SUDBURY AREA RISK ASSESSMENT

VOLUME II – CHAPTER 2
PHASE 1: PROBLEM FORMULATION AND SLRA

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2.0 PHASE 1: PROBLEM FORMULATION AND SLRA

Phase 1 of the Human Health Risk Assessment (HHRA) laid the foundation for the entire assessment process by outlining the key issues to be addressed and the process the HHRA would follow to successfully achieve the objectives of the study. The two primary elements of Phase 1 are: i) Problem Formulation; and ii) Screening Level Risk Assessment (SLRA).

Beyond delineating the physical and temporal dimensions of the Study Area, the Problem Formulation step identified chemicals of concern, receptors and exposure pathways, as well as uncertainties and data gaps that needed to be addressed. Where significant and relevant data gaps were found, Phase 2 sampling and analysis activities were conducted to provide sufficient information to address and/or fill these gaps.

It should be noted that the initial identification of chemicals of concern (COC) and communities of interest (COI) was conducted by the Ontario Ministry of the Environment (MOE) and other Technical Committee (TC) stakeholders during the initial phases of the Sudbury Soils Study. The reader is referred to Volume I for detailed information related to the selection of COC and study area definition.

2.1 Problem Formulation

The first step in any HHRA process is an information gathering and interpretation stage that plans and focuses the approach of the study on critical areas of concern for the site or area being evaluated. Problem formulation defines the nature and scope of the work to be conducted, permits practical boundaries to be placed on the overall scope of work and ensures that the assessment is directed at the key areas and issues of concern. This step is critical to the success of a risk assessment. Careful planning during the problem formulation step reduces the need for significant modifications once the risk assessment has begun. The data gathered and evaluated in this step provides information on the physical layout and characteristics of the study area, possible exposure pathways, potential human receptors, COC and any other specific areas or issues of concern to be addressed.

The key tasks requiring evaluation within the problem formulation step include the following:

Site characterization – delineation of study area, and review of available site data to identify factors affecting the availability of contaminants to potential receptors, such as location and medium of contamination (Section 2.1.1);

Identification COC – identification of the primary COC based on site environmental monitoring data (Section 2.1.3);

Receptor characterization – identification of "receptors of concern", including those with the greatest probability of exposure to chemicals from the site and those that have the greatest sensitivity to these chemicals (Section 2.1.4); and

Identification of exposure pathways – consideration of various factors that influence the means by which receptors come into contact with COC in environmental media, including: chemical-specific parameters, such as solubility and volatility; characteristics of the site, such as physical geography, geology, and hydrogeology; as well as the physiology and behaviour patterns of the receptors (Section 2.1.5).

The outcome of these tasks form the exposure scenarios (Section 2.1.6), which are the basis of the approach taken in the risk assessment; define the scope of the HHRA; and, ensure that the concerns of all stakeholders are adequately addressed. Stakeholder consultation is a critical component of the problem formulation step. During the problem formulation phase, there was considerable dialogue with members of the Sudbury community, local stakeholders and the Technical Committee to help focus and define the scope of the Study. Input from the public was sought during a series of workshops, open houses and public lectures. The extent of the public participation and stakeholder consultation process is described in detail in Volume I.

2.1.1 Site Characterization

Site characterization typically includes the following activities:

- Establishment of spatial and temporal boundaries;
- Site visit(s) and reconnaissance;
- Review of past site reports/investigations;
- Interviews with persons knowledgeable about the site;
- Description of the physical characteristics of the site (*e.g.,* geology, hydrogeology, and general topography);
- Consideration of historical and potential future land uses; and
- An overview of site regulatory status (*e.g.,* classifications of site by regulatory agencies, description of agreements, compliance issues, *etc.),* if applicable.

The focus of the current assessment is the Greater Sudbury Area (GSA), located in Northern Ontario, including the City of Greater Sudbury and the surrounding region (approximately 40,000 km^2) located just south of the Sudbury Basin in the core of the Canadian shield in Northern Ontario. The Sudbury Basin is an elliptically shaped geological structure framed by a rock formation rich in mineral deposits, surrounding a large flat area known as "The Valley". The Sudbury Basin is approximately 27 km long and 21 km wide, and has been the primary physical influence on the settlement of the Sudbury area (Saarinen and Tanos, 2002).

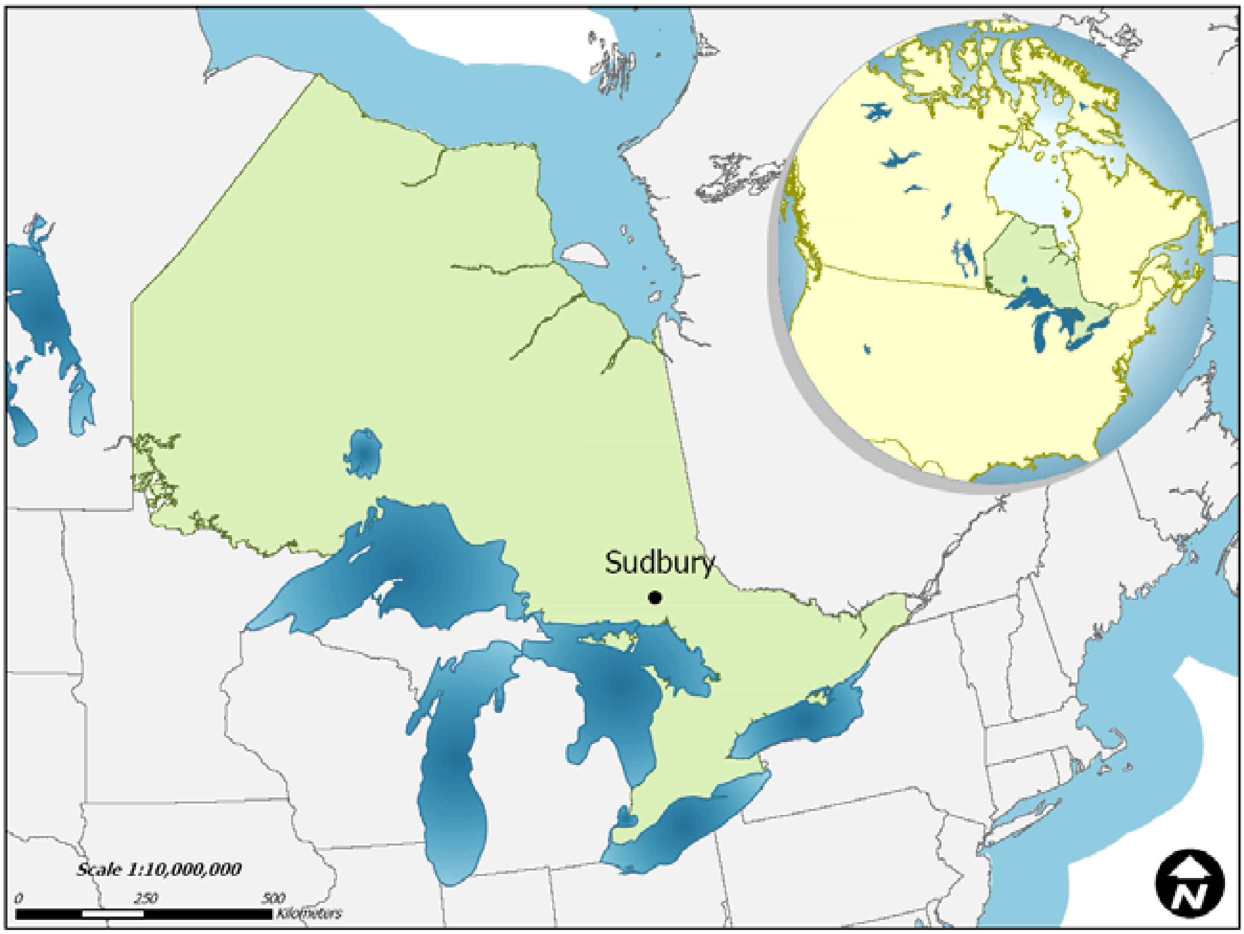

Figure 2-1 Location of Sudbury Basin within Ontario

The Sudbury Basin is rich in mineral deposits and has been a prime area in Ontario for mining and processing of minerals for more than a century (Pearson *et al.*, 2002). However, it is the ore transportation, smelting and refining operations in the GSA that have generated concern regarding the levels of various metals in the environment and their impact on terrestrial and aquatic ecosystems, and human health.

2.1.1.1 Delineation of Study Area

The temporal and spatial boundaries of the study area were determined by several factors. The temporal boundary of the study area was defined as the current and future conditions in the GSA. The spatial boundary of the study area included the politically-defined borders of the City of Greater Sudbury and the surrounding area from which soil samples were collected for metal analyses in 2001 as part of the first phase of the Study (CEM, 2004). Remote and undisturbed areas surrounding the City of Greater Sudbury were included in the study area in order to determine the geographical area impacted by the smelters and to provide background metal concentrations (see Volume I).

Sampling of soils for the Study was undertaken in 2001 under the direction of the MOE and the smelting companies (Inco and Falconbridge). The MOE focused on collecting soils from urban areas within the boundaries of the City of Greater Sudbury (MOE, 2003). The companies retained the services of the Centre for Environmental Monitoring (CEM) at Laurentian University, and Golder Associates Ltd. to complete the remainder of the sampling. CEM was contracted to design and undertake a regional soil sampling survey to help define the spatial limits of the "soil footprint" formed by atmospheric deposition of particulate associated metals and metalloids from the three smelting centers at Copper Cliff, Coniston and Falconbridge (CEM, 2004). Golder Associates collected additional soil samples within the Town of Falconbridge (Golder Associates, 2001). Details on the number of soil samples, collection methods and locations are provided in the referenced reports.

The regional soil survey undertaken by CEM covered the broadest geographic area and was used to define the total sampling area for this study (see regional soil survey map in CEM, 2004). The sampling grid designed by CEM covered an area of approximately 200 km by 200 km (40,000 km^2), with the centre of the grid in the vicinity of the Copper Cliff smelter. Data from all soil samples collected in this investigation were used in the statistical analysis of soil chemistry results to select COC, to describe existing soil conditions, and to attempt to quantify "background" metal concentrations specific to the Sudbury area.

There are benefits to evaluating human health risks for a single large, defined area *versus* considering numerous small parcels of land within the GSA (*i.e.,* several site-specific risk assessments or SSRAs). The SSRA approach is designed to evaluate risks in an individual property setting, and would be impractical given the size of the study area and scope of the current assessment. Unlike the SSRA approach, an area-wide risk assessment allows for:

- Consideration of relevant geographic areas for key receptors of concern;
- Assessment of possible health risks to a broader population base;

- Development of risk management options that do not stop at a specific property's borders; and
- Potential development of a single risk management plan, if required, rather than the development of numerous separate plans.

The area-wide approach does require the collection of a significant amount of data, from a variety of exposure media, across a larger geographical area. This results in significantly greater time and cost implications for completion of a study with this scope. The area-wide approach to risk assessment has been used at other mining and smelter-impacted communities in Canada such as Trail, B.C., and Port Colborne and Deloro, Ontario (Hilts *et al.*, 2001; JWEL, 2004; CEI, 1999).

2.1.1.2 Historical Meteorological Data for the GSA

A primary consideration when evaluating the potential impacts of emissions from the current-day and historical smelter operations within the GSA is how wind direction and wind speed affect deposition of particulate-bound COC in the various communities of interest. As such, the following summary is provided to illustrate any meteorological trends, which may influence the concentration and speciation of specific COC (refer to Chapters 3 and 4 for further discussion of these topics).

Meteorological data are collected in a number of locations throughout the Sudbury area, including the Sudbury airport, and the Vale Inco and Xstrata Nickel operations in Copper Cliff and Falconbridge, respectively (as part of their ongoing emissions monitoring and modelling exercises for regulatory compliance purposes). The current summary is based upon wind speed and direction data collected at the Xstrata Nickel facility (Butler, 2006 pers. comm.) on an hourly basis for a recent five year period (*i.e.*, 2001 to 2005). Note that this information is only provided for illustrative purposes, and has not been used quantitatively in the current risk assessment.

The typical approach to providing a descriptor for wind direction is through the use of a wind rose depicting the direction of the wind based upon compass degrees, like that shown in Figure 2-2. The average wind direction over this five-year time period was 191.1 ± 97.2°, which corresponds to a wind originating approximately from the NNE, ranging between WNW and ESE. However, this average is somewhat misleading, as it is more representative of the fact that wind direction is typically well spread out among all compass directions throughout the year (see discussion below). The average wind speed from any direction was 18.6 ± 8.9 km/hr.

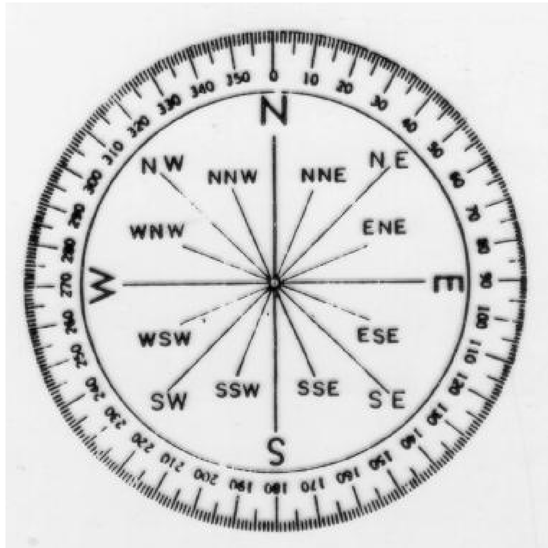

Figure 2-2 Compass Rose depicting Wind Directions

For the current discussion, wind direction has also been divided into four specific compass sections indicating the direction from which the wind was blowing: SW (south-west) for 0 to 90°**;** NW (north-west) for 90 to 180°**;** NE (north-east) for 180 to 270°; and, SE (south-east) for 270 to 360°.

Over the past five years in Sudbury the wind originated from the NE 36% of the time, with an average speed of 19.7 ± 8.9 km/hr and 24% of the time from the SE at 19.4 ± 9.5 km/hr. The wind blew from the SW 21% of the time with a speed of 17.6 ± 8.3 km/hr and 19% from the NW at 16.6 ± 8.4 km/hr.

Seasonal trends in wind direction occurred over the evaluated five year period, despite yearly variations (see Figure 2-3). The wind originated from the NE predominantly during the summer and early fall (May to November). The highest occurrence of wind originating from the SW occurred during the spring (March to June) and from the SE during the fall and winter (October to February). No significant pattern in average wind speed was observed.

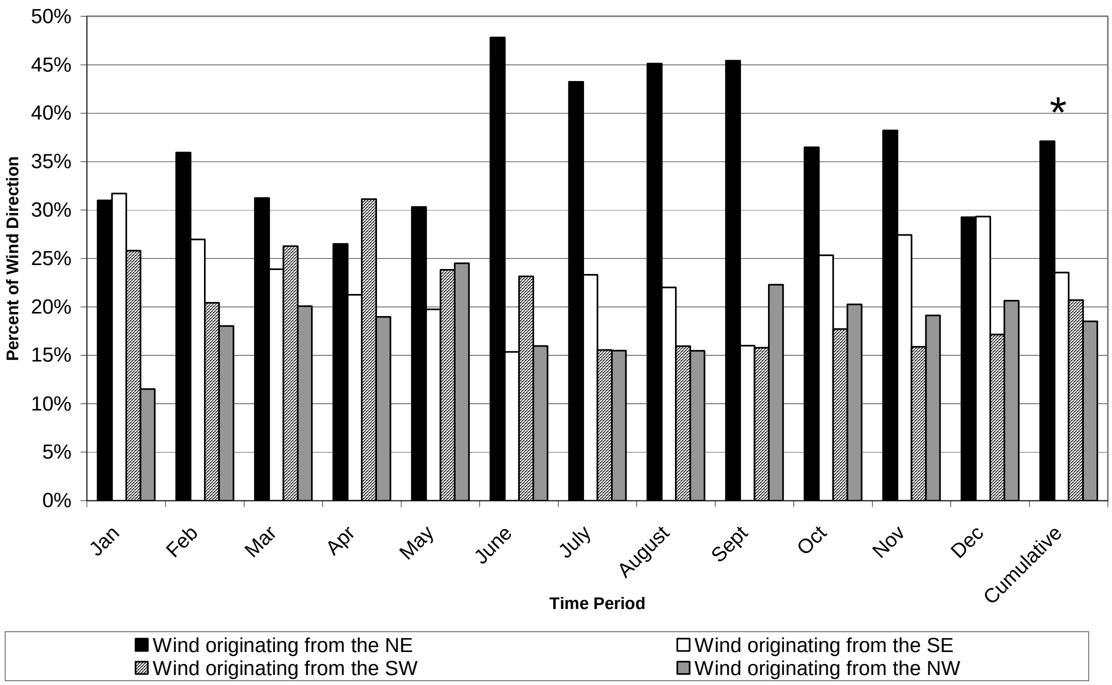

Figure 2-3 Wind direction incidence (NE, SE, SW, and NW) in the GSA between 2001 and 2005

For the purpose of the current discussion, and for use as part of the speciation analyses, wind direction has also been categorized into east *versus* west. In other words, wind direction was classified as originating from the east (>180 to <360°) or west (0 to <180°). Over the assessed five year period, the wind originated from the east 61% of the time with an average speed of 19.6 ± 8.4 km/h, and from the west 39% of the time blowing at an average speed of 17.1 ± 9.1 km/h.

