	0.14	0.068

Note: Data used to develop this scenario are from all areas within mine permit boundary, with all water sources, including streams and the tailings pond, and overwintering defined as 5 months in mine area, 7 months migrating.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table A-2. Food-web model exposure results for resident caribou

Analyte	Concentration						Daily Exposure			Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV		Year-Round Hazard Quotient	
	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Shrub (mg/kg dw)	Lichen (mg/kg dw)	Moss (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)			NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	388	3,774	1,341	25.7	1,820	4,211	2.6	1,283	9,159	10,445	97.6	1.9	19	37	3.7
Barium	25.2	8,011	232	82.4	532	1,661	0.167	2,724	2,848	5,572	52.1	5.1	20	7.0	1.8
Cadmium	186	37.7	1.10	4.18	6.61	17.5	1.2	12.8	34.5	48.5	0.454	1.0	10	0.31	0.031
Lead	200	2,086	29.8	4.97	232	838	1.32	709	1,248	1,959	18.3	11	90	1.1	0.14
Zinc	14,893	3,488	165	238	772	2,961	99	1,186	4,384	5,669	53.0	160	320	0.23	0.11

Note: Data used to develop this scenario are from all areas within mine permit boundary, with all water sources, including streams and the tailings pond, and resident defined as 8 months in mine area, 4 months in reference area.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table A-3. Food-web model exposure results for ptarmigan

Analyte	Concentration				Daily Exposure			Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV		Year-Round Hazard Quotient	
	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Shrub (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)			NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	388	3,774	1,341	25.7	0.0149	21.1	9.43	30.5	58.0	120	--	0.48	--
Barium	25.2	8,011	232	82.4	0.00097	44.7	5.84	50.5	96.1	21	42	4.6	2.3
Cadmium	186	37.7	1.10	4.18	0.007	0.210	0.232	0.449	0.85	1.5	20	0.57	0.043
Lead	200	2,086	29.8	4.97	0.0077	11.64	0.447	12.10	23.0	3.9	11	5.9	2.1
Zinc	14,893	3,488	165	238	0.57	19.5	13.9	33.9	64.4	130	--	0.50	--

Note: Data used to develop this scenario are from all areas within mine permit boundary, with all water sources, including streams and the tailings pond.

-- - appropriate TRV not found for analyte
CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table A-4. Food-web model exposure results for ptarmigan in near-facilities areas

Analyte	Concentration: Water (µg/L)	Concentration: Soil/ Sediment (mg/kg dw)	Concentration: Herb. Plant (mg/kg dw)	Concentration: Shrub (mg/kg dw)	Daily Exposure: Water (mg/day)	Daily Exposure: Soil/ Sediment (mg/day)	Daily Exposure: Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV: NOAEL (mg/kg-day)	TRV: LOAEL (mg/kg-day)	Year-Round Hazard Quotient: NOAEL Hazard Quotient	Year-Round Hazard Quotient: LOAEL Hazard Quotient
Aluminum	4,300	7,893	1,341	25.7	0.165	44.0	9.43	53.6	102.0	120	--	0.85	--
Barium	32.0	52,957	232	82.4	0.00123	296	5.84	301	573	21	42	27	13.6
Cadmium	5,400	65.5	1.10	4.18	0.207	0.366	0.232	0.805	1.53	1.5	20	1.02	0.076
Lead	2,200	10,805	29.8	4.97	0.0844	60.3	0.447	60.8	115.6	3.9	11	30	10.5
Zinc	416,000	11,335	165	238	16.0	63.3	13.9	93.1	177	130	--	1.4	--

Note: Data used to develop this scenario are from near-facilities areas (excludes Tundra Area 4), with 100% usage of tailings pond water.

-- - appropriate TRV not found for analyte
CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table A-5. Food-web model exposure results for fox

	Concentration			Daily Exposure					TRV		Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Small Mammals (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	388	3,774	540	0.109	11.7	59.7	71.5	22.3	1.9	19	12	1.2
Barium	25.2	8,011	56.4	0.00711	24.8	6.23	31.0	9.70	5.1	20	1.9	0.48
Cadmium	186	37.7	0.406	0.052	0.117	0.0449	0.214	0.067	1.0	10	0.07	0.007
Lead	199.5	2,086	13.7	0.056	6.46	1.51	8.03	2.51	11	90	0.23	0.028
Zinc	14,893	3,488	138	4.2	10.8	15.2	30.2	9.4	160	320	0.06	0.030

Note: Data used to develop this scenario are from all areas within mine permit boundary, with all water sources, including streams, and the tailings pond.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value
UCL - upper confidence limit

Table A-6. Food-web model exposure results for fox in near-facilities areas

Analyte	Concentration: Water (µg/L)	Concentration: Soil/ Sediment (mg/kg dw)	Concentration: Small Mammals (mg/kg dw)	Daily Exposure: Water (mg/day)	Daily Exposure: Soil/ Sediment (mg/day)	Daily Exposure: Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV: NOAEL (mg/kg-day)	TRV: LOAEL (mg/kg-day)	Hazard Quotient: NOAEL Hazard Quotient	Hazard Quotient: LOAEL Hazard Quotient
Aluminum	4,300	7,893	677	1.21	24.4	74.8	100.4	31.4	1.9	19	17	1.7
Barium	32.0	52,957	56.4	0.00902	164	6.23	170	53.2	5.1	20	10.4	2.7
Cadmium	5,400	65.5	0.406	1.52	0.203	0.0449	1.77	0.553	1.0	10	0.55	0.055
Lead	2,200	10,805	13.7	0.620	33.4	1.51	35.6	11.11	11	90	1.01	0.123
Zinc	416,000	11,335	141	117	35.1	15.6	168	52.5	160	320	0.33	0.16

Note: Data used to develop this scenario are from near-facilities areas (excludes Tundra Area 4), with 100% usage of tailings pond water.

CoPC - chemical of potential concern

LOAEL - lowest-observed-adverse-effect level

NOAEL - no-observed-adverse-effect level

TRV - toxicity reference value

UCL - upper confidence limit

Table A-7. Food-web model exposure results for teal

Analyte	Concentration: Water (µg/L)	Concentration: Soil/ Sediment (mg/kg dw)	Concentration: Herb. Plant (mg/kg dw)	Concentration: Invert. (mg/kg dw)	Daily Exposure: Water (mg/day)	Daily Exposure: Soil/ Sediment (mg/day)	Daily Exposure: Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	Time Use Adjusted Exposure (mg/kg-day)	Ref. Time Use Adjusted Exp. (mg/kg-day)[a]	Total Exposure (mg/kg-day)	TRV: NOAEL (mg/kg-day)	TRV: LOAEL (mg/kg-day)	Year-Round Hazard Quotient: NOAEL Hazard Quotient	Year-Round Hazard Quotient: LOAEL Hazard Quotient
Aluminum	388	3,774	64.5	107	0.0107	3.83	3.78	7.62	23.8	8.03	37.0	45.0	120	--	0.38	--
Barium	25.2	8,011	53.0	30.5	0.000694	8.12	2.65	10.77	33.7	11.34	6.72	18.1	21	42	0.86	0.43
Cadmium	186	37.7	0.126	7.78	0.0051	0.0382	0.0680	0.111	0.348	0.117	0.0225	0.140	1.5	20	0.09	0.007
Lead	200	2,086	0.00363	16.0	0.0055	2.11	0.128	2.25	7.03	2.37	0.0627	2.43	3.9	11	0.62	0.22
Zinc	14,893	3,488	60.8	373	0.41	3.54	5.74	9.7	30.3	10.2	3.49	13.7	130	--	0.11	--

Note: Data used to develop this scenario are from all areas within mine permit boundary, with all water sources, including streams and the tailings pond.

-- - appropriate TRV not found for analyte
CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

[a] Based on mean daily exposure for teal in pond reference station 3 multipled by 0.66.

Table A-8. Food-web model exposure results for teal in near-facilities areas

Analyte	Concentration				Daily Exposure			Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	Time Use Adjusted Exposure (mg/kg-day)	Ref. Time Use Adjusted Exp. (mg/kg-day)[a]	Total Exposure (mg/kg-day)	TRV		Year-Round Hazard Quotient	
	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Invert. (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)						NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	4,300	7,893	64.5	107	0.118	8.00	3.78	11.9	37.2	12.5	37.0	49.5	120	--	0.41	--
Barium	32.0	52,957	53.0	56.7	0.000880	53.7	2.86	56.5	177	59.5	6.72	66.3	21	42	3.2	1.6
Cadmium	5,400	65.5	0.126	7.78	0.148	0.0664	0.0680	0.283	0.884	0.298	0.0225	0.320	1.5	20	0.21	0.016
Lead	2,200	10,805	0.00363	20.3	0.0605	10.95	0.163	11.18	34.9	11.77	0.0627	11.83	3.9	11	3.0	1.08
Zinc	416,000	11,335	60.8	373	11.4	11.5	5.74	28.7	89.6	30.2	3.49	33.7	130	--	0.26	--

Note: Data used to develop this scenario are from near-facilities areas (excludes Tundra Area 4), with 100% usage of tailings pond water.

