FINAL REPORT
ON

HUMAN HEALTH
SCREENING LEVEL RISK ASSESSMENT
FOR RADIO ISLAND
FORMER MILITARY SITE

Prepared for:

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and Northern Development

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EXECUTIVE SUMMARY

Screening Level Risk Assessments (SLRAs) of the potential impacts on human health from exposure to hazards at eleven mine sites and thirteen former military sites in northern Canada have been carried out to provide the Department of Indian Affairs and Northern Development (DIAND) with a basis of ranking the relative risks presented by the sites for input to a process for prioritizing reclamation funding in future years.

This report summarizes the screening level risk assessment for human health that was carried out for existing conditions at the Radio Island former military site. The human health risk assessment was undertaken for the purpose of determining whether there are contaminant levels present in the aquatic and soil environments that may have an adverse effect on humans that either use, or may potentially use the site. The assessment included the following elements, which are proposed and readily accepted by regulatory agencies such as Environment Canada and the U.S. Environmental Protection Agency:

- receptor characterization;
- exposure assessment;
- hazard assessment; and
- risk characterization.

Measured concentrations of contaminants in soil were used in the assessment. A statistical assessment of soil data presented in the Remedial Action Plan (PWGSC 2002) was carried out to determine the appropriate concentrations to use in the assessment.

An assessment of the potential implications to human health from exposure to contaminants was considered for an adult spending 2 months of the year at the site, consuming some food, and inadvertently ingesting and coming in contact with contaminated soil. Exposure information, such as soil ingestion and body weight was obtained from data on the general Canadian population. Dietary characteristics were obtained from a food survey of indigenous populations in the Northwest Territories.

The human health risk assessment was conducted using conservative assumptions that lead to an overestimate of potential exposure. The estimated exposures (or intakes) by the human receptors were compared to intake levels considered to be protective of human health (i.e. reference doses), calculating hazard quotients (HQ) for non-carcinogenic effects, and risk levels for carcinogenic effects. These values are shown in Tables ES.1 and ES.2. Values in **bold** are those exceeding the designated levels for this site (0.2 for HQ, and 1 x 10^{-5} for risk level).

TABLE ES.1
CALCULATED HAZARD QUOTIENT VALUES

Contaminant	Hazard Quotient
Antimony	**0.2**
Barium	0.03
Cadmium	0.05
Cobalt	0.004
Copper	0.005
Lead	**1.1**
Mercury	0.02
Nickel	0.06
Tin	0.0002
Zinc	0.05
Petroleum Hydrocarbon (TPH)-F2 Aliphatic	**0.4**
Petroleum Hydrocarbon (TPH)-F2 Aromatic	**1.3**
Petroleum Hydrocarbon (TPH)-F3 Aliphatic	0.0005
Petroleum Hydrocarbon (TPH)-F3 Aromatic	0.1
TOTAL SITE	**3.3**

TABLE ES.2
CALCULATED RISKS OF CARCINOGENIC EFFECTS

Contaminant	Risk Level
Arsenic	6.0×10^{-6}
Cadmium	5.3×10^{-7}
Cobalt	1.6×10^{-8}
Nickel	3.1×10^{-8}
TOTAL SITE	$\mathbf{6.5 \times 10^{-6}}$

The assessment of intake showed that the hazard quotient of antimony, lead and Petroleum Hydrocarbons (F2 Aliphatic and F2 Aromatic Fractions) exceeded the value of 0.2 selected for this site. The main source of these contaminants was consumption of soil. None of the carcinogenic chemicals result in risks that are above 1×10^{-5}.

Physical hazards at Radio Island pertain mainly to the condition of the buildings, which have yet to be demolished, and debris, which is strewn across the site. There are also some hazardous materials that have not been disposed of in a secure manner. In summary there are no significant structures that pose a risk of physical injury at the site other than the buildings. Hazardous and non-hazardous materials remain on-site.

1.0 INTRODUCTION

In September 2003, SENES Consultants Limited was retained by the Department of Indian Affairs and Northern Development (DIAND) to undertake Screening Level Risk Assessments (SLRAs) of the potential impacts on human health from exposure to hazards at eleven mine sites and thirteen former military sites in northern Canada, for which DIAND has responsibility. The purpose of the SLRAs is to provide DIAND with a basis to characterize the relative risks presented by the sites for input to a process for prioritizing reclamation funding in future years.

To provide a common basis for comparing human health risks between the sites, a consistent set of conservative assumptions was applied to all sites, with exception of those sites where more detailed assessments have been previously reported. For example, quantitative Tier 2 level risk assessments have previously been completed for the Colomac, Giant and Port Radium mine sites. In these cases, the results of the Tier 2 risk assessment are presented in the current series of reports, where applicable.

To characterize the human health risks, standard approaches were developed for application to mine sites and former military sites, respectively. In both cases, the risk assessments were based on maximum likely exposures to chemical, radiological (where applicable) and physical hazards. In all cases, it was assumed that people would be on the sites for some portion of the year, even though some of the sites are at remote locations.

It should be noted that risk assessment does not provide a precise measure of risk due to the fact that many assumptions must typically be made. To reduce the uncertainty in a risk assessment, measured contaminant data are required. Therefore, sites which have extensive analytical data have less uncertainty in their risk assessments than sites for which less data exist. In cases where only water and soil data exist, assumptions can be made to determine the concentrations of contaminants in other media. If no data exist then quantification of risk associated with that particular contaminant cannot be done.

Many of the former military sites have asbestos containing material (e.g. insulated piping, floor tiles, and asbestos board) on-site. As there are no measured concentrations associated with this material, a quantitative risk assessment was not attempted. However, in general, the asbestos fibres associated with these types of asbestos containing material are not readily released to the environment hence, it can be reasonably concluded that these materials pose a low risk to individuals using the sites.

Similarly, PCB contamination associated with paint and electrical equipment on-site are low in volatility, hence, exposure to PCBs from this material can only come from ingestion of this material, a highly unlikely scenario. Therefore, exposure to PCB in these materials was not considered in the assessment.

For the mine sites, the assessments were carried out for a scenario involving suspension of ongoing care and maintenance activities. A three-pronged approach was undertaken to assess the risks posed by the mine sites:

1. First, the implications of discontinuing care and maintenance activities (e.g. stop treatment of mine water and/or tailings pond water, leave waste areas exposed to weathering conditions, etc.) were assessed to quantify the effects of the release of untreated waters and uncovered contaminated soils on human health;

2. Secondly, the hazards posed by on-site facilities (e.g. open pits, mine openings, waste rock piles, buildings, etc.) were assessed to quantify the potential risks of physical harm (fatality) to people accessing the sites; and

3. Thirdly, an inventory of chemical and fuel containers (e.g. barrels, tanks) and other equipment that pose potential hazards to people were compiled.

For the former military sites, the SLRAs focussed on quantifying the chemical hazards associated with the residual contaminants left on-site (item #1 above) and identifying potential hazards (item #3 above).

This report details the methodology and assumptions and presents the results of the SLRA for the Radio Island former military site.

1.1 SLRA APPROACH FOR CHEMICAL AND RADIOLOGICAL EXPOSURES

The SLRA for exposure to chemical (or radiological) hazards undertaken in the assessment evaluated the probability of adverse health consequences to humans caused by the presence of chemical or radiological contaminants in the environment. Receptor characteristics (e.g. proportion of time spent in the study area, source of drinking water, composition of diet) and exposure pathways (e.g. inhalation and ingestion) were taken into consideration.

Very few sites have measured concentrations of contaminants in air. In the absence of these concentrations, representative air concentrations from rural locations were used to calculate exposure from the air pathway. Professional experience suggests that the inhalation exposure pathway related to metals and less volatile organic contaminants such as polychlorinated aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) is insignificant in comparison to the oral pathway. Therefore, the assumption of using representative rural concentrations is not unreasonable.

The receptors selected for the SLRA took into account the proximity of nearby communities as well as the accessibility of the site. The assumptions made for the screening level risk assessment are intended to err on the side of caution and therefore to result in over-estimation of contaminant intakes. The level of caution in these assumptions is consistent with the approach typically adopted at the screening stage.

1.2 SLRA APPROACH FOR PHYSICAL HAZARDS

The SLRA of physical harm evaluated the risk of fatal injury to visitors to the sites due to the presence of unsafe features (e.g. open pits, mine openings, waste rock piles, structures, etc.) remaining at the site. The assessments took into consideration fatality statistics for abandoned mine sites in the United States, accessibility of the sites, proximity of nearby communities, presence/absence of unsafe features and the scale (size) of the mining operation.

An inventory of the number/quantity and condition of all physical features at the mine sites and former military sites (e.g. pits, tailings areas, waste rock piles, chemical storage containers, tank farms, waste dumps, structures) that pose potential hazards to people who may access the sites was prepared using information reported in previous investigations. Only a portion of this information was used in the evaluation of physical risks discussed above. The remaining information is provided to allow comparison of residual issues between the sites.

1.3 REPORT STRUCTURE

The report has been structured into several sections, each of which describes specific aspects of the SLRA. These aspects include:

Section 2 – Site Characterization: This section provides a brief description of the site, discusses the accessibility to the site and the proximity of nearby communities. It also summarizes the physical structures on-site.

Section 3 – Hazard Identification: Summarizes the data pertaining to the site for soil and surface water and identifies the Contaminants of Potential Concern (COPC) which are selected by comparing measured concentrations in air and soil with guideline and background concentrations. Other available data for sediments, vegetation and air are also summarized.

Section 4 – Receptor Characterization: Identifies the human receptors (i.e. adults) who may spend time in the study area based on the accessibility to the site and the proximity of nearby communities. The pathways of exposure of human receptors and their respective dietary characteristics are described.

Section 5 – Exposure Assessment: Provides a summary of the predicted exposures to human receptors.

Section 6 – Dose Response Assessment: Details the toxicity benchmarks used in the assessment.

Section 7 – Risk Characterization: Presents the results of the pathways modelling and risk assessment. Physical hazards are also identified.

2.0 SITE CHARACTERIZATION

This section provides a brief description of the Radio Island former military site and its physical characteristics.

2.1 RADIO ISLAND SITE DESCRIPTION

The Radio Island site is located at the tip of Resolution Island (which is at the southeastern tip of Baffin Island in Nunavut), 340 km southeast of Iqaluit. Figure 2.1 shows Radio Island's general location, and Figure 2.2 shows the overall site plan, highlighting the areas of potential concern.

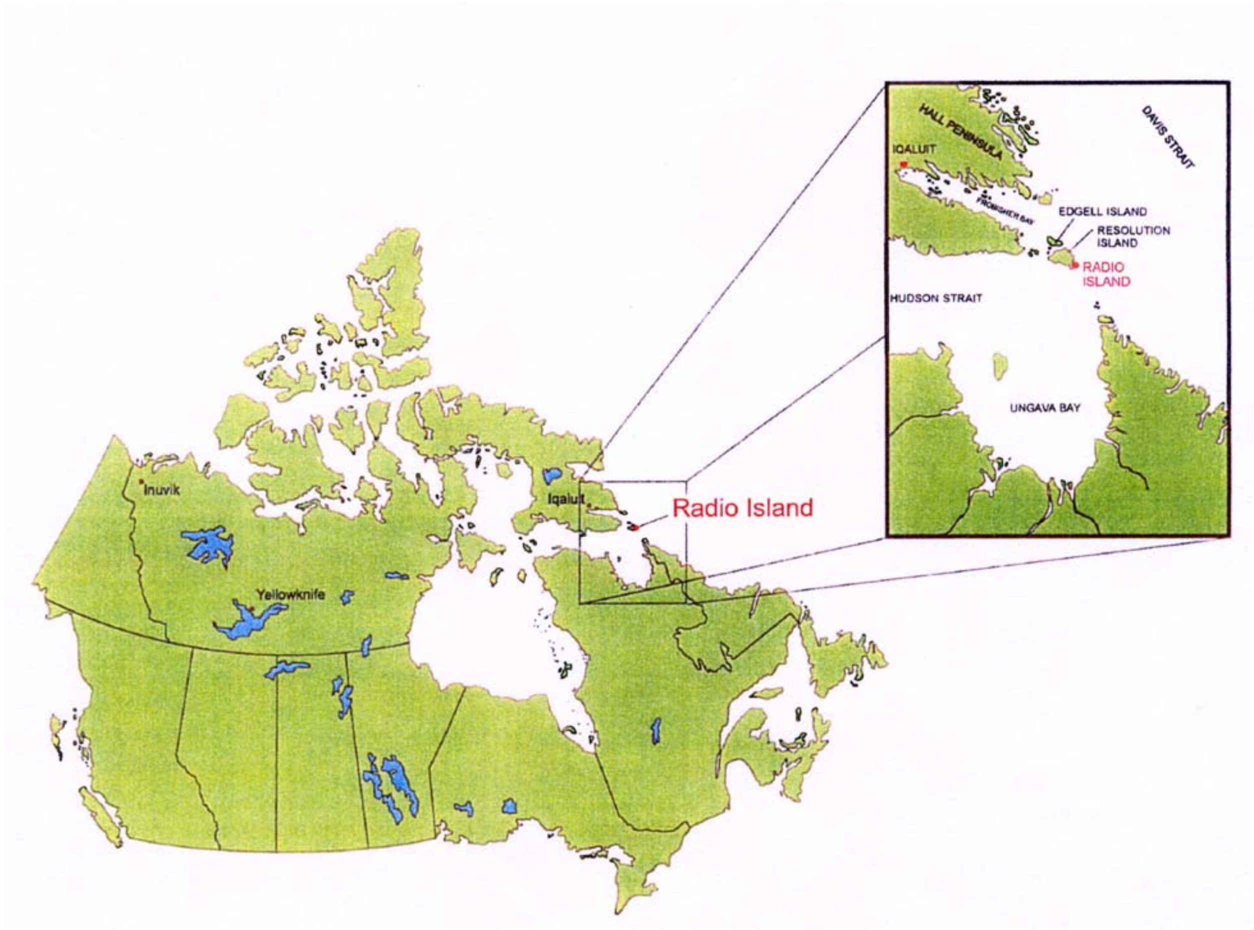
The station, originally known as Resolution Island, was set up in 1929 by the Canadian Department of Transport, and operated year round as a navigational aid and weather station until October 1961 when the station was moved to Cape Warwick.

The site is accessible by sea at Acadia Cove (summer months) and air only by helicopter. The island consists of tilted bedrock, knolls and gullies. Soil is restricted to the gullies and valleys, and surface drainage at the site flows along the gullies to the ocean. The site is relatively small, and consists of two standing buildings, the remains of three buildings, two helipads and a light beacon tower (currently operational). Vegetation is limited, and marine mammals, such as walrus, seal, whale and polar bears are common to the region.

Two environmental site assessments were conducted at this site. The first in 1996 by the Environmental Sciences Group (ESG) of the Royal Military College in Kingston, and the second in 2001 by Earth Tech Canada of Edmonton. The site was primarily powered by coal, reducing the amount of fuel and barrels required on-site. No covered landfill was identified, but hazardous and non-hazardous debris was scattered across the site. Numerous empty barrels were located throughout the site. No potential borrow source areas were identified.