Despite yearly variation in wind patterns, the wind always blew from an easterly direction at the highest frequency during the summer months (June to September) (see Figure 2-4). Conversely, the highest incidence of wind originating from the west occurred during the spring (March to May). No significant differences were observed between average wind speeds.

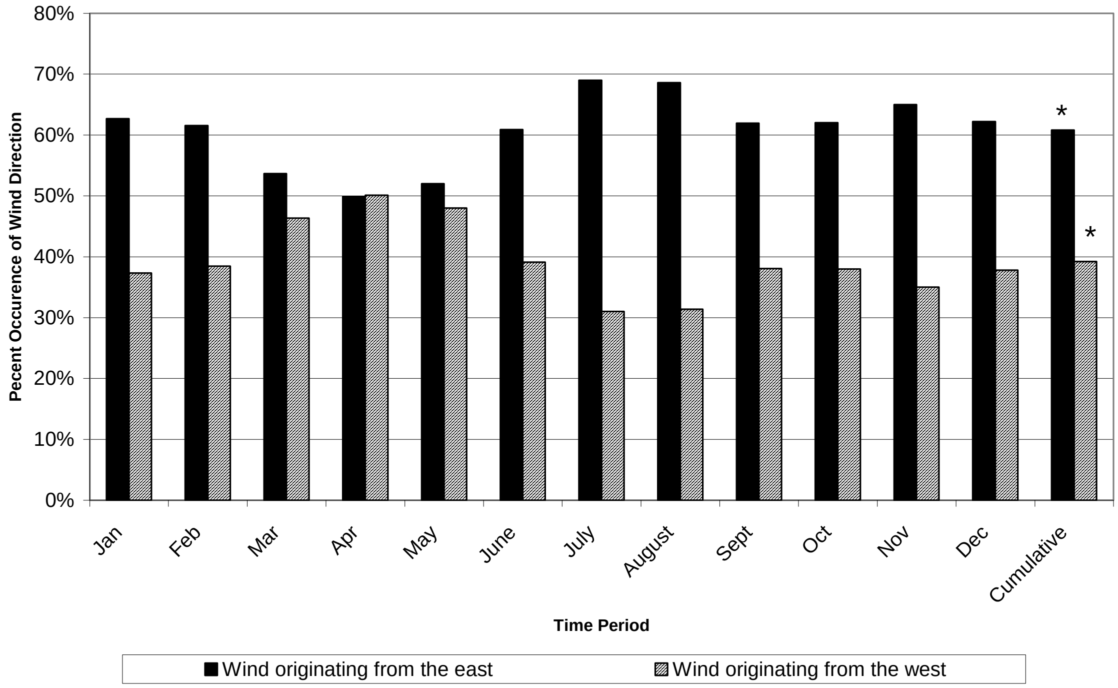

Figure 2-4 Wind Direction Incidence (east *versus* west) in the GSA between 2001 and 2005

2.1.2 Existing Information Review

A comprehensive literature search was performed to determine the current state of knowledge relating to metals in the GSA. Studies and reports were identified and reviewed in detail to determine their potential relevance to the current HHRA. The initial search effort involved the identification of applicable studies from existing collections of local human health and environmental quality research documents. These collections are housed in various locations throughout Sudbury and Ontario including the MOE, City of Greater Sudbury, Sudbury & District Health Unit, Sudbury Public Library and local educational institutions including the J.N. Desmarais Library and the Centre for Environmental Monitoring (CEM) at Laurentian University. A literature search of relevant peer-reviewed journals, dissertations, government publications and databases was conducted using selected keywords and concepts developed in collaboration with team members to ensure that the most effective search strategies possible were used. Searches focused on the COC (*i.e.,* nickel, copper, cobalt, arsenic, lead and selenium) in the aquatic and terrestrial environments, atmospheric deposition of these substances and their human health effects. Searches were also conducted to identify recent literature pertinent to conducting HHRAs in smelter-impacted communities in general, as well as gathering additional information on important issues and supplemental studies conducted to fill identified data gaps within the assessment.

Some of the key literature databases searched included the following:

- Biological Abstracts;
- Canadian Government Resources and Databases;
- Canadian Research Index and Conference Papers Index;
- Environmental Sciences and Pollution Management;
- Toxline;
- Medline/PubMed;
- UMI Library of Dissertations and Theses;
- TOXNET (cluster of databases on toxicology, hazardous chemicals and related areas); and
- CESARS (Chemical Evaluation Search and Retrieval Database)

Those studies identified as being applicable to the HHRA were reviewed in detail by the study team and entered in the SARA Group library database. The database can be easily exported into "csv" files and imported into other databases such as MS Excel, MS Access, Imagic DBtext Works and other reference managing software.

2.1.3 Identification of COC

It is common practice in HHRA to limit the number of chemicals evaluated to those chemicals that, due to their environmental concentrations, distribution, or chemical and toxicological properties, have the greatest potential to contribute to health risks to individuals residing in the study area. However, it is important to note that the identification of a substance as a chemical of concern (COC) does not automatically lead to the conclusion that the substance is, in fact, a contributor to health risk. Rather, the appropriate conclusion is that those substances identified as COC should be the subject of further evaluation. This is done because it is impractical in terms of time and cost to conduct a risk assessment for every chemical that has been found to occur in a particular area. In addition, the concentrations of many chemicals associated with a particular site may be similar to chemical concentrations found naturally in the area, rather than as a result of current or former activities on a site.

The identification and selection of COC is a multifaceted approach that typically involves a detailed review of:

- Site-specific analytical chemistry data;
- Previous environmental site investigation reports; and

- Physical-chemical properties, environmental fate characteristics, and toxic potency of the chemicals.

The application of chemical screening techniques is required and typically employs professional judgement in addition to considering key exposure scenarios, pathways, routes and potential human receptors. The selection process for identifying COC for this study is described in Chapter 8 of Volume I. A brief overview of the selection process is provided here.

Soil sampling programs have been conducted by the MOE, the mining companies, and various researchers in the Sudbury region since 1971, to determine the concentrations of metals in soils and vegetation. Following the 2001 Soil Sampling Study (refer to Chapter 7 of Volume I for further details), the accumulated sampling data was compiled in one master database (the *2001 Soil Sampling Database*) for further analyses. Further information on site-specific analytical chemistry data can be found in SARA (2004).

As part of the first phase of the Study, the Technical Committee identified four elements, which met the criteria as COC set forth by the committee to be carried forward in the assessment. These were: arsenic, copper, cobalt, and nickel. As part of the problem formulation step of both the HHRA and ERA, additional statistical screening of the 2001 soil sampling database was conducted to determine whether any other candidates should be added to the list of COC. Candidate COC were selected from a list of 20 inorganic parameters, which were measured in soil samples collected in the 2001 sampling program.

The following three criteria were established as requirements for a particular chemical to be considered a COC in soil:

- Chemical concentration in soil must be above the MOE Table A soil remediation guideline for a residential/park land use (MOEE, 1997);
- Chemical must be present at elevated levels in soils across the study area; and
- Chemical must be scientifically demonstrated to originate, at least in part, from the local mining/smelting operations.

As a result of the statistical screening of the 2001 soil database, lead and selenium were also identified as candidate COC. Therefore, these two chemicals were added to the established list, bringing the total of COC recommended for further assessment in the HHRA to six. Metal concentrations in additional media (*i.e.*, air, water, food, dust) subsequently collected to fill identified data gaps (see Chapter 3) were also compared with regulatory and SARA-specific screening criteria (*i.e.*, vegetable garden survey screening criteria). However, no additional COC were included beyond those already established using soil screening criteria. Therefore, the following COC were carried forward for detailed assessment in the HHRA: arsenic, copper, cobalt, lead, nickel, and selenium.

2.1.4 Receptor Identification and Characterization

The receptor identification and characterization step involves the recognition of Communities of Interest (COI) and persons within these communities who may be affected by chemical exposures originating from within the study area. Special attention is afforded to susceptible individuals or sensitive or potentially higher exposed subpopulations (*e.g.*, infants and young children, the elderly, individuals with compromised health, members of First Nation communities).

2.1.4.1 Communities of Interest (COI) for the Sudbury Soils Study

As part of the analyses in Phase 1 of the Study, the Technical Committee clearly identified Copper Cliff, Coniston and Falconbridge as the three primary COI. Other potential candidates were also evaluated as potential COI in the problem formulation step of the HHRA including:

- Sudbury Center;
- Gatchell;
- Garson;
- Lively;
- Hanmer; and
- The First Nation communities of Whitefish and Wanapitei.

From the perspective of the HHRA, the definition of a COI is closely related to the objectives of the HHRA. Two of the key goals of the GSA HHRA that were considered during the identification of additional COI were to:

- Assess whether human health in the GSA is currently, or in the future will be, adversely affected by elevated metal levels in the soil, and other local environmental media, impacted by historic and/or present day particulate smelter emissions (this goal does not include an evaluation of past health impacts, rather it focuses on historic emissions and related impacts now and into the future); and

- Establish soil intervention levels (*i.e.*, site-specific remediation goals or clean-up criteria) and/or other risk management options (*e.g.*, decreasing bioavailability of metals, blocking exposure pathways) protective of human health, now and into the future, if required.

The definition of COI relates to this second objective in that the intervention levels and risk management activities must apply on an area-wide basis; however, in cases where there are distinct differences in a particular community, a unique intervention level may be established or other risk management activities implemented for that community.

Differences that may influence an intervention level or implementation of a particular risk management activity for a specific community can include, but are not limited to, the following:

- Unique secondary media concentrations (those not directly related to soil concentration; *i.e.,* air, water, fish, food);
- Unique exposure pathways;
- Unique receptor behaviours (increased sensitivity, increased exposure); and,
- Unique media characteristics (*e.g.,* pH, soil organic carbon content, *etc*.).

The most likely of these factors to influence the ultimate soil intervention levels or other risk management activities established through the Study is secondary media concentrations (*e.g.*, vegetable gardens, potable water, *etc*.). For example, since different communities in the GSA have different drinking water sources (surface and ground), exposures related to the drinking water pathway differed between many of the communities. Additionally, air monitors were installed in a number of the communities within the GSA allowing community-specific air concentrations to be established. Typically, as secondary media concentrations vary, the allocation of exposure available for the soil intervention level will vary, potentially resulting in community-specific intervention levels.

In addition to the three primary COI (*i.e.*, Copper Cliff, Coniston, and Falconbridge), Hanmer and Sudbury Centre were selected from the list of possible COI based on the criteria described previously and the unique characteristics of each of the two communities. Sudbury Centre represents the greatest population of residents in the GSA. This COI is clearly defined by municipal borders and is located in the core of the GSA in the vicinity of current and historical smelter activities. Hanmer is also clearly defined geographically, and although part of the GSA, is not in close proximity to the smelter activities.

Based upon the evaluation of available data, the following communities were selected as COI for ongoing assessment in the current HHRA:

- Copper Cliff;
- Coniston;
- Falconbridge;

- Sudbury Centre (the 'core' and surrounding urban areas making up the original town of Sudbury); and
- Hanmer.

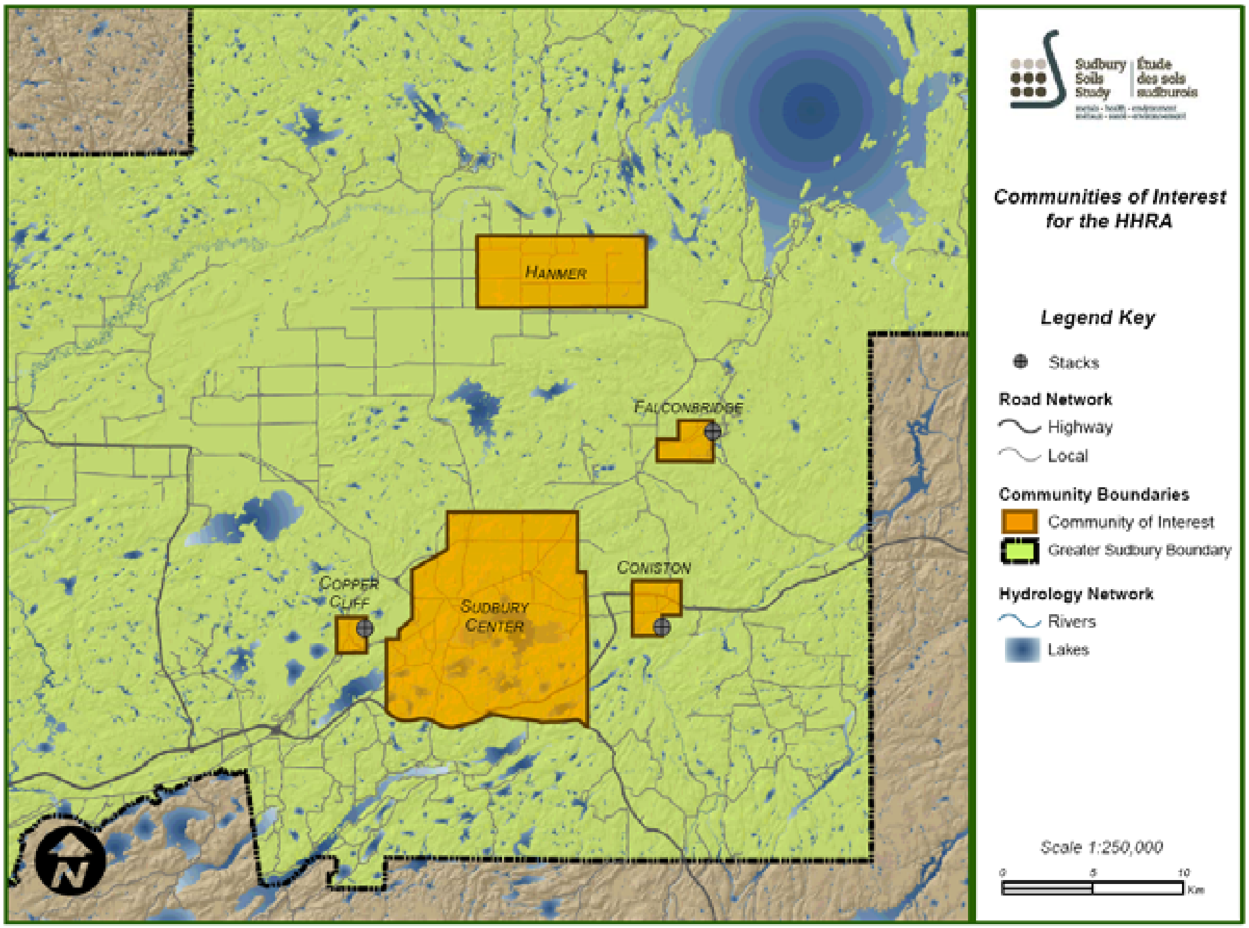

Figure 2-5 Map of the Communities of Interest (COI) for the Sudbury HHRA

As noted previously, the communities of Copper Cliff, Coniston, and Falconbridge were initially selected as COI because they are the locations of historic and ongoing smelting activities within Sudbury. Sudbury Centre represents the largest area of residential occupation within the GSA and is central to potential deposition from each of the smelters (depending on wind direction). Finally, Hanmer was selected as a nearby area that is not impacted by deposition from the existing smelters based on the concentration of COC measured in soil in the community. In addition, air dispersion modeling demonstrated little deposition in this area (refer to Appendix F for further discussion of this point). Therefore, Hanmer was used in the current study to represent a non-smelter exposed GSA community for comparative purposes.

Figures 2-6 through 2-10 provide a more detailed delineation of the established Communities of Interest for the current Study.

Potential exposures of First Nation community members are addressed in the current assessment by evaluating risks related to the unique activities and lifestyle of First Nation peoples living within the established COI, rather than assessing either Whitefish or Wanapitei communities as a unique COI. The Whitefish and Wanapitei communities are located further from the historical smelters than the established COI, and soil concentrations of the COC are lower at these distances (see Volume I). Therefore, exposures experienced by First Nation members living in one of the established COI, but partaking in traditional First Nation activities, would be expected to be greater than those experienced by individuals living in either of the two established First Nation communities. In other words, they would experience both the potentially higher exposures expected by living in the COI, as well as the different exposures related to the traditional dietary habits of a First Nation member. Therefore, this approach was considered conservative and protective in evaluating potential health risks to members of the First Nation community living within the Sudbury area.

A background community/typical Ontario resident (TOR) was also evaluated for comparative purposes, based on available data from various regulatory and published scientific sources. Further details on the criteria used to select the COI are provided in Volume I of this Study.