-- - appropriate TRV not found for analyte
CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

[a] Based on mean daily exposure for teal in pond reference station 3 multipled by 0.66.

Table A-9. Food-web model exposure results for muskrat

	Concentration			Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	388	3,774	1,341	0.036	5.29	94.0	99.3	107	1.9	19	56	5.6
Barium	25.2	8,011	232	0.00234	11.23	16.3	27.5	29.5	5.1	20	5.8	1.5
Cadmium	186	37.7	1.10	0.017	0.0528	0.0769	0.147	0.158	1.0	10	0.16	0.016
Lead	200	2,086	29.8	0.019	2.92	2.09	5.03	5.40	11	90	0.49	0.060
Zinc	14,893	3,488	165	1.4	4.89	11.6	17.9	19.2	160	320	0.12	0.06

Note: Data used to develop this scenario are from all areas within mine permit boundary, with all water sources, including streams and the tailings pond.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table A-10. Food-web model exposure results for muskrat in near-facilities areas

Analyte	Concentration			Daily Exposure			Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV		Year-Round Hazard Quotient	
	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)			NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	4,300	7,893	1,341	0.400	11.06	94.0	105	113	1.9	19	60	6.0
Barium	32.0	52,957	232	0.00297	74.2	16.3	90.5	97.1	5.1	20	19	4.9
Cadmium	5,400	65.5	1.10	0.502	0.0918	0.0769	0.670	0.719	1.0	10	0.72	0.072
Lead	2,200	10,805	29.8	0.204	15.1	2.09	17.4	18.7	11	90	1.7	0.21
Zinc	416,000	11,335	165	38.7	15.9	11.6	66.1	71.0	160	320	0.44	0.22

Note: Data used to develop this scenario are from near-facilities areas (excludes Tundra Area 4), with 100% usage of tailings pond water.

CoPC - chemical of potential concern

LOAEL - lowest-observed-adverse-effect level

NOAEL - no-observed-adverse-effect level

TRV - toxicity reference value

Table A-11. Food-web model exposure results for shrew in Tundra Area 1

	Concentration			Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Soil Inverts. (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	13,733	107	0.000268	1.51	0.220	1.73	270	1.9	19	142	14
Barium	25.0	19,148	105	0.0000263	2.11	0.215	2.32	363	5.1	20	71	18
Cadmium	9.7	65.3	7.78	0.0000102	0.00718	0.0159	0.0231	3.61	1.0	10	3.6	0.36
Lead	131.9	23,563	24.8	0.0001385	2.59	0.0508	2.64	413	11	90	38	4.6
Zinc	1,331	14,176	373	0.001397	1.56	0.765	2.33	363	160	320	2.3	1.1

Note: Data used to develop this scenario are from Tundra Area 1, with stream water only.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table A-12. Food-web model exposure results for shrew in Tundra Area 2

Analyte	Concentration			Daily Exposure			Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV		Year-Round Hazard Quotient	
	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Soil Inverts. (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)			NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	7,217	107	0.000268	0.794	0.220	1.014	158	1.9	19	83	8.3
Barium	25.0	6,892	66.4	0.0000263	0.758	0.136	0.894	140	5.1	20	27	7.0
Cadmium	9.7	65.2	7.78	0.0000102	0.00717	0.0159	0.0231	3.61	1.0	10	3.6	0.36
Lead	131.9	5,012	23.0	0.0001385	0.551	0.0471	0.599	93.5	11	90	8.5	1.0
Zinc	1,331	11,182	373	0.001397	1.23	0.765	2.00	312	160	320	1.9	1.0

Note: Data used to develop this scenario are from Tundra Area 2, with stream water only.

CoPC - chemical of potential concern

LOAEL - lowest-observed-adverse-effect level

NOAEL - no-observed-adverse-effect level

TRV - toxicity reference value

Table A-13. Food-web model exposure results for shrew in Tundra Area 3

Analyte	Concentration			Daily Exposure			Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV		Year-Round Hazard Quotient	
	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Soil Inverts. (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)			NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	6,999	107	0.000268	0.770	0.220	0.990	155	1.9	19	81	8.1
Barium	25.0	4,351	54.1	0.0000263	0.479	0.111	0.590	92.1	5.1	20	18	4.6
Cadmium	9.7	42.9	7.78	0.0000102	0.00471	0.0159	0.0207	3.23	1.0	10	3.2	0.32
Lead	131.9	4,614	20.0	0.0001385	0.507	0.0409	0.549	85.7	11	90	7.8	0.95
Zinc	1,331	8,875	373	0.001397	0.976	0.765	1.74	272	160	320	1.7	0.85

Note: Data used to develop this scenario are from Tundra Area 3, with stream water only.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table A-14. Food-web model exposure results for shrew in Tundra Area 4

	Concentration			Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Soil Inverts. (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	3,129	107	0.000268	0.344	0.220	0.565	88.2	1.9	19	46	4.6
Barium	25.0	979	27.9	0.0000263	0.108	0.0571	0.165	25.8	5.1	20	5.1	1.3
Cadmium	9.7	33.3	7.78	0.0000102	0.00366	0.0159	0.0196	3.06	1.0	10	3.1	0.31
Lead	131.9	722	15.6	0.0001385	0.0795	0.0319	0.112	17.4	11	90	1.6	0.19
Zinc	1,331	2,260	373	0.001397	0.249	0.765	1.02	159	160	320	0.99	0.50

Note: Data used to develop this scenario are from Tundra Area 4, with stream water only.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table A-15. Food-web model exposure results for vole in Tundra Area 1

	Concentration					Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Lichen (mg/kg dw)	Moss (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	13,733	12.8	1,820	23,914	0.001615	2.80	11.0	13.8	294	1.9	19	155	15
Barium	25.0	19,148	119	3,177	34,713	0.000158	3.91	17.0	20.9	445	5.1	20	87	22
Cadmium	9.7	65.3	0.300	9.38	148	0.000061	0.0133	0.0694	0.0827	1.76	1.0	10	1.8	0.18
Lead	131.9	23,563	5.10	325	1,283	0.000833	4.81	0.722	5.53	118	11	90	11	1.3
Zinc	1,331	14,176	91.2	1,016	24,892	0.00841	2.89	11.7	14.6	311	160	320	1.9	0.97

Note: Data used to develop this scenario are from Tundra Area 1, with stream water only.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table A-16. Food-web model exposure results for vole in Tundra Area 2

Analyte	Concentration					Daily Exposure			Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV		Year-Round Hazard Quotient	
	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Lichen (mg/kg dw)	Moss (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)			NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	7,217	12.8	1,820	10,312	0.001615	1.47	5.25	6.73	143	1.9	19	75	7.5
Barium	25.0	6,892	93.0	1,629	10,552	0.000158	1.41	5.89	7.29	155	5.1	20	30	7.8
Cadmium	9.7	65.2	0.300	9.37	51.9	0.000061	0.0133	0.0283	0.0417	0.887	1.0	10	0.89	0.089
Lead	131.9	5,012	5.10	307	1,192	0.000833	1.02	0.676	1.70	36.1	11	90	3.3	0.40
Zinc	1,331	11,182	91.2	1,015	8,763	0.00841	2.28	4.85	7.14	152	160	320	0.95	0.47

Note: Data used to develop this scenario are from Tundra Area 2, with stream water only.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table A-17. Food-web model exposure results for vole in Tundra Area 3

	Concentration					Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Lichen (mg/kg dw)	Moss (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	6,999	12.8	1,820	9,858	0.001615	1.43	5.06	6.49	138	1.9	19	73	7.3
Barium	25.0	4,351	83.2	1,206	6,175	0.000158	0.887	3.77	4.66	99.1	5.1	20	19	5.0
Cadmium	9.7	42.9	0.300	7.46	49.1	0.000061	0.00874	0.0263	0.0351	0.748	1.0	10	0.75	0.075
Lead	131.9	4,614	5.10	275	1,040	0.000833	0.941	0.598	1.54	32.8	11	90	3.0	0.36
Zinc	1,331	8,875	91.2	849	8,287	0.00841	1.81	4.58	6.40	136	160	320	0.85	0.43

Note: Data used to develop this scenario are from Tundra Area 3, with stream water only.

