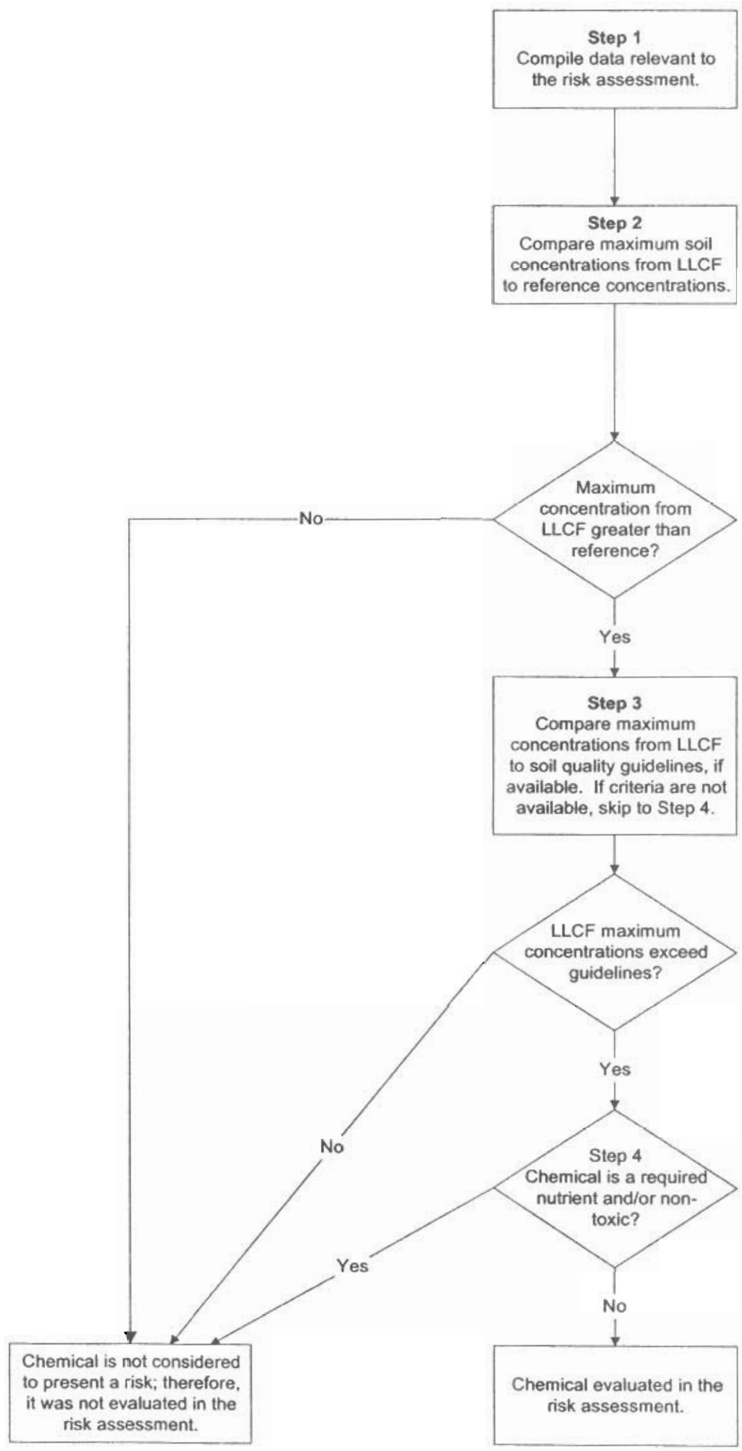
Table II-1
Comparison of Metal Concentration in Soil from LLCF to Reference Concentrations

Parameter	Concentration (mg/kg)			
	Near Field Reference	Far Field Reference		
	Mine Site Mean Concentration	Arnie Exploration Camp Mean Concentration	Wet Meadow Mean Concentration	Maximum Concentration in Soil-Amended Processed Kimberlite
Aluminum	9,863	12,133	15,500	9,740
Arsenic	3.7	3.9	5.6	6.1
Barium	65	197	97	685
Beryllium	0.4	0.4	0.5	0.5
Bismuth	<0.5	<0.5	<0.5	0
Boron	3.3	5.67	3	5
Cadmium	<0.1	<0.1	<0.1	0.5
Calcium	1533	2367	1400	17,700
Chromium	32	54	52.9	328
Cobalt	7	8	7.7	79.7
Copper	13	14	23	20
Iron	11,600	16,200	18,000	43,200
Lead	3.4	4.5	4.5	6.9
Magnesium	5,433	7,393	7,270	193,000
Manganese	137	176	165	851
Molybdenum	0.6	0.5	0.5	2.6
Nickel	22	37	33.1	1,430
Selenium	<0.2	<0.2	<0.2	0.8
Silver	<0.1	<0.1	<0.1	0.1
Sodium	170	127	150	310
Strontium	9	22	10	263
Tin	1	0.1	0.8	0.7
Titanium	649	814	918	358
Thallium	0.2	0.2	0.3	0.3
Uranium	2	2.2	3.3	2.5
Vanadium	27	36	39	33.7
Zinc	38	38	53	68

Note: Shaded cells indicate concentrations from the LLCF that are greater than reference concentrations.