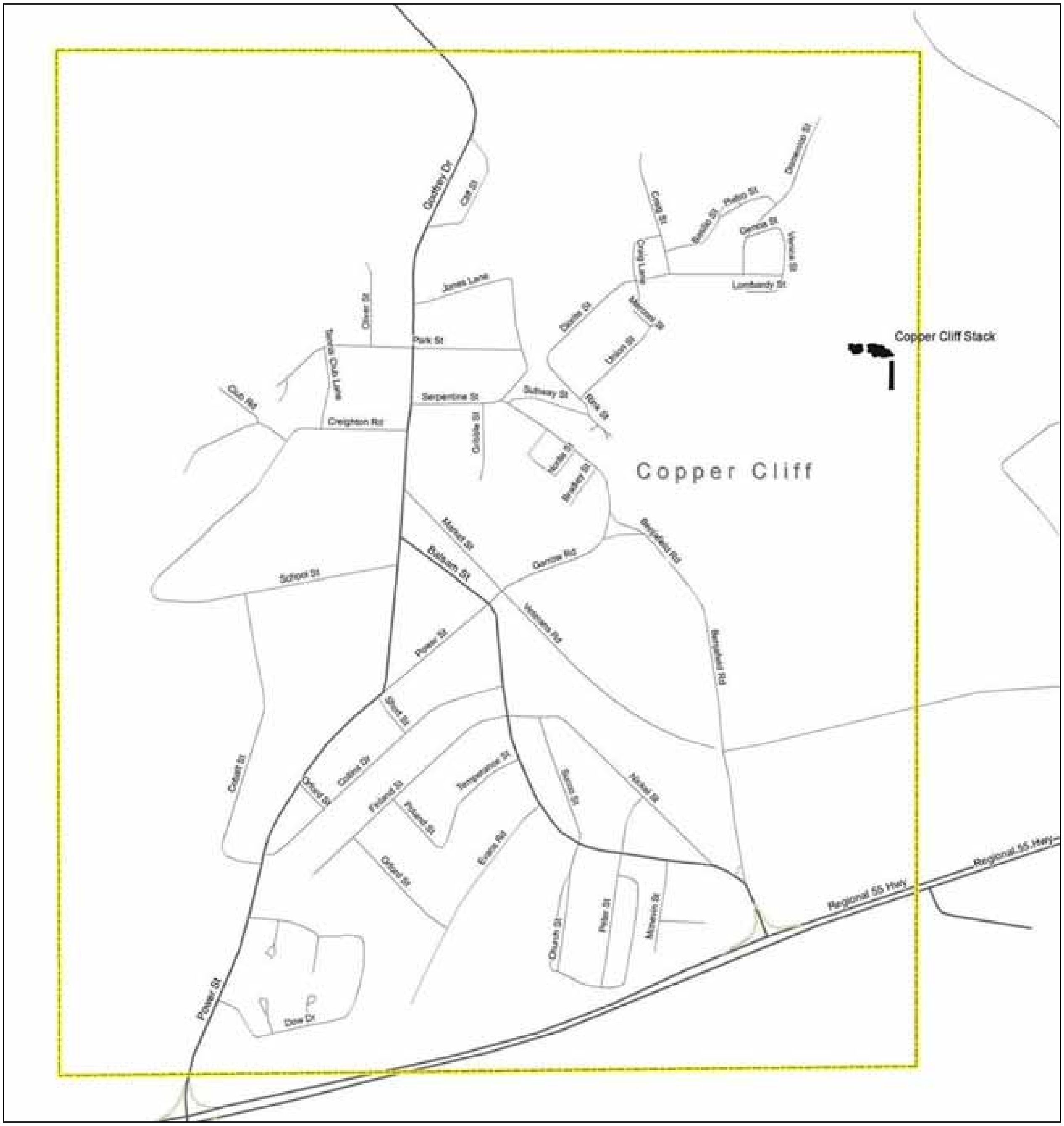

Figure 2-6 Map of the *Copper Cliff* Community of Interest

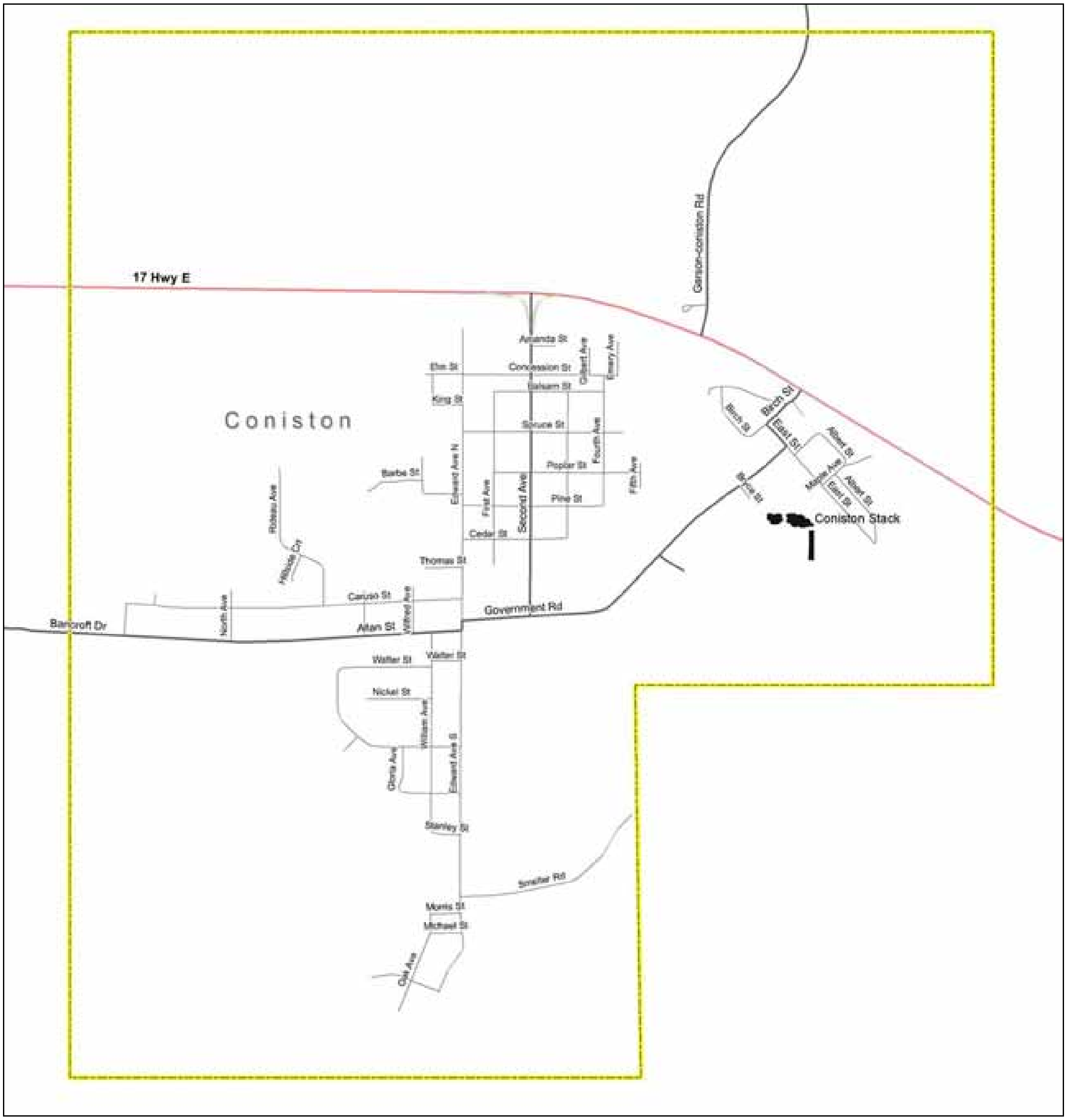

Figure 2-7 Map of the *Coniston* Community of Interest

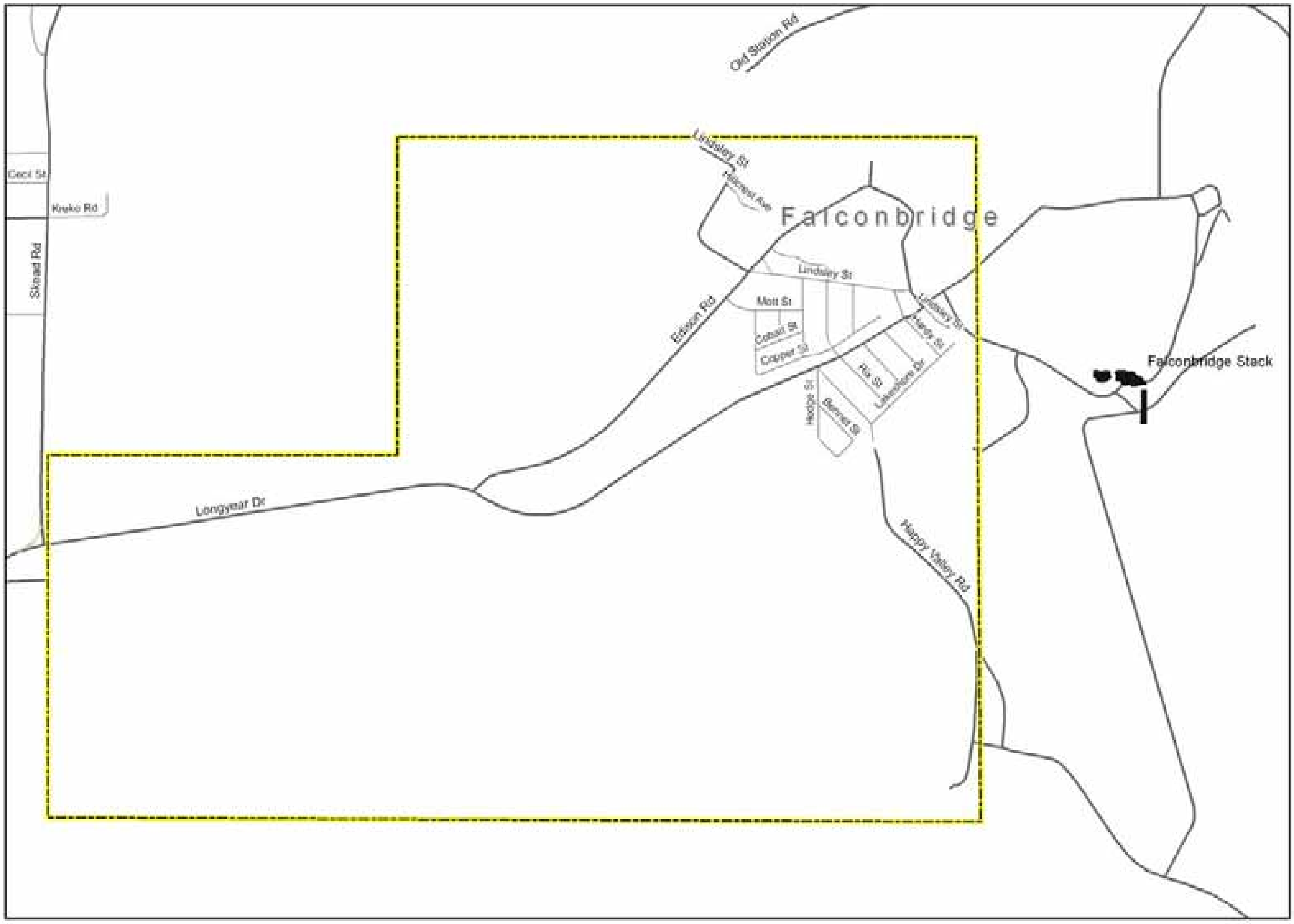

Figure 2-8 Map of the *Falconbridge* Community of Interest

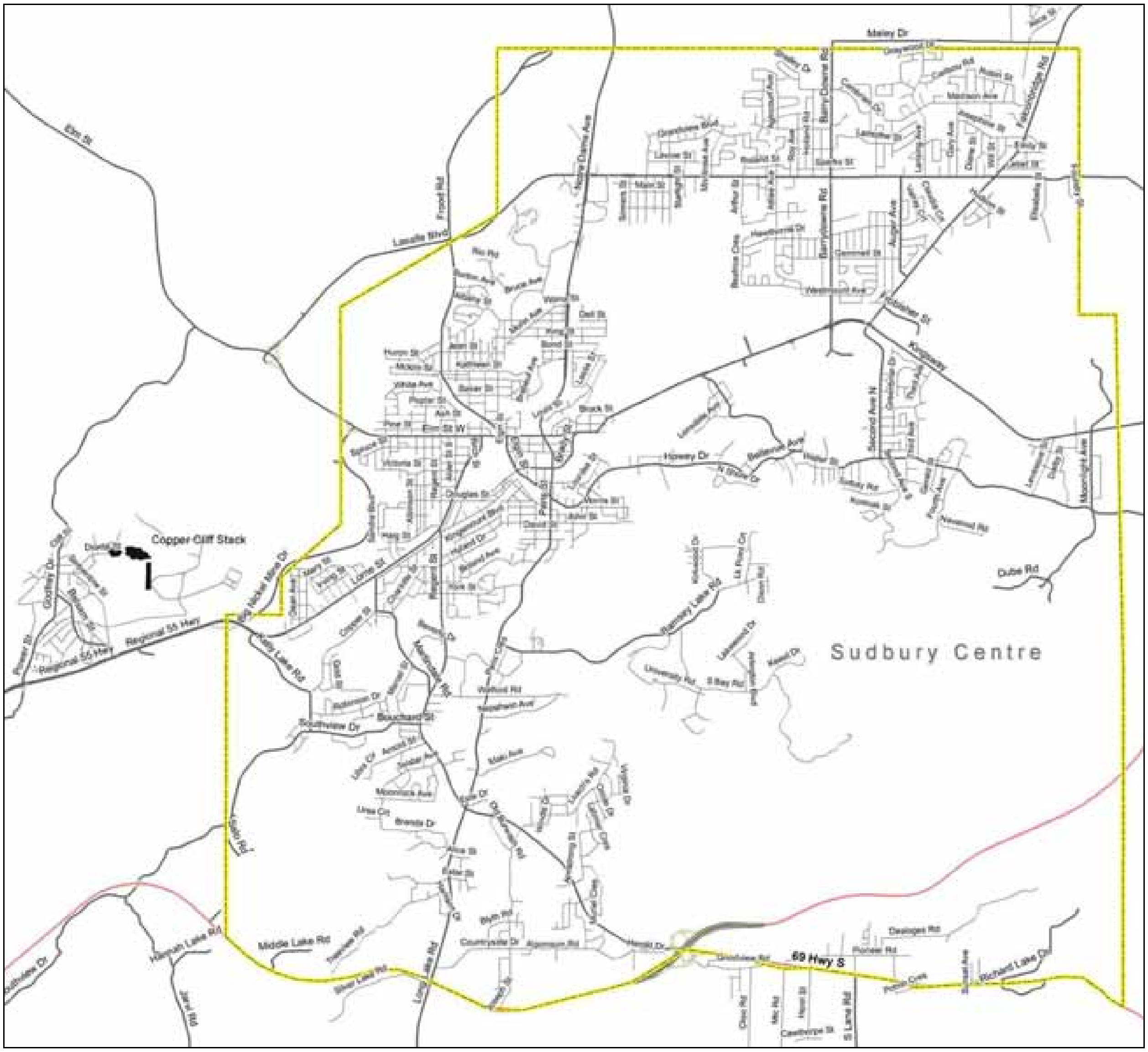

Figure 2-9 Map of the *Sudbury Centre* Community of Interest

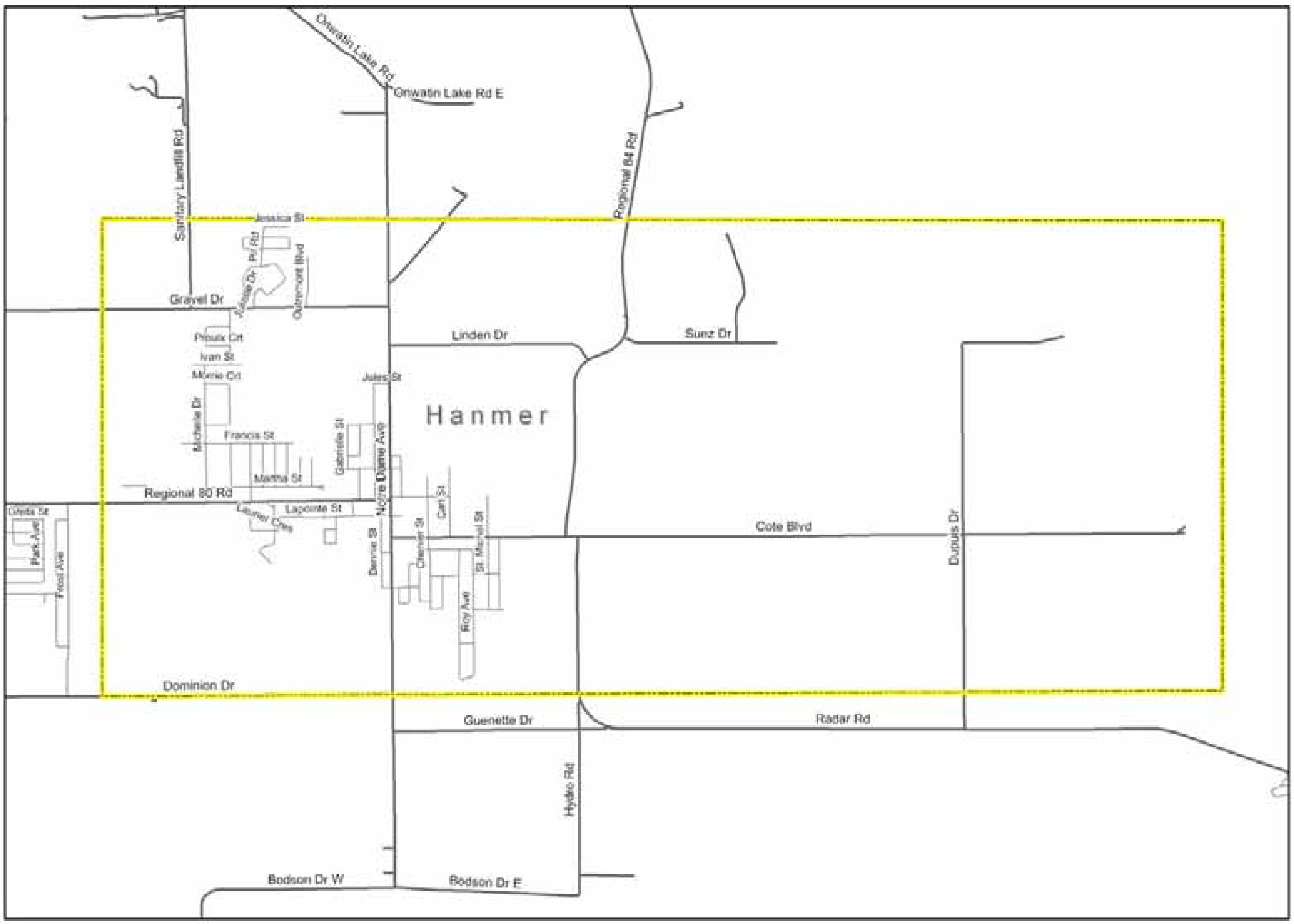

Figure 2-10 Map of the *Hanmer* Community of Interest

2.1.4.2 Human Receptors within the COI

A human receptor is any person who resides, visits, or works in the area being investigated and is, or could potentially be, exposed to COC. It is important to note, however, that occupational exposure to the COC and associated risk is not evaluated in this HHRA (see Section 6.3). General physical and behavioural characteristics specific to the receptor type (*e.g.,* body weight, breathing rate, amount of food consumed, *etc*.) are used to estimate the amount of chemical exposure received by each receptor. Due to differences in physiological characteristics and activity patterns between children and adults and between males and females, the exposures received by a female child, a male child, a female adult or a male adult are somewhat different. Consequently, the potential risks estimated for the same COC may differ depending on the receptor chosen for evaluation.

Human receptors are typically selected such that the most sensitive and/or most exposed individuals are represented. Consideration was given to such characteristics as body weight, breathing rate, dietary habits and daily activity pattern (*e.g.,* time spent at a work place, and time spent at home either indoors or outdoors). Chemical sensitivity, as a function of either physiological maturity or personal afflictions, which could compromise an individual's ability to effectively cope with otherwise harmless levels of exposure, was also considered. For example, because small children are in a state of rapid growth and still immature in terms of development, they are often more sensitive then adults to certain chemicals in their environment.

For the current comprehensive risk assessment, male and female receptors in each of the following five life stages were evaluated to predict risks associated with exposure to COC:

- Infant (0 to < 6 months);
- Preschool child (6 months to < 5 years);
- Child (5 years to 11 years);
- Adolescent (12 to 19 years); and,
- Adult (20 years and over).

The toddler is considered to be the life stage most exposed to chemical in soil due to their habit of playing and crawling on the ground or floors, and hand to mouth activities.

Chemicals considered to be carcinogenic must be evaluated over an appropriate period of time (*i.e.,* a lifetime), as the development of cancer is a long-term process that may take many years to manifest. For this reason, a special type of receptor called a "lifetime" or "composite" receptor is selected for evaluation of potential carcinogenic risks. This receptor is a "composite" of all relevant life stages for which exposure will be evaluated. Health risks associated with exposure to carcinogenic compounds are usually expressed as an estimate of excess or *incremental lifetime cancer risk* (ILCR) resulting from exposures to a particular source. Thus, risks associated with carcinogenic compounds are predicted using the average daily dose over a human receptor's entire life span.

In order to evaluate potential exposure, it is necessary to characterize the physiological and behavioural characteristics of each receptor group evaluated. Several published sources have been considered in the selection of these parameters. The Compendium of Canadian Human Exposure Factors for Risk Assessment (Richardson, 1997), Health Canada (2005, pers. comm.), and the U.S. EPA's Exposure Factors Handbooks (U.S. EPA, 1997a,b) were used as the primary sources of the receptor parameter data for the HHRA. These sources have been used in numerous HHRAs that have been critically reviewed and accepted by regulatory agencies across Canada and the United States. The Compendium of Canadian Human Exposure Factors for Risk Assessment relies on data from published and reliable Canadian sources, such as Health Canada, Statistics Canada, and the Canadian Fitness and Lifestyles Research Institute. Where insufficient data were available in these sources to appropriately characterize relevant activity patterns and/or behavioural/physiological characteristics of a certain receptor group, other appropriate sources, such as the U.S. EPA Exposure Factors Handbooks (U.S. EPA, 1997a,b), were used to supplement the receptor parameter dataset.

For certain receptor parameters, site-specific data were gathered from investigations of populations within the GSA (where available) to enable a more GSA-specific HHRA (*e.g.,* food consumption survey, *Have Your Say* workshops, *etc.*). Tables 2.1 through 2.5 present the detailed physiological and behavioural parameters for male and female receptors at each life stage (*i.e.*, infant, preschool child, child, adolescent, adult) that were used in the HHRA. Exposures of each receptor to each COC were modeled based on these receptor characteristics. Additional information is also provided in Appendix B of this volume.

The receptor characteristics presented in Tables 2.1 through 2.5 were based primarily on data provided by:

- U.S. EPA. 2002. Child-Specific Exposure Factors Handbook. National Center for Environmental Assessment – Washington, DC. EPA-600-P-00-002B. September, 2002;
- U.S. EPA. 1997b. Exposure Factors Handbook. Volume I – General Factors. Office of Research and Development. United States Environmental Protection Agency. EPA/600/P-95/002Fa. August 1997;

- Richardson. G.M. 1997. Compendium of Canadian Human Exposure Factors for Risk Assessment. O'Connor Associates, Ottawa, Ontario; and
- Burmaster, D.E. 1998. Lognormal distributions of skin area as a function of body weight. Risk Anal 18(1): 27-32.

It should be noted that the detailed receptor data obtained from Health Canada for use in the current assessment (Health Canada, 2005 pers. comm.) is the complete dataset used to generate receptor statistical summaries presented in the *Compendium of Canadian Human Exposure Factors for Risk Assessment* (Richardson, 1997). This dataset is based upon the original Nutrition Canada survey (1970-1972), and has been peer reviewed both by Nutrition Canada (prior to its release to Health Canada) and Health Canada itself. Use of this complete dataset, rather than the statistical summaries provided in Richardson (1997), allows the current assessment to account for bodyweight adjustments on an individual basis, rather than as an overall receptor age group. This allows for a more accurate and precise characterization of receptor assumptions, and reduces the overall uncertainty inherent in each particular modeled receptor characteristic. Selection of this receptor dataset is discussed in further detail in Section 2.1.4.3.

For the current assessment, the lengths of the "summer" and "winter" exposure periods in Sudbury were conservatively assumed to be eight and four months, respectively, for all receptors. The difference between the two periods pertains to the degree to which an individual may be exposed to soils. During the "winter" period the ground is either frozen or covered by snow, minimizing the degree to which one can come in direct contact with impacted soils. A greater amount of clothing is also employed in the winter period due to the temperature, further limiting exposures to soil. While it is likely that the winter period may be considered longer than four months in Sudbury, it is conservative to err on the side of a longer "summer" period (which includes spring and fall), due to the greater potential for direct exposure to impacted soils.