CoPC - chemical of potential concern

LOAEL - lowest-observed-adverse-effect level

NOAEL - no-observed-adverse-effect level

TRV - toxicity reference value

Table A-18. Food-web model exposure results for vole in Tundra Area 4

Analyte	Concentration: Water (µg/L)	Concentration: Soil/ Sediment (mg/kg dw)	Concentration: Herb. Plant (mg/kg dw)	Concentration: Lichen (mg/kg dw)	Concentration: Moss (mg/kg dw)	Daily Exposure: Water (mg/day)	Daily Exposure: Soil/ Sediment (mg/day)	Daily Exposure: Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV: NOAEL (mg/kg-day)	TRV: LOAEL (mg/kg-day)	Year-Round Hazard Quotient: NOAEL Hazard Quotient	Year-Round Hazard Quotient: LOAEL Hazard Quotient
Aluminum	256	3,129	12.8	1,820	3,599	0.001615	0.638	2.40	3.04	64.7	1.9	19	34	3.4
Barium	25.0	979	57.9	455	1,086	0.000158	0.200	1.10	1.30	27.6	5.1	20	5.4	1.4
Cadmium	9.7	33.3	0.300	6.51	14.0	0.000061	0.00679	0.0110	0.0178	0.380	1.0	10	0.38	0.038
Lead	131.9	722	5.10	227	816	0.000833	0.147	0.482	0.630	13.4	11	90	1.2	0.15
Zinc	1,331	2,260	91.2	763	2,373	0.00841	0.461	2.03	2.50	53.2	160	320	0.33	0.17

Note: Data used to develop this scenario are from Tundra Area 4, with stream water only.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Appendix B

Food-Web Model Tables—Post-Closure Conditions

Table B-1. Food-web model exposure results for overwintering caribou

Analyte	Concentration: Water (µg/L)	Concentration: Soil/ Sediment (mg/kg dw)	Concentration: Herb. Plant (mg/kg dw)	Concentration: Shrub (mg/kg dw)	Concentration: Lichen (mg/kg dw)	Concentration: Moss (mg/kg dw)	Daily Exposure: Water (mg/day)	Daily Exposure: Soil/ Sediment (mg/day)	Daily Exposure: Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV: NOAEL (mg/kg-day)	TRV: LOAEL (mg/kg-day)	Hazard Quotient: NOAEL Hazard Quotient	Hazard Quotient: LOAEL Hazard Quotient
Aluminum	985	8,771	3,354	64.2	4,550	10,528	6.54	2,982	22,898	25,887	242	1.9	19	52	5.2
Barium	25.0	6,262	580	206	1,329	4,152	0.166	2,129	7,120	9,250	86.4	5.1	20	7.0	1.8
Cadmium	231	84.2	2.74	10.4	16.5	43.6	1.53	28.6	86.3	116	1.09	1.0	10	0.45	0.045
Lead	162.1	3,140	74.5	12.4	580	2,095	1.076	1,068	3,120	4,189	39.1	11	90	1.5	0.18
Zinc	12,586	7,175	414	596	1,930	7,404	83.6	2,439	10,961	13,484	126	160	320	0.32	0.16

Note: Data used to develop this scenario are from all areas within mine permit boundary, with all water sources, including streams, tailings pond, and pit lake, and overwintering defined as 5 months in mine area, 7 months migrating.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table B-2. Food-web model exposure results for resident caribou

Analyte	Concentration: Water (µg/L)	Concentration: Soil/ Sediment (mg/kg dw)	Concentration: Herb. Plant (mg/kg dw)	Concentration: Shrub (mg/kg dw)	Concentration: Lichen (mg/kg dw)	Concentration: Moss (mg/kg dw)	Daily Exposure: Water (mg/day)	Daily Exposure: Soil/ Sediment (mg/day)	Daily Exposure: Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV: NOAEL (mg/kg-day)	TRV: LOAEL (mg/kg-day)	Year-Round Hazard Quotient: NOAEL Hazard Quotient	Year-Round Hazard Quotient: LOAEL Hazard Quotient
Aluminum	985	8,771	3,354	64.2	4,550	10,528	6.54	2,982	22,898	25,887	242	1.9	19	88	8.8
Barium	25.0	6,262	580	206	1,329	4,152	0.166	2,129	7,120	9,250	86.4	5.1	20	11	2.9
Cadmium	231	84.2	2.74	10.4	16.5	43.6	1.53	28.6	86.3	116.4	1.09	1.0	10	0.73	0.073
Lead	162.1	3,140	74.5	12.4	580	2,095	1.076	1,068	3,120	4,189	39.1	11	90	2.4	0.29
Zinc	12,586	7,175	414	596	1,930	7,404	83.6	2,439	10,961	13,484	126	160	320	0.53	0.26

Note: Data used to develop this scenario are from all areas within mine permit boundary, with all water sources, including streams, tailings pond, and pit lake, and resident defined as 8 months in mine area, 4 months in reference area.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table B-3. Food-web model exposure results for ptarmigan

Analyte	Concentration: Water (µg/L)	Concentration: Soil/ Sediment (mg/kg dw)	Concentration: Herb. Plant (mg/kg dw)	Concentration: Shrub (mg/kg dw)	Daily Exposure: Water (mg/day)	Daily Exposure: Soil/ Sediment (mg/day)	Daily Exposure: Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV: NOAEL (mg/kg-day)	TRV: LOAEL (mg/kg-day)	Year-Round Hazard Quotient: NOAEL Hazard Quotient	Year-Round Hazard Quotient: LOAEL Hazard Quotient
Aluminum	985	8,771	3,354	64.2	0.0378	48.9	23.6	72.6	138	120	--	1.1	--
Barium	25.0	6,262	580	206	0.000960	34.9	14.6	49.5	94.2	21	42	4.5	2.2
Cadmium	231	84.2	2.74	10.4	0.00884	0.470	0.580	1.06	2.01	1.5	20	1.3	0.10
Lead	162.1	3,140	74.5	12.4	0.00622	17.5	1.12	18.6	35.5	3.9	11	9.1	3.2
Zinc	12,586	7,175	414	596	0.483	40.0	34.6	75.2	143	130	--	1.1	--

Note: Data used to develop this scenario are from all areas within mine permit boundary, with all water sources, including streams, tailings pond, and pit lake.

-- - appropriate TRV not found for analyte
CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table B-4. Food-web model exposure results for ptarmigan with 50% impoundment use

	Concentration				Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Shrub (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	11,137	8,771	3,354	64.2	0.427	48.9	23.6	73.0	139	120	--	1.2	--
Barium	25.0	6,262	580	206	0.000960	34.9	14.6	49.5	94.2	21	42	4.5	2.2
Cadmium	3,018	84.2	2.74	10.4	0.116	0.470	0.580	1.17	2.22	1.5	20	1.5	0.11
Lead	567	3,140	74.5	12.4	0.0217	17.5	1.12	18.7	35.5	3.9	11	9.1	3.2
Zinc	159,165	7,175	414	596	6.11	40.0	34.6	80.8	154	130	--	1.2	--

Note: Data used to develop this scenario are from all areas within mine permit boundary, with 50% usage of stream water and 50% usage of tailings pond water.

-- - appropriate TRV not found for analyte
CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table B-5. Food-web model exposure results for ptarmigan in near-facilities areas

	Concentration				Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Shrub (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	22,315	14,828	3,354	64.2	0.856	82.7	23.6	107.2	204	120	--	1.7	--
Barium	25.8	30,641	580	206	0.000991	171	14.6	186	353	21	42	17	8.4
Cadmium	6,687	90.5	2.74	10.4	0.257	0.505	0.580	1.34	2.55	1.5	20	1.7	0.13
Lead	1,045	11,672	74.5	12.4	0.0401	65.1	1.12	66.3	126	3.9	11	32	11
Zinc	341,717	16,921	414	596	13.1	94.4	34.6	142	270	130	--	2.1	--

Note: Data used to develop this scenario are from near-facilities areas (excludes Tundra Area 4), with 100% usage of tailings pond water.

-- - appropriate TRV not found for analyte
CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table B-6. Food-web model exposure results for ptarmigan in near-facilities areas with pit lake water only

Analyte	Concentration				Daily Exposure			Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV		Year-Round Hazard Quotient	
	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Shrub (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)			NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	50,000	14,828	3,354	64.2	1.92	82.7	23.6	108.2	206	120	--	1.7	--
Barium	100	30,641	580	206	0.00384	171.0	14.6	185.6	353	21	42	17	8.4
Cadmium	67,000	90.5	2.74	10.4	2.57	0.505	0.580	3.66	6.95	1.5	20	4.6	0.35
Lead	5,000	11,672	74.5	12.4	0.192	65.1	1.12	66.4	126	3.9	11	32	11
Zinc	2,600,000	16,921	414	596	99.7	94.4	34.6	229	435	130	--	3.3	--

Note: Data used to develop this scenario are from near-facilities areas (excludes Tundra Area 4), with 100% usage of the pit lake water.

