SUDBURY AREA RISK ASSESSMENT

CHAPTER 1.0
INTRODUCTION TO THE SUDBURY SOILS STUDY

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1.0 INTRODUCTION TO THE SUDBURY SOILS STUDY

1.1 Study Rationale

The Sudbury Basin is an area rich in mineral deposits, particularly in the nickel and copper ores that have drawn people to the region for the past 125 years. Since 1971, the Ontario Ministry of the Environment (MOE), Vale Inco (formerly Inco Limited) and Xstrata Nickel (formerly have conducted soil-sampling programs to determine the concentrations of metals in soils and vegetation across the Sudbury region. Those studies have demonstrated there are areas in Sudbury with elevated metal levels in the soil. These areas are generally close to the historic smelting sites of Copper Cliff, Coniston and Falconbridge, but elevated metal levels are found throughout the city. The smelter operation at Coniston was closed by Inco in 1971. Vale Inco still operates the smelter at Copper Cliff, while the smelter in the town of Falconbridge is operated by Xstrata Nickel.

Although metals do occur naturally in all soils, the studies indicate that elevated metal concentrations in surface soil (the top 5 cm) are the result of local mining, smelting, and refining operations, including the original roast yards.

In 2001, the MOE released a report entitled *Metals in Soil and Vegetation in the Sudbury Area (Survey 2000 and Additional Historic Data)* (MOE, 2001). That report reviewed and summarized the results of the previous 30 years of studies, comparing metal levels in local soils to the criteria listed in the MOE's *Guideline for Use at Contaminated Sites in Ontario* (MOE, 1997). During this evaluation, the MOE identified that concentrations of nickel (Ni), cobalt (Co), copper (Cu) and arsenic (As) in Sudbury soils exceeded the MOE criteria.[1] In addition, the MOE review identified significant gaps in the existing data in terms of spatial coverage (geographic area) and changing methods over the 30 year period, making direct comparison of much of the data impossible. Therefore, the 2001 MOE report made two primary recommendations:

- That a more detailed soil study be undertaken to fill data gaps; and
- That a human health risk assessment (HHRA) and ecological risk assessment (ERA) be undertaken.

[1] Note: In chemical terms, As is considered a metalloid and not a metal. However, for ease of terminology the elements considered in this study will be referred to as metals throughout the reports.

These recommendations provided the impetus for the Sudbury Soil Study. Both Vale Inco and Xstrata Nickel voluntarily accepted these recommendations, and in 2001, the Sudbury Soils Study was initiated. The study is overseen by a collaborative Technical Committee (TC), comprised of Vale Inco, Xstrata Nickel, the MOE, the Sudbury & District Health Unit (SDHU), the City of Greater Sudbury, and the First Nations and Inuit Health Branch of Health Canada. The study organization and development are described in more detail in Section 1.5.

It must be noted that the MOE soil criteria published in the *Guideline for Use at Contaminated Sites in Ontario* (MOE, 1997) are not “action levels”. Therefore, exceeding the generic criteria does not automatically imply that clean up is required (MOE, 2001). However, soil contaminant concentrations in excess of the criteria listed in the guideline (MOE, 1997) do indicate the need for further investigation and/or a risk assessment.

Several jurisdictions (*e.g.*, Health Canada, MOE, United States Environmental Protection Agency [U.S. EPA], European Union) have published guidance documents outlining procedures for conducting a “Site-specific Risk Assessment”, or SSRA. SSRA guidelines were developed to address concerns at relatively small, well-defined, industrial properties where off-site contamination is not an issue. The broad geographic scope of the Sudbury Soils Study goes far beyond an SSRA. The term “Area-Wide Risk Assessment” (AWRA) or Community-Based Risk Assessment (CBRA), has been applied in Ontario to studies of larger magnitude. For the purposes of this study the term AWRA is adapted to be more consistent with recent MOE guidance on risk assessment (MOE 2004a). AWRA is a relatively new form of risk assessment for which no formal guidance or protocols currently exist in Ontario or Canada. At the time of this report, an AWRA of this scope had never been completed in Canada. The ERA and HHRA for the Sudbury area were, therefore, conducted in general accordance with the available Canadian, U.S. EPA, and MOE framework and regulatory guidance for SSRAs, with emphasis on those provided in the *Guideline for Use at Contaminated Sites in Ontario* (MOE, 1997).

An AWRA must take into account a wide range of technical or scientific, regulatory, and social considerations. Although the impetus for the study was soil quality, all potential exposure pathways must be considered for both the HHRA and ERA. To make the risk assessment as directly relevant to Sudbury as possible, a considerable amount of local or site-specific exposure data were gathered. This included data on the concentrations of metals in air, drinking water, food, indoor dust, and various other environmental media. The risk assessments also consider a range of human and ecological receptors and assessment end points to determine potential risk. These are all described in detail in Volumes II and III of the study report, the HHRA and ERA, respectively.