Receptor-specific data is presented in the following tables for both the *central tendency estimate* (CTE) and *reasonably maximally exposed* (RME) exposure scenarios, as well as the underlying mean and standard deviation of the overall receptor characterization dataset. Refer to Chapter 4 for a detailed discussion of these two exposure scenarios. While probabilistic frequency distribution selection information is provided, it should be noted that this level of detail is provided for informational purposes only and probabilistic analyses were ultimately not conducted for the current assessment (refer to Chapter 5 for further discussion).

Table 2.1 Receptor Characteristics – Infant (0 to 6 months)

Receptor Parameter	Female[a]					Male[a]					Reference
	Mean	SD	CTE[c]	RME[d]	PDF[b]	Mean	SD	CTE[c]	RME[d]	PDF	
Body weight (kg) [e]	8.2	2.9	8.2	8.2	L	8.2	2.9	8.2	8.2	L	Richardson, 1997
Amount of Air Inhaled (m^3/day)	2.1	0.60	2.0	2.9	L	2.1	0.60	2.0	2.9	L	Richardson, 1997
Amount of Soil Ingested (g/day)	0.009	-	0.009	0.009	na	0.009	-	0.009	0.009	na	Health Canada (2004) [f]
Amount of Dust Ingested (g/day)	0.011	-	0.011	0.011	na	0.011	-	0.011	0.011	na	Health Canada (2004) [f]
Total Skin Surface Area (m^2)	na	na	0.43	0.43	na	na	na	0.43	0.43	na	Burmaster, 1998
Amount of Drinking Water Ingested (L/day)	0.3	0.2	0.25	0.54	L	0.3	0.2	0.25	0.54	L	Richardson, 1997
Amount of Formula Consumed (g/kg/day)	82.0	45.9	63.2	101.6	N	53.3	30.8	50.0	65.9	N	Health Canada, 2005 pers. comm.
Amount of Milk and Dairy Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Meat and Eggs Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Fish and Shellfish Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Root Vegetables Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Other Vegetables Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Fruits and Juices Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Cereal and Grains Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Sugar and Sweets Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Fats and Oils Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Nuts and Seeds Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Exposure Frequency – Summer (days/ year)	243	na	229	243	na	243	na	229	243	na	Assumed
Exposure Frequency – Winter (days/ year)	122	na	122	122	na	122	na	122	122	na	Assumed
Time Spent Outdoors (min/day)	91	83	67.2	182.2	L	91	83	67.2	182.2	L	Richardson, 1997

na Not applicable

\- Not provided

[a] Whole body surface area was calculated using body weight from Richardson (1997) and the univariate model developed by Burmaster (1998) as described below.

[b] N- Normal PDF, L- Lognormal PDF, ME- Max Extreme (Truncated). Normal PDFs represent uncertainty around the arithmetic mean and all other PDFs represent variability of the sample population.

[c] With the exception of body weight, all parameters representing the *central tendancy estimate* (CTE) were characterized using 50th percentile values to represent the central tendency.

[d] With the exception of body weight and food intake rates, all parameters representing the *reasonably maximally exposed* (RME) individual were characterized using upper percentile (*i.e.,* 90 to 95th percentile) values. The upper 95 percent confidence limit (95 UCL) on the arithmetic mean was used to characterize chronic food intake rates.

[e] Equivalent average body weights (arithmetic mean values reported by Richardson, 1997) were used for both CTE and RME exposure scenarios, as recommended by the U.S. EPA (1989) for the derivation of a reasonable maximum exposure (RME) scenario.

[f] Default data used by the U.S EPA's IEUBK model (U.S. EPA 1994a) was employed to develop outdoor soil and indoor dust ingestion rates. The IEUBK model uses a default outdoor:indoor 45/55 split which applies 55% of the total soil and dust ingestion rate to indoor dust with the remaining 45% being applied to soil. Refer to Section 4.1.6.2 for a discussion of soil and dust ingestion rates.

Table 2.2 Receptor Characteristics – Preschool Child (7 months to 4 years)

Receptor Parameter	Female[a]					Male[a]					Reference
	Mean	SD	CTE[c]	RME[d]	PDF[b]	Mean	SD	CTE[c]	RME[d]	PDF	
Body weight (kg) [f]	16.4	4.5	16.4	16.4	L	16.5	4.6	16.5	16.5	L	Richardson, 1997
Amount of Air Inhaled (m^3/day)	8.8	2.4	8.5	11.9	L	9.7	2.7	9.4	13.3	L	Richardson, 1997
Amount of Soil Ingested (g/day)	0.036	na	0.036	0.036	na	0.036	na	0.036	0.036	na	Health Canada (2004) [e]
Amount of Dust Ingested (g/day)	0.044	na	0.044	0.044	na	0.044	na	0.044	0.044	na	Health Canada (2004) [e]
Total Skin Surface Area (m^2)	na	na	0.69	0.69	na	na	na	0.69	0.69	na	Burmaster, 1998
Amount of Drinking Water Ingested (L/day)	0.6	0.4	0.5	1.09	L	0.6	0.4	0.5	1.09	L	Richardson, 1997
Amount of Milk and Dairy Consumed (g/kg/day)	44.5	38.8	28.7	46.7	N	45.1	30.0	38.1	47.2	N	Health Canada, 2005 pers. comm.
Amount of Meat and Eggs Consumed (g/kg/day)	6.2	5.2	5.7	6.5	N	6.2	5.8	5.1	6.6	N	Health Canada, 2005 pers. comm.
Amount of Fish and Shellfish Consumed (g/kg/day)	3.0	2.6	2.5	3.8	N	4.4	4.4	2.6	5.5	N	Health Canada, 2005 pers. comm.
Amount of Root Vegetables Consumed (g/kg/day)	7.4	5.3	7.1	9.5	N	7.9	6.9	5.90	8.5	N	Health Canada, 2005 pers. comm.
Amount of Other Vegetables Consumed (g/kg/day)	4.7	2.9	5.3	6.3	N	4.8	5.2	3.1	6.3	N	Health Canada, 2005 pers. comm.
Amount of Fruits and Juices Consumed (g/kg/day)	17.8	13.6	14.5	20.8	N	16.9	12.8	14.2	17.9	N	Health Canada, 2005 pers. comm.
Amount of Cereal and Grains Consumed (g/kg/day)	11.7	8.7	9.6	13.5	N	12.2	10.6	9.1	13.4	N	Health Canada, 2005 pers. comm.
Amount of Sugar and Sweets Consumed (g/kg/day)	4.0	1.8	4.6	6.7	N	3.7	4.9	1.9	4.4	N	Health Canada, 2005 pers. comm.
Amount of Fats and Oils Consumed (g/kg/day)	1.8	1.1	2.1	2.4	N	0.87	0.79	0.7	1.2	N	Health Canada, 2005 pers. comm.
Amount of Nuts and Seeds Consumed (g/kg/day)	1.0	0.7	0.9	1.4	N	0.9	0.79	0.7	1.2	N	Health Canada, 2005 pers. comm.
Exposure Frequency – Summer (days/ year)	243	Na	229	243	na	243	na	229	243	na	Assumed
Exposure Frequency – Winter (days/ year)	122	Na	122	122	na	122	na	122	122	na	Assumed
Time Spent Outdoors (min/day)	91	83	67.2	182.2	L	91	83	67.2	182.2	L	Richardson, 1997

na Not applicable
- Not provided
[a] Whole body surface area was calculated using body weight from Richardson, 1997 and the univariate model developed by Burmaster (1998) as described below.
[b] N- Normal PDF, L- Lognormal PDF, ME- Max Extreme (Truncated). Normal PDFs represent uncertainty around the arithmetic mean and all other PDFs represent variability of the sample population.
[c] With the exception of body weight, all parameters representing the *central tendancy estimate* (CTE) were characterized using 50th percentile values to represent the central tendency.
[d] With the exception of body weight and food intake rates, all parameters representing the *reasonably maximally exposed* (RME) individual were characterized using upper percentile (*i.e.,* 90 to 95th percentile) values. The upper 95 percent confidence limit (95 UCL) on the arithmetic mean was used to characterize chronic food intake rates.
[e] Default data used by the U.S EPA's IEUBK model (U.S. EPA 1994a) was employed to develop outdoor soil and indoor dust ingestion rates. The IEUBK model uses a default outdoor:indoor 45/55 split which applies 55% of the total soil and dust ingestion rate to indoor dust with the remaining 45% being applied to soil. Refer to Section 4.1.6.2 for a discussion of soil and dust ingestion rates.
[f] Equivalent average body weights (arithmetic mean values reported by Richardson, 1997) were used for both CTE and RME exposure scenarios, as recommended by the U.S. EPA (1989) for the derivation of a reasonable maximum exposure (RME) scenario.