-- - appropriate TRV not found for analyte

CoPC - chemical of potential concern

LOAEL - lowest-observed-adverse-effect level

NOAEL - no-observed-adverse-effect level

TRV - toxicity reference value

Table B-7. Food-web model exposure results for fox

	Concentration			Daily Exposure					TRV		Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Small Mammals (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	985	8,771	1,351	0.278	27.1	149	177	55.2	1.9	19	29	2.9
Barium	25.0	6,262	141	0.00706	19.4	15.6	35.0	10.9	5.1	20	2.1	0.55
Cadmium	231	84.2	1.02	0.0650	0.261	0.112	0.438	0.137	1.0	10	0.14	0.014
Lead	162.1	3,140	34.3	0.0457	9.72	3.79	13.5	4.23	11	90	0.38	0.047
Zinc	12,586	7,175	345	3.55	22.2	38.1	63.8	19.9	160	320	0.12	0.062

Note: Data used to develop this scenario are from all areas within mine permit boundary, with all water sources, including streams, tailings pond, and pit lake.

CoPC - chemical of potential concern

LOAEL - lowest-observed-adverse-effect level

NOAEL - no-observed-adverse-effect level

TRV - toxicity reference value

UCL - upper confidence limit

Table B-8. Food-web model exposure results for fox with 50% impoundment use

	Concentration			Daily Exposure					TRV		Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Small Mammals (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	11,137	8,771	1,351	3.14	27.1	149	180	56.1	1.9	19	30	3.0
Barium	25.0	6,262	141	0.00705	19.4	15.6	35.0	10.9	5.1	20	2.1	0.55
Cadmium	3,018	84.2	1.02	0.851	0.261	0.112	1.22	0.382	1.0	10	0.38	0.038
Lead	567	3,140	34.3	0.160	9.72	3.79	13.7	4.27	11	90	0.39	0.047
Zinc	159,165	7,175	345	44.9	22.2	38.1	105	32.9	160	320	0.21	0.103

Note: Data used to develop this scenario are from all areas within mine permit boundary, with 50% usage of stream water and 50% usage of tailings pond water.

CoPC - chemical of potential concern

LOAEL - lowest-observed-adverse-effect level

NOAEL - no-observed-adverse-effect level

TRV - toxicity reference value

UCL - upper confidence limit

Table B-9. Food-web model exposure results for fox in near-facilities areas

Analyte	Concentration: Water (µg/L)	Concentration: Soil/ Sediment (mg/kg dw)	Concentration: Small Mammals (mg/kg dw)	Daily Exposure: Water (mg/day)	Daily Exposure: Soil/ Sediment (mg/day)	Daily Exposure: Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV: NOAEL (mg/kg-day)	TRV: LOAEL (mg/kg-day)	Hazard Quotient: NOAEL Hazard Quotient	Hazard Quotient: LOAEL Hazard Quotient
Aluminum	22,315	14,828	1,691	6.29	45.9	187	239	74.7	1.9	19	39	3.9
Barium	25.8	30,641	141	0.00729	94.8	15.6	110.4	34.5	5.1	20	6.8	1.7
Cadmium	6,687	90.5	1.02	1.89	0.280	0.112	2.28	0.712	1.0	10	0.71	0.071
Lead	1,045	11,672	34.3	0.295	36.1	3.79	40.2	12.6	11	90	1.1	0.14
Zinc	341,717	16,921	353	96.4	52.4	39.0	188	58.7	160	320	0.37	0.18

Note: Data used to develop this scenario are from near-facilities areas (excludes Tundra Area 4), with 100% usage of tailings pond water.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value
UCL - upper confidence limit

Table B-10. Food-web model exposure results for teal

	Concentration				Daily Exposure								TRV		Year-Round Hazard Quotient	
Analyte	Water (μg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Invert. (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	Time Use Adjusted Exposure (mg/kg-day)	Ref. Time Use Adjusted Exp. (mg/kg-day)[a]	Total Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	985	8,771	161	268	0.0271	8.89	9.46	18.4	57.4	19.4	37.0	56.3	120	--	0.47	--
Barium	25.0	6,262	132	76.2	0.000688	6.35	6.62	13.0	40.5	13.7	6.72	20.4	21	42	0.97	0.49
Cadmium	231	84.2	0.316	19.4	0.00634	0.0854	0.170	0.262	0.818	0.276	0.0225	0.298	1.5	20	0.20	0.015
Lead	162.1	3,140	0.00908	40.0	0.00446	3.18	0.321	3.51	11.0	3.70	0.0627	3.76	3.9	11	0.96	0.34
Zinc	12,586	7,175	152	933	0.346	7.27	14.4	22.0	68.7	23.1	3.49	26.6	130	--	0.20	--

Note: Data used to develop this scenario are from all areas within mine permit boundary, with all water sources, including streams, tailings pond, and pit lake.

-- - appropriate TRV not found for analyte
CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

[a] Based on mean daily exposure for teal in pond reference station 3 multipled by 0.66.

Table B-11. Food-web model exposure results for teal with 50% impoundment use

Analyte	Concentration				Daily Exposure								TRV		Year-Round Hazard Quotient	
	Water (μg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Invert. (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	Time Use Adjusted Exposure (mg/kg-day)	Ref. Time Use Adjusted Exp. (mg/kg-day)[a]	Total Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	11,137	8,771	161	268	0.306	8.89	9.46	18.7	58.3	19.6	37.0	56.6	120	--	0.47	--
Barium	25.0	6,262	132	76.2	0.000688	6.35	6.62	13.0	40.5	13.7	6.72	20.4	21	42	0.97	0.49
Cadmium	3,018	84.2	0.316	19.4	0.0830	0.0854	0.170	0.338	1.06	0.356	0.0225	0.379	1.5	20	0.25	0.019
Lead	567	3,140	0.00908	40.0	0.0156	3.18	0.321	3.52	11.0	3.71	3.77	3.77	3.9	11	0.97	0.34
Zinc	159,165	7,175	152	933	4.38	7.27	14.4	26.0	81.3	27.4	3.49	30.9	130	--	0.24	--

Note: Data used to develop this scenario are from all areas within mine permit boundary, with 50% usage of stream water and 50% usage of tailings pond water.

-- - appropriate TRV not found for analyte
CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

[a] Based on mean daily exposure for teal in pond reference station 3 multipled by 0.66.

Table B-12. Food-web model exposure results for teal in near-facilities areas

	Concentration				Daily Exposure								TRV		Year-Round Hazard Quotient	
Analyte	Water (μg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Invert. (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	Time Use Adjusted Exposure (mg/kg-day)	Ref. Time Use Adjusted Exp. (mg/kg-day)[a]	Total Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	22,315	14,828	161	268	0.614	15.0	9.46	25.1	78.5	26.4	37.0	63.4	120	--	0.53	--
Barium	25.8	30,641	132	142	0.000711	31.1	7.14	38.2	119.4	40.2	6.72	47.0	21	42	2.2	1.12
Cadmium	6,687	90.5	0.316	19.4	0.184	0.0917	0.170	0.446	1.39	0.469	0.0225	0.492	1.5	20	0.33	0.025
Lead	1,045	11,672	0.00908	50.8	0.0287	11.8	0.407	12.3	38.3	12.9	0.0627	13.0	3.9	11	3.3	1.2
Zinc	341,717	16,921	152	933	9.40	17.2	14.4	40.9	128	43.1	3.49	46.6	130	--	0.36	--

Note: Data used to develop this scenario are from near-facilities areas (excludes Tundra Area 4), with 100% usage of tailings pond water.

-- - appropriate TRV not found for analyte
CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

[a] Based on mean daily exposure for teal in pond reference station 3 multipled by 0.66.

Table B-13. Food-web model exposure results for teal in near-facilities areas with 50% pit lake water use

	Concentration				Daily Exposure								TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Invert. (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	Time Use Adjusted Exposure (mg/kg-day)	Ref. Time Use Adjusted Exp. (mg/kg-day)[a]	Total Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	36,000	14,828	161	268	0.990	15.0	9.46	25.5	79.6	26.8	37.0	63.8	120	--	0.53	--
Barium	62.5	30,641	132	142	0.00172	31.1	7.14	38.2	119.4	40.2	6.72	47.0	21	42	2.2	1.12
Cadmium	36,500	90.5	0.316	19.4	1.00	0.0917	0.170	1.27	3.95	1.33	0.0225	1.35	1.5	20	0.90	0.068
Lead	3,000	11,672	0.00908	50.8	0.0825	11.8	0.407	12.3	38.5	13.0	0.0627	13.0	3.9	11	3.3	1.2
Zinc	1,458,000	16,921	152	933	40.1	17.2	14.4	71.6	224	75.4	3.49	78.9	130	--	0.61	--

Note: Data used to develop this scenario are from near-facilities areas (excludes Tundra Area 4), with 50% usage of tailings pond water and 50% usage of pit lake water.

-- - appropriate TRV not found for analyte
CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

[a] Based on mean daily exposure for teal in pond reference station 3 multipled by 0.66.

