RE-EVALUATION OF LEAD AS A POTENTIAL CHEMICAL OF CONCERN (CoC)

PORT COLBORNE COMMUNITY BASED RISK ASSESSMENT
PORT COLBORNE, ONTARIO

JWEL Project No. ONT35313

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PORT COLBORNE COMMUNITY
BASED RISK ASSESSMENT
PORT COLBORNE, ONTARIO

VOLUME I - MAIN REPORT

Prepared For

INCO LIMITED

Prepared By

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This document represents results and findings of a single component of the Community Based Risk Assessment (CBRA) that is being conducted in the City of Port Colborne. This report should not be taken out of the overall context, goals and scope of the CBRA being conducted by Jacques Whitford Environment Limited.

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1.0 INTRODUCTION

1.1 BACKGROUND

Jacques Whitford Environment Limited (JWEL) was retained by Inco Limited (Inco) to carry out a Community Based Risk Assessment (CBRA) for the City of Port Colborne. As part of the CBRA requirements, JWEL has undertaken various environmental studies and investigations to identify and evaluate the chemicals of concern (CoCs) originating from historical emissions from the Inco Refinery in Port Colborne.

The definition for a CoC within the CBRA is a chemical found in Port Colborne soils originating from an industrial source(s) where all of the following **Conditions** are met:

Condition 1) Chemicals that were historically used or generated by the industrial source(s) or its processes, **and**

Condition 2) Chemicals that are present at a community level at concentrations greater than MOE generic effects-based guidelines, **and**

Condition 3) Chemicals whose presence in soil show a scientific linkage to the historical operations of that industrial source(s).

MOE generic effects-based guidelines as defined in Condition 2 refer to the MOE Table ‘A’ Generic Guidelines (MOE, 1998).

Inco is the proponent of the Port Colborne CBRA. As such, only chemicals that meet all of the three above-described CoC conditions and originate from Inco's historical operations are considered CoCs for the CBRA.

Documentation of the previous studies and investigations undertaken by JWEL in evaluating each of these three Conditions are as follows:

- “*Potential CoC Identification using an Emissions Inventory and Dispersion Modelling*” dated November 23, 2001 (JWEL, 2001a);

- “*Potential CoC Identification using Soil Chemical Concentration Data in Exceedance of MOE Generic Guidelines*” dated November 23, 2001 (JWEL, 2001b); and

- “*Potential CoC Identification using Statistical Analyses*” dated November 16, 2001 (JWEL, 2001c) and “*CoC Identification using an Emissions Inventory and Dispersion Modelling*” dated November 23, 2001 (JWEL, 2001b).

The Ministry of the Environment (MOE) conducted a review of the above-mentioned reports and produced a letter (letter of January 11, 2002 “*Review of JWEL CBRA CoC Reports*”) that concurred with the outcome of JWEL's findings that the CoCs related to Inco are ***nickel, copper, cobalt*** and ***arsenic***.

The MOE January 11, 2002 letter stated that the MOE did not concur that Algoma Steel, situated upwind of the East Side Community and Inco, was a significant source of the randomly-observed localized soil ***lead*** levels on some residential properties in the East Side Community. Instead, the MOE related these observed localized soil ***lead*** levels in the East Side Community to domestic and general urban sources of ***lead***. The East Side Community is defined as a community within the City of Port Colborne, situated between Inco and the former Algoma Steel site, and is bounded by Davis Street or the Inco Refinery to the east, Welland Street or the vacant Seaway properties to the west, the south side of Louis Street to the north and both sides of Rodney Street to the south.

After the release of JWEL’s November CoC reports (JWEL, 2001a,b,c), additional sources of soil lead data became available for review. The first source of additional data on concentrations of soil lead by others were samples taken and analysed by AMEC Earth & Environmental (AMEC) from federally-owned, surplus Seaway properties bordered by the Rodney St. area to the east and the Welland Canal to the west. AMEC presented their findings at a public meeting held in Port Colborne on February 15, 2002 and distributed four reports, entitled:

- *“Phase I Environmental Site Assessment on Parcel #NP-021-B (Site #1) Vacant Lands Between Clarence & Rodney Streets, Port Colborne, Ontario”*, dated November 2001,
- *“Phase II Environmental Site Assessment on Parcel #NP-021-B (Site #1) Vacant Lands Between Clarence & Rodney Streets, Port Colborne, Ontario”*, dated December 2001 (AMEC, 2001a),
- *“Phase I Environmental Site Assessment on Parcel #NP-022-B (Site #2) Vacant Lands Between Rodney Street & East Breakwater, Port Colborne, Ontario”*, dated November 2001,
- *“Phase II Environmental Site Assessment on Parcel #NP-022-B (Site #2) Vacant Lands Between Rodney Street & East Breakwater, Port Colborne, Ontario”*, dated December 2001 (AMEC, 2001b).

Elevated concentrations of soil lead, with concentrations as high as 3100-ug/g were found by AMEC on these former industrial lands. Further details are provided in Section 3.1.2.4 of this report.

A second source of additional data on soil lead became available on April 24, 2002 regarding concentrations of soil lead north of the Rodney Street area, in particular north of Louis Street and south of Durham Street. These data were provided by Inco, through their consultant DCS. Detailed interpretation of these data is provided in Section 3.1.2.3 of this report.

The third source of additional soil lead data was from the MOE in their final report entitled *“Soil Investigation and Human Health Risk Assessment for the Rodney Street Community, Port Colborne”* released in March 2002. (Earlier versions of these data were available in previous MOE reports (MOE, 2001a,b). Within the MOE (2002) report, the MOE mapped soil lead concentrations within the Rodney Street area. The maps produced by the MOE indicated several ‘areas’ or ‘pockets’ where the soil lead values were above the MOE Table ‘A’ Generic Guidelines (MOE, 1998). The MOE explained the source(s) of these ‘pockets’ to be domestic and urban sources, including but not limited to lead paint, lead acid batteries, leaded gasoline etc. Specific reference to these ‘areas’ or ‘pockets’ of elevated soil lead concentration is discussed in Section 3.1.4 of this report.

A fourth source of additional soil lead data were soil samples collected by JWEL from 2001 to 2003 to satisfy other requirements of the CBRA, such as the Human Health and Ecological Risk Assessment. Soil samples included those collected in woodlots, open spaces, for the biomonitoring and field crop studies, the food basket survey, and the indoor dust study. Soil samples collected by Inco on a farm southeast of the plant have also been included in this report.

MOE-published studies examining soil lead concentrations in woodlots, schools, beaches and additional residential properties have also been included in this report.

Finally, JWEL included the findings from the report titled “Lead Screening Report East Side Community, Port Colborne April – June, 2001” and dated August 2001 by the Regional Niagara Public Health Department (NPH). NPH initiated the study because of a community concern that elevated soil lead levels may have resulted in unusual exposure, especially among children.

Understanding the potential sources of lead in contributing to the measured soil lead exceedances in the East Side Community is a complicated issue with many confounding influences and effects. This report details the history, background and analysis of potentially multiple sources of lead in the East Side Community. The report is presented in nine sections, which detail the various aspects of the lead in soil issue in the East Side Community:

- Section 1.0 provides a description of Conditions 1, 2 and 3, all of which need to be met for lead to be considered a CoC under the terms of reference for the Port Colborne CBRA. Section 1.0 also details the objectives of the current study.

- Section 2.0 provides a general description of the site characteristics.

- Section 3.0 provides a compilation of databases on lead concentrations in soils in the Port Colborne area and delineation of horizontal and vertical distribution of soil lead.

- Section 4.0 provides a literature review of Inco’s historical processes and a lead emission inventory.

- An air modelling approach to determine if Inco emissions can be scientifically linked to soil lead in the East Side Community is presented in Section 5.0.

- An empirical and statistical approach to determine if Inco emissions can be scientifically linked to soil lead in the East Side Community is presented in Section 6.0.

- A review of potential other sources of lead contamination of soil in the East Side Community, besides the Inco Refinery, such as from other local industries, nearby commercial operations and domestic practices, is provided in Section 7.0.

- Section 8.0 provides a summary of findings of Conditions 1, 2 and 3 in the re-evaluation of lead as a potential CoC related to the Inco Refinery, as well as attributing the relative contributions of soil lead by source.

- Overall conclusions are found in Section 9.0.

Supporting documentation for the re-evaluation of lead as a CoC are contained in Appendices A through N.

1.2 OBJECTIVES

The objectives for the re-evaluation of lead as a potential Port Colborne CBRA CoC were two fold:

1) Re-evaluate ***lead*** as a potential CoC that may have been derived from the historical operations of the Inco Refinery taking into consideration the existing soil lead data provided in JWEL's CoC reports (JWEL, 2001a,b, c) ***and*** the new information on soil ***lead*** data taken from other independent studies including AMEC (2001a,b), DCS (2001/2002), JWEL (2001/2002/2003) and MOE (2002); and,

2) Provide plausible explanation(s) for the localized soil ***lead*** exceedances (MOE, 2002) observed within the East Side Community neighbourhood.

1.3 REVIEW AND INTERPRETATION OF CRITERIA FOR COC EVALUATION

The definition for a CoC within the CBRA is a chemical found in Port Colborne soils originating from an industrial source(s) where all of the following **Conditions** are met:

Condition 1) Chemicals that were historically used or generated by the industrial source(s) or its processes, **and**

Condition 2) Chemicals that are present at a community level at concentrations greater than MOE generic effects-based guidelines, **and**

Condition 3) Chemicals whose presence in soil show a scientific linkage to the historical operations of that industrial source(s).

The three conditions specified above were developed based on discussions between Inco Limited, the Ministry of Environment, Jacques Whitford Environment Limited and Stantec (formerly Beak Environmental). The definition for each condition was developed through consultations between professional environmental scientists and engineers in all of the above companies and organisations. The development was conducted during the summer and fall of 2000 and the definitions were finalised and accepted by all stakeholders in the Technical Scope of Work (TSOW) dated November 2000. During the development, the basis for interpretation of these definitions was implicitly understood to be the professional judgement and expertise of the environmental experts. The following section details the interpretation of these conditions as understood by Jacques Whitford and Inco.

Condition 1 - Chemicals that were historically used or generated by the industrial source(s) or its processes.

Condition 1 will be met if a contaminant of concern was manufactured, processed or otherwise used by the Inco Limited Port Colborne Nickel Refinery (PCNR). Implied in this definition was that the contaminant had to have been used in the PCNR in quantities large enough to have a significant potential emission with respect to the MOE soil criteria for the particular contaminant. For instance, a potential contaminant which might have been used only in very small amounts in the refinery (i.e., kilograms per year) would not meet Condition 1 if emissions required to produce concentrations in the soil (in the contaminated area) above the MOE generic criteria would require much larger emissions (i.e., tonnes per year of emissions).

Condition 2 - Chemicals that are present at a community level at concentrations greater than MOE generic effects-based guidelines.

This condition specifies that the contaminant must be present in the soil in concentrations greater then the MOE generic effects-based guidelines as defined in MOE Table ‘A’ Generic Guidelines (MOE, 1998). In this condition, an exact definition of “community level” was not specified, but was understood between the stakeholders during development, to refer to contamination spread over a large percentage of the area of the community. The community area has typically been taken to be about 29 square kilometres. This definition would preclude considering a chemical that occurs in concentrations exceeding its MOE generic criteria in only a small area (such as a single residential property) as being considered a community wide exceedance.

Condition 3 - Chemicals whose presence in soil shows a scientific linkage to the historical operations of that industrial source(s).

A further clarification of condition (3) is necessary. When the conditions were formulated in consultation with the MOE, it was pointed out by the MOE that the interpretation of condition (3) would have to be carried out not simply to show any amount of a chemical in soil originated from Inco, but to show that a significant fraction of the chemical found in the soil came from Inco. The question of what constitutes a significant fraction is one of judgement. According to the MOE, their judgement on this matter would be based on issuing an order to Inco concerning lead in soil. Such an order would rely on deciding what was a reasonable basis on which to hold Inco responsible for lead. Although this basis is not quantitatively defined by the MOE, JWEL considers significant to be greater than 25% contribution to the total for the purposes of evaluating condition (3) of this report.

If there is no information linking the PCNR to the chemical presence in the Port Colborne soils, or the contribution of the PCNR to the chemical’s presence is unclear or not significant, then no scientific linkage can be substantiated and Condition 3 would not be met.

2.0 SITE CHARACTERISTICS

2.1 IDENTIFICATION OF THE STUDY AREA

The Study Area is identified as those lands in and around Port Colborne where soil concentrations of one or more of the CoCs exceed MOE (MOEE 1997) guidelines. The approximate soil nickel:soil copper, soil nickel:soil cobalt and soil nickel:soil arsenic ratios within the Study Area are 10:1, 50:1 and 120:1. Since exceedances of the soil nickel guideline are much more significant and wide spread than the other 3 CoCs, nickel has been used as the indicator element. Areas of soil nickel concentrations in Port Colborne greater than 200 mg/kg (MOE Table A generic guideline for nickel) are considered to be within the Study Area (approximately 29 km^2). Figure 2.1 shows contours of concentrations of nickel in surface soils (0-5 cm) in the Port Colborne area, with the highest concentrations found on Inco property immediately northeast and east of the Refinery.

2.2 HISTORICAL OVERVIEW OF INCO REFINERY OPERATIONS

Inco began operations in the City of Port Colborne in 1918. Historical operations at the Inco Refinery produced particulate emissions that subsequently resulted in atmospheric deposition of these particulates on soils surrounding the Inco Refinery.

Based on an assessment of historic emissions from the Inco Refinery, peak particulate air emissions occurred during the period 1918-1930, during which total dust emissions were greater than 1,300 tonnes/year. During this period, nickel emissions were estimated to be about 700 tonnes/year. Through the 1960s to mid 1980s, particulate emissions were significantly reduced, with about 60 tonnes airborne particulate matter produced annually.

Based on historical emissions data, the local natural environment predominately down wind or northeast (refer to Section 2.4) of the Refinery was directly exposed to the heaviest atmospheric deposition of particulates for a period of about forty years (1918-1960). It is during this period that the particulate matter principally accumulated in the local soils.

2.3 HISTORICAL OVERVIEW OF OTHER LOCAL INDUSTRIES

JWEL conducted a detailed historical background review of adjacent areas north, west and south of the Inco Refinery to determine if other local industrial/commercial operations within the East Side Community may have resulted or contributed to the observed pattern of CoCs and other metals analyzed in soil taken from the East Side Community during the CBRA. Historical findings are detailed in Section 7.1. Figure 2.2 identifies locations of former and present industrial and commercial operations within the East Side Community that may have had a collective impact on the present day observed distribution of CoCs and metals in soils in this community.

Re- Evaluation of Lead As A CoC - Community Based Risk Assessment, Port Colborne, ON

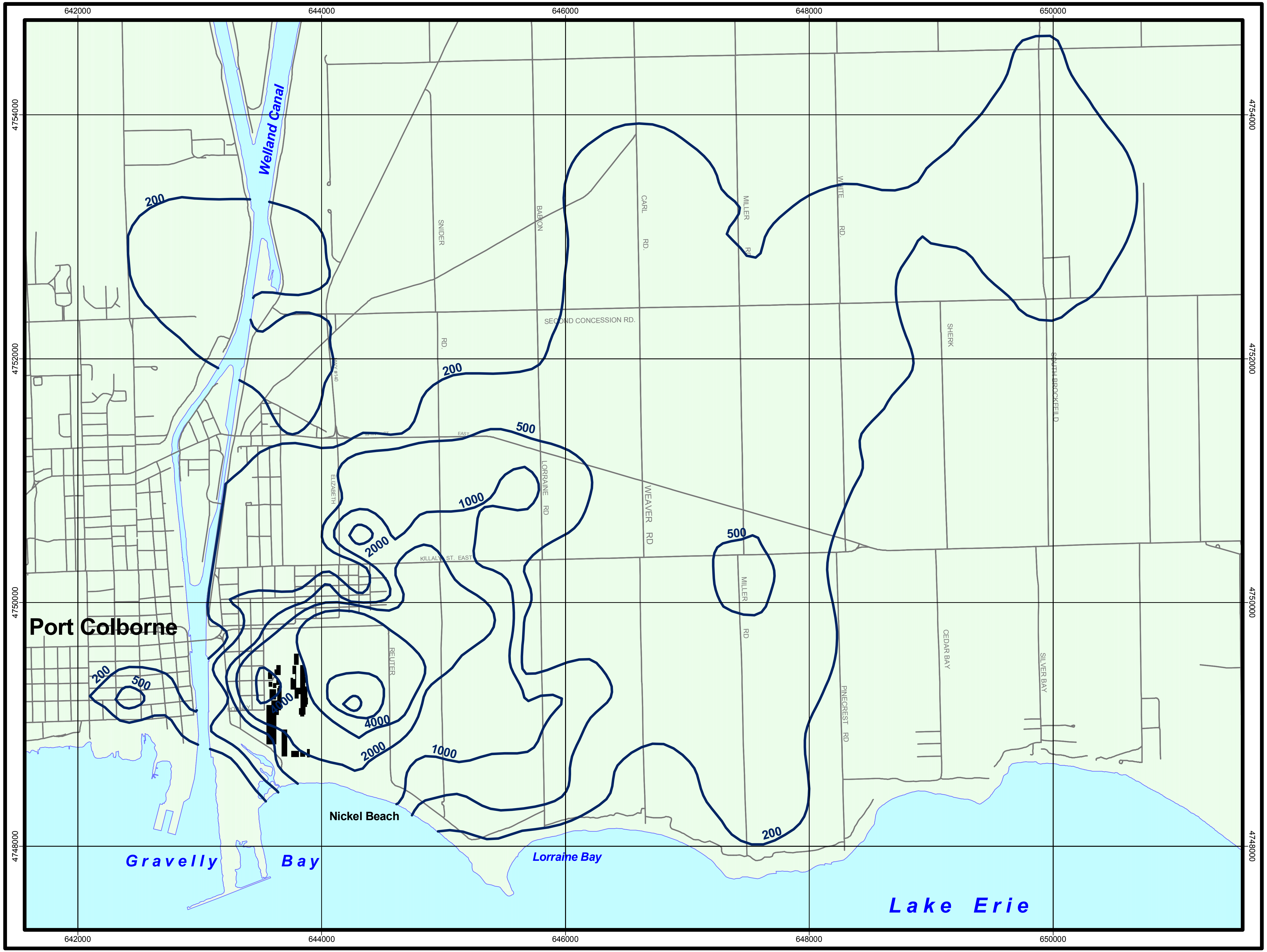

Figure 2-1

Nickel in Soils (0-5 cm deep) Port Colborne CBRA

0 500 1000 1500
Metres

N

Legend

Soil Nickel Concentration Contours (ug/g) (0 - 5cm Depth)

Topographic Features

■ Inco Refinery

Roads

The approximation is based on:
- 0-5cm surface soil data from MOE 1999, MOE 2000 (Rodney Street Community)
- AMEC 2001 (Seaway Properties)
- JWEL 2001 Programs

Job Number: ONT34644
Date: October 2003
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 30,000

Regional NIAGARA

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Consulting Engineers
Environmental Scientists
Risk Consultants

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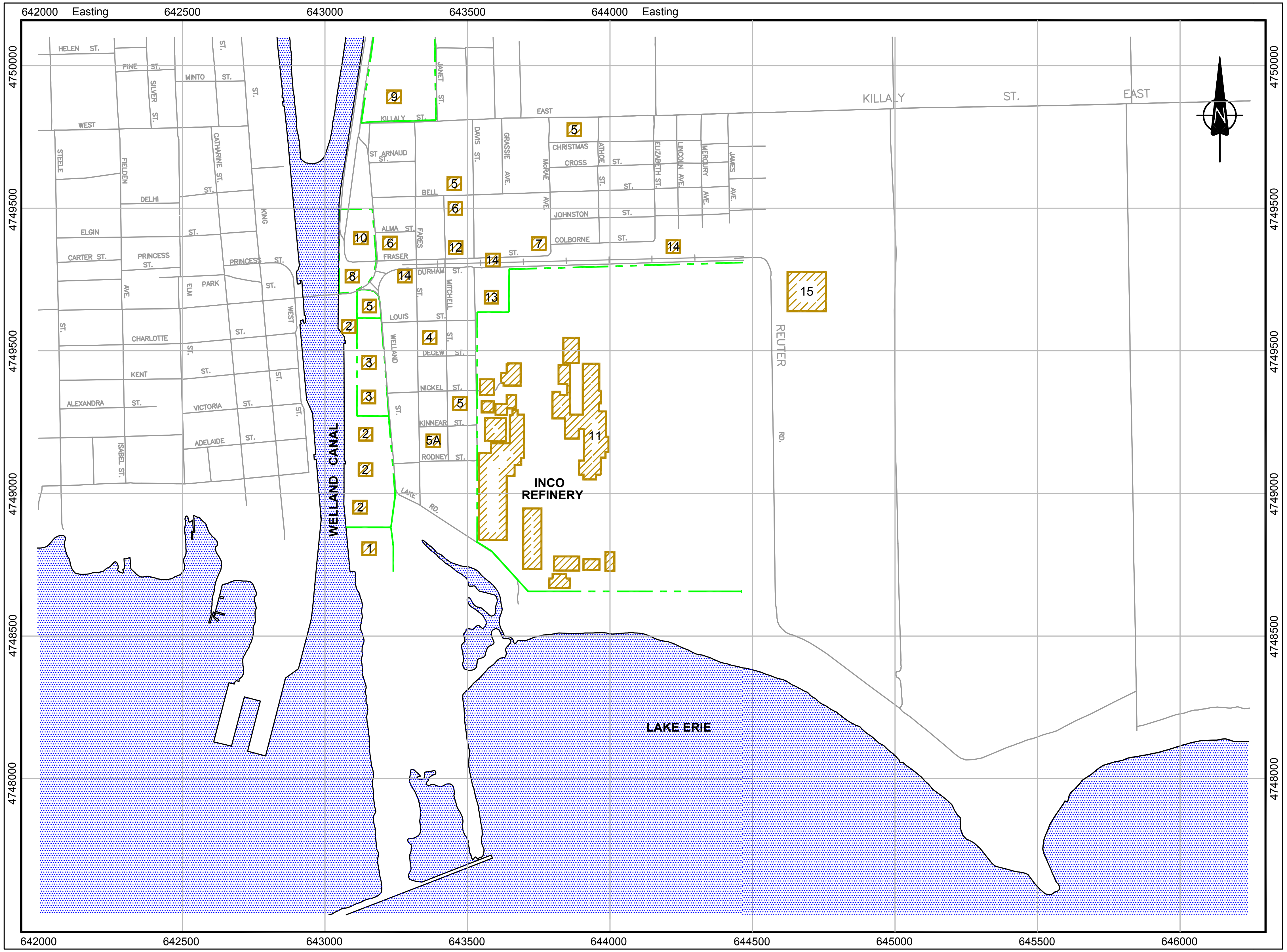
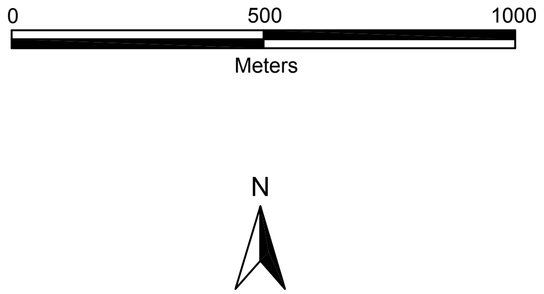
Re-Evaluation of Lead as a Potential CoC - Community Based Risk Assessment - Port Colborne, ON

Figure 2.2
Potential Industrial/Commercial Sources of Lead East Side of Port Colborne, ON





Legend

- 1 ALGOMA STEEL PLANT
- 2 CN RAILWAY YARD, COAL STORAGE YARD
- 3 SCRAP YARD, DWOR METAL
- 4 MACHINE SHOP (THURSTON MACHINE WORKS)
- 5 GAS STATIONS AND AUTO REPAIR SHOP
- 5A AUTO BODY REPAIR SHOP
- 6 DRY CLEANING AND AUTO SERVICE STATIONS
- 7 PORT COLBORNE IRON WORKS
- 8 INDUSTRIAL LAND USE (FORMER FUEL, PAINT AND COAL STORAGE)
- 9 INDUSTRIAL LAND USE (FORMER FOUNDRY, CHEMICAL PLANT MOVING AND STORAGE FACILITIES)
- 10 INDUSTRIAL LAND USE (FORMER WATER TREATMENT PLANT)
- 11 INCO REFINERY
- 12 JOE'S RADIATOR AND SOLDER WORKSHOP
- 13 OPG TRANSFORMER
- 14 FORMER CN TRACK
- 15 FORGE

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NOTE: LOCATIONS OF UTILITIES AND OFFSITE FEATURES ARE APPROXIMATE AND MAY VARY FROM THAT SHOWN.

POTENTIAL INDUSTRIAL / COMMERCIAL SOURCES OF LEAD

EAST SIDE OF PORT COLBORNE, ONTARIO

Job No.: ONT35313		Fig.: 2.2	
Date: 04/02/16	Dwn. by: LMV PC	Appd.: KW	

Jacques Whitford

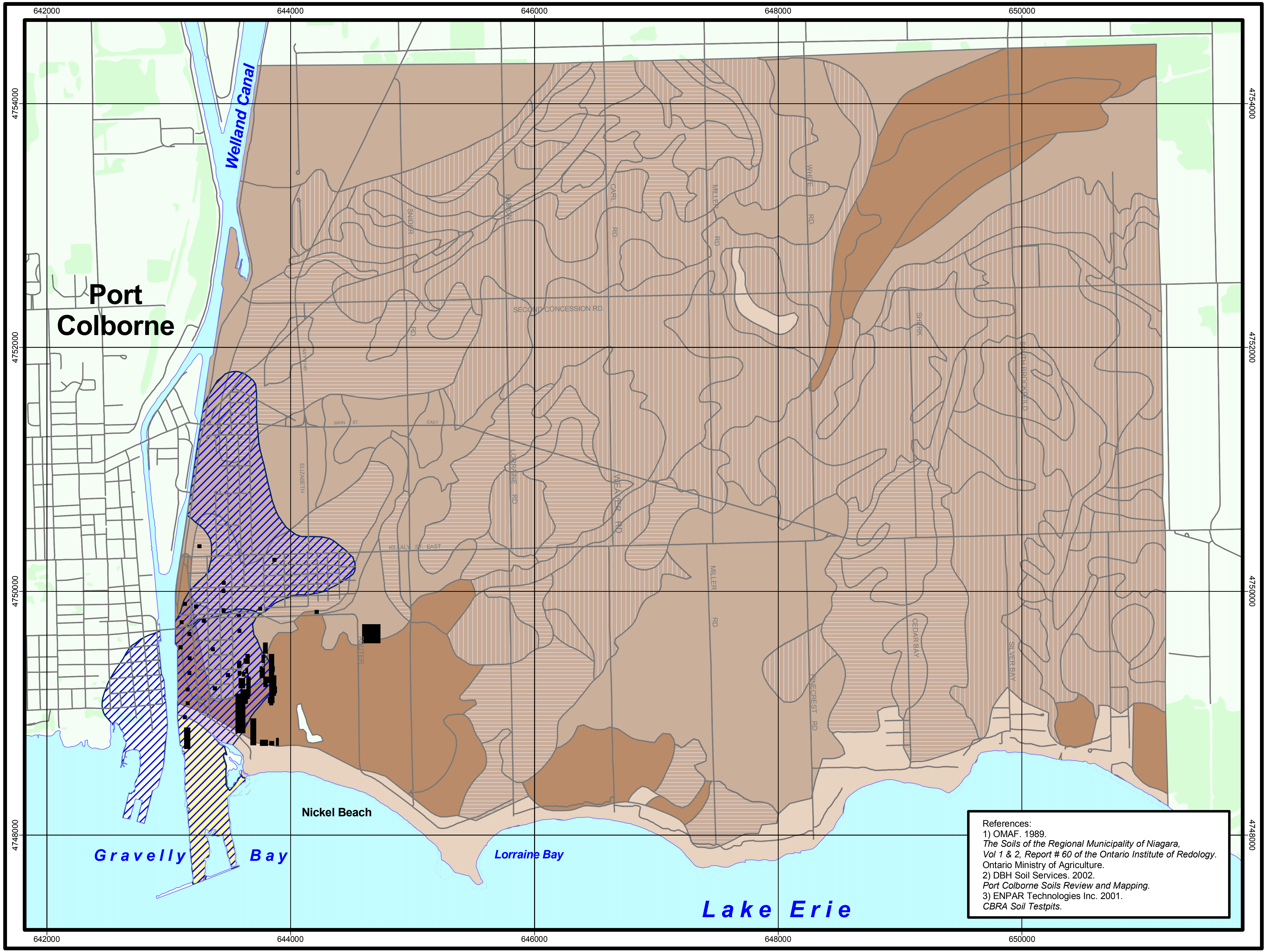
Of the other local industries identified, Algoma Steel produced historical particulate emissions of similar magnitude to that of the Inco Refinery. Algoma Steel had an iron smelting operation from 1913 to 1977 located southwest of the Inco Refinery and southwest of the East Side Community. Algoma Steel used coke, iron ore, limestone and iron shot as raw materials. Coal stockpiles, iron ore stockpiles and spent material including slag are all known to contain metals. In particular, the types of metals from the Algoma Steel plant include iron, arsenic, cadmium, zinc, copper, nickel, lead, chromium, manganese, molybdenum, magnesium and sulphur. Some of these metals were released as particulates to the atmosphere and subsequently resulted in atmospheric deposition on soils on Algoma Steel's property and downwind, i.e., deposited within the East Side Community. Another possible mode of transport of these metals to the environment of the East Side Community was the use of the Algoma Steel slag by local residents in the past as imported backfill material on their properties (e.g., backfilling of basements, driveways, low spots, etc).

2.4 LOCAL METEOROLOGY

The local meteorology of the region must be known to evaluate the atmospheric dispersion and transport of historical emissions released by a plant, such as from the Inco Refinery or the Algoma Steel facility. The dominant winds for the Port Colborne area are from the southwest to the northeast direction. The least frequent direction is winds blowing from the east to the west. Details on the frequency distribution of wind speed and direction for the Port Colborne area are found in Section 5.2 of this text.

2.5 GENERAL SOIL TYPE

Detailed soil studies of the Port Colborne area, primarily undertaken for the purpose of the CBRA Crops study component, have identified and mapped five primary soil groupings on the east side of the Welland canal. The five soil groups identified are heavy clay (glaciolacustrine origin), shallow clay (till clay), clay loam (till clay), organic muck and sand. A sixth soil type is a fill clay-like material, which is found overlying the parent material within the East Side Community. Figure 2.3 illustrates parent soil groupings and approximate fill areas found in the Study Area.



References:
1) OMAF. 1989.
The Soils of the Regional Municipality of Niagara,
Vol 1 & 2, Report # 60 of the Ontario Institute of Redology.
Ontario Ministry of Agriculture.
2) DBH Soil Services. 2002.
Port Colborne Soils Review and Mapping.
3) ENPAR Technologies Inc. 2001.
CBRA Soil Testpits.

Figure 2-3

Soil Groupings East Side Port Colborne, ON

0 500 1000 1500
Metres

N

Legend

Parent Soil Groupings
▨ Heavy Clay
▨ Shallow Clay
▨ Clay Loam
▨ Organic
▨ Sand
▨ Built Land

Approximate Fill Areas
▨ Fill Topsoil

Topographic Features
■ Commercial/ Industrial Sources
╱╲ Roads

Job Number: ONT34644
Date: July 15, 2003
Dwn by: C. Amirault
Approved by: K. Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 30,000

Regional NIAGARA

Jacques Whitford
Consulting Engineers
Environmental Scientists
Risk Consultants

3.0 DISTRIBUTION OF SOIL LEAD IN THE PORT COLBORNE AREA

3.1 SOURCES OF INFORMATION

Information pertaining to the soil lead distribution in Port Colborne and vicinity were obtained from a number of sources. The majority of this information was derived from three sources. These were:

- The MOE investigations conducted from 1998 to 2002;
- The investigations conducted by JWEL, as part of the CBRA requirements, to identify and evaluate the CoCs originating from historical emissions from the Inco Refinery; and,
- The investigations conducted by other consultants in Port Colborne.

JWEL reviewed all of this information in an exercise to re-evaluate the potential of lead as a CoC. The following subsections summarise the sources of the soil lead data sets that were reviewed and considered in this re-evaluation.

3.1.1 MOE 1998/1999: Soil Lead Data Set - MOE Regional Soils Investigation

Between 1998 and 1999, the MOE (MOE, 2000a,b) conducted a soil-sampling program in the Port Colborne area, through which 153 soil samples (MOE samples #1 to #233) were collected and analysed for a suite of inorganic elements, including lead. This sampling program was restricted to open spaces and did not include soils from woodlots.

3.1.2 Consultants' Data Sets on Soil Lead

Several additional studies in the Port Colborne area conducted by the MOE, JWEL and other consulting firms have complemented the original soil lead database from the MOE 1998 and 1999 soil investigations. These are summarized in the following subsections.

3.1.2.1 JWEL 2000/2001: Soil Lead Data for Residential Yards

In December 2000 and January 2001, JWEL collected and analysed 13 soil samples (JWEL samples SS1-1 to SS13-1) from the front yards and/or back yards of residential dwellings across the Port Colborne area. Soil samples at each of these 13 locations were collected from the 0 to 5-cm depth interval. Soil sampling and analyses for metals, including lead, were conducted in accordance with the CBRA protocol (JWEL, 2001d) as found in **Appendix B-2.**

3.1.2.2 JWEL 2001/2002: Soil Lead Data for Residential Yards and Industrial Lands

In August of 2001, JWEL collected soils from 17 test pits excavated on the eastern side of Port Colborne, covering the East Side Community, the former Algoma Steel property and areas east of the Inco Refinery (JWEL TP-1 to TP17). These test pits were excavated to a depth of 1.0 m below grade and the findings were documented in JWEL's draft report "Potential CoC Identification Using Soil Chemical Concentration Data in Exceedance of MOE Generic Guidelines Port Colborne, Ontario" (JWEL 2001b).

In October 2001, JWEL conducted another soil sampling program in the Port Colborne area involving 24 test pits, TP-A to TP-X, inclusive. The purpose of this sampling was to fill in data gaps to the west of the Welland Canal, and on an arc from north to southeast of the Inco Refinery. These test pits were excavated to a depth of 30 cm below grade and the findings are documented in JWEL's draft report "Soil Characterization, Port Colborne Community Based Risk Assessment, Port Colborne, Ontario" (JWEL 2003).

The final series of JWEL test pits were collected between September and October 2002 (JWEL samples TP-201 to TP-211) on the east side of Port Colborne to determine the chemical quality of the fill materials overlying the native soil horizons on industrial properties, including existing and abandoned railway tracks and roadbeds. Test pits TP-201, TP-202 and TP-205 were excavated on abandoned railway tracks, test pits TP-207 through TP-211 were excavated on the former CNR yard and the remaining test pits were excavated below roadbeds. It should be noted that none of these series of JWEL test pits were excavated on residential properties.

Soil sampling and analyses for metals, including lead, in each of the above-described programs were conducted according to CBRA protocol (JWEL, 2001d) as found in **Appendix B-2.**

3.1.2.3 DCS 2001/2002: Soil Lead Data for Residential Yards

In December 2001 and January/February 2002, Decommissioning Services (DCS) collected 590 soil samples (depth 0 to 30 cm) from 82 residential properties in Port Colborne (DCS 2001/2002). The focus of the investigation was on collecting information on soil metal data in areas north of Louis Street.

It should be noted that the DCS sampling methodology was different than that used by the MOE and JWEL. An intensive audit overseen by the MOE of the DCS sampling and analytical methods showed that the methods used by the MOE and DCS both produced similar lead results, and thus no correction factor for soil lead was required (DCS, 2003a,b).

3.1.2.4 AMEC 2001: Soil Lead Data for SEAWAY Industrial Lands

In November/December 2001, AMEC collected and chemically analysed soil samples for metals, including lead, from 88 sampling locations on properties currently owned by St. Lawrence Seaway Management Corporation.

In order to maintain consistency in reporting of data, only the surface soil grab samples (0-5 cm) collected by AMEC are included in this report. The AMEC investigation area was divided into a northern site and a southern site.

The northern site sampled by AMEC was west of Welland Street, east of Welland Canal and north of Nickel Street (AMEC, 2001a). At this site, AMEC analysed 37 soil samples for metals, including lead, at depths ranging from 0 to 1.4 m below grade. The southern site sampled by AMEC was east of Welland Canal, south of Rodney Street and Lake Road (AMEC, 2001b). At this site, AMEC analysed 15 surficial soil samples (AMEC samples SSS-1 to SSS-15; 0 to 5 cm depth) for metals, including lead.

3.1.2.5 JWEL 2001: Soil Lead Data for Woodlots

In 2001, JWEL conducted a series of investigations for the purpose of an ecological risk assessment in woodlots located along the east side of Reuter Road approximately 1.2 km east of the Inco Refinery. The investigations included studies of leaf litter, maple sap and earthworms in relation to soil metal concentrations. Sampling and analyses of soil for metals, including lead, were conducted in accordance with the CBRA protocol (JWEL, 2001d) as found in **Appendix B-2.** The soil lead results obtained from these investigations were also reviewed and their findings incorporated into the current re-evaluation report.