Table 2.3 Receptor Characteristics – Child (5 to 11 years)

Receptor Parameter	Female[a]					Male[a]					Reference
	Mean	SD	CTE[c]	RME[d]	PDF[b]	Mean	SD	CTE[c]	RME[d]	PDF	
Body weight (kg) [e]	33.6	9.3	33.6	33.6	L	32.2	8.0	32.2	32.2	L	Richardson, 1997
Amount of Air Inhaled (m^3/day)	14.0	3.0	13.7	17.9	L	15.1	3.4	14.7	19.6	L	Richardson, 1997
Amount of Soil Ingested (g/day)	0.009	-	0.009	0.009	na	0.009	-	0.009	0.009	na	Health Canada (2004) [f]
Amount of Dust Ingested (g/day)	0.011	-	0.011	0.011	na	0.011	-	0.011	0.011	na	Health Canada (2004) [f]
Total Skin Surface Area (m^2)	na	na	1.1	1.1	na	na	na	1.1	1.1	na	Burmaster, 1998
Amount of Drinking Water Ingested (L/day)	0.8	0.4	0.72	1.3	L	0.8	0.4	0.72	1.3	0.8	Richardson, 1997
Amount of Milk and Dairy Consumed (g/kg/day)	22.1	15.6	19.5	24.3	N	24.5	17.4	21.6	26.9	N	Health Canada, 2005 pers. comm.
Amount of Meat and Eggs Consumed (g/kg/day)	4.2	3.0	3.5	4.4	N	4.8	3.9	4.1	5.3	N	Health Canada, 2005 pers. comm.
Amount of Fish and Shellfish Consumed (g/kg/day)	3.5	4.6	2.2	4.2	N	3.5	3.9	2.1	5.1	3.5	Health Canada, 2005 pers. comm.
Amount of Root Vegetables Consumed (g/kg/day)	5.3	5.3	4.3	6.5	N	6.6	5.8	5.2	7.8	6.6	Health Canada, 2005 pers. comm.
Amount of Other Vegetables Consumed (g/kg/day)	3.4	3.5	2.3	3.6	N	3.7	4.5	2.2	4.4	3.7	Health Canada, 2005 pers. comm.
Amount of Fruits and Juices Consumed (g/kg/day)	9.6	8.9	7.4	10.9	N	10.8	9.5	7.7	12.3	10.8	Health Canada, 2005 pers. comm.
Amount of Cereal and Grains Consumed (g/kg/day)	9.2	7.7	6.9	10.6	N	10.6	7.9	8.3	11.9	N	Health Canada, 2005 pers. comm.
Amount of Sugar and Sweets Consumed (g/kg/day)	2.5	3.6	1.5	2.8	N	2.8	3.5	1.6	3.1	2.8	Health Canada, 2005 pers. comm.
Amount of Fats and Oils Consumed (g/kg/day)	1.4	1.9	0.9	1.5	N	1.4	1.7	0.9	1.5	1.4	Health Canada, 2005 pers. comm.
Amount of Nuts and Seeds Consumed (g/kg/day)	0.8	0.7	0.6	0.9	N	0.8	0.82	0.6	0.9	0.8	Health Canada, 2005 pers. comm.
Exposure Frequency – Summer (days/ year)	243	na	229	243	na	243	na	229	243	na	Assumed
Exposure Frequency – Winter (days/ year)	122	na	122	122	na	122	na	122	122	na	Assumed
Time Spent Outdoors (min/day)	91	83	67.2	182.2	L	91	83	67.2	182.2	L	Richardson, 1997

na Not applicable

\- Not provided

[a] Whole body surface area was calculated using body weight from Richardson, 1997 and the univariate model developed by Burmaster (1998) as described below.

[b] N- Normal PDF, L- Lognormal PDF, ME- Max Extreme (Truncated). Normal PDFs represent uncertainty around the arithmetic mean and all other PDFs represent variability of the sample population.

[c] With the exception of body weight, all parameters representing the *central tendancy estimate* (CTE) were characterized using 50th percentile values to represent the central tendency.

[d] With the exception of body weight and food intake rates, all parameters representing the *reasonably maximally exposed* (RME) individual were characterized using upper percentile (*i.e.,* 90 to 95th percentile) values. The upper 95 percent confidence limit (95 UCL) on the arithmetic mean was used to characterize chronic food intake rates.

[e] Equivalent average body weights (arithmetic mean values reported by Richardson, 1997) were used for both CTE and RME exposure scenarios, as recommended by the U.S. EPA (1989) for the derivation of a reasonable maximum exposure (RME) scenario.

[f] Default data used by the U.S EPA's IEUBK model (U.S. EPA 1994a) was employed to develop outdoor soil and indoor dust ingestion rates. The IEUBK model uses a default outdoor:indoor 45/55 split which applies 55% of the total soil and dust ingestion rate to indoor dust with the remaining 45% being applied to soil. Refer to Section 4.1.6.2 for a discussion of soil and dust ingestion rates.

Table 2.4 Receptor Characteristics – Teen (adolescent) (12 to 19 years)

Receptor Parameter	Female[a]					Male[a]					Reference
	Mean	SD	CTE[c]	RME[d]	PDF[b]	Mean	SD	CTE[c]	RME[d]	PDF	
Body weight (kg) [e]	56.2	10.2	56.2	56.2	L	63.1	15.3	63.1	63.1	L	Richardson, 1997
Amount of Air Inhaled (m^3/day)	14.0	2.9	13.7	17.8	L	17.7	4.1	17.2	23.1	L	Richardson, 1997
Amount of Soil Ingested (g/day)	0.009	-	0.009	0.009	na	0.009	-	0.009	0.009	na	Health Canada (2004) [f]
Amount of Dust Ingested (g/day)	0.011	-	0.011	0.011	na	0.011	-	0.011	0.011	na	Health Canada (2004) [f]
Total Skin Surface Area (m^2)	na	na	1.6	1.6	na	na	na	1.7	1.7	na	Burmaster, 1998
Amount of Drinking Water Ingested (L/day)	1.0	0.6	0.9	1.7	L	1.0	0.6	0.9	1.7	L	Richardson, 1997
Amount of Milk and Dairy Consumed (g/kg/day)	10.2	9.1	8.1	11.9	N	12.7	10.5	10.4	14.8	N	Health Canada, 2005 pers. comm.
Amount of Meat and Eggs Consumed (g/kg/day)	2.8	1.9	2.4	2.9	N	3.7	2.5	3.0	3.9	N	Health Canada, 2005 pers. comm.
Amount of Fish and Shellfish Consumed (g/kg/day)	1.9	1.7	1.3	2.1	N	2.2	2.1	1.6	2.5	N	Health Canada, 2005 pers. comm.
Amount of Root Vegetables Consumed (g/kg/day)	3.9	3.3	3.2	4.6	N	5.1	4.2	4.1	5.8	N	Health Canada, 2005 pers. comm.
Amount of Other Vegetables Consumed (g/kg/day)	2.4	2.8	1.6	2.9	N	2.3	2.8	1.5	2.9	N	Health Canada, 2005 pers. comm.
Amount of Fruits and Juices Consumed (g/kg/day)	5.3	5.0	4.0	6.4	N	5.0	4.8	3.5	5.8	N	Health Canada, 2005 pers. comm.
Amount of Cereal and Grains Consumed (g/kg/day)	4.8	4.8	3.5	5.4	N	6.5	5.3	5.0	7.2	N	Health Canada, 2005 pers. comm.
Amount of Sugar and Sweets Consumed (g/kg/day)	1.4	1.9	0.8	1.7	N	1.8	2.3	1.0	2.2	N	Health Canada, 2005 pers. comm.
Amount of Fats and Oils Consumed (g/kg/day)	1.1	1.6	0.7	1.2	N	1.0	1.2	0.6	1.2	N	Health Canada, 2005 pers. comm.
Amount of Nuts and Seeds Consumed (g/kg/day)	0.5	0.6	0.3	0.7	N	0.6	0.8	0.4	0.9	N	Health Canada, 2005 pers. comm.
Exposure Frequency – Summer (days/ year)	243	na	229	243	na	243	na	229	243	na	Assumed
Exposure Frequency – Winter (days/ year)	122	na	122	122	na	122	na	122	122	na	Assumed
Time Spent Outdoors (min/day)	91	83	67.2	182.2	L	91	83	67.2	182.2	L	Richardson, 1997

na Not applicable
- Not provided
[a] Whole body surface area was calculated using body weight from Richardson, 1997and the univariate model developed by Burmaster (1998) as described below.
[b] N- Normal PDF, L- Lognormal PDF, ME- Max Extreme (Truncated). Normal PDFs represent uncertainty around the arithmetic mean and all other PDFs represent variability of the sample population.
[c] With the exception of body weight, all parameters representing the *central tendancy estimate* (CTE) were characterized using 50th percentile values to represent the central tendency.
[d] With the exception of body weight and food intake rates, all parameters representing the *reasonably maximally exposed* (RME) individual were characterized using upper percentile (*i.e.,* 90 to 95th percentile) values. The upper 95 percent confidence limit (95 UCL) on the arithmetic mean was used to characterize chronic food intake rates.
[e] Equivalent average body weights (arithmetic mean values reported by Richardson, 1997) were used for both CTE and RME exposure scenarios, as recommended by the U.S. EPA (1989) for the derivation of a reasonable maximum exposure (RME) scenario.
[f] Default data used by the U.S EPA's IEUBK model (U.S. EPA 1994a) was employed to develop outdoor soil and indoor dust ingestion rates. The IEUBK model uses a default outdoor:indoor 45/55 split which applies 55% of the total soil and dust ingestion rate to indoor dust with the remaining 45% being applied to soil. Refer to Section 4.1.6.2 for a discussion of soil and dust ingestion rates.

Table 2.5 Receptor Characteristics – Adult (>20 years)

Receptor Parameter	Female[a]					Male[a]					Reference
	Mean	SD	CTE	RME	PDF	Mean	SD	CTE	RME	PDF	
Body weight (kg)[e]	63.1	11.9	63.1	63.1	L	78.8	12.3	78.8	78.8	L	Richardson, 1997
Amount of Air Inhaled (m^3/day)	14.9	2.9	14.6	18.7	L	17.2	4.1	16.7	22.6	L	Richardson, 1997
Amount of Soil Ingested (g/day)	0.009	-	0.009	0.009	na	0.009	-	0.009	0.009	na	Health Canada (2004)[f]
Amount of Dust Ingested (g/day)	0.011	-	0.011	0.011	na	0.011	-	0.011	0.011	na	Health Canada (2004)[f]
Total Skin Surface Area (m^2)	na	na	1.7	1.7	na	na	na	2.0	2.0	na	Burmaster, 1998
Amount of Drinking Water Ingested (L/day)	1.5	0.8	1.3	2.5	L	1.5	0.8	1.3	2.5	L	Richardson, 1997
Amount of Milk and Dairy Consumed (g/kg/day)	4.1	4.4	2.6	4.5	N	4.8	5.1	3.1	5.4	N	Health Canada, 2005 pers. comm.
Amount of Meat and Eggs Consumed (g/kg/day)	2.2	1.6	1.8	2.2	N	4.8	5.1	3.1	5.4	N	Health Canada, 2005 pers. comm.
Amount of Fish and Shellfish Consumed (g/kg/day)	1.7	1.8	1.3	2.1	N	1.7	1.6	1.2	2.0	N	Health Canada, 2005 pers. comm.
Amount of Root Vegetables Consumed (g/kg/day)	2.6	2.3	2.1	2.8	N	3.2	2.6	2.6	3.5	N	Health Canada, 2005 pers. comm.
Amount of Other Vegetables Consumed (g/kg/day)	2.1	2.0	1.6	2.2	N	2.0	2.1	1.4	2.3	N	Health Canada, 2005 pers. comm.
Amount of Fruits and Juices Consumed (g/kg/day)	3.9	3.3	3.1	4.2	N	3.5	3.0	2.7	3.8	N	Health Canada, 2005 pers. comm.
Amount of Cereal and Grains Consumed (g/kg/day)	3.0	2.8	2.3	3.2	N	3.9	3.0	3.1	4.1	N	Health Canada, 2005 pers. comm.
Amount of Sugar and Sweets Consumed (g/kg/day)	1.0	1.1	0.6	1.1	N	1.1	1.3	0.7	1.2	N	Health Canada, 2005 pers. comm.
Amount of Fats and Oils Consumed (g/kg/day)	0.8	0.9	0.5	0.8	N	0.7	0.7	0.4	0.7	N	Health Canada, 2005 pers. comm.
Amount of Nuts and Seeds Consumed (g/kg/day)	0.3	0.4	0.2	0.4	N	0.3	0.6	0.2	0.4	N	Health Canada, 2005 pers. comm.
Exposure Frequency – Summer (days/ year)	243	-	229	243	-	243	-	229	243	-	Assumed
Exposure Frequency – Winter (days/ year)	122	-	122	122	-	122	-	122	122	-	Assumed
Time Spent Outdoors (min/day)	91.0	83.0	67.2	182.2	L	91.0	83.0	67.2	182.2	L	Richardson, 1997

na Not applicable
- Not provided
[a] Whole body surface area was calculated using body weight from Richardson, 1997 and the univariate model developed by Burmaster (1998) as described below.
[b] N- Normal PDF, L- Lognormal PDF, ME- Max Extreme (Truncated). Normal PDFs represent uncertainty around the arithmetic mean and all other PDFs represent variability of the sample population.
[c] With the exception of body weight, all parameters representing the *central tendancy estimate* (CTE) were characterized using 50th percentile values to represent the central tendency.
[d] With the exception of body weight and food intake rates, all parameters representing the *reasonably maximally exposed* (RME) individual were characterized using upper percentile (*i.e.,* 90 to 95th percentile) values. The upper 95 percent confidence limit (95 UCL) on the arithmetic mean was used to characterize chronic food intake rates.
[e] Equivalent average body weights (arithmetic mean values reported by Richardson, 1997) were used for both CTE and RME exposure scenarios, as recommended by the U.S. EPA (1989) for the derivation of a reasonable maximum exposure (RME) scenario.
[f] Default data used by the U.S EPA's IEUBK model (U.S. EPA 1994a) was employed to develop outdoor soil and indoor dust ingestion rates. The IEUBK model uses a default outdoor:indoor 45/55 split which applies 55% of the total soil and dust ingestion rate to indoor dust with the remaining 45% being applied to soil. Refer to Section 4.1.6.2 for a discussion of soil and dust ingestion rates.

2.1.4.3 Selection of Dietary Consumption Rates for the GSA

As noted previously, the Compendium of Canadian Human Exposure Factors for Risk Assessment (Richardson, 1997), Health Canada (2005, pers. comm.) and the U.S. EPA's Exposure Factors Handbooks (U.S. EPA, 1997a,b) were used as the primary sources of the receptor parameter data for the HHRA. The dietary consumption rates used to evaluate both GSA residents and the typical Ontario resident (TOR) were based upon anonymized data collected in the 1970 to 1972 Nutrition Canada Survey on food use and biometrics, of which summarized versions were published as the Richardson (1997) document. The raw data from 1970 to 1972 Nutrition Canada Survey, which has previously undergone QA/QC by both Statistics Canada and Health Canada, was provided by Health Canada (2005, pers. comm.) and was used in the current HHRA. This data set is somewhat dated. Health Canada is currently completing a more current consumption survey; however, the new consumption data were not available while this assessment was being completed (Health Canada, 2006, pers. comm.).

The 1970 to 1972 Nutrition Canada Survey represents information for Canadian populations (unlike similar surveys conducted in the United States), and is recommended by recent Health Canada guidance (Health Canada, 2004). However, to ensure that this older data does not grossly underestimate potential consumption rates, the Nutrition Canada survey raw data (Health Canada, 2005) were compared to the United States Department of Agriculture (USDA) 1994 to 1996 Continuing Survey of Food Intakes by Individuals (CSFII) and the 1994 to 1996 Diet and Health Knowledge Survey (DHKS) three year national wide food consumption survey data set.

The USDA 1994 to 1996 CSFII and DHKS data was collected for all age groups on two non-consecutive days of food intake, three to 10 days apart from one another, from January, 1994 to January, 1997 (n=16,103). The overall day-one response rate was 80% and day two response rate was 76.1%. The DHKS was filled out by adults 20 years or older answering questions on their attitudes and knowledge about dietary guidance and health.

As outlined in Tables 2.6 and 2.7, the Northeast (NE) region of the U.S. (refer to Table set 13 in USDA, 1998) and total results for all U.S. regions (refer to Table set 10 in USDA, 1997) were compared to relevant statistical grouping of the Health Canada (2005) data. Of all the regions evaluated in the CSFII survey, the Northeast region of the U.S. was considered to be closest in food consumption patterns to what would be expected for GSA residents and the TOR. One should note that USDA (1997 and 1998) intake values were reported in grams per day. As no specific average weights for age groups were reported in USDA (1997 and 1998) data set, g/day intakes were adjusted to g/kg/day by using mean weights, specific to gender, from Health Canada (2005) data to facilitate the appropriate comparisons.

Table 2.6 Comparison of USDA (1997 and 1998) Consumption Rates with Health Canada (2005) Consumption Rates for the Preschool Child Lifestage

Receptor Parameter	Males and Females			Relative Difference in Consumption Rates if USDA substituted for HC value	
	HC (2004)	USDA (1997/1998)		HC *vs.* USDA NE	HC *vs.* USDA All regions
	Combined mean	NE	All regions		
Body weight (kg)	16.45	NA	NA		
Milk and Dairy	44.80	31.4	28.3	-30%	-37%
Meat and Eggs	6.20	5.3	6.0	-14%	-4%
Fish and Shellfish	3.70	0.2	0.2	-95%	-95%
Vegetables Consumed	12.40	5.0	5.0	-60%	-60%
Fruits and Juices	17.35	17.2	13.5	-1%	-22%
Cereal and Grains	11.95	13.9	12.9	16%	8%
Sugar and Sweets	3.85	1.1	1.4	-72%	-64%
Fats and Oils	1.34	0.2	0.2	-82%	-86%
Nuts and Seeds	0.95	0.2	0.2	-74%	-74%

Notes: All values are expressed in units of g/kg/day, unless otherwise indicated.
Relative Difference is calculated as the following (USDA - HC) / HC.
"NA" means not provided.