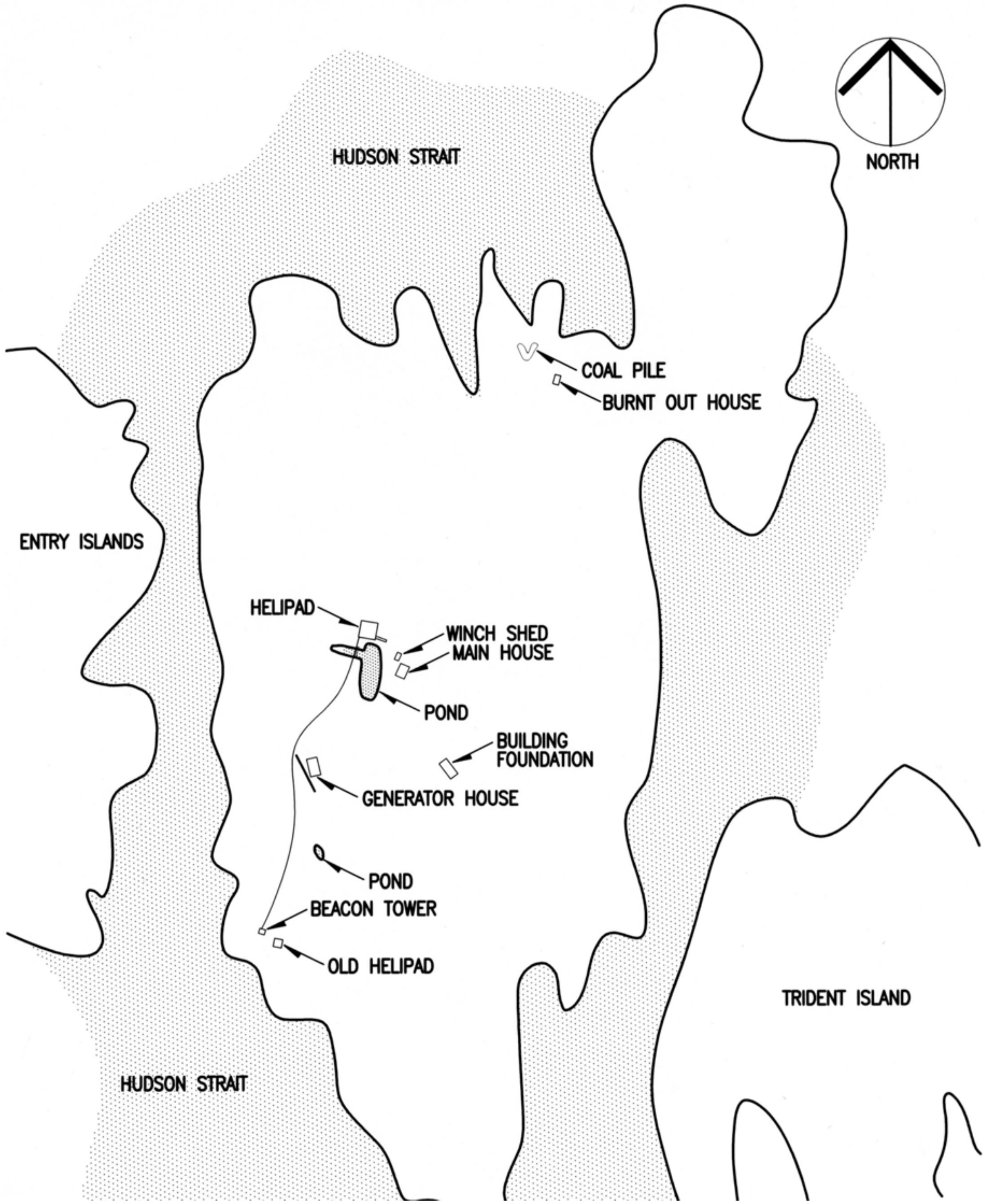
Table 2.1 summarizes some of the main physical features of the site.

FIGURE 2.1
RADIO ISLAND GENERAL LOCATION



Source: PWGSC (2002).

FIGURE 2.2
RADIO ISLAND SITE MAP



Source: PWGSC (2002).

TABLE 2.1
PHYSICAL FEATURES OF RADIO ISLAND SITE

Physical Parameter	Key Features	Characteristics	Description
Infrastructure		General Information	Includes two intact buildings (Main House, Winch Shed), the remains of three buildings (Generator House, burnt out house and a building foundation), two helipads, and a light beacon tower.
		Date of Construction	Early 1930s
		Type of Construction	Concrete foundations, steel frame columns and beams, wooden sill foundations
		Condition/Stability	All remaining buildings to be demolished, except for Main House, which will act as an emergency shelter; and the beacon tower, which is still operational
		Accessibility	Not specified that the buildings are locked.
Fuels, Chemicals, PCBs	**PCBs**	General Information	No PCB concentrations in soils exceeding guidelines identified.
	Hydrocarbons	Volume	400 m^3 of soils with concentrations of petroleum hydrocarbons.
	Asbestos	Type of Contaminant	Asbestos insulation and board
		Volume	Approx. 15 m^3 of lead acid batteries, lead paint and asbestos identified
	Metals	Volume	1,100 m^3 of metals contaminated soils.
Additional Physical Hazards		General Information	400 m^3 of non-hazardous debris identified (cables, scrap metal, barrels, wood, building demolition material); 15 m^3 of hazardous materials (lead acid batteries, lead paint, asbestos) Approximately 135 empty barrels; No potential borrow sources; Denning area for polar bears, frequently sited.

As seen in Table 2.1, the main areas of concern for the Radio Island Site are:

- Soil contaminated with metals;
- Non-hazardous material scattered across the site – cables, scrap metal, barrels, wood, building demolition material;
- Hazardous materials identified around the site – lead acid batteries, lead paint, asbestos insulation and boards;
- Approximately 135 empty barrels identified around the site; and
- Island is denning area for polar bears.

Asbestos Containing Materials (ACM) in various forms exist at several of the sites assessed in this study. In most jurisdictions, ACM is defined as any material containing more than one percent (1%) asbestos. Based on this definition, most asbestos containing material found at the abandoned mine sites and former military sites (e.g. insulated piping, asbestos board) would be classified as ACM. Accidental or intentional disturbances of ACM can result in fibre release and consequently pose a health hazard to individuals handling the material. This particular health hazard has not been considered in these SLRAs.

3.0 HAZARD IDENTIFICATION

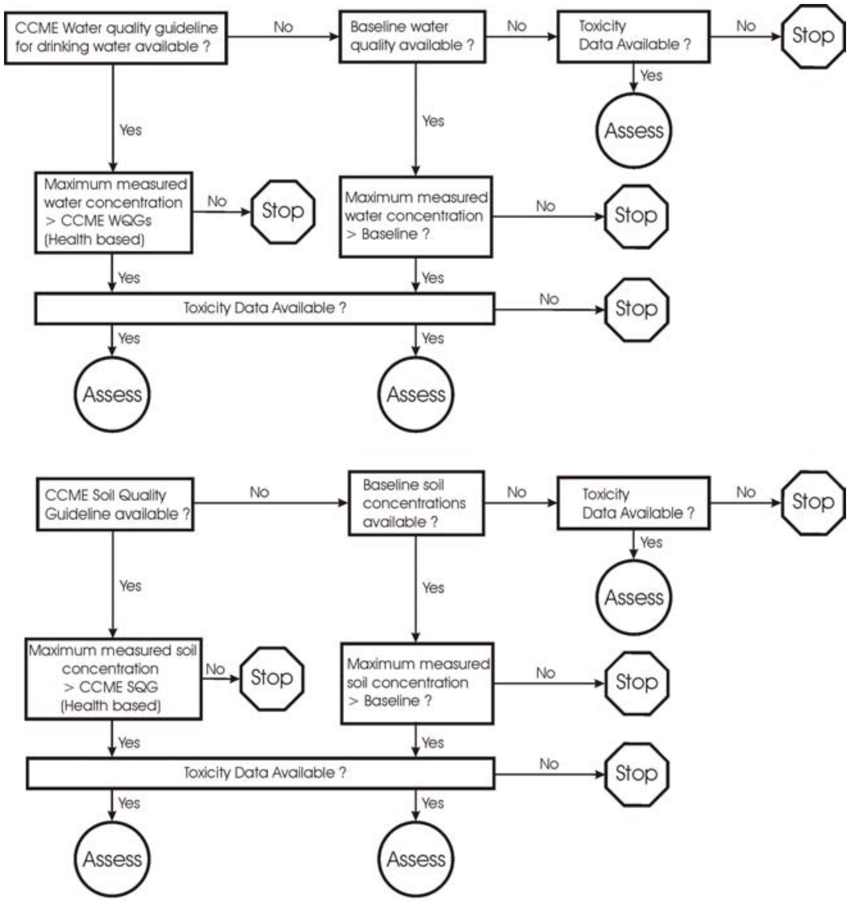
This section identifies the contaminants of concern that are selected for this assessment or potential human health effects from exposure to chemical contaminants.

3.1 SELECTION OF CONTAMINANTS OF POTENTIAL CONCERN

A selection process was performed to identify contaminants of potential concern (COPC) at the various sites based on human health considerations. The procedure followed for selection of COPC for human health is illustrated in Figure 3.1 and described below. COPC were selected by comparing measured concentrations in water and soil/tailings to the Canadian Council of Ministers of the Environment (CCME) guidelines. Drinking water guidelines developed by the Canadian Council of Ministers of the Environment (CCME), which are intended to protect human health and to provide water of a good aesthetic quality (CCME 2002), were used for surface water bodies. In addition, the human health component of CCME soil quality guidelines for residential/parkland use were applied to the soils or tailings data. It is recognized that comparing tailings to soil guidelines is not necessarily appropriate as the guidelines were not developed for application to this type of material; however, for the purpose of identifying COPC at a site (e.g. in wind blown dust and site drainage) it was felt to represent a reasonable approach.

All contaminants with concentrations below the respective guidelines were dropped from the assessment. Typically, if no guidelines were available, then the contaminants were compared to baseline concentrations. If measured concentrations were found to be below baseline concentrations then those contaminants were also dropped from further consideration. Only contaminants which exceeded guidelines or baseline levels (when no guidelines were available) were selected for further consideration. The final step in the selection of COPC involved determining whether toxicity benchmarks for human health were available for the contaminants selected for further assessment. Only contaminants for which toxicity benchmarks exist were retained on the COPC list.

FIGURE 3.1
SELECTION PROCEDURE FOR CONTAMINANTS OF POTENTIAL CONCERN



Note: Maximum is either the absolute maximum measured value, or the 95th percentile value where there were more than 10 samples.

Water Quality

Water quality data were taken from work reported by ESG (1997). Water quality was measured on surface water samples for metals and PCBs. The results, which are based on the single set of data, are shown in Table 3.1 together with the CCME Guidelines for Drinking Water Quality (CCME 2002).

TABLE 3.1
SUMMARY OF WATER QUALITY DATA

Contaminant	CCME Drinking Water Guidelines[a] (mg/L)	Maximum Measured Water Quality[d] (mg/L)	Background Measured Water Quality[d] (mg/L)
Arsenic	0.025	0.0005[c]	0.0005[c]
Cadmium	0.005	0.0005[c]	0.0005[c]
Cobalt	-	0.005[c]	0.005[c]
Chromium	0.05	0.005[c]	0.005[c]
Copper	1[b]	0.01	0.03
Nickel	-	0.005[c]	0.005[c]
Lead	0.01	0.005[c]	0.005[c]
PCBs	-	0.00044	0.00044
Zinc	5[b]	0.3	0.01[c]

Notes: **Bold** values indicate that measured water concentration is greater than the CCME guideline.
Dash (-) indicates that guideline is not available.
a - CCME (2002) guidelines are for drinking water quality.
b - Guidelines for copper and zinc are aesthetic objectives.
c - Measured value was less than method detection limit (MDL), thus was set to half MDL.
d - Measured water quality data from Appendix D, ESG (1997).

As seen in the table, the measured concentrations of arsenic, cadmium, chromium, copper, lead and zinc are well below the CCME drinking water quality guidelines. Also, the measured cobalt, nickel and PCB levels are comparable to the reported background levels. Therefore, there are no COPC identified from the water quality screening analysis.

Soil Quality

Soil quality data were obtained from PWGSC (2002). Soil was tested in several locations around the Main Station Area and Beach Area. The highest concentrations of antimony, cadmium, lead, nickel, and zinc occurred at the ravine south of the generator house in the Main Station Area. The highest concentrations for barium, mercury, and petroleum hydrocarbons (TPH-F2 and TPH-F3 fractions) occurred at the Generator House in the Main Station Area. Arsenic, cobalt, selenium and tin concentrations were highest north to northwest of the helipad in the Main Station Area, and PCB concentrations were highest northwest of the burnt out house in the Beach Area. The concentrations listed in Table 3.2 are either calculated 95th percentile concentrations, (derived from statistical analysis of pooled data sets of more than ten samples) or maximum concentrations (when fewer than ten samples were available), and are compared to CCME guidelines for residential/parkland soil quality (CCME 2002).

TABLE 3.2
SUMMARY OF SOIL QUALITY DATA

Contaminant	CCME Soil Quality Guideline[a] (Human Health) (mg/kg)	Measured Soil Concentration[b] (mg/kg)	Typical Soil Concentration [c] (mg/kg)
Metals			
Antimony	20[*]	**93.2**	5.3
Arsenic	12	**18.1**	0.98[d]
Barium	500 [*]	**714.6**	1800
Beryllium	4 [*]	0.8	20.1
Cadmium	14	**23.8**	0.5[d]
Chromium	220	55	46[d]
Cobalt	50 [*]	**116**	12.7[d]
Copper	1,100	763	24[d]
Lead	140	**19,328**	5[d]
Mercury	6.6	**14.1**	-
Molybdenum	10 [*]	7.8	2.6
Nickel	50 [*]	**486.8**	42[d]
Selenium	28	8.4	1.05
Silver	20 [*]	1.3	2.6
Thallium	1.0	0.5	6.1
Tin	50 [*]	**152.4**	101
Vanadium	130 [*]	41.2	260
Zinc	200 [*]	**7,484**	42[d]
Organics			
Benzene	0.5	0.02	-
Ethylbenzene	1.4	0.05	-
PCBs	1.3	0.49	0.01[d]
Toluene	0.8	0.08	-
TPH – F1 Fraction	50[e]	50	-
TPH – F2 Fraction	240[e]	**29,000**	-
TPH – F3 Fraction	18,000[f]	**30,000**	-
TPH – F4 Fraction	25,000[f]	15,000	-
Xylene	1.0	0.4	-

Notes: **Bold** values indicate that measured concentration is greater than the CCME guideline.

\- Not available.

a- From CCME (2002) Guidelines for residential/parkland soil quality, except as noted (*) where the soil quality guideline is used in the absence of a human health component.

b- From Appendix B, PWGSC (2002) except PCBs – Table III – 2 ESG (1997). For metals PCBs: 95th percentile (>10 samples) concentrations, for TPH/BTEX: maximum (<10) concentrations.

c- Typical soil levels from Dragun (1988).

d- Site-specific background soils data from areas removed from the influence of site activities from Table III-2 ESG (1997).

e- From CCME (2000) vapour inhalation component of Canada-wide Standards for petroleum hydrocarbons in soil (residential land use).

f- From CCME (2000) soil ingestion component of Canada-wide Standards for petroleum hydrocarbons in soil (residential land use).