Figure II-3
Chemical Screening Process



3.3 Step 3: Comparison to Regulatory Guidelines

The next step in the screening process compared metals retained from Step 2 to applicable regulatory criteria (Table II-2). There are no soil quality guidelines for the protection of wildlife; therefore, CCME soil quality guidelines for the protection of livestock were used as a surrogate for wildlife health. The use of agricultural guidelines as a surrogate for wildlife is considered applicable since the guidelines consider mammalian and avian toxicity studies (CCME 1999). People would not be exposed to soil directly; therefore, comparison to human soil quality guidelines was not conducted. If metal concentrations from the LLCF exceeded regulatory criteria, they were carried forward to Step 4 of the screening process. In addition, if regulatory criteria were not available, metals from Step 3 were retained and evaluated in Step 4 of the screening process.

Table II-2
Soil Concentrations from LLCF to Soil Quality Guidelines for the Protection of Wildlife Health

Parameter	Concentration (mg/kg)	
	CCME Soil Quality Guidelines for the Protection of Livestock [a]	Maximum Concentration in Soil-Amended Processed Kimberlite
Arsenic	12	6.1
Barium	750	685
Cadmium	1.4	0.5
Calcium	No guideline	17,700
Chromium	64	328
Cobalt	No guideline	79.7
Iron	No guideline	43,200
Lead	70	6.9
Manganese	No guideline	851
Magnesium	No guideline	193,000
Molybdenum	No guideline	2.6
Nickel	50	1,430
Selenium	1	0.8
Silver	20	0.1
Sodium	No guideline	310
Strontium	No guideline	263
Zinc	200	68

(a) CCME 1999

Note: Shaded cells indicate concentrations that exceed guidelines or for which guidelines are not available.

3.4 Step 4: Essential Nutrients and Fundamentally Non-Toxic Substances

Essential nutrients can be removed from evaluation in the human and wildlife health risk assessments because they are non-toxic or have very low toxicity. These substances are discussed below.

Calcium

Calcium is a structural component of bones and teeth and is required for regulation of hormone secretion, muscular contraction, blood clotting and enzyme activation. Calcium toxicity may occur as a result of excessive dietary supplementation. Symptoms such as reduced fat digestibility and bone structure may occur (Puls 1994). However, these health effects would not occur as a result of ingestion of soil because calcium is tightly bound to the soil matrix and is not available for uptake into wildlife (Kabata-Pendias and Pendias 1992). Thus, calcium was not evaluated in the wildlife health risk assessment.

Iron

Iron is the second most abundant metal in the earth's crust (TOXNET 2003). Thus, iron is abundant in soils and sediment. The majority of this iron is tightly bound within the soil matrix and is not available for uptake into mammals or birds. Iron is an essential element, since it is a required component in blood cells and necessary for transporting oxygen in the body. Since iron is an essential element for both wildlife and humans and since environmental exposure to iron would not lead to adverse health effects, iron was not evaluated further in the risk assessment.

Magnesium

Magnesium is an essential mineral that is important for biochemical reactions of cells and is a component of bone. It is also commonly found in grains. Excessive magnesium intake is unlikely to cause toxicity because the doses required to cause toxicity are much higher than typically measured in the environment (Puls 1994). Excessive concentrations of magnesium salts may lead to diarrhea and dehydration; however, these symptoms have only been observed due to excessive exposure from dietary supplements. Therefore, magnesium was not evaluated in the wildlife health risk assessment.

Sodium

Sodium is the most abundant cation present in the body. Approximately 30% of the total sodium is on the surface of bone crystals. The remainder is found in nerve and muscle tissue and extra-cellular fluid (Groff et al. 1995). Sodium in the body that is not used is eliminated primarily by the kidneys and also through the skin via sweating (Groff et al. 1995). Excessive concentrations of sodium (e.g., greater than 7,000 mg/L) can affect health. Symptoms may include thirst, abdominal pain, vomiting and diarrhea (Puls 1994). Concentrations of sodium in the environment are less than 7,000 mg/L, thus sodium was not evaluated in the wildlife health risk assessment.

3.5 Final List of Chemicals of Concern

Metals that are present in the LLCF in concentrations greater than in the reference locations, that exceed applicable regulatory guidelines or for which no guidelines are available, and that are not essential nutrients were evaluated in the risk assessment. The final chemicals of concern were evaluated for all exposure pathways for the wildlife (i.e., soil, water and food ingestion) and human (i.e., meat ingestion) health assessments. The following chemicals of concern were evaluated in the risk assessment:

- chromium;
- cobalt;
- manganese;
- molybdenum;
- nickel; and
- strontium.