Table B-14. Food-web model exposure results for muskrat

	Concentration			Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	985	8,771	3,354	0.0915	12.3	235	247	265	1.9	19	140	14
Barium	25.0	6,262	580	0.00233	8.78	40.6	49.4	53.0	5.1	20	10	2.7
Cadmium	231	84.2	2.74	0.0214	0.118	0.192	0.332	0.356	1.0	10	0.36	0.036
Lead	162.1	3,140	74.5	0.01506	4.40	5.22	9.63	10.3	11	90	0.94	0.11
Zinc	12,586	7,175	414	1.17	10.05	29.0	40.2	43.1	160	320	0.27	0.13

Note: Data used to develop this scenario are from all areas within mine permit boundary, with all water sources, including streams, tailings pond, and pit lake.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table B-15. Food-web model exposure results for muskrat with 50% impoundment use

	Concentration			Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	11,137	8,771	3,354	1.03	12.3	235	248	266	1.9	19	140	14
Barium	25.0	6,262	580	0.00232	8.78	40.6	49.4	53.0	5.1	20	10	2.7
Cadmium	3,018	84.2	2.74	0.280	0.118	0.192	0.591	0.634	1.0	10	0.63	0.063
Lead	567	3,140	74.5	0.0527	4.40	5.22	9.67	10.4	11	90	0.94	0.12
Zinc	159,165	7,175	414	14.8	10.05	29.0	53.8	57.7	160	320	0.36	0.18

Note: Data used to develop this scenario are from all areas within mine permit boundary, with 50% usage of stream water and 50% usage of tailings pond water.

CoPC - chemical of potential concern

LOAEL - lowest-observed-adverse-effect level

NOAEL - no-observed-adverse-effect level

TRV - toxicity reference value

Table B-16. Food-web model exposure results for muskrat in near-facilities areas

	Concentration			Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	22,315	14,828	3,354	2.07	20.8	235	258	277	1.9	19	146	15
Barium	25.8	30,641	580	0.00240	42.9	40.6	83.6	89.7	5.1	20	18	4.5
Cadmium	6,687	90.5	2.74	0.621	0.127	0.192	0.940	1.01	1.0	10	1.0	0.10
Lead	1,045	11,672	74.5	0.0971	16.4	5.22	21.7	23.3	11	90	2.1	0.26
Zinc	341,717	16,921	414	31.8	23.7	29.0	84.4	90.6	160	320	0.57	0.28

Note: Data used to develop this scenario are from near-facilities areas (excludes Tundra Area 4), with 100% usage of tailings pond water.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table B-17. Food-web model exposure results for shrew in Tundra Area 1

Analyte	Concentration: Water (µg/L)	Concentration: Soil/ Sediment (mg/kg dw)	Concentration: Soil Inverts. (mg/kg dw)	Daily Exposure: Water (mg/day)	Daily Exposure: Soil/ Sediment (mg/day)	Daily Exposure: Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV: NOAEL (mg/kg-day)	TRV: LOAEL (mg/kg-day)	Year-Round Hazard Quotient: NOAEL Hazard Quotient	Year-Round Hazard Quotient: LOAEL Hazard Quotient
Aluminum	256	85,832	671	0.000268	9.44	1.38	10.82	1,690	1.9	19	890	89
Barium	25	119,677	654	0.0000263	13.2	1.34	14.5	2,267	5.1	20	444	113
Cadmium	9.7	408	48.6	0.0000102	0.0449	0.0996	0.145	22.6	1.0	10	23	2.3
Lead	131.9	147,271	155	0.0001385	16.2	0.317	16.5	2,581	11	90	235	29
Zinc	1,331	88,602	2,333	0.001397	9.75	4.78	14.5	2,270	160	320	14	7.1

Note: Data used to develop this scenario are from Tundra Area 1, with stream water only.

CoPC - chemical of potential concern

LOAEL - lowest-observed-adverse-effect level

NOAEL - no-observed-adverse-effect level

TRV - toxicity reference value

Table B-18. Food-web model exposure results for shrew in Tundra Area 2

	Concentration			Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Soil Inverts. (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	45,105	671	0.000268	4.96	1.38	6.34	990	1.9	19	521	52
Barium	25.0	43,073	415	0.0000263	4.74	0.851	5.59	873	5.1	20	171	44
Cadmium	9.7	407	48.6	0.0000102	0.0448	0.0996	0.144	22.6	1.0	10	23	2.3
Lead	131.9	31,325	144	0.0001385	3.45	0.294	3.74	584	11	90	53	6.5
Zinc	1,331	69,890	2,333	0.001397	7.69	4.78	12.5	1949	160	320	12	6.1

Note: Data used to develop this scenario are from Tundra Area 2, with stream water only.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table B-19. Food-web model exposure results for shrew in Tundra Area 3

	Concentration			Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Soil Inverts. (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	43,742	671	0.000268	4.81	1.38	6.19	967	1.9	19	509	51
Barium	25.0	27,196	338	0.0000263	2.99	0.694	3.69	576	5.1	20	113	29
Cadmium	9.7	268	48.6	0.0000102	0.0295	0.0996	0.129	20.2	1.0	10	20	2.0
Lead	131.9	28,835	125	0.0001385	3.17	0.256	3.43	536	11	90	49	6.0
Zinc	1,331	55,469	2,333	0.001397	6.10	4.78	10.9	1701	160	320	11	5.3

Note: Data used to develop this scenario are from Tundra Area 3, with stream water only.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table B-20. Food-web model exposure results for shrew in Tundra Area 4

Analyte	Concentration			Daily Exposure			Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV		Year-Round Hazard Quotient	
	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Soil Inverts. (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)			NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	19,557	671	0.000268	2.15	1.38	3.53	551	1.9	19	290	29
Barium	25.0	6,122	174	0.0000263	0.673	0.36	1.03	161	5.1	20	32	8.1
Cadmium	9.7	208	48.6	0.0000102	0.0229	0.0996	0.123	19.1	1.0	10	19	1.9
Lead	131.9	4,514	97.4	0.0001385	0.497	0.200	0.70	109	11	90	10	1.2
Zinc	1,331	14,126	2,333	0.001397	1.55	4.78	6.34	990	160	320	6.2	3.1

Note: Data used to develop this scenario are from Tundra Area 4, with stream water only.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table B-21. Food-web model exposure results for vole in Tundra Area 1

Analyte	Concentration					Daily Exposure			Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	TRV		Year-Round Hazard Quotient	
	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Lichen (mg/kg dw)	Moss (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)			NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	85,832	80	11,375	149,460	0.001615	17.5	69.0	86.5	1,840	1.9	19	968	97
Barium	25	119,677	745	19,855	216,953	0.000158	24.4	106	131	2,781	5.1	20	545	139
Cadmium	9.7	408	1.9	58.6	928	0.000061	0.0832	0.433	0.517	11.0	1.0	10	11	1.1
Lead	131.9	147,271	32	2,032	8,017	0.000833	30.0	4.51	34.6	735	11	90	67	8.2
Zinc	1,331	88,602	570	6,347	155,572	0.00841	18.1	73.2	91.2	1,941	160	320	12	6.1

Note: Data used to develop this scenario are from Tundra Area 1, with stream water only.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table B-22. Food-web model exposure results for vole in Tundra Area 2

	Concentration					Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Lichen (mg/kg dw)	Moss (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	45,105	80.2	11,375	64,451	0.001615	9.20	32.8	42.0	894	1.9	19	471	47
Barium	25.0	43,073	582	10,180	65,947	0.000158	8.78	36.8	45.6	970	5.1	20	190	48
Cadmium	9.7	407	1.88	58.6	325	0.000061	0.0831	0.177	0.260	5.54	1.0	10	5.5	0.55
Lead	131.9	31,325	31.9	1,918	7,452	0.000833	6.39	4.22	10.6	226	11	90	21	2.5
Zinc	1,331	69,890	570	6,344	54,769	0.00841	14.3	30.3	44.6	949	160	320	5.9	3.0

Note: Data used to develop this scenario are from Tundra Area 2, with stream water only.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table B-23. Food-web model exposure results for vole in Tundra Area 3

	Concentration					Daily Exposure				BW	TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Lichen (mg/kg dw)	Moss (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	43,742	80.2	11,375	61,614	0.001615	8.92	31.6	40.5	863	1.9	19	454	45
Barium	25.0	27,196	520	7,537	38,591	0.000158	5.55	23.6	29.1	620	5.1	20	122	31
Cadmium	9.7	268	1.88	46.6	307	0.000061	0.0546	0.165	0.219	4.67	1.0	10	4.7	0.47
Lead	131.9	28,835	31.9	1,720	6,498	0.000833	5.88	3.74	9.62	205	11	90	19	2.3
Zinc	1,331	55,469	570	5,307	51,793	0.00841	11.3	28.6	39.9	850	160	320	5.3	2.7

Note: Data used to develop this scenario are from Tundra Area 3, with stream water only.