3.1.2.6 JWEL 2001: Soil Lead Data for Open Spaces - ERA Study

In 2001, JWEL conducted a series of soil sampling and analyses programs for the Ecological Risk Assessment (ERA), Natural Environment component of the CBRA in open spaces in the east side of Port Colborne. *Open spaces are defined as open fields and do not include woodlot areas.* A total of sixty-four soil samples were collected at a depth of 0 to 5-cm. Soil sampling and analyses for metals, including lead, were conducted in accordance with the CBRA protocol (JWEL, 2001d) as found in **Appendix B-2.** Soil lead results obtained from these investigations were reviewed and their findings incorporated into the current re-evaluation report.

3.1.2.7 JWEL 2001: Soil Lead Data for Open Spaces – Crops Study

In 2001, JWEL conducted a series of soil sampling and analyses programs for the Crop Studies component of the CBRA in open spaces in the east side of Port Colborne. A total of eighty-seven (87) soil samples at depths between 0 to 15 cm were collected and analysed. Soil sampling and analyses for metals, including lead, were conducted in accordance with the CBRA protocol (JWEL, 2001d) as found in **Appendix B-2.** Soil lead results obtained from these investigations were reviewed and their findings incorporated into the current re-evaluation report.

3.1.2.8 JWEL 2000/2001: Soil Lead Data for Residential Yards and Gardens

In September 2000, JWEL conducted a food basket survey program involving soil sampling and analyses on residential backyard lawns and gardens at twenty-nine (29) locations in Port Colborne, and two background locations at the Wainfleet Bog area. A total of thirty-one soil samples were collected at the 0 to 15 cm depth and analysed for metals, including lead.

In September 2001, JWEL conducted a subsequent food basket survey program involving soil sampling and analyses in residential gardens in Port Colborne. A total of two hundred and forty soil samples were collected at the 0 to 15 cm depth from the root zones of plants and analysed for metals, including lead.

Sampling and analyses of the above described programs were conducted in accordance with the CBRA protocol (JWEL, 2001d) as found in **Appendix B-2.**

3.1.2.9 JWEL 2002: Soil Lead Data for Residential Yards - Indoor Air Study

In the fall of 2002, JWEL conducted an indoor air and settled dust sampling and analysis program in selected residences in the east side of Port Colborne as part of the CBRA. Sampling and analyses were conducted in accordance with the CBRA protocol (JWEL, 2001d) as found in **Appendix B-2.** Soil samples were collected and analyzed for metals, including lead, only if existing soil lead data for these residences were not available.

3.1.3 MOE 2000: Soil Lead Data for Woodlots

In October 2000, MOE collected soil samples from five rural woodlots (woodlots 1 to 5) in the Port Colborne area. MOE report "Soil Contamination in Selected Port Colborne Woodlots: 2000" (Report No. SDB-012-3511-2001) was reviewed by JWEL. Three of the woodlots (woodlots 1, 2 and 3) were located within 2.5 km of the refinery in the direction of the prevailing winds (east to northeast of Inco). Woodlot 4 was located at Forks Road East and Green Road, about 11 km northeast of Inco. Woodlot 5 was located at Highway 3 and Bassie Road in Wainfleet, about 5 km west of Inco.

A review of the MOE (2000) woodlot soil investigation report revealed that soil lead concentrations in woodlots in the Port Colborne area *do not* exceed the MOE Table A parkland/residential guideline value for lead (i.e., 200 ug/g).

In addition, the MOE also conducted an investigation in November 2000, at the premises of one residence abutting a woodlot on the west side of Port Colborne, i.e., west of the Welland Canal and approximately 800 m west of the Inco Refinery. This woodlot had a concentration of soil lead of 1510 ug/g, i.e., well above the MOE Table A value.

3.1.4 MOE 2000-2002: Soil Lead Data for Residential Yards–East Side Community

Between September 2000 and May 2001, the MOE collected almost 2000 soil samples from residential properties in the East Side Community. Soil samples were analyzed for metals, including lead, and these data are presented in their final report entitled "Soil Investigation and Human Health Risk Assessment for the Rodney Street area, Port Colborne: March 2002" (MOE, 2002). This report supersedes two earlier versions of the report (MOE, 2001a and MOE, 2001b).

Soils from a total of 59 out of 372 properties sampled and analyzed in the East Side Community had lead levels greater than 400 ug/g and 11 sites with soil lead concentrations greater than 1000 ug/g. The levels of 400 ug/g and 1000 ug/g represent US EPA lead intervention levels for children's exposure to bare soil and sodded/covered areas, respectively. The average concentration of lead in the surficial (0-5 cm depth) soil samples taken from the East Side Community was 201 ug/g, the same (within the margin of analytical error) as the 200 ug/g MOE Table A generic guideline for lead.

Table 3.1 shows a statistical summary of soil lead levels based on MOE findings in the East Side Community.

Table 3-1 MOE-Reported Lead Concentrations in Residential Soil Samples from East Side Community, Port Colborne (adapted from Table 5 – Table 7, MOE 2002)

Soil Sample Depth (cm)	Number of Samples Analysed	Minimum Lead Concentration in Soil (ug/g)	Maximum Lead Concentration in Soil (ug/g)	Number of Samples above 1000 ug/g	Mean Lead Concentration in Soil (ug/g)
0 - 5	394	8	1350	3	201
5 - 10	487	6	1430	4	216
10- 20	490	11	1800	6	238

Drawings 1, 2, and 3 in **Appendix A** of this text, which are reproductions of Maps 19, 20 and 21 in the MOE (2002) report, indicate that soil lead exceedances above 1000 ug/g are localized within the soil profile of the upper 20 cm in no more than 11 areas.

As shown on Drawing 1 in **Appendix A-1,** the soil lead concentration distribution at the 0 to 5 cm depth, indicates seven (7) 'areas' where the soil lead values are above 1000 ug/g and identified as areas MOE1, MOE2, MOE3, MOE4, MOE5, MOE6 and MOE6A. These identified areas of high soil lead concentrations appear randomly scattered with no evident lateral soil lead concentration gradient increasing in the directions of either the Refinery or the former Algoma Steel plant. The absence of clear soil lead gradients suggests that the major source of lead is not atmospherically deposited from either the Refinery or the former Algoma Steel plant.

At the 5 to 10 cm depth interval as shown on Drawing 2 in **Appendix A-2,** the soil lead distributions are different from those in the 0 to 5 cm depth interval. At the 5 to 10 cm depth, the soil lead concentrations in area MOE3 decreases, area MOE4 extends further to the west close to Fares Street and area MOE6A disappears.

At the 10 to 20 cm depth interval as shown on Drawing 3 in **Appendix A-3,** area MOE6 disappears, and four (4) new areas of high soil lead concentrations, areas MOE7, MOE8, MOE9 and MOE10, appear.

In summary, the measured soil lead distributions within the 0 to 20 cm depth interval in the eleven above-described areas, MOE1 to MOE 10, indicate vertical gradients of soil lead concentrations with depth that show no clear pattern.

The MOE concluded that the randomly scattered areas of high soil lead concentrations (i.e., above 1000 ug/g) in the East Side Community were similar to those found in any old urban setting and were not linked to either the Inco or Algoma industries.

The following is an excerpt from the MOE Executive Summary (MOE, 2002):

> *"Elevated soil lead levels were found on some properties randomly scattered in the Rodney Street area. This is considered typical of domestic residential lead sources in older urban communities and is not attributed to either Inco or Algoma emissions. The erosion and flaking of old lead-based paint from exterior structures such as house and shed walls, porches, fences, poles and playground equipment is a common source of soil lead contamination in older urban communities. The soil lead levels found in the Rodney Street area are not unusual, either in extent or concentration, relative to other similar communities in Ontario."*

The MOE report goes on to comment that lead levels in the East Side Community are similar to levels of lead in soils found in Welland, Ontario where soil lead levels averaged between 237 ug/g and 329 ug/g and ranged up to 1796 ug/g (MOE 2002). The Welland homes are similar in age and construction to many homes in the East Side Community.

In section 8.7 of the MOE 2002 report:

> *"Current levels of lead in soil in Port Colborne in general, and the Rodney Street area specifically, have no consistent spatial relationship relative to Inco or Algoma. Although Inco and Algoma emissions may have contributed to the overall soil lead burden in the Rodney Street community, historic vehicle emissions from the combustion of leaded gasoline and residential sources, such as weathered exterior lead-based paint, are both far more significant and known lead sources that could account entirely for the soil lead levels encountered in this study, and so any Inco or Algoma lead contributions cannot be measured above the normal urban domestic residential lead loading."*

Evaluation of soil lead contribution from urban or domestic sources of lead in the East Side Community will be examined further in this report in Sections 7.0, 8.0 and 9.0.

3.1.5 MOE 2000: Soil Lead Data for Schools and Beaches

In April 2000, MOE collected and analysed thirty-seven soil samples from sixteen sampling locations that included twelve schoolyards, one day care and three beaches in the Port Colborne area. The samples were collected at 0 to 5 cm depth and analysed for metals, including lead. The soil lead analytical results of these investigations were reviewed by JWEL in this re-evaluation report.

3.1.6 MOE 2001: Soil Lead Data for Schools

In February and April 2001, MOE re-sampled soils at the Humberstone and St. Therese School sites previously studied (April 2000).

In February 2001, MOE collected and analysed twenty-seven soil samples from the Humberstone schoolyard. In April 2001, the MOE collected and analysed twenty-four soil samples from the St. Therese schoolyard and five soil samples from east and west of the school fence. All these soil samples were analyzed for metals, including lead. The soil lead results obtained from these investigations were reviewed by JWEL, and their findings were incorporated into the current re-evaluation report.

3.1.7 MOE 2002: Soil Lead Data for Additional Residential Yards

Between years 2000 and 2002, the MOE collected and analysed 52 additional soil samples from 24 residences at the request of various homeowners. The soil samples were collected at 0 to 5 cm depth and analyzed for metals, including lead. These data sets were made available to JWEL in 2003. The soil lead results obtained from these investigations were also reviewed and their findings were incorporated into the current re-evaluation report.

3.1.8 Inco 2002: Soil Lead Data for Farm Southeast of the Refinery

In the summer of 2002, Inco collected twenty-two soil samples at 0 to 5-cm depth from a farm located on the east side of Snider Road, approximately 2 km east of the Inco Refinery. All soil samples were analyzed for metals, including lead. The soil lead results obtained from this investigation were reviewed and their findings were incorporated into the current re-evaluation report.

3.1.9 JWEL 2003: Soil Lead Data for Open Lands and Woodlot on Refinery Property

In September 2003, Jacques Whitford sampled and analysed 24 surface soil samples of a peaty substance (bog material) in a wetland from open spaces and a woodlot on the Refinery property. Soil samples were taken in a grid pattern along three north-south transects running parallel to Reuter Road and directly to the east of the Inco landfill. In each transect, eight composite samples were taken. At each sampling location, a composite of at least 10 sample cores were collected, each core was separated into a 0-5 cm depth sample, a 5-10 cm depth sample and a 10-15 cm depth sample. For each soil depth interval, the soil core segments were composited in a plastic bag and clearly labelled.

In addition, three test pits were advanced to a depth of 30 cm, with samples taken at every 5cm.

Sampling locations are found in Drawing 3.1. All soil sampling and analyses for metals, including lead, were conducted in accordance with the CBRA protocol (JWEL, 2001d) as found in **Appendix B-2.** Soil analytical data are found in the laboratory certificates of analyses as provided in **Appendix B-3.**

Visual observation of samples of peat soils taken from this wetland in open spaces and the wood lot showed a consistency of very light soils, with a high moisture content, which is very different from the physical appearance of soils previously taken during the CBRA. For example, the moisture content of these peat soils ranged up to 85 % in some of the samples, as shown in the laboratory certificates of analyses in **Appendix B-3.**

3.2 MAPPING OF SOIL LEAD DISTRIBUTION IN PORT COLBORNE

3.2.1 Sample Locations

Figure 3.1 shows locations of all of the soil lead data points for the Port Colborne area collected from the CBRA and other sources (Section 3.1). The total number of soil lead data points was 1505 which included soil lead data points from both open space and woodlot settings. The sources of these data points originated from the MOE (approximately 782 sites), JWEL (518 sites), DCS (156 sites), AMEC (27 sites) and INCO (22 sites). The compiled data set on soil lead concentrations (ug/g units) is found in Appendix C.

3.2.2 Soil Lead Distribution in Open Spaces, 0-5 cm depth

Figure 3.2 shows the resulting soil lead concentration distribution map using the combined soil lead data set for open spaces at the 0 to 5 cm depth. In general, measured soil lead above the 200-ug/g MOE Table A generic guideline were observed mainly west of the Refinery (i.e., within the East Side Community). In particular, the distribution of soil lead concentrations in Figure 3.2 reveals the following:

- To the west of the Inco Refinery, in the vicinity of the industrial Seaway properties and the former Algoma Steel plant, the soil lead concentrations are well above the MOE Table A generic guideline of 200-ug/g and as high as 3000-ug/g.
- To the west of the Inco Refinery, in the residential East Side Community, there are several randomly-scattered areas with elevated soil lead concentrations. As mentioned in Section 3.1.4, there are at least 11 of these areas with soil lead concentrations above 1000-ug/g.
- To the north and east of the Inco Refinery (ie. in the prevailing wind direction), lead concentrations in soil are for the most part less than the 200-ug/g MOE Table A generic guideline. Several, randomly-scattered, small pockets of soil lead above 200-ug/g are evident.

The same soil lead data as plotted on Figure 3.2 is reproduced on Figure 3.3, with the only exception that soil lead concentrations are mapped below the 200-ug/g MOE Table A generic guideline, i.e., below 50% of the generic guideline, or 100-ug/g. The purpose of a comparison to 50 % below the 200-ug/g MOE Table A generic guideline was to allow the detection of any evident patterns in the distribution of soil lead originating from an industrial or commercial source(s). A contour interval below 100-ug/g was not achievable because the upper limit for natural background for this area is approximately 98-ug/g (Section 6.3.4).

An examination of the distribution of the measured soil lead concentrations in Figure 3.3 reveals similar findings as found in Figure 3.2. The only noticeable difference was an isolated area on Inco property, directly north and east of the facility, with soil lead at concentrations below the 200-ug/g MOE generic guideline yet above 100 ug/g. The major observation in both Figures 3.2 and 3.3 are that the randomly-scattered pockets of elevated soil lead concentrations observed in the East Side Community to the west of the Refinery are not present in as high amount at an equal distance east of the Refinery, as would be expected if the lead in these areas had come from an Inco source.

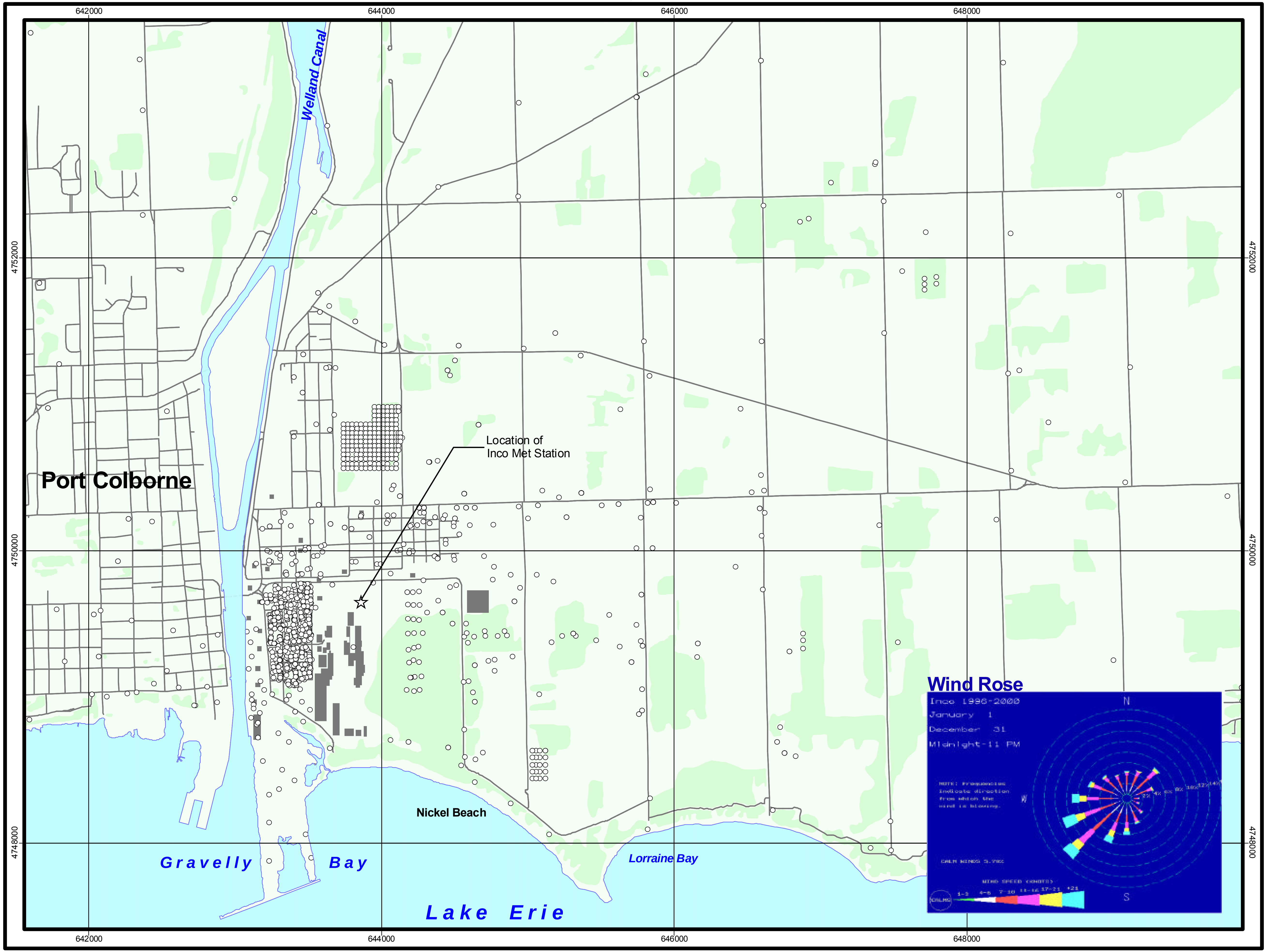


Figure 3-1

All Soil Sample Locations Port Colborne CBRA

0 500 1000 1500
Metres

N

Legend

○ Soil Sample Location

☆ Location of Inco Met Station

Topographic Features

▬ Commercial/ Industrial Sources

╱╲ Road

Job Number: ONT34561
Date: October 2003
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 30,000

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Environmental Scientists
Risk Consultants

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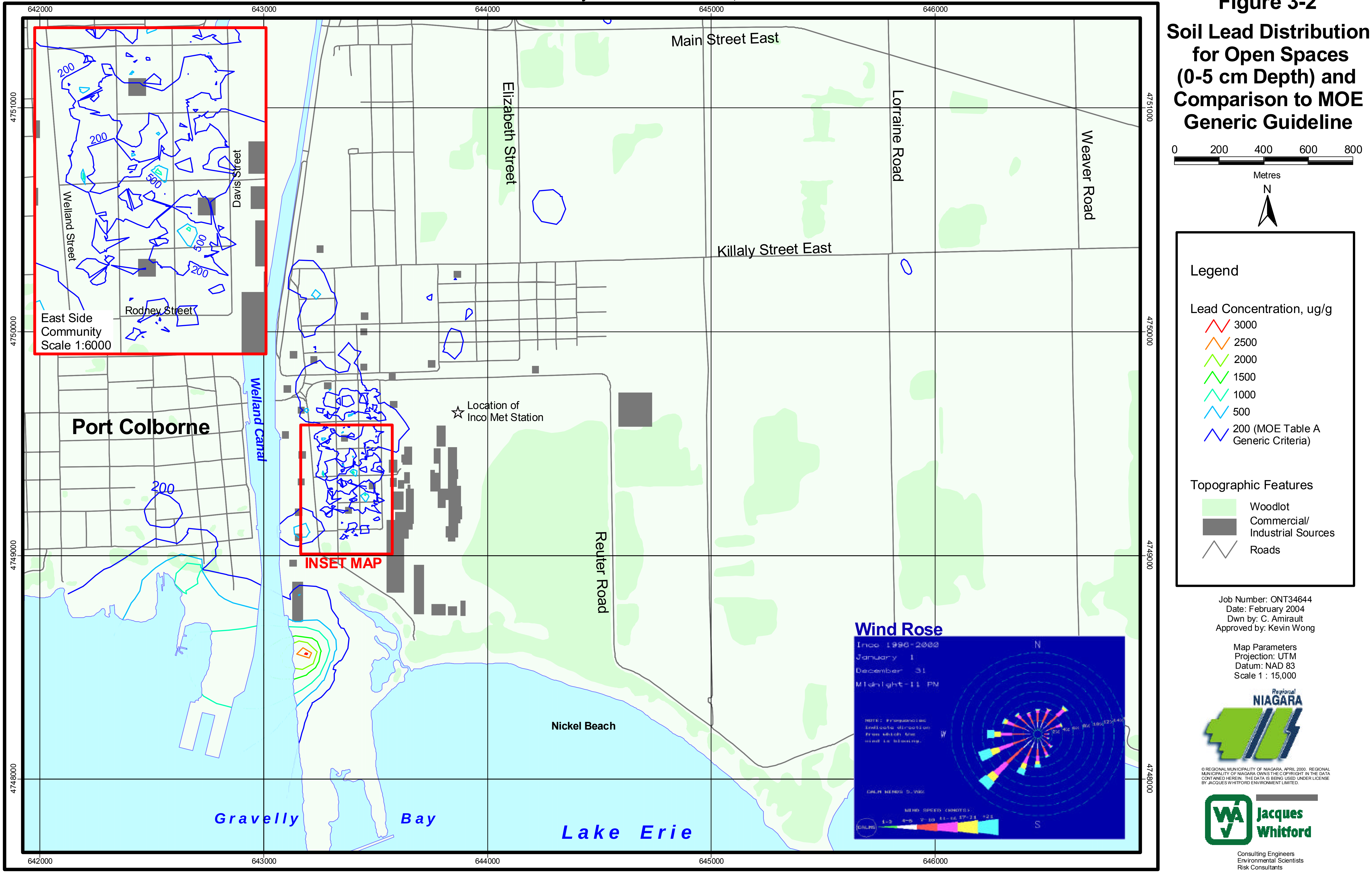
Figure 3-2

Soil Lead Distribution for Open Spaces (0-5 cm Depth) and Comparison to MOE Generic Guideline



Job Number: ONT34644
Date: February 2004
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 15,000

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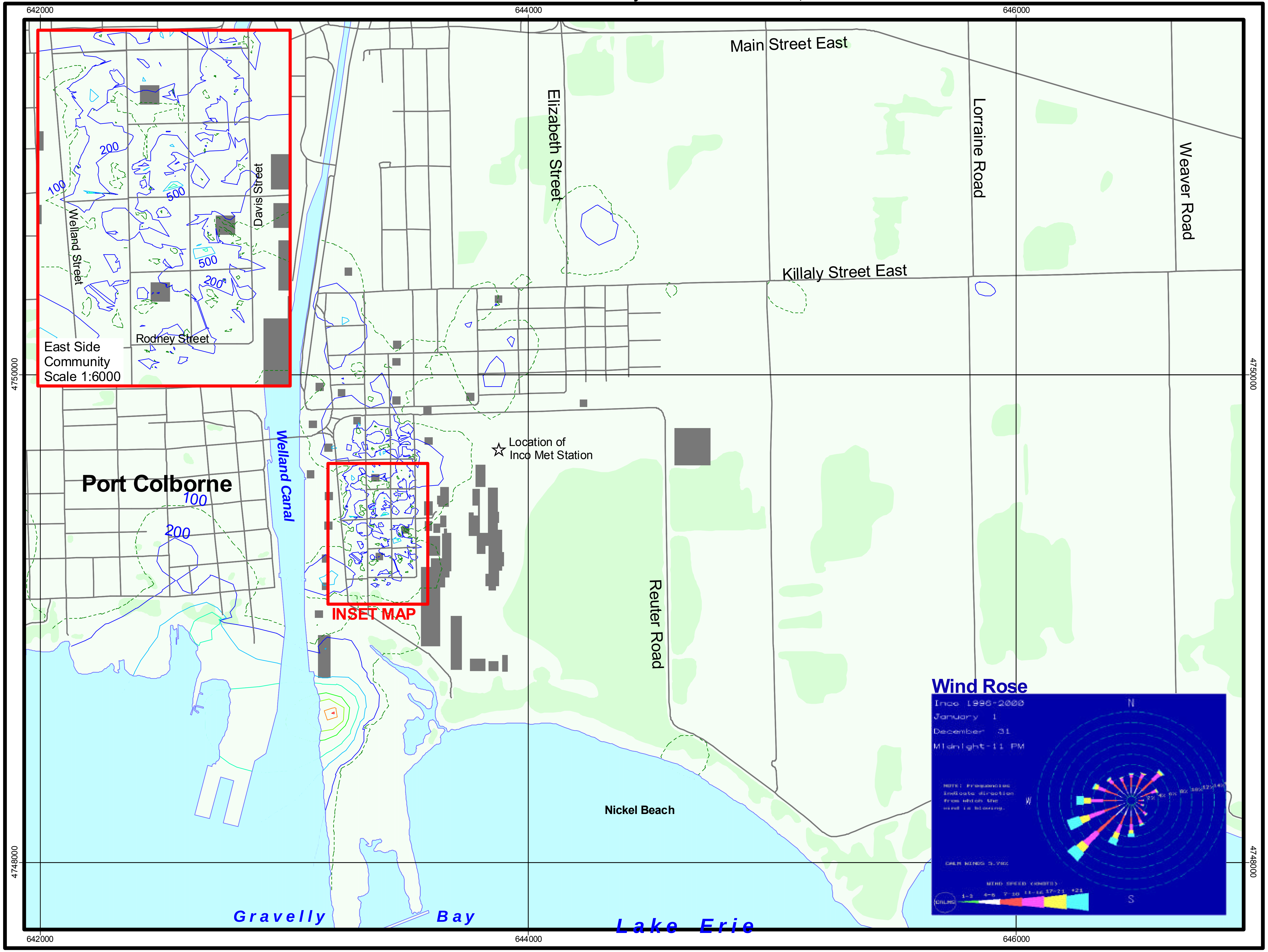

Figure 3-3

Soil Lead Distribution for Open Spaces (0-5 cm Depth) and Comparison to 1/2 MOE Generic Guideline

0 200 400 600 800

N

Legend

Lead Concentration, ug/g

- 3000
- 2500
- 2000
- 1500
- 1000
- 500
- 200 (MOE Table A Generic Criteria)
- 100

Topographic Features

- 🟩 Woodlot
- ▨ Commercial/ Industrial Sources
- Roads

Job Number: ONT34644
Date: February 2004
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 15,000

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3.2.3 Soil Lead Distribution in Woodlots and Open Spaces, 0-5 cm depth

Woodlots, unlike open spaces, are known to pre-concentrate atmospheric pollutants in soil. The MOE report “Soil Contamination in Selected Port Colborne Woodlots: 2000” (MOE (2000)) found that in woodlots downwind of the Inco Refinery, the soil metal concentration gradients showed a ‘snow fence shadow’ effect; i.e., soil metal levels were highest at the windward side of the field/woodlot interface, consistently higher in the woodlot than in adjacent open spaces by factors between 2 to 7, and lowest in the open fields immediately downwind of the woodlot (leeward side).

The MOE (2000) report gave five reasons for woodlots concentrating atmospheric pollutants. These reasons given by the MOE were as follows:

1. *Leaves which act as a sponge to absorb pollutant-laden air, eventually fall to the ground, decompose and release their contaminant loading to the soil;*
2. *Rough bark of tree branches intercept metal particulates from the air and these particulates are removed from the bark during precipitation events and washed into the soil;*
3. *The physical structure of the woodlot creates turbulence in the lateral flow of the air stream, slowing down air movement and causing eddies, which result in particulates falling out and depositing to the soil at the windward edge of the woodlot;*
4. *The woodlot floor cover is high in organic matter that retain the metal particulates that fall onto this floor and become concentrated in the upper few centimetres; and*
5. *The woodlot floor is less disturbed than cultivated agricultural fields or urban lawns and thus are concentrated more in the upper few centimetres.*

The combined data base of soil lead concentrations in both woodlots and open spaces are mapped on Figure 3.4. Figure 3.4 show the same observations in soil lead patterns as noted in Figure 3.3 with some additional observations. These additional observations included:

- To the west of the Inco Refinery and west of the Welland Canal, there exists a woodlot with a concentration of soil lead of 1510 ug/g.

- In the near field directly east of the Refinery but on the Inco property, there is a distribution pattern of elevated soil lead in the woodlot at concentrations above the 200-ug/g MOE generic guideline. It is clear that a ‘snow fence shadow effect’ for this woodlot was responsible for concentrating the atmospheric particulates historically released from the Inco Refinery. As previously mentioned, a similar effect was observed for nickel by the MOE in their woodlot study (MOE, 2000) further northeast of this particular woodlot.

Re-Evaluation of Lead as A CoC- Community Based Risk Assessment, Port Colborne ON

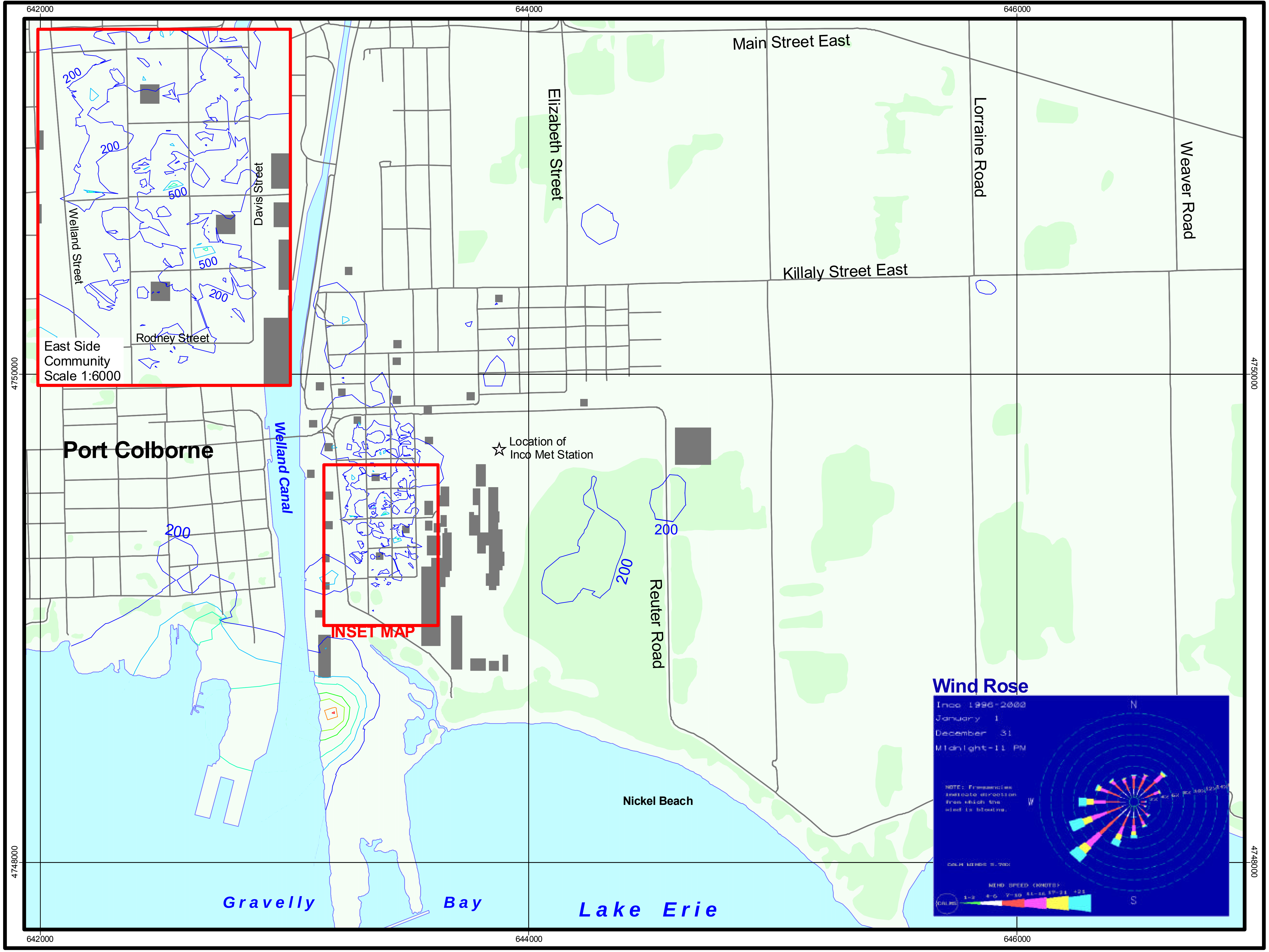

Figure 3-4

Soil Lead Distribution in Woodlots and Open Spaces (0-5 cm Depth)

0 200 400 600 800
Metres

N

Legend

Lead Concentration (ug/g)
- 3000
- 2500
- 2000
- 1500
- 1000
- 500
- 200 (MOE Table A Generic Criteria)

Topographic Features
- ▨ Commercial/ Industrial Sources
- 🟩 Woodlot
- Roads

Job Number: ONT34644
Date: October 2003
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 15,000

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Risk Consultants

3.3 VERTICAL DISTRIBUTION OF SOIL LEAD IN WOODLOTS AND OPEN SPACES, 5-10 CM DEPTH AND 10-20 CM DEPTH

To identify any patterns in soil lead concentrations in sampling locations with depth and with distance from the Inco Refinery, soil depth profiles for soil lead below the 0 to 5 cm depth interval were examined. In particular, soil lead concentrations at selected depth intervals of 5 to 10 cm and 10 to 20 cm were plotted (Figures 3.5 and 3.6, respectively).

The soil lead patterns with depth and with lateral distance east and west of Inco, as shown in Figures 3.4 (0 to 5 cm depth), 3.5 (5 to 10 cm depth) and 3.6 (10 to 20 cm depth), are found to differ. East of the Inco Refinery, the lead concentrations found in surficial (0 to 5 cm) soil diminishes in a sharp decline to background concentration levels at a depth below 10 cm. West of the Inco Refinery, the opposite is true. The soil lead distribution pattern with depth shows high soil lead concentrations occurring at all depth intervals. The soil lead concentrations increase in depth in some areas, while in other areas, the soil lead concentrations remain the same with depth. These patterns west of the Inco Refinery were also observed by the MOE in their soil investigation of the East Side Community (MOE(2002), and Section 3.1.4 of this report).

The observed differences in vertical distribution of soil lead with depth, between the east and west of the Inco Refinery, is another piece of information indicating that most of the lead present in the East Side Community came from a source(s) other than atmospheric deposition from the Inco Refinery.