The purpose of gathering site-specific exposure data is to reduce the level of uncertainty in the predictions of risk. It can never be unequivocally stated that a particular exposure to a chemical poses absolutely no risk. Therefore, it becomes a matter of deciding what is the level of "acceptable" risk. The degree of acceptable uncertainty is then closely associated with the level of acceptable risk. This becomes a complex discussion and is dependent upon many factors, including the particular receptor under consideration. Of paramount importance are the consequences of an incorrect prediction of acceptable risk.

The concepts of risk and uncertainty are intentionally introduced early in this report, as they represent the inherent basis for many decisions made throughout the study. Entire textbooks have been written on these subjects, and they will be discussed further in Volumes II and III.

The last point to make in this introduction is to differentiate between Risk Assessment and Risk Management; the two are often mistakenly interchanged. However, the difference is considerable and important. Risk Assessment (either HHRA or ERA) is a process for collecting, organizing, and analyzing information to estimate the likelihood of undesired effects on human (HHRA) or non-human (ERA) receptors (after Suter *et al*., 2000).

If potential risk is identified or predicted, risk management initiatives can be undertaken to reduce the predicted risk. Risk Management decisions will be made based on a wide range of considerations and input from the stakeholders involved. Public regulatory agencies have legislated mandates for the protection of human or environmental health, while proponents or potentially responsible parties have legal, ethical and economic considerations. The public at large has a wide range of societal values that are also imposed on risk management decisions.

The Sudbury area risk assessment forms the basis on which future decisions on Risk Management will be made. The reports for the risk assessment cover three report volumes; the contents and organization of these reports are discussed in Section 1.6.

The following sections provide a broad synopsis of the background for this study (Section 1.2), describe the study area (Section 1.3), outline the organization of the study (Section 1.4) and describe the three volumes comprising the Sudbury Soils Study report (Section 1.5).

1.2 Background and Setting for the Study

The Sudbury Soils Study is not just about atmospheric emissions and soil quality, it is a story about people and their relationship with the environment. For this reason a considerable amount of time, effort and space in this report has been devoted to providing a detailed background to the study. Chapter 2 provides a detailed historical review of the development of Sudbury and the socio-economic impacts of the mining and smelting operations.

Conducting this HHRA/ERA represents a significant and logical step in the history of the City of Greater Sudbury. There have been tremendous social, technical and economic benefits from the mining and smelting activities at Sudbury, not just for the City, but for Canada as a whole. However, these benefits have also come with considerable cost to the environment.

Environmental degradation was apparent in the early 1900s, and by the early 1940s, government representatives were already meeting with local industry to discuss the smelter emissions and damage to the forests and local agriculture. By the late 1980s, significant ecological recovery was underway in the area due to reduced emissions from the smelters and restoration efforts by many groups and stakeholders. A detailed overview of the “regreening” of Sudbury’s landscape was provided in a book in the mid-1990s (Gunn *et al.,* 1995). That monograph and related activities began to change the global perception of Sudbury to a community committed to environmental protection, while still continuing active development of the natural mineral resources of the area. A number of key events and dates related to the smelters and environmentally related programs are summarized in Table 1.1.

The Sudbury landscape of today is the result of many factors and activities interacting over a period of nearly a century: sulphur dioxide fumigations, metal deposition, intense logging, wild fires, water and wind erosion, and enhanced frost action (Winterhalder, 1984). Until relatively recently it was assumed that vegetation damage in the Sudbury area was the direct result of sulphur dioxide emissions. However, during the late 1960s, there was increasing interest and examination of the effects of soil acidity (due to acid rain resulting from sulphur dioxide emissions) and elevated metal concentrations.

The ecological effects associated with smelter emissions in Sudbury have been widely studied and reported. Now, with this study, the human health implications of metals in soil and the environment are addressed. This is the first comprehensive study to examine the potential human and ecological risks associated with metals in air, soil, water, vegetation, and other environmental matrices in the Sudbury area.