As seen in the table, antimony, arsenic, barium, cadmium, cobalt, lead, mercury, nickel, tin, zinc, TPH – F2 Fraction, and TPH – F3 Fraction all exceed the CCME guidelines, and therefore were considered to be COPC.

The COPC determined for water and soil data assessments are then combined to form a list of designated COPC to use in the assessment. These are summarized on Table 3.3.

TABLE 3.3
COPC SELECTED FOR THE ASSESSMENT

Antimony
Arsenic
Barium
Cadmium
Cobalt
Lead
Mercury
Nickel
Tin
Zinc
TPH – F2 Fraction
TPH – F3 Fraction

3.2 SUMMARY OF OTHER CHEMICAL DATA FOR SLRA

Vegetations samples were obtained from the site and were analyzed for inorganic elements (ESG 1997). Vegetation from the willow family (arctic willow) were assumed to reflect browse concentrations, and vegetation from the grass family (cottongrass) were assumed to reflect forage concentrations. Table 3.4 summarizes the vegetation concentrations. For contaminants that do not have measured vegetation concentrations, transfer factors were used to determine concentrations in vegetation, as outlined in Appendix A.

TABLE 3.4
MEASURED CONTAMINANT LEVELS IN VEGETATION

COPC	Browse Concentration (mg/kg (dw))	Forage Concentration (mg/kg (dw))
Antimony	-	-
Arsenic	0.5	0.3
Barium	-	-
Cadmium	39	0.9
Cobalt	5	5.2
Lead	382	27
Nickel	74	28
Tin	-	-
Zinc	1840	466
TPH	-	-

Note: Obtained from Table B, Appendix D, ESG (1997).
- No data available.

4.0 RECEPTOR CHARACTERIZATION

This section of the report discusses the characteristics of the receptor selected as well as the exposure pathways considered in this assessment.

4.1 EXPOSURE SCENARIO AND RECEPTOR SELECTION

One hypothetical human receptor (Inuk) was considered for the assessment of potential exposures from the Radio Island Site. The adult was assumed to visit the site annually and to camp on the site for a maximum of 2 months of the year. While on-site, the individual was assumed to inadvertently come in contact with and ingest contaminated soil. Drinking water quality was well below CCME Guidelines and generally below analytical detection limits for most COPC. Therefore, the consumption of water was not considered in this assessment.

The gathering of food from Radio Island by people living in or near Iqaluit or elsewhere on Baffin Island has been historically limited, for two main reasons: (i) the weather conditions, sea surface and shifting ice cover around the island make travel difficult and risky, and (ii) the low productivity of the island's terrestrial environment relative to other areas of lower Baffin Island are further deterrents for travel to the site (Golder 1997). However, to be conservative, it was assumed that an Inuk person would be on-site and would consume hare and grouse while on-site.

Since the site is neither close to nor easily accessible by any other communities, an adult defined above is the only human receptor considered in this assessment.

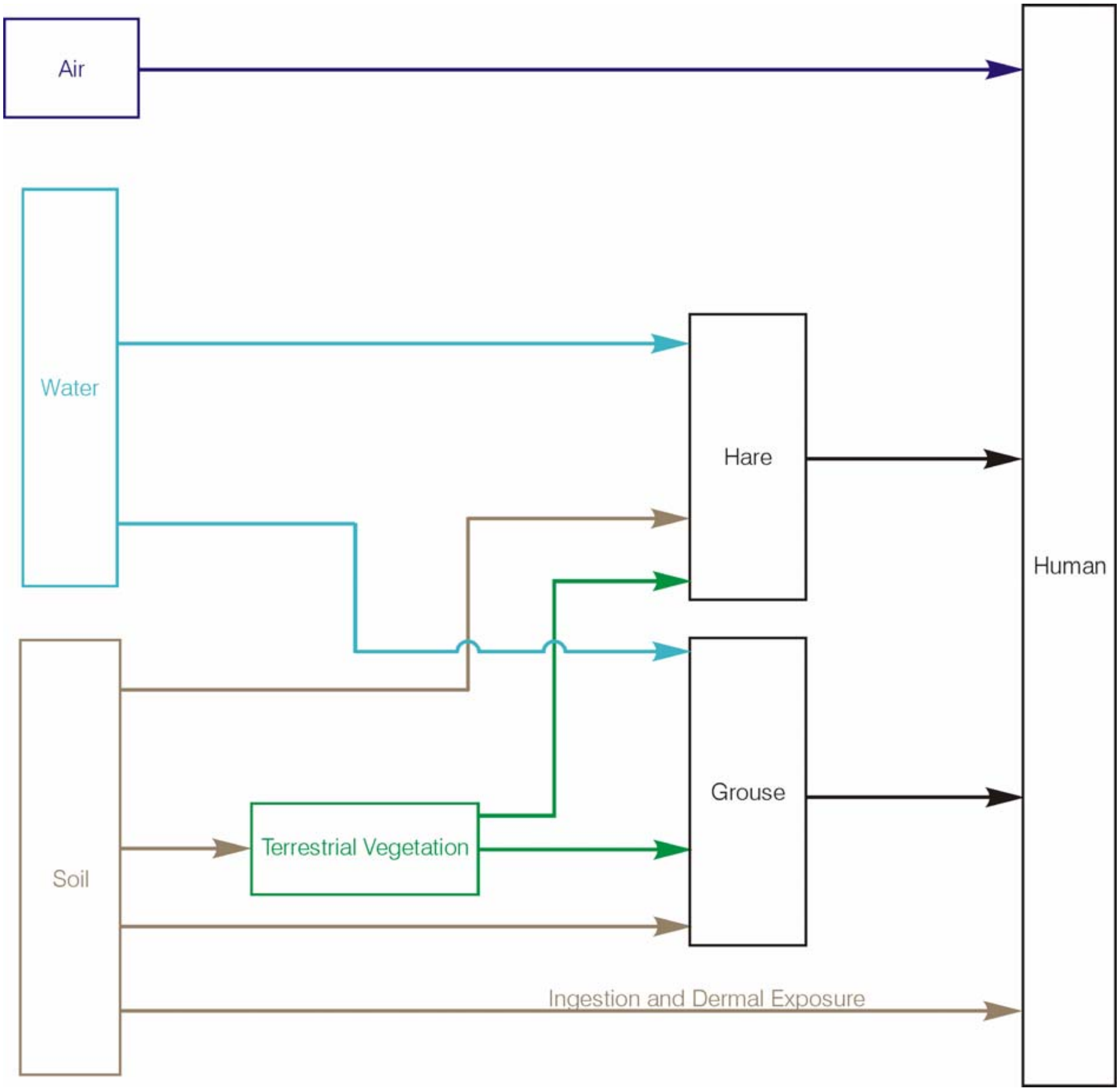
4.2 EXPOSURE PATHWAYS CONSIDERED

Figure 4.1 provides the conceptual model for the assessment. The pathways of exposure include:

- inhalation of air;
- consumption of hare and grouse;
- inadvertent ingestion of soil; and
- dermal contact with soil.

In the assessment, 95th percentile concentrations of the metal COPC and maximum concentrations of petroleum hydrocarbons in soils from across the site were used in estimating receptor exposures.

FIGURE 4.1
EXPOSURE PATHWAYS FOR HUMAN RECEPTORS



4.3 RECEPTOR CHARACTERISTICS

Water intake, breathing rate, soil ingestion rate, body weight and other exposure properties for the human receptor were obtained from the *"Compendium of Canadian Human Exposure Factors for Risk Assessment"* (Richardson 1997) and are summarized in Table 4.1, along with other receptor characteristics used for the exposure calculations. There are no reported surveys for the Inuit people in this area. Therefore, food intake values were obtained from a food survey of indigenous populations in the Northwest Territories (Receveur *et al.* 1996). The dietary characteristics of a community that was assumed to be similar to the Inuit was selected for the assessment. In this case, the Gwichin community intake was selected for this assessment.

TABLE 4.1
HUMAN RECEPTOR CHARACTERISTICS

Human Characteristic	**Adult**	**Reference**
Fraction of year at site	0.17	Assumed on-site 2 months/year
Breathing rate (m^3/d)	15.8	Richardson, 1997
Soil ingestion rate (g/d)	0.02	Richardson, 1997
Water intake (L/d)	1.5	Richardson, 1997
Arctic hare ingestion rate (g/d)	5.0	Receveur *et al.*, 1996 for Gwichin Communities
Grouse ingestion rate (g/d)	3.0	Receveur *et al.*, 1996 for Gwichin Communities
Body weight (kg)	70.7	Richardson, 1997
Skin surface area – Total (m^2)	0.911	Richardson, 1997
Exposed fraction of skin (-)	0.26	Assumed for short sleeves
Soil loading to exposed skin (g/cm^2) – hands Surface other than hands	1×10^{-3} 1×10^{-4}	Kissel *et al.*, 1996, 1998

Note: The soil loading values provided are for construction workers. The use of this number results in overestimate of exposure.

5.0 EXPOSURE ASSESSMENT

The exposure assessment phase of the SLRA entailed the quantification of exposure for the selected receptor. The pathways and assumptions applied in this assessment are described in this section.

Appendix A documents the pathways calculations used in the assessment of contaminant intakes by the human receptor and the detailed results of the exposure assessment by pathway.

5.1 METAL BIOAVAILABILITY

Bioavailability of a chemical can be defined as the fraction of an administered dose that reaches the central (blood) compartment, whether through the gastrointestinal tract, skin or lungs (NEPI 2000). This type of bioavailability is known as “absolute bioavailability”.

In risk assessments, oral exposures are generally described in terms of an external dose or intake, as opposed to an absorbed dose or uptake. Intake occurs as an agent enters the body of a human or animal without passing an absorption barrier (e.g., through ingestion or inhalation), while uptake occurs as an agent passes across the absorption barrier (IPCS 2000). Not all materials (e.g., metals, nutrients) that enter the body as intake are absorbed into the body as uptake. Many are passed through the body and expelled without effect.

When calculating the intake via the oral route of exposure, it is customary to take into account the food, water and soil pathways. The default bioavailability value used in the screening level calculations is 100%.

5.2 CALCULATED INTAKES

The total intake of each contaminant by the human receptor was calculated using the equations provided in Appendix A.

Table 5.1 shows the calculated intake from inhalation of air, ingestion of food, and soil and dermal contact.

TABLE 5.1
TOTAL INTAKE TO ADULT RECEPTOR

COPC	Ingestion Intake (mg/(kg d))			Inhalation Intake (mg/(kg d))	Dermal Exposure (mg/(kg d))
	Food	**Soil**	**Total**		
Antimony	6.5 x 10^{-6}	4.5 x 10^{-6}	1.1 x 10^{-5}	0	5.3 x 10^{-5}
Arsenic	5.3 x 10^{-7}	8.7 x 10^{-7}	1.4 x 10^{-6}	3.8 x 10^{-8}	3.3 x 10^{-6}
Barium	1.0 x 10^{-6}	3.4 x 10^{-5}	3.5 x 10^{-5}	0	4.1 x 10^{-4}
Cadmium	2.2 x 10^{-5}	1.1 x 10^{-6}	2.3 x 10^{-5}	2.9 x 10^{-8}	1.9 x 10^{-5}
Cobalt	9.4 x 10^{-6}	5.6 x 10^{-6}	1.5 x 10^{-5}	3.8 x 10^{-9}	6.6 x10^{-5}
Lead	5.0 x 10^{-4}	9.3 x 10^{-4}	1.4 x 10^{-3}	7.6 x 10^{-8}	6.6 x 10^{-4}
Mercury	1.5 x 10^{-6}	6.8 x 10^{-7}	2.2 x 10^{-6}	1.8 x 10^{-9}	4.0 x 10^{-6}
Nickel	2.0 x 10^{-4}	2.3 x 10^{-5}	2.2 x 10^{-4}	2.3 x 10^{-8}	9.7 x 10^{-4}
Tin	2.1 x 10^{-6}	7.3 x 10^{-6}	9.4 x 10^{-6}	0	8.7 x 10^{-5}
Zinc	1.5 x 10^{-2}	3.6 x 10^{-4}	1.5 x 10^{-2}	4.2 x 10^{-7}	8.5 x 10^{-4}
TPH – F2 Fraction/Aliphatic	2.0 x 10^{-4}	1.1 x 10^{-3}	1.3 x 10^{-3}	7.9 x 10^{-2}	1.3 x 10^{-2}
TPH – F2 Fraction/Aromatic	6.7 x 10^{-7}	2.79 x 10^{-4}	2.8 x 10^{-4}	7.1 x 10^{-2}	3.3 x 10^{-3}
TPH – F3 Fraction/Aliphatic	1.0 x 10^{-4}	1.2 x 10^{-3}	1.3 x 10^{-3}	7.6 x 10^{-5}	1.4 x 10^{-2}
TPH – F3 Fraction/Aromatic	5.9 x 10^{-6}	2.89 x 10^{-4}	2.9 x 10^{-4}	1.3 x 10^{-9}	3.4 x 10^{-3}

6.0 DOSE RESPONSE ASSESSMENT

The dose response assessment phase of a human health risk assessment involves identification of contaminant concentrations or doses, which have been shown to have adverse effects on the receptors of concern. The exposure concentrations or doses are generally determined from controlled laboratory tests or from epidemiology studies and are used to establish toxicity benchmarks, which are protective of the receptors.

6.1 TOXICITY TO HUMANS

The dose response assessment involves the identification of the potentially toxic effects of contaminants, and the determination of the appropriate toxicity benchmarks for the various contaminants. The toxicity benchmark is defined as the amount of contaminant exposure that can occur without any adverse health effects (for threshold or non-cancer causing contaminants), or that is associated with an acceptable level of risk (for non-threshold or cancer causing contaminants).

For this assessment, toxicity benchmarks were obtained from reputable regulatory agencies, such as Health Canada and the U.S. EPA. Data were obtained on:

- Slope Factor (SF) - (for carcinogens) comprises a plausible upper bound estimate of the probability of a response per unit intake of a contaminant over a lifetime. It is used to evaluate the probability of a cancer developing due to a lifetime of exposure. For carcinogens, no threshold is assumed to exist (i.e., every dose presents some risk); or

- Tolerable Daily Intake (TDI) or Reference Dose (RfD) - (for non-carcinogens) comprises an estimate of the daily exposure level for a contaminant for the entire population, including sensitive people, that is not anticipated to present an appreciable risk of an adverse effect.

Toxicity benchmarks from Health Canada were selected first; however, if more restrictive benchmarks were available from another regulatory agency such as the U.S. EPA, those values were selected instead of the Health Canada values to ensure that the risks calculated in the assessment were over-estimated. Additionally, if a contaminant had properties of both a carcinogen and a non-carcinogen by a specific pathway (i.e. oral exposure), then only the carcinogenic effects were assessed.

Table 6.1 provides a summary of the toxicity benchmarks for all the COPC for the northern sites. Contaminants that are shaded and bolded are the ones that pertain to the Radio Island site.