Re-Evaluation of Lead as A CoC- Community Based Risk Assessment, Port Colborne ON

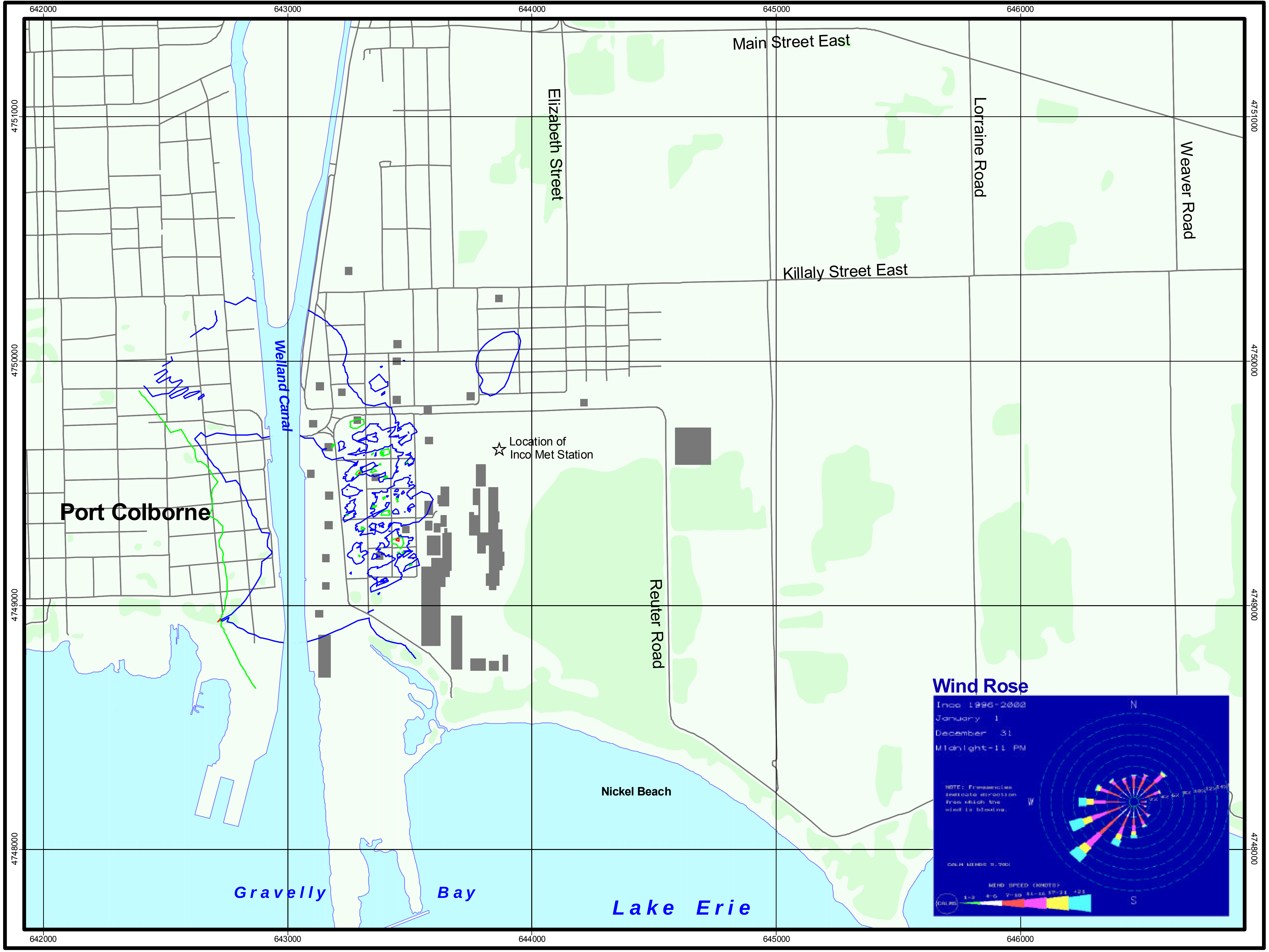

Figure 3-5

Soil Lead Distribution for Woodlots and Open Spaces 5 - 10 cm Depth

0 200 400 600 800
Metres

N

Legend

Lead Concentration (ug/g)

╱╲	1000	5 to 10 cm Depth
╱╲	500	
╱╲	200	

Topographic Features

■	Commercial/ Industrial Sources
🟩	Woodlot
╱╲	Roads

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Date: February 2004
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 15,000

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Re-Evaluation of Lead as A CoC- Community Based Risk Assessment, Port Colborne ON

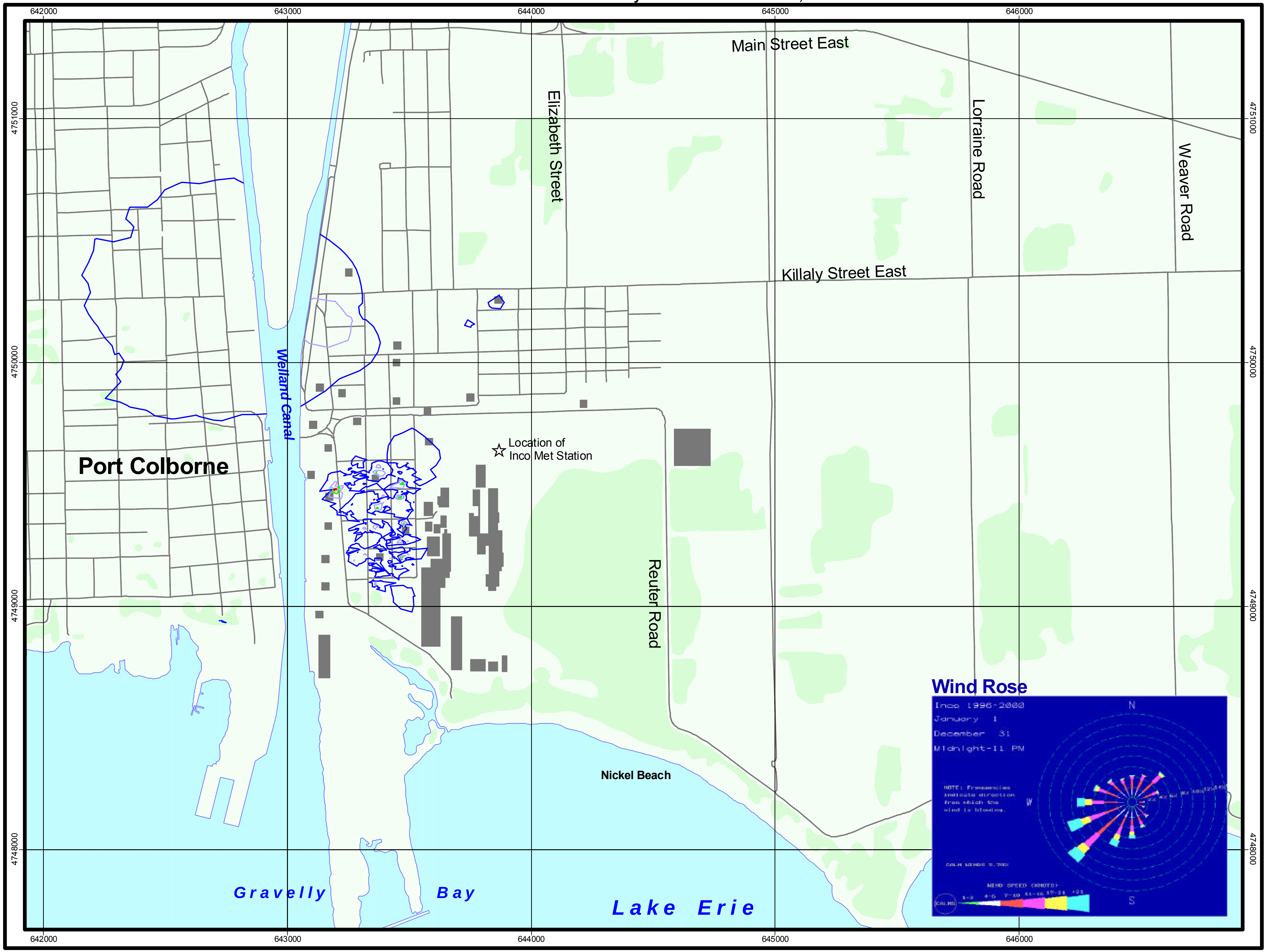

Figure 3-6

Soil Lead Distribution in Woodlots and Open Spaces 10 - 20 cm Depth

0 200 400 600 800
Metres

N

Legend

Lead Concentration (ug/g)

- 2500
- 2000
- 1500
- 1000
- 500
- 200

Topographic Features

- ■ Commercial/ Industrial Sources
- 🟩 Woodlot
- Roads

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Date: October 2003
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 15,000

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3.4 SOIL NICKEL TO SOIL LEAD RATIOS

Nickel is the principal indicator CoC arising out of the operations from the Inco Refinery, and any relationship of any element (e.g., lead) to nickel would be indicative of that element's impact on the surrounding areas resulting from atmospheric deposition from the Inco Refinery. Figure 3.7 shows a map of the study area with plotted contours of soil nickel to soil lead ratios from all of the collected surface soils from the 0 to 5 cm depth. The average soil nickel to soil lead ratio within the East Side Community is approximately 10:1, which concurs with MOE findings (MOE, 2002). The average soil nickel to soil lead ratio found in Figure 3.7 for the far field areas north and east of the Inco Refinery is roughly 20:1, which also concurs with MOE findings (MOE, 2000,a,b).

Downwind of the refinery in the near field (within the Inco property boundary), Figure 3.7 shows an evident plume shape pattern of higher soil nickel to soil lead ratios ranging from 50:1 to 200:1 and the axis of this plume appears to be elongated along the predominant wind direction from the southwest to the northeast.

About 50% of the historical nickel emissions from Inco occurred from stacks much taller than the stack from which the majority of the lead from the facility was emitted. Given the differences in stack heights, one would not expect the soil nickel to soil lead ratio to be constant throughout the region (as lower stacks will impinge/deposit contaminants on the ground closer to the source than a taller stack). However, it would be expected that the ratio of nickel to lead at any given distance from the facility, regardless of direction, would have a similar ratio. As can be seen in Figure 3.7, at similar distances to the east and west of Inco, the ratios are not the same (i.e., there are large differences in soil nickel to soil lead ratios in areas west of the Refinery (ie. East Side Community) at 10:1 versus those in areas east of the Refinery ranging from 50:1 to 200:1).

The comparatively lower soil nickel to soil lead ratios in the East Side Community reflects an area of elevated soil lead concentrations relative to soil nickel concentrations, which cannot be explained due to atmospheric deposition from the Inco Refinery alone. To achieve the soil nickel to soil lead ratio seen in the East Side Community, other sources of lead besides air deposition from the Inco Refinery must have contributed to the lead concentrations in the East Side Community. Discussion of these other lead sources and their relative contribution to the soil lead concentrations in the East Side Community will be presented in Sections 7.0, 8.0 and 9.0.

3.5 RELIABILITY OF SOIL LEAD DETERMINATIONS

Reliable analytical data is the cornerstone for sound environmental decision-making. It is important that the databases as described and interpreted in Sections 3.1, 3.2, 3.3 and 3.4 can be trusted. To that end, JWEL, other consultants and the MOE have taken great efforts in the Port Colborne CBRA to ensure that their contract laboratories have reported reliable analytical data.

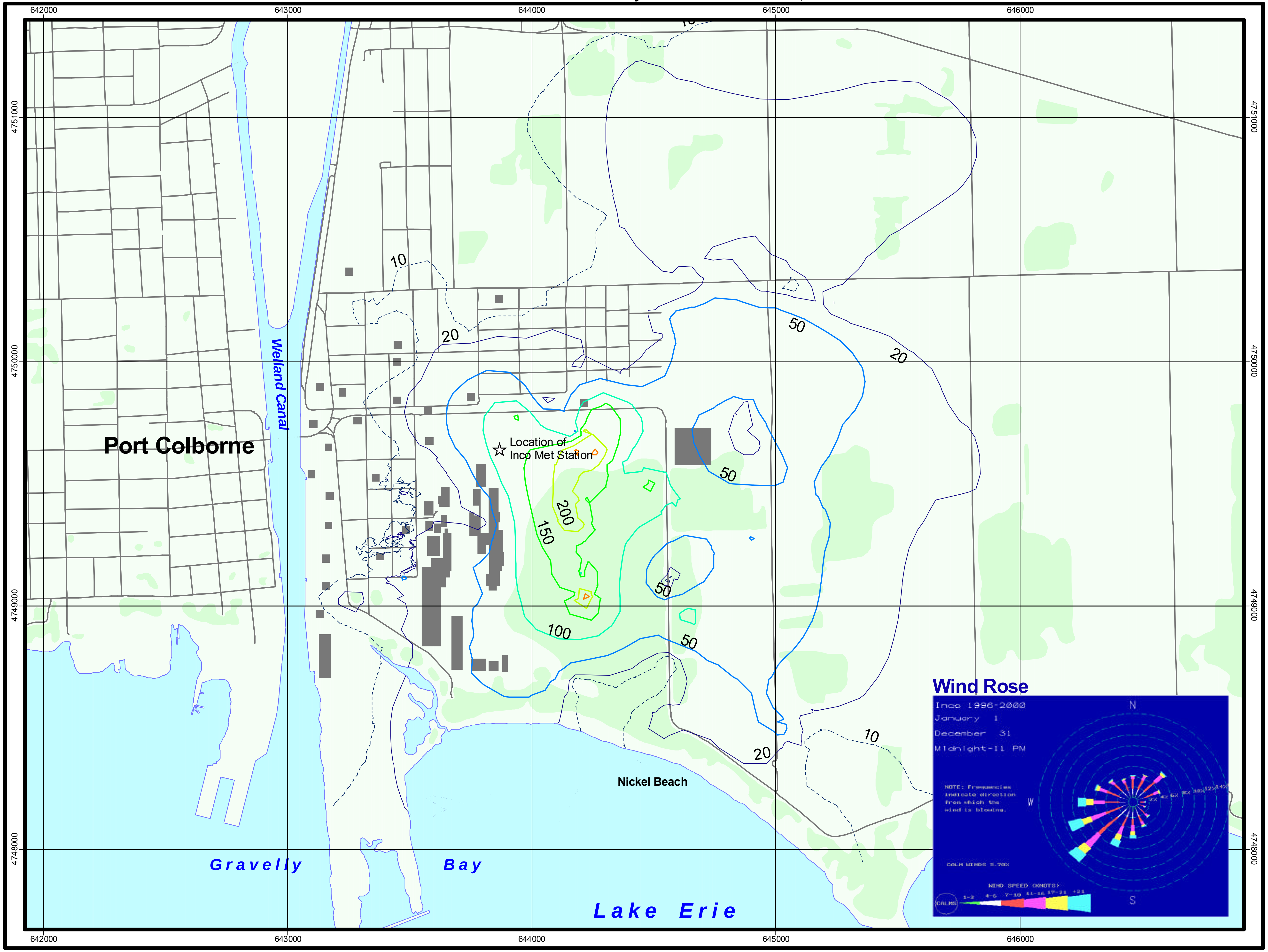
Philip Analytical Services Inc. (PASI) labs in Mississauga has been JWEL's analytical laboratory of choice for the Port Colborne CBRA because of their proven performance. PASI are accredited by the Canadian Association for Environmental Analytical Laboratories/Standards Council of Canada (CAEAL/SCC, respectively) for the analysis of metals, including the Port Colborne CoCs, for water, soil and in tissue samples. PASI is also accredited by various professional associations including the American Industrial Hygiene Association and the Association of the Chemical Profession of Ontario, eleven U.S. states, and others. PASI has been successful in all external audits with government authorities such as New York State, the State of Washington and New Hampshire, and leading industrial auditors from Ford, General Motors, Imperial Oil/Exxon, Petro Canada and others. PASI participates in numerous interlaboratory round robins and blind studies.

Throughout the CBRA, there have been numerous quality control checks on test samples, as well as on blind reference materials, submitted by JWEL to PASI as part of on-going quality assurance/quality control (QA/QC) program. Findings of the QA/QC program as given in **Appendix B-1** indicate that the accuracy and precision of the measured lead concentrations by PASI in the analyses of JWEL's samples was excellent.

Re-Evaluation of Lead as A CoC- Community Based Risk Assessment, Port Colborne ON

Figure 3-7

Soil Nickel: Lead Ratio in Woodlots and Open Spaces



0 250 500 750 1000

Metres

N

Legend

Soil Nickel: Lead Ratio

250	20
200	10
150	
100	
50	

Topographic Features

- ■ Commercial/ Industrial Sources
- 🟩 Woodlot
- ╱╲ Roads

Job Number: ONT34644
Date: October 2003
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 30,000

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4.0 HISTORY OF INCO OPERATIONS

This chapter presents an overview of the Inco operations in Port Colborne, and details the development of an inventory of air emissions of lead-containing compounds from the facility.

4.1 INCO PROCESS DESCRIPTION

The Inco Port Colborne facility was constructed in 1916 and became operational in 1918. Since that time the facility has undergone a large number of process, operational and equipment changes. Lead-containing compounds (in trace amounts) were present in the various feed materials used in the processes (i.e., mattes, coal, coke, etc) and therefore would be present in trace amounts in the particulate emitted into the air from the refining operations.

Initial operations were conducted using the Orford process for copper and nickel separation from matte supplied from Copper Cliff. The Orford process at the PCNR separated nickel “bottoms” and copper “tops”, which were passed to additional on-site operations. The nickel "bottoms” underwent leaching, roasting, reducing and fire refining to produce nickel ingots. The copper “tops” were processed to blister copper for sale. The primary operations for these processes included furnaces for roasting and sintering, mechanical separation, grinding and crushing.

In the 1930’s, the Orford process ceased in Port Colborne and was transferred to Copper Cliff. The Port Colborne facility continued to treat the Orford bottoms received from Copper Cliff.

In the mid 1920’s, electro-refining operations were introduced, which allowed for the production of nickel in electrolytic tanks, removing the need for fire refining. From the mid 1920’s onward, the proportion of fire refining conducted by the facility was gradually reduced in favour of an increased emphasis on electro-refining. Electrolytic refining (as carried out in the Number 5 Building), did not result in any significant air emissions as it was an aqueous-based, low temperature, wet process. The electro-refining of nickel was ceased in 1984.

Additional processes introduced at the Port Colborne facility included precious metal upgrading, and the production of cobalt by electrowinning. Current operations consist primarily of cobalt refining and precious metal processing (since 1987). Electrowinning of cobalt has negligible air emissions.

From 1975 to 1987, the Number 2 Research Station (which was an independent business unit from the nickel refinery) processed relatively small amounts of a high sulphur, precious metals-containing by-product from Copper Cliff, in a top blown rotary converter (TBRC). Stack testing of this source was conducted during operation, including measurement of lead emissions. The by-product from Copper Cliff processed in the TBRC during this period had a lead content significantly higher (between 0.12 to 18.6% Pb content) than any other feed material used in the PCNR. This resulted in higher lead emissions from the #2 Research Station TBRC than any source in the PCNR.

Figure 4.1 provides a photograph of the Inco Port Colborne facility in the background and the neighbouring Algoma Steel facility in the foreground from a period in the 1950’s. The schematics in Figures 4.2 and 4.3 provide a series of process flow diagrams for the facility ranging from 1918 through to 1984.

Figure 4-1 Inco – Port Colborne circa 1950s (Courtesy of the Port Colborne Historical Museum)

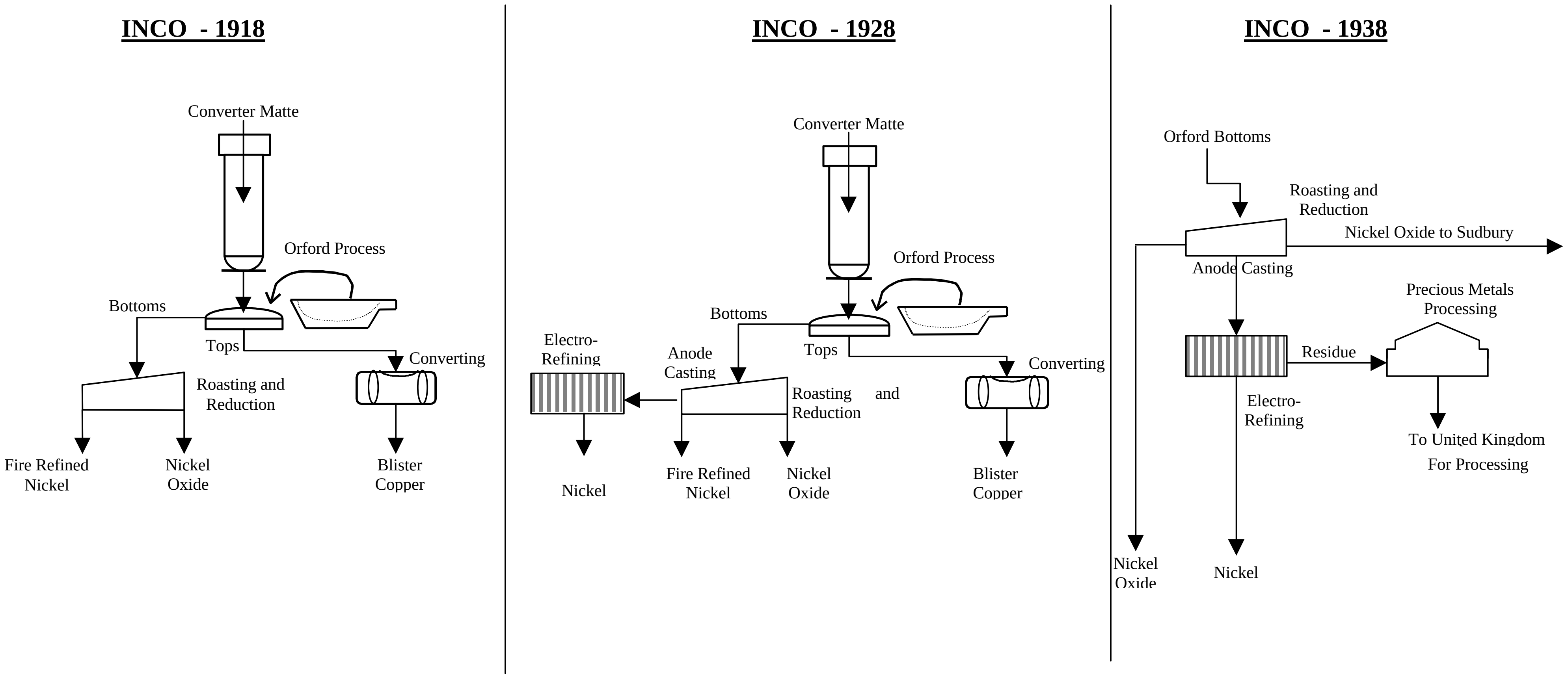


Figure 4-2 Historic Operations at Inco – Process Schematics – 1918, 1928, 1938
Ref.:Renzoni, L.S. "Extractive Metallurgy at International Nickel - A Half Century of Progress" Feb, 1969 (Modified – JWEL 2001)

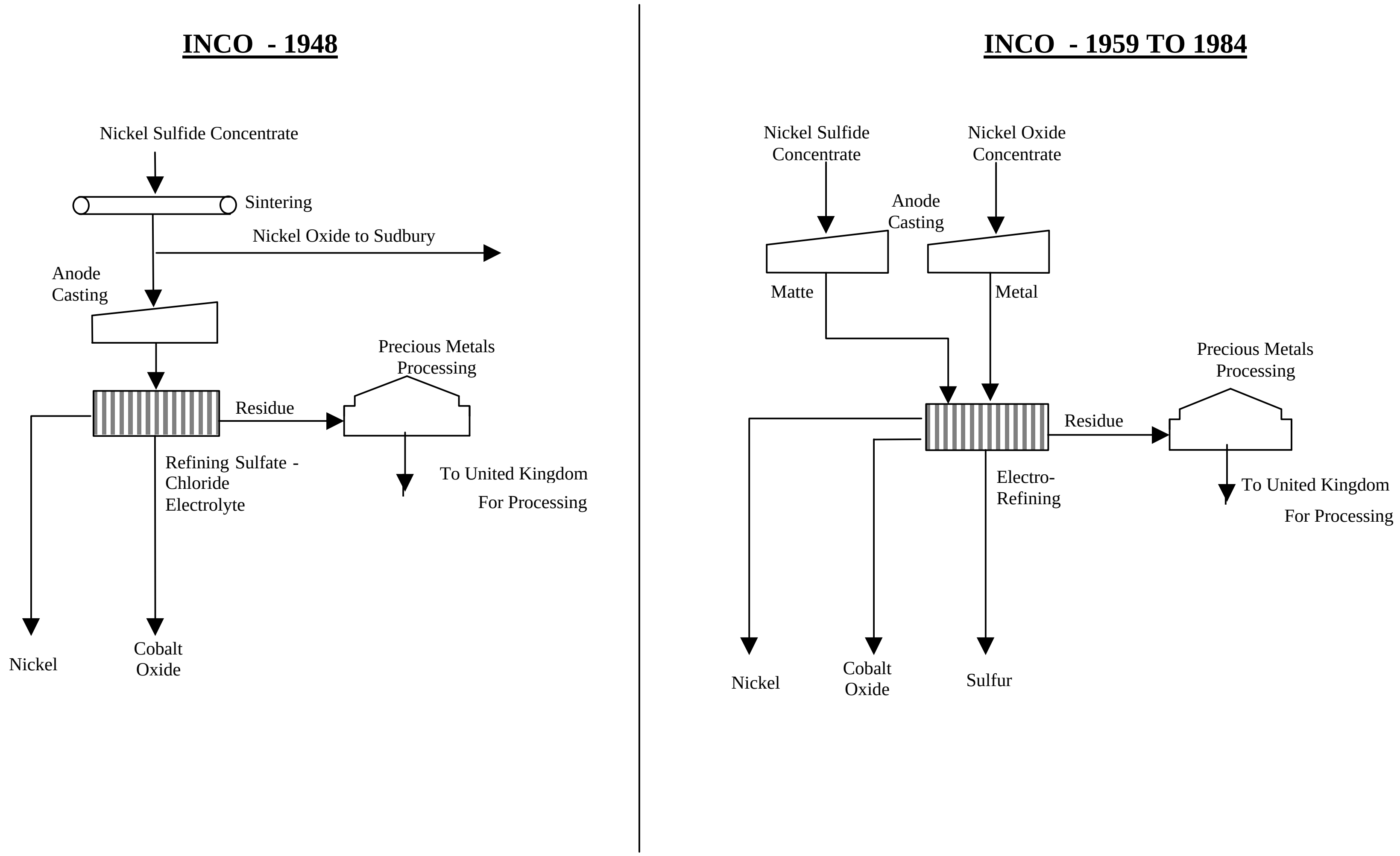


Figure 4-3 Historic Operations at Inco – Process Schematics – 1948, 1959-84
Ref.:Renzoni, L.S. "Extractive Metallurgy at International Nickel - A Half Century of Progress" Feb, 1969 (Modified – JWEL 2001)

4.2 OVERVIEW OF INVENTORY AND APPLICABILITY

A series of air emission inventories were developed to cover the historic operating periods of the Inco facility. The inventories were developed following the protocols of an Emission Summary and Dispersion Modelling Report as stipulated in the Ontario Ministry of the Environment guideline document *Procedure for Preparing an Emission Summary and Dispersion Modelling Report*, dated June 1998. The procedure followed for each scenario was to develop a particulate emissions inventory utilising US EPA particulate emissions factors for similar processes/equipment and then calculate the lead component of the particulate emissions based on available lead composition data for the various feed materials and products.

In order to account for the changes in equipment, production methods and manufactured materials over the course of the historic operating periods of the facilities, a series of separate inventories were compiled. Each air emission inventory scenario was designed to cover a period of years where the operating conditions were relatively consistent for the facility.

The design of the inventory scenarios included the following considerations:

- Major modifications to facility operations and processing equipment;
- Major changes to production levels and/or types of materials produced; and,
- Availability of reliable information sources.

For each scenario, an air emission inventory was developed for a representative year of operations. The estimated air emissions for these representative years were taken to be indicative of the emissions for each year of that scenario period.

It should be noted that the emissions estimated by this methodology are based on the available data, which was scarce in some instances. The inventory is therefore used as an indicator of what the potential emissions of lead containing compounds might have been over the history of the PCNR operations. As with any emission inventory, there are uncertainties and approximations associated with it. The methodology used to develop the lead inventory for the PCNR followed the same methodology used for developing a nickel emissions inventory (JWEL, March 2003). In that study, comparisons between the predicted nickel depositions and field measurements of nickel in soil suggested that the inventory and modelling predictions were within a factor of between 2-3 of actual measurements.

4.3 INVENTORY SCENARIOS AND SOURCES

Given the available information resources, the historic operations of the PCNR and the No. 2 Research Station were separated into six distinct operating periods as shown in Table 4.1.

Table 4-1 Inco Air Emission Inventory Scenarios

SCENARIO	OPERATING YEARS	REFERENCE YEAR	OPERATIONAL HIGHLIGHTS
1 - PCNR	1918 - 1930	1928	Orford Process and electro-refining, Cu and Ni only
2 - PCNR	1931 - 1938	1938	Orford Process ceased, electro-refining and precious metals processing
3 - PCNR	1939 - 1959	1958	Electro-refining upgrades
4 - PCNR	1960 - 1979	1968	New Cottrell ESP start-up, sintering ceased.
5- PCNR	1980 - 1990	1983	Electro Co refining start-up
6 – No. 2 Research Station	1975 - 1987	1983	Precious Metals Upgrading

In the period from 1991 to 2001, a negligible quantity of lead was emitted from the PCNR (based on Inco's NPRI submissions to Environment Canada).

The primary data references for development of the Inco scenarios were:

- Historic facility site plans;
- Inco "Metals Practice Sheets" spreadsheet;
- Inco internal report, "Appendix I: History of Operations" and historic Port Colborne Refinery process flow diagrams; and,
- Inco NPRI submissions.

A summary of the processes that occurred for each emission scenario, and their potential for lead emissions, is presented below.

4.3.1 Scenario 1 – PCNR, 1918-1930

The original Orford process operations were conducted during this time period and consisted of three cupola furnaces (two for nickel, one for copper), three copper reverberatory furnaces, three copper converter stands and two slag reverberatory furnaces. All of these operations were conducted in the original Number 1 building (see Figure 5-5) located at the east end of the property. The combined air emissions from these operations were routed through two common plenums that discharged to a 350-foot stack (source B1-01 in Figure 5-5). Significant material handling operations, matte and coal storage, as well as fugitive losses from the furnaces, were associated with these processes. These materials all contained trace amounts of lead. The matte received from Copper Cliff for this process had previously been smelted at high temperature, so the majority of low-boiling-point materials (such as elemental lead or lead oxide, if they had been present) would have been emitted in Copper Cliff as opposed to Port Colborne.

The nickel bottoms from the Orford Process were converted into nickel oxide using calcining furnaces located in Building 3. Incoming material was ground, crushed and partially roasted on the upper deck of the calcining hearth furnace. The partially roasted material was mixed with salt for chloridizing the copper and nickel and transferred to a series of leaching tanks (located in Building 2). As leaching was a wet process, there was negligible potential for air emissions. At this stage, the majority of the copper had been removed, and the left over material was impure nickel oxide. Subsequent roasting at high temperatures (1,200°C) and additional leaching resulted in a nickel oxide material with an approximate composition of 77.5% nickel, 0.1% copper, 0.25% iron and 0.008% sulphur.

Air emissions from the grinding, material handling and calcining operations were routed through an underground flue to a large dust chamber for the inertial separation of particulate matter before being exhausted to the atmosphere through a dedicated 350 foot exhaust stack (source DC01 in Figure 5-5). As with the Orford Process, any lead emissions from this process would be due to trace amounts of lead-containing compounds in the feed materials.

Sintering operations were used to convert nickel sulphides to nickel oxides through desulphurisation, with the sulphur content being reduced from approximately 25% to 0.4%. The incoming matte and nickel oxide materials were crushed through a series of jaw crushers and cone crushers, prior to high temperature roasting to reduce sulphur. Some of the resulting sinter was further refined on-site, while some was shipped as a market product. The air emissions were exhausted through the same underground flue/ dust chamber as used for the calcining furnace emissions. Sintering operations were conducted in Building 3.

The crude oxide, or sinter, was further processed on-site using a series of reverberatory type anode furnaces located in Building 4. These operations consisted of high temperature reduction of the nickel oxide to produce impure nickel metal, which was cast into nickel shot (a direct market product) and/or nickel anodes for electrolytic nickel production.

4.3.2 Scenario 2 – PCNR, 1931-1938

The Orford Process in Building 1 was discontinued in 1930. Following this, Building 1 was utilised for raw material storage, drying of iron slimes (a by-product of the electro-refining process) in a drying kiln prior to shipment to Copper Cliff, and nickel precipitation tanks. The lead emissions associated with this building would have significantly decreased due to the decrease in process activities. Potential lead emissions would still be associated with trace impurities in feed materials stored in the building and in the iron slimes.

This scenario also marked the beginning of electro-refining (located in Building 5) and precious metals refining. As noted above, electro-refining is a wet process with negligible air emissions. Sintering operations continued in Building 3 during this period. All anode production and anode casting occurred in Building 4 (with the exception of secondary anodes, which were located in Building 3).

4.3.3 Scenario 3 – PCNR, 1939-1959

During this period, the electro-refining operations increased and operations such as sintering, nickel anode and wrought nickel production, and calcining continued. Multi-clones were installed on the anode furnaces in Building 4, significantly lowering their air emissions. An electric slag furnace was installed in Building 1 in 1941.

4.3.4 Scenario 4 – PCNR, 1960-1978

During this period, sintering in Building 3 was discontinued and calcining significantly curtailed. An induction furnace in a Foundry Additives Plant (FAP), controlled by a baghouse, was installed in Building 2. A Cottrell precipitator that controlled emissions from the anode furnaces in Building 4, was also installed during this period. Lead emissions during this period, as with the previous scenarios, were associated with trace impurities in feed materials.

4.3.5 Scenario 5 – PCNR, 1980-1990

During this period, overall emissions from the PCNR were further reduced. Emissions sources included the slimes dryer in Building 1, the Cottrell precipitator stacks controlling the anode furnaces and the FAP baghouse. These processes would all be sources of trace amounts of lead-containing compounds due to impurities in the feed materials.

4.3.6 Scenario 6 – Research Station, 1975-1987

From 1975 to 1987, the Number 2 Research Station processed high-sulphur precious metals containing materials in a top blown rotary converter (TBRC). During this time, the TBRC process was recorded to have processed materials with lead-containing compounds at greater than trace levels. Although only a relatively small amount of material was processed, the lead content of the material ranged from 1 to 12% of the feed. The sulphur content was between 10-15% and the nickel content about 1-2%. The purpose of the TBRC was to reduce the sulphur content of the feed to about 1%.

The feed for the TBRC, referred to as "TOL Residue" was shipped to the research station as a wet filter cake (i.e., "sludge"). The point of origin of the TOL residue was Inco's Copper Refinery Electrowinning Department (CRED), Copper Cliff, Ontario. The "TOL Residue", which contained valuable quantities of the platinum group metals (PGMs), gold, and silver, was transported from Copper Cliff by truck in closed containers. The containers were unloaded from the trucks and moved into a feed preparation building (for security and to avoid losses) where the "TOL Residue" was unloaded and mixed (inside the building) with other additives for processing. The mixed product was then placed in tote bins (still inside the building), which were then moved by forklift from the feed preparation building to the nearby #2 Research Station. Once inside the #2 Research Station building, the tote bins were hoisted to the conveyors to feed the TBRC, all in the same end of the building. The feed mix was still moist, and great care was taken to ensure that losses did not occur as it contained precious metals. The handling procedures necessary to ensure that there were no losses of valuable metals also ensured that negligible fugitive emissions of lead would have escaped during material handling.

A feed system comprised of two nine-ton bins equipped with vibratory feeders was used to charge concentrate to the furnace. A third bin was used for the addition of flux. The furnace was a 12-foot long vessel with a conical refractory lining of 6-foot maximum diameter. A rotation mechanism was used to impart speeds of up to 20-rpm to the vessel. The molten mixture in the TBRC was blown with pure oxygen through a lance (see Figure 4-4).

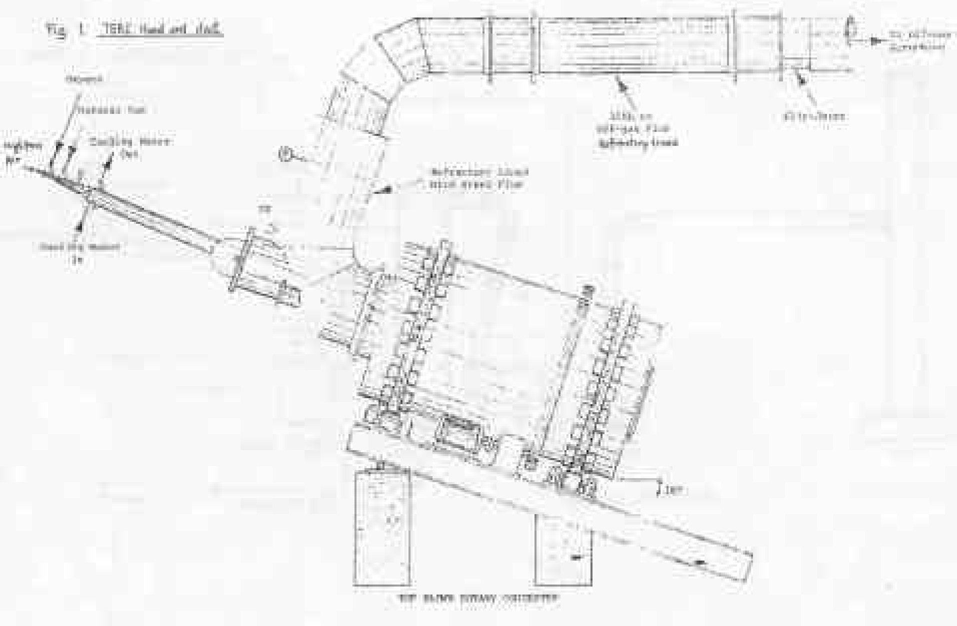


Figure 4-4 Diagram of TBRC

The TBRC off-gas was collected by a movable, refractory lined hood. An approximately 15-cm gap was kept between the hood and the TBRC to allow infiltration of air into the exhaust stream to cool the gas. The hot exhaust gas (approximately 2500 F) was very efficiently collected by the hood, due to its high thermal buoyancy. The exhaust gas was diluted with 5000 scfm of air to reduce the temperature to 1250 F prior to delivery to the off-gas handling system.

The off-gas gas handling system consisted of:

1. A Waterloo spray to further cool the gas and remove particulate;
2. A Venturi scrubber;
3. A second Waterloo spray;
4. An Absorption tower;
5. A third Waterloo spray;
6. A Euroform mist eliminator;
7. Exhaust Fan; and
8. A 38-m stack.

A diagram of the TBRC off-gas system is shown in Figure 4-5. The removal efficiency of the Venturi scrubber and Absorption tower (steps 2 and 4 in the system) were designed for a 95% removal of SO_2 and 99% of particulate. The additional control equipment (Waterloo sprays and mist eliminator) would have further increased the removal efficiency of the system.