4. WILDLIFE HEALTH RISK ASSESSMENT

4.1 Problem Formulation

4.1.1 Ecological Receptor Screening

There are many wildlife species that could be present in the tundra environment in the vicinity of the LLCF. However, it is not practical to evaluate all species. Receptors selected for the risk assessment were considered to be representative of the local ecosystem. Representative receptors are those that have the greatest potential for exposure, that play a key role in the food web, and that have sufficient characterization data to facilitate calculations of exposure and health risks. Receptors were also selected to include animals that are considered to be vulnerable by COSEWIC (2002). According to CCME (1996), species identified as endangered, threatened or of special concern should be considered in the risk assessment. The short-listed receptors are called valued ecosystem components (VECs). VECs are defined as resources or environmental features with the following characteristics:

- are important to human populations (i.e., used as a food source);
- have economic and/or social value (i.e., animals that are trapped for furs, recreational value);
- have intrinsic ecological significance (i.e., endangered species, key species in the food web); and
- serve as a baseline from which the impacts can be evaluated (CCME 1996).

The risk assessment focused on birds and mammals that are herbivorous or that prey on herbivores in the vicinity of the LLCF. Selection rationale for the VECs within the bird and mammal groups is presented in Table II-3.

Table II-3
Valued Ecosystem Components Evaluated in the Risk Assessment

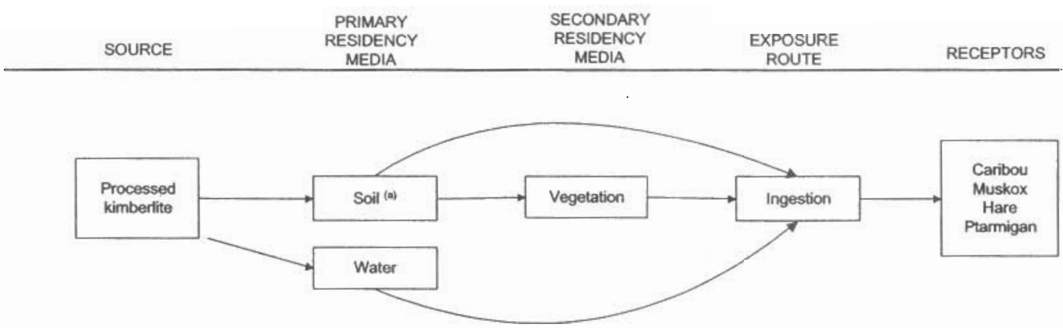
Classification	Common Name	Scientific Name	Rationale
Large Carnivorous/ Omnivorous Mammal	Grizzly Bear	*Ursus arctos horribilis*	The grizzly bear is a socially important species and represents an omnivorous receptor. Grizzly bear may feed on vegetation and prey that have been exposed to metals from the LLCF. Grizzly bears are listed as species of special concern by COSEWIC. Therefore, Grizzly bears were evaluated in the risk assessment.
	Wolf	*Canis lupus*	The wolf is a primary predator of caribou and is considered to be one of the species at the top of the food chain. Wolves have been observed near the EKATI Diamond Mine. Therefore, due to their position in the food web and their presence near the mine, wolves were evaluated in the risk assessment.
Small carnivore	Wolverine	*Gulo gulo*	The wolverine is a carnivore. It is primarily a scavenger rather than a hunter and is usually dependent on other carnivores, such as wolves, to kill the animals for it to eat. Some individual wolverines can become good hunters and can kill young and adult ungulates, such as caribou, if the prey is in poor physical condition or if the wolverine has manoeuvred it into a disadvantaged position, such as in heavy snow. Wolverines are listed as species of special concern by COSEWIC. Therefore, due to its COSEWIC classification and position in the food chain, wolverines were evaluated in the risk assessment.
Large Herbivores	Caribou	*Rangifer tarandus*	Caribou are an ecologically important species in the north. They are an important prey item for wolves and grizzlies and are an important food item for people. Thousands of caribou can pass through or near EKATI while travelling to and from their calving grounds. Due to their importance as a food item for both people and wildlife, caribou were evaluated in the risk assessment.
	Muskox	*Ovibos moschatus*	Muskoxen are arctic dwelling animals with relatively small home ranges. Muskoxen are slow-moving animals that must dig through snow to consume vegetation. They are also important prey items for wolves. Muskoxen have been observed occasionally near EKATI. Therefore, muskoxen were evaluated in the risk assessment.
Small Herbivores	Arctic hare	*Lepus arcticus*	Arctic hare are important prey items for carnivorous wildlife such as wolves and grizzly bears. Therefore, hare were evaluated in the risk assessment to represent all small herbivores in the study area.
	Ptarmigan	*Lagopus lagopus*	Ptarmigan are important prey items for carnivorous wildlife such as wolves. In addition, they are one of few species of birds that have a small home range. Therefore, ptarmigan were evaluated in the risk assessment to represent small avian herbivores in the study area.

4.1.2 Wildlife Exposure Pathway Screening

Exposure pathways are the means by which a substance comes into contact with receptors and are largely dependent on the physical-chemical properties of the substances, the environment in which the receptor lives and the likely receptor behaviour. The results of the exposure pathway screening are summarized in the Conceptual Exposure Model, which details the source of the metal, the release mechanisms, environmental transport and residency media, exposure routes and receptors (Figures II-4 and II-5).