TABLE 6.1
TOXICITY BENCHMARKS

Contaminant	Dermal	Oral Toxicity Benchmarks[b]				Inhalation Toxicity Benchmarks			
	RAF [a]	SFo		(TDI/RfDo)		SFi		RfDi	
	(-)	$(mg/(kg\text{-}d))^{-1}$		(mg/(kg-d))		$(mg/(kg\text{-}d))^{-1}$		(mg/(kg-d))	
Aluminum	0.1	na		1	N	na		na	
Antimony	**0.1**	**na**		**0.0004**	**I**	**na**		**na**	
Arsenic	**0.032**	**2.8**	**HC**	**na**		**28**	**HC**	**na**	
Barium	**0.1**	**na**		**0.016**	**HC**	**na**		**0.00014**	**H**
Benzene	0.08	0.31	HC	na		0.027	I		
Benzo(a)pyrene	0.2	7.3	I	na		0.22	HC	na	
Beryllium	0.03	na		0.002	I	8.4	H	na	
Boron	0.1	na		0.0175	HC	na		0.0057	H
Cadmium	**0.14**	**na**		**0.0008**	**HC**	**42.9**	**HC**	**na**	
Chromium	0.09	na		0.001	HC	47.6	HC	na	
Cobalt	**0.1**	**na**		**0.02**	**N**	**9.8**	**N**	**na**	
Copper	0.1	na		0.03	HC	na		na	
Cyanide	0.3	na		0.02	HC	na		0.0009	HC
Lead	**0.006**	**na**		**0.0019**	**I**	**na**		**na**	
Manganese	0.1	na		0.14	I	na		na	
Mercury	**0.05**	**na**		**0.0003**	**H**	**na**		**na**	
Molybdenum	0.1	na		0.005	I	na		na	
Nickel	**0.35**	**na**		**0.02**	**I**	**3.13**	**HC**	**na**	
Nitrate	0.1	na		1.6	I	na		na	
Polychlorinated biphenyls (PCBs)	0.1	2.0	I	0.001	HC	2.0	I	na	
Selenium	0.002	na		0.005	I	na		na	
Silver	0.25	na		0.005	I	na		na	
Strontium	0.1	na		0.6	I	na		na	
Thiocyanate	0.1	na		0.05	N	na		na	
Tin	**0.1**	**na**		**0.6**	**H**	**na**		**na**	
Uranium	0.1	na		0.0002	N	na		na	
Vanadium	0.1	na		0.007	H	na		na	
Xylene	0.12	na		0.2	I	na		0.03	I
Zinc	**0.02**	**na**		**0.3**	**I**	**na**		**na**	

TABLE 6.1 (Cont'd)
TOXICITY BENCHMARKS

Contaminant	Dermal	Oral Toxicity Benchmarks[b]				Inhalation Toxicity Benchmarks			
	RAF [a]	SFo		(TDI/RfDo)		SFi		RfDi	
	(-)	$(mg/(kg\text{-}d))^{-1}$		(mg/(kg-d))		$(mg/(kg\text{-}d))^{-1}$		(mg/(kg-d))	
TPH F1 –Aliphatic	**0.1**	**na**		**3.10**	**TP**	**na**		**3.30**	**TP**
TPH F1 – Aromatic	**0.1**	**na**		**0.04**	**TP**	**na**		**0.057**	**TP**
TPH F2 –Aliphatic	**0.1**	na		**0.1**	**TP**	**na**		**0.290**	**TP**
TPH F2 – Aromatic	**0.1**	na		**0.04**	**TP**	**na**		**0.057**	**TP**
TPH F3 –Aliphatic	0.1	na		32	TP	na		na	
TPH F3 – Aromatic	0.1	na		0.03	TP	na		na	

Notes: a - Dermal Relative Absorption Factors (RAF) from MOE (1996) unless noted otherwise. Dermal RAF set to default value of 0.1 (U.S. EPA 1992) where no data available.

b - In the absence of toxicity benchmarks for dermal exposure, the oral toxicity benchmarks are used

SF Slope Factor for carcinogenic effects.

RfD Reference Dose for threshold acting chemical (i.e., non-carcinogenic effects).

na	Not applicable
I	U.S. EPA IRIS (2002)
H	U.S. EPA HEAST (1997)
HC	Health Canada (2003) – see Appendix B
N	U.S. EPA NCEA (2002)
TP	CCME (2000)

7.0 RISK CHARACTERIZATION

Risk characterization involves the integration of the information from the exposure assessment and the toxicity assessment.

For carcinogenic contaminants, a risk is calculated by multiplying the estimated dose (in mg/(kg d)) by the appropriate slope factor (in per mg/(kg d)). This is shown in equation (7.1). The estimate corresponds to an incremental risk of an individual developing cancer over a lifetime as a result of exposure.

Risk is defined as follows:

$$Risk = \left(D_i \times SF_i\right) + \left(D_o \times SF_o\right) + \left(D_d \times SF_d\right) \tag{7.1}$$

Where:

D_i = Dose due to inhalation exposure (mg/(kg d))
D_o = Dose due to oral (ingestion) exposure (mg/(kg d))
D_d = Dose due to dermal exposure (mg/(kg d))
SF_i = Slope Factor for inhalation exposure $(mg/(kg\ d))^{-1}$
SF_o = Slope Factor for oral exposure $(mg/(kg\ d))^{-1}$
SF_d = Slope Factor for dermal exposure $(mg/(kg\ d))^{-1}$ (assumed equal to SF_o)

The doses for the different pathways of exposure are presented in Section 5 and the slope factors used in this assessment are presented in Section 6. The calculated risk is then compared to an acceptable benchmark. A risk level of $1x10^{-5}$ was used for the SLRA. Risk levels for child receptors are generally not calculated since the exposure of a child is not sufficient for carcinogenic effects to be observed. In this case a composite receptor is assessed. This composite receptor encompasses the exposure of a child to the site for 10 years and the exposure of this child as an adult for another 60 years. In simple terms, the SLRA considers that someone would visit the site throughout his/her lifetime from child to an adult.

For many non-carcinogenic effects, protective biological mechanisms must be overcome before an adverse effect is manifested from exposure to the contaminant. This is known as a "threshold" concept. A reference dose (RfD) is the value most often used in the evaluation of non-carcinogenic effects. Reference doses are discussed in Section 6.

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

$$HQ = \frac{D_i}{RfD_i} + \frac{D_o}{RfD_o} + \frac{D_d}{RfD_d} \tag{7.2}$$

Where:

D_i = Dose due to inhalation exposure (mg/(kg d))
D_o = Dose due to oral (ingestion) exposure (mg/(kg d))
D_d = Dose due to dermal exposure (mg/(kg d))
RfD_i = Reference Dose for inhalation exposure (mg/(kg d))
RfD_o = Reference Dose for oral exposure (mg/(kg d))
RfD_d = Reference Dose for dermal exposure (mg/(kg d)) (assumed equal to RfD_o)

In SLRAs, 20% of the dose or a hazard quotient of 0.2 is generally used to assess acceptable exposure from each individual pathway. In the SLRAs for mines and former military sites, the following hazard quotient values are used:

- In applications where only a few pathways are considered in the assessment, a HQ value of 0.2 is used to identify acceptable exposure.
- Where multiple pathways such as inhalation, ingestion of water, soil and food from the site and dermal exposure are considered, a HQ value of 0.5 is used to assess acceptable exposures, given that the major dietary components are being included.

For the Radio Island site, a HQ value of 0.2 was used to assess acceptable exposures.

7.1 NON-CARCINOGENIC EFFECTS

Estimated exposures for the adult receptor were calculated using the human intakes presented in Section 5.2. These estimates were based on the 95th percentile measured metal concentrations in soil. Estimated exposures were divided by the toxicity benchmarks (RfDs), presented in Section 6.1, to calculate the hazard quotients (HQ) shown in Table 7.1. HQ values in **bold** are those exceeding the value of 0.2 selected for this site.

TABLE 7.1
CALCULATED HAZARD QUOTIENT VALUES

Contaminant	**Hazard Quotient**
Antimony	**0.2**
Barium	0.03
Cadmium	0.05
Cobalt	0.004
Copper	0.005
Lead	**1.1**
Mercury	0.02
Nickel	0.06
Tin	0.0002
Zinc	0.05
TPH – F2 Aliphatic	**0.4**
TPH – F2 Aromatic	**1.3**
TPH – F3 Aliphatic	0.0005
TPH – F3 Aromatic	0.1
TOTAL SITE	**3.3**

As seen in the above table, antimony, lead, TPH-F2 Aliphatic and TPH-F2 Aromatic fractions exceed the hazard quotient of 0.2. For these contaminants, ingestion and inhalation intake to soil are the largest pathways. The sum of all HQs was determined to be 3.3.

7.2 CARCINOGENIC EFFECTS

Table 7.2 shows the risk levels calculated for the adult receptor for carcinogenic contaminants, namely arsenic, cadmium, cobalt, nickel and PCBs. Risk levels higher than 1 x 10^{-5} are indicated in **bold.**

TABLE 7.2
CALCULATED RISKS OF CARCINOGENIC EFFECTS

Contaminant	Risk Level
Arsenic	6.0×10^{-6}
Cadmium	5.3×10^{-7}
Cobalt	1.6×10^{-8}
Nickel	3.1×10^{-8}
TOTAL SITE	**6.5×10^{-6}**

As seen in Table 7.2, risk levels for all contaminants are lower than 1×10^{-5}. The total risk (sum of all risks) is 6.5×10^{-6}.

7.3 PHYSICAL HAZARDS

The Radio Island site may also pose a potential safety risk to human receptors. As summarized in Table 2.1, non-hazardous debris and hazardous materials were identified at the site. Physical hazards include:

- Non-hazardous debris, such as cables, scrap metal, barrels wood, and building demolition material, scattered all around the site;
- Hazardous materials, such as lead acid batteries, lead paint and asbestos insulation identified in and on buildings and infrastructures;
- 135 empty barrels; and
- The remains of buildings and infrastructure.

8.0 REFERENCES

Canadian Council of Ministers of the Environment (CCME) 2002. *Canadian Environmental Quality Guidelines*.

Canadian Council of Ministers of the Environment (CCME) 2000. *Canada Wide Standards for Petroleum Hydrocarbons in Soil.*

Dragun, J. 1988. *The Soil Chemistry of Hazardous Materials.* Hazardous Materials Control Research Institute, Silver Springs, MD.

Environmental Services Group (ESG) (Royal Military College) 1997. *An Environmental Assessment of Radio Island, NWT.*

Health Canada 2003. *Health Canada Toxicological Reference Values* (see Appendix B).

International Programme for Chemical Safety (IPCS) 2000. Short list definitions. Harmonization Project (Terminology). Exposure Assessment Planning Workgroup. (http://www.ipcsharmonize.org/).

Kissel J.C., J.H. Shirai, K.Y. Richter and R.A. Fenske 1998. *Investigation of Dermal Contact with Soil in Controlled Trails.* J. Soil Contam., 7(6) 737-752.

Kissel, J.C., K.Y. Richter and R.A. Fenske 1996. *Field Measurements of Dermal Soil Loading Attributable to Various Activities: Implications for Exposure Assessment.* Risk Anal., 16(1):115-125.

National Environmental Policy Institute (NEPI) 2000. *Assessing the Bioavailability of Metals in Soil for Use in Human Health Risk Assessments*. Bioavailability Policy Report Phase II: Metals Task Force Report. Summer 2000.

Ontario Ministry of the Environment (MOE). 1996. *Rationale for the Development and Application of Generic Soil, Groundwater and Sediment Criteria for Use at Contaminated Sites in Ontario*. May.

Public Works and Government Services Canada (PWGSC) 2002. *Remedial Action Plan Former Navigational Aid and Weather Station Radio Island, Nunavut.*

Receveur, O., M. Boulay, C. Mills, W. Carpenter and H. Kuhnlein 1996. *Variance in Food Use in Dene/Metis Communities.* Centre for Indigenous Peoples' Nutrition and Environment (CINE). October.

Richardson, G.M. 1997. *Compendium of Canadian Human Exposure Factors for Risk Assessment.* O'Connor Associates Environmental Inc.

United States Environmental Protection Agency (U.S. EPA) IRIS 2002. *Integrated Risk Information System - IRIS.* On-line database. http://www.epa.gov/iris/.

United States Environmental Protection Agency (U.S. EPA) NCEA 2002. *National Center for Environmental Assessment - NCEA*.

United States Environmental Protection Agency (U.S. EPA) 1997. *Health Effects Assessment Summary Tables - HEAST.* EPA/540/R-97-036. July.

United States Environmental Protection Agency (U.S. EPA) 1992. *Dermal Exposure Assessment: Principles and Applications.* Interim Report. EPA/600/8-91/011B. January.

FINAL

APPENDIX A

DETAILED EXPOSURE CALCULATIONS FOR THE HUMAN HEALTH RISK ASSESSMENT

LIST OF TABLES

APPENDIX A: DETAILED EXPOSURE CALCULATIONS FOR THE HUMAN HEALTH RISK ASSESSMENT

The exposure assessment for contaminants to humans considered the inhalation, dermal and ingestion pathways.

A.1 INHALATION PATHWAY

Inhalation intake by human receptors was calculated using the equation (A-1) for the air pathway:

$$I_{air} = \frac{C_{air} \times R_{air} \times F_{site}}{BW} \qquad \text{(A-1)}$$

where:

I_{air} = exposure to contaminant through the air pathway [mg/(kg d)]
C_{air} = air concentration [mg/m^3]
R_{air} = air inhalation rate [m^3/d]
F_{site} = fraction of time at site [-]
BW = body weight [kg]

Contaminant concentrations in air were used from measured data, if available. In the absence of measured air concentrations, typical air concentrations for rural areas (shown in Table A1.1) were used.