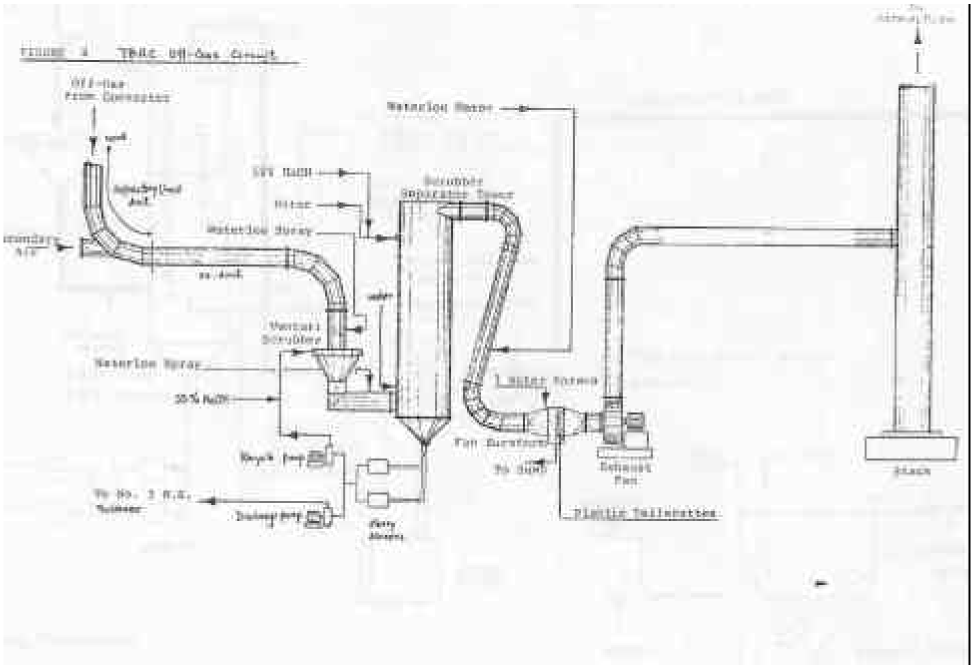


Figure 4-5 TBRC Off-Gas Collection System

By-products from TOL processing in the No. 2 Research Station were recycled to recover the precious metals content. This included settling pond solids (from the scrubbers and mist eliminator) and internal dust handling. All materials containing precious metals, even things like press-cloths and gloves were recycled. Any and all dust collector dust from refinery operations were recycled either internally or recycled to Sudbury.

Scrubber solids were collected in a concrete settling pond and periodically removed as wet (settled) sludge to an asphalt-paved ore pad from where it was shipped by truck to Sudbury. Pond overflow went to the PCNR effluent treatment plant (ETP) where the TBRC effluent joined other effluents from the PCNR and were treated with lime. The resultant sludge from the ETP was recovered. The TBRC slag, TBRC scrubber solids, and used TBRC refractory were all regularly reverted to the Copper Cliff Smelter for recovery of their residual PGM values.

Lead contained in the matte produced from the TBRC was further upgraded by leaching impurities. Lead so leached was precipitated as $PbCO_3$ and was either sold or sent to a secure landfill outside Port Colborne.

4.4 EMISSION INVENTORY DESIGN

The design of each of the air emission inventories was based on the following:

- Availability of a direct historic reference for each emission source included in the inventory;
- Availability of a direct, validated emission estimation technique for each identified emission source type;
- Availability of a direct, site-specific reference regarding trace lead composition for each identified emission source type; and
- Consistency of emission estimation techniques for similar processes between each scenario.

This approach was used to ensure that all data used for the inventories were traceable to a reference document, and based on validated emission estimation techniques.

Using this basis, the inventories were developed according to the following methodology:

- ➢ Emission estimates were developed for the principal process operations referenced in the historic documentation, including furnaces, material handling (crushing/grinding) and material storage stockpiles;
- ➢ Standard U.S. EPA emission factors for total particulate matter were used for the appropriate process for all emission sources to provide a baseline “template” particulate emission inventory for each scenario; and,
- ➢ Site-specific, lead composition data were used for various materials (such as feed materials, coal, slag, and material from dust collection systems) and applied to the template particulate emission inventory to produce the lead emission inventory.

4.4.1 Emission Estimation Methodologies

The following emission estimation methodologies were used to develop the baseline particulate matter, air-emission estimates for each of the operational scenarios. Several simplifying assumptions were made during the development of the air emission inventories:

- ➢ Fugitive air emissions relating to specific processes were assigned to a single emission point from the roof of the associated building. Given the relative scarcity of data for the earlier years of operation of the PCNR, fugitive emissions sources for a process were lumped into a single fugitive source and located approximately in the centre of the area where the process creating the emissions occurred. In instances where emissions due to general material handling activities, etc occurred throughout a long rectangular building (such an Building 1, Scenario 1) these emissions were modelled as several emission points along the length of the building. In later years, when more source data was available, process changes in the PCNR (now mainly electrowinning) resulted in less fugitive releases;
- ➢ Material loading/unloading emissions were assigned to the same locations as the material stockpiles (if applicable); and,
- ➢ Minor emissions sources and processes with negligible potential to emit lead compounds were not included in the inventories.

4.4.2 Inco Process Emissions

The primary process operations of concern from the Inco PCNR were:

- Cupola furnaces;
- Reverberatory furnaces;
- Calcining furnaces;
- Electric furnaces;
- Ball mills / material grinding;
- Foundry additives production;
- Sintering; and,
- Nickel refining furnaces.

Within the Research Station, the only process of concern was the TBRC and its related gas handling system.

Air emissions from electro refining and precious metals processing (other than the TBRC emissions from Research Station 2) were not included in the inventories as these processes were not significant contributors of particulate or lead.

The U.S. EPA compilation of air pollutant emission factors does not specifically include data for particulate emissions from nickel refining. Emission factors were therefore taken from analogous processes, including general ore handling/grinding operations and similar furnaces from the iron and steel manufacturing data compilation.

4.4.3 Facility Activity Data

Activity data for the Inco facility for each of the historical emissions scenarios considered, were developed from Inco records of annual material production and raw material receipts by averaging the data over each time period. The average activity data for each emissions scenario are presented in Table 4.2.

Table 4-2 Average Activity Data (tonnes/year) for each Inco Emission Scenario

	Scenario 1 (1918-1930)	Scenario 2 (1931-1939)	Scenario 3 (1940-1959)	Scenario 4 (1960-1979)	Scenario 5 (1980-1990)	Scenario 6 [1] (1975-1987)
Product						
NiO for Market	9451.4	2739.7	2016.3	245.6	0.0	N/A
Sinter	4994.0	37846.8	43757.4	0.0	0.0	N/A
Blister Cu	12870.8	2830.1	0.0	0.0	0.0	N/A
Ni Anodes	7362.5	42960.3	92539.1	64776.6	9039.1	N/A
Wrought Ni	8465.5	2734.1	4268.2	2998.2	0.0	N/A
Secondary Anodes	127.1	736.8	2685.0	2725.2	0.0	N/A
Reduced Ni	312.8	1897.3	3925.9	1676.7	0.0	N/A
Sulphide Anodes	0.0	0.0	1892.1	8368.4	0.0	N/A
FAP	0.0	0.0	0.0	1959.9	2076.1	N/A
Utility Nickel	0.0	0.0	0.0	1737.2	18647.8	N/A
Receipts						
Bessemer matte (CC+Coniston)	39154.3	6364.5	0.0	72.7	0.0	N/A
Orford Sulphide - CC	0.0	52066.3	44332.0	0.0	0.0	N/A
Sulphide Conc (MEP)	0.0	0.0	9471.0	2637.6	0.0	N/A
SEP –CC Sinter	0.0	0.0	32532.1	6283.3	0.0	N/A
MZP - Sec Metallics	0.0	0.0	1147.8	1922.2	0.0	N/A
Ni Oxide FEP	0.0	0.0	126.6	43205.6	0.0	N/A
MRP Sulphide Conc	0.0	0.0	631.9	176.9	0.0	N/A
MNP Sulphide Conc	0.0	0.0	1983.5	0.0	0.0	N/A
RGP Activated Ni	0.0	0.0	0.0	1703.8	0.0	N/A

[1] Activity data not used in emission estimation technique for Research Station lead emissions.

4.4.4 Lead Composition Data

Development of the lead emission inventory for each of the scenarios involved the application of a composition factor for lead to the baseline particulate emission inventory. The composition data used for PCNR emissions are presented in Table 4.3.

Table 4-3 Metal Composition Data for Inco

MATERIAL	LEAD CONTENT (%)
Matte	0.0154
Sinter	0.0018
Nickel Oxide	0.0043
Coal/Coke	0.032
Slag	0.012
Cottrell Precipitator Dust	0.8

The lead composition factor for the matte, sinter and nickel oxides were taken from graphite furnace lead (Pb) assays (January 2003 analysis) on historical samples. For the matte, Coniston and Copper Cliff Bessemer matte (circa 1930-40) sample data were examined. The larger of the Pb values for these two materials (0.0154% for the Coniston Matte versus 0.0055% for the Bessemer Matte) was conservatively applied to both materials.

Composition factors for the nickel oxide and sinter were taken as the maximum lead content of the graphite furnace analyses (2003) of green NiO and black NiO, and sinter respectively.

Lead composition of the slag was taken from analysis of the Orford slag conducted in 1991.

Lead composition factors for the Cottrell Precipitator were taken from the analysis of inlet dust to the ESP presented in an Inco memo from W. Gibbs to A. Manson, December 1977. It should be noted that several analyses of the Cottrell precipitator dust were also available and showed varying lead content (from 0.08% to 10.48%). However, these data were measurements of the dust collected by the ESP, as opposed to the material that actually was emitted from the stack. Therefore, the measurements of lead concentration of the air stream (into the ESP) were used in the analysis, as they were expected to be more representative of the lead concentration of the stack exhaust (from the Cottrell) than the dust collected by the Cottrell (and not emitted).

4.5 TBRC LEAD EMISSION CALCULATIONS

Lead emissions from the TBRC were calculated for both the stack emissions of the off-gas system and fugitive emissions from around the hood of the off-gas collection system. Stack emissions were calculated based on the results of 24 stack tests conducted between 1982 and 1985 (providing lead emissions in g/s), assay data of all TOL shipments received by the #2 Research Station (providing % elemental lead in feed), weights of each TOL shipment and processing times. These data were utilised to calculate an average emission factor for kg of lead emitted (from the stack) per tonne of lead in the feed material. This emission factor was used with the average lead content of the feed in each year of operation of the TBRC to calculate total lead emitted from the #2 Research Station stack during that year.

The only potential source of fugitive emissions due the TBRC operations would be due to leakage from around the fume collection hood over the TBRC. Material handling emissions are expected to be negligible due to the precautions taken to minimise the loss of the precious metal containing feed. This included the use of covered trucks and bins, handling and blending of only wet feed materials, and storage of all material indoors. Fugitive emissions from the hood were calculated using an uncontrolled lead emission factor for a copper reverberatory furnace (7% lead in feed) from US EPA, AP-42 and an assumed capture efficiency of 95% for the hood. Given the basic operating premise of the system (that the gap would provide an influx of air into the system to cool the off-gas) and the high buoyancy of the off-gas (due to its high temperature), it is expected that the estimate of 95% capture efficiency will be conservative (i.e., underestimate the hood's capture efficiency). Utilising this methodology, fugitive lead emissions of 0.45 tonnes over the operating life of the TBRC were estimated to have been emitted.

4.6 INVENTORY SUMMARY

Tables 4.4 and 4.5 provide a summary of the estimated annual emissions for each scenario. The detailed emission inventory data are provided in **Appendix E.**

Table 4-4 Summary of Annual Emissions – Emissions Scenarios

SCENARIO	PARTICULATE MATTER (TONNES PER YEAR)	LEAD (TONNES PER YEAR)
1	1365	0.165
2	441	0.017
3	402	0.015
4	60.8	0.035
5	3.19	0.014
6	N/A	0.17-5.6

Lead emissions from the Inco PCNR for the period from 1991 to 2001 were determined from the facility's NPRI reports to Environment Canada and were found to be negligible (reported to be 0.0 tonnes/year).

Utilising the emissions inventories for the various operations scenarios presented in the preceding sections, total emissions were determined. Total facility emissions were calculated by summing the estimated annual emissions for all years that the facility was operating (1918-1990) and are presented in Table 4.5. Also presented in this table, are the total estimated emissions of particulate matter and nickel for comparison. The materials received and processed at the PCNR were mattes or oxides that had already been processed in Sudbury to increase their nickel content. The Ni contents of the initial materials entering the PCNR were relatively high. As would be expected (based on the feed material compositions), lead (in various forms) was emitted from the PCNR in much smaller amounts than particulate or nickel.

Table 4-5 Summary of Estimated Total Contaminant Emissions from the PCNR and Research Station Facility

CONTAMINANT	INCO EMISSIONS (TONNES)
Particulate Matter	31,000
Lead	30.3
Nickel	19,500

The PCNR lead emissions (Scenarios 1 to 5) are presented in Figures 4.6 and 4.7. Figure 4.6 shows the variation of lead emissions with respect to the variations in facility operations, while Figure 4.7 shows the cumulative lead release to the atmosphere from the PCNR over the operating history of the facility.

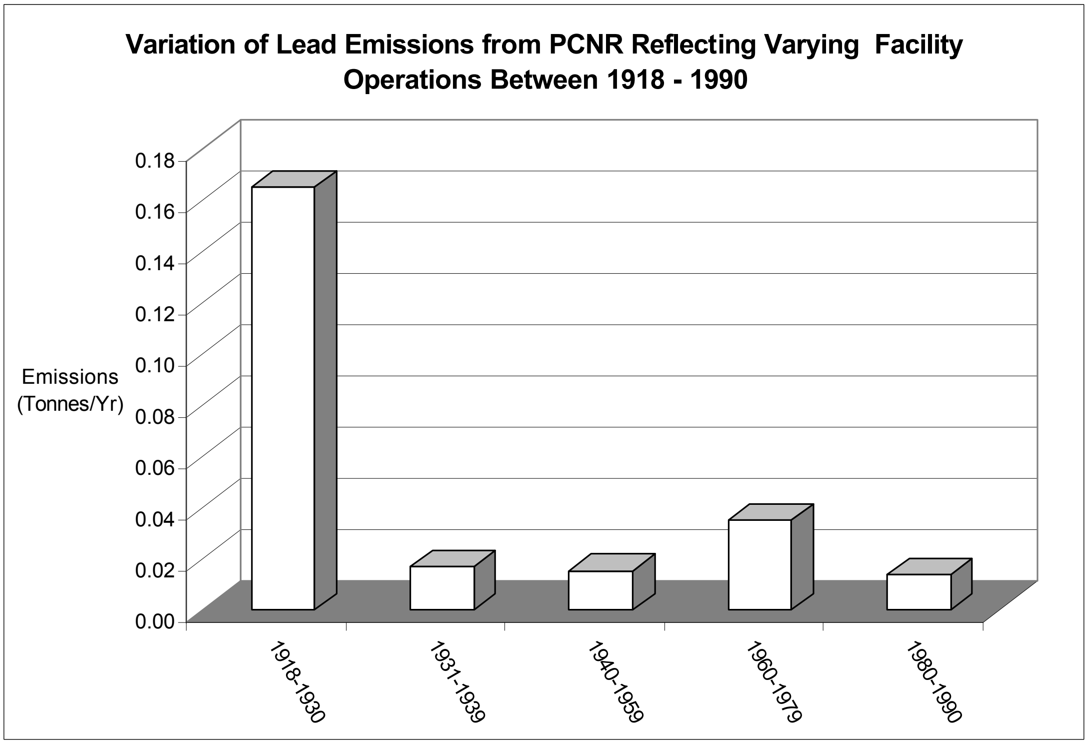


Figure 4-6 Variation of Lead Emissions (tonnes/year) due to Varying PCNR Facility Operations

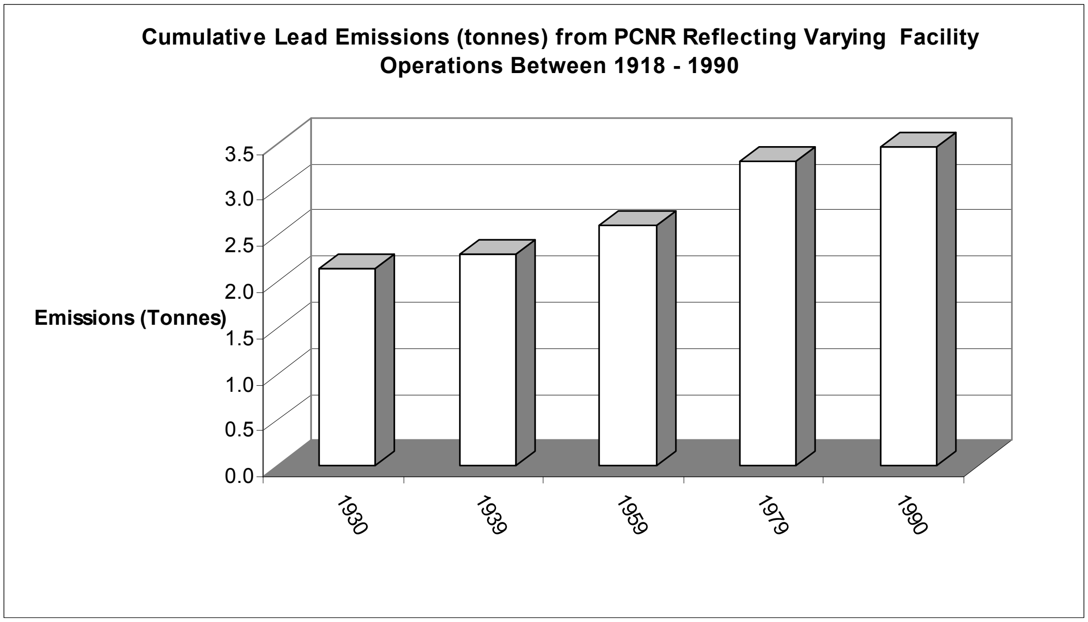
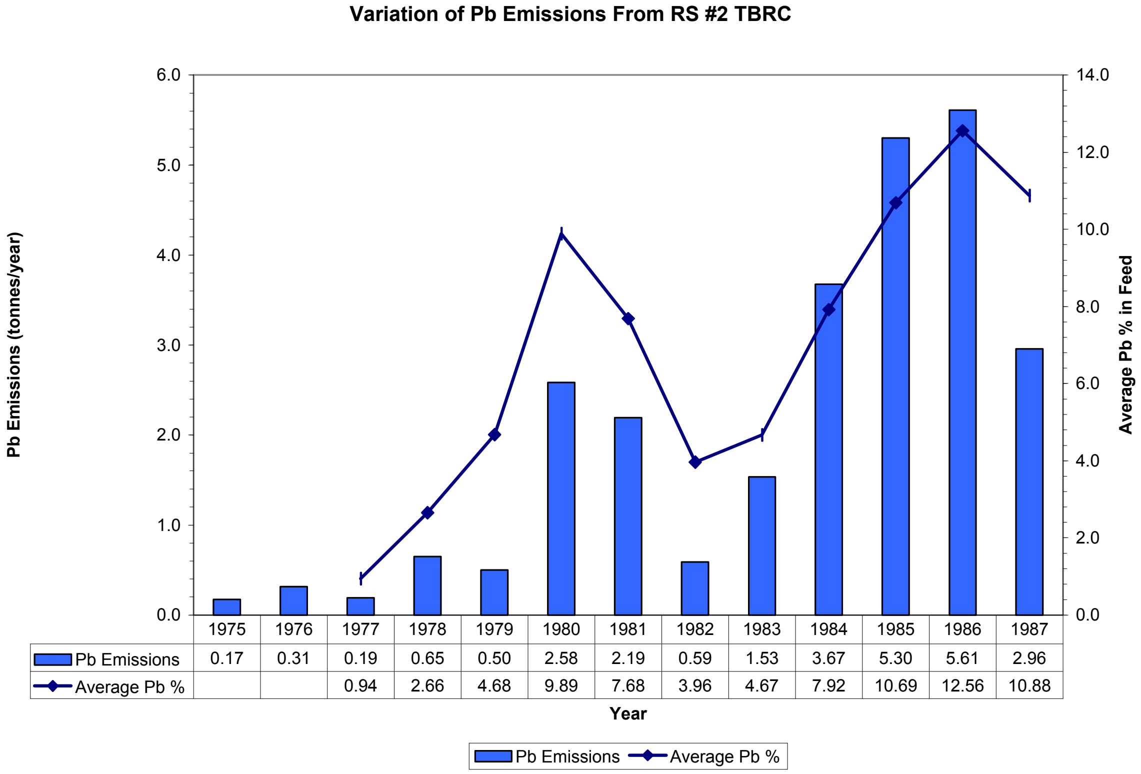


Figure 4-7 Cumulative Lead Releases (tonnes) from the PCNR

The variation in lead emissions from the Research Station TBRC stack (Scenario 6) is presented in Figure 4.8. Also presented in this figure are the annual average percentages of lead in the feed material (where data was available). As can be seen in this plot, lead emissions from the No. 2 Research Station TBRC increased as the percentage of lead in the feed material increased. In addition, in the later years of this operation, shipments of the residue being processed also increased. Between 1975 and 1987 about 26.3 tonnes of lead (stack emissions only) were estimated to have been emitted to the air due to the TBRC in the No.2 Research Station.

The Research Station’s emissions are estimated to account for the majority of the lead emitted from Inco (26.8 tonnes (stack plus fugitive) from the No. 2 Research Station versus 3.5 tonnes from the nickel refining operations).



	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Pb Emissions	0.17	0.31	0.19	0.65	0.50	2.58	2.19	0.59	1.53	3.67	5.30	5.61	2.96
Average Pb %			0.94	2.66	4.68	9.89	7.68	3.96	4.67	7.92	10.69	12.56	10.88

Figure 4-8 Lead Emissions from the Research Station (Scenario 6)

4.7 COMPARISON OF INCO LEAD EMISSIONS TO CANADIAN INDUSTRY

A comparison of Inco lead emissions to other Canadian industrial sources was requested by the PLC. A review of air emissions of lead from Canadian industry was conducted utilizing data reported in the 2001 National Pollutant Release Inventory (NPRI) from Environment Canada. Some major lead emitters and their recorded annual releases are presented in Table 4-6. By comparison, the Inco TBRC emitted on average about 2 tonnes/year of lead during its years of operation.

Table 4-6 Major Lead Emitters in Canadian Industry (2001 NPRI Reports)

Company	Annual Air Emission (tonnes/year) in 2001 of lead and its compounds
Hudson Bay Mining and Smelting	176.9
St Mary's Cement, St, Mary's Ontario	101.38
Noranda Inc, Fonderie Horne	65.44
Inco, Sudbury Operations	70.08
Falconbridge, Kidd Metallurgical	31.63
Noranda, Gaspe	30.4
Noranda, Brunswick Mine	14.44
Noranda, Brunswick Smelter	8.05
McCoy Foundry, Troy Ont	7.89
Falconbridge, Sudbury Smelter Complex	6.24
Teck Cominco, Trail Operations	4.34
Ingot Metal Company, Weston Ont	6.28

4.8 TBRC LEAD MASS BALANCE

Based on detailed process/composition data available for several of the TOL processing campaigns for the TBRC (campaigns 29 to 34), a lead mass balance for the TBRC system was developed. A summary of the lead mass balance is provided in Table 4-7. In the mass balance, data on lead in the input feed to the TBRC and in the outputs from the process (the product matte, waste slag, scrubber solids, etc) are provided. This mass balance accounts for 87.3% of the lead that was processed through the TBRC. The remaining unaccounted for 12.7% of the lead would be due to stack losses, TBRC brick infiltration, chute and tundish infiltration, flue build-up, and fugitive losses.

Table 4-7 Mass Balance of Lead in TBRC Feed Material and Products

Process Stream	Campaign #					Totals (kg)	% of Input Feed
	29	30	31	32	33-34		
Total Feed In (kg)	5978	10593	9774	8005	16452	50802	-
Matte Produced (kg)	1062	1453	570	74	1311	4470	8.8
Slag Produced (kg)	612	1780	2107	863	1295	6657	13.1
Scrubber Solids (kg)	2136	8636	6714	4660	10630	32776	64.5
In process Inv. (kg)	122	116	138	70	303	303	0.6
Pond over flow (kg)	6.3	12.5	0	90	28	137	0.3
Total products/by-products (kg)	3939	11998	9529	5756	13568	44343	87.3
Unaccounted For						6459	12.7

The TBRC emissions calculation (utilising the stack testing data) outlined in Section 4.6 predicted a total emission of 26.8 tonnes of lead over the life of the TBRC (stack plus fugitive). A total of 219.9 tonnes of lead were contained in the feed material processed in the TBRC. Utilising the mass balance approach detailed in Table 4-7 (i.e., 12.7% of the lead was unaccounted for), a total of 27.9 tonnes of lead would be unaccounted for that could have been emitted from the stack. These two approaches (mass balance 27.9 tonnes and source testing 26.8 tonnes) produce very similar lead emissions estimates from the TBRC.

4.9 LEAD CHARACTERISTICS AND BEHAVIOUR

The chemical and physical forms of lead in air emissions are directly related to the type of emission source. Elemental lead rarely occurs in nature. Lead most commonly occurs as lead sulphide (PbS), as well as PbO, PbO_2[2], $PbSO_4$ and $PbCO_3$. It should be noted that the physical characteristics of these lead compounds are very different than elemental lead. For instance, the melting point of elemental lead is 327.5 ^{o}C, while that for $PbSO_4$ is 1170 ^{o}C and PbS is 1118 ^{o}C. By comparison, the melting point of nickel sulphide (the primary form of nickel emitted from the PCNR) is 976 ^{o}C.

Combustion and smelting processes emit submicron size particles due to the high temperatures at which these processes take place. Particles emitted by handling and mechanical processes (i.e., ore handling and processing) are typically several times larger than particles emitted by combustion sources. Airborne lead-containing particles can be placed into three size ranges:

- The nuclei mode (less than 0.1 um);
- The accumulation mode (0.1 – 2 um); and,
- The large particle mode (greater than 2 um).

Lead-containing particles emitted at a source are generally in the nuclei and large particle size range. During atmospheric dispersion, lead transformations can occur and include physical changes in particle size distribution (due to coagulation of particles and condensation of vapour onto particles in the accumulation size range which have the largest surface area), organic to inorganic chemical phase changes, and chemical changes in the inorganic phase of lead particles. Within a few hundred metres of a source, the particle size distribution of lead likely stabilizes and remains roughly constant with transport distance.

It should be noted that the off-gas handling system for the TBRC utilised water sprays and a venturi scrubber to remove contaminants from the gas stream. The operating temperatures of the off-gases in these systems were below 100 C (the boiling point of water) to allow for proper operation of the control equipment. Therefore, formation of lead-containing particulate would have occurred within the off-gas handling system, prior to emission to the atmosphere. The off-gases would have contained high concentrations of sulphur dioxide (the objective of the TBRC was removal of sulphur from the feed material), thus the most likely forms for the lead to occur in the particulate emitted from the off-gas handling system would be lead sulphate or lead oxide.

5.0 AIR DISPERSION MODELLING

5.1 INTRODUCTION

Lead was a minor component in the material feeds used in the Inco Port Colborne Nickel Refinery (PCNR) and Research Station. Particulate emissions from the PCNR are therefore expected to contain small quantities of lead (in various forms) in addition to nickel (the major metal constituent). This section details the dispersion modelling of these emissions to estimate the deposition pattern of lead from the PCNR. The procedures used to develop the lead emission inventory for the PCNR are presented in Section 4.

Estimates of the relative deposition of lead from the facility over the course of its operations were predicted using the US EPA Industrial Source Complex – PRIME (ISC-PRIME) atmospheric dispersion model. This model was chosen due to the proximity of the PCNR to the East Side area. The ISC-PRIME model contains the state-of-the-science building wake effects model, which was considered of primary importance when choosing a dispersion model for the project. While the ISC-PRIME model does not include a shore-line effects model, this effect is not expected to substantially affect the model predictions, and was approximately accounted for in the method used to develop the meteorological data set.

A meteorological data set, consisting of five years of local, hourly wind data (which is expected to be representative of the historical meteorology of the region) were used to calculate contaminant depositions over the surrounding area. These meteorological data were used to represent atmospheric conditions over the entire 90-year period of the dispersion modelling.

The following sections detail the methodologies, results and conclusions of the dispersion and deposition modelling.

5.2 LOCAL METEOROLOGY

The local meteorology of the region must be known to evaluate the atmospheric dispersion and transport of emissions released to air by point sources in the region. Data required to predict the dispersion and transport includes wind velocities and direction; temperature; atmospheric stability; and mixing layer depth. Wind and temperature data are readily available from meteorological stations, but atmospheric stability and mixing layer depth are calculated from additional raw meteorological data including cloud cover, snow cover and solar radiation. Raw hourly meteorological data for 1996 to 2000 from the Environment Canada (Meteorological Service of Canada) were used in the analysis, as were twice daily, upper air sounding data from the US National Centre of Atmospheric Research. These data were merged with Port Colborne station data obtained from Atmospheric Environment Service and then Inco meteorological station data. Table 5-1 presents the stations and parameters obtained.

The Inco meteorological station, which is 5.5-m tall, is located to the north-east of the Refinery operations (about 150-m from the nearest building), and about 180-m south of Durham Street in a flat open area. The tower's calibrations are verified on an annual basis by Inco technicians.

Table 5-1 Meteorological Stations

Type Of Station	Upper Air	Surface Station	Surface Station
Station Name	Buffalo, NY	Niagara Falls, NY	Inco On-Site Met Station
Location	78.73°W 42.56°N	78.95°W, 43.1°N	79.14°W, 42.53°N
Years	Jan. 96 – Dec. 00	Jan. 96 – Dec. 00	Jan. 96 – Dec. 00
Parameters	Pressure Altitude Temperature Wind Direction and Speed Relative Humidity	Cloud Cover Snow Cover Relative Humidity	Wind Speed and direction Temperature

In addition to meteorological data, site geophysical data are also required to characterize the dispersion region of the area. These parameters include surface roughness, Bowen ratio and Albedo. Table 5-2 presents these selected parameters for the area, following the guidelines as described in AERMET (1998). The facilities are located very close to Lake Ontario to the south, with urban conditions to the north-west and agricultural conditions to the north-east and east. These surface conditions are reflected in Table 5-2 below.

The stability of the atmosphere is defined as its tendency to resist or enhance vertical motion. Three states of atmospheric stability are distinguished: convective, neutral and stable, depending on the vertical temperature profile or lapse rate. Vertical dispersion of pollutants is greatest under convective atmospheric conditions when the temperature decreases with height at a rate greater than the adiabatic lapse rate of 0.98EC/100 m. An air parcel, which is forced to rise in a convective atmosphere, will cool adiabatically, and hence remain warmer than the surrounding air and continue to rise. The air pollution potential is generally lowest under convective conditions.

In a neutral atmosphere, the temperature lapse rate is equal to the adiabatic lapse rate of 0.98EC/100 m. A rising air parcel in a neutral atmosphere will remain at the same level once the force causing it to rise has been removed. Horizontal dispersion will dominate over vertical dispersion under neutral conditions.

Vertical dispersion of pollutants is least effective in a stable atmosphere when the temperature lapse rate is less than the adiabatic lapse rate of 0.98EC/100 m. An air parcel forced to rise under such conditions will become cooler than the surrounding air and tend to sink back down to its original level, once the force causing it to rise has been removed. Light winds frequently accompany stable conditions, reducing horizontal dispersion and increasing the air pollution potential.

In the case of an elevated temperature inversion (increase in temperature with height) above a neutral or convective layer, the base of the inversion effectively forms a lid - leading to a build-up of pollutants beneath the lid. Surface based inversions are most common during the early morning hours following radiative cooling of the earth's surface during clear nights.

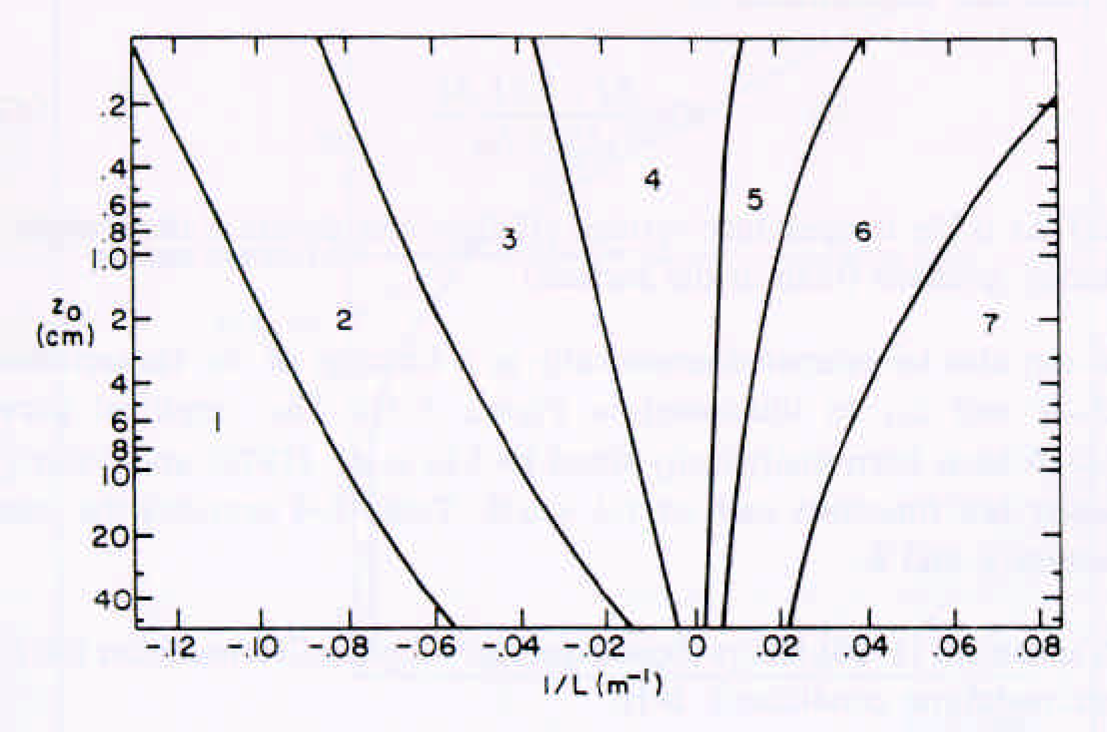
Table 5-2 Site Characteristics Around Port Colborne

Month	ESE To W Lake Surface Characteristics			W To NNE Urban Surface Characteristics			NNE To ESE Cultivated Land Surface Characteristics		
	Albedo	Bowen Ratio	Surface Roughness (m)	Albedo	Bowen Ratio	Surface Roughness (m)	Albedo	Bowen Ratio	Surface Roughness (m)
Jan	0.2	1.5	0.0001	0.25	1.5	0.5	0.6	1.5	0.01
Feb	0.2	1.5	0.0001	0.25	1.5	0.5	0.6	1.5	0.01
Mar	0.12	0.1	0.0001	0.14	1.0	0.5	0.14	0.3	0.03
April	0.12	0.1	0.0001	0.14	1.0	0.5	0.14	0.3	0.03
May	0.12	0.1	0.0001	0.14	1.0	0.5	0.14	0.3	0.03
June	0.1	0.1	0.0001	0.16	2.0	1.0	0.2	0.5	0.2
July	0.1	0.1	0.0001	0.16	2.0	1.0	0.2	0.5	0.2
Aug	0.1	0.1	0.0001	0.16	2.0	1.0	0.2	0.5	0.2
Sept	0.14	0.1	0.0001	0.18	2.0	1.0	0.18	0.7	0.05
Oct	0.14	0.1	0.0001	0.18	2.0	1.0	0.18	0.7	0.05
Nov	0.14	0.1	0.0001	0.18	2.0	1.0	0.18	0.7	0.05
Dec	0.2	1.5	0.0001	0.35	1.5	0.5	0.6	1.5	0.01

AERMET calculates the hourly surface heat flux and subsequently determines the surface friction velocity (u_*) and the Monin-Obukhov (L) through an iterative procedure using surface layer similarity for each hour. These hourly values (u_* and L) were subsequently used to generate P-G dispersion classification following the method developed by Golder (1972) as shown in Figure 5-1. Here, the Monin-Obukhov lengths along with the surface roughness conditions were used to classify the atmospheric conditions. The MOE has previously reviewed and approved this approach.

An advantage of this methodology is that it allows for the calculation of direction dependent mixing layer heights and stabilities (based on the surface roughness, albedo, etc. of each sector). The approach used will generate lower mixing layer heights for winds carried across water (blowing from southerly directions) than winds blowing across land (northerly directions) due to the difference in surface roughness included in the meteorological model inputs.