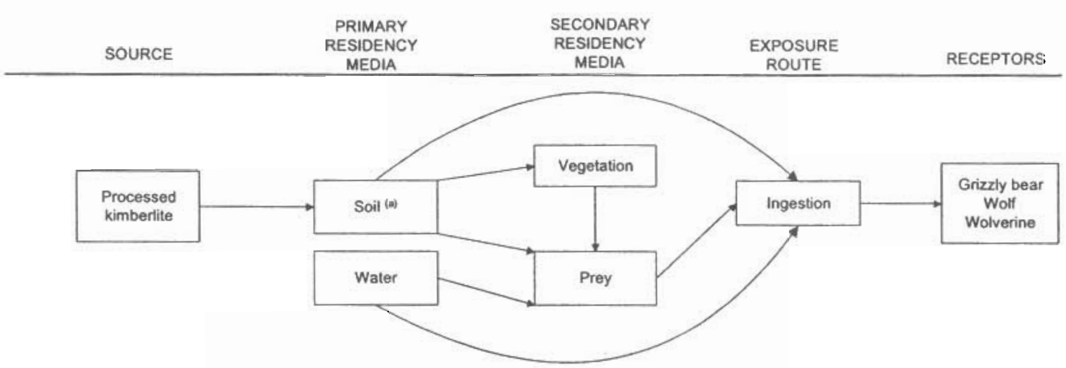
VECs may be exposed to metals through direct and indirect pathways. Direct pathways are those in which the receptor comes into direct contact with the source of metals and include soil and water ingestion. Indirect exposure pathways are those in which the exposure results from a secondary source (i.e., food chain). Ingestion of vegetation and prey would be examples of indirect exposure pathways.

Figure II-4
Herbivore Exposure Pathway



(a) Soil is soil-amended processed kimberlite.

Figure II-5
Carnivore Exposure Pathway



(a) Soil is soil-amended processed kimberlite.

Dietary assumptions and exposure pathways for each VEC are presented in Table II-4 and described in the following paragraphs.

Table II-4
Dietary Preferences of the Valued Ecosystem Components

Species	Diet Preference[a]	Soil Ingestion	Water Ingestion
Caribou	100% vegetation	Evaluated for all VECs	Evaluated for all VECs
Grizzly Bear	50% vegetation 50% caribou [b]		
Muskox	100% vegetation		
Wolf	100% mammal		
Wolverine	100% mammal		
Hare	100% vegetation		
Ptarmigan	100% vegetation		

[a] CWS 2003.
[b] Gau and Case 1998.

Ingestion of Soil

All wildlife may ingest soil either inadvertently when ingesting vegetation or grooming or purposely (Beyer et al. 1994). Since the soil used as the media for vegetation is amended processed kimberlite, this exposure pathway is important. Ingestion of soil was evaluated for all receptors in the risk assessment.

Ingestion of Vegetation

Vegetation may take up metals from soil. Grasses planted on the LLCF are assumed to be consumed by all herbivorous wildlife. The pathway of vegetation ingestion was evaluated for hare, ptarmigan, caribou, muskoxen and grizzly bears.

Ingestion of Water

There will be standing water in the LLCF resulting from the deposition of effluent from processed kimberlite. All wildlife may use this water as a drinking water source while in the vicinity of the LLCF. Therefore, ingestion of water was evaluated for all receptors in the risk assessment.

Ingestion of Prey

Predatory animals will consume herbivores that have consumed water, soil and vegetation from the LLCF. Since herbivores consumed may accumulate metals into their tissue, predatory animals may subsequently be exposed to metals as well. Therefore, the pathway of prey ingestion was evaluated for grizzly bears, wolves and wolverine.

Inhalation of Air

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

4.2 Exposure Assessment

4.2.1 Spatial and Temporal Boundaries

It was assumed that all wildlife could be exposed to maximum metal concentrations measured in soil, water and plants while in the vicinity of the LLCF. Animals with relatively small home ranges (i.e., hare, ptarmigan and muskoxen) were assumed to spend 365 days per year at the LLCF. Caribou, wolverines and wolves were assumed to spend 6 months per year at the LLCF and the remaining time they are assumed to be in other locations of their home range. Grizzly bears were assumed to spend 6 months per year at the LLCF and the remaining time is assumed to be hibernation (Gau and Case 1998). These assumptions are conservative (i.e., protective) since the LLCF is small (389 ha) and the home range of these receptors is considerably larger.

4.2.2 Exposure Estimate Equations

Exposure estimate equations used for the wildlife health exposure assessments are presented in Table II-5. Exposure was calculated based on maximum metal concentrations in soil, water and food.