CoPC - chemical of potential concern
LOAEL - lowest-observed-adverse-effect level
NOAEL - no-observed-adverse-effect level
TRV - toxicity reference value

Table B-24. Food-web model exposure results for vole in Tundra Area 4

	Concentration					Daily Exposure					TRV		Year-Round Hazard Quotient	
Analyte	Water (µg/L)	Soil/ Sediment (mg/kg dw)	Herb. Plant (mg/kg dw)	Lichen (mg/kg dw)	Moss (mg/kg dw)	Water (mg/day)	Soil/ Sediment (mg/day)	Food (mg/day)	Total Daily Intake (mg/day)	BW Normalized Exposure (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	NOAEL Hazard Quotient	LOAEL Hazard Quotient
Aluminum	256	19,557	80.2	11,375	22,494	0.001615	3.99	15.0	19.0	404	1.9	19	213	21
Barium	25.0	6,122	362	2,843	6,789	0.000158	1.25	6.86	8.11	173	5.1	20	34	8.6
Cadmium	9.7	208	1.88	40.7	87.2	0.000061	0.0424	0.0687	0.111	2.37	1.0	10	2.4	0.24
Lead	131.9	4,514	31.9	1,420	5,101	0.000833	0.92	3.01	3.94	83.7	11	90	7.6	0.93
Zinc	1,331	14,126	570	4,766	14,829	0.00841	2.88	12.7	15.6	331	160	320	2.1	1.0

Note: Data used to develop this scenario are from Tundra Area 4, with stream water only.

CoPC - chemical of potential concern

LOAEL - lowest-observed-adverse-effect level

NOAEL - no-observed-adverse-effect level

TRV - toxicity reference value

Appendix C

Data Tables

Table C-1. Road surface soil concentration data from 2003 XRF survey

Station	Date	Longitude	Latitude	XRF Lead	XRF Zinc	XRF Cadmium
MRS-01	July-03	-162.90951	68.02989	215	652	<LOD
MRS-02	July-03	-162.89498	68.03627	256	926	<LOD
MRS-03	July-03	-162.87635	68.04115	282	818	<LOD
MRS-04	July-03	-162.87914	68.04498	535	1,669	<LOD
MRS-05	July-03	-162.87517	68.04747	1,985	3,015	<LOD
MRS-06	July-03	-162.88309	68.05334	668	1,895	<LOD
MRS-07	July-03	-162.86108	68.04869	988	2,653	<LOD
MRS-08	July-03	-162.85628	68.05321	801	2,120	<LOD
MRS-09	July-03	-162.85322	68.05786	1,119	2,145	<LOD
MRS-10	July-03	-162.85248	68.05968	1,477	3,199	<LOD
MRS-11	July-03	-162.85104	68.06262	1,235	4,118	<LOD
MRS-12	July-03	-162.84790	68.06685	1,538	4,491	171
MRS-13	July-03	-162.88063	68.06307	602	1,267	<LOD
MRS-14	July-03	-162.86858	68.06855	2,631	5,552	115
MRS-15	July-03	-162.85692	68.07020	1,644	4,817	<LOD
MRS-16	July-03	-162.85538	68.07097	1,825	5,545	<LOD
MRS-17	July-03	-162.87340	68.07315	260	818	<LOD
MRS-18	July-03	-162.84991	68.07028	1,970	6,913	74
MRS-19	July-03	-162.84712	68.07091	7,584	22,801	362
MRS-20	July-03	-162.84883	68.07093	4,136	12,354	180
MRS-21	July-03	-162.85165	68.07125	2,766	9,289	66
MRS-22	July-03	-162.85048	68.07192	3,377	11,023	134
MRS-23	July-03	-162.84735	68.07242	3,834	12,401	194
MRS-24	July-03	-162.85430	68.07219	2,968	11,924	104
MRS-25	July-03	-162.85106	68.07367	4,090	15,095	131
MRS-35	July-03	-162.85899	68.07432	1,356	4,921	88
MRS-37	July-03	-162.84698	68.07180	2,931	9,594	97
MRS-38	July-03	-162.88293	68.05912	494	4,397	281
MRS-39	July-03	-162.88187	68.06103	273	2,398	102
MRS-40	July-03	-162.87173	68.06691	1,719	2,581	<LOD
MRS-41	July-03	-162.85143	68.07157	1,859	6,977	<LOD
MRS-42	July-03	-162.84904	68.07054	2,279	8,637	84

Source: 2003 XRF survey data from Harbke (2006a).

Note: <LOD - indicates below detection limit of the XRF field instrument
XRF - x-ray fluorescence

Table C-2. Road surface soil concentration data from 2004 XRF survey

Station	Collection Date	Longitude	Latitude	Lead (ppm)	Zinc (ppm)
MRS-01	07/26/04	-162.90951	68.02989	336	1,049
MRS-02	07/26/04	-162.89498	68.03627	387	1,191
MRS-03	07/26/04	-162.87635	68.04114	520	1,345
MRS-07	07/26/04	-162.86107	68.04869	1,223	2,546
MRS-08	07/26/04	-162.85627	68.05320	1,508	3,232
MRS-09	07/26/04	-162.85322	68.05786	1,554	3,295
MRS-10	07/26/04	-162.85249	68.05968	1,716	4,381
MRS-11	07/26/04	-162.85104	68.06262	2,464	5,758
MRS-12	07/26/04	-162.84790	68.06685	3,133	9,216
MRS-18	07/26/04	-162.84990	68.07028	1,478	4,060
MRS-21	07/26/04	-162.85165	68.07124	4,819	11,076
MRS-41	07/26/04	-162.85145	68.07159	6,742	17,873
MRS-24	07/26/04	-162.85431	68.07219	1,593	5,739
MRS-25	07/26/04	-162.85106	68.07367	3,829	13,409
MRS-23	07/26/04	-162.84734	68.07242	4,073	10,626
MRS-37	07/26/04	-162.84691	68.07180	3,590	11,143
MRS-19	07/26/04	-162.84712	68.07091	4,786	13,965
MRS-42	07/26/04	-162.84897	68.07055	2,585	7,730
MRS-20	07/26/04	-162.84883	68.07093	2,571	8,303
MRS-22	07/26/04	-162.85048	68.07192	2,412	8,193
MRS-17	08/01/04	-162.87340	68.07314	389	864
MRS-35	08/01/04	-162.85903	68.07432	1,832	4,237
Dupe MRS-18	07/26/04	-162.84990	68.07028	1,563	4,509
Dupe MRS-03	07/26/04	-162.87635	68.04114	621	1,221

Source: 2003 XRF survey data from Harbke (2006a).

Note: XRF analyses conducted *ex situ* .

XRF - x-ray fluorescence

Table C-3. Road and facility surface soil concentration data from 2005 XRF survey

Date/Time	Sieve #	Barium	Barium Error	Cadmium	Cadmium Std. Error	Lead	Lead Std. Error	Zinc	Zinc Std. Error
10/09/2005 15:40	20	19,037	225	9	28	303	56	865	101
10/09/2005 16:27	20	25,331	203	21	23	429	48	1,492	92
10/09/2005 16:41	20	32,420	241	4	24	984	65	2,871	115
10/09/2005 18:43	20	33,065	309	39	32	1,286	90	3,492	156
10/10/2005 07:14	20	24,210	260	13	29	630	69	3,858	158
10/22/2005 16:08	20	32,428	308	47	32	1,022	84	1,582	125
10/22/2005 16:28	20	18,023	178	35	24	1,499	74	4,257	130

Source: 2005 XRF data from Harbke (2006a)

Note: All concentrations provided in mg/kg.
Sieve size #20 is 0.85 mm.
Cadmium data not used because values near or below XRF instrument detection limit.

XRF - x-ray fluorescence

Table C-4. Laboratory concentration data for road and facility area surface soils

Station Name	Station Site or Depth	Material Sampled	Longitude	Latitude	Lab Pb (mg/kg)	Lab Zn (mg/kg)	Lab Cd (mg/kg)
MRS-13	NRS	R	-162.88069	68.06309	309	648	1.9
MRS-18	WRS	R	-162.84997	68.07026	2,888	7,040	46.2
MRS-08	WT	R	-162.85682	68.05333	2,628	6,806	42.6
MRS-01	ET	R	-162.90928	68.02982	303	950	5.4
MRS-01	WT	R	-162.90974	68.02996	540	2,130	11.1
MRS-02	WSh	R	-162.89513	68.03632	440	1,558	8.2
MRS-03	WT	R	-162.87652	68.04122	541	1,682	8.2
MRS-07	WRS	R	-162.86123	68.04871	1,313	3,088	19.7
MRS-09	RSh	R	-162.85299	68.05785	1,811	4,121	23.9
MRS-09	RT	R	-162.85292	68.05784	1,847	4,731	39.9
MRS-10	RT	R	-162.85206	68.05967	3,084	1,004	5.0
MRS-10	LT	R	-162.85304	68.05969	1,657	7,164	36.6
MRS-17	MRS	R	-162.87340	68.07314	159	708	3.8
MRS-07	ET	R	-162.86072	68.04863	1,207	3,069	18.3
MRS-09	ERS	R	-162.85307	68.05785	1,133	1,777	9.8
MRS-12	ESh	R	-162.84768	68.06685	5,933	11,746	61.7

Source: Harbke (2006b)

Note: Coordinates in NAD27, AK Zone 7.