Figure 5-1 Relationship between Monin-Obukhov Length and Pasquill-Gifford Stability



The five-year data meteorological set was compared to available parameters in the Canadian Climate Normals (long-term average meteorological data) for the area (Port Colborne 1966 to1980) to ensure the representativeness of the data for the historical period being examined. The five-year data set and the Canadian Climate Normals both show the same trends in wind directionality (SW is the predominant wind direction) and speed, suggesting that the five-year set will provide an adequate representation of the historical meteorological conditions in the area.

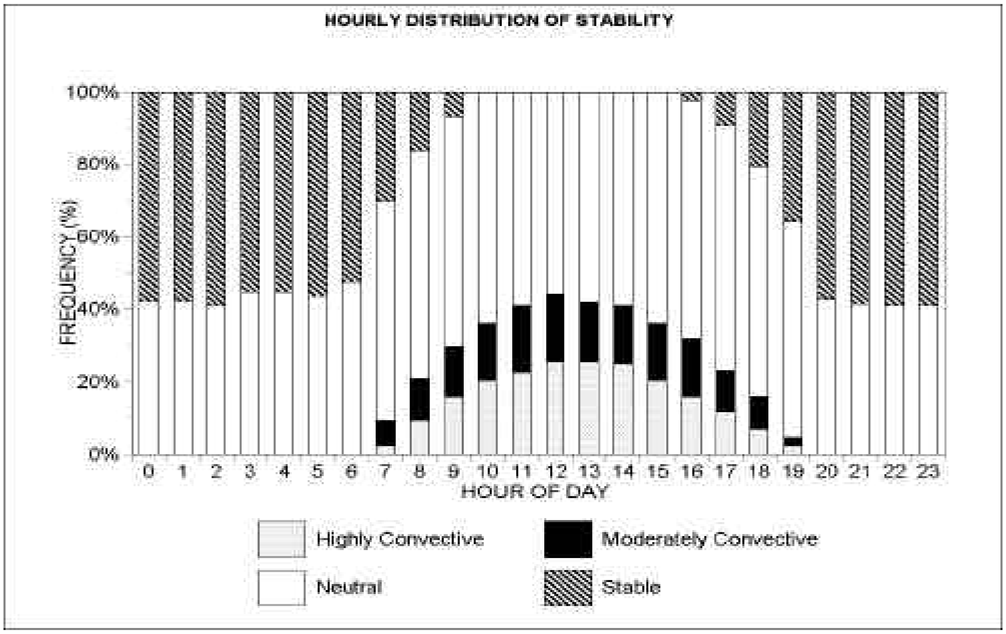
The following sections present an overview of the meteorology of the Port Colborne area. Further details of the analysis and results are presented in JWEL 2001a, *Potential CoC Identification using Emission Inventories and Dispersion Modelling of Inco and Algoma Operations.*

5.2.1 Atmospheric Stability

The stability of the atmosphere is defined as its tendency to resist or enhance vertical motion. Three states of atmospheric stability are distinguished: convective, neutral and stable, depending on the vertical temperature profile or lapse rate. Vertical dispersion of pollutants is greatest under convective atmospheric conditions when the temperature decreases with height at a rate greater than the adiabatic lapse rate of 0.98EC/100 m. An air parcel, which is forced to rise in a convective atmosphere, will cool adiabatically, and hence remain warmer than the surrounding air and continue to rise.

The diurnal variation of atmospheric stability with hour of day is presented in Figure 5.2, where time is given in local time. The occurrence of convective conditions is limited to between 7:00 LST and 19:00 LST, with the most frequent occurring around 12:00 LST. Stable conditions have a similar trend, with a higher frequency during the night-time than during the daytime, which is consistent with the decreased surface insolation during this period.

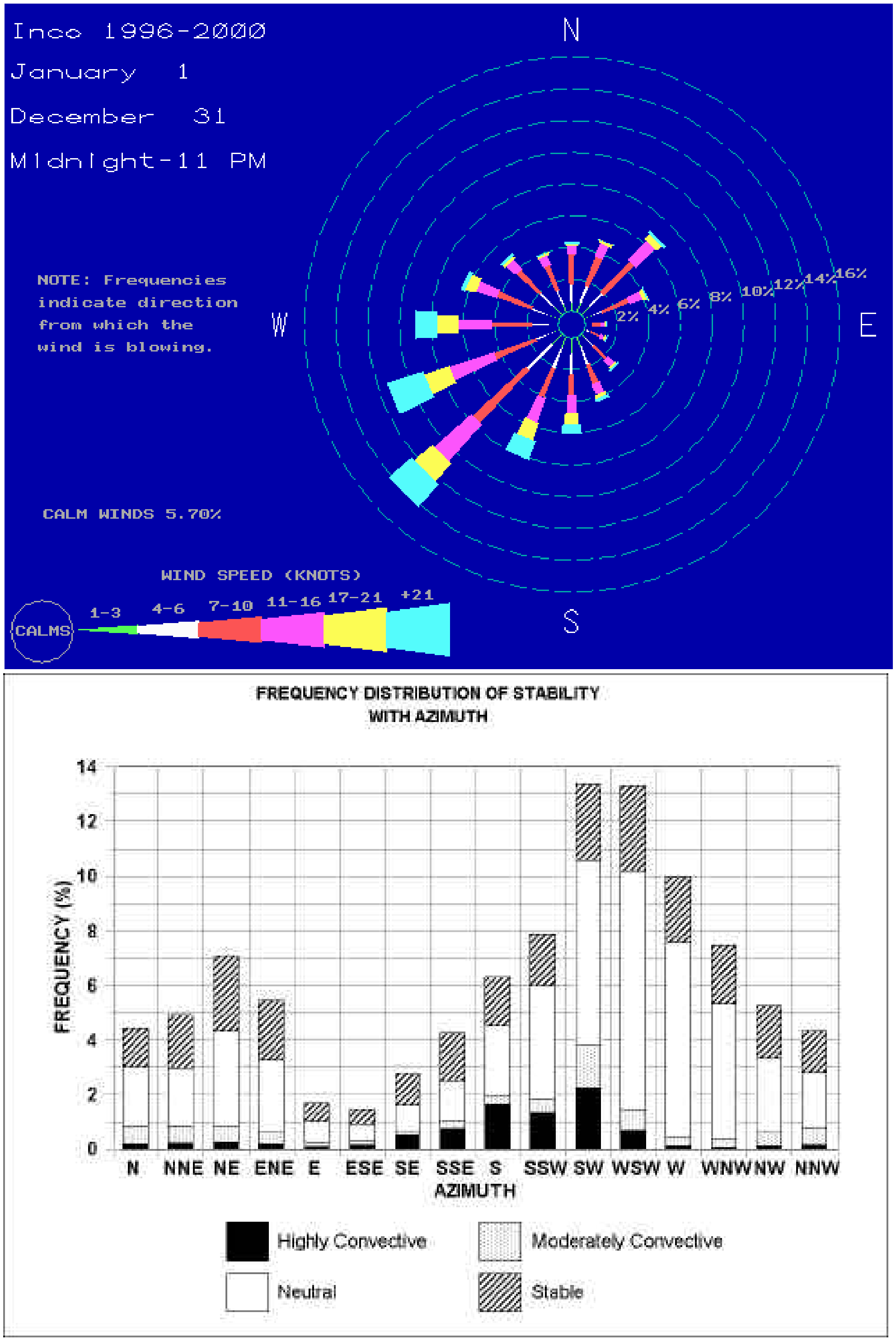
Figure 5-2 Atmospheric Stability Conditions for the Inco Port Colborne Site (1996-2000)



5.2.2 Wind Speed and Direction

The annual average joint frequency distribution of wind speed and direction for the Port Colborne area is presented in Figure 5.3. The dominant winds are from southwestern to westerly directions. The predominant wind direction is from the southwest (14.2% of the time) while the least frequent direction is from the east (1.3% of the time). Very low wind speeds occur infrequently. The directional preference of stability is also presented in Figure 5.3. Stable conditions (little vertical turbulence or mixing) occur most frequently with winds blowing from southwesterly directions (with northeast directions also being relatively frequent), while neutral conditions (mechanically driven turbulence and mixing) occur most frequently with winds blowing from the southwest.

Figure 5-3 Wind Rose and Stability Conditions



It should be noted that Figure 5.2 indicates that stable atmospheric conditions occur only during the night-time, as would be expected (due to the lack of solar insolation during this time). The stability data presented in Figure 5.3 therefore indicates that the night-time stable conditions are as likely to occur from southwesterly directions (blowing to the northeast) as stable winds from the north-east (blowing to the southwest). Figure 5.3 also indicates that stable wind conditions blow less frequently from the east to the west (i.e., from the Inco facility over the East Side Community) than in any other direction. Stable wind conditions coupled with low wind speeds often produce the highest ground level concentrations for low-level emissions sources.

5.2.3 Precipitation

Precipitation data for the period of the meteorological data set was obtained for the Environment Canada meteorological station in Port Colborne for inclusion in the dispersion model analysis of plume deposition. The frequency of occurrence of precipitation with wind direction (direction wind is blowing from) is presented in Figure 5-4. This figure shows that most precipitation occurs for winds blowing from south to southwesterly directions, and very infrequently for winds blowing from the southeast (from the refinery towards the East Side Community).

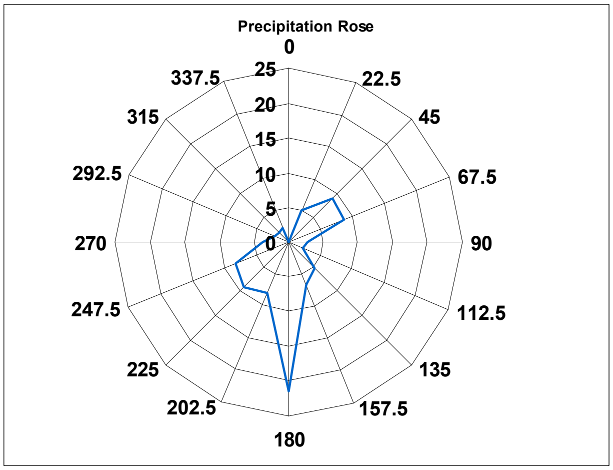


Figure 5-4 Precipitation Rose for the Port Colborne Area

5.3 DISPERSION MODELLING METHODOLOGY

5.3.1 Approach

Predicted lead depositions over Port Colborne were based on hourly meteorological data for the region. Quality checked data from January 1996 to December 2000 were used in the ISC-PRIME dispersion model predictions. Short-term (1 hour average) numerical estimates of the ground-level concentrations resulting from the facility were made for each hour of the five years. The predicted 1-hour average lead depositions were summed over the length of the meteorological data set to determine the total lead deposition for a five-year period, for each emission scenario examined.

The five-year total depositions predicted from the modelling for each scenario over the modelling domain were then weighted by the ratio of the number of years of operation of that particular scenario to the five years used to calculate the total expected deposition for that scenario period. This approach takes advantage of the fact that the meteorology of a region tends to be historically relatively consistent. Therefore, it is expected that the five-year meteorological data for 1996 to 2000 will be representative of the meteorological conditions experienced by Port Colborne in previous decades.

Details of the US EPA ISC-PRIME dispersion model are presented in detail in **Appendix H.**

In order to examine the relative magnitudes and deposition patterns of low level fugitive sources versus stack emissions, dispersion modelling for each emission scenario was performed using:

1. Fugitive emissions sources only;
2. Stack emissions sources only; and,
3. All sources (stack and fugitive emissions).

The deposition of particles or gases onto the ground is due to two removal processes - dry deposition and wet deposition. Dry deposition is the removal of particles or gases due to interception with the ground. Many factors influence dry deposition including: meteorological variables, properties of the depositing pollutant and properties of the intercepting surface. The ISC-PRIME model uses a scavenging ratio approach to model the deposition of gases and particles through wet removal. The scavenging coefficient depends on the characteristics of the pollutant and the type of precipitation (liquid or frozen). Liquid scavenging ratios for particulate are dependent on the particle size, and were taken from literature values (ISC3 Users Guide, Vol. II, Figure 1-11) for the particle size distributions used in the dispersion modelling. The scavenging rates for frozen precipitation were taken as 1/3 of that of the liquid scavenging rates (ISC3 Users Guide, Vol. II, Section 1.4).

For the #2 Research Station (which accounts for about 90% of the lead emissions), the particle size distribution was taken from AP-42 Table 12.10-8 for a cupola furnace controlled by a venturi scrubber (as this was expected to most closely resemble the actual configuration of TBRC plus venturi scrubber). Particle size distributions in the copper smelting section were not used for this source as they all utilize an ESP as the control technology. Particle size distributions for other sources in the PCNR were taken from US EPA AP-42 Sections 12.10, 12.5 and 13.2.

5.3.2 Dispersion Model Inputs

The inputs required to model particulate deposition are presented in the following sections. These inputs include characteristics of each particulate emission source (e.g., stack height, stack diameter, exit velocity, temperature and contaminant emission rate), building data for the calculation of the effects of structures on dispersing plumes, and a grid of receptors at which particulate/metals depositions were predicted.

5.3.2.1 Source Parameters

The particulate emissions inventory and emissions scenarios for each facility are presented in Section 4 and **Appendix E.** The physical parameters of the stacks, volume and area sources are listed in the input files, also presented in **Appendix E** for all scenarios.

5.3.2.2 Building Data

The ISC-PRIME model requires direction dependent building information for use in the building wake and building downwash calculations. These data were generated with the US EPA building pre-processor (BPIP-PRIME) using the building data presented in Figures 5.5 to 5.10 for the various building/emission (both stack and fugitive) scenarios. The building pre-processor was used to produce direction dependent building widths and heights for each stack for input to the ISC-PRIME model. The Inco buildings and their primary purposes during each emissions scenario are summarised in Table 5.3 below.

Table 5-3 Summary of Inco Buildings for each Emission Scenario.

Scenario	Building 1	Building 2	Building 3	Building 4	Building 5
1 (1918-30)	Orford Process	Leaching	Calcining and Sintering	Wrought nickel and anode casting	Not Built
2 (1931-38)	Raw material storage/slimes drying/nickel precipitation	Leaching	Calcining and Sintering	Wrought nickel and anode casting	Electro Refinery
3 (1939-59)	Raw material storage/slimes drying/nickel precipitation	Leaching	Calcining and Sintering	Wrought nickel and anode casting	Electro Refinery
4 (1960-79)	Raw material storage/slimes drying/nickel precipitation	Leaching and Foundry Additives Production	Storage	Wrought nickel and anode casting	Electro Refinery
5 (1980–90)	Raw material storage/slimes drying/nickel precipitation	Leaching and Foundry Additives Production	Storage	Utility Nickel Production	Electro Refinery
6 (1975-1987)	Same as Scenario 5 with emissions from Research Station				

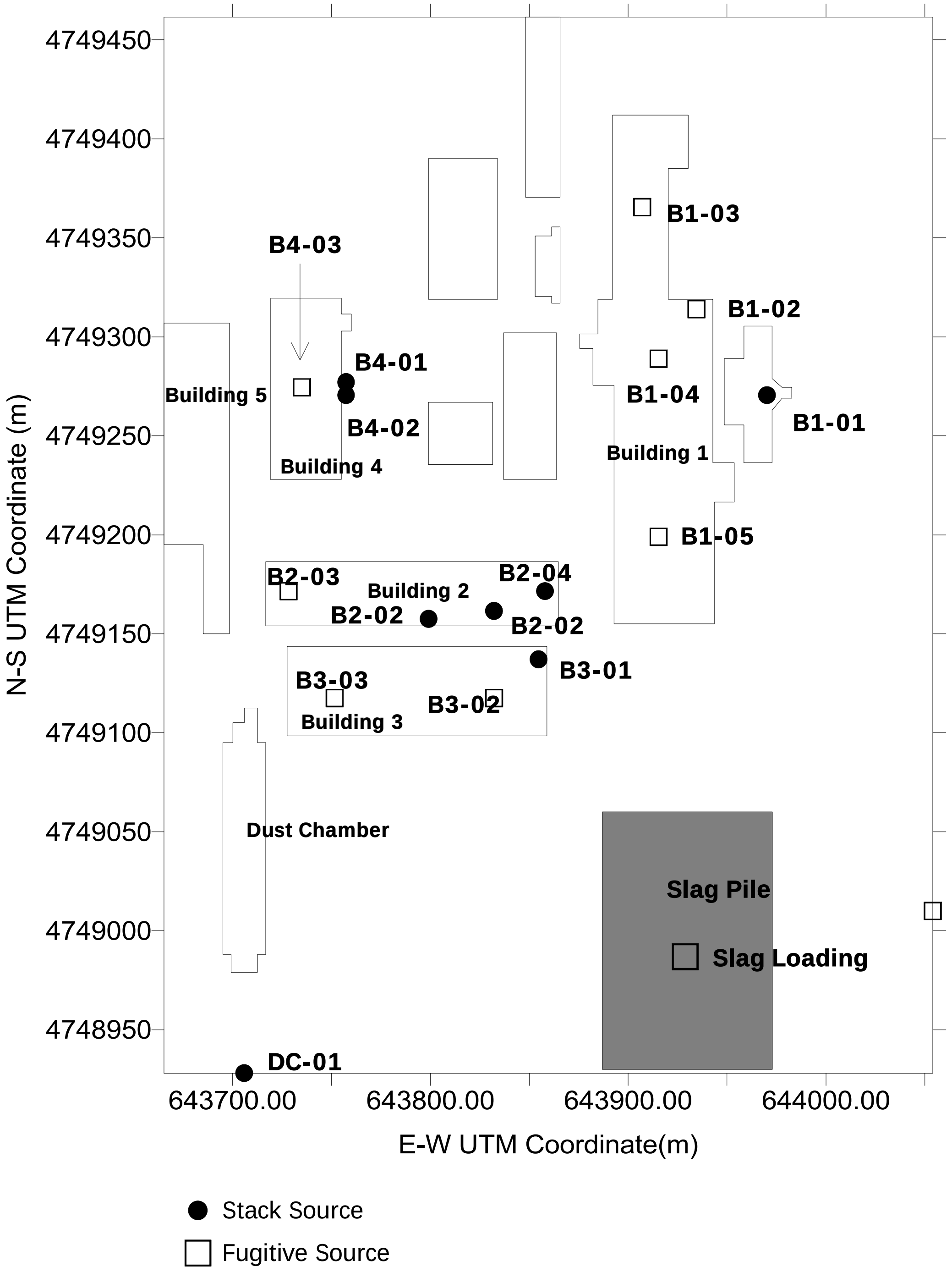


Figure 5-5 Building and Emissions Sources Layout for Inco Scenario 1 (1918-30)

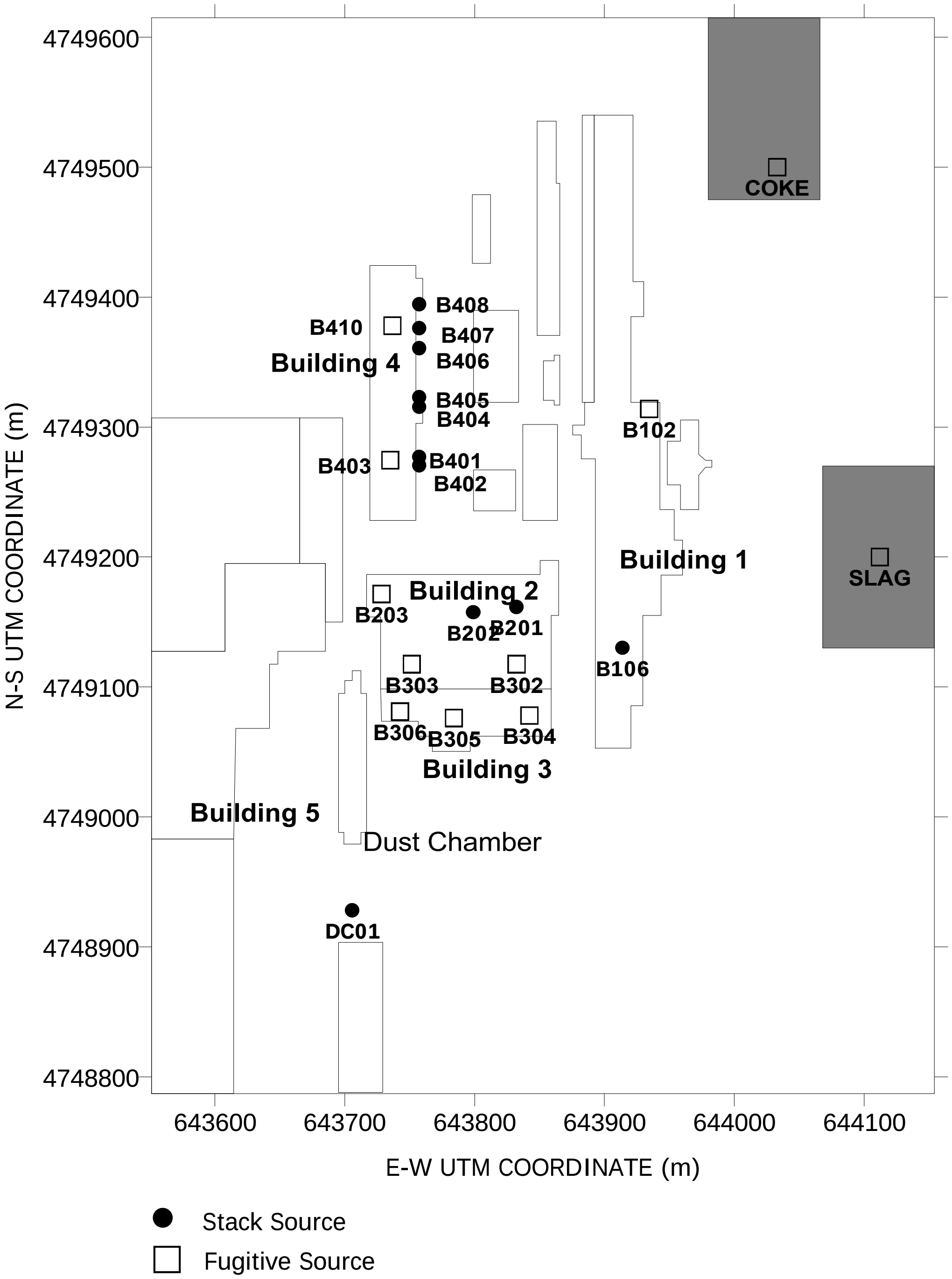


Figure 5-6 Building and Emissions Sources Layout for Inco Scenario 2 (1931-38)

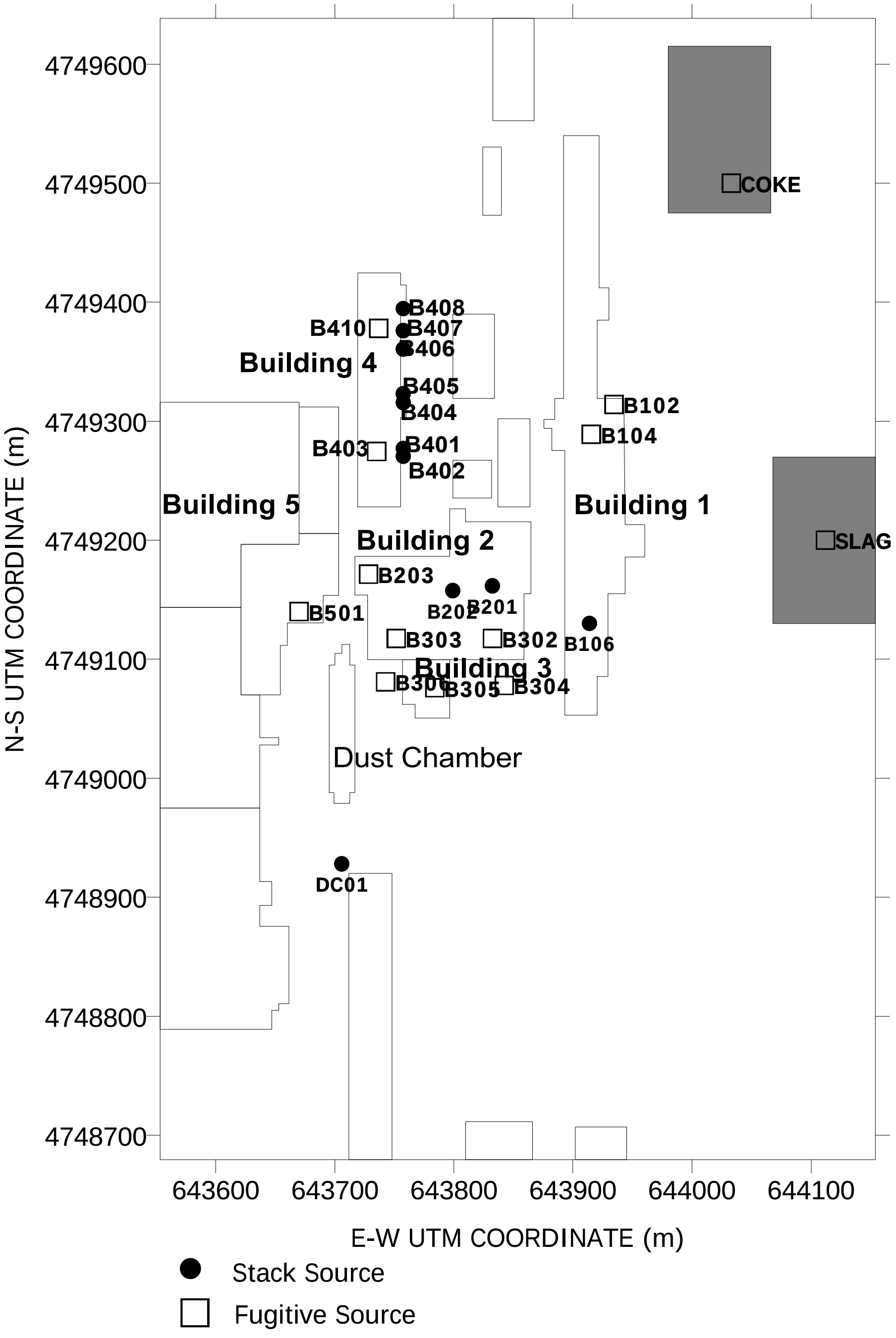


Figure 5-7 **Building and Emissions Sources Layout for Inco Scenario 3 (1939-59)**

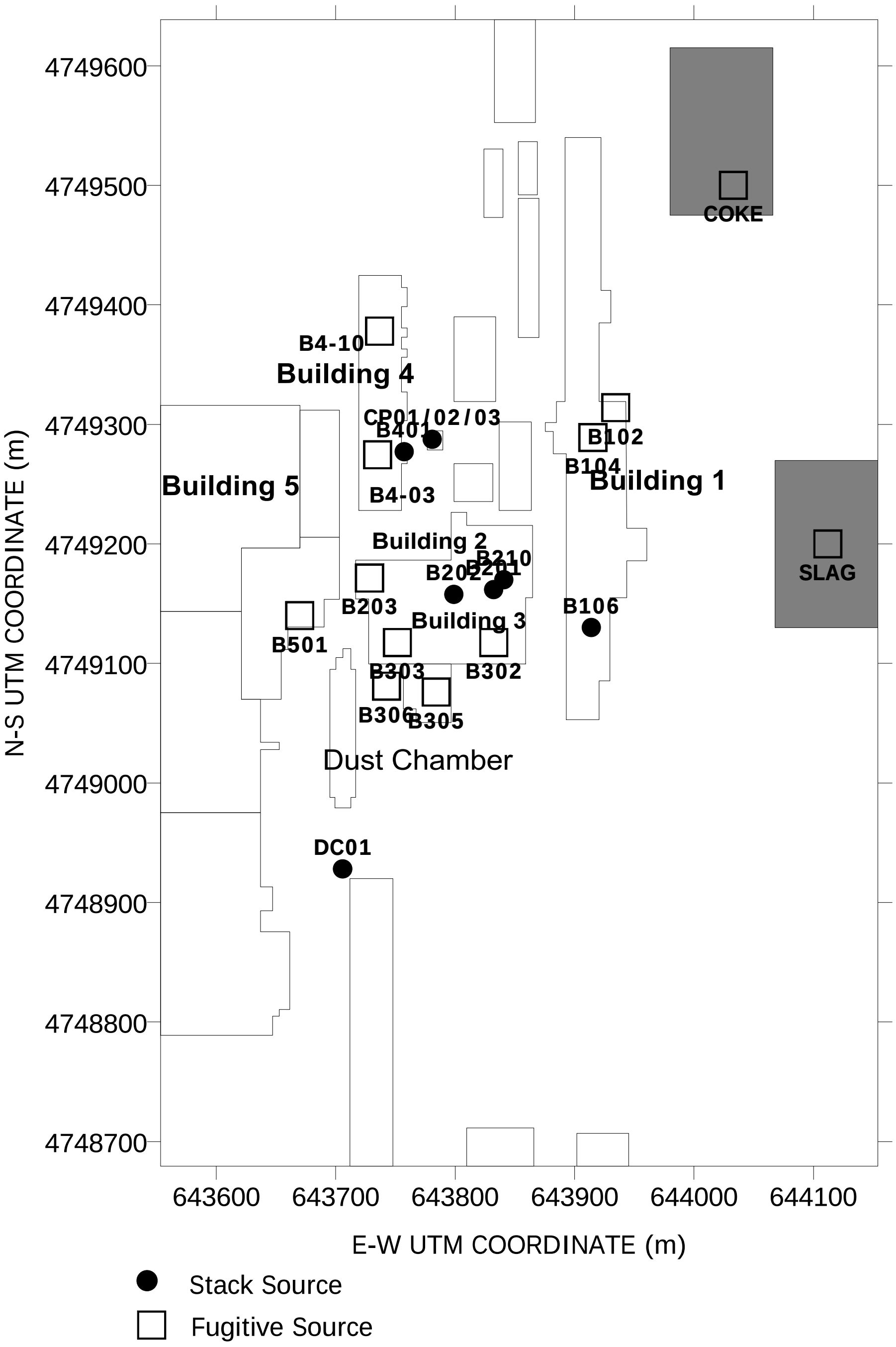


Figure 5-8 Building and Emissions Sources Layout for Inco Scenario 4 (1960-79)

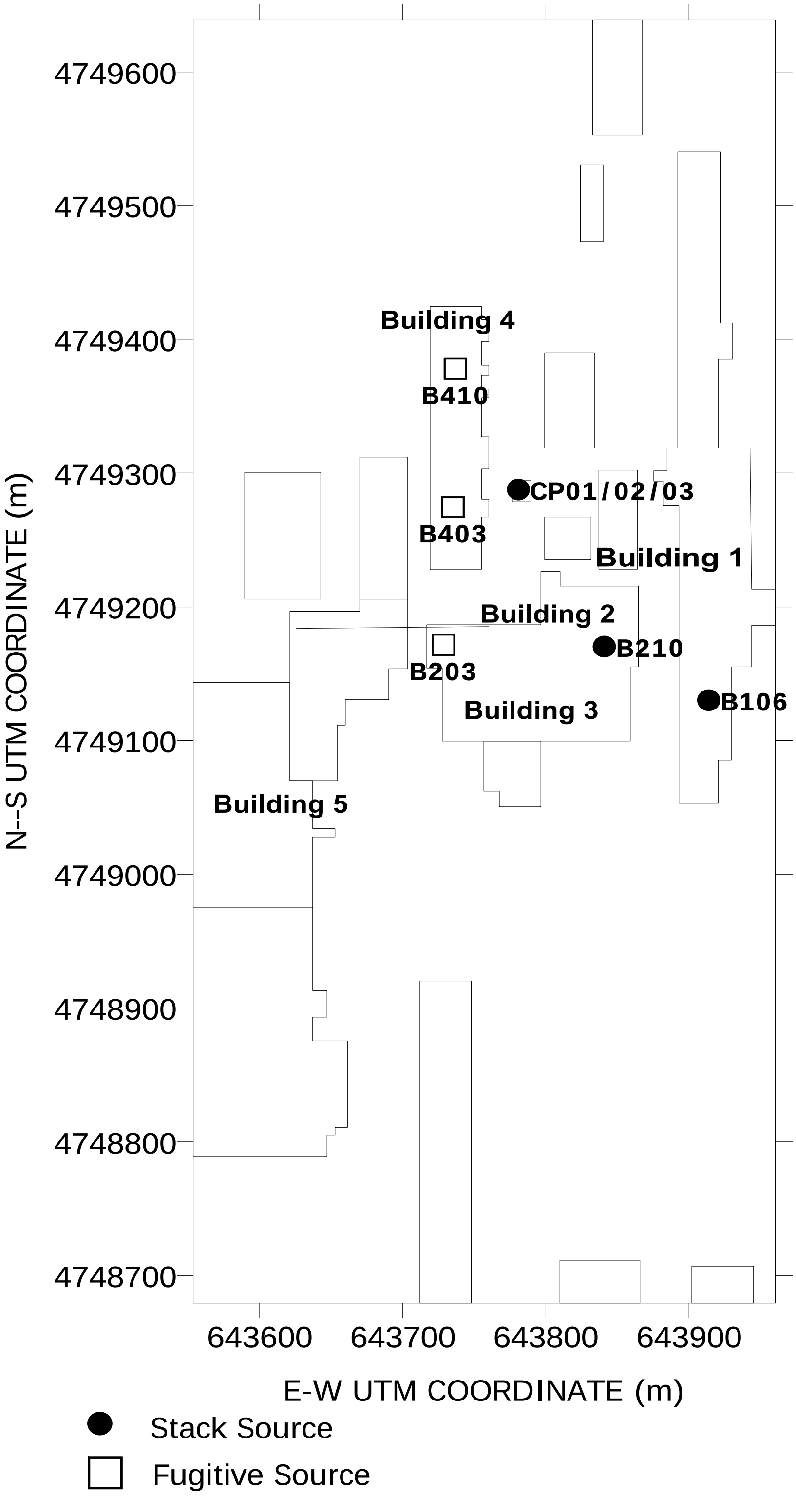


Figure 5-9 Building and Emissions Sources Layout for Inco Scenario 5 (1980-90)

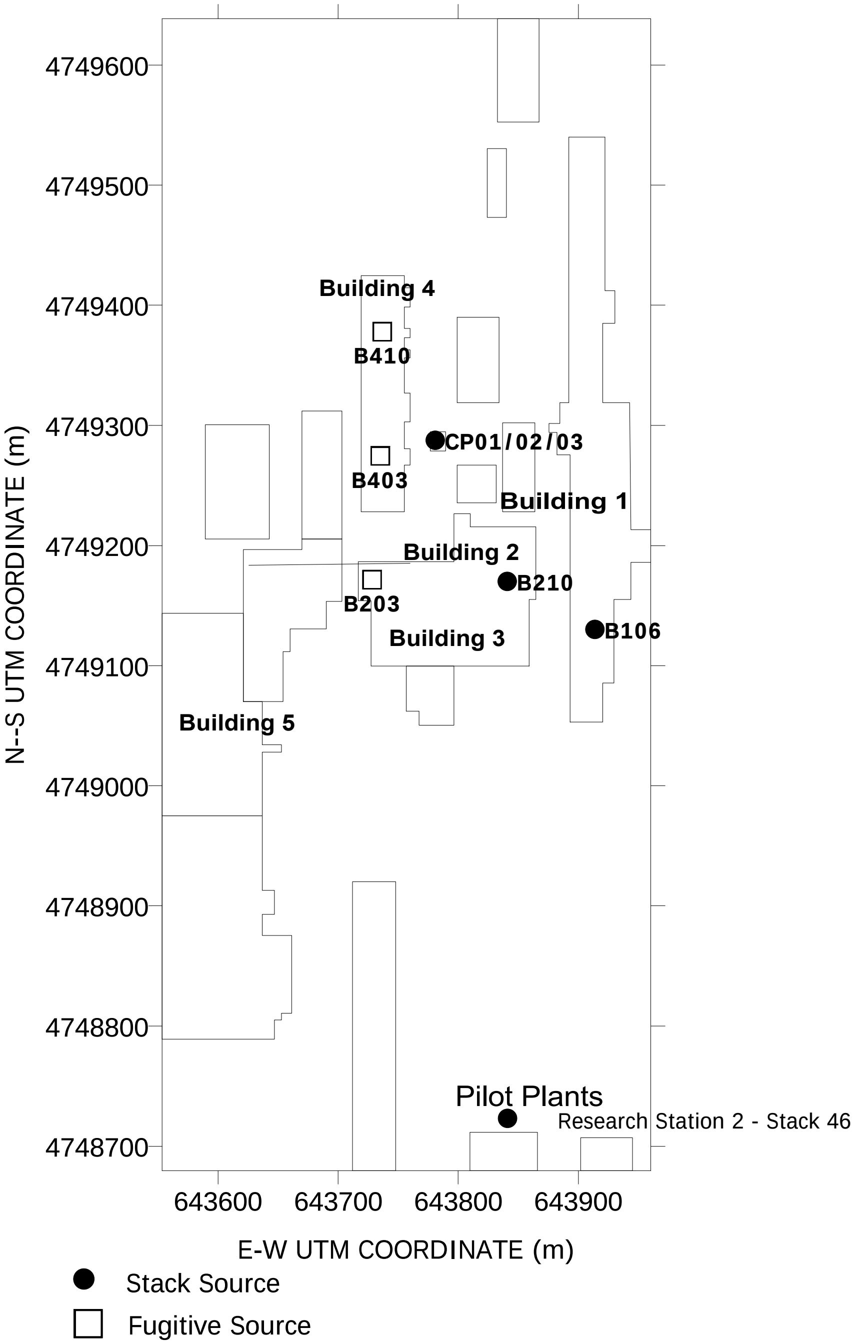


Figure 5-10 Building and Emissions Sources Layout for Inco Scenario 6 (1975-87)

5.3.2.3 Receptor Grid

Ground level concentrations were calculated over a 7 km by 7 km grid with varying grid spacing. The locations of the receptors used in the analysis are presented in Figure 5.11.