Table II-5
Wildlife Exposure Equations

Pathway	Equation and Equation Parameters
Soil ingestion	$EDI_{soil} = \frac{IR \times C_{soil} \times ET}{BW}$
	EDI_{soil} = exposure due to ingestion of soil (mg metal/kg body weight - day) IR = ingestion rate (kg/day) C_{soil} = metal concentration in soil (mg/kg) ET = exposure time (days/year) BW = receptor body weight (kg)
Vegetation ingestion	$EDI_{veg} = \frac{IR \times C_{veg} \times ET}{BW}$
	EDI_{veg} = exposure due to ingestion of vegetation (mg metal/kg body weight - day) IR = ingestion rate from LLCF in wet weight (kg/day) C_{veg} = metal concentration in vegetation in wet weight (mg/kg) ET = exposure time (days/year) BW = receptor body weight (kg)
Prey ingestion	$EDI_{prey} = \frac{IR_{prey} \times C_{prey} \times ET}{BW}$
	EDI_{prey} = exposure due to ingestion of prey (mg metal/kg body weight-day) IR_{prey} = food ingestion rate (kg/day) C_{prey} = concentration in prey (mg/kg) ET = exposure time (days/year) BW = receptor body weight (kg)
Water ingestion	$EDI_{water} = \frac{IR_{water} \times C_{water} \times ET}{BW}$
	EDI_{water} = exposure due to ingestion of water (mg metal/kg body weight-day) IR_{water} = water ingestion rate (L/day) C_{water} = concentration in water (mg/L) ET = exposure time (days/year) BW = receptor body weight (kg)

4.2.3 Wildlife Exposure Parameters

Details on the body weights, food, water and soil ingestion rates, dietary compositions and time spent near the LLCF for VECs are presented in Table II-6.

Table II-6
Wildlife Parameters Used in the Risk Assessment

Receptor	Body weight (kg)	Food Ingestion Rate (kg/day) [e]	Soil Ingestion Rate (kg/day) [f]
Caribou	108 [a][b]	3.2	0.06 [g]
Grizzly bear	171 [a][b]	4.7	0.09 [g]
Musk oxen	295 [b]	7.4	0.2 [g]
Wolves	35 [b]	1.3	0.04 [h]
Wolverines	9.4 [a]	0.4	0.009 [g]
Hare	4.8 [a]	0.3	0.005 [g]
Ptarmigan	0.5 [c][d]	0.04	0.0007 [g]

[a] Dunning 1993.
[b] RWED 2003.
[c] CWS 2003.
[d] Silva and Downing 1995.
[e] U.S. EPA 1993.
[f] Beyer et al. 1994.
[g] Assumed 2.0% of food ingestion was soil (Beyer et al. 1994).
[h] Assumed 2.8% of food ingestion was soil; used red fox as a surrogate (Beyer et al. 1994).

4.3 Bioavailability

Bioavailability (also referred to as absorption efficiency) is a measure of the amount of a chemical that is absorbed and retained within the body. Consideration of bioavailability may be important under the following circumstances (Health Canada 1995; U.S. EPA 1989):

- if the medium of exposure is different than the medium on which the TRV is based (e.g., exposure is from soil, but the TRV is based on exposure from water);
- if the route of exposure is different than the routes of exposure in the study used to derive the TRV (e.g., oral route of exposure, but based on an inhalation study); and
- the TRV derived by the regulatory agency has been adjusted for bioavailability.

In the wildlife health assessment, exposure estimates were not adjusted for bioavailability because in the majority of cases, TRVs were expressed as the administered dose (i.e., amount taken into the body), rather than the absorbed dose (i.e., amount absorbed and retained in the body). The toxicity reference value was based on the same route of exposure as that being evaluated and/or because bioavailability rates were not available. The lack of adjustment for bioavailability may introduce additional conservatism if the form of the metal administered in laboratory toxicity tests is more soluble than the form of the metal in soil, plants and caribou meat. For example, metals are often introduced to water or food as metal salts during laboratory tests. Metal salts are more readily taken up into the body once administered. Therefore, a given concentration of metal salts may cause effects at lower thresholds than would have occurred had the metals been administered in more environmentally-realistic forms such as a mixture of salts, metal-organic complexes, and particulates.

4.4 Toxicity Assessment

Toxicity Reference Values (TRV) (or toxicity benchmarks) used in the wildlife health assessment are based on laboratory toxicity studies. Toxicity test species should ideally be the same species being evaluated in the risk assessment, but this is rarely possible. Most often, toxicity studies are conducted with rats and mice. Laboratory toxicity studies conducted using rats, mice, mallard ducks or other captive species provide dose-response information that can be extrapolated to wildlife. TRVs for the wildlife health assessment were obtained from Sample et al. (1996). The Lowest-Observed-Adverse-Effect Level (LOAEL) for sublethal effects was selected for each metal, where available. In studies where mortality was the endpoint or where a LOAEL was not identified, the No-Observed-Adverse-Effect Level (NOAEL) was selected. The LOAELs and NOAELs from laboratory studies were extrapolated, incorporating differences in physiology between large and small animals according to the allometric method described in Sample and Arenal (1999). The allometric method is based on the observation that many biological properties vary with body weight (Sample and Arenal 1999).