Table 2.7 Comparison of USDA (1997 and 1998) Consumption Rates with Health Canada (2005) Consumption Rates for the Child, Adolescent, and Adult Lifestages

Receptor Parameter	Female					Male				
	USDA (1997/1998)		HC (2004)	Relative Difference if USDA substituted for HC value		USDA (1997/1998)		HC (2004)	Relative Difference if USDA substituted for HC value	
	NE	All regions	Mean	HC *vs.* USDA NE	HC *vs.* USDA All regions	NE	All regions	Mean	HC *vs.* USDA NE	HC *vs.* USDA All regions
Children										
Body weight (kg)	NA	NA	33.6			NA	NA	32.2		
Milk and Dairy	11.9	11.4	22.1	-46%	-48%	13.2	13.9	24.5	-46%	-43%
Meat and Eggs	3.9	4.0	4.2	-7%	-5%	4.3	5.0	4.8	-10%	4%
Fish and Shellfish	0.1	0.1	3.5	-97%	-97%	0.3	0.2	3.5	-91%	-94%
Vegetables Consumed	3.3	3.5	8.7	-62%	-60%	3.8	3.5	10.3	-63%	-66%
Fruits and Juices	5.6	4.9	9.6	-42%	-49%	6.8	5.5	10.8	-37%	-49%
Cereal and Grains	7.8	8.2	9.2	-15%	-11%	10.7	9.6	10.6	1%	-9%
Sugar and Sweets	1.0	1.3	2.5	-60%	-48%	1.2	1.2	2.8	-57%	-57%
Fats and Oils	0.2	0.2	1.4	-86%	-86%	0.3	0.2	1.4	-79%	-86%
Nuts and Seeds	0.2	0.1	0.8	-75%	-88%	0.2	0.2	0.8	-75%	-75%

Table 2.7 Comparison of USDA (1997 and 1998) Consumption Rates with Health Canada (2005) Consumption Rates for the Child, Adolescent, and Adult Lifestages

Receptor Parameter	Female					Male				
	USDA (1997/1998)		HC (2004)	Relative Difference if USDA substituted for HC value		USDA (1997/1998)		HC (2004)	Relative Difference if USDA substituted for HC value	
	NE	All regions	Mean	HC *vs.* USDA NE	HC *vs.* USDA All regions	NE	All regions	Mean	HC *vs.* USDA NE	HC *vs.* USDA All regions
Adolescent										
Body weight (kg)	NA	NA	56.2			NA	NA	63.1		
Milk and Dairy	4.8	4.8	10.2	-53%	-53%	6.4	6.5	12.7	-50%	-49%
Meat and Eggs	2.5	2.9	2.8	-11%	4%	3.5	4.1	3.7	-5%	11%
Fish and Shellfish	0.1	0.1	1.9	-95%	-95%	0.2	0.1	2.2	-91%	-95%
Vegetables Consumed	2.3	2.6	6.3	-63%	-59%	2.7	2.8	7.4	-64%	-62%
Fruits and Juices	3.4	2.8	5.3	-36%	-47%	4.1	2.8	5.0	-18%	-44%
Cereal and Grains	6.5	5.4	4.8	35%	13%	6.4	6.4	6.5	-2%	-2%
Sugar and Sweets	0.6	0.1	1.4	-57%	-93%	0.5	0.1	1.8	-72%	-94%
Fats and Oils	0.1	0.2	1.1	-91%	-82%	0.3	0.2	1.0	-70%	-80%
Nuts and Seeds	0.1	0.6	0.5	-80%	20%	0.1	0.6	0.6	-83%	0%
Adult										
Body weight (kg)	NA	NA	63.1			NA	NA	78.8		
Milk and Dairy	3.2	3.1	4.1	-22%	-24%	3.1	3.1	4.8	-35%	-35%
Meat and Eggs	2.7	2.7	2.2	23%	23%	3.4	3.5	4.8	-29%	-27%
Fish and Shellfish	0.2	0.2	1.7	-88%	-88%	0.2	0.2	1.7	-88%	-88%
Vegetables Consumed	3.2	3.1	4.7	-32%	-34%	3.2	3.1	5.2	-38%	-40%
Fruits and Juices	2.7	2.5	3.9	-31%	-36%	2.6	2.2	3.5	-26%	-37%
Cereal and Grains	5.1	4.1	3.0	70%	37%	4.8	4.6	3.9	23%	18%
Sugar and Sweets	0.3	0.3	1.0	-70%	-70%	0.3	0.3	1.1	-73%	-73%
Fats and Oil	0.3	0.3	0.8	-63%	-63%	0.3	0.2	0.7	-57%	-71%
Nuts and Seeds	0.05	0.05	0.3	-83%	-83%	0.1	0.1	0.3	-67%	-67%

Notes: All values are expressed in units of g/kg/day, unless otherwise indicated.
Relative Difference is calculated as the following (USDA - HC) / HC.
"NA" means not provided.

USDA (1997; 1998) receptor parameters (*i.e.*, amount consumed) differ from the Health Canada (2005) data in some aspects. The mean quantities per individual were matched, as best fit, to suit Health Canada (2005) receptor parameters to facilitate the current comparison. The following explains data selection, rationale and discrepancies for the construction of a meaningful comparison of USDA (1997; 1998) to Health Canada (2005) data for infant, preschool child, child, adolescent, and adult receptors and the specific parameters:

- **Infants**: The USDA combines male and female data for individuals five years of age and under, which includes infants under one; excluding breast-fed children. No data comparison was made for infants zero to six months, as no specific USDA data for this age group was available.
- **Preschool Child**: Combined USDA data for males and females under the ages of five did not reflect the age range for Health Canada data for preschool children (seven months to four years). Therefore, a male and female mean intake amount for toddlers was calculated from Health Canada data and compared to USDA data for males and females five and under.
- **Child**: Gender-specific USDA data for an age range of six to eleven for males and females was compared to Health Canada range for children of five to eleven years.
- **Adolescent** and **Adult**: Gender-specific USDA and Health Canada adolescent (12 to 19) and adult (20 and over) age ranges were identical.
- *Total Milk and Milk Products* data from the USDA were compared to milk and dairy products from the Health Canada data.
- The USDA has separates tables for *Meat, Poultry, and Fish* and *Eggs* with related subcategories.
- Eggs and the sum of all meat subcategories (including mixtures), not including fish and shellfish, were added together from the USDA data and compared to Health Canada data.
- The USDA *Fish and Shellfish* subcategory was compared to Health Canada fish and shellfish data.
- The USDA does not distinguish between root vegetables and non-root vegetables; therefore,
- Health Canada root vegetables and other vegetables data were totalled and compared to USDA *Total Vegetables* data.
- The USDA *Total Fruits* category *(*which includes citrus fruits and juices, dried fruits and other fruits, mixtures and fruit juices) was compared to Health Canada Fruits and Juices data.
- The USDA has categories for *Sugars and Sweets, Fats and Oils and Nuts and Seeds* which were directly compared to identical parameter categories of the Health Canada data.
- Additionally, the USDA (1997 and 1998) notes any intake data within their database, which may be unreliable. The following decision rules were applied to the incorporation of such data: values indicated as "less than 0.5 but greater than 0" were substituted with a value of 0.5, to be conservative, and data reported but "flagged" as statistically unreliable (*e.g.*, the coefficient of variation exceeded 30%) were left as reported and applied.

As can be observed in Tables 2.6 and 2.7, for each of the receptor groupings and nearly every food category, the food consumption rates derived from the Health Canada (2005, pers. comm.) raw data were higher and more conservative (*i.e.*, would predict higher daily exposure rates) than those calculated based upon the USDA (1997 and 1998) data (*i.e.*, substituting the USDA data for the Health Canada data would result in a decrease in the consumption rate for nearly every food category). As such, based upon this analyses, and that they are recommended for use by Health Canada and represent sampled data from a Canadian population, the intake rates derived from the Nutrition Canada 1970 to 1972 survey were considered the most appropriate for use in the current HHRA. However, the age of the Nutrition Canada data is discussed further in the uncertainty section of this document (Chapter 7).

2.1.4.4 Local First Nation Wild Game and Fish Consumption Rates

Local First Nation people living in one of the five COI within the GSA may participate in a variety of hunting and fishing activities, and therefore, may consume significant amounts of local wild game and fish. Such local foods may contain different levels of the COC than store-bought foods. First Nation members are often considered a high exposure population subgroup due to potentially higher chemical exposures *via* game and fish consumption arising from subsistence hunting and/or fishing (Richardson, 1997). As the existing reserve areas are outside the primary area of influence of smelter emissions, only those First Nation individuals living off-reserve and in one of the identified COI were evaluated for potential health risks. Therefore, while it was assumed that these individuals may hunt and/or fish to a greater degree than the general population, they were not assumed to be subsistence hunters and/or fishers for the purpose of the current assessment. The rationale behind this assumption will be discussed further in the sections below.

Given the potential differences in concentrations of COC between local and store-bought foods, higher game and fish intakes within certain subgroups may increase risks between these groups, relative to the general population. The risks for individuals among the general population in households that participate in hunting and fishing activities (the Hunters and Anglers population subgroup) were specifically assessed based on local food consumption data collected using the Local Food Consumption Survey (discussed in Chapter 3 with complete data report in Appendix K of this Volume). Data regarding the local consumption patterns of the First Nation population subgroup were also collected as part of this survey.

U.S. EPA (1997a,b) reviewed several studies which indicate that fish consumption among the Native American general population is very similar (maximum 50 to 100% higher) to that of the general non-Native population. However, they note that the fish consumption rate for subsistence Native populations is much higher than that of either the general Native or non-Native populations. The Local Food

Consumption Survey conducted as part of the Study also indicated that fish consumption in the local First Nation community is very similar to that of the general population. The Survey reported the number of times per year that respondents from the general population of the GSA, Hunters and Anglers living in the GSA, and residents of the Whitefish Lake First Nation reserve consumed local game and fish species. The total game and total lake fish consumptions of the Whitefish First Nation respondents were higher than those of the general population, but lower than those of the Hunters and Anglers (Table 2.8).

Table 2.8 Local Game and Fish Consumption Rates (times consumed per year) in the GSA for the General Population, Hunters and Anglers Subgroup and Residents of the Whitefish Reserve

Category	General Population (n = 1,226)		Whitefish First Nation (n = 218 households)		Hunters & Anglers (n = 70)	
	CTE [a]	RME [b]	CTE	RME	CTE	RME
Moose	4.5	6.7	18.5	41.5	24.6	48.6
Deer	4.3	8.5	16.5	39.5	10.8	20.8
Grouse	2.8	5.73	4.1	8.1	12.5	27.5
TOTAL GAME	**11.6**	**20.9**	**39.1**	**89.1**	**47.9**	**96.9**
Walleye	5.4	12.1	14.2	36.2	18.2	42.2
Trout	4.7	10.7	-- [c]	--	--	--
Pike	5.9	21.3	10.2	20.2	17.6	46.6
Perch	4.0	10.5	--	--	21.5	48.5
Bass	--	--	9.2	19.2	--	--
TOTAL FISH	**20**	**54.6**	**33.6**	**75.6**	**57.3**	**137.3**

[a] CTE Central Tendency Estimate; mean of self-reported values for eaters only, both sexes combined, and all age groups.
[b] RME Reasonable Maximum Estimate; mean plus standard deviation of reported values.
[c] --- While respondants indicated some consumption of these fish, statistics representing serving sizes could not be calculated from the available data.

The Survey data presented in Table 2.8 indicate that the local game and fish consumption patterns of the First Nation population subgroup may place them at increased risk relative to the general population, but not relative to the hunters and anglers subgroup. This evidence indicates that risk management measures protective of the hunters and anglers subgroup will also be protective of the First Nation population subgroup. However, several issues with the survey data should be noted:

- Local food consumption rates were self-reported and not confirmed by any other survey method;
- After non-consumers of local fish and game were excluded, the number of respondents was relatively small;
- Data from both sexes and the different age groups were combined; and

- Local game and fish consumption rates for residents of the Whitefish Lake First Nation reserve (which is not a COI) can only provide *reasonable estimates* of the same parameters for First Nation individuals living in one of the COI.

Given the above limitations of the survey data, there is a possibility that the dietary habits of First Nation individuals living in the COI could differ significantly from those reported for the Whitefish First Nation in the Local Food Consumption Survey. For that reason, further information regarding the local game and fish consumption habits of First Nation populations was considered in a weight-of-evidence approach.

Wild game and fish consumption data for Native Canadian individuals are compiled in the Compendium of Canadian Human Exposure Factors for Risk Assessment (Richardson, 1997). Comparison of the Richardson data with those obtained from the Survey show that the consumption rates reported by Richardson (1997) are much higher than any of the rates obtained from the Survey (Table 2.9).

Table 2.9 Local Game and Fish Consumption Rates (g/day) from the Local Food Consumption Survey (all age groups), Richardson, 1997 (adults) and U.S. EPA, 1997a (adults)

Consumption Category	General Population[a]		Whitefish[a]		Hunters & Anglers[a]		Richardson [b]		U.S. EPA[c]	
	CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME
Total Game	7	13	24	55	30	60	270	570	63	125
Total Fish	12	34	21	47	36	85	220	400	70	170

[a] Survey data were converted from units of times consumed per year to g/day by assuming a serving size of 227g and dividing by 365 days in a year; CTE mean of self-reported values, in times consumed per year, for eaters only, both sexes combined, and all age groups, converted to g/day as above; RME mean, in times consumed per year, plus standard deviation of reported values, converted to g/day as above.

[b] Richardson (1997) data were collected in 1971 and 1972 from Native Canadians (both Inuit and Amerindian); CTE mean of self-reported values for eaters only, both sexes combined, 20 years of age and older; RME mean plus standard deviation of reported values.

[c] U.S. EPA (1997a) estimated intakes for U.S. Native American subsistence fishing populations; and U.S. EPA (1997b) intake values for home-produced meat among eaters only of the general population of the Northeast, adjusted for cooking and post-cooking losses using the factors for beef, converted from units of g/kg/day by assuming a body weight of 78 kg (note that this may be inappropriate for use in risk assessment as children were included among the respondents, but the conversion was done to allow comparisons between the intake values); CTE mean; RME 95th percentile.

The Richardson (1997) data provide useful information for this discussion, however, the following limitations should be noted:

- The data were collected in 1971 and 1972, and may not reflect current dietary patterns;

- Wild game and fish consumption of Native Canadians may vary across geographic regions, however, since the geographic region of the respondents was not recorded with the consumption data, it is not possible to compare the Survey data to other data from the Sudbury area; and,
- Wild game and fish consumption of Native Canadians varies between ethnic groups, however data for Inuit and Amerindian respondents were combined and it is not possible to compare the Survey data to other data for only other First Nation individuals.

The data reported by Richardson (1997) indicate that the local game and fish consumption rates of some Native Canadian populations may exceed those of the GSA General Population, and the Hunters and Anglers. However, it is unlikely that the O'Connor data apply to First Nation individuals living in GSA COI because of the age of the data, the inclusion of Inuit respondents (the Inuit are high game and fish consumers), and the likelihood that a significant proportion of respondents were subsistence hunters and/or fishers.

Kearney and Cole (2003) also presented data concerning inland sport fish consumption rates by licensed anglers from two Great Lakes area communities: Cornwall and Mississauga, Ontario. Their study included information regarding First Nations' communities around the Great Lakes region. Comparison of data attained by Kearney and Cole against the First Nations' communities showed that the sport fish consumption rates of the First Nations are similar to that of the general angler population in Cornwall and Mississauga (Table 2.10).