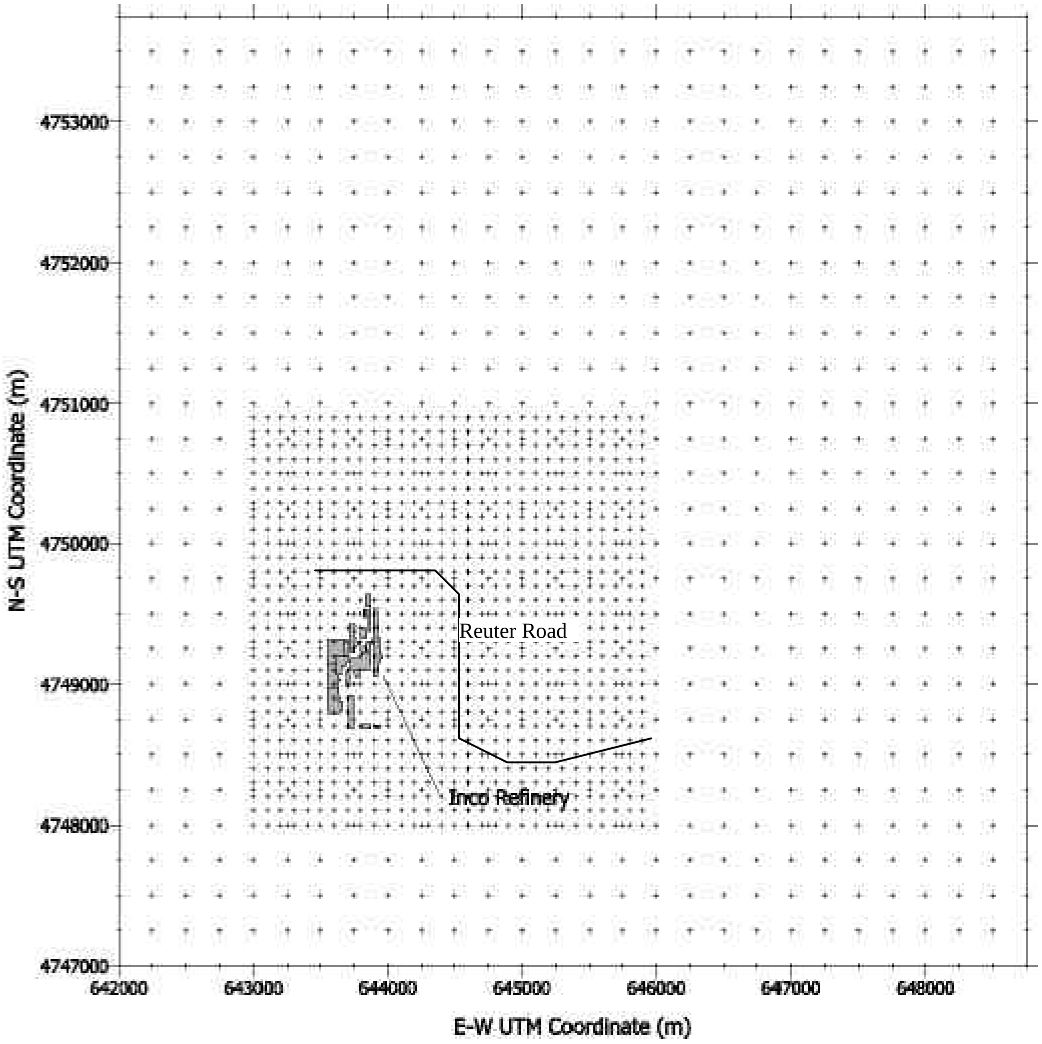


Figure 5-11 Receptor Grid Used in Analysis

5.4 RESULTS OF ISC-PRIME ANALYSIS

The following sections present the results of the dispersion modelling of Inco lead emissions. The ISC-PRIME model deposition predictions for each scenario were used to calculate a concentration in soil due to the historical PCNR operations using the following methodology:

1. The dispersion model predictions of accumulated lead deposition for each emissions scenario (in g/m^2) over the length of the meteorological data set (about 5-years) were converted into a deposition over the length of the entire emissions scenario (from 9-years for Scenario 2 to 20-years for Scenario 3 and 4). This was done by multiplying the model predictions by the ratio of the number of hours in the met data set (excluding hours for which meteorological parameters were missing or calm) to the number of hours in the total period of each emissions scenario.
2. The accumulated depositions at each receptor for each emissions scenario (1 to 6) were then summed to obtain a predicted lead deposition over the period 1918-1990.
3. The accumulated lead depositions (in grams of lead per square metre) were converted to ug/cm^3 values in the soil by assuming the lead accumulated in the top 5 cm of the soil.

5.4.1 Comparison of Measured and Predicted Soil Lead Contour Plots

The contents of metals and metalloids in contaminated soils is usually given in mass units ug/g from chemical analyses of mass of an element per unit mass of soil. While these units provide a measure of the relative concentrations of the elements in the soils, they are of less use in assessing the aerial distribution of contaminant elements in soils with diverse properties. To assess the extent of contaminant distribution from point source emissions, such as refineries, it is more appropriate to convert the mass ratio concentrations (ug/g) to a mass per volume of soil measurement, that is ug/cm^3. To do this, the value of the soil bulk density must be known.

This approach has been used to assess the loading of metals in soils of the upland areas of the UK (refer to website:www.bradford.ac.uk/acad/envsci/Research/PIG). The question of loads is an issue, like the present issue of trying to model lead deposition, having to do with estimating what is falling on the top of the soil and thereafter entering and becoming distributed to some extent in the upper centimeters of the soil.

This approach of assessing loads of metals in soils was undertaken in the present study so that the actual distribution patterns of atmospheric deposition of particulate-containing CoCs, and potentially lead, in soils surrounding the Inco facility could be determined. For this purpose, all measured mass ratio concentrations (ug/g) from the CBRA database were converted to mass per unit volume concentrations (in ug/cm^3) using bulk density values, either measured or derived, for the various representative soil types in the Port Colborne area. For example, a measured soil lead mass concentration of 200 ug/g in an organic muck soil sample with a measured bulk density of 0.5 g/cm^3 was converted to its mass per volume equivalent in ug/cm^3 units using the following equation:

[Soil Lead Concentration, Mass per Volume] = [Soil Lead Concentration, Mass per Mass] x Bulk Density
= 200 ug/g x 0.5 g/cm^3
=100 ug/cm^3

For this assessment, a total of 23 archived duplicate samples of various soil types from the Port Colborne area were submitted to Philip Analytical Services Inc. for bulk density determinations. Values of the laboratory-measured bulk densities on the selected soil samples are found below in Table 5.4. Laboratory findings indicated that the bulk density of the organic muck soil was on average 0.5 g/cm^3 (ranging between 0.4 to 0.7 g/cm^3). The bulk densities of clay-like heavy (Welland) clay and shallow clay ranged between 0.7 to 1.1 g/cm^3. The bulk density of clay-like fill material in the East Side Community was on average 1.0 g/cm^3. The sands were measured to have a bulk density between 0.8 and 0.9 g/cm^3.

Table 5-4 Measured Bulk Densities For Soil in the Port Colborne Area

Soil Sample	Location	Depth (cm)	Soil Type	Bulk Density, g/cm^3
IP01-03A-C	Inco	0-5	Organic Muck	0.4
IP01-03A-C	Inco	10-15	Organic Muck	0.5
IP01-03A-C	Inco	5-10	Organic Muck	0.5
IP04-06A-C	Inco	0-5	Organic Muck	0.5
IP04-06A-C	Inco	5-10	Organic Muck	0.5
IPO4-06A-C	Inco	10-15	Organic Muck	0.6
CCLYGROD9-2	Inco	0-15	Organic Muck	0.7
TP IP 01	Inco	0-5	Organic Muck	0.7
TILL BCKG	Wainfleet	0-15	Shallow Clay	1.0
WEL	Inco	0-15	Heavy Clay	1.1
IP07-08A-C	Inco	0-5	Heavy Clay	0.7
IP07-08A-C	Inco	10-15	Heavy Clay	0.9
IP07-08A-C	Inco	5-10	Heavy Clay	0.9
RODNEY 1	ESA	0-10	Clay Fill	1.1
RODNEY 1	ESA	0-10	Clay Fill	1.0
RODNEY 2	ESA	0-10	Clay Fill	1.2
FARES 1	ESA	0-10	Clay Fill	1.0
FARES 1	ESA	0-10	Clay Fill	1.0
FARES 2	ESA	0-10	Clay Fill	1.1
DAVIS 1	ESA	0-10	Clay Fill	1.0
SND	Inco	0-15	Sand	0.9
TP IP 02	Inco	0-5	Sand	0.8
TP IP 03	Inco	0-5	Sand	0.9

Note- ESA: East Side Community Inco: Inco property - NE & E locations

Other CBRA soil samples not submitted for bulk density testing were assigned bulk density values according to the averages of reported values for samples of the same soil type that had been submitted for bulk density testing. Bulk density assignments were made for each CBRA soil sample (locations shown on Figure 3-1) with respect to the specific soil type of each sample identified and recorded in the field. The bulk densities that were assigned per soil type are shown in Table 5-5. A map identifying the location of the various soil types is presented in Figure 2.3.

Table 5-5 Assigned Composite Bulk Density For Port Colborne Soils

Soil Type	Assigned Bulk Density, g/cm^3
Fill – East Side Community	1.0
Heavy Clay	1.0
Shallow Clay	1.0
Clay Loam	1.0
Sand	0.9
Organic	0.5

The converted CBRA soil chemical database from measured mass per unit mass concentrations (in ug/g) to measured mass per unit volume concentrations (in ug/cm^3) using bulk density values are presented in **Appendix D.** These measured values were plotted in Figure 5.14 and used to compare against the predicted values from air dispersion modelling. Measured soil lead data for only open spaces are plotted on Figure 5.14, as the dispersion model does not predict deposition in woodlots.

5.4.2 Fugitive Source Emissions

Isopleths of predicted total lead depositions due to emissions from Inco low-level, fugitive emissions sources (over the operating life-span of the facility) are presented in Figure 5.12. The dispersion modelling predicts that the highest lead depositions due to fugitive emissions sources will occur to the north-east of the Inco facility.

In the East Side Community, lead depositions due to Inco emissions were predicted to be between 2 to 5 times less than those to the north-east of the PCNR. The predominant wind direction in the Port Colborne area is from the south-west, therefore Inco emissions will be most frequently carried to the north-east of the facility. Inco is located to the east of the East Side Community and winds blowing Inco emissions over the East Side Community (winds blowing from the east) occur less frequently (1.3% of the time), and therefore emissions from Inco will impact this area (i.e., East Side Community) much less frequently. In addition, stable wind conditions, which typically produce the highest ground level concentrations from low-level fugitive sources occur more frequently for winds blowing from the south-west than from the east (over East Side Community).

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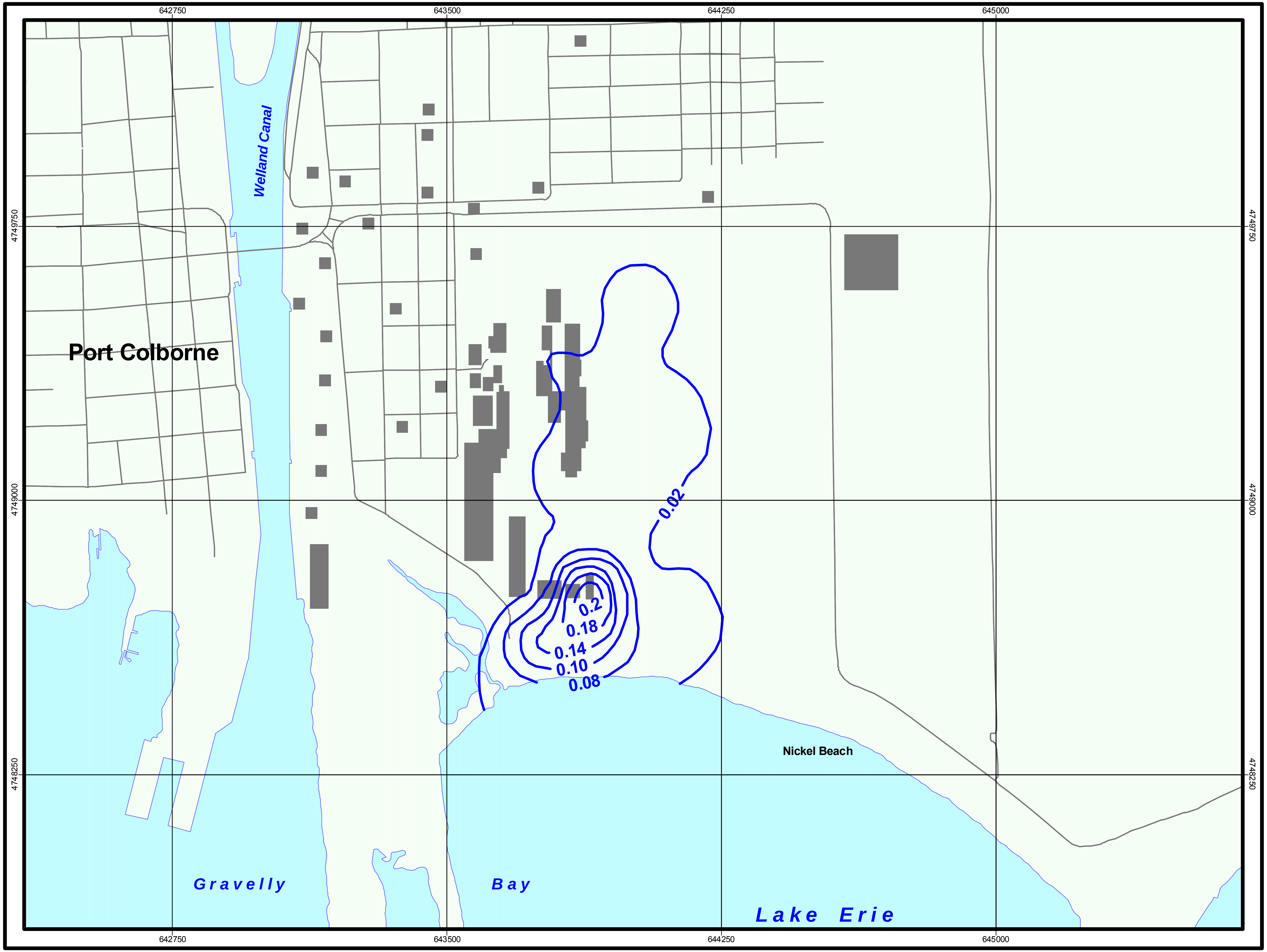

Figure 5-12

Contours of Predicted Lead Deposition due to Inco Fugitive Sources Port Colborne CBRA

0 250 500
Metres

N

Legend

Predicted Soil Lead Deposition Content (ug/cm)

Topographic Features

▨ Commercial/ Industrial Sources

Road

Job Number: ONT34561
Date: June 2004
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 10,000

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5.4.3 Stack Source Emissions

Isopleths of predicted total lead depositions due to emissions from Inco stacks (over the operating life-span of the facility) are presented in Figure 5.13. The dispersion modelling predicts that the highest lead depositions due to stack emission sources will occur to the east and northeast of the Inco facility and are due to emissions from the Research Station #2 stack. Higher lead depositions are seen to the north-east of the PCNR than to the north-west.

In the East Side Community, lead depositions due to Inco stack emissions were predicted to be about 2 to 4-ug/cm^3 over the entire lifetime of the facility.

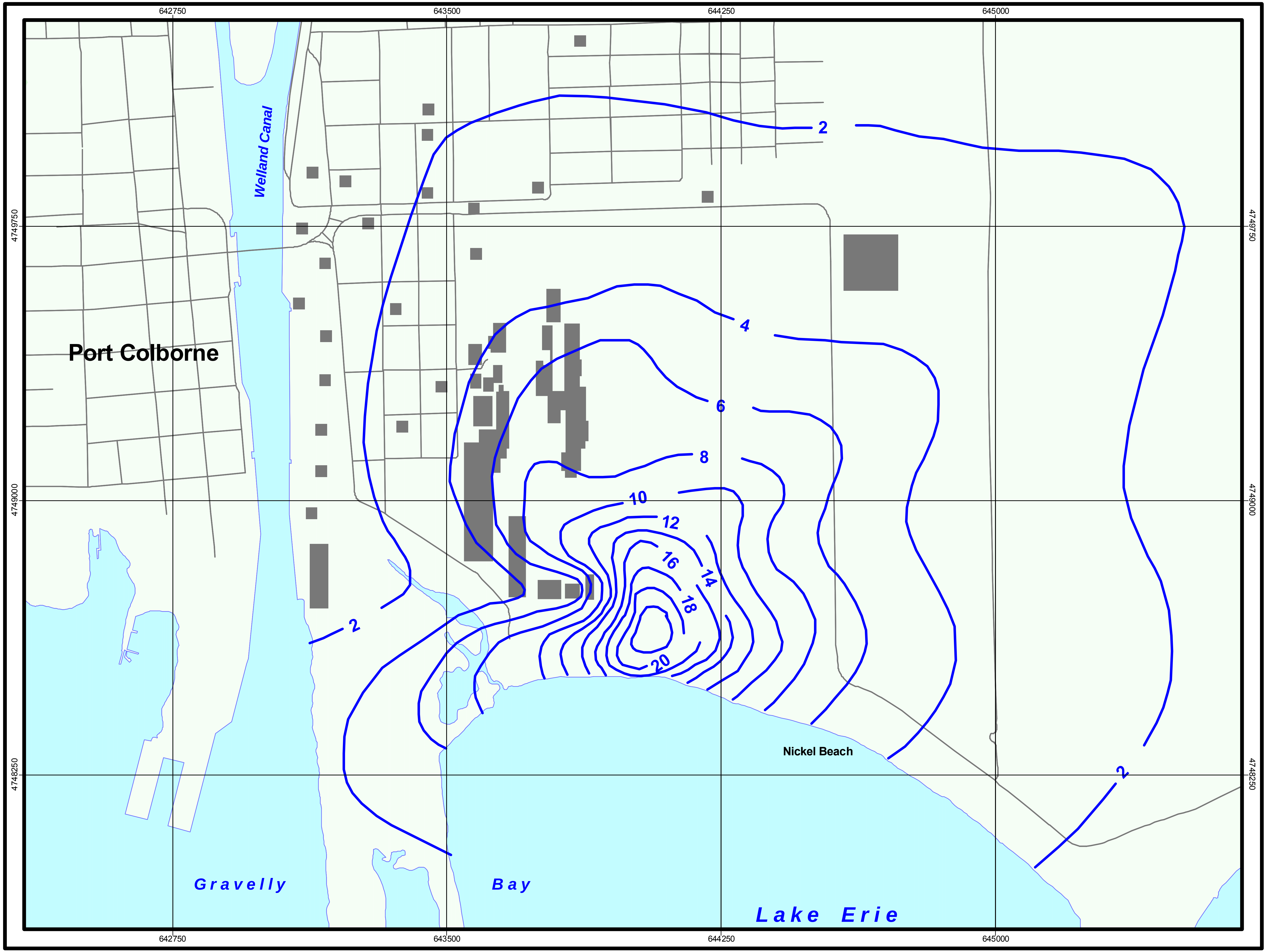

Figure 5-13

Contours of Predicted Lead Deposition due to Inco Stack Sources Port Colborne CBRA

Legend

Predicted Soil Lead Deposition Content (ug/cm)

Topographic Features

▨ Commercial/ Industrial Sources

Road

Job Number: ONT34561
Date: June 2004
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 10,000

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5.4.4 Lead Deposition due to Emissions from all Inco Sources

Isopleths of predicted total lead depositions due to emissions from all Inco emissions sources (over the operating life-span of the facility) are presented in Figure 5.14. The dispersion modelling predicts that the highest lead depositions due to all emissions sources will occur to the east and north-east of the Inco facility (due to the #2 Research Station emissions).

In the East Side Community, lead depositions due to Inco emissions were predicted to be between 2 to 4 times less than those at a same distance to the north-east of the PCNR. The model-predicted lead depositions of 2 to 4 ug/cm^3 in the East Side Community due to PCNR emissions are several orders of magnitude less than the measured soil concentrations for this community (e.g., maximum soil lead concentration of 1,350 ug/g at 0-5 cm depth).

Figure 5.14 also shows the superimposed pattern of the actual measured soil lead concentrations, which enables a comparison to the pattern of the predicted soil lead concentrations through dispersion modelling. It is noteworthy that the actual and predicted soil lead concentration patterns do not match. The predicted pattern indicates a soil lead deposition plume to the east and northeast of the Inco facility, which is intuitively expected based on the prevailing wind direction for this area (i.e., southwest to northeast). The actual pattern shows the highest soil lead concentrations in areas west (upwind) of Inco, which is completely opposite to that of the predicted pattern.

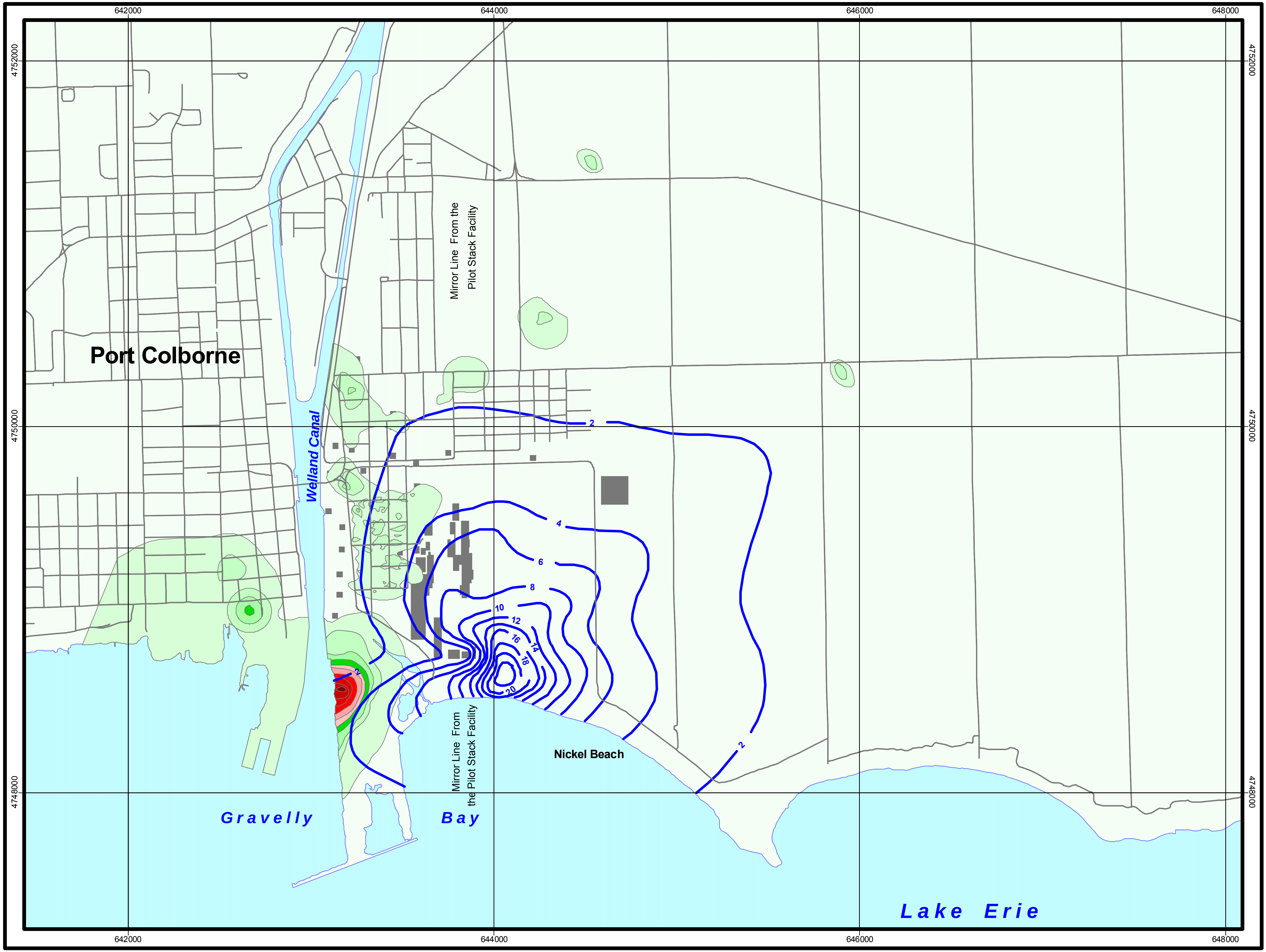

Figure 5-14

Contours of Predicted Lead Deposition for Open Spaces due to Inco Fugitive & Stack Sources and Comparison to Actual Soil Lead Patterns Port Colborne CBRA

0 250 500 750 1000

Metres

N

Legend

Predicted Soil Lead Deposition Content (ug/cm^3)

Measured Soil Lead in Open Spaces (ug/cm^3)

- 🟩 100-199
- 🟩 200-399
- 🟩 400-599
- 🟩 600-999
- 🟥 1000-1399
- 🟥 1400-1799
- 🟥 1800-2199
- 🟥 2200-2599
- 🟥 2600-2999
- 🟥 >3000

Topographic Features

- ■ Commercial/ Industrial Sources
- Road

Job Number: ONT35313
Date: June 2004
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 20,000

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5.4.5 Dispersion Model Validation

The methodology used to estimate the lead emissions inventory and predict lead depositions was identical to that used to predict nickel deposition in the Port Colborne area (JWEL, March 2003). A summary of this methodology is presented in **Appendix F.** As Inco was the only significant emitter of nickel in the region, comparison of the dispersion model predictions to actual nickel concentrations in the soil should gauge the accuracy of the nickel emission inventory and dispersion modelling. Since the lead emission and modelling study used the same estimation methodologies as for nickel, this comparison will also provide a good indication of the relative accuracy of the lead dispersion modelling.

Figure 5.15 presents the results of the dispersion modelling of nickel emissions from the Inco operations. In Figure 5.15, the predicted 1000-ug/cm^3 nickel contour from the dispersion modelling has been increased by factors of two (x2) and three (x3) over the base inventory of one (x 1). For comparison purposes, the 1000-ug/cm^3 actual soil nickel contour (from measured data) is presented as a dashed black line in Figure 5.15. It is evident from Figure 5.15 that the dispersion model predictions resemble the measured soil nickel concentrations when the nickel emissions are increased by between 1-2 times the original inventory. An important feature of both the predicted and actual (measured in soil) nickel concentrations are that the plumes predominantly extend to the north-east of the PCNR, which is indicative of the predominant wind direction in the area (blowing from the south-east). The fact that the dispersion model predictions for nickel are comparable to the measured nickel in soil data is a good indicator that the dispersion model methodology (used for lead as well as nickel) provides a good estimate of the deposition of Inco emissions in the area.

Figure 5.16 indicates that the predicted deposition patterns for nickel and lead, when superimposed, are similar. This is expected, as the winds will carry the majority of the Inco emissions (particulate containing both nickel and lead) in the direction of the predominant winds – blowing to the northeast of the nickel refinery. Given the meteorology of the region, it would be expected that the majority of lead emissions from the PCNR and the #2 Research Station will be carried to the east-north-east of the Inco facilities, as were the nickel emissions.

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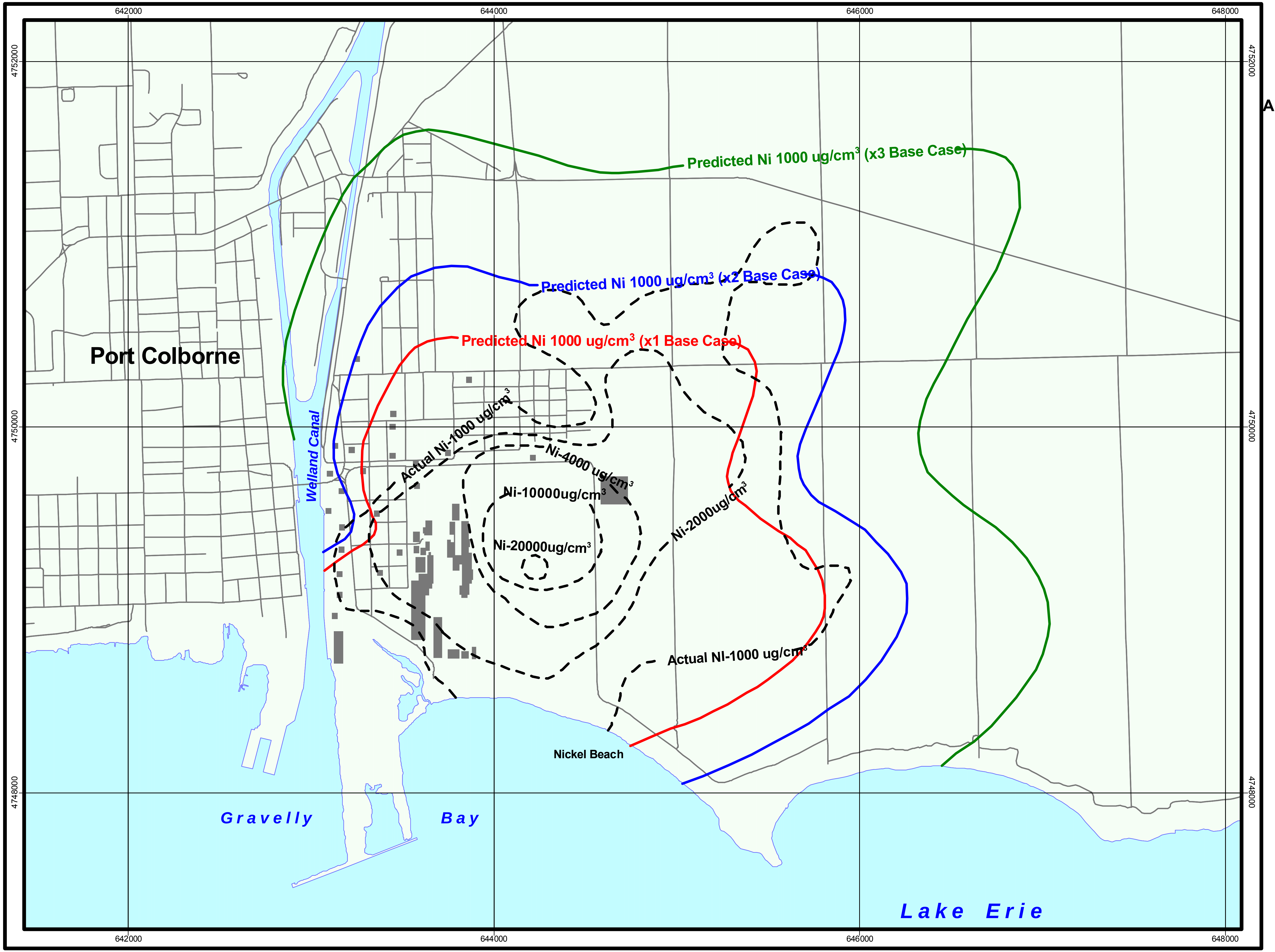
Figure 5-15

Comparison of Predicted Nickel Distribution to Actual Nickel Concentrations Port Colborne CBRA



0 250 500 750 1000

Metres

N

Legend

- Actual Soil Nickel Concentration (ug /cm³)
- Predicted Soil Nickel (x1) Scenario (ug /cm³)
- Predicted Soil Nickel (x2) Scenario (ug /cm³)
- Predicted Soil Nickel (x3) Scenario (ug /cm³)
- **Ni** Nickel

Topographic Features

- ▨ Commercial/ Industrial Sources
- Road

Job Number: ONT34561
Date: June 2004
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 20,000

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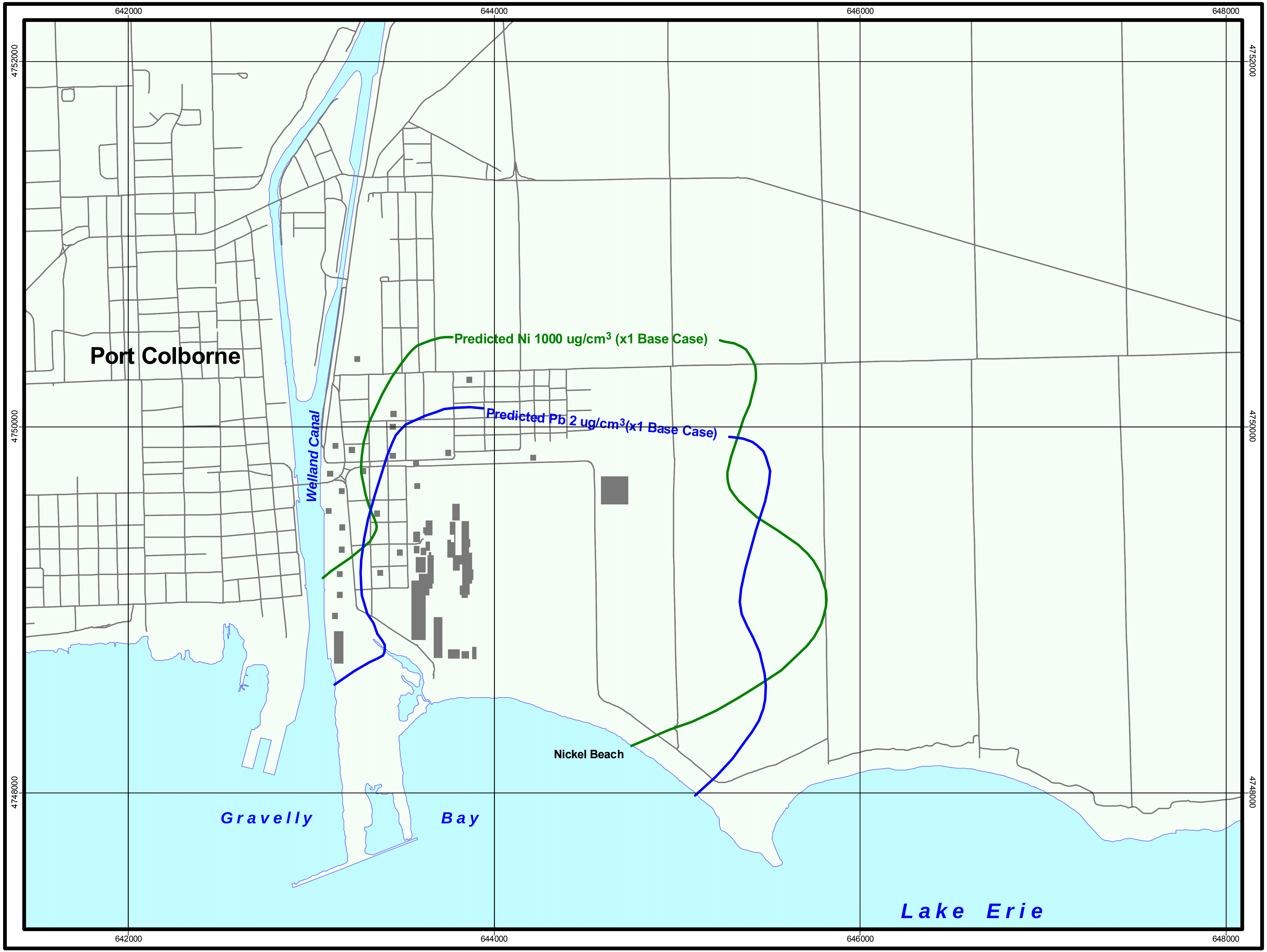
Re-Evaluation of Lead as A CoC- Community Based Risk Assessment, Port Colborne ON

Figure 5-16

Comparison of Predicted Nickel and Lead Distribution Patterns Using Dispersion Modelling Port Colborne CBRA



0 250 500 750 1000

Metres

N

Legend

Predicted Soil Lead Deposition Content (ug/cm^3) (x1 Base Case)

Predicted Soil Nickel Deposition Content (ug/cm^3) (x1 Base Case)

Topographic Features

▇ Commercial/ Industrial Sources

Road

Job Number: ONT34561
Date: June 2004
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 20,000

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5.4.6 Sensitivity Analysis

Due to the relative scarcity of historical operations and emissions data for the PCNR, a sensitivity analysis was conducted to examine the effect of variations in PCNR lead emissions on the magnitude of lead depositions in the Port Colborne area.

It should be noted that the estimated lead emissions inventory is an indicator of what the potential emissions of lead-containing compounds might have been over the history of the PCNR operations. As with any emission inventory, there are uncertainties and approximations associated with it. In Table 5-6 below, lead emissions from the PCNR have been increased by factors of 2 and 3 over the estimated lead emissions from the PCNR. Table 5-6 shows a comparison of the predicted soil lead concentrations from the total lead emitted over the lifetime of the PCNR for each scenario and the actual soil lead concentrations, with special focus on areas in the East Side Community and to the north-east of the PCNR.