TABLE A1.1
TYPICAL AIR CONCENTRATIONS IN RURAL AREAS

Contaminant	Value	Reference
Metals (mg/m^3)		
Aluminum	1.6×10^{-4}	Lee *et al.* 1994
Antimony		
Arsenic	1.0×10^{-6}	U.S. EPA 1996 – for rural areas
Barium		
Beryllium		
Boron		
Cadmium	7.6×10^{-7}	Lee *et al.* 1994
Chromium	9.5×10^{-7}	Lee *et al.* 1994
Cobalt	1.0×10^{-7}	U.S. EPA 1996 – for rural areas
Copper	3.0×10^{-6}	U.S. EPA 1996 – for rural areas
Lead	2.0×10^{-6}	U.S. EPA 1996 – for rural areas
Manganese		
Mercury	4.7×10^{-8}	Lee *et al.* 1994
Molybdenum	1.0×10^{-6}	U.S. EPA 1996 – for rural areas
Nickel	6.0×10^{-7}	U.S. EPA 1996 – for rural areas
Selenium	1.0×10^{-8}	U.S. EPA 1996 – for rural areas
Silver	7.0×10^{-8}	Lee *et al.* 1994
Strontium		
Tin		
Uranium		
Vanadium	4.5×10^{-6}	Lee *et al.* 1994
Zinc	1.1×10^{-5}	U.S. EPA 1996 – for rural areas
Organics and other contaminants (mg/m^3)		
Benzene	0.0	Assumed
Benzo(a)pyrene	0.0	Assumed
Cyanide	0.0	Assumed
Nitrate	0.0	Assumed
PCBs	0.0	Assumed
Thiocyanate	0.0	Assumed
Xylene	0.0	Assumed
Radionuclides (Bq/m^3)		
Thorium-230		
Lead-210		
Radium-226		
Polonium-210		

A.2 DERMAL PATHWAY

Dermal exposure for human receptors was calculated using equation (A-2) for the dermal pathway.

$$I_{dermal} = \frac{C_{soil} \times SA \times EA \times SL \times RAF \times EF \times F_{site}}{BW} \qquad \text{(A-2)}$$

where:

I_{dermal} = exposure to contaminant in soil through the dermal pathway [mg/(kg d)]
C_{soil} = soil concentration [mg/kg (dw)]
SA = skin surface area – total [cm^2]
EA = exposed fraction of skin [-]
SL = loading to exposed skin [kg (dw)/(cm^2 event)]
RAF = dermal absorption factor [-]
EF = exposure frequency [events/d]
F_{site} = fraction of time at site [-]
BW = body weight [kg]

Contaminant concentrations in soil were represented by measured data from the site, if available. In the absence of measured site data, soil concentrations were calculated using deposition from air, shown in equation (A-3). This incremental calculation neglects contaminant concentrations in soil from sources other than air (i.e., rock mineralization) and soil loss due to leaching, erosion and surface runoff.

$$C_{soil} = \frac{C_{air} \times V_{dep}}{d_s \times \rho} \times \left(\frac{3600 \times 24 \times 365 \times 1000}{100^3} \right) \times T \qquad \text{(A-3)}$$

where:

C_{soil} = soil concentration [mg/kg (dw)]
C_{air} = air concentration [mg/m^3]
V_{dep} = deposition velocity [cm/s] {assumed 2 cm/s, from SENES (1987)}
d_s = soil mixing depth [cm] {assumed 1 cm}
ρ = bulk soil density [g (dw)/cm^3] {assumed 1.5 g/cm^3, from Beak (1987)}
T = soil exposure duration [yr] {assumed 10 yr}
3600 = unit conversion factor [s/hr]
24 = unit conversion factor [hr/d]
365 = unit conversion factor [d/yr]
1000 = unit conversion factor [g/kg]
$1/100^3$ = unit conversion factor [m^3/cm^3]

A.3 INGESTION PATHWAY

Ingestion intake by human receptors was calculated using equation (A-4) for the water pathway, equation (A-5) for the soil pathway and equation (A-6) for the food pathway:

$$I_{water} = \frac{C_{water} \times R_{water} \times F_{site}}{BW} \tag{A-4}$$

where:

I_{water} = exposure to contaminant through the water pathway [mg/(kg d)]
C_{water} = measured water concentration [mg/L]
R_{water} = water ingestion rate [L/d]
F_{site} = fraction of time at site [-]
BW = body weight [kg]

$$I_{soil} = \frac{C_{soil} \times R_{soil} \times F_{site}}{BW} \times \frac{1}{1000} \tag{A-5}$$

where:

I_{soil} = exposure to contaminant through the soil pathway [mg/(kg d)]
C_{soil} = soil concentration [mg/kg (dw)]
R_{soil} = soil ingestion rate [g (dw)/d]
F_{site} = fraction of time at site [-]
BW = body weight [kg]
1/1000 = unit conversion factor [kg/g]

$$I_{food\ x} = \frac{C_x \times R_x \times F_{site}}{BW} \times \frac{1}{1000} \tag{A-6}$$

where:

$I_{food\ x}$ = exposure to contaminant through the food pathway [mg/(kg d)], where x is berry, caribou, fish, grouse, hare, mallard, moose, muskrat and sheep, as applicable
C_x = concentration of contaminant [mg/kg (ww)] for each x, such that
C_{berry} –{calculated in equation (A-7)}
$C_{caribou}$ –{calculated in equation (A-8)}
C_{fish} –{calculated in equation (A-12)}
C_{grouse} –{calculated in equation (A-13)}
C_{hare} –{calculated in equation (A-14)}
$C_{mallard}$ –{calculated in equation (A-15)}
C_{moose} –{calculated in equation (A-19)}

$C_{muskrat}$ –{calculated in equation (A-20)}
C_{sheep} –{calculated in equation (A-21)}
R_x = food ingestion rate of x [g (ww)/d], where x is berry, caribou, fish, grouse, hare, mallard, moose, muskrat and sheep, as applicable
F_{site} = fraction of time at site [-]
BW = body weight [kg]
1/1000 = unit conversion factor [kg/g]

Contaminant concentrations in berry were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for berries, contaminant concentrations were calculated using equation (A-7):

$$C_{berry} = C_{soil} \times TF_{soil-to-berry} \qquad \text{(A-7)}$$

where:

C_{berry} = concentration of contaminant in berries [mg/kg (ww)]
C_{soil} = soil concentration [mg/kg (dw)]
$TF_{soil\text{-}to\text{-}berry}$ = soil-to-berry transfer factor [(mg/kg (ww))/(mg/kg (dw))] {Table A3.1}

The soil-to-berry transfer factors from literature used for this assessment are summarized in Table A3.1.

TABLE A3.1
SOIL-TO-BERRY TRANSFER FACTORS

Contaminant	Value	Reference
Metals ((mg/kg (ww))/(mg/kg (dw)))		
Aluminum	$2.6 \text{x} 10^{-3}$	NCRP 1996, Baes *et al*. 1984
Antimony	$8.0 \text{x} 10^{-5}$	U.S. NRC 1992
Arsenic	$9.5 \text{x} 10^{-4}$	NCRP 1996, Baes *et al*. 1984, U.S. EPA 1998
Barium	$9.7 \text{x} 10^{-3}$	U.S. EPA 1998
Beryllium	$7.7 \text{x} 10^{-4}$	U.S. EPA 1998
Boron	0.03	NCRP 1996
Cadmium	$3.8 \text{x} 10^{-2}$	U.S. EPA 1998
Chromium	$1.5 \text{x} 10^{-3}$	U.S. EPA 1998
Cobalt	$7.0 \text{x} 10^{-3}$	U.S. NRC 1992
Copper	0.26	Baes *et al*. 1984
Lead	9.0×10^{-2}	U.S. NRC 1992
Manganese	0.05	U.S. NRC 1992
Mercury	$4.4 \text{x} 10^{-3}$	U.S. EPA 1998
Molybdenum	0.12	NCRP 1996, Baes *et al*. 1984
Nickel	$1.8 \text{x} 10^{-1}$	Baes *et al*. 1984
Selenium	2.9×10^{-3}	NCRP 1996, Baes *et al*. 1984, U.S.EPA 1998
Silver	$4.1 \text{x} 10^{-2}$	U.S. EPA 1998
Strontium	0.2	IAEA 1994
Tin	$6.0 \text{x} 10^{-3}$	Baes *et al*. 1984
Uranium	1.1×10^{-3}	Cassaday *et al.* 1985
Vanadium	$3.0 \text{x} 10^{-3}$	Baes *et al*. 1984
Zinc	0.99	NCRP 1996, IAEA 1994, Baes *et al*. 1984
Organics and other contaminants ((mg/kg (ww))/(mg/kg (dw)))		
Benzene	0.675	U.S. EPA 1998
Benzo(a)pyrene	0.003	U.S. EPA 1998
Cyanide	0.0	no transfer to vegetation
Nitrate	0.0	no transfer to vegetation
PCBs	$3.0 \text{x} 10^{-3}$	U.S. EPA 1998
Thiocyanate	3.5	McKone 1994
Xylene	$9.4 \text{x} 10^{-2}$	McKone 1994
Radionuclides ((Bq/kg (ww))/(Bq/kg (dw)))		
Thorium-230	8.5×10^{-5}	Baes *et al*. 1984
Lead-210	9.0×10^{-2}	U.S. NRC 1992
Radium-226	7.2×10^{-4}	Cassaday *et al.* 1985
Polonium-210	4.0×10^{-4}	Baes *et al*. 1984

Contaminant concentrations in woodland caribou were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for woodland caribou, contaminant concentrations were calculated using equation (A-8):

$$C_{caribou} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_i (Q_i \times C_i) \times \frac{1}{1000} + Q_{soil} \times C_{soil} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-caribou} \quad \text{(A-8)}$$

where:

$C_{caribou}$ = concentration of contaminant in caribou flesh [mg/kg (ww)]
Q_{water} = water ingestion rate [g/d] {9,500 g/d, based on Kirk (1977) and Wales *et al.* (1975)}
C_{water} = measured water concentration [mg/L]
1/1000 = units conversion factor [L/g] or [kg/g]
Q_i = food ingestion rate [g/d] for each i, such that
Q_{forage} – 80 {calculated from U.S. EPA (1993) and based on Thomas and Barry (1991)}
Q_{browse} – 400 {calculated from U.S. EPA (1993) and based on Thomas and Barry (1991)}
Q_{lichen} – 7,520 {calculated from U.S. EPA (1993) and based on Thomas and Barry (1991)}
C_i = concentration of food [mg/kg (ww)] for each i, such that
C_{forage} – {calculated in equation (A-9)}
C_{browse} – {calculated in equation (A-10)}
C_{lichen} – {calculated in equation (A-11)}
Q_{soil} = soil ingestion rate [g/d] {104 g/d, calculated from Beyer *et al.* (1994)}
C_{soil} = soil concentration [mg/kg (dw)]
F_{site} = fraction of time caribou at site [-] {assumed to be 0.10}
$TF_{feed-to-caribou}$ = feed-to-caribou transfer factor [d/kg (ww)] {Table A3.4}

Measured contaminant concentrations in forage were used from the site, when available. In the absence of measured data, contaminant concentrations in forage were estimated following equation (A-9):

$$C_{forage} = C_{soil} \times TF_{soil-to-forage} \quad \text{(A-9)}$$

where:

C_{forage} = concentration of contaminant in forage [mg/kg (ww)]
C_{soil} = soil concentration [mg/kg (dw)]
$TF_{soil-to-forage}$ = soil-to-forage transfer factor [(mg/kg (ww))/(mg/kg (dw))] {Table A3.2}

The soil-to-forage transfer factors from literature used for this assessment are summarized in Table A3.2.

TABLE A3.2
SOIL-TO-FORAGE TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals ((mg/kg (ww))/(mg/kg (dw)))		
Aluminum	0.03	NCRP 1996
Antimony	0.20	Baes et al. 1984
Arsenic	0.1	NCRP 1996, U.S. EPA 1998
Barium	0.029	NCRP 1996, U.S. EPA 1998, CSA 1987
Beryllium	0.017	NCRP 1996, U.S. EPA 1998
Boron	0.03	NCRP 1996
Cadmium	0.2	NCRP 1996, U.S. EPA 1998
Chromium	0.013	NCRP 1996, U.S. EPA 1998, CSA 1987
Cobalt	0.045	NCRP 1996, IAEA 1994, CSA 1987
Copper	0.8	NCRP 1996
Lead	0.03	Létourneau 1987, NCRP 1996, U.S. EPA 1998
Manganese	0.29	U.S. NRC 1992
Mercury	0.3	NCRP 1996
Molybdenum	0.4	NCRP 1996
Nickel	0.07	NCRP 1996, IAEA 1994, U.S. EPA 1998
Selenium	0.25	NCRP 1996, U.S. EPA 1998
Silver	0.35	NCRP 1996, U.S. EPA 1998, CSA 1987
Strontium	0.13	U.S. NRC 1992
Tin	0.03	Baes et al. 1984
Uranium	1.8×10^{-2}	Létourneau 1987, NCRP 1996, IAEA 1994
Vanadium	0.1	NCRP 1996
Zinc	0.24	NCRP 1996, IAEA 1994, U.S. EPA 1998
Organics and other contaminants ((mg/kg (ww))/(mg/kg (dw)))		
Benzene	0.675	U.S. EPA 1998
Benzo(a)pyrene	0.003	U.S. EPA 1998
Cyanide	0.0	no transfer to vegetation
Nitrate	0.0	no transfer to vegetation
PCBs	$3.0\text{x}10^{-3}$	U.S. EPA 1998
Thiocyanate	3.5	McKone 1994
Xylene	$9.4\text{x}10^{-2}$	McKone 1994
Radionuclides ((Bq/kg (ww))/(Bq/kg (dw)))		
Thorium-230	9.2×10^{-3}	Létourneau 1987, NCRP 1996, IAEA 1994
Lead-210	0.03	Létourneau 1987, NCRP 1996, U.S. EPA 1998
Radium-226	0.093	Létourneau 1987, NCRP 1996, IAEA 1994
Polonium-210	0.021	Létourneau 1987, NCRP 1996, IAEA 1994

Measured contaminant concentrations in browse were used from the site, when available. In the absence of measured data, contaminant concentrations in browse were estimated following equation (A-10):

$$C_{browse} = C_{soil} \times TF_{soil-to-browse} \qquad \text{(A-10)}$$

where:

C_{browse} = concentration of contaminant in browse [mg/kg (ww)]
C_{soil} = soil concentration [mg/kg (dw)]
$TF_{soil\text{-}to\text{-}browse}$ = soil-to-browse transfer factor [(mg/kg (ww))/(mg/kg (dw))] {Table A3.3}

The soil-to-browse transfer factors from literature used for this assessment are summarized in Table A3.3.

TABLE A3.3
SOIL-TO-BROWSE TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals ((mg/kg (ww))/(mg/kg (dw)))		
Aluminum	2.6×10^{-3}	NCRP 1996, Baes et al. 1984
Antimony	0.20	Baes et al. 1984
Arsenic	7.7×10^{-3}	NCRP 1996, Baes et al. 1984, U.S. EPA 1998
Barium	4.5×10^{-3}	U.S. EPA 1998
Beryllium	4.5×10^{-4}	U.S. EPA 1998
Boron	0.03	NCRP 1996
Cadmium	1.9×10^{-2}	U.S. EPA 1998
Chromium	1.4×10^{-3}	U.S. EPA 1998
Cobalt	0.045	NCRP 1996, IAEA 1994, CSA 1987
Copper	0.055	NCRP 1996, Baes et al. 1984
Lead	5.0×10^{-3}	Baes et al. 1984, IAEA 1994, NCRP 1996, U.S. EPA 1998
Manganese	0.29	U.S. NRC 1992
Mercury	0.3	NCRP 1996
Molybdenum	0.07	NCRP 1996, Baes et al. 1984
Nickel	8.6×10^{-3}	NCRP 1996, Baes et al. 1984, U.S.EPA 1998
Selenium	0.01	NCRP 1996, Baes et al. 1984, U.S.EPA 1998
Silver	3.0×10^{-2}	U.S. EPA 1998
Strontium	0.13	U.S. NRC 1992
Tin	0.03	Baes et al. 1984
Uranium	1.2×10^{-3}	Baes et al. 1984, IAEA 1994, NCRP 1996
Vanadium	5.5×10^{-3}	Baes et al. 1984
Zinc	0.27	NCRP 1996, IAEA 1994, Baes et al. 1984
Organics and other contaminants ((mg/kg (ww))/(mg/kg (dw)))		
Benzene	0.47	McKone 1994
Benzo(a)pyrene	0.022	McKone 1994
Cyanide	0.0	no transfer to vegetation
Nitrate	0.0	no transfer to vegetation
PCBs	3.0×10^{-3}	U.S. EPA 1998
Thiocyanate	3.5	McKone 1994
Xylene	9.4×10^{-2}	McKone 1994
Radionuclides ((Bq/kg (ww))/(Bq/kg (dw)))		
Thorium-230	1.4×10^{-4}	Baes et al. 1984, IAEA 1994, NCRP 1996
Lead-210	5.0×10^{-3}	Baes et al. 1984, IAEA 1994, NCRP 1996, U.S. EPA 1998
Radium-226	3.7×10^{-3}	Baes et al. 1984, IAEA 1994, NCRP 1996
Polonium-210	6.9×10^{-4}	Baes et al. 1984, NCRP 1996

Measured contaminant concentrations in lichen were used from the site, when available. In the absence of measured data, contaminant concentrations in lichen were estimated following equation (A-11). It is assumed that contaminant transfer to lichen occurs entirely through the air pathway and therefore, there is no contaminant transfer to lichen through the soil pathway.

$$C_{lichen} = \frac{C_{air} \times V_{dep} \times F_{in} \times F_{rv} \times E_v}{Y_v \times \lambda_w} \times \frac{1000}{100} \qquad \text{(A-11)}$$

where:

C_{lichen} = concentration of contaminant in lichen [mg/kg (ww)]
C_{air} = air concentration [mg/m^3]
V_{dep} = deposition velocity [cm/s] {assumed 2 cm/s, from SENES (1987)}
F_{in} = fraction of deposition intercepted by lichen [-] {assumed to be 1}
F_{rv} = fraction of deposition retained on lichen [-] {0.95, from SENES (1987)}
E_v = fraction of deposition on edible portion of lichen [-] {1, from SENES (1987)}
Y_v = yield density [g (ww)/m^2] {500 g/m^2, from SENES (1987)}
λ_w = weathering loss decay constant [1/s] {2.2x10^{-9}, from SENES (1987)}
1000 = units conversion factor [g/kg]
1/100 = units conversion factor [m/cm]

Feed-to-caribou transfer factors were obtained from literature sources, as summarized in Table A3.4.