The equation used to calculate a TRV specific for mammals is based on the allometric scaling from toxicity laboratory studies is as follows:

$$A_w = A_t\,(BW_t/BW_w)^{1-0.94}$$

Where:

A_w = toxicity value for mammals

A_t = toxicity value for test species

BW_t = body weight for the test species

BW_w = body weight for mammals

A similar scaling process was done for birds. The equation used to calculate a TRV specific for birds is based on the allometric scaling from toxicity laboratory studies is as follows:

$$A_w = A_t (BW_t/BW_w)^{1-1.2}$$

Where:

A_w = toxicity value for birds

A_t = toxicity value for test species

BW_t = body weight for the test species

BW_w = body weight for birds

The wildlife TRVs used in the wildlife health risk assessment are presented in Table II-7.

Table II-7
Toxicity Reference Values Used in the Wildlife Health Assessment

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Wildlife TRV (mg/kg-day)	Reference
Caribou							
Cobalt	pig	225	anorexia, neurological effects	8	108	8.4	NAS 1980
Chromium	rat	0.35	reproductive effects	284	108	201	Sample et al. 1996
Manganese	rat	0.35	reproductive effects, longevity	2,737 [a]	108	1,940	Sample et al. 1996
Molybdenum	mouse	0.03	reproductive effects	0.26 [a]	108	0.2	Sample et al. 1996
Nickel	rat	0.35	reproductive effects	80	108	56.7	Sample et al. 1996
Strontium	rat	0.35	body weight, bone changes	263 [a]	108	186	Sample et al. 1996
Grizzly Bear							
Cobalt	pig	225	anorexia, neurological effects	8	171	8.1	NAS 1980
Chromium	rat	0.35	reproductive effects	284	171	196	Sample et al. 1996
Manganese	rat	0.35	reproductive effects, longevity	2,737 [a]	171	1,887	Sample et al. 1996
Molybdenum	mouse	0.03	reproductive effects	0.26 [a]	171	0.2	Sample et al. 1996
Nickel	rat	0.35	reproductive effects	80	171	55.2	Sample et al. 1996
Strontium	rat	0.35	body weight, bone changes	263 [a]	171	181	Sample et al. 1996
Muskox							
Cobalt	pig	225	anorexia, neurological effects	8	295	7.9	NAS 1980
Chromium	rat	0.35	reproductive effects	284	295	190	Sample et al. 1996
Manganese	rat	0.35	reproductive effects, longevity	2,737 [a]	295	1,827	Sample et al. 1996

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Wildlife TRV (mg/kg-day)	Reference
Molybdenum	mouse	0.03	reproductive effects	0.26 [(a)]	295	0.1	Sample et al. 1996
Nickel	rat	0.35	reproductive effects	80	295	53.4	Sample et al. 1996
Strontium	rat	0.35	body weight, bone changes	263 [(a)]	295	176	Sample et al. 1996
Wolf							
Cobalt	pig	225	anorexia, neurological effects	8	35	8.9	NAS 1980
Chromium	rat	0.35	reproductive effects	284	35	215	Sample et al. 1996
Manganese	rat	0.35	reproductive effects, longevity	2,737 [(a)]	35	2,076	Sample et al. 1996
Molybdenum	mouse	0.03	reproductive effects	0.26 [(a)]	35	0.2	Sample et al. 1996
Nickel	rat	0.35	reproductive effects	80	35	60.7	Sample et al. 1996
Strontium	rat	0.35	body weight, bone changes	263 [(a)]	35	200	Sample et al. 1996
Wolverine							
Cobalt	pig	225	anorexia, neurological effects	8	9.4	9.7	NAS 1980
Chromium	rat	0.35	reproductive effects	284	9.4	233	Sample et al. 1996
Manganese	rat	0.35	reproductive effects, longevity	2,737 [(a)]	9.4	2,246	Sample et al. 1996
Molybdenum	mouse	0.03	reproductive effects	0.26 [(a)]	9.4	0.2	Sample et al. 1996
Nickel	rat	0.35	reproductive effects	80	9.4	65.7	Sample et al. 1996
Strontium	rat	0.35	body weight, bone changes	263 [(a)]	9.4	216	Sample et al. 1996
Hare							
Cobalt	pig	225	anorexia, neurological effects	8	4.8	10.1	NAS 1980
Chromium	rat	0.35	reproductive effects	284	4.8	243	Sample et al. 1996
Manganese	rat	0.35	reproductive effects, longevity	2,737 [(a)]	4.8	2,339	Sample et al. 1996
Molybdenum	mouse	0.03	reproductive effects	0.26 [(a)]	4.8	0.2	Sample et al. 1996
Nickel	rat	0.35	reproductive effects	80	4.8	68.4	Sample et al. 1996
Strontium	rat	0.35	body weight, bone changes	263 [(a)]	4.8	225	Sample et al. 1996
Birds							
Ptarmigan							
Cobalt	chicken	1.5	emaciation, mortality	0.33 [(a)]	0.5	0.4	NAS 1980
Chromium	black duck	0.072	growth, aggression	977	0.5	663	Sample et al. 1996
Manganese	Japanese quail	1.25	reproductive effects	5	0.5	6.0	Sample et al. 1996
Molybdenum	chicken	1.5	reproductive effects	35.3	0.5	44.0	Sample et al. 1996
Nickel	mallard duckling	0.782	mortality	77.4	0.5	84.6	Sample et al. 1996
Strontium	chicken	1.5	bone, egg shell calcium levels	353	0.5	440	NAS 1980

[(a)] NOAEL was used because a LOAEL was not available or because the LOAEL endpoint was mortality.