Station Site Key
WT = Westside Toe
ESh = Eastside Shoulder
MRS = Middle Road Surface
NRS = Northside Road Surface

Material Sampled Key
R = Roadbed Materials

Table C-5. Geochemical data for tailings and waste rock samples

	Sample ID	Lead (ppm) (M-AqReg)	Zinc (ppm) (M-AqReg)	Cadmium (ppm) (M-AqReg)	Barium (ppm) (M-AqReg)	Aluminum (percent) (M-AqReg)	Barium (percent) (M-AqReg)
Tailings							
	RDP1-48	21139	52937	341	3	0.07	9.55
Kivalina							
	RDP1-26	567	1,338	5.1	13	0.7	0.35
	RDP1-27	1,014	3,470	38	15	0.7	0.62
	RDP1-28	478	2,956	44.4	25	0.69	0.47
	RDP1-29	164	1,282	4.3	13	0.54	0.33
	RDP1-43	4,030	741	6.9	29	1.04	2.3
	Average	**1,251**	**1,957**	**19.7**	**19**	**0.73**	**0.81**
Siksikpuk							
	RDP1-04	125	185	0.2	759	1.88	1.54
	RDP1-05	107	343	2.2	258	1.06	1.09
	RDP1-06	199	360	2.4	203	1.01	1.9
	RDP1-08	20,497	25,166	135.5	13	0.71	14.01
	RDP1-09	18,652	10,678	65.7	10	0.7	16.75
	RDP1-16	14,795	3,423	30.1	72	0.76	7.58
	RDP1-24	8,107	3,422	24.7	2	0.32	3.19
	RDP1-33	58	1,175	11.1	80	0.16	44.19
	RDP1-34	141	5,964	28.6	15	1.13	2.99
	RDP1-36	139	2,281	25.7	181	1.57	1.78
	RDP1-44	481	2,281	21.9	10	0.95	2.68
	RDP1-57	80	1,123	7.2	455	2.94	0.54
	Average	**5,282**	**4,700**	**29.6**	**172**	**1.10**	**8.19**
Main Waste							
	RDP1-01	23,425	4,029	45.4	17	0.04	25.83
	RDP1-02	294	775	6.5	298	2.46	0.56
	RDP1-03	21,374	23,440	198.5	7	0.13	1.81
	RDP1-07	25,307	1,469	10.5	29	0.07	26.28
	RDP1-08	20,497	25,166	135.5	13	0.71	14.01
	RDP1-09	18,652	10,678	65.7	10	0.7	16.75
	RDP1-10	16,252	7,999	49	9	0.56	13.07
	RDP1-11	580	1,556	9.7	24	1.06	1
	RDP1-12	1,105	1,423	9.7	20	1.07	1.52
	RDP1-13	240	395	1.2	48	2.09	0.32
	RDP1-14	10,870	33,053	272.4	314	0.44	34.27
	RDP1-15	24,071	2,614	31.5	23	0.32	6.71
	RDP1-16	14,795	3,423	30.1	72	0.76	7.58
	RDP1-17	14,537	34,908	236.4	1	0.21	9.61
	RDP1-18	13,952	1,094	11.7	44	0.25	5.39
	RDP1-19	7,687	551	4.8	88	0.36	4.07
	RDP1-20	218	5,937	9.7	8	0.5	0.38
	RDP1-21	6,866	19,928	97.1	155	0.42	41.64
	RDP1-22	20,958	9,605	81.3	10	0.07	12.08
	RDP1-23	21,552	9,624	89	15	0.06	14.45
	RDP1-24	8,107	3,422	24.7	2	0.32	3.19
	RDP1-25	21,377	995	6.9	4	0.09	2.76
	RDP1-40	23,192	3,935	29.8	28	0.28	6.29
	RDP1-42	22,945	3,319	26.8	8	0.1	20.78
	Average	**14,119**	**8,722**	**62**	**52**	**0.54**	**11.26**

Source: SRK (2003)

Note: Kivalina is Kivalina shale waste rock.
Siksikpuk is a rock type used in construction of the main dam.
Main waste refers to the primary waste rock piles.
M-AqReg - analytical method using aqua regia digestion

Table C-6. Exposure point concentrations selected for disturbed soil exposure areas

Metal	Units	Method	N	Min	Max	Mean	StDev	Normal	Gamma	Lognormal	UCL	Method	EPC
Kivalina													
Lead	(ppm)	(M-AqReg)	5	164	4,030	1,251	1,583	No	Yes	Yes	5,026	Approximate Gamma	4,030
Zinc	(ppm)	(M-AqReg)	5	741	3,470	1,957	1,184	Yes	Yes	Yes	3,086	Student's-t	3,086
Cadmium	(ppm)	(M-AqReg)	5	4.3	44.4	19.7	19.7	Yes	Yes	Yes	38.6	Student's-t	38.6
Barium	(ppm)	(M-AqReg)	5	13.0	29.0	19.0	7.5	Yes	Yes	Yes	26.1	Student's-t	26.1
Aluminum	(%)	(M-AqReg)	5	0.54	1.0	0.73	0.18	Yes	Approx.	Yes	0.91	Student's-t	0.91
Barium	(%)	(Total)	5	0.33	2.3	0.81	0.84	No	Approx.	Yes	2.3	Approximate Gamma	2.3
Siksikpuk													
Lead	(ppm)	(M-AqReg)	12	58.0	20,497	5,282	8,080	No	No	No	28,491	99% Chebyshev	20,497
Zinc	(ppm)	(M-AqReg)	12	185	25,166	4,700	7,100	No	Yes	Yes	10,116	Approximate Gamma	10,116
Cadmium	(ppm)	(M-AqReg)	12	0.2	136	29.6	37.9	No	Yes	Yes	64.3	Approximate Gamma	64.3
Barium	(ppm)	(M-AqReg)	12	2	759	172	230	No	Yes	Yes	408	Approximate Gamma	408
Aluminum	(%)	(M-AqReg)	12	0.16	2.9	1.1	0.75	Yes	Yes	Yes	1.5	Student's-t	1.5
Barium	(%)	(Total)	12	0.54	44.2	8.2	12.5	No	Approx.	Yes	17.0	Approximate Gamma	17.0
Main Waste													
Lead	(ppm)	(M-AqReg)	24	218	25,307	14,119	8,884	No	No	No	32,162	99% Chebyshev	25,307
Zinc	(ppm)	(M-AqReg)	24	395	34,908	8,722	10,521	No	Yes	Yes	13,618	Approximate Gamma	13,618
Cadmium	(ppm)	(M-AqReg)	24	1.2	272	61.8	76.2	No	Yes	Yes	97.1	Approximate Gamma	97.1
Barium	(ppm)	(M-AqReg)	24	1.0	314	52.0	85.5	No	No	Yes	128	Chebyshev (MVUE)	128
Aluminum	(%)	(M-AqReg)	24	0.040	2.5	0.54	0.61	No	Yes	Yes	0.80	Approximate Gamma	0.80
Barium	(%)	(Total)	24	0.32	41.6	11.3	11.3	No	Yes	Yes	17.3	Approximate Gamma	17.3

Note: The minimum of the UCL or the maximum value are used as the exposure point concentration.