TABLE A3.4
FEED-TO-CARIBOU[a] TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals (d/kg (ww))		
Aluminum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Antimony	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Arsenic	2.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Barium	1.6×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Beryllium	2.3×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Boron	6.7×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Cadmium	5.2×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Chromium	5.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Cobalt	1.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Copper	1.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Lead	1.0×10^{-3}	Thomas *et al.* 1994[b]
Manganese	5.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Mercury	8.8×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Molybdenum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Nickel	6.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Selenium	1.5×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Silver	3.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Strontium	5.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Tin	4.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Uranium	3.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Vanadium	2.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Zinc	1.0×10^{-1}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Organics and other contaminants (d/kg (ww))		
Benzene	3.4×10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	3.4×10^{-2}	U.S. EPA 1998
Cyanide	1.6×10^{-2}	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	4.0×10^{-2}	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	9.5×10^{-8}	McKone 1994
Xylene	4.0×10^{-5}	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	2.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Lead-210	1.0×10^{-3}	Thomas *et al.* 1994[b]
Radium-226	1.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Polonium-210	8.5×10^{-3}	Thomas *et al.* 1994[b]

Note : a – Based mainly on feed-to-beef transfer factors.

b – Calculated from lichen to caribou data for Pb-210 and Po-210 in Thomas *et al.* 1994.

c – Based on feed-to-beef transfer factor information available in IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987.

Contaminant concentrations in fish were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for fish, contaminant concentrations were calculated using equation (A-12):

$$C_{fish} = C_{water} \times TF_{water-to-fish} \qquad \text{(A-12)}$$

where:

C_{fish} = concentration of contaminant in fish [mg/kg (ww)]
C_{water} = water concentration [mg/L]
$TF_{water\text{-}to\text{-}fish}$ = water-to-fish transfer factor [(mg/kg (ww))/(mg/L)] {Table A3.5}

The water-to-fish transfer factors from literature used for this assessment are summarized in Table A3.5.

Cyanide water-to-fish transfer factors were not considered since there are no reports of cyanide biomagnification or cycling in living organisms since it is rapidly detoxified (Eisler 1991). In addition, fish retrieved from cyanide-poisoned environments can be consumed by humans because muscle cyanide residues are generally considered as low (Eisler 1991).

TABLE A3.5
WATER-TO-FISH TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals ((mg/kg (ww))/(mg/L))		
Aluminum	500	NCRP 1996
Antimony	100	IAEA 1994
Arsenic	1000	CSA 1987
Barium	210	IAEA 1994, NCRP 1996, CSA 1987, U.S. EPA 1998
Beryllium	100	IAEA 1994, NCRP 1996
Boron	5.0	NCRP 1996
Cadmium	200	NCRP 1996
Chromium	200	IAEA 1994, NCRP 1996, CSA 1987
Cobalt	300	IAEA 1994, NCRP 1996
Copper	200	IAEA 1994, NCRP 1996
Lead	300	IAEA 1994, NCRP 1996
Manganese	400	IAEA 1994
Mercury	4000	IAEA 1994, NCRP 1996, CSA 1987
Molybdenum	10	IAEA 1994
Nickel	310	U.S. EPA 1998
Selenium	130	U.S. EPA 1998, ATSDR 1997
Silver	10	NCRP 1996, CSA 1987
Strontium	60	IAEA 1994
Tin	3000	IAEA 1994
Uranium	20	CSA 1987
Vanadium	200	IAEA 1994, NCRP 1996
Zinc	1000	IAEA 1994
Organics and other contaminants ((mg/kg (ww))/(mg/L))		
Benzene	25	U.S. EPA 1998
Benzo(a)pyrene	9950	U.S. EPA 1998, BAF
Nitrate	0.0	no food chain transfer
PCBs	6.6×10^5	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	0.0	no food chain transfer
Xylene	160	U.S. EPA 1998, m-xylene
Radionuclides ((Bq/kg (ww))/(Bq/L))		
Thorium-230	100	IAEA 1994, NCRP 1996
Lead-210	300	IAEA 1994, NCRP 1996
Radium-226	50	IAEA 1994, NCRP 1996
Polonium-210	50	IAEA 1994

Contaminant concentrations in grouse were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for grouse, contaminant concentrations were calculated using equation (A-13):

$$C_{grouse} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_{i} \left(Q_i \times C_i \right) \times \frac{1}{1000} + Q_{soil} \times C_{soil} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-grouse} \quad \text{(A-13)}$$

where:

C_{grouse} = concentration of contaminant in grouse flesh [mg/kg (ww)]
Q_{water} = water ingestion rate [g/d] {51 g/d, calculated from U.S. EPA (1993)}
C_{water} = measured water concentration [mg/L]
1/1000 = units conversion factor [L/g] or [kg/g]
Q_i = food ingestion rate [g/d] for each i, such that
  Q_{browse} – 97 {U.S. EPA (1993)}
  Q_{berry} – 12 {U.S. EPA (1993)}
C_i = concentration of food [mg/kg (ww)] for each i, such that
  C_{browse} – {calculated in equation (A-10)}
  C_{berry} – {calculated in equation (A-7)}
Q_{soil} = soil ingestion rate [g/d] {1.02 g/d, calculated from Beyer *et al.* (1994)}
C_{soil} = soil concentration [mg/kg (dw)]
F_{site} = fraction of time grouse at site [-] {assumed to be 1.0}
$TF_{feed-to-grouse}$ = feed-to-grouse transfer factor [d/kg (ww)] {Table A3.6}

Feed-to-grouse transfer factors were obtained from literature sources, as summarized in Table A3.6.

TABLE A3.6
FEED-TO-GROUSE[a] TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals (d/kg (ww))		
Aluminum	0.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Antimony	0.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Arsenic	1.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Barium	0.08	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Beryllium	1.15	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Boron	0.34	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cadmium	0.8	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Chromium	6.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cobalt	2.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Copper	0.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead	0.2	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Manganese	0.05	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Mercury	0.027	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Molybdenum	1.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Nickel	3.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Selenium	9.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Silver	2.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Strontium	0.06	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Tin	20	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Uranium	1.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Vanadium	1.3	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Zinc	7.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Organics and other contaminants (d/kg (ww))		
Benzene	2.7×10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	0.027	U.S. EPA 1998
Cyanide	8.0	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	0.032	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	4.8×10^{-5}	McKone 1994
Xylene	0.032	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	0.10	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead-210	0.20	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Radium-226	0.30	Clulow *et al.* 1992[c]
Polonium-210	2.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]

Note : a – Based on information for poultry.

b – Based on feed-to-poultry information available in IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987. When transfer factors were not available for poultry (As, Pb, Ni, V, Po, Th) the beef transfer factors was multiplied by a factor of 500 derived from the geometric mean of the ratio between the transfer factors for beef:chicken for Cd, Cu, Mo, Se, Zn, U, Ra.

c – Default value for radium based on grouse from Clulow *et al.* 1992. Based on a concentration ratio (CR) of 0.075fw and a feed ingestion rate of 224 g/d.

Contaminant concentrations in hare were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for hare, contaminant concentrations were calculated using equation (A-14):

$$C_{hare} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_i \left(Q_i \times C_i \right) \times \frac{1}{1000} + Q_{soil} \times C_{soil} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-hare} \quad \text{(A-14)}$$

where:

C_{hare} = concentration of contaminant in hare flesh [mg/kg (ww)]

Q_{water} = water ingestion rate [g/d] {140 g/d, calculated from U.S. EPA (1993)}

C_{water} = measured water concentration [mg/L]

1/1000 = units conversion factor [L/g] or [kg/g]

Q_i = food ingestion rate [g/d] for each i, such that
Q_{forage} – 120 {Pease *et al.* (1979), U.S. EPA (1993)}
Q_{browse} – 180 {Pease *et al.* (1979), U.S. EPA (1993)}

C_i = concentration of food [mg/kg (ww)] for each i, such that
C_{forage} – {calculated in equation (A-9)}
C_{browse} – {calculated in equation (A-10)}

Q_{soil} = soil ingestion rate [g/d] {7.0 g/d, calculated from Beyer *et al.* (1994)}

C_{soil} = soil concentration [mg/kg (dw)]

F_{site} = fraction of time hare at site [-] {assumed to be 1.0}

$TF_{feed-to-hare}$ = feed-to-hare transfer factor [d/kg (ww)] {Table A3.7}

Feed-to-hare transfer factors were obtained from literature sources, as summarized in Table A3.7.

TABLE A3.7
FEED-TO-HARE[a] TRANSFER FACTORS

Contaminant	Value	Reference
Metals (d/kg (ww))		
Aluminum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Antimony	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Arsenic	2.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Barium	1.6×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Beryllium	2.3×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Boron	6.7×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Cadmium	5.2×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Chromium	5.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Cobalt	1.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Copper	1.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Lead	1.4×10^{-1}	Thomas 1997[b]
Manganese	5.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Mercury	8.8×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Molybdenum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Nickel	6.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Selenium	1.5×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Silver	3.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Strontium	5.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Tin	4.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Uranium	3.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Vanadium	2.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Zinc	1.0×10^{-1}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Organics and other contaminants (d/kg (ww))		
Benzene	3.4×10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	3.4×10^{-2}	U.S. EPA 1998
Cyanide	1.6×10^{-2}	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	4.0×10^{-2}	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	9.5×10^{-8}	McKone 1994
Xylene	4.0×10^{-5}	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	2.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Lead-210	1.4×10^{-1}	Thomas 1997[b]
Radium-226	2.5	Thomas 1997[b]
Polonium-210	4.3×10^{-1}	Thomas 1997[b]

Note : a – Based in part on feed-to-beef transfer factors.

b – Based on food chain concentration ratios for vegetation and voles in Thomas 1997.

c – Based on feed-to-beef transfer factor information available in IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987.

Contaminant concentrations in mallard were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for mallard, contaminant concentrations were calculated using equation (A-15):

$$C_{mallard} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_i \left(Q_i \times C_i \right) \times \frac{1}{1000} + Q_{sed} \times C_{sed} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-mallard} \quad \text{(A-15)}$$

where:

$C_{mallard}$ = concentration of contaminant in mallard flesh [mg/kg (ww)]
Q_{water} = water ingestion rate [g/d] {64 g/d, U.S. EPA (1993)}
C_{water} = measured water concentration [mg/L]
1/1000 = units conversion factor [L/g] or [kg/g]
Q_i = food ingestion rate [g/d] for each i, such that
$Q_{\text{aquatic vegetation}}$ – 47 {U.S. EPA (1993)}
$Q_{\text{benthic invertebrates}}$ – 142 {U.S. EPA (1993)}
C_i = concentration of food [mg/kg (ww)] for each i, such that
$C_{\text{aquatic vegetation}}$ – {calculated in equation (A-16)}
$C_{\text{benthic invertebrate}}$ – {calculated in equation (A-17)}
Q_{sed} = sediment ingestion rate [g/d] {1.89 g/d, calculated from Beyer *et al.* (1994)}
C_{sed} = sediment concentration [mg/kg (dw)] {calculated in equation (A-18)}
F_{site} = fraction of time mallard at site [-] {assumed to be 0.50}
$TF_{\text{feed-to-mallard}}$ = feed-to-mallard transfer factor [d/kg (ww)] {Table A3.11}

Contaminant concentrations in aquatic vegetation were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for aquatic vegetation, contaminant concentrations were calculated using equation (A-16):

$$C_{aqveg} = C_{water} \times TF_{water-to-aqveg} \quad \text{(A-16)}$$

where:

C_{aqveg} = concentration of contaminant in aquatic vegetation [mg/kg (ww)]
C_{water} = water concentration [mg/L]
$TF_{\text{water-to-aqveg}}$ = water-to-aquatic vegetation transfer factor [(mg/kg (ww))/(mg/L)] {Table A3.8}

The water-to-aquatic vegetation transfer factors from literature used for this assessment are summarized in Table A3.8.

TABLE A3.8
WATER-TO-AQUATIC VEGETATION TRANSFER FACTORS

Contaminant	Value	Reference
Metals ((mg/kg (ww))/(mg/L))		
Aluminum	0.0	not available
Antimony	1500	NRCC 1983
Arsenic	200	NTIS 1988, CSA 1987
Barium	500	NRCC 1983
Beryllium	38	Santschi and Honeyman 1989
Boron	0.0	not available
Cadmium	1900	Bird and Schwartz 1996
Chromium	0.12	Bird and Schwartz 1996
Cobalt	1200	Bird and Schwartz 1996
Copper	1000	ORNL 1976
Lead	320	Santschi and Honeyman 1989, ORNL 1976
Manganese	170	Bird and Schwartz 1996
Mercury	530	Bird and Schwartz 1996
Molybdenum	1000	ORNL 1976, NTIS 1989
Nickel	50	ORNL 1976
Selenium	63	Santschi and Honeyman 1989
Silver	200	NRCC 1983
Strontium	260	Bird and Schwartz 1996
Tin	100	NRCC 1983
Uranium	200	Santschi and Honeyman 1989, ORNL 1976, Bird and Schwartz 1996, Létourneau 1987
Vanadium	2000	U.S. NRC 1977
Zinc	550	NTIS 1988, CSA 1987
Organics and other contaminants ((mg/kg (ww))/(mg/L))		
Benzene	15	Freitag et al. 1984
Benzo(a)pyrene	3100	Freitag et al. 1985
Cyanide	0.0	not available
Nitrate	0.0	not available
PCBs	0.0	not available
Thiocyanate	0.0	not available
Xylene	0.0	not available
Radionuclides ((Bq/kg (ww))/(Bq/L))		
Thorium-230	2600	Santschi and Honeyman 1989, ORNL 1976, Bird and Schwartz 1996, Létourneau 1987
Lead-210	320	Santschi and Honeyman 1989, ORNL 1976
Radium-226	970	Santschi and Honeyman 1989, ORNL 1976, Bird and Schwartz 1996, Létourneau 1987
Polonium-210	1800	Santschi and Honeyman 1989, ORNL 1976

Contaminant concentrations in benthic invertebrates were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for benthic invertebrates, contaminant concentrations were calculated using equation (A-17):

$$C_{benthos} = C_{water} \times TF_{water-to-benthos} \qquad \text{(A-17)}$$

where:

$C_{benthos}$ = concentration of contaminant in benthic invertebrates [mg/kg (ww)]
C_{water} = water concentration [mg/L]
$TF_{water\text{-}to\text{-}benthos}$ = water-to-benthic invertebrate transfer factor [(mg/kg (ww))/(mg/L)] {Table A3.9}

The water-to-benthic invertebrate transfer factors from literature used for this assessment are summarized in Table A3.9.