4.4.1.1 Toxicity Profiles for Mammals

Chromium

A NOAEL of 2,737 mg/kg-day was reported for effects on reproduction and longevity of rats that were exposed to trivalent chromium in the diet for 90 days and 2 years (Ivankovic and Preussman 1975 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic NOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-7).

Cobalt

A NOAEL of 200 mg/kg cobalt in the diet and a LOAEL of 400 mg/kg cobalt in the diet was observed for effects on behaviour and neurological endpoints (e.g., anorexia, stiff legs, incoordination and muscular tremors) in pigs (Huck and Clawson 1976 in NAS 1980). The length of the study was not reported. Considering an average body weight and food ingestion rate for pigs of 225 kg and 4.5 kg/day (U.S. EPA 1988), the LOAEL and NOAEL were converted to a LOAEL of 8 mg/kg-day and a NOAEL of 4 mg/kg-day. For this assessment, the chronic LOAEL for pigs was used to estimate TRVs for mammalian wildlife (Table II-7).

Manganese

No specific data were identified regarding the oral toxicity of manganese to mammalian wildlife. A LOAEL of 284 mg/kg-day and a NOAEL of 88 mg/kg-day were reported for reproductive effects (i.e., pregnancy percentage and fertility) in laboratory rats that were exposed to manganese oxide in the diet for 224 days (Laskey et al. 1982 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., gestation). For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-7).

Molybdenum

A LOAEL of 2.6 mg/kg-day was reported for reproductive effects (i.e., reduced reproductive success, high incidence of runts) in laboratory mice that were exposed to molybdate in their drinking water for three generations (Schroeder and Mitchener 1971 in Sample et al. 1996). An uncertainty factor of 10 was applied to the LOAEL to extrapolate from the LOAEL to a NOAEL of 0.26 mg/kg-day. Exposure was considered to be chronic because it occurred for longer than one year and occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL was used to estimate TRVs for mammalian wildlife (Table II-7).

Nickel

A LOAEL of 80 mg/kg-day and a NOAEL of 40 mg/kg-day were reported for effects on reproduction (i.e., reduced offspring body weights) in laboratory rats that were exposed to nickel sulfate in their diet for three generations (Ambrose et al. 1976 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction) and for greater than one year. For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-7).

Strontium

A NOAEL of 263 mg/kg-day was reported for effects on growth (i.e., body weight and bone changes) in laboratory rats that were exposed to strontium chloride in drinking water for 3 years (Skoryna 1981 in Sample et al. 1996). A LOAEL was not reported for this study. Exposure was considered chronic because it occurred for longer than one year. For this assessment, the chronic NOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-7).

4.4.1.2 Toxicity Profiles for Ptarmigan

Chromium

A LOAEL of 5 mg/kg-day and a NOAEL of 1 mg/kg-day were reported for effects on reproduction for black ducks exposed to trivalent chromium in the diet for ten months (Haseltine et al. 1985 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction) and for greater than ten weeks. For this assessment, the chronic LOAEL for black ducks was used to estimate the TRV for ptarmigan (Table II-7).

Cobalt

A NOAEL of 4.7 mg/kg of cobalt in the diet was reported for chickens for emaciation and mortality (Turk and Kratzer 1960 in NAS 1980). Considering an average body weight and food ingestion rate for chickens of 1.5 kg and 0.106 kg/day (U.S. EPA 1988), the NOAEL was converted to 0.33 mg/kg-day. Since the endpoint for this toxicity study was mortality, the chronic NOAEL for chickens was used to estimate the TRV for ptarmigan (Table II-7).

Manganese

A NOAEL of 977 mg/kg-day was reported for growth and aggressive behaviour effects in male Japanese quail exposed to manganese oxide in their diet for 75 days (Laskey and Edens 1985 in Sample et al. 1996). A LOAEL was not observed during this study. Exposure was considered to be chronic because its duration was 75 days. For this assessment, the chronic NOAEL for Japanese quail was used to estimate the TRV for ptarmigan (Table II-7).

Molybdenum

A LOAEL of 35.3 mg/kg-day and a NOAEL of 3.5 mg/kg-day were reported for effects on reproduction for chickens exposed to sodium molybdenum in their diet for 21 days during reproduction (Lepore and Miller 1965 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for chickens was used to estimate the TRV for ptarmigan (Table II-7).