Data provided by Kearny and Cole (2003), provided valuable comparison between sports fish consumption by recreational anglers in the Great Lakes region against consumption of First Nation populations. However some limitations need to be addressed, including:

- Consumption data were collected from questionnaires filled out by participants between years 1992 and 1993. With increased health awareness and information about the possible contamination about the fish contained in the great lakes area (*i.e.*, "Guide to Eating Ontario Sport Fish" containing details of fish consumption advisories, 85% of participants were aware of this guide), sport fish consumption has been declining from previous 10 years. Hence, their data may not be reflective of the sport fish consumption rates of current conditions.
- Recruitment methods focused on selective sample populations and thus, cannot be generalized to the general angler population

Table 2.10 Local Sport Fish Consumption Rates (g/day) from the Great Lakes Region

Study	Data type	Sample Size (persons)	Consumption category		
			Meals/year	Meal Size (g)	(g/day)
Licensed anglers – Unspecified					
Kearney and Cole[b]	CTE	113	37.3	194.0	21.3
	CTE	631	19.3	303.3	21.1
First Nations fishermen					
Chan *et al.*[c]	CTE	22	-	-	33
Fitzgerald *et al.* [d]	CTE	139	21.2	-	13.81
Gerstenberger *et al.* [e]	CTE	89	29	-	18.01
Richardson and Currie [f]	CTE	4327	-	-	16.2

References: Kearney and Cole, (2003); Chan *et al*., (1999) Fitzgerald *et al*., (1999); Gerstenberger *et al*., (1997) and Richardson and Currie (1993)[a]

[a] Adapted from Kearney and Cole (2003)

[b] Kearney and Cole (2003) data were collected between 1992-1993 from Cornwall and Mississauga, Ontario. CTE mean of self-reported values for eaters only, where consumption were highest in summer and spring, and lower in fall winter. In order to convert the data into meal sizes, authors used density estimates, and individual meal sizes were estimated by multiplying surface area of the model piece; age range 23-69; CTE mean consumption value reflect both average male and female consumption

[c] Chan *et al*. (1999) data were collected between 1996-1997 from the Kahnawake Mohawk community; CTE mean of self-reported values for eaters only, where consumption was highest in the spring and summer, with reported frequency usually less than once per week.

[d] Fitzgerald *et al*. (1999) data were collected between 1992-1995 from the Akwesasne Mohawk community; CTE mean of self-reported values for eaters only; age range 15-77, with average 21.2 local fish meals per year

[e] Gerstenberger *et al*. (1997) data were collected from the Great Lakes' region Ojibwa tribal members; CTE mean of self reported values for eaters only, fish were consumed at the highest rates in April, May, June, and July.

[f] Richardson and Currie (1993) estimated fish consumption rate were determined from data on the concentration of mercury in the hair of 4,327 Amerindians residing in 58 reserves across Ontario, combined with data on mercury concentrations in three commonly consumed species of fish collected from lakes surrounding these reserves; Estimated rates of fish consumption were found to differ between sexes; Fish consumption rate was found to increase with increasing latitude, a surrogate measure of community isolation, and to increase with age; Seasonal variation was also noted, with fish consumption rates being highest during summer months and lowest in winter; CTE mean consumption value reflect both average male and female consumption.

The sport fish consumption data reported by Chan *et al*. (1999), collected from the Mohawk community in Kahnawake, demonstrated that their consumption rates were slightly higher (55.7%) than the Great Lakes communities in Cornwall and Mississauga, Ontario. Some limitations of this study include:

- A focused semi-quantitative food frequency questionnaire was used to obtain the data. Hence, the accuracy and precision of the results obtained may have been lower than other dietary assessment methods (Gibson, 1990);

- The greater the lapse of time since a fish meal, the more difficult for the respondents to accurately recall their frequency of fish consumption;
- With the nature of this study, and increased concern about fish contamination, participants in the survey may have underreported their fish intakes; and,
- Since the study was carried out between years 1996-1997, it may not reflect the current fish consumption rates of the First Nation anglers in the Kahnawake Mohawk community.

Data from Kearney and Cole (2003) report studies conducted by Fitzgerald *et al*. (1999), Gerstenberger *et al*. (1997), and Richardson and Currie (1993) on fish consumption rates of First Nations communities. Kearney and Cole (2003) found that the sport fish consumption rates of the First Nations' population are similar (generally 50% to 100% less) to those of the general angler population residing in the Great Lakes region. Some general limitations of these studies include:

- The periods of the studies conducted by Gerstenberger *et al*., (1997) and Richardson and Currie (1993) were not reported in Kearney and Cole (2003); and,
- Due to the age of the studies included, the data may not adequately characterize current sport fish consumption rates of the First Nation's angler population.

Volume II (Food Ingestion Factors) of the U.S. EPA's Exposure Factors Handbook (U.S. EPA, 1997a) is another source of information on food consumption. The U.S. EPA (1997a) provides recommended fish intake values for Native American populations relying on subsistence fishing (Table 2.9). As expected, the intake values recommended by U.S. EPA (1997a) for subsistence populations are higher than any of the intake values derived from the Local Food Consumption Survey. The fact that the recommended, conservative fish intake values for a subsistence Native American population are only approximately twice the intake values from the Survey for Hunters and Anglers suggests that it is highly unlikely that a First Nation individual living in one of the COI, who is not a subsistence fisher, would consume more fish than the reasonable maximum amount for Hunters and Anglers.

The U.S. EPA (1997a) does not provide recommended game intake values for Native American populations; therefore, the intake values for home-produced meat (including game) among eaters only in the general population of the Northeast U.S. were considered as an alternate point of comparison (Table 2.9). Although they do not represent Native American dietary habits, these values do represent a conservative approximation since they include farm-raised animals in addition to wild game. The intake values for home-produced meat are only twice the Hunters and Anglers' intake values for game. While these values are not strictly applicable, they do suggest that it is unlikely that a First Nation individual in a

COI, who is not a subsistence hunter, would consume more game than the reasonable maximum amount for Hunters and Anglers.

For the purpose of the risk assessment, the First Nation and Hunters and Anglers population subgroups were considered to differ from the general population only in their local food intake rates. The majority of the evidence suggests that the game and fish intake rates of First Nation individuals who are not subsistence hunters and/or fishers do not exceed those of Hunters and Anglers. Based on the weight of evidence, it is concluded that any risk management measures that are protective of the Hunters and Anglers population subgroup will also be protective of the First Nation subgroup.

2.1.5 Identification of Exposure Pathways

People can come into contact with chemicals in their environment in a variety of ways, depending on their daily activities and use of local resources (*i.e.,* land, water bodies). The means by which a person comes into contact with a chemical in an environmental medium is referred to as an *exposure pathway*. The means by which a chemical enters the body from the environmental medium is referred to as an *exposure route*. There are three major exposure routes through which chemicals can enter the body: inhalation, ingestion and dermal absorption (*i.e.,* uptake through the skin). For each of these major exposure routes, there are a number of potential sources of chemical exposure or exposure pathways:

- Inhalation of air, vapours, and dust through the lungs;
- Ingestion of soil, dust, drinking water, garden produce, food and accidental ingestion of water and sediments; and
- Dermal absorption from soil, dust and water contact with skin.

Exposure pathways may require direct contact between receptors and media of concern (*e.g.,* incidental ingestion of soil), or may rely on indirect pathways which require movement of the chemical from one environmental medium to another (*e.g.,* the uptake and/or transfer of a chemical from soil into home garden vegetables which are then ingested by an individual).

The potential for adverse health effects is dependent, in part, upon the existence of an exposure pathway. In other words, if there is no possible exposure to a chemical, regardless of its concentration or toxic potency, then there is no potential for the development of adverse health effects from that chemical. However, it is important not to overlook relevant and/or potentially significant exposure pathways within the HHRA process.

Within the GSA, there are a variety of exposure pathways that could result in receptors coming into contact with COC. The Vale Inco and Xstrata Nickel smelting facilities, as part of normal operations, release various chemicals and particulate matter to air. As these materials descend to ground level, human exposure could occur *via* direct exposure pathways such as inhalation and dermal contact directly with the primary media (*e.g.* particulate from the smelter stacks). Over time, the particulate and some gaseous substances associated with this plume settle out of the air and are deposited onto local soils and other surfaces. The rate of this deposition process depends upon local meteorological conditions, such as wind speed and precipitation rates, as well as the physical characteristics of the substance.

As a result of chemical deposition, human exposure may also occur through indirect pathways. Individuals may come in contact with these chemicals in secondary media as the chemicals move through the environment after release. Indirect exposure may include inhalation and ingestion of chemicals present in dusts generated from soil, soil ingestion itself (particularly for children), and ingestion of garden produce grown in the study area. Given the abundance of wildlife and fish habitat in the GSA, and that dietary preferences of many of the GSA residents (and First Nation communities, in particular) include wild fish and game, the assessment also considered potential exposures to the COC arising from the consumption of wild plants, fish and game animals obtained from within the study area.

GSA residents also utilize surface and groundwater resources within the study area that may be impacted by the COC. Therefore, it is important to consider potential exposures related to ingestion (*i.e.,* drinking) and dermal uptake (*i.e.,* showering, swimming, or bathing) of COC due to contact with surface and ground water resources. However, some of these potential pathways contribute minimally to the overall exposure to Sudbury residents (*e.g.,* dermal exposure to water while showering or swimming), when compared to other direct exposure pathways (*e.g.,* consumption of potable water).

Table 2.11 lists all of the theoretically possible pathways of exposure screened in the current assessment. Only those pathways considered to be of greatest significance have been evaluated in the quantitative exposure assessment. The relative contributions of the various pathways is not expected to be equal. Several of the pathways made only a very small contributions to the total estimated daily intake (*i.e.,* total exposure), while others were more important. The benefits gained by inclusion of minor pathways into the quantitative phase of the assessment are very limited.

Further discussion of those pathways considered less significant and therefore not carried forward into the detailed HHRA, is provided in Table 2.12.

Table 2.11 Exposure Pathways Evaluated / Screened

Potential Exposure Pathways	Exposure Route		
	Inhalation	Ingestion	Dermal
Air	■ **indoor air** ■ **outdoor air**		□
Soil (outdoors)	□ resuspended soil	■	■
Dust (indoors)	□ living spaces □ attic dust □ resuspended dust	■ **living spaces** □ attic dust	■ **living spaces** □ attic dust
Potable water		■	□ showering/bathing
Surface water		□	□ swimming
Food (market basket)		■	
Food (local)		■ **fish** ■ **game** ■ **vegetables** □ livestock ■ **berries** ■ **fruit** □ mushrooms	
Food (home grown)		■ **vegetables** ■ **fruits**	
Mother's milk		□	
Infant formula		■	
Transplacental transfer		□	

Note: □ indicates that the pathway was excluded (see Table 2.11 for detailed explanation).
■ **indicates that the pathway was quantitatively evaluated in detailed HHRA.**

Table 2.12 Exposure Pathways Excluded from Assessment

Exposure Route	Exposure Pathway	Basis for Exclusion
Inhalation	attic dust	Intermittent and short-term concern only.
	indoor dust	Particulates entering buildings are likely to settle out and not be inhaled. For the purpose of the risk assessment, it was assumed that airborne particulates, as measured by the air monitoring study, will be inhaled throughout the day, both indoors and outdoors (U.S. EPA, 1998).
	outdoor dust	Assumed to be captured *via* the air monitors that collected data for TSP, PM_{10} and $PM_{2.5}$ particulate bound contaminants. For the purpose of the risk assessment, it was assumed that airborne particulates, as measured by the air monitoring study, will be inhaled throughout the day, both indoors and outdoors.
	re-suspended dust (further details provided below in Section 2.1.5.1)	U.S. EPA recommends that inhalation of resuspended dust be evaluated only if site-specific exposure setting characteristics indicate that this is potentially a significant pathway (U.S. EPA, 1998). This could potentially be the case in areas of tailing piles. However, the air monitoring program was designed to capture dust-borne contaminants originating from the tailing piles, and this data was incorporated into the indoor air concentration set.

Table 2.12 Exposure Pathways Excluded from Assessment

Exposure Route	Exposure Pathway	Basis for Exclusion
Ingestion	Livestock (further details provided below)	Not considered due to the limited grazing lands within the areas of Sudbury directly impacted by the facilities. Results of livestock sampling in the GSA indicated local livestock COC levels were similar to those found elsewhere in Ontario (see summary of data in Table 2.13). Details for Sudbury specific livestock data are provided in Appendix H.
	Food (local mushrooms)	Local mushrooms were considered as part of the overall above ground vegetable food group (*i.e.*, not individually). It should be noted that the Nutrition Canada food consumption survey indicated that 0.3% (33/12,732) of the Canadian population typically consume raw mushrooms.
	Surface water (swimming)	Ingestion of surface water was not considered to be a significant exposure pathway because the estimated ingestion rate while swimming is 50ml.hour (U.S. EPA, 1989), which amounts to only 150 mL/day if child swims 3 hr/day. This will result in an approximately 5% annual increase in water-borne exposures if child swims 3 hrs/day for 4 months of the year in a local lake.
	Sediment	Ingestion of sediment while wading or playing on the beach was evaluated quantitatively as part of the screening process. Assuming the typical receptor parameters listed above and an assumed exposure duration of 1 hour/day for a two month period, using conservative upper end sediment concentrations, predicted oral risks related to incidental ingestion of sediment were between a factor of approximately 1,000 to 1,000,000 below the acceptable risk benchmark, depending on the COC. Given the low potential risk and the intermittent nature of these exposure, this pathway was not considered significant and not evaluated further.
	Attic dust	Intermittent and short-term concern only.
	Mother's milk (further details provided below)	No published methodology is available for consideration of mother's milk exposures to inorganic compounds. Maternal transfer exposures are considered by the IEUBK model for lead, but no such model is available for the other COC. A simple comparison indicates that formula exposures to arsenic, cobalt, copper and nickel are similar to or higher than estimated mother's milk exposures (see Table 2.14). (Formula is considered as part of the background market basket exposure, and the water used in preparation is considered as part of local drinking water exposure.)
Dermal	Air	Not a significant exposure route for inorganic compounds, including COC.
	Potable water (showering/bathing)	Not a significant exposure route for the COC. (U.S. EPA, 2004a).
	Surface water (swimming)	Not a significant exposure route for the COC (U.S. EPA, 2004a). Assuming a child swims 3 hrs/day for 4 months of the year in a local lake, swimming exposure less than 10% of potable water exposure. Considered insignificant by U.S. EPA.
	Sediment	Dermal exposure to sediment while wading or playing on the beach was evaluated quantitatively as part of the screening process. Assuming the typical receptor parameters listed above and an assumed exposure duration of 1 hour/day for a two month period, using conservative upper end sediment concentrations, the predicted dermal risks related to dermal contact with sediment were between a factor of approximately 1,000 to 1,000,000,000 below the acceptable risk benchmark, depending on the COC. Given the low potential risk and the intermittent nature of these exposure, this pathway was not considered significant and not evaluated further.

Table 2.12 Exposure Pathways Excluded from Assessment

Exposure Route	Exposure Pathway	Basis for Exclusion
Transplacental transfer	Maternal exposure can be important for establishing the body burden of certain metals prior to birth, as a result of transplacental transfer. For metals that have long retention times in tissues, the maternal tissues can serve as a reservoir for exposures during fetal development or infancy, long after cessation of maternal exposure. This can be a particularly important exposure pathway for metals that accumulate in the inorganic matrix of bone (*e.g.*, lead), as mobilization of bone minerals to develop the fetal skeleton can result in a transfer of maternal bone stores of metals to the fetus (U.S. EPA, 2004b). Transplacental exposures cannot be directly estimated from environmental measurements, and such assessments require the use of pharmacokinetic models. A few models of transplacental transfer of lead in humans have been developed; models for other metals are not available for use in risk assessment (U.S. EPA, 2004b). The IEUBK lead model has been used as part of this assessment to ensure that transplacental transfer of lead was considered in the HHRA.	

2.1.5.1 Resuspended Dust

As noted above, U.S. EPA recommends that inhalation of resuspended dust be evaluated only if site-specific exposure setting characteristics indicate that this is potentially a significant pathway (U.S. EPA, 1998). Therefore, the potential impacts of resuspended dust were evaluated to determine if it was an important exposure pathway for the current assessment. The assumption that 100% of indoor dust (PM_{10}) originated from settled dust was compared with the assumption utilized in the assessment (*i.e.*, that indoor air-borne dust is equivalent to outdoor air/dust). To conduct this comparison, it was assumed that indoor airborne dust (PM_{10}) levels were 29.8 $\mu g/m^3$ (*i.e.*, the typical indoor suspended dust level reported in Pellizzari *et al*., 1999) and that, conservatively, 100% of this dust originated from settled dust. Settled dust concentrations were estimated based on the regression relationship between outdoor soil and indoor dust derived as part of the dust study (refer to Appendix M). The following table (Table 2.13) provides a comparison between the estimated indoor dust concentrations (re-suspended) and the measured outdoor air (dust) concentrations used in the assessment (*i.e.*, the 95 UCLM in Table 3.5).