TABLE A3.9
WATER-TO-BENTHIC INVERTEBRATE TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals ((mg/kg (ww))/(mg/L))		
Aluminum	0.0	not available
Antimony	10	NRCC 1983
Arsenic	1700	U.S. EPA 1979
Barium	200	NRCC 1983
Beryllium	0.0	not available
Boron	0.0	not available
Cadmium	4000	U.S. EPA 1979
Chromium	20	NRCC 1983
Cobalt	1000	assumed from copper, nickel and selenium
Copper	1000	U.S. EPA 1979
Lead	100	U.S. EPA 1979
Manganese	7.5×10^{-2}	Bird and Schwartz 1996
Mercury	530	Bird and Schwartz 1996
Molybdenum	4000	U.S. EPA 1979, NTIS 1989
Nickel	100	U.S. EPA 1979
Selenium	680	NTIS 1985 and measured data from Northern Ontario, Elliot Lake
Silver	770	NRCC 1983
Strontium	450	Bird and Schwartz 1996
Tin	1000	NRCC 1983
Uranium	100	U.S. EPA 1979
Vanadium	100	NRCC 1983, assumed same as niobium
Zinc	40000	U.S. EPA 1979
Organics and other contaminants ((mg/kg (ww))/(mg/L))		
Benzene	0.0	not available
Benzo(a)pyrene	0.0	not available
Cyanide	0.0	not available
Nitrate	0.0	not available
PCBs	0.0	not available
Thiocyanate	0.0	not available
Xylene	0.0	not available
Radionuclides ((Bq/kg (ww))/(Bq/L))		
Thorium-230	500	U.S. EPA 1979, Létourneau 1987
Lead-210	100	U.S. EPA 1979
Radium-226	250	U.S. EPA 1979
Polonium-210	20000	U.S. EPA 1979

Contaminant concentrations in sediment were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for sediment, contaminant concentrations were calculated using equation (A-18):

$$C_{sed} = C_{water} \times K_d \qquad \text{(A-18)}$$

where:

C_{sed} = concentration of contaminant in sediment [mg/kg (dw)]
C_{water} = water concentration [mg/L]
K_d = water-to-sediment distribution coefficient [(mg/kg (dw))/(mg/L)] {Table A3.10}

The water-to-sediment distribution coefficients from literature used for this assessment are summarized in Table A3.10.

TABLE A3.10
WATER-TO-SEDIMENT DISTRIBUTION COEFFICIENTS

Contaminant	**Value**	**Reference**
Metals ((mg/kg (dw))/(mg/L))		
Aluminum	1500	Baes et al. 1998
Antimony	45	U.S. EPA 1998
Arsenic	31	U.S. EPA 1998
Barium	60	Bechtel Jacobs 1998
Beryllium	790	U.S. EPA 1998
Boron	3.0	Baes et al. 1998
Cadmium	4300	U.S. EPA 1998
Chromium	30	Bechtel Jacobs 1998
Cobalt	5000	IAEA 1994, Bechtel Jacobs 1998
Copper	10000	U.S. EPA 1998
Lead	900	U.S. EPA 1998
Manganese	1000	IAEA 1994
Mercury	1000	U.S. EPA 1998
Molybdenum	900	Sheppard and Thibault 1990, for clay soil with a factor of 10
Nickel	1900	U.S. EPA 1998
Selenium	2.2	U.S. EPA 1998
Silver	1100	U.S. EPA 1998
Strontium	1000	IAEA 1994
Tin	13000	U.S. NRC 1992
Uranium	50	IAEA 1994, Bechtel Jacobs 1998
Vanadium	50	U.S. EPA 1998
Zinc	500	IAEA 1994, Bechtel Jacobs 1998
Organics and other contaminants ((mg/kg (dw))/(mg/L))		
Benzene	4.7	U.S. EPA 1998
Benzo(a)pyrene	730	U.S. EPA 1998
Cyanide	0.0	not available
Nitrate	0.0	not available
PCBs	3930	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	0.0	not available
Xylene	23	U.S. EPA 1998, for p-xylene
Radionuclides ((Bq/kg (dw))/(Bq/L))		
Thorium-230	10000	IAEA 1994, Bechtel Jacobs 1998
Lead-210	900	U.S. EPA 1998
Radium-226	500	IAEA 1994, Bechtel Jacobs 1998
Polonium-210	150	Bechtel Jacobs 1998

Feed-to-mallard transfer factors were obtained from literature sources, as summarized in Table A3.11.

TABLE A3.11
FEED-TO-MALLARD[a] TRANSFER FACTORS

Contaminant	Value	Reference
Metals (d/kg (ww))		
Aluminum	0.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Antimony	0.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Arsenic	1.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Barium	0.08	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Beryllium	1.15	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Boron	0.34	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cadmium	0.8	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Chromium	6.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cobalt	2.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Copper	0.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead	0.2	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Manganese	0.05	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Mercury	0.027	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Molybdenum	1.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Nickel	3.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Selenium	9.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Silver	2.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Strontium	0.06	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Tin	20	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Uranium	1.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Vanadium	1.3	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Zinc	7.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Organics and other contaminants (d/kg (ww))		
Benzene	2.7×10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	0.027	U.S. EPA 1998
Cyanide	8.0	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	0.032	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	4.8×10^{-5}	McKone 1994
Xylene	0.032	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	0.10	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead-210	0.20	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Radium-226	0.30	Clulow *et al.* 1992[c]
Polonium-210	2.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]

Note : a – Based on information for poultry.

b – Based on feed-to-poultry information available in IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987. When transfer factors were not available for poultry (As, Pb, Ni, V, Po, Th) the beef transfer factors was multiplied by a factor of 500 derived from the geometric mean of the ratio between the transfer factors for beef:chicken for Cd, Cu, Mo, Se, Zn, U, Ra.

c – Default value for radium based on grouse from Clulow *et al.* 1992. Based on a concentration ratio (CR) of 0.075fw and a feed ingestion rate of 224 g/d.

Contaminant concentrations in moose were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for moose, contaminant concentrations were calculated using equation (A-19):

$$C_{moose} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_i \left(Q_i \times C_i \right) \times \frac{1}{1000} + Q_{sed} \times C_{sed} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-moose} \quad \text{(A-19)}$$

where:

C_{moose} = concentration of contaminant in moose flesh [mg/kg (ww)]
Q_{water} = water ingestion rate [g/d] {32,000 g/d, calculated from U.S. EPA (1993)}
C_{water} = measured water concentration [mg/L]
1/1000 = units conversion factor [L/g] or [kg/g]
Q_i = food ingestion rate [g/d] for each i, such that
Q_{aqveg} – 2,300 {Canadian Wildlife Service (1997), Belovsky *et al.* (1973)}
Q_{browse} – 20,700 {Canadian Wildlife Service (1997), Belovsky *et al.* (1973)}
C_i = concentration of food [mg/kg (ww)] for each i, such that
C_{browse} – {calculated in equation (A-10)}
C_{aqveg} – {calculated in equation (A-16)}
Q_{sed} = sediment ingestion rate [g/d] {184 g/d, calculated from Beyer *et al.* (1994)}
C_{sed} = sediment concentration [mg/kg (dw)] {calculated in equation (A-18)}
F_{site} = fraction of time moose at site [-] {assumed to be 1.0}
$TF_{feed\text{-}to\text{-}moose}$ = feed-to-moose transfer factor [d/kg (ww)] {Table A3.12}

Feed-to-moose transfer factors were obtained from literature sources, as summarized in Table A3.12.

TABLE A3.12
FEED-TO-MOOSE[a] TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals (d/kg (ww))		
Aluminum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Antimony	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Arsenic	2.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Barium	1.6×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Beryllium	2.3×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Boron	6.7×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cadmium	5.2×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Chromium	5.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cobalt	1.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Copper	1.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead	4.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Manganese	5.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Mercury	8.8×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Molybdenum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Nickel	6.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Selenium	1.5×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Silver	3.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Strontium	5.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Tin	4.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Uranium	3.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Vanadium	2.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Zinc	1.0×10^{-1}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Organics and other contaminants (d/kg (ww))		
Benzene	3.4×10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	3.4×10^{-2}	U.S. EPA 1998
Cyanide	1.6×10^{-2}	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	4.0×10^{-2}	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	9.5×10^{-8}	McKone 1994
Xylene	4.0×10^{-5}	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	2.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead-210	4.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Radium-226	1.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Polonium-210	5.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]

Note : a – Based on feed-to-beef transfer factors.

b – Based on feed-to-beef transfer factor information available in IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987.

Contaminant concentrations in muskrat were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for muskrat, contaminant concentrations were calculated using equation (A-20):

$$C_{muskrat} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_i \left(Q_i \times C_i \right) \times \frac{1}{1000} + Q_{sed} \times C_{sed} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-muskrat} \quad \text{(A-20)}$$

where:

$C_{muskrat}$ = concentration of contaminant in muskrat flesh [mg/kg (ww)]

Q_{water} = water ingestion rate [g/d] {120 g/d, calculated from U.S. EPA (1993)}

C_{water} = measured water concentration [mg/L]

1/1000 = units conversion factor [L/g] or [kg/g]

Q_i = food ingestion rate [g/d] for each i, such that
Q_{aqveg} – 356 {U.S. EPA (1993)}

C_i = concentration of food [mg/kg (ww)] for each i, such that
C_{aqveg} – {calculated in equation (A-16)}

Q_{sed} = sediment ingestion rate [g/d] {4.0 g/d, calculated from Beyer *et al.* (1994)}

C_{sed} = sediment concentration [mg/kg (dw)] {calculated in equation (A-18)}

F_{site} = fraction of time muskrat at site [-] {assumed to be 1.0}

$TF_{feed-to-muskrat}$ = feed-to-muskrat transfer factor [d/kg (ww)] {Table A3.13}

Feed-to-muskrat transfer factors were obtained from literature sources, as summarized in Table A3.13.

TABLE A3.13
FEED-TO-MUSKRAT[a] TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals (d/kg (ww))		
Aluminum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Antimony	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Arsenic	2.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Barium	1.6×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Beryllium	2.3×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Boron	6.7×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Cadmium	5.2×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Chromium	5.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Cobalt	1.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Copper	1.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Lead	1.4×10^{-1}	Thomas 1997[b]
Manganese	5.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Mercury	8.8×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Molybdenum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Nickel	6.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Selenium	1.5×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Silver	3.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Strontium	5.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Tin	4.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Uranium	3.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Vanadium	2.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Zinc	1.0×10^{-1}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Organics and other contaminants (d/kg (ww))		
Benzene	3.4×10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	3.4×10^{-2}	U.S. EPA 1998
Cyanide	1.6×10^{-2}	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	4.0×10^{-2}	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	9.5×10^{-8}	McKone 1994
Xylene	4.0×10^{-5}	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	2.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Lead-210	1.4×10^{-1}	Thomas 1997[b]
Radium-226	2.5	Thomas 1997[b]
Polonium-210	4.3×10^{-1}	Thomas 1997[b]

Note : a – Based in part on feed-to-beef transfer factors.
b – Based on food chain concentration ratios for vegetation and voles in Thomas 1997.
c – Based on feed-to-beef transfer factor information available in IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987.

Contaminant concentrations in sheep were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for sheep, contaminant concentrations were calculated using equation (A-21):

$$C_{sheep} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_i \left(Q_i \times C_i \right) \times \frac{1}{1000} + Q_{soil} \times C_{soil} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-sheep} \quad \text{(A-21)}$$

where:

C_{sheep} = concentration of contaminant in sheep flesh [mg/kg (ww)]
Q_{water} = water ingestion rate [g/d] {4,500 g/d, calculated from U.S. EPA (1993)}
C_{water} = measured water concentration [mg/L]
1/1000 = units conversion factor [L/g] or [kg/g]
Q_i = food ingestion rate [g/d] for each i, such that
Q_{forage} – 5,760 {U.S. EPA (1993)}
C_i = concentration of food [mg/kg (ww)] for each i, such that
C_{forage} – {calculated in equation (A-9)}
Q_{soil} = soil ingestion rate [g/d] {76.9 g/d, calculated from Beyer *et al.* (1994)}
C_{soil} = soil concentration [mg/kg (dw)]
F_{site} = fraction of time sheep at site [-] {assumed to be 0.25}
$TF_{feed-to-sheep}$ = feed-to-sheep transfer factor [d/kg (ww)] {Table A3.14}

Feed-to-sheep transfer factors were obtained from literature sources, as summarized in Table A3.14.

TABLE A3.14
FEED-TO-SHEEP[a] TRANSFER FACTORS

Contaminant	Value	Reference
Metals (d/kg (ww))		
Aluminum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Antimony	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Arsenic	2.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Barium	1.6×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Beryllium	2.3×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Boron	6.7×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cadmium	5.2×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Chromium	5.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cobalt	1.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Copper	1.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead	4.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Manganese	5.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Mercury	8.8×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Molybdenum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Nickel	6.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Selenium	1.5×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Silver	3.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Strontium	5.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Tin	4.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Uranium	3.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Vanadium	2.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Zinc	1.0×10^{-1}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Organics and other contaminants (d/kg (ww))		
Benzene	3.4×10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	3.4×10^{-2}	U.S. EPA 1998
Cyanide	1.6×10^{-2}	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	4.0×10^{-2}	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	9.5×10^{-8}	McKone 1994
Xylene	4.0×10^{-5}	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	2.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead-210	4.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Radium-226	1.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Polonium-210	5.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]

Note : a – Based on feed-to-beef transfer factors.

b – Based on feed-to-beef transfer factor information available in IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) 1997. *Toxicological Profile for Selenium.* December.

Baes, C.F., R.D. Sharp, A.L. Sjoreen, and R.W. Shar 1984. *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture*. ORNL-5786.

Beak Consultants Limited (Beak) 1987. *Application of the National Uranium Tailings Program Probabilistic System Model (UTAP) to the Rabbit Lake Uranium Tailings Site.* Research report prepared for the National Uranium Tailings Program, CANMET, EMR, Ottawa.

Bechtel Jacobs. 1998. *Radiological Benchmarks for Screening Contaminants of Potential Concern for Effects on Aquatic Biota at ORNL*. BJC/OR-80.

Belovsky, G.E., P.A. Jordan, and D.B. Botkin. 1973. *Summer Browsing by Moose in Relation to Preference, and Animal Density: A New Quantitative Approach*. Proceedings of the 9th North American Moose Conference and Workshop, Quebec, City, March.