Nickel

A LOAEL of 107 mg/kg-day and a NOAEL of 77.4 mg/kg-day were reported for effects on mortality, growth and behaviour for mallards that were exposed to nickel sulfate in their diet for 90 days during reproduction (Cain and Pafford 1981 in Sample et al. 1996). Exposure was considered to be chronic because it occurred for longer than 10 weeks (i.e., 90 days). For this assessment, the chronic NOAEL for mallards was used to estimate the TRV for ptarmigan, since mortality occurred at the LOAEL dose.

Strontium

A LOAEL of 50,000 mg/kg-day and a NOAEL of 30,000 mg/kg in the diet were reported for effects on egg production, egg weight and body weight for mature hens exposed to strontium carbonate in the diet for 4 weeks (Dobrenz et al. 1969 in NAS 1980). The NOAEL and LOAEL were adjusted to account for body weight and food ingestion rate of 1.5 kg and 0.106 kg/d (U.S. EPA 1988), respectively. An uncertainty factor of 10 was applied to extrapolate from subchronic to chronic exposure. Exposure was considered to be sub-chronic because it occurred for only 4 weeks. The resulting LOAEL and NOAEL are 353 mg/kg-day and 212 mg/kg-day, respectively. For this assessment, the chronic LOAEL for hens was used to estimate the TRV for ptarmigan (Table II-7).

4.5 Risk Characterization

Risk estimates or Exposure Ratios (ERs) were calculated as the ratio of the estimated exposure to the TRV, as follows:

$$\text{Risk Estimate} = \frac{\text{Estimated Exposure}}{\text{TRV}}$$

For wildlife, the acceptable risk threshold is an ER of 1, since the risk assessment evaluated exposure from all sources (i.e., food, water and soil ingestion) from the LLCF. ERs were calculated individually for exposure from soil, water and food (Tables II-8 to II-10). The ERs from each exposure route were summed to calculate the total ER from the LLCF (Table II-11).

Table II-8
Mammal and Bird ER Values for Exposure to Metals in Soil from the LLCF

Parameter	Caribou	Grizzly Bear	Muskox	Wolf	Wolverine	Hare	Ptarmigan
Chromium	0.0005	0.0005	0.0009	0.0008	0.0006	0.001	0.0007
Cobalt	0.003	0.003	0.005	0.005	0.004	0.008	0.3
Manganese	0.0001	0.0001	0.0002	0.0002	0.0002	0.0004	0.2
Molybdenum	0.005	0.005	0.009	0.008	0.007	0.01	0.00009
Nickel	0.008	0.007	0.01	0.01	0.01	0.02	0.03
Strontium	0.0004	0.0004	0.0008	0.0007	0.0006	0.001	0.0009

Table II-9
Mammal and Bird ER Values for Exposure to Metals in Food Sources from the LLCF

Parameter	Caribou	Grizzly Bear	Muskox	Wolf	Wolverine	Hare	Ptarmigan
Chromium	0.00002	0.00002	0.00004	0.00002	0.00002	0.00006	0.00003
Cobalt	0.0002	0.0001	0.0003	0.000001	0.000001	0.0004	0.02
Manganese	0.0003	0.0002	0.0005	0.0000007	0.0000008	0.0008	0.4
Molybdenum	0.1	0.1	0.2	0.001	0.001	0.4	0.002
Nickel	0.0006	0.0005	0.001	0.0002	0.0002	0.002	0.002
Strontium	0.0003	0.0003	0.0005	0.00006	0.00006	0.0009	0.0006

Table II-10
Mammal and Bird ER Values for Exposure to Metals in Water from the LLCF

Parameter	Caribou	Grizzly Bear	Muskox	Wolf	Wolverine	Hare	Ptarmigan
Chromium	0.000005	0.00001	0.00001	0.000005	0.000006	0.00001	0.000004
Cobalt	no data	no data	no data	no data	no data	no data	no data
Manganese	no data	no data	no data	no data	no data	no data	no data
Molybdenum	0.1	0.1	0.2	0.1	0.1	0.3	0.001
Nickel	0.00006	0.00006	0.0001	0.00006	0.00006	0.0001	0.00009
Strontium	0.001	0.001	0.002	0.001	0.001	0.003	0.001

Table II-11
Mammal and Bird Total ER Values for Exposure to Metals from the LLCF

Parameter	Caribou	Grizzly Bear	Muskox	Wolf	Wolverine	Hare	Ptarmigan
Chromium	0.0005	0.0005	0.0009	0.0008	0.0007	0.002	0.0008
Cobalt	0.003	0.003	0.005	0.005	0.004	0.009	0.3
Manganese	0.0004	0.0004	0.0007	0.0002	0.0002	0.001	0.6
Molybdenum	0.3	0.3	0.5	0.1	0.1	0.7	0.004
Nickel	0.008	0.008	0.01	0.01	0.01	0.02	0.03
Strontium	0.002	0.002	0.004	0.002	0.002	0.005	0.003