Table 5-6 Predicted versus Measured Soil Lead Concentrations

Scenario	Soil Lead Concentrations in East Side Community* (ug/ cm^3) Open spaces 0 - 5 cm depth		Soil Lead Concentrations North East and East of Inco* (ug/ cm^3) Open spaces 0 - 5 cm depth	
	Predicted	Measured	Predicted	Measured
A. (base case – Section 5.4.3)	2	201 – avg 1350 - max	4 to 8	54– avg 64 - max
B. Base emissions x 2	4		8 to 16	
C. Base emissions x 3	6		12 to 24	

Note* Locations at equal distance from the Inco Refinery stacks to the NE (on Inco property)

It should be noted that Scenario C, in which it was assumed that the lead emission estimate was increased by a factor of 3, is considered an extreme worst-case scenario. Even under this extreme worst-case scenario, the deposition modelling does not account for the elevated measured soil lead pockets in the East Side Community (e.g., 6 ug/cm^3 predicted versus maximum value of 1350 ug/ cm^3 measured at the 0 to 5 cm depth in the East Side Community).

Percentage contribution of Inco's aerial emissions to the randomly-scattered pockets of elevated measured soil lead concentrations in the East Side Community was calculated with the above information. For conservatism, assume the predicted value of 4 ug/cm^3 from Scenario B represents Inco's contribution to the community. The measured bulk density of soils in this community is 1 g/cm^3 on average. Conversion of the 4 ug/cm^3, from its mass/volume unit to mass/mass unit based on the bulk density of 1 g/cm^3 is 4 ug/g. **Therefore, aerial emissions of lead from Inco were predicted to account for only 0.3 % of the maximum measured soil lead concentration (1,350 ug/g at the 0-5 cm depth) in the East Side Community. This percentage contribution from Inco is not significant.** This is compelling evidence that there is a more significant source(s) of lead besides the Inco Refinery that accounts for the randomly-scattered pockets of elevated measured soil lead concentrations in the East Side Community.

A limitation to the dispersion modelling undertaken in this section was that it predicted soil lead concentrations in open spaces only, but not soil lead concentrations in woodlots. The air dispersion model does not account for the change in surface characteristics of woodlots and cannot duplicate the measured soil lead concentrations in the woodlot immediately downwind of the Inco Refinery. The MOE report "Soil Contamination in Selected Port Colborne Woodlots: 2000" (MOE (2000)) found that in woodlots downwind of the Inco Refinery, the soil metal concentration gradients showed a 'snowfence shadow' effect; i.e., soil metal levels were highest at the windward side of the field/woodlot interface, consistently higher in the woodlot than in adjacent open spaces, and lowest in the open fields immediately downwind of the woodlot. In these woodlots, the MOE observed higher surface soil nickel concentrations inside of or at the very edge of the woodlot than in the adjacent open fields by factors between 2 to 7.

5.5 PEER REVIEW OF AIR DISPERSION MODELLING

A draft copy of this report was provided to Rowan, Williams, Davies and Irwin (RWDI) to conduct a peer review of the air dispersion modelling. The review comments from RWDI are provided in **Appendix G** along with the JWEL responses to their comments. In their review, RWDI notes the following:

*"If the missing information and details about the air quality assessment are shown to support the text in the report, and based on the assumption that the information provided in the report pertaining to emission sources of lead, soil concentrations and densities is correct (it was not within the scope of our work to confirm these data), **we concur with the conclusion that the high lead levels measured in the East Side Community do not appear to be as a result of historical air emissions of lead from Inco."***

As mentioned above, the RWDI review identified some data (with respect to detailed model inputs) missing from the draft report. Previous draft versions of this report contained references to these data in another JW CBRA report, but were not specifically included in their copy of the draft report. These data (to support the text of the report as per RWDI's comment) have been included in this final version of the report.

6.0 EMPIRICAL AND STATISTICAL EVALUATION

6.1 INTRODUCTION

JWEL's report "*Potential CoC Identification using Statistical Analyses*" dated November 16, 2001 (JWEL, 2001c) provided a statistical evaluation of whether soil chemical concentrations at and surrounding the Inco Refinery, were scientifically related to the historical emissions from the refinery. Elements emitted from the Inco Refinery were predicted to be in high concentration close to the refinery, and to decrease in concentration with distance from the property.

Soil concentrations of nickel, copper, cobalt, and arsenic were high near the Inco refinery, and generally decreased with distance, consistent with Inco as their principal source. Lead did not vary with distance in a manner similar to the CoCs. Such behaviour is inconsistent with Inco being the principal source (JWEL, 2001c).

Since the original JWEL (2001c) study, new soils data have been collected. This section of the report re-evaluates distribution of the measured soil-metal concentrations, and demonstrates that lead concentrations in the East Side Community were derived from a number of sources other than Inco.

As a hypothesis, **if it is assumed** that Inco was the principal source of lead in the East Side Community, then two main predictions could be made. They are:

1. Soil-lead concentrations would be higher north east of the refinery (in the direction of the prevailing wind direction) than in the East Side Community, **and**,
2. The distribution of soil-lead concentrations would vary with concentrations of CoCs. Based on this second prediction, the ratio of Pb to CoCs should be similar both within and outside the East Side Community.

These predictions were tested using a variety of simple and complex statistical approaches as described below.

6.2 METHODS

The data sets used for the statistical evaluation are provided in Appendices I1 and I2. These include soil lead concentrations (ug/g units) in both woodlots and open spaces at the 0 to 5 cm depth. Chemical data on the surface soil samples were divided into three groups for the statistical analysis as follows:

I. East Side Community Data on samples collected in the East Side Community as bounded by Davis Street to the east, Welland Street to the west, the south side of Louis Street to the north, and both sides of Rodney Street to the south.

II. Outside and East of the East Side Community
Data on samples collected from an arc from directly north to southeast of the Inco facility using an Easting of 643780.7 as the dividing line.

III. Outside and West of the East Side Community

Data on samples collected from an arc from directly north to southwest of the Inco facility using an Easting of 643780.7 as the dividing line, excluding the East Side Community area.

Three sets of statistical analyses were used to examine if the principal source of lead in the East Side Community was, or was not, the Inco Refinery.

- Simple descriptive statistics and *t*-tests;
- Principal Components Analysis (PCA); and,
- Analysis of Covariance (ANCOVA).

6.2.1 Descriptive Statistics

Mean soil concentrations of the four CoCs (nickel, cobalt, copper, arsenic) as well as Pb were calculated. For each soil sample, the ratio of lead to each of the CoCs was also determined, as was the mean of the ratios. Student's *t*-tests were used to determine the likelihood that mean metal concentrations were different between inside and outside the East Side Community (using both raw and log10 transformed concentrations), and the likelihood that soil lead:CoC ratios differed between inside and outside the East Side Community.

6.2.2 Principal Components Analysis

Principal components analysis (PCA) is a statistical tool for illustrating patterns in multivariate data sets (Zitko, 1994). The method can be used here to illustrate similarities among samples in their elemental composition, in a two-dimensional plot. PCA calculates "axes" that are new variables (linear combinations of the original variables) that can be used to portray the similarities among samples. Samples with similar elemental composition will produce similar axis scores, and will appear close together in biplots of axis scores. Assuming that the principal source of lead is from the Inco Refinery, soil samples from the East Side Community should not form a distinct cluster in a biplot of PCA axis scores, but rather should overlap with samples from outside the community. PCA has been used by others to distinguish lead sources in Sweden (Zhang et al., 1999) and for distinguishing between natural and anthropogenic inputs of arsenic in soils in Yellowknife, NWT (Reimer et al, 2003; Ollson, 2003).

This analysis used solid-phase compositions of all surficial soil samples (using the suite of four CoCs, nickel, cobalt, copper, arsenic, plus lead). The PCA was carried out using SYSTAT® 10.0. The data for each metal were normalized ($\log_{10}$ transformed) to reduce the effects of extremely high concentrations and to linearize relationships among elements. Discriminant analysis was used to determine if PCA axes separated samples from the East Side Community from samples outside that area. The discriminant model was developed with a set of "calibration sites (*n*=644)", and tested with an equal number of validation samples.

6.2.3 Analysis of Covariance

Assuming the Inco refinery was the principal source of lead, soil-lead concentrations should vary with soil-CoC concentrations in the same fashion both inside and outside the East Side Community.

Analysis of Covariance (ANCOVA) was used to determine if the relationship between lead and CoC concentrations differed inside and outside the East Side Community area. In these analyses, all metal concentrations were $\log_{10}$ transformed to increase the linearity of relationships. Soil-lead concentrations were set as the dependant variable, with nickel (or other CoCs) used as the covariate. The analysis tested whether the slopes of the relationships between soil-lead and soil-CoCs were the same within and outside the East-Side Community.

6.2.4 Regression Modelling

The contribution of Inco emissions to soil-lead concentrations in the East Side Community can be predicted based on the relationships between soil-lead and soil-CoCs outside the East Side Community. Knowing that Inco emitted some lead, lead should fall out in the environment in a fashion that is similar to the CoCs. The relationship between soil-lead and soil-CoC concentrations east of the Inco refinery, as determined through regression modelling, was used to predict the contribution of soil-lead concentrations attributable to Inco within the East Side Community (Figure 6-1). The use of CoCs as markers of lead deposition, then, inherently takes into account all factors that influence deposition such as wind speed, fallout patterns with distance from the stack, etc.

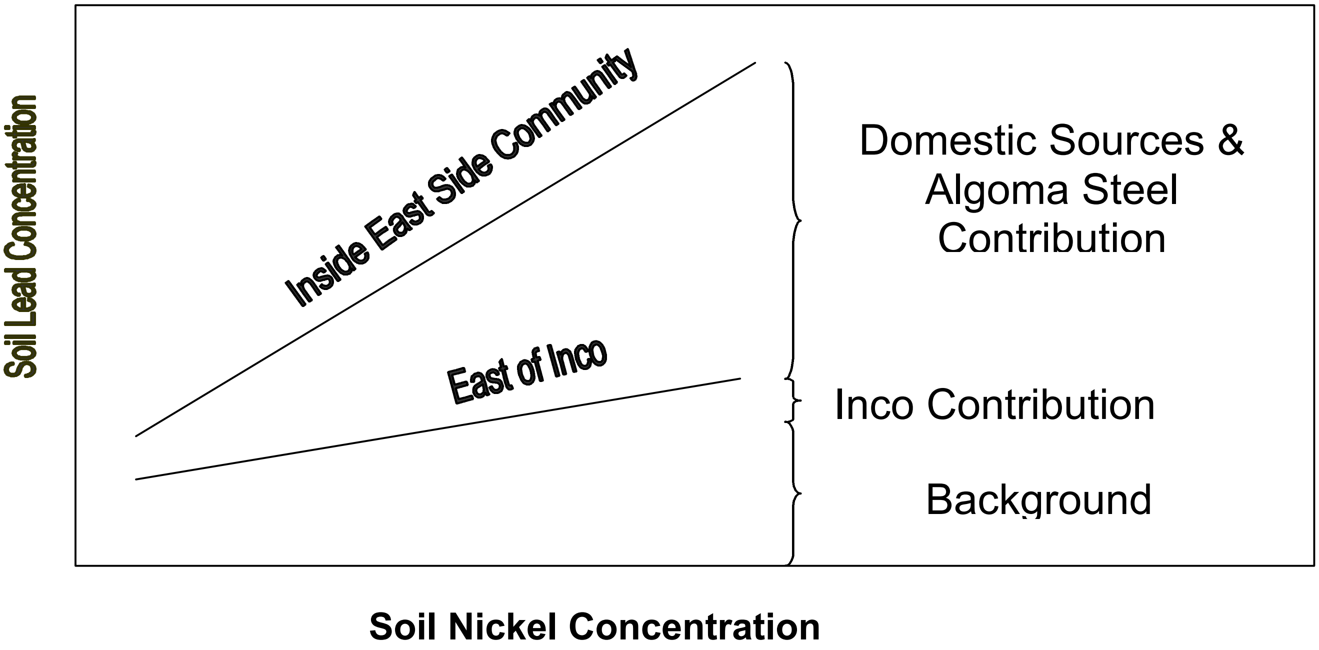

Figure 6-1 Conceptual illustration of the relationships between soil-lead and soil-nickel within the East Side Community, and East of Inco, indicating how the contributions to the total amount of soil-lead within the East Side Community can be estimated from the two relationships.

Linear regression equations describing the relationships between lead and CoC concentrations were determined for the area outside the East Side Community. Those models were then used to estimate the soil-lead concentrations inside the East Side Community. The predicted soil-lead concentration is the best estimate (from this exercise) of the contribution to the soil-lead concentrations in the East

Side Community from background and aerial emissions (Inco and Algoma). The difference between observed and predicted soil-lead concentrations is the best estimate (in this exercise) of the contribution from local or domestic sources within the East Side Community.

6.3 RESULTS AND DISCUSSION

6.3.1 Descriptive Statistics

Mean elemental concentrations of nickel (Ni), cobalt (Co), arsenic (As) and lead (Pb) were higher within the East Side Community, while copper (Cu) concentrations were lower ($P<0.05$, Table 6-1). The ratios of nickel to other CoCs as well as lead were calculated, and the mean ratios inside and outside the East Side Community determined. The Ni:Cu, Ni:Co and Ni:As ratios were higher inside the East Side Community than outside (all $P<0.001$). That contrasted with the Ni:Pb ratio which was higher outside the East Side Community ($P<0.001$).

Table 6-1 Mean (± 1 standard deviation) Soil Metal Concentrations and Ratios of Ni:Cu, Ni:Co, Ni:As and Ni:Pb.

Sample Location	Mean soil Metal Concentration (ug/g)					Soil Metal Ratios			
	Ni	Cu	Co	As	Pb	Ni:Cu	Ni:Co	Ni:As	Ni:Pb
Outside East Side Community (East/West) (n=934)	1850 ± 5690	259 ± 776	34 ± 77	9.9 ± 15	68 ± 146	5.5 ± 3.8	30.4 ± 19.9	79.7 ± 162	21.9 ± 38.0
East Side Community (n=415)	1900 ± 1640	202 ± 142	45 ± 33	14 ± 20	199* ± 158	8.6 ± 2.7	38.5 ± 12.6	146 ± 84.1	10.6 ± 7.9

* The calculated mean value of soil Pb for the East Side Community at 199 ug/g is marginally different from the MOE-reported 201 ug/g value given earlier in Section 3.1.4. The discrepancy between the two calculated mean values is that more soil lead data were used from consultants'databases (Section 3.2.1) in addition to the MOE database.

Figure 6.2 illustrates that the Ni:Pb ratio varies with distance and direction from Inco. To the northeast of Inco, the Ni:Pb ratio is 20:1 or greater (as high as 200:1). Within the East Side Community, Figure 6.2 shows a Ni:Pb ratio contour line of 10:1 and Table 6-1 above indicates an average Ni:Pb ratio of 10.6:1, reflecting higher soil lead concentrations in the East Side Community than observed outside that area. This observed difference in the spatial distribution pattern for lead provides one piece of evidence that soil lead within the East Side Community originated from a different source than did the four CoCs.

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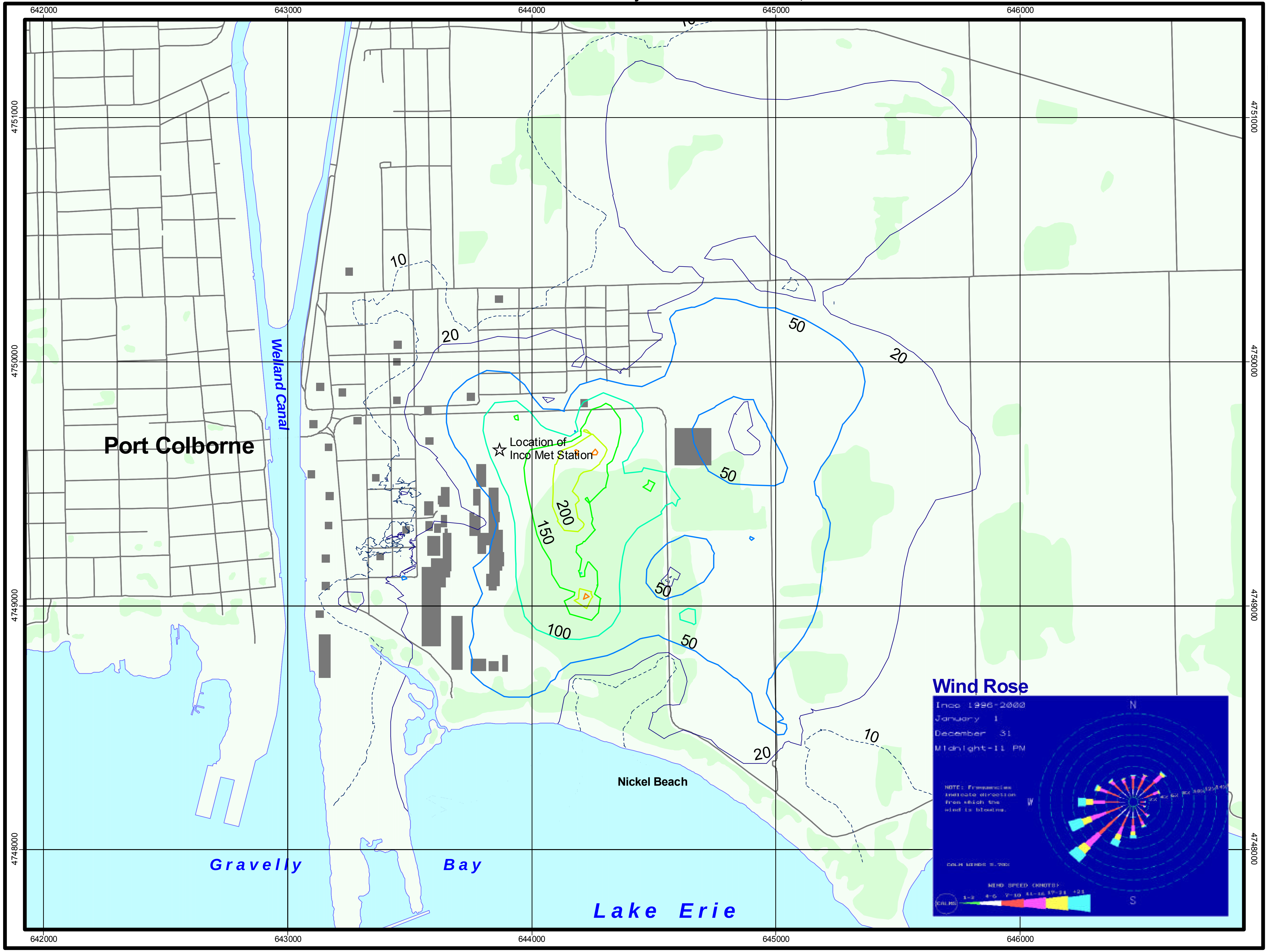

Figure 6-2

Soil Nickel: Lead Ratio in Woodlots and Open Spaces

0 250 500 750 1000
Metres

N

Legend

Soil Nickel: Lead Ratio

- 250
- 200
- 150
- 100
- 50
- 20
- 10

Topographic Features

- ■ Commercial/ Industrial Sources
- 🟩 Woodlot
- ╱╲ Roads

Job Number: ONT34644
Date: October 2003
Dwn by: C. Amirault
Approved by: Kevin Wong

Map Parameters
Projection: UTM
Datum: NAD 83
Scale 1 : 30,000

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6.3.2 Principal Components Analysis

Two principal components were considered representative of the major variations in metals concentrations. All of the metals (including lead) had strong positive correlations with the first principal component axis indicating that the first axis represented a gradient of metal exposure (Figure 6-3). Only lead was strongly associated with the second axis, indicating that lead concentrations varied independently of the CoCs, i.e., nickel, copper, cobalt and arsenic (Figure 6-3). The biplot indicates that soil samples from the East Side Community had overall high concentrations of metals (including lead and the four CoCs). Lead, however, was more strongly associated with samples from the East Side Community.

Samples from the East Side Community formed a distinct cluster (Figure 6-3). A discriminant model based on a subset of samples (n=644) was significant (Wilks' lambda 0.607; $p<0.0001$). Classification of 644 calibration and 644 validation samples to inside and outside the East Side Community, based on the discriminant model were accurate in 84 and 88% of the cases (for calibration and validation sets respectively). The overlap of samples from the East Side Community and those from outside that area was, therefore about 12 to 17%. Further evaluation with analysis of variance (ANOVA) demonstrated that samples from inside the East Side Community had both higher PC Axis 1 scores and lower PC Axis 2 scores than samples from outside the community ($P<0.001$ in both cases), reflecting higher overall concentrations of metals, and higher relative concentrations of lead.

This PCA demonstrated that relative metal concentrations in the East Side Community area had a distinct soil-metal makeup and that lead contamination is higher in this area than can reasonably be expected from the levels of other CoCs. This suggests that the source of lead in the East Side Community area cannot be solely attributed to emissions from the Inco facility.

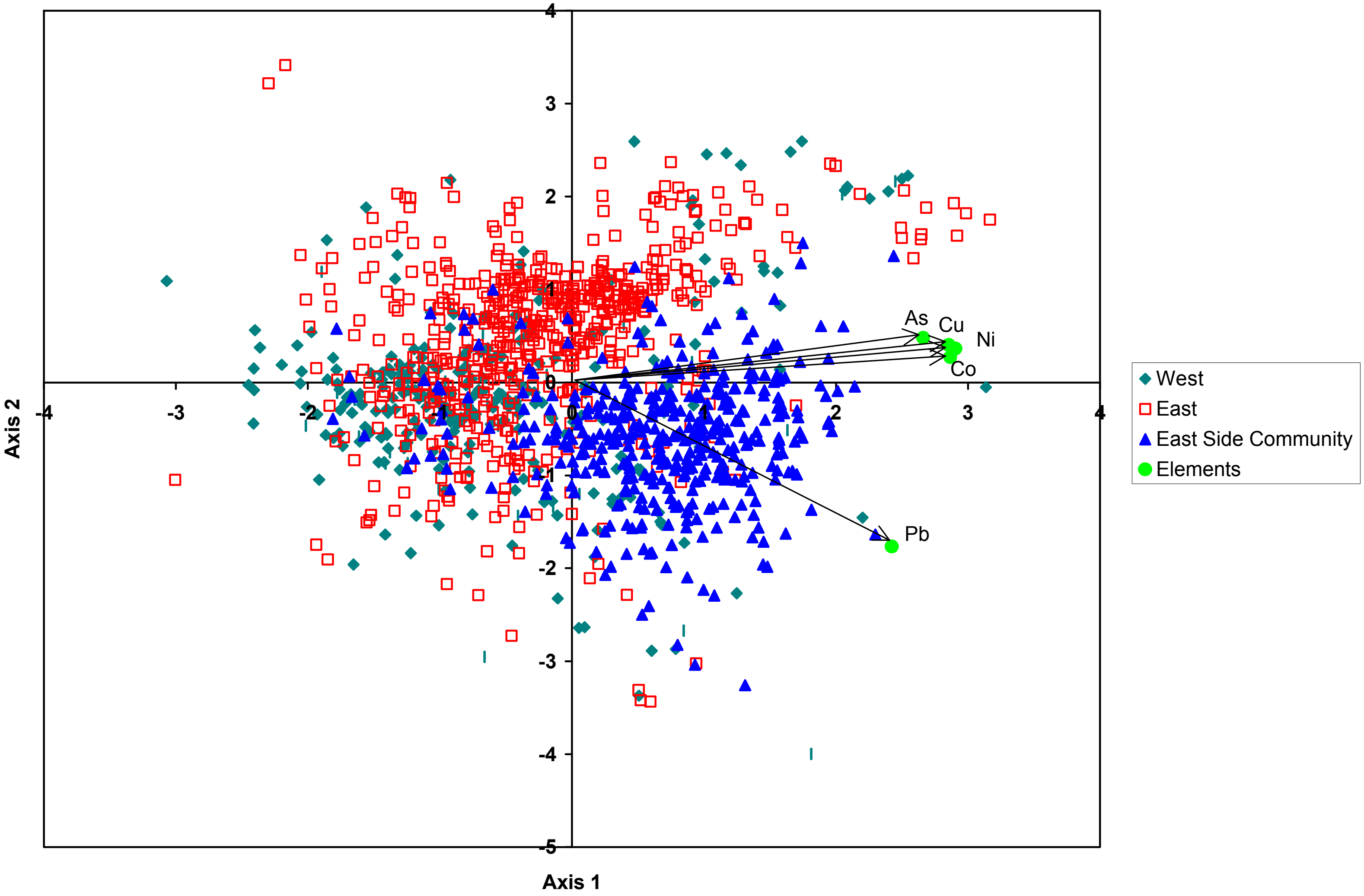


Figure 6-3 Principal components analysis of all sample locations with Ni, Cu, Co, As, and Pb. Factor loadings (elements) are scaled by 3x original variable for illustrative purposes.

6.3.3 Analysis of Covariance

Lead concentrations generally increased with CoC concentrations, both within the East Side Community and east of the Inco Refinery. However, the slopes of relationships between lead and nickel inside the East Side Community and east of the Inco Refinery were different (Table 6-2). Lead concentrations inside the East Side Community were higher per unit nickel than outside the community (Figure 6-4). That tendency with nickel was consistent with the other three CoCs (Table 6-2; Figure 6-4).

Table 6-2 Results of ANCOVA testing for differences in the relationship between log of lead concentrations and log of CoC concentrations, inside the East Side Community vs east of the Inco Refinery. The significant interactions indicate differences in slopes between areas.

Model	n	R^2	Source	Sum of squares	Degrees of Freedom	F Ratio	p
log(Nickel) Area Interaction	1052	0.66	Log(nickel)[1]	47.8	1	654	<0.0001
			Location[2]	0.204	1	2.79	0.095
			Location*log(nickel)[3]	2.87	1	39.3	<0.0001
			Error[4]	76.5	1048		
log(Arsenic) Area Interaction	999	0.62	Log(arsenic)	42.1	1	568	<0.0001
			Location	2.95	1	39.8	<0.0001
			Location*log(arsenic)	0.899	1	12.1	0.0001
			Error	73.7	1021		
log(Copper) Area Interaction	1052	0.68	Log(copper)	53.8	1	805	<0.0001
			Location	0.533	1	7.97	0.005
			Location*log(copper)	4.67	1	69.8	<0.0001
			Error	70.1	1048		
log(Cobalt) Area Interaction	1052	0.65	Log(cobalt)	47.5	1	663	<0.0001
			Location	0.426	1	5.95	0.015
			Location*log(cobalt)	1.02	1	14.2	<0.0001
			Error	75.1	1048		

Notes:

1 The "Log(nickel)" term tests for an overall relationship between lead and nickel concentrations.

2 The "Location" term tests for differences in lead concentrations between the two locations (East Side Community and northeast of Inco).

3 The interaction term [Location*log(nickel)] tests for differences in slopes of the relationship between lead and nickel between the two sampling locations. When the interaction term is significant, interpretation of the previous two terms is not relevant.

4 The error term represents the variation in lead levels that is unexplained by location and nickel.

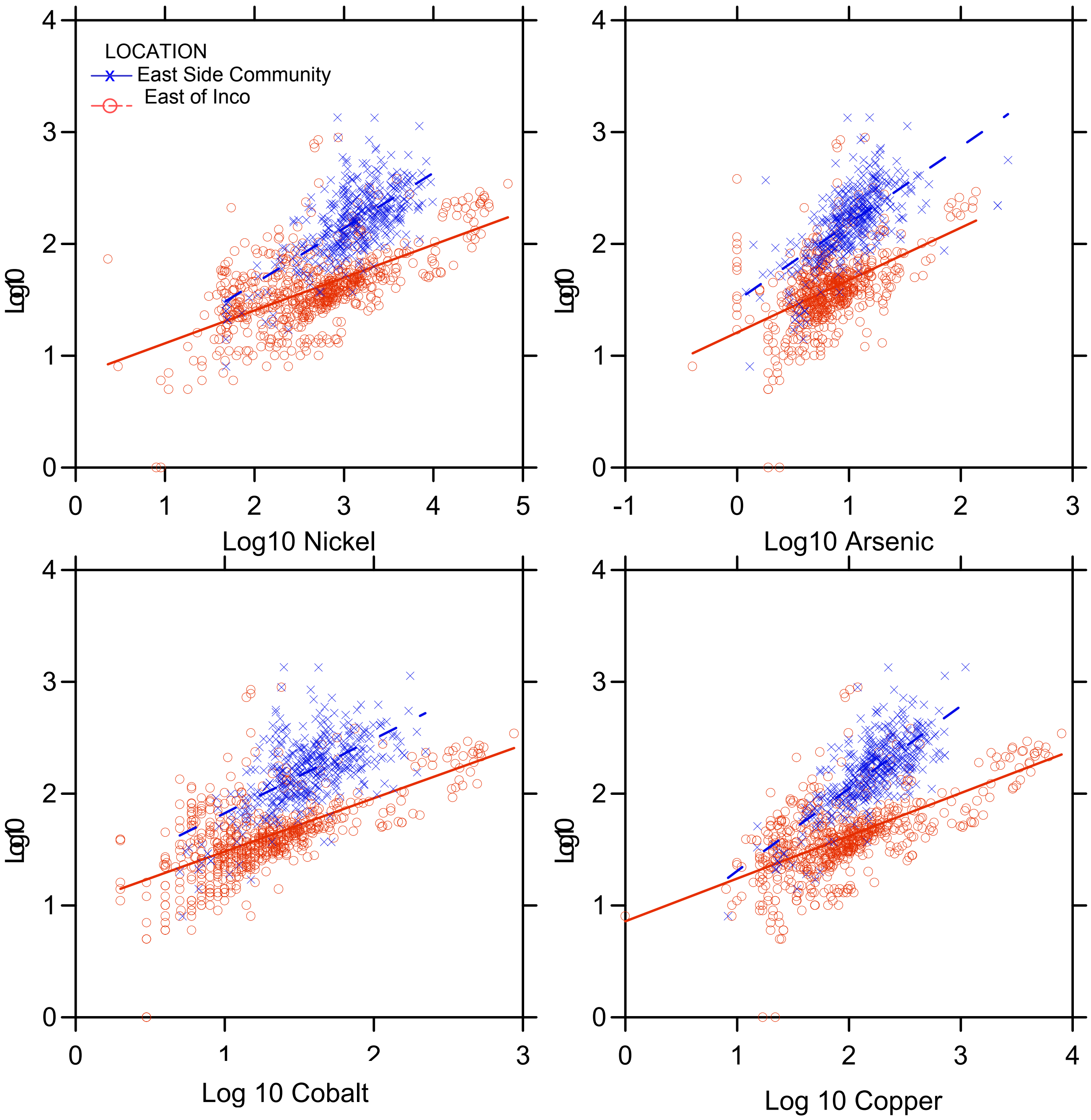


Figure 6-4 ANCOVA comparisons lead vs. CoC regression models within the East Side Community area and for the rest of Port Colborne all show significant interaction terms ($p<0.05$).

6.3.4 Regression Modelling

As significant relationships between lead and each of the four CoCs east of the Inco Refinery indicated a dispersion pattern for lead that was similar to the CoCs, Inco’s aerial emissions contribution (Figure 6-1) to soil lead levels in the East Side Community were predicted through regression modelling.

The mean concentration of soil lead predicted for the East Side Community was 56 ug/g (Table 6-3) uncorrected for natural background based on the relationship between soil lead and soil nickel east of the Inco Refinery (Figure 6-1). Using other soil lead-CoC relationships, the predicted average soil-lead concentration inside the East Side Community varied from a low of 51 ug/g based on the Pb-As relationship to a high of 59 ug/g based on the Pb-Co relationship (Table 6-3). The average of the predicted mean soil-lead concentrations for the East Side Community was 54.5 ug/g (Table 6-3) uncorrected for natural background based on the relationship between soil lead and the four CoCs east of the Inco Refinery.

The predicted maximum soil lead concentrations varied between 97 ug/g based on Pb-Ni relationship and 219 ug/g based on Pb-As relationship (Table 6-3). The average of the predicted maximum soil lead concentrations for the East Side Community was 138.5 ug/g (Table 6-3) uncorrected for natural background based on the relationship between lead and the four CoCs east of the Inco Refinery.

Table 6-3 Measured and Predicted Lead Concentrations (ug/g) in the East Side Community.

Parameter	**Lead (mg/g) in East Side Community based on:**					
	Measured Pb	**Pb-Ni Relation**	**Pb-Cu Relation**	**Pb-Co Relation**	**Pb-As Relation**	**Average of predicted values**
Mean	199*	56	52	59	51	54.5
Std. Dev.	158	15	14	19	20	
Maximum	1350	97	105	133	219	138.5

* The calculated mean value of soil Pb for the East Side Community at 199 ug/g is marginally different from the MOE-reported 201 ug/g value given earlier in Section 3.1.4. The discrepancy between the two calculated mean values is that more soil lead data were used from consultants’databases (Section 3.2.1) in addition to the MOE database.

Of the above predicted soil lead concentrations in the East Side Community, a certain fraction is natural or background, and the remainder is from deposition of Inco aerial emissions (Figure 6-1). The mean soil lead background concentration outside the Port Colborne soil nickel plume (i.e., outside the MOE nickel generic guideline of 200 ug/g contour line) was determined by the geographic information system (GIS) at 33 ug/g. The upper limit of the soil lead background concentration outside the Port Colborne soil nickel plume was determined through GIS at 98-ug/g. These soil lead background-derived values for the site compare well with the MOE Ontario Typical Range (OTR) soil-lead concentration values (eg. 34 ug/g for the average and 98 ug/g for the reasonable upper limit) for urban areas in Ontario (MOE, 1993).

Percentage contributions of soil lead to the East Side Community from Inco's emissions were calculated. The equation used to calculate the percentage of Inco's contribution was as follows:

% Soil Lead Contribution from Inco =

[(Predicted Soil Lead Concentration due to Inco's Contribution Uncorrected for Background – Background)/Actual Measured Soil Lead Concentration in the East Side Community] x 100%

Calculations were done for two scenarios. The first scenario involved the calculation of the percentage contribution of Inco's aerial emissions responsible for the reported *mean* soil lead concentration of 201 ug/g (0-5 cm) for the East Side Community using information on mean values of measured and predicted soil lead concentrations for this community and the mean value of the natural background level for Port Colborne.

The second scenario involved the calculation of the percentage contribution of Inco's aerial emissions responsible for the reported *maximum* soil lead concentration of 1,350 ug/g (0-5 cm) for the East Side Community using information on maximum values of measured and predicted soil lead concentrations for this community and the maximum value of natural background for Port Colborne.

The calculated values are shown in Table 6-4. For the first scenario, Inco's contribution to the mean measured soil lead concentration of 201 ug/g for the East Side Community was 21.5 ug/g, or 11% (Table 6-4).

For the second scenario, Inco's contribution to the maximum measured soil lead concentration of 1350 ug/g for the East Side Community was 40.5 ug/g, or 3% (Table 6-4).

Table 6-4 Measured and predicted mean and maximum soil-lead concentrations, and the percent contributions from Inco aerial emissions

	Scenario 1 Mean Values	Scenario 2 Maximum Values
Measured [Soil-Pb] East Side Community (0-5 cm depth)	201 ug/g*	1350 ug/g
Predicted [Soil-Pb] from Inco uncorrected for background	54.5 ug/g	138.5 ug/g
Background [Soil-Pb]	33 ug/g	98 ug/g
Residual [Soil-Pb] to the East Side Community due to Inco emissions	21.5 ug/g	40.5 ug/g
% soil-Pb contribution to the East Side Community due to Inco emissions	11 %	3 %

*As opposed to the use of the 199 ug/g value derived from this section to represent the measured mean value of soil Pb in the East Side Community, the 201 ug/g value was used in these calculations for consistency with the mean value used in Section 5 of this report.

Predicted soil-lead concentrations resulting from Inco's contribution for the East Side Community, based on soil-lead to soil-CoC relationships east of Inco, were clearly lower than the measured soil-lead concentrations in the East Side Community. For example**, aerial emissions of lead from Inco**

were predicted to account for only 3 % of the maximum measured soil lead concentration (1,350 ug/g at the 0-5 cm depth) in the East Side Community. This percentage contribution from Inco is not significant. Similar to the findings reached in Section 5.4.6 regarding the predictions of the air dispersion modelling, the findings of the regression modelling provide compelling evidence that there is a more significant source(s) of lead besides the Inco Refinery that accounts for the randomly-scattered pockets of elevated measured soil lead concentrations in the East Side Community.

6.4 STATISTICAL CONCLUSIONS

In the introduction to this section it was hypothesized that, if Inco was the principal source of lead in the East Side Community, then:

- Overall lead concentrations in soil in the East Side Community should have been no higher than lead concentrations outside that specific area.
- Soil-based concentrations of lead should have varied with the other CoCs. That is, where nickel (for example) concentrations were high, lead concentrations should also have been high. The ratio of lead to the CoCs should also have been similar both within the East Side Community and east of the Inco Refinery.