EPC - exposure point concentration
M-AqReg - analytical method using aqua regia digestion
UCL - upper confidence limit

Table C-7. Summary of stream water quality monitoring data (1998–2004)

Station	Description	Statistics	Aluminum	Cadmium	Lead	Zinc
Red Dog Creek and Tributaries Upstream of Mine						
Station 145	Middle Fork Red Dog Creek upstream of Hilltop	Median	60	12	24	2510
		Count	*86*	*103*	*102*	*86*
		Count < DL	*20*	*1*	*15*	*0*
Rachael	Tributary upstream of mine	Median	846	1.5	0.6	367
		Count	*84*	*100*	*99*	*84*
		Count < DL	*1*	*11*	*32*	*0*
Connie	Tributary upstream of mine	Median	88	0.30	2.4	117
		Count	*86*	*102*	*101*	*86*
		Count < DL	*10*	*26*	*29*	*0*
Shelly	Tributary upstream of mine	Median	151	3.3	24	248
		Count	*87*	*104*	*103*	*87*
		Count < DL	*2*	*8*	*7*	*0*
Sulfur	Tributary upstream of mine	Median	52	4.2	421	846
		Count	*59*	*70*	*69*	*59*
		Count < DL	*11*	*7*	*1*	*0*
Station 140	Middle Fork Red Dog Creek upstream of Outfall 001	Median	89	21	49	2655
		Count	*130*	*131*	*132*	*132*
		Count < DL	*18*	*0*	*0*	*0*
Discharge Stations						
Outfall 001	Mine Discharge	Median	–20	0.80	0.70	52
		Count	*78*	*143*	*144*	*145*
		Count < DL	*49*	*13*	*23*	*12*
Mainstem Red Dog Creek Downstream of Mine						
Station 20	Red Dog Creek downstream of Outfall 001	Median	37	12	16	1220
		Count	*106*	*107*	*107*	*106*
		Count < DL	*31*	*0*	*0*	*0*
Station 12	North Fork Red Dog Creek (background station)	Median	30	0.08	0.30	13
		Count	*111*	*111*	*111*	*111*
		Count < DL	*27*	*40*	*29*	*13*
Station 151	Red Dog Creek downstream of North Fork Red Dog Creek	Median	18	5.7	4.5	495
	(end of mixing zone)	*Count*	*19*	*19*	*19*	*19*
		Count < DL	*4*	*0*	*0*	*0*
Station 10		Median	26	6.1	2.8	647
	Red Dog Creek downstream of North Fork Red Dog Creek	*Count*	*95*	*95*	*95*	*95*
		Count < DL	*33*	*0*	*6*	*0*

Table C-7. (cont.)

Station	Description	Statistics	Aluminum	Cadmium	Lead	Zinc
Ikalukrok Creek						
Station 9	Ikalukrok Creek upstream of Red Dog Creek (background station)	Median	217	1.6	0.90	465
		Count	*114*	*113*	*113*	*113*
		Count < DL	*3*	*2*	*22*	*0*
Station 150	Ikalukrok Creek downstream of Red Dog Creek (end of mixing zone)	Median	87	2.1	1.3	363
		Count	*54*	*54*	*54*	*54*
		Count < DL	*1*	*0*	*4*	*0*
Station 73s	Ikalukrok Creek downstream of Red Dog Creek	Median	104	2.3	1.0	345
		Count	*100*	*100*	*100*	*100*
		Count < DL	*20*	*3*	*15*	*0*
Station 160	Ikalukrok Creek downstream of Dudd Creek (replaces baseline Station 7)	Median	51	1.3	0.50	195
		Count	*77*	*77*	*77*	*77*
		Count < DL	*18*	*6*	*19*	*1*
	Mean of the Median Values		**120**	**18**	**44**	**730**

Source: Hockley (2006a, pers. comm.)

Note: Data reported in μg/L.
Negative signs (–) denote values that are less than detection limits.
< *DL* - below detection limit

Table C-8. Stream water upper confidence limits

	Summary Statistics					Distributional Tests				
	N	Min	Max	Mean	StDev	Normal	Gamma	Lognormal	UCL	UCL Method
Aluminum										
Excluding Wulik river stations, full detection limit	15	18.0	846	125	207	No	No	Yes	241	95% Chebyshev
Excluding Wulik river stations, half detection limit	15	10.0	846	124	207	No	Approx.	Yes	218	95% Approx. Gamma
Excluding Wulik river stations and mine outfall	14	18.0	846	133	212	No	No	Yes	256	95% H-statistic
Cadmium										
Excluding Wulik river stations	15	0.080	21.1	4.9	5.8	No	Yes	Yes	9.0	95% Approx. Gamma
Excluding Wulik river stations and mine outfall	14	0.080	21.1	5.2	5.9	No	Yes	Yes	9.7	95% Approx. Gamma
Lead										
Excluding Wulik river stations	15	0.30	421	36.5	107.2	No	No	Yes	159	99% Chebyshev
Excluding Wulik river stations and mine outfall	14	0.30	421	39.0	111	No	Approx.	Yes	132	95% Adjusted Gamma
Zinc										
Excluding Wulik river stations	15	12.7	2,655	702	825	No	Yes	Yes	1,254	95% Approx. Gamma
Excluding Wulik river stations and mine outfall	14	12.7	2,655	749	836	No	Yes	Yes	1,331	95% Approx. Gamma

Note: Aluminum in the mine outfall was reported as "-20." This was interpreted as 20 *U*. No other results were reported as undetected.
All concentrations reported in µg/L.
UCLs calculated from data in Table C-7.
UCL - upper confidence limit

Table C-9. Tailings pond water quality data

	Average	Median	Standard Deviation
2005 Reclaim Water Quality Data			
Aluminum	4.3	3.6	2.2
Barium	0.032	0.011	0.049
Cadmium	5.4	5.7	2.1
Lead	2.2	2.3	0.82
Zinc	416	455	107
2003 Reclaim Water Quality Data			
Aluminum	3.6	3.3	2.1
Barium	0.025	0.018	0.023
Cadmium	4.2	4.2	0.9
Lead	2.4	2.3	0.8
Zinc	305	310	50

Source: Hockley (2006b, pers. comm.)

Note: Data reported in mg/L (total).

Reclaim water quality is tailings pond water sampled at the water treatment plant intake from the tailings impoundment.

Appendix D

Chronology of Dust Control Improvements to the Red Dog Mine Operation

Chronology of Dust Control Improvements to the Red Dog Mine Operation

The following is a summary of improvements that have been made to the Red Dog Mine operations for dust control.

January 1991–August 1992

- Tarps installed, repaired, and improved in various ways to enclose the coarse ore stockpile and contain fugitive dust.

April 1992

- Calcium chloride applications intensified for all mill site roads and application areas.

June 1992

- Hoppers installed at the mill site conveyor take-up pulleys and temporary curtains hung around the take up pulley towers.

June 1992–October 1992

- Some crusher feed stockpiles maintained in the mine pit instead of on the crusher feed stockpile pad.

July 1992

- 18,000-gallon water truck purchased and arrives onsite. Watering of site intensified.
- Water spray bar installed and in use for the coarse ore stockpile conveying system until coarse ore stockpile receives hard-sided enclosure.

August 1992

- Coarse ore stockpile hard-sided enclosure completed.
- Mine concentrate storage building (CSB) vents covered.

September 1992

- Mine CSB vents retrofitted to hold passive filter cartridges as alternative to covering them.

October 1992

- Mine CSB truck loading bay fully enclosed.
- Mill site ore conveyer take-up pulleys, except the mine CSP take-up pulley, relocated to inside the mill.

May 1993–Fall 1993

- Water sprays installed and utilized on jaw crusher drop box.
- Below-freezing temperatures result in system being abandoned.

January–November 1995

- Nine of 15 ore stockpiles built during this time period constructed and maintained within the pit to minimize exposure of ore stockpiles to wind. This represents approximately 60% of all crusher feed for the period.

December 1995

- Existing 5,000-cfm baghouse for jaw crusher dust control replaced with new 7,000-cfm baghouse.

Winter 2000/2001

- Eight “windrows” constructed using waste rock on tailings beach perpendicular to the tailings dam. Windrows are approximately 6 ft high, 16 ft wide and 150 ft long.

Summer 2000

- Soil-Sement® palliative applied to a portion of the tailings beach.

July 2001

- Concentrate truck wash system fabricated and used at mine site (non-freezing periods only).

November 2001

- Stilling curtains installed in the concentrate truck loading stations.

March 2002

- Stilling curtains installed for the gyratory crusher drop box.

Summer 2003

- Tailings water level raised to keep tailings beach covered.

February 2003

- Door installed on gyratory crusher maintenance bay opening.

October 2003

- Mine CSB take-up pulley relocated to inside the mill to eliminate potential spillage.

April 2004

- Steel grating installed in the CSB truck drive-through floor to allow improved spotting of trucks for loading and thereby reduce concentrate spillage onto truck and drive-through floor, where it could be picked up on the tires.

July 2004

- Dust control system installation completed for the mine CSB truck loading bay. System consists of a stilling shed and curtains to contain any entrained dust during loading operations and fans to draw the entrained dust back into the mine CSB, and away from the concentrate trucks and trailers.

November 2004

- In-pit stockpiling of ore re-introduced to minimize exposure of stockpiles to wind.

December 2004

- Concentrate truck traffic separated from general mine equipment traffic and segregated truck road resurfaced.

Summer 2005

- New water fill station and associated tanks installed to greatly reduce water truck fill time and increase water truck cycle times in the pit and on pit haul roads.

December 2005

- Concentrate truck traffic segregation found to be ineffective and discontinued.

June 2006

- New gyratory crusher dump pocket baghouse started up.

July 2006

- New jaw crusher dump pocket baghouse started up.