Table 1.1 Chronology of Events Influencing the Sudbury Region

	Year
Formation of Sudbury Basin	~2 billion years ago
Ojibway, Huron and Ottawa First Nations settle in the area	~10,000 years ago
First European explorer (Champlain)	1750
First mapping of mineralization in Sudbury area	1856
Discovery of mineralization in Sudbury during construction of transcontinental railway	1883
First purchase of mining lands by Murray	1884
First use of corrosion resistant nickel steel	1885
First smelting of Sudbury ores by roast heap	1888
Parent company of Inco Limited established	1902
First geological map of Sudbury Basin	1905
Ontario Royal Commission of Nickel	1915
Damages by Sulphur Fumes Arbitration Act proclaimed	1921
Founding of International Nickel of Canada Ltd. (Inco)	1928
Formation of Falconbridge Nickel Mines Ltd.	1928
First ambient SO_2 monitoring network established	mid-1940s
Formation of the Sulphur Dioxide Committee	1944
First acid plant established to produce elemental sulphur from SO_2	1958
Ontario issues control orders to reduce emissions from area smelters	1969
First provincial control order on Falconbridge	1969
Sudbury Environmental Enhancement Programme (SEEP) Committee initiated	1969
First provincial control order on Inco	1970
First published concerns of long-range atmospheric damage from Sudbury	1970
Completion of Inco's "Superstack" and major emission controls	1972
Vegetation Enhancement Technical Advisory Committee (VETAC) initiated	1973
MOE - Sudbury Environmental Study	1973-80
First International Conference on Acid Rain at Ohio State University	1976
Regional Land Reclamation initiated	1978
Muskoka Acidic Precipitation Conference	1985
Ontario government initiates Countdown Acid Rain Program	1985
First published evidence of reversal of acidification, Sudbury lakes	1986
U.N. Local Government Honours Award to Sudbury	1992
Production of Canadian (CCME) Approaches to Ecological Risk Assessment at Contaminated Sites	1993
Development of MOEE Generic Soil Cleanup Criteria (Guideline for Use at Contaminated Sites - Revised 1997)	1993
Legislated reductions in sulphur dioxide emissions achieved	1994
Publication of book "Restoration and Recovery of an Industrialized Region" (J. Gunn, ed.)	1995
Beginning of the Sudbury Soils Study	2001

1.3 Study Area

The City of Greater Sudbury is located in central northern Ontario (Figure 1-1). This new city represents the amalgamation of the towns and cities which comprised the former Regional Municipality of Sudbury (Sudbury, Capreol, Nickel Centre, Onaping Falls, Rayside-Balfour, Valley East and Walden), as well as several unincorporated townships (Fraleck, Parkin, Aylmer, Mackelcan, Rathbun, Scadding, Dryden, Cleland and Dill). Based on the 2001 Census, the total population of the new City of Greater Sudbury is 155,219. Sudbury is considered the largest municipality in Ontario, with its total area encompassing 3,627 km^2 including 330 lakes, many wetlands and different types of natural habitat and vegetation communities (City of Sudbury, 2005). The study area also encompasses two First Nations communities, Whitefish Lake First Nation in the southern portion of the study area, and Wanapitei First Nation, situated on the shore of Wanapitei Lake.

Sudbury functions as the service hub for all of northeastern Ontario, a market estimated at 550,000 people. While mining remains a major influence on the local economy, the city has diversified significantly in recent years to establish itself as a major centre of financial and business services, tourism, health care and research, education and government. In addition to Sudbury’s diverse economy, the city is proud of its three post-secondary institutions: Laurentian University, Cambrian College, and Collège Boréal (City of Sudbury, 2005).

The initial study area for the Sudbury Soils Study is best defined as the area from which soil samples were collected during the 2001 Sudbury Regional Soils Project. The extensive 2001 soil survey was undertaken to address data gaps in the concentration of metals and metalloids identified by the MOE in their review of the historical soil and vegetation quality data for the Sudbury area (MOE, 2001).

The Sudbury Regional Soils Project was developed in consultation with the Technical Committee and the Centre for Environmental Monitoring (CEM) at Laurentian University. The CEM designed the regional soil sampling survey to collect data from rural and remote areas with undisturbed soils. The MOE designed and implemented the urban soil-sampling program, which focused on residential properties, schools and parks within the City of Greater Sudbury. Details on the sampling programs, methodology and results are provided in separate reports (MOE, 2004b; CEM, 2004).

This initial study area for the Sudbury Soils Study encompasses approximately 40,000 km^2, including the City of Greater Sudbury and its outlying regions (Figure 1-2).