The three statistical methods employed in this section all provided similar findings. That is, soil-lead concentrations were higher in the East Side Community than elsewhere, and the ratio of lead to the CoCs in the East Side Community were different than patterns observed elsewhere. The elevated soil lead concentrations in the East Side Community were not consistent with the distribution of soil lead elsewhere in the study area, and were therefore not principally associated with aerial emissions of lead from the Inco facility.

Regression models of the relationship between soil lead and soil CoC concentrations east of Inco were used to estimate expected soil lead concentrations for the East Side Community. Those models indicated that contributions from the Inco emissions were only 3% of the maximum measured soil lead concentration (1,350 ug/g at the 0-5 cm depth) found within the East Side Community.

7.0 POTENTIAL SOURCES OF LEAD OTHER THAN INCO

7.1 HISTORICAL BACKGROUND REVIEW

JWEL conducted a detailed historical background review of adjacent areas north, west and south of the Inco Refinery to determine if evidence exists on industrial operations other than Inco and domestic practices within the East Side Community that may have resulted or contributed to the observed irregular pattern of soil lead contamination in the East Side Community. Findings are summarised in Table 7.1. Details of the review findings are provided in **Appendix J.**

Table 7-1 Findings of Site Background History Review

Potential Sources of Lead (for individual location, refer to Figures 2.2 and 7.1)	Historical Activity	"Likely" Contaminants Released to Environment
1). Algoma Steel Plant	Historical iron smelting operation active since 1913 to its closure in 1977. The plant used coke, iron ore, limestone and iron shot ball as raw materials. Coal stockpiles, iron ore and slag all contained spent metals.	Iron, Arsenic, Beryllium, Selenium and associated metals such as **Lead** and coal dust from metal smelting operations. Metal containing slag later used as road bases and fill materials in the development of neighbouring eastside of the City of Port Colborne.
2). CN Railway Yard, Coal Storage Yard	Historical operation of a railway yard along the eastside of the Welland Canal since 1860s to 1980s. The activities included, coal yard, grain storage and associated railway operations such as fuel oil storage, railway ties and maintenance.	Coal dust, petroleum hydrocarbons, arsenic (from railway ties) and other metals including **Lead** associated with railway yard.
3). Scrap Yard (Dwor Metal), Trucking Facilities and other industrial operations along eastside of Welland Canal west of Welland Street.	Historical industrial land use along the eastern part of the CN railway yard since 1930s. The activities included, a scrap yard, junk metal stock piles, generation of heavy metal shavings, a degreasing operation involved in metal scrapping and salvage, trucking facilities with fuel storage.	Metals including **Lead**, petroleum hydrocarbons from scrap yard operations and metal shavings.
4). Machine Shop (Thurston Machine Works)	Historical industrial use of the property located at the northeast corner of Fares Street and Decew Street was as a tool and die operation and a machine works. This operation was present at current location from prior to 1941 to the present.	Metals including **Lead**, petroleum hydrocarbons and volatile organic compounds

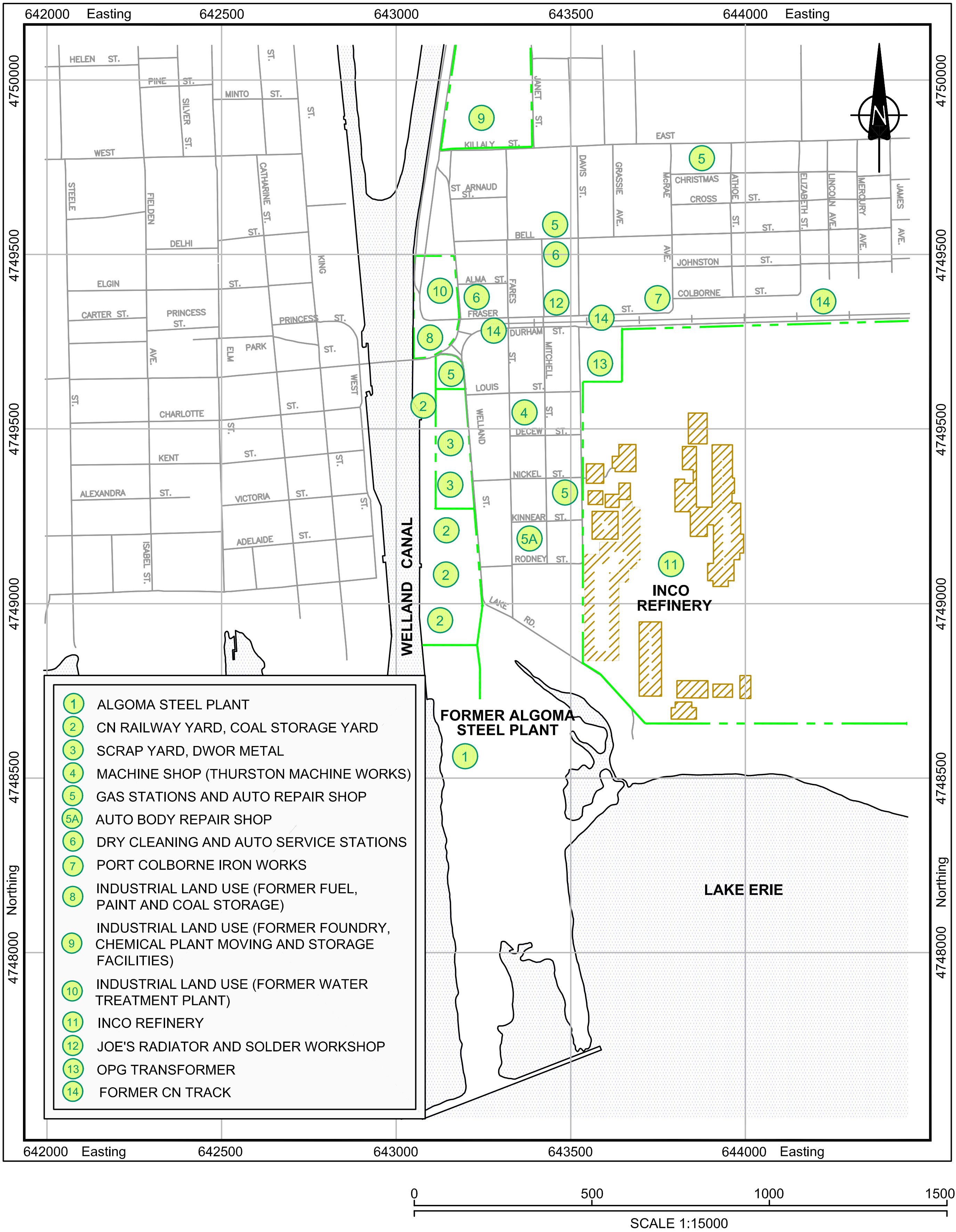
Potential Sources of Lead (for individual location, refer to Figures 2.2 and 7.1)	**Historical Activity**	**"Likely" Contaminants Released to Environment**
5). Gas Stations and Auto Repair Facilities.	Historical commercial/residential land uses for the area north of Rodney Street, south of Killaly Street, west of Davis Street and east of Welland Street. A gasoline station/auto repair garage was located at the southwest corner of Nickel Street and Davis Street from at least 1941 to the 1980s. An auto body and Fender workshop was located at the backyard of 109 Fares Street from at least early 1950's to 1970's.	**Lead**, antimony, cadmium, petroleum hydrocarbons from gasoline, paint, batteries and fill materials.
6). Dry cleaning operations and Auto Service Stations	Historical activities associated with gasoline service stations, auto repair facilities, and dry cleaning operations located at various areas in the Port Colborne area (as indicated above) from prior to 1941 to the present.	Petroleum hydrocarbons, volatile organic compounds, perchloroethylene, trichloroethylene, vinyl chloride, solvents, polycyclic hydrocarbons (PAHs), metals including **Lead**.
7). Port Colborne Iron Works	Historical operation of an iron works from prior to 1941 to the present.	Metals including **Lead**, solvents, petroleum hydrocarbons, lead (from soldering).
8). Industrial use (Former Fuel, Paint and Coal Storage) of the Area west of Welland Street and North of CNR	This area of Port Colborne has historically been utilised for industrial uses such as aluminium storage, plating company, fuel, paint and coal storage from at least 1941 to the early 1980s.	Metals including **Lead**, polycyclic hydrocarbons, petroleum hydrocarbons, solvents, and volatile organic compounds.
9). Industrial use (Foundary, Chemical Plant) of the area north of Killaly Street East and east of the CNR	This area of Port Colborne has historically been utilised for industrial uses and is currently occupied by a moving and storage operation and has been at this location since the early 1980s. From prior to 1941 to the early 1980s a chemical plant and a foundry occupied this property.	Metals including **Lead**, polycyclic hydrocarbons, solvents.
10). Industrial use (Former Water Treatment Plant) Area North of Durham Street and West of Welland Street.	Currently this area of Port Colborne is unoccupied. However, from prior to 1941 to the early 1990s the Port Colborne Scrap Iron and Metal Yard (Industrial Disposal) and the Port Colborne Vinyl Window Company occupied this area of Port Colborne. Also the former site of the water treatment plant.	Metals including **Lead**, solvents, volatile organic compounds, and polycyclic hydrocarbons.
11) Inco Refinery	(refer to Section 4).	CoCs and possibly **Lead.**
12) Joe's Radiator and Solder Workshop	Repair of automotive radiators.	Metals including **Lead**, polycyclic hydrocarbons, and solvents.
13) OPG Transformer	Electrical transformer.	Oils, PCBs, metals and possibly **Lead.**

Potential Sources of Lead (for individual location, refer to Figures 2.2 and 7.1)	**Historical Activity**	**"Likely" Contaminants Released to Environment**
14) Former CN Track	Railway ties, ballast material and maintenance.	Petroleum hydrocarbons, arsenic (from railway ties) and other metals including **Lead**.
15) Forge	Forge operations.	Metals including **Lead**.
Domestic Sources within the residential East Side Community	The majority of the urban areas of the East Side Community south of East-West running CN railway tracks were developed after the 1910s and 1920s. In this area, 94% of the houses were constructed before 1949. Site development and road construction involved use of fill (slag and spent materials) most likely obtained from the Algoma Plant and other industrial sources, (as these were the cheapest sources of fill).	**Lead** and other metals.
	Older houses used lead-based paints on both exterior and interior surfaces. Lead leached from the paints by rain and removed from exterior surfaces by peeling, flaking, scrapping, sand blasting and grinding, resulted in the surrounding soil becoming lead contaminated.	**Lead,** barium, zinc and other metals.
	Historically, the use of lead additives in gasoline resulted in the release of lead in automobile exhaust and contamination of soil near the roadways. As the East Side Community is a mature urban residential area (from 1910 to present), it received significant contribution of leaded gasoline exhaust until 1978 when the use of lead additives in gasoline was finally phased out.	**Lead** and other metals and petroleum hydrocarbons
	Traditional old urban domestic land use practices included lead soldered plumbing fittings, lead based pesticides for gardening, lead containing debris from automobile batteries, glassware, ceramics, and fishing sinkers.	**Lead** and other metals.

The East Side of the City of Port Colborne is an old urban area that started development at the beginning of the last century. Historically, the land use was mixed industrial/commercial and residential, that included Algoma Steel, Inco Refinery, CN Railway yard, coal storage yards, scrap metal yards, foundaries, a forge shop, gas stations, a lumber yard, a water treatment plant, auto body shops, metal fabrication, a plating company, dry cleaning facilities, as well as domestic activities. It is possible that any one or more of these potential industrial/commercial point sources may have contributed to the elevated concentrations of soil lead found in the East Side Community as depicted by the 11 MOE-identified areas (Section 3.1.4) of soil lead concentrations exceeding 1000 ug/g. The locations of these 11 MOE-identified areas of soil lead exceedances, in relation to the above mentioned potential industrial/commercial point sources, are found on Figure 7.1.

Inco is identified as one of these point sources, but contribution from deposition of particulate-containing lead from Inco aerial emissions was predicted to account for only 0.3% (via air dispersion modelling - Section 5.4.6) to 3 % (via regression modelling - Section 6.3.4) of the elevated lead in these 11 areas. Thus other sources of lead from industrial/commercial operations and domestic activities are responsible for the majority of the soil lead composition in the East Side Community.

Table 7.2 outlines some geographic linkages between the 11 MOE-identified areas of elevated soil lead (MOE 1-10) and adjacent or nearby industrial /commercial/domestic operations as potential lead sources within or abutting the East Side Community.



POTENTIAL INDUSTRIAL / COMMERCIAL SOURCES OF LEAD

EAST SIDE OF PORT COLBORNE, ONTARIO

Job No.:	Dwg. No.:	
ONT35313	**5.1**	
Date:	Dwn. by:	Appd.:
03/01/03	**LMV** LMV	**MA**

Jacques Whitford

Table 7-2 Potential Sources of Localized Soil Lead Exceedances in East Side of Port Colborne, Ontario

MOE-Identified Area of Soil Lead Exceedance (Fig. 7.1)	Potential Source(s) of Lead	Potential Industrial/Commercial Source (refer to number in legend of Fig. 7.1)
MOE1	Domestic	--
MOE2	1) Domestic 2) MOE10 is next to Historic Gas Station	5
MOE3	1) Domestic 2) MOE3 is down wind of Scrap Metal Piles at DWOR Yard	3
MOE4	1) Domestic 2) Lead-Acid Batteries 3) Thurston Machine Works	4
MOE5	Domestic	--
MOE6	1) Domestic 2) MOE6 is down wind of Scrap Metal Piles at DWOR Yard	3
MOE6A	1) Domestic 2) MOE6A is down wind of Scrap Metal Piles at DWOR Yard	3
MOE7	Domestic	--
MOE8	Domestic	--
MOE9	1) Domestic 2) MOE9 is down wind of Historic Auto Body Workshop	5A
MOE10	1) Domestic 2) MOE10 is next to Historic Gas Station	5

7.2 DOMESTIC SOURCES OF LEAD IN URBAN COMMUNITIES: LITERATURE REVIEW

JWEL conducted a literature review of the common sources of lead; along with the average lead levels in soil, in old urban communities throughout the United States and Canada.

Lead is naturally present in soil at levels of less than 120 parts per million (ug/g) (MOE, 1996; Table F). Lead in surface soil in residential communities is commonly higher than 200 ug/g. In older, urban residential areas, lead in soil on some properties may range from 500 to 1,000 ug/g, even when there is no local industrial source (MOE, 2001).

Lead has several chemical properties, which have made it very attractive for use in many different products; including abundance, high density, softness, malleability, low melting point, resistance to corrosion, poor electrical conductivity, shielding from gamma and X-rays and ability to reduce sound (Metropolitan Toronto Teaching Health Units and the South Riverdale Community Health Centre, 1995).

A steady stream of lead has entered the environment during the past century from several major sources: leaded paint, leaded gasoline, tin food and beverage cans, drinking water, lead-acid batteries, lead-glazed ceramic ware, pottery, leaded crystal and industry (Mielke, 1997a; Bisessar and McLaughlin, undated; Kinder, 1997).

The plumbing inside houses built before the 1950s may partly consist of lead pipes and the service connection that leads into some older houses may also be made of lead (Health and Welfare Canada, 1992; CMHC, 1997; Regional Niagara Public Health Department, 2001).

Lead-acid batteries are also a major source of environmental lead. Batteries are the single largest use for lead, with typical passenger car batteries comprised of approximately 50 % lead. In 1986, with over 11 million cars registered in Canada, this resulted in over 100,000 tons of lead in circulation on the roads. The estimated scrappage rate of batteries is four million units per year or 75,000 tons of lead (Metropolitan Toronto Teaching Health Units and the South Riverdale Community Health Centre, 1995).

Some types of pottery are decorated with lead-based glazes, beverages or other liquids stored in lead crystal for long periods may contain high levels of lead, some cans are sealed with lead solder and some hobby materials used in crafts may contain lead (CMHC, 1997). However, of all the contributors to lead in the environment, the two major sources of soil-lead contamination are lead-based paint and lead from auto emissions (Rosen, 2002; Logan and Miller, 1983; Mielke 1999; Logan, 1993).

7.2.1 Leaded Paint

Although all children are exposed to some lead from food, air, dust and soil, lead-based paint is the most widespread and dangerous high-dose source of lead exposure for pre-school children. Lead paint exposure still accounts for as much as 90% of childhood lead poisoning (Kinder, 1997) even though lead-based paint is no longer used in most consumer goods. In 1978 the Consumer Product Safety Commission (CPSC) banned its sale for use in residences, on children’s toys or on household furniture (US EPA, 1998b) but lead paint that already exists in the environment continues to cause problems.

The use of leaded paint peaked during the 1920s and gradually fell off until its ban in the 1970s (Mielke, 1997a; Kinder, 1997). Until shortly after World War II, lead was used as a pigment in many paints, especially white and pastel shades (Health and Welfare Canada, 1992). Manufacturers used lead pigments in paint because the pigments make the paint last longer and cling to surfaces better (US EPA, 1998b; Health Canada, 1995). Some paints contained as much as 70 % lead by weight, with paints prior to the 1970s containing lead levels up to 500,000 ug/g (Metropolitan Toronto Teaching Health Units and the South Riverdale Community Health Centre, 1995).

Other pigments began to replace lead in the 1950s, but smaller amounts were still used in some paints as a sealant or to speed up drying. In 1976, Canadian federal government regulations limited the amount of lead in interior paint to 0.5 % by weight. Exterior paint may contain more lead, but must be labelled with a warning. Most paint manufacturers have now voluntarily stopped using lead altogether (Health and Welfare Canada, 1992; Health Canada, 1995).

The Canadian Paints and Coatings Association suggests that any home or apartment built before 1980 may contain lead-based interior or exterior paint, and that homes built prior to 1950 may contain especially high amounts (Metropolitan Toronto Teaching Health Units and the South Riverdale Community Health Centre, 1995; CMHC, 1997; Health Canada, 1995; CPCA, undated).

In the U.S. it is estimated that about 3 million tons of lead remain in an estimated 57 million (74 %) private homes built before 1980 (Metropolitan Toronto Teaching Health Units and the South Riverdale Community Health Centre, 1995). As many as 60% of all housing units in Massachusetts (up to 85% in urban areas) contain lead paint. This is approximately 1.2 million dwellings in Massachusetts alone (Kinder, 1997).

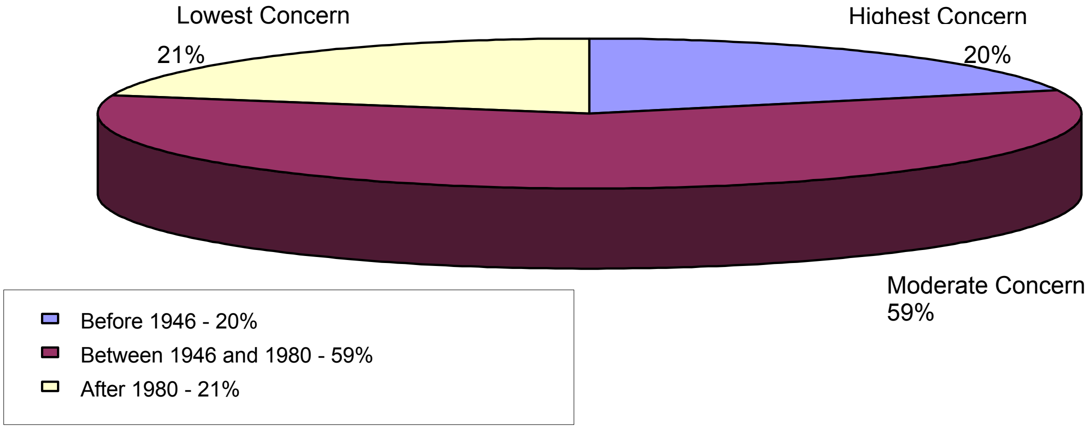


Figure 7-2 Age of Housing Stock and Lead Concern (Metropolitan Toronto Teaching Health Units and the South Riverdale Community Health Centre, 1995)

In Ontario, it is estimated that there are over 2 million private dwellings that were built prior to 1970 that could contain heavily leaded paints. Approximately 20 % of the dwellings in Ontario were built prior to 1946 and are of the highest concern because of the high levels of lead in paint prior to 1950. Approximately 59 % of Ontario’s dwellings were built between 1946 and 1980, and are associated with a moderate level of concern because leaded paints were still in use (Figure 7.2) (Metropolitan Toronto Teaching Health Units and the South Riverdale Community Health Centre, 1995; Regional Niagara Public Health Department, 2001). All post 1992 consumer paint produced in Canada or the U.S. is virtually lead-free (Health Canada, 1995).

The major cause of soil contamination by lead in populated areas is the weathering, chipping, or sandblasting of structures bearing lead-based paint (SLUG, 2002). The paint can flake or peel and fall into the soil around the area. Dust can become contaminated with lead when lead-based paint is dry scraped or sanded (US EPA, 1998b), or from friction from opening and closing doors or windows with painted frames (Health and Welfare Canada, 1992). The Environmental Protection Agency (EPA) found in a literature search that lead-based paint is often cited as the source responsible for higher concentrations of lead in the surrounding soil; homes with extreme lead levels in their soil were often found to be coated with lead-based paint (US EPA, 1998a).

In their 1995 report, Bissear and McLaughlin, of the Ontario Ministry of the Environment, reported data that clearly establishes a link between higher concentrations of lead and other metals in soil near the walls of houses painted with lead-based paints. **Analysis of paint chips collected from residential yards of older urban homes in Ontario showed that the paint contains up to 31% or 310,000 ug/g of lead (Bisessar and McLaughlin, undated). Soils adjacent to houses painted with exterior lead based paint may contain lead levels as high as 10,000 ug/g.**

Exterior lead-based paint in Minnesota was the major source of soil contamination near private dwellings (Trippler et al., 1988). A soil survey conducted in Christchurch New Zealand showed that wooden houses painted with lead-based paints had higher lead concentrations in their surrounding soil than houses constructed of other materials (Jordan and Hogan, 1975).

In Toronto, the mean metal concentrations (ug/g, dry weight) in paint chips from the exterior of residential properties, show that metal concentrations are clearly much higher in older, pre-1975, lead-based paint. Furthermore, soil lead concentrations within 3 m of the exterior wall of older buildings that had been painted with lead-based paint were consistently higher than soil at least 5 m from the wall. The mean lead concentration from paint samples collected from the exterior walls of older houses was 64,355 ug/g, compared to only 35 ug/g lead in paint from newer homes painted with low-lead paint (Bisessar and McLaughlin, undated). In the same study, lead concentrations of soil within 3 m of the exterior walls were significantly greater ($p<0.001$) than the soil further than 5 m from the walls. As an example, one property with crumbling layers of paint on a brick wall and a wood porch, had a mean soil concentration of 890 ug/g of lead within 3 m of the external wall, and a 290 ug/g lead concentration 5-m from the wall (Figure 7.3) (Bisessar and McLaughlin, undated).

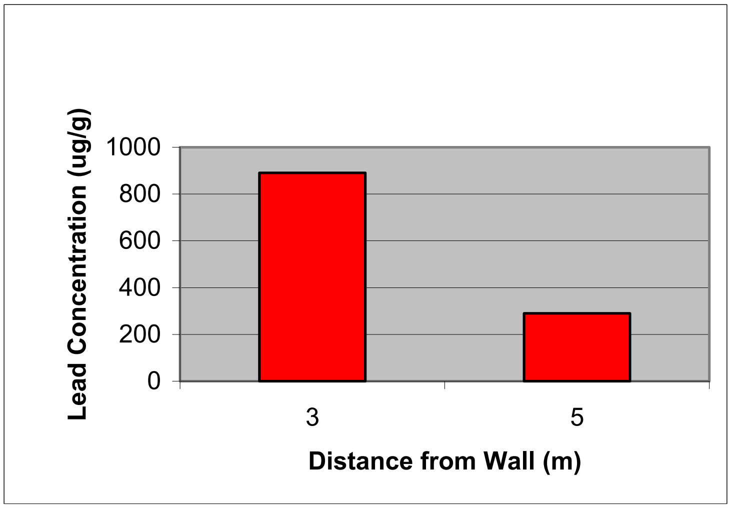


Figure 7-3 Mean Soil Lead Concentration in Proximity to a Wall with Crumbling Layers of Lead Paint (Bisessar and McLaughlin, undated)

Many studies identified in the February 1998 literature review (reviewing 36 relevant studies), *Sources of Lead in Soil*, by the Battelle Memorial Institute, distinguished an area pattern to lead contamination of soil at a residence. In general, samples collected near the foundation of residences had higher lead concentrations than samples collected at more remote locations. Virtually every sample exceeding 2,000 ug/g and 140 of 160 samples exceeding 1,000 ug/g were collected near house foundations (Battelle Memorial Institute, 1998).

7.2.2 Leaded Gasoline

In the past, the use of tetraethyl lead as an anti-knock ingredient in gasoline was a significant cause of soil contamination by lead (SLUG, 2002). Leaded gasoline released 250,000 tons per year of the heavy metal into the environment during the 1970s before its use was curtailed in 1986 (Mielke, 1997a; US EPA, 1998b). Soil lead levels increased during the 1970s and 80s when emissions from cars with leaded gasoline reached their peak (Mielke, 1999). In 1985, motor vehicle emissions accounted for 81 % of lead emissions nation-wide in the U.S. (DEQ, 2001). Between 1976 and 1990, lead used in gasoline declined by 99.8 % in the United States (Kinder, 1997).

Lead contaminated soil's associated health problems became well known after an expressway in San Francisco collapsed during an earthquake. Children playing in the soil next to the broken structure were lead poisoned. The soil, in this case tainted from decades of leaded gasoline use, contained many hundreds of parts per million of lead (ECME, 2001).

Studies conducted in urban areas have shown that soil lead levels are highest around building foundations and within a few feet of busy streets (Rosen, 2002). Soils near a heavily travelled roadway are typically 30 to 2,000 ug/g higher than soils in a natural area. In Honolulu, Hawaii, Fu (Fu et al., 1989) noted that soil-lead concentrations in a boulevard median strip adjacent to a park was 1650 ug/g, and that, elsewhere through the park, soil lead levels fell with distance from the boulevard. A longitudinal study of soil-lead concentrations adjacent to a newly constructed roadway conducted near Beltsville, Maryland noted that, soil lead levels decreased with distance from the roadway and with depth in the soil profile (Milberg et al., 1980). Francek measured a median soil-lead concentration in roadside soils of 280-ug/g (range: 100-840-ug/g), compared to 200-ug/g (range: 100 to 220-ug/g) in background soils (Francek, 1992).

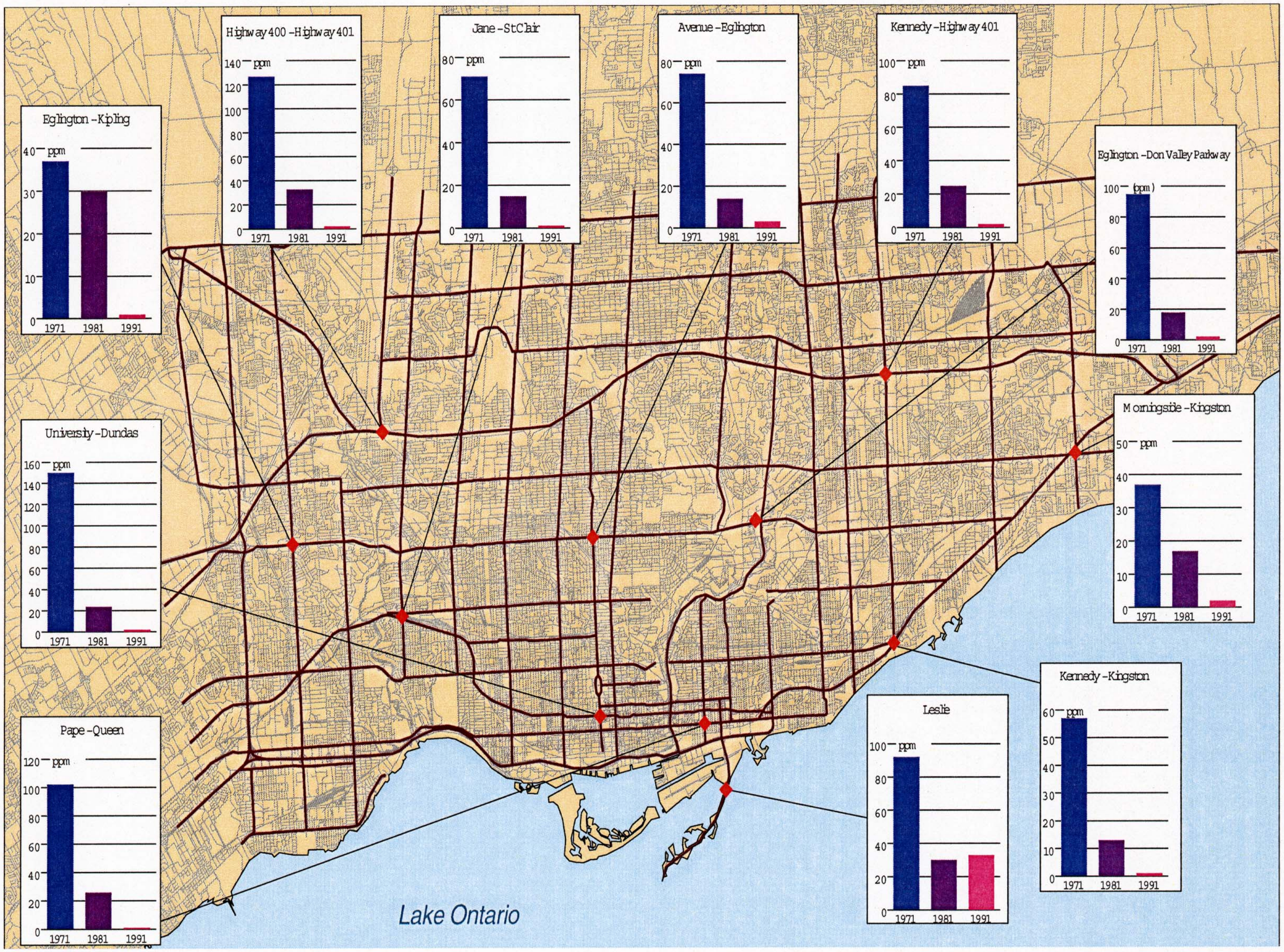
Figure 7.4 (MOE, undated) shows plots of the tree lead concentration distribution in various parts of the City of Toronto in 1971, 1981 and 1991. These plots show lead concentrations in trees decreasing notably with time reflecting the phasing out of leaded gasoline.

Since lead is not biodegradable and migrates very little through the soil, it persists over many hundreds of years (SLUG, 2002; Rosen, 2002; Logan, 1993). This results in past uses of leaded paint and gasoline to continue to be present problems (SLUG, 2002; Rosen, 2002).

7.2.3 Soil-Lead Concentrations in Urban Residential Areas

The EPA has established a bare soil standard of 400 ug/g (ASA, 2003; US EPA, 1994) and it has been considered safe to use garden produce grown in soils with total lead levels less than 300 ug/g (Rosen, 2002). In the range of 400 to 5,000 ug/g, only limited interim controls are recommended for the site (US EPA, 1994). The EPA has estimated that more than 12 million children living within U.S. urban environments are exposed to risk from about 10 million metric tonnes of lead residues resulting from the use of leaded gasoline and lead-based paint (Mielke 1999).

Toronto Tree Lead Concentraion Draft Map

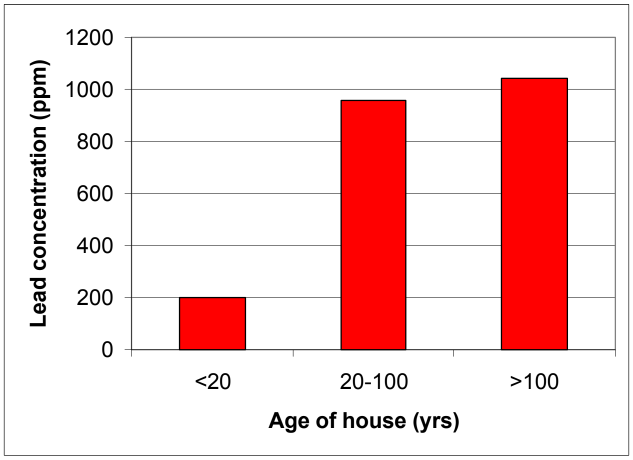


There is no federal statutory limit for lead in soil in Canada. The Ontario Ministry of the Environment has established a generic guideline for lead in urban residential surface soil (0-5 cm) in Ontario of 200 ug/g (MOE, 1996; Table A).

The International Joint Commission has estimated atmospheric lead deposition to the Great Lakes to be over 2 million kg/year. Lead sediment concentrations in the Great Lakes region range from 5 ug/g to 20,000 ug/g with a Provincial Sediment Guideline of 31 ug/g proposed as the lowest effect level on aquatic organisms. Levels as high as 850 ug/g dry weight have been measured in sediments taken from Toronto harbour (Metropolitan Toronto Teaching Health Units and the South Riverdale Community Health Centre, 1995). Deposition to soils is not well documented, although it is recognised that urban soils tend to have higher lead concentrations than rural soils due to the presence of industries and higher traffic volume (Metropolitan Toronto Teaching Health Units and the South Riverdale Community Health Centre, 1995).

An article published in the Journal of the American Medical Association noted that in the U.S. approximately 11 % of pre-1980 homes are estimated to have soil lead concentrations exceeding 1,000 ug/g (Matte, 1999). According to a 1996 National Survey by the EPA, it is estimated that 23 %, or 18 million, of the privately-owned homes in the United States built before 1980 have soil lead levels that exceed the 400 ug/g “further evaluation” guideline. An estimated 8 %, or 6 million, of the privately-owned homes in the United States built before 1980 have soil lead levels that exceed the 2,000 ug/g “interim control” guideline. Finally, an estimated 3 %, or 2.5 million, of the privately-owned homes in the United States built before 1980 have soil lead levels that exceed the 5,000 ug/g soil abatement guideline (US EPA, 1996). Francek (Francek, 1992) in Mt. Pleasant, Michigan, completed another study, looking at building age as a predictor of soil-lead level. **The following relationship was found between age of home and median soil-lead concentration at the home’s foundation: less than 20 years, 200 ug/g; 20 to 100 years, 960 ug/g; greater than 100 years, 1040 ug/g (Figure 7.5). The majority of homes in the East Side Community of Port Colborne fall in the 20-100 year (960 ug/g) category.**

Figure 7-5 Median Soil Lead Concentration versus House Age (Francek, 1992)



In a 1996 EPA national survey, the strongest predictor of soil lead was found to be the building age, with housing units built before 1940 having significantly higher lead in soil around them, than those built between 1960 and 1979 (Figure 7.6) (US EPA, 1996). This is in agreement with the fact that older houses are more likely to have been painted with lead-based paint.

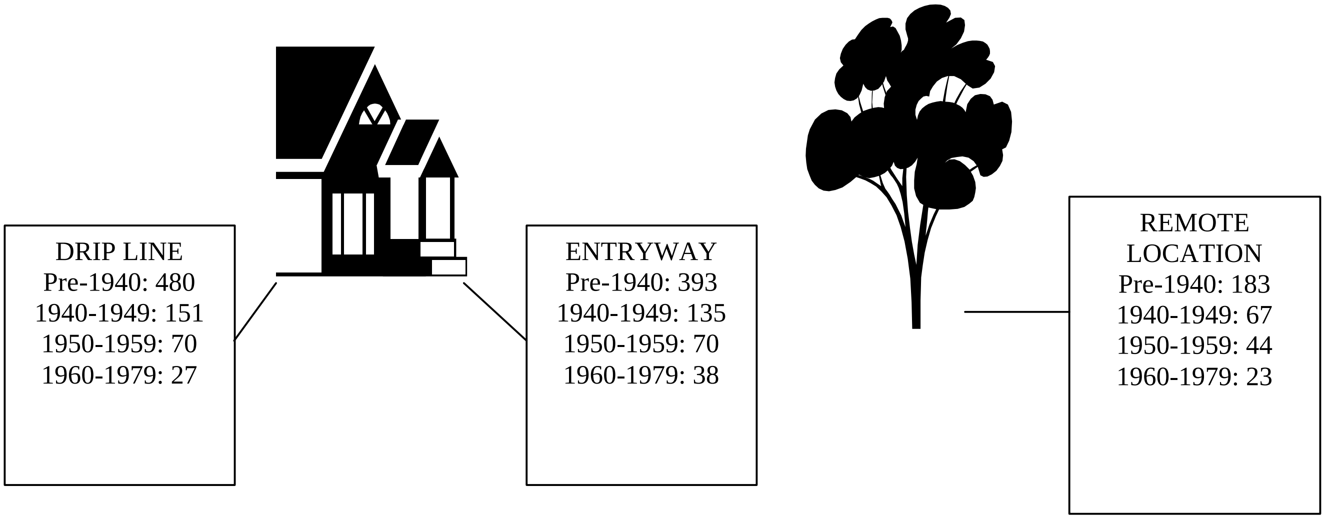


Figure 7-6 Weighted Geometric Means for Soil Lead Concentrations (ug/g) by Soil Location and Housing Unit Characteristic for