Beyer, W. N., E. Connor, and S. Gerould. 1994. *Survey of Soil Ingestion by Wildlife*. Journal of Wildlife Management 58:375-382.

Bird, G.A. and W. Schwartz. 1996. *Nuclide Concentration Factors for Freshwater Biota*. AECL. Technical Record TR-703.

Canadian Standards Association (CSA). 1987. *Guidelines for Calculating Derived Release Rate Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities*. CAN ICSA-N288.1-M87.

Canadian Wildlife Service (CWS). 1997. *Hinterland Who's Who: Moose On-Line Report*. Environment Canada. http://www.cws-scf.ec.gc.ca/. Accessed on June 10, 2003.

Cassaday, V.J., B.E. Halbert and D. Stone. 1985. *The Data Base Available to Develop Distributions for Use in Modelling the Transfer of Airborne Radioactivity to Terrestrial Vegetation. Presented in a Report Entitled – Probabilistic Model Development for the Assessment of the Long-Term Effects of Uranium Mill Tailings in Canada*: Phase II, Vol. 2. Prepared by SENES Consultants Limited for the National Uranium Tailings Program, Canada Centre for Mineral and Water Technology, Energy, Mines and Resources Canada, Ottawa, Ontario.

Clulow, F.V., T.P. Lim, N.K. Davé and R. Avadhanula. 1992. *Radium-226 Levels and Concentration Ratios Between Water, Vegetation, and Tissues of Ruffed Grouse (Bonasa umbellus) from a Watershed with Uranium Tailings Near Elliot Lake, Canada*. Environmental Pollution Vol. 77:39-50. September.

Eisler, R. 1991. *Cyanide Hazards to Fish, Wildlife, and Invertebrates: a Synoptic Review. Contaminant Hazard Reviews Report 23*. U.S. Department of the Interior Fish and Wildlife Service. December.

Freitag, D. 1984. *Environmental hazard profile-test results as related structures and translation into the environment*. In: QSAR in Environmental Toxicology. Kaiser, K.L.E., Editor, D. Reidel Publishing Company, Dordrect, Netherlands.

Freitag, D., L. Ballhorn, H. Geyer, F. Korte. 1985. *Environmental hazard profile of organic chemicals. An experimental method for the assessment of the behaviour of chemicals in the ecosphere by simple laboratory tests with c-14 labelled chemicals*. Chemosphere 14, 1589-616.

International Atomic Energy Agency (IAEA). 1994. *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments*. International Atomic Energy Agency, Vienna.

Kirk, R.W. (ed.) 1977. *Current Veterinary Therapy.* W.B. Saunders Co., Toronto, pp 1418.

Lee, D.S., J.A. Garland, A.A. Fox 1994. *Atmospheric Concentrations of Trace Elements in Urban Areas of the United Kingdom.* Atmos. Environ.28(16): 2691-2713.

Létourneau, C. 1987. *Transfer of Radionuclides of the Uranium and Thorium Decay Chains in Aquatic and Terrestrial Environments*. Prepared for Atomic Energy Control Board. April.

McKone, T. E. 1994. *Uncertainty and variability in human exposures to soil contaminants through home-grown food: a Monte Carlo assessment*. Risk Anal. 14(4):449-463.

National Research Council of Canada (NRCC). 1983. *Radioactivity in the Canadian Aquatic Environment*. 19250.

Oak Ridge National Laboratory (ORNL). 1976. *A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment*. Environmental Sciences Division Publication No. 660, March.

Pease, J.L., R.H. Vowles and L.B. Keith. 1979. *Interaction of Snowshoe Hares and Woody Vegetation*. J. Wildl. Manage. 43: 43-60.

Santschi, P.H. and B.D. Honeyman. 1989. *Radionuclides in Aquatic Environments Radiation*. Physics and Chemistry. Volume 34, No. 2.

SENES Consultants Limited (SENES) 1987. *Uranium Tailings Assessment Program (UTAP.3): Component Model Documentation.* Prepared for National Uranium Tailings Program, CANMET, EMR under Contract No. 23317-6-1728/01-SQ.

Sheppard, M.I. and D.H. Thibault 1990. *Default soil solid/liquid partition coefficients, K_Ds, for four major soil types: a compendium*. Health Physics, Vol. 59, No. 4, pp. 471-482.

Thomas, D.C. and S.J. Barry. 1991. *Microhistological Analyses of Caribou Diet: Fecal Versus Rumen Samples and Other Variables*. Pages 516-529 in Proc. Fourth North Amer. Caribou Workshop. C.E. Buttler and S.P. Mahoney (eds). Newf.-Lab. Wildl. Div., St. John's, Newfoundland.

Thomas, P.A. 1997. *The Ecological Distribution and Bioavailability of Uranium-Series Radionuclides in Terrestrial Food Chains: Key Lake Uranium Operations, Northern Saskatchewan*. Prepared for Environment Canada – Environmental Protection – Prairie and Northern Region, December.

Thomas, P.A., J.W. Sheard and S. Swanson 1994. *Transfer of Po-210 and Pb-210 Through the Lichen-Caribou-Wolf Food Chain of Northern Canada*. Health Physics, Vol. 66, No. 6, June, pp. 666-677.

United States Department of Commerce (U.S. DOC) National Technical Information Service (NTIS). 1985. *Selenium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*. Ronald Eisler, U.S. Fish & Wildlife Service. October.

United States Department of Commerce (U.S. DOC) National Technical Information Service (NTIS) 1988. *Arsenic Hazards to Fish, Wildlife, and Invertebrates: a synoptic review.* Ronald Eisler, U.S. Fish & Wildlife Service. January.

United States Department of Commerce (U.S. DOC) National Technical Information Service (NTIS) 1989. *Molybdenum Hazards to Fish, Wildlife, and Invertebrates: a synoptic review*. U.S. Patuxent Wildlife Research Center, Laurel, M.D. August.

United States Environmental Protection Agency (U.S. EPA). 1979. *Water-Related Environmental Fate of 129 Priority Pollutants, Volume 1*. EPA-4401 4-79-029a. Office of Water Planning and Standards, Washington, D.C.

United States Environmental Protection Agency (U.S. EPA). 1993. *Wildlife Exposure Factors Handbook*. EPA/600/R-93/187).

United States Environmental Protection Agency (U.S. EPA) 1996. *Particulate Matter: Air Quality Criteria.* EPA/600/AP-95/001. Research Triangle Park, NC: Environmental Protection Agency.

United States Environmental Protection Agency (U.S. EPA). 1998. *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*. Peer Review Draft. EPA 530-D-98-001.

United States National Council on Radiation Protection and Measurements (NCRP). 1996. *Screening Models for Release of Radionuclides to Atmosphere, Surface Water and Ground*. NCRP Report No. 123.

United States National Research Council (U.S. NRC) 1977. *Drinking Water and Health. Volume 1*. Washington, D.C. National Research Council, National Academy Press.

United States Nuclear Regulatory Commission (U.S. NRC) 1992. *Residual Radioactive Contamination from Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent*. NUREG/CR-5512.

Wales, R.A., L.P. Milligan and E.H. McEwan. 1975. *Urea Recycling in Caribou, Cattle and Sheep*. In First Int. Reindeer and Caribou Sympo. J.R. Luick, P.C. Lent, D.R. Klein and R.G. White (eds), Univ. Alaska, Fairbanks, pp. 297-307.

FINAL

APPENDIX B

HEALTH CANADA
TOXICOLOGICAL REFERENCE VALUES

Prepared by:
Dr. Mark Richardson

APPENDIX B: HEALTH CANADA TOXICOLOGICAL REFERENCE VALUES

Name	Non-Carcinogenic Toxicological Reference Values		Carcinogenic Toxicological Reference Values			
	HC TDI [a] mg/kg-d	HC TDC mg/m3	Oral slope factor from TD_{05} [b] $(mg/kg\text{-}d)^{-1}$	Inhalation slope factor from TC_{05} [b,c] $(mg/kg\text{-}d)^{-1}$	Inhalation unit risk from TC_{05} [b] $(mg/m^3)^{-1}$	Oral slope factor from DWQG [a] $(mg/kg\text{-}d)^{-1}$
Aldicarb	0.001					
Aldrin + dieldrin	0.0001					
Aniline	0.007 [b]					
Arsenic			2.8	2.80E+01	6.40E+00	1.7 [g]
atrazine + metabolites	0.0005					
azinphos-methyl	0.0025					
barium	0.016					
Bendiocarb	0.004					
Benzene				1.46E-02	3.30E-03	3.10E-01
Benzo(a)pyrene				1.37E-01	3.10E-02	2.30
Benzo(b)fluoranthene				8.20E-03	1.90E-03	
Benzo(j)fluoranthene				6.80E-03	1.60E-03	
Benzo(k)fluoranthene				5.50E-03	1.30E-03	
Bis(2-ehtyl-hexyl) phthalate	0.044 [b]					
Bis(Chloro-methyl) ether				4.13E+01	9.43E+00	
Boron	0.0175					
Bromoxynil	0.0005					
Cadmium	0.0008			4.29E+01	9.80E+00	
Carbaryl	0.01					
Carbofuran	0.01					
Carbon tetrachloride						4.90E-02
Chloramine, mono	0.048					
Chlorobenzene	0.43 [b]	0.01 [b]				
Chlorpyrifos	0.01					
Chromium, hexavalent	0.001			3.31E+02	7.58E+01	
Chromium, total	0.001			4.76E+01	1.09E+01	
Copper	0.03 [d]					
Cyanazine	0.0013					
Cyanide, free	0.02 [d]					
DDT	0.01 [e]					
Diazinon	0.002					
Dibutyl phthalate	0.063 [b]					
Dicamba	0.0125					
Dichlorobenzene, 1,2-	0.43 [b]					
Dichlorobenzene, 1,4-	0.11 [b]	0.095 [b]				
Dichlorobenzidine, 3,3'-			6.76E-02			

Name	Non-Carcinogenic Toxicological Reference Values		Carcinogenic Toxicological Reference Values			
	HC TDI [a] mg/kg-d	HC TDC mg/m3	Oral slope factor from TD_{05} [b] (mg/kg-d)$^{-1}$	Inhalation slope factor from TC_{05} [b,c] (mg/kg-d)$^{-1}$	Inhalation unit risk from TC_{05} [b] (mg/m^3)$^{-1}$	Oral slope factor from DWQG [a] (mg/kg-d)$^{-1}$
Dichloroethane, 1,2-			8.06E-03			7.50E-02 [h]
Dichloroethylene, 1,1	0.003					
Dichloromethane	0.05 [b]			9.90E-05	2.30E-05	7.90E-05
2,4-D	0.01					
Dichorophenol, 2,4-	0.1					
Diclofop-methyl	0.001					
Dimethoate	0.002					
Dinoseb	0.001					
Diquat	0.008					
Diuron	0.0156					
Fluoride, inorganic	0.122					
Glyphosate	0.03					
Hexachlorobenzene	0.0005 [b]		8.33E-01			
Indeno(1,2,3-cd)pyrene				1.62E-02	3.70E-03	
Lead	0.0035					
Malathion	0.02					
Mercury, inorganic (ionic)	0.0003 [d]					
Methoxychlor	0.1					
Methyl methacrylate	0.01 [b]	0.037 [b]				
Metolachlor	0.005					
Metribuzin	0.0083					
Monochlorobenzene	0.0089					
Nickel chloride	0.0013 [b]					
Nickel oxide		0.00002 [b]				
Nickel subsulphide		0.000018 [b]				
Nickel sulfate	0.05 [b]	0.0000035 [b]				
Nickel, metallic		0.000018 [b]				
Nickel, oxidic				5.47E+00	1.25E+00	
Nickel, soluble				3.13E+00	7.14E-01	
Nickel, sulphidic						
Nitrilotriacetic acid (NTA)	0.01					
Paraquat (as dichloride)	0.001					
Parathion	0.005					
Pentachlorobenzene	0.001 [b]					
Pentachlorophenol	0.006					
Phenol	0.06 [d]					
Phorate	0.0002					
Picloram	0.02					
PCBs	0.001					
PCDD/PCDF	1.00E-08 [b]					

Name	Non-Carcinogenic Toxicological Reference Values		Carcinogenic Toxicological Reference Values			
	HC TDI [a] **mg/kg-d**	**HC TDC** **mg/m3**	**Oral slope factor from TD_{05} [b]** **(mg/kg-d)$^{-1}$**	**Inhalation slope factor from TC_{05} [b,c]** **(mg/kg-d)$^{-1}$**	**Inhalation unit risk from TC_{05} [b]** **(mg/m^3)$^{-1}$**	**Oral slope factor from DWQG [a]** **(mg/kg-d)$^{-1}$**
PCDD/PCDF	2.3E-09 [g]					
Simazine	0.0013					
Styrene	0.12 [b]	0.092 [b]				
Terbufos	0.00005					
Tetrachlorobenzene, 1,2,3,4-	0.0034 [b]					
Tetrachlorobenzene, 1,2,3,5-	0.00041 [b]					
Tetrachlorobenzene, 1,2,4,5-	0.00021 [b]					
Tetrachloroethylene	0.014 [b]	0.36 [b]				
Tetrachlorophenol, 2,3,4,6-	0.01					
Toluene	0.22 [b]	3.8 [b]				
Trichlorobenzene, 1,2,3-	0.0015 [b]					
Trichlorobenzene, 1,2,4-	0.0016 [b]	0.007 [b]				
Trichlorobenzene, 1,2,5-	0.0015 [b]	0.0036 [b]				
Trichloroethylene			2.50E-04	2.70E-03	6.10E-04	
Trichlorophenol,2,4,6-						2.00E-02
Trifluralin	0.0048					
Uranium (non-radiological)	0.0006 [d]					
Vinyl chloride						2.60E-01
Xylene, mixed isomers	1.5 [b]	0.18 [b]				

Notes:

a – from Canadian Guidelines for Drinking Water Quality, Supporting Documentation, unless otherwise indicated.

b – from HC, 1996

c – inhalation slope factor derived assuming 24 hour adult inhalation rate of 16 m^3/24 hours (Allan and Richardson, 1998; Richardson, 1997) and an adult body weight of 70.7 kg (Richardson, 1997)

d – from CCME Soil Quality Guidelines and supporting documentation on health-based guidelines prepared by Health Canada

e – WHO/FAO Joint Meeting on Pesticide Residues (the Food Directorate, Health Canada, generally endorses and applies the TDIs for pesticide residues derived by the JMPR)

f – Grant, D.L. 1983 (this TDI is still applied by Health Canada for the assessment of PCB exposure from foods and other sources)

g – Officially, the Health Canada TDI for PCDD/PCDF is 10 pg/kg-d; however the WHO/FAO Joint Expert Committee on Food Additives and Contaminants recently proposed a revised TDI of 2 pg/kg-d. The Food Directorate, Health Canada, generally endorses and applies the TDIs for food contaminants derived by the JECFA and it is anticipated that this revised TDI will be implemented. Therefore, it is recommended that SLRAs for PCDD/PCDF in Canada employ this more conservative TDI.

h – although the TRV from the Canadian Drinking Water Quality Guidelines Supporting Documentation is presented, it is recommended that the comparable TRV from the more recent assessment (HC, 1996) be employed for risk characterization.