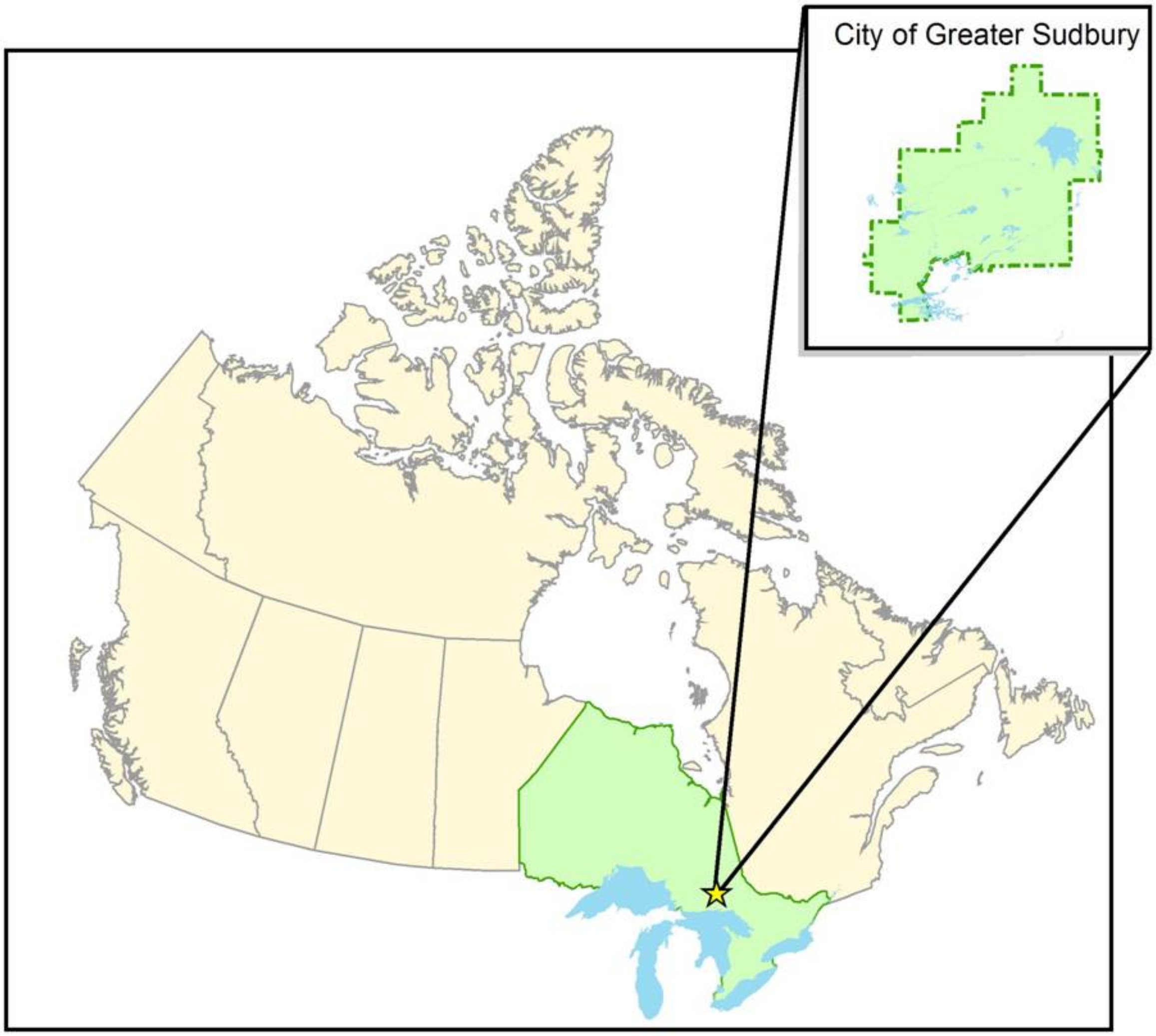

Figure 1-1 Location of the City of Greater Sudbury

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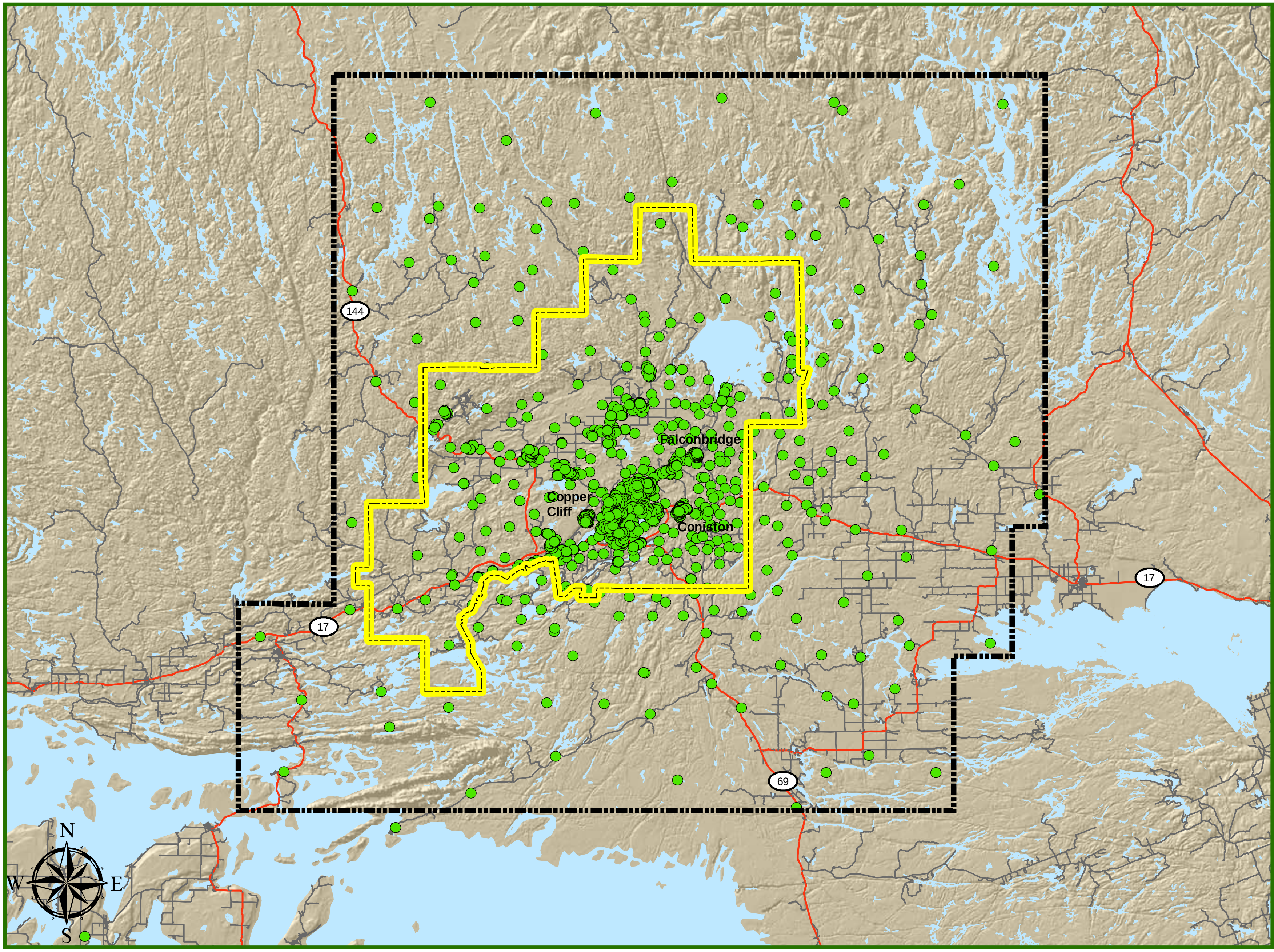

Sudbury Soils Study | Étude des sols sudburois
metals • health • environment
métaux • santé • environnement

Figure 1-2
Study Area

Study Boundary Area
Greater Sudbury Boundary
Soil Samples 0-5cm

Scale 1:970,000

0 10 20 Km

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Although the entire area was considered as the initial study area, the HHRA tended to concentrate on smaller areas dictated by elevated soil metal concentrations. For the purposes of conducting detailed evaluation in the HHRA, five specific Communities of Interest (COI) were identified:

- Copper Cliff
- Coniston
- Falconbridge
- Hanmer
- Sudbury centre

The HHRA needed to consider these independently, as each community contains varying concentrations and proportions of the COC considered in the risk assessment. The community metal concentrations are described in Chapter 10. For the purposes of the ERA, the initial study area was considered appropriate.

1.4 Study Organization and Process

The Technical Committee (TC) was formed in 2001, and provides the technical focus for the Sudbury Soils Study. The TC is comprised of the following partners:

- Vale Inco
- Xstrata Nickel
- Ontario Ministry of the Environment
- Sudbury & District Health Unit
- The City of Greater Sudbury
- First Nations and Inuit Health Branch of Health Canada.

Each of the partners is eligible to have three representatives on the TC. However, the First Nations and Inuit Health Branch of Health Canada appointed only one representative, while the City of Greater Sudbury appointed two representatives.

The study is funded by the two mining companies, Vale Inco and Xstrata Nickel. A facilitator was retained to help organize and run the monthly TC meetings, with an administrative assistant to record developments and decisions at meetings. All decisions were made by consensus.

As the study progressed, additional committees, subcommittees and other stakeholders became involved. The relationship between these groups is conceptually illustrated in Figure 1-3. A Public Advisory Committee (PAC) was established early in the process to help coordinate contact with the general public and to promote the flow of information between the TC and the public. A more complete description of the PAC and public consultation activities is provided in Chapter 6.

The overall vision of the Technical Committee for the HHRA and ERA was to develop:

"A transparent process that provides a thorough scientifically sound assessment of the environmental and health risks to the Sudbury community, and effectively communicates the results so that future decisions are informed and valued."

The TC has gone to considerable effort to ensure the process is thorough and transparent. These efforts have been driven, in part, by scepticism early in the process by members of the public that the companies funding the study would somehow be able to influence the results and outcome.

An Independent Process Observer (IPO) was brought into the study to participate in all TC and PAC meetings and observe how decisions are achieved. The IPO selected for this role was Mr. Franco Mariotti. Mr. Mariotti is a biologist by training, and a staff scientist at Science North in Sudbury. He is well known for promoting science education and advocating the virtues of Sudbury. As IPO, he has complete autonomy and publishes a quarterly IPO report on the study. The reports contain his observations and comments on the process of the study. His role is to help ensure that no one TC partner unduly influences the process, and that community interests are being met.

Members of the PAC and the IPO regularly attend and observe TC meetings. In addition, two Locals of major labour unions in Sudbury, the Canadian Auto Workers (CAW) and the United Steelworkers of America (USWA), were granted observer status at TC meetings. Each union routinely sent a representative to the meetings.

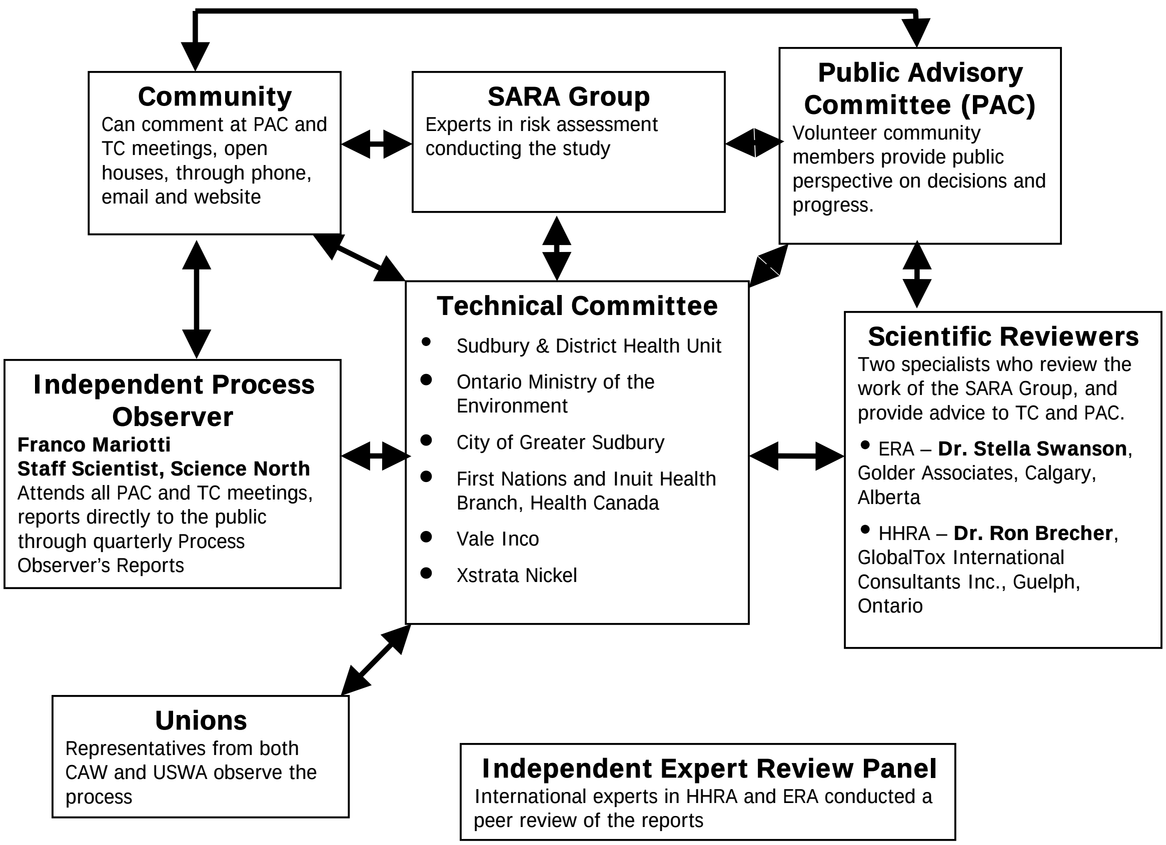

Figure 1-3 Stakeholder Linkages within the Sudbury Soils Study

The comprehensive soil sampling and analysis program was undertaken in the summer and fall of 2001 (Figure 1-4). As mentioned previously, the data from that survey formed the basis for both the HHRA and ERA. The companies and the MOE worked through 2001 and 2002 to collect and analyze the soil samples, and the TC worked during this time to define the scope of the HHRA and ERA.

The Sudbury Area Risk Assessment (SARA) Group was retained early in 2003 to undertake the HHRA and ERA. An overview of the study schedule is provided in Figure 1-4. The SARA Group is an affiliation of several Ontario-based consulting firms specializing in different scientific disciplines required to carry out a study of this broad scope.

Input from, and contact with, the community can occur at different levels, either through the PAC, directly to members of the TC, or to the SARA Group.

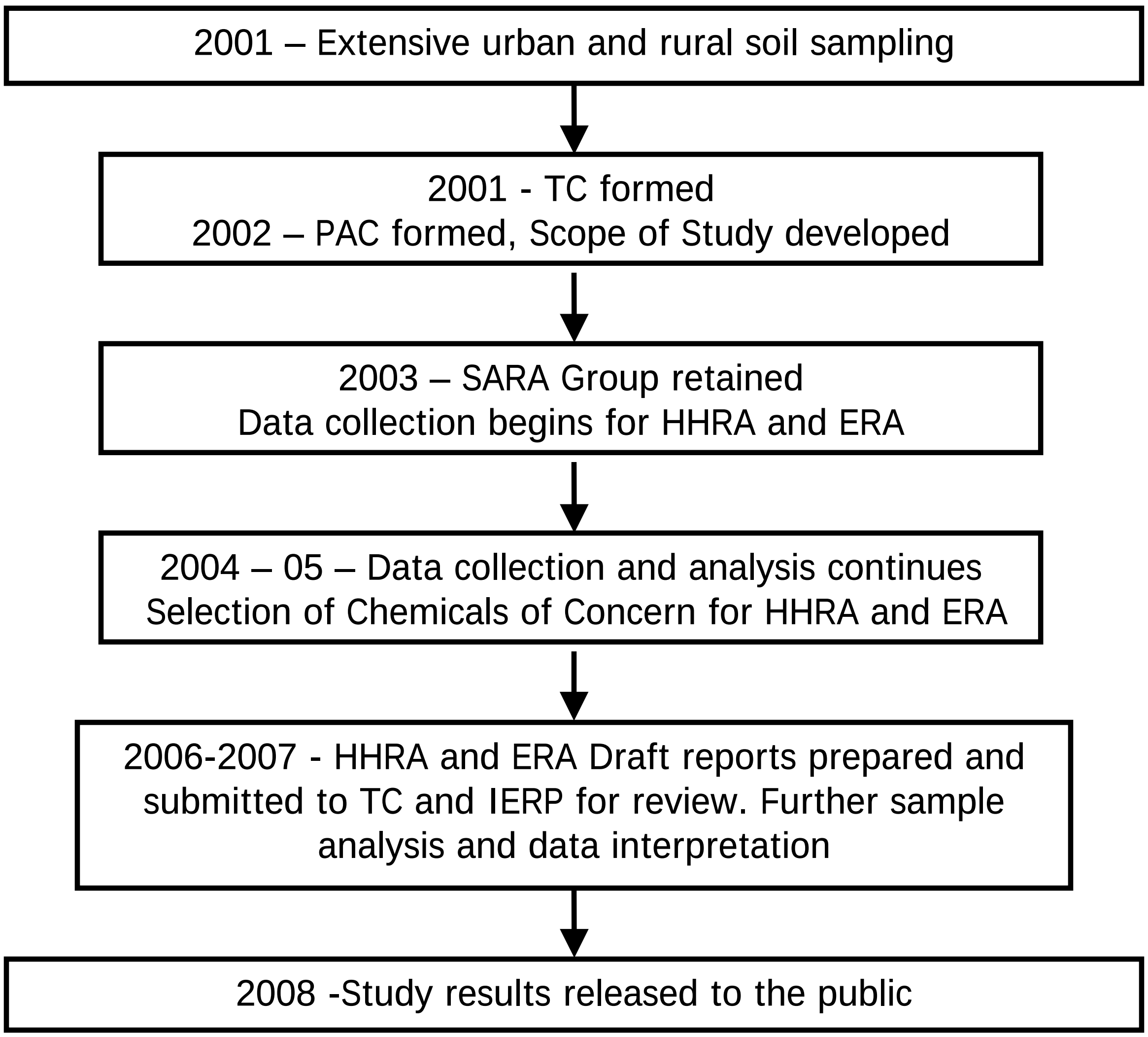

Figure 1-4 General Schedule for the Sudbury Soils Study

Each of the stakeholders on the TC has its own technical specialists for reviewing reports and material provided by the SARA Group. Some members of the TC retain outside consultants to assist with their review of technical material. As an additional transparent check of the scientific quality of the data and reports, the TC retained two additional experts, referred to as Scientific Advisors, in 2004. The Scientific

Advisors are Dr. Stella Swanson for the ERA, and Dr. Ronald Brecher for the HHRA (Figure 1-3). They were retained to provide advice and technical review of documents for the TC. They do not dialogue directly with the SARA Group and report to the TC as a whole, not to any one member. In addition, the Scientific Advisors are available to the PAC for presentations or to answer questions.

Lastly, all reports generated by the SARA Group were subject to external scientific peer review by an Independent Expert Review Panel (IERP). The IERP process developed by the TC and the group responsible for the external review (the Toxicology Excellence in Risk Assessment (TERA) Group) were selected by the TC with no input from the SARA Group.

1.5 Report Organization

The amount of material and information gathered and presented for the study covers thousands of pages that cannot practically be contained in a single report or volume. Therefore, the information and results are divided into three distinct volumes as follows:

Volume I. Background, Study Organization and 2001 Soils Survey

Volume I lays the foundation for the human health and ecological risk assessments that follow in Volumes II and III, respectively. This volume provides the rationale and background for the study, including an introduction to the historical and current physical and socio-economic characteristics of the study area, and describes the organization of the study, which is central to the process. A historical review of smelter air emissions and discussion of the history and current status of regreening efforts in the study area are presented along with an evaluation of the current vegetative cover. An overview of the public consultation and stakeholder involvement process is also provided, as considerable effort was dedicated to ensure that the general public were kept informed of the study process and results as they came available, and most importantly, that the public had ample opportunity to provide input and comment on the study as it proceeded. An overview of the 2001 Soils Survey results is provided, along with a description of the process for selecting the Chemicals of Concern (COC), which are common to both the HHRA and the ERA (arsenic, cobalt, copper, nickel, lead, and selenium). The spatial distribution of the COC in soil is provided both regionally and in detail for each of the communities. The soil data collected during the 2001 survey delineate the study area and provide the basis for both the HHRA and ERA.

Volume II. Human Health Risk Assessment (HHRA)

The methodology and findings of the HHRA are presented in detail in this report. This includes a description of the various human receptor groups (defined by sex and age) within the communities and toxicological profiles for each of the COC. Exposure modelling and risk assessments were undertaken for numerous combinations of receptors, COC and COI, providing for a wide range of risk scenarios.

A significant component of the HHRA was the collection of various environmental media and measurement of metal concentrations to develop Sudbury-specific exposure information. These data were then used in the exposure pathway model to help reduce uncertainty for the estimate of potential risk for each of the COC. Thus, Volume II also includes detailed appendices describing the collection and analysis of samples of ambient air, garden vegetables, wild blueberries, freshwater fish, cattle tissue, drinking water and indoor dust. Select media types (primarily soil, air filters, indoor dust) were further analyzed to determine the chemical form (speciation) of key metals (nickel, arsenic) and bioaccessibility of the metals for human uptake.

The combined results were integrated to identify potential risk to the most sensitive human receptor for each COC in each Community of Interest. If risk is identified, a soil intervention value (clean up criterion) will be developed if soil is deemed to be an important exposure pathway.

Volume III. Ecological Risk Assessment (ERA)

The primary goals of the ERA were to a) evaluate potential risk to terrestrial ecological receptors, and b) determine if the COC are preventing the recovery of regionally representative self-sustaining forest ecosystems. The primary study goal was subsequently divided into four separate objectives. Since the foundation of the study is soils, the focus of the ERA is on the terrestrial environment.

A detailed risk assessment of the multitude of lakes and rivers in the study area was outside the scope of work for the study and was not undertaken. However, an aquatic problem formulation was developed to lay the foundation for possible future studies or a more detailed aquatic ecological risk assessment.

Volume III describes the selection and identification of the Valued Ecosystem Components (VECs) considered in the detailed terrestrial ERA. The ERA report organization departs from what may be construed as a more “typical” study approach, in that it is largely organized around the four key objectives. These are:

Objective 1: Evaluate the extent to which the COC are preventing the recovery of regionally representative self-sustaining terrestrial plant communities.

Objective 2: Evaluate risks to terrestrial wildlife populations and communities due to COC.

Objective 3: Evaluate risks to individuals of threatened or endangered terrestrial species due to COC.

Objective 4: Problem formulation for the aquatic and wetland environments.

To address Objective 1 (Chapter 3) the terrestrial ERA used four lines of investigation and evaluation:

1. Detailed soil characterization
2. Field surveys and vegetation community evaluations
3. Soil toxicity tests under controlled laboratory conditions
4. Leaf litter decomposition rates.

This weight-of-evidence approach identified areas of different levels of potential risk for each of the COC for various ecological receptors.

To address Objectives 2 and 3 (Chapter 4), a desk-top modelling exercise was undertaken to predict risk based on exposure and toxicity reference values derived from the scientific literature.

To address Objective 4 (Chapter 5), existing information and data on Sudbury area lakes and wetlands were collected and reviewed. A study area was defined, and Chemicals of Concern (COC) Valued Ecosystem Components (VECs) for the aquatic environment were identified. Data gaps for future study were then identified.

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