Table 2.13 Comparison of Estimated Indoor (Re-suspended) Dust and Outdoor Air Concentrations

COC	COI	95 UCLM [soil] µg/g	Settled Dust Concentration (µg/g)	Indoor Dust (PM10) Level (2.98×10^{-5} g/m^3)	Indoor Airborne Dust Concentration (µg/m^3)	Outdoor Air Concentration (µg/m^3)
As	Coniston	12.1	16.8	2.98×10^{-5}	5.0×10^{-4}	2.4×10^{-3}
Co	Coniston	18.4	42.6		1.3×10^{-3}	9.0×10^{-4}
Cu	Coniston	315.5	619.2		1.8×10^{-2}	1.6×10^{-2}
Ni	Coniston	432.8	668.7		2.0×10^{-2}	1.2×10^{-2}
Pb	Coniston	52.0	127.4		3.8×10^{-3}	8.0×10^{-3}
Se	Coniston	1.3	2.7		8.0×10^{-5}	3.4×10^{-3}
As	Copper Cliff	19.0	18.5	2.98×10^{-5}	5.5×10^{-4}	5.0×10^{-3}
Co	Copper Cliff	33.4	59.7		1.8×10^{-3}	2.5×10^{-3}
Cu	Copper Cliff	1370.0	842.8		2.5×10^{-2}	8.1×10^{-2}
Ni	Copper Cliff	976.1	896.1		2.7×10^{-2}	6.0×10^{-2}
Pb	Copper Cliff	97.9	150.2		4.5×10^{-3}	2.2×10^{-2}
Se	Copper Cliff	7.5	15.4		4.6×10^{-4}	5.5×10^{-3}
As	Falconbridge	78.6	25.3	2.98×10^{-5}	7.5×10^{-4}	2.4×10^{-3}
Co	Falconbridge	56.5	80.6		2.4×10^{-3}	2.5×10^{-3}
Cu	Falconbridge	1005.5	789.8		2.4×10^{-2}	2.6×10^{-2}
Ni	Falconbridge	1071.5	926.7		2.8×10^{-2}	2.8×10^{-2}
Pb	Falconbridge	82.3	143.6		4.3×10^{-3}	1.5×10^{-2}
Se	Falconbridge	3.1	6.3		1.9×10^{-4}	3.4×10^{-3}
As	Sudbury Centre	7.2	14.9	2.98×10^{-5}	4.4×10^{-4}	6.1×10^{-3}
Co	Sudbury Centre	11.3	32.1		9.6×10^{-4}	9.7×10^{-3}
Cu	Sudbury Centre	204.0	565.0		1.7×10^{-2}	1.7×10^{-1}
Ni	Sudbury Centre	210.1	515.5		1.5×10^{-2}	9.5×10^{-2}
Pb	Sudbury Centre	35.9	115.7		3.4×10^{-3}	2.5×10^{-2}
Se	Sudbury Centre	1.3	2.7		7.9×10^{-5}	9.2×10^{-3}
As	Hanmer	4.3	13.3	2.98×10^{-5}	4.0×10^{-4}	5.6×10^{-3}
Co	Hanmer	6.5	23.6		7.0×10^{-4}	7.0×10^{-4}
Cu	Hanmer	67.0	447.2		1.3×10^{-2}	9.9×10^{-2}
Ni	Hanmer	67.9	343.3		1.0×10^{-2}	1.2×10^{-2}
Pb	Hanmer	19.2	98.4		2.9×10^{-3}	9.8×10^{-3}
Se	Hanmer	0.7	1.4		4.1×10^{-5}	4.0×10^{-3}

As noted in Table 2.13, the use of the measured outdoor air concentration to represent indoor dust concentrations is conservative as compared to predicted indoor dust levels based on re-suspension of settled dust (*i.e.*, assuming concentrations in indoor dust are equivalent to that present in outdoor air would lead to a higher COC concentrations than those predicted based upon resuspended dust). As such, the current assessment conservatively assumed that indoor air concentrations of the assessed COC were equivalent to those measured outdoors, and resuspended dust was not assessed separately.

2.1.5.2 Livestock

Ingestion of livestock from the GSA was not considered due to the limited grazing lands within the areas of Sudbury directly impacted by the facilities. Results of livestock sampling in the GSA indicated that COC levels in local livestock were generally similar to those found elsewhere in Ontario (see summary of data in Table 2.14). Details of Sudbury specific livestock data are provided in Appendix H and those for livestock concentrations typical of Ontario in Appendix D.

Table 2.14 Mean Livestock Concentrations (ng/g)[a]

Studies	As	Co	Cu	Ni	Pb	Se
Sudbury	15.2	10.8	1,060	22.4	6.6	247
Port Colborne	30.6	14.2[b]	21,935[b]	14.5		
MOE (red meat and poultry combined)	34-49					
Health Canada		10.4	3495[b]		13.1	
Dabeka [c]	24.3	8.7-10.7	11,000	385	5.2-20.2	
U.S. FDA				39		268

Note: Complete references and additional sources included in Appendix D of this volume.
[a] Meat, poultry and eggs combined, organ meats excluded; 95UCL presented where available
[b] Organ Meats
[c] Several references (see Appendix D for a complete list of references)

2.1.5.3 Mother's Milk

A review of the literature indicated no published methodology for consideration of mother's milk exposures to inorganic compounds. In the specific case of exposure to lead, maternal transfer exposures are considered by the IEUBK model, but no such model is available for the other COC. As an alternative to mother's milk, infants may consume formula. A simple exposure comparison indicates that formula exposures to arsenic, cobalt, copper and nickel are similar to or higher than estimated mother's milk exposures (Table 2.15). (Note that the values for mother's milk exposure given in Table 2.14 are not reliable estimates suitable for use in this risk assessment; however, they are useful for making the comparison between formula and mother's milk exposures.) Given that formula exposures are likely similar to or higher than mother's milk exposures, and that mother's milk exposures cannot be reliably estimated, consumption of mother's milk was not considered further in the current assessment. Consumption of infant formula was considered as part of the overall market basket EDI route-of-exposure (see Appendix D of this volume for further information).

Table 2.15 Comparison of Estimated Mother's Milk[a] (MM) *versus* Formula-Fed Exposure for Female Infants in the Copper Cliff COI

Parameter	Arsenic	Cobalt	Copper	Nickel
Canadian background MM concentrations (μg/L) (provided for comparison only)	0.83 – 7.6 [b]	nd – 6 [c]	210-570 [c]	nd – 28 [c]
Transfer Factor[d] [TF] (day/L)	0.012	0.53	0.54	0.28
Adult Body Weight[e] [BW_{adult}] (kg)	70.7	70.7	70.7	70.7
SARA Adult Exposure, Copper Cliff [D_{adult}] (modeled value)	0.1	0.37	23	2.3
Estimated Concentration in Milk (μg/L) [$C_{milk} = TF \times D_{adult} \times BW_{adult}$]	0.085	14	880	46
Infant MM Ingestion Rate[f] [IR_{milk}] (L/day)	0.8	0.8	0.8	0.8
Infant Body Weight[e] [BW_{infant}] (kg)	8.2	8.2	8.2	8.2
Infant MM Exposure[a], Copper Cliff (μg/kg/day) [$E_{milk} = C_{milk} \times IR_{milk} / BW_{infant}$]	**0.008**	**1.35**	**85.67**	**4.44**
Infant Formula Ingestion Rate[g] [$IR_{formula}$] (g/kg/day)	102	102	102	102
Canadian background formula concentrations[h] [$C_{formula}$] (μg/g)	7.15×10^{-6}	4.57×10^{-3}	8.99×10^{-1}	1.10×10^{-2}
Infant Drinking Water Ingestion Rate[e] [WIR_{infant}] (L/day)	0.543	0.543	0.543	0.543
Concentration in Local Drinking Water, Copper Cliff [C_{water}] (μg/L)	2.53	0.045	170.11	49.26
Infant Formula-fed Exposure, Copper Cliff (μg/kg/day) [$E_{formula} = (IR_{formula} \times C_{formula}) + (WIR_{infant} \times C_{water} / BW_{infant})$]	**0.17**	**0.47**	**103**	**4.4**

[a] Estimated exposure calculated using the mother's milk approach developed by JWEL (2004). This mother's milk approach relies on a series of simplifying assumptions, that although useful for making comparisons between mother's milk and formula fed infant exposures, are not appropriate for assessing exposure in this risk assessment. Note that transfer factors have not been developed for lead and selenium, so the approach cannot be applied to all of the COC.
[b] Concha *et al*., 1998
[c] Friel *et al*., 1999
[d] JWEL, 2004
[e] Richardson, 1997
[f] Emmett *et al*., 2000
[g] Health Canada, 2005 pers. comm.
[h] See the Market Basket EDI (Apx. D) for complete referencing and derivation information

2.1.6 Exposure Scenarios

A key requirement of any exposure assessment is the ability to evaluate changing levels of exposure under a variety of different scenarios. Exposure scenarios describe the situations and conditions in which receptors may be exposed to COC in environmental media. In developing an exposure scenario, a variety of factors are considered, including human access to specific areas or environmental media, physical activities/behavioural patterns, time spent in contact with exposure media, other potential sources of exposure to COC, lifestyle factors (*e.g.,* hunting, fishing and other uses of natural resources) and the existence of sensitive sub-populations or sensitive locations within the community (*e.g.,* children at schools, playgrounds; the elderly at nursing homes).

Evaluation of different exposure scenarios can also be performed in an iterative manner to assess the efficacy of various remedial options during the risk management phase of a project. In general, while all receptors may potentially be subject to the same or a similar set of exposure pathways and environmental concentrations, the magnitude of exposure experienced by an individual *via* those pathways is, to some extent, dependent on the behavioural and physical characteristics of that individual.

For the current assessment of the GSA, a number of exposure scenarios were developed based on the applicability of particular activities and behaviour patterns to certain groups or subpopulations. Consideration was given to provide a sufficient level of protection for GSA residents, as well as a sufficient level of sensitivity to enable, if necessary, the potential comparison of exposure estimates to biological monitoring data (*e.g.,* urinary arsenic levels). The exposure scenarios were deliberately selected to be conservative in nature (*i.e.,* reasonable worst case), ensuring that potential exposures to chemicals and the resultant risks are neither overlooked nor underestimated.

Selected Exposure Scenarios:

- Typical Ontario resident (background): In this scenario, it was assumed that exposure to COC occurs at typical Ontario background (or ambient) levels. Background exposures from the general food basket survey were incorporated into all final exposure estimates for all receptors in this scenario.
- Typical GSA resident: This scenario considered individuals currently living in the GSA. This included both receptors that would likely be away from home for regular scheduled periods due to either work or school, and those receptors who do not leave the home area on a regularly scheduled basis *(i.e.,* stay-at-home receptors/primary care-givers). It was assumed that "stay-at-home" receptors (*e.g.,* infants, preschool children and adults that care for them, retired persons *etc*.) would occasionally leave the home area for such reasons as shopping, visiting, vacations, *etc.* The amount of time in different areas of the GSA as well as the time spent indoors and outdoors during summer/winter months was evaluated as a function of receptor age class. A complete sensitivity analysis of exposure pathways was conducted to identify the most critical pathways with respect to significance of contribution and associated uncertainty.

The following additional scenarios were designed in order to account for certain subgroups within the overall GSA population that were of potential concern due to specific behavioural or activity patterns:

- First Nation residents: Local First Nation people living in the GSA participate in a variety of hunting and trapping activities and therefore can consume significant amounts of local wild game and fish. In order to account for these specific behaviours, wild game and fish consumption patterns for the Typical GSA resident were adjusted to address these potentially higher dietary exposures.

- Recreational Hunters/Anglers: Local residents who participate in seasonal hunting and fishing activities can also consume significant amounts of local wild game and fish. As with First Nation residents, the wild game and fish consumption patterns for the Typical GSA resident were adjusted to address these potentially higher dietary exposures.

One exposure scenario that was not evaluated is that of local residents who are additionally exposed to the COC at their workplace (*e.g.,* in the mines or at the smelting/processing facilities). Assessments of occupational exposures are outside the scope of the HHRA. Occupational exposure studies are dealt with by the Vale Inco and Xstrata Nickel medical departments and the various Joint Occupational Health and Safety Committees.

2.1.7 HHRA Conceptual Model

A primary tool in the problem formulation step is to develop a conceptual model that illustrates all potential human receptors and the related exposure pathways. Typically, each relevant pathway is illustrated, including those that may be eliminated through screening or risk management measures. Therefore, the conceptual model should be able to distinguish between routes of exposure that would potentially exist without risk management measures (*i.e.*, existing or future pathway barriers), and routes that are expected to exist under conditions which include risk management measures.

Figure 2-11 provides a conceptual model for the Sudbury HHRA. Under the current assessment scenarios, risk management measures are not being considered, and all potential pathways of exposure are available to the applicable receptors (*i.e.*, GSA residents).

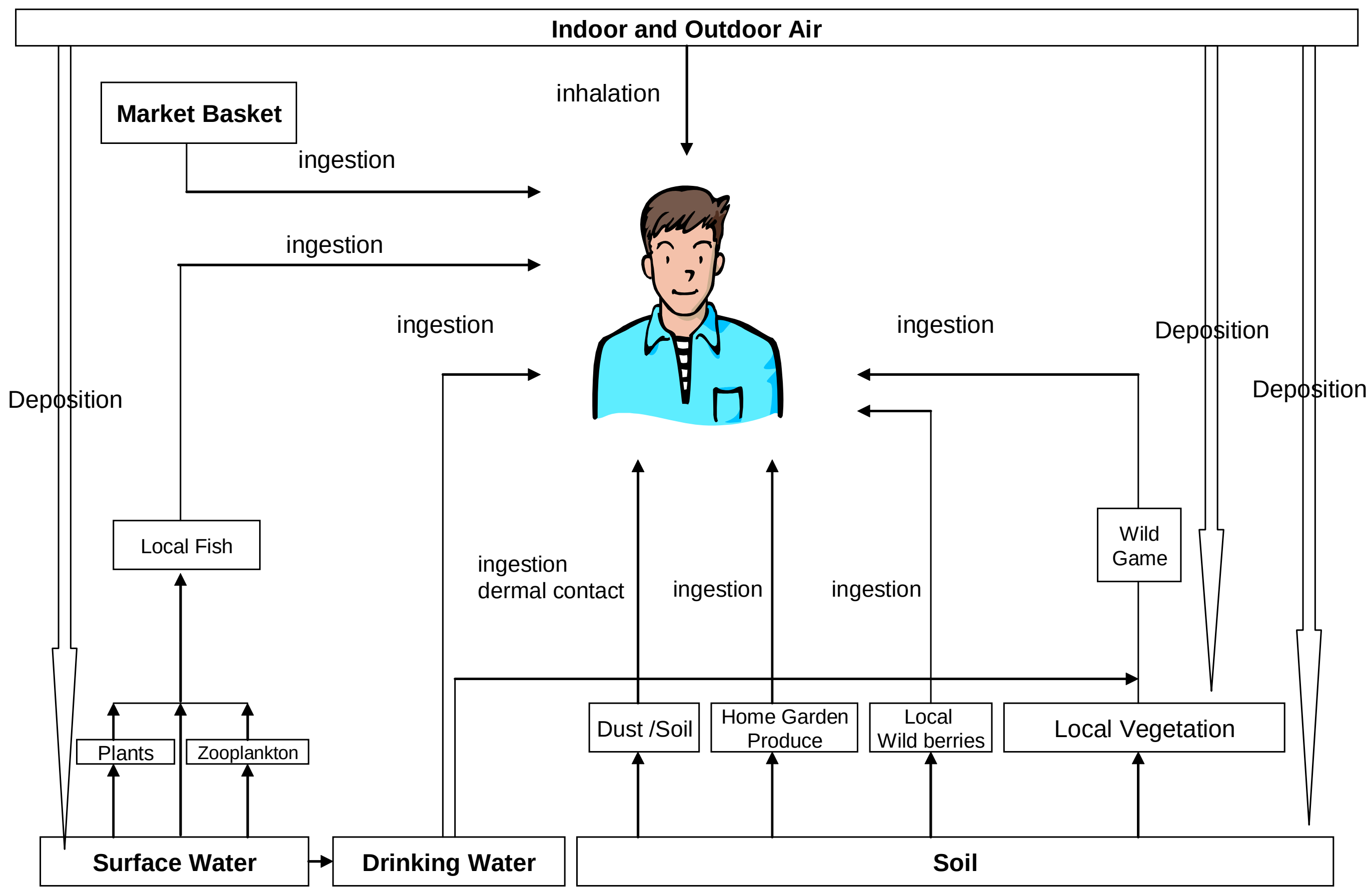

Figure 2-11 Conceptual Model for the Sudbury HHRA

2.2 Screening Level Risk Assessment

Typically, a SLRA is a cursory, deterministic, quantitative HHRA, employing a multitude of conservative and non-site-specific assumptions. The results of the SLRA are generally considered a significant over-estimation of actual exposures and related health risks. As a result, those communities, chemicals, receptors and pathways that are not identified by the SLRA as being of concern to human health can confidently be removed from the lists of communities, chemicals, pathways and receptors of concern.

For the current risk assessment, much of the work to screen and select COC had already been completed in Phase 1 of the Study, and was outlined in the RFP upon which the current risk assessment was built. It has always been the expectation of the Technical Committee, and members of the Sudbury community at large, that a full detailed HHRA would be conducted for each of the COC. Therefore, a formal quantitative SLRA was not evaluated by the study team. Rather, components of an SLRA were evaluated qualitatively to help guide the detailed risk assessment.

2.3 Identification of Data Gaps

A key task conducted as part of the Problem Formulation step involved the identification of key data gaps which required further sampling and/or analysis prior to conducting the detailed HHRA (*i.e.*, Phase 3). These data gaps represented areas of uncertainty in the data or assumptions used within the HHRA. The key areas of uncertainty identified during Phase I work included collecting additional COC-specific data in:

- Ambient outdoor air;
- Home-grown fruits and vegetables;
- Wild blueberries and mushrooms;
- Wild game and fish from local lakes;
- Indoor dust; and
- Drinking water from private residential wells or lakes

These and other issues were addressed in Phase 2 of the HHRA (Chapter 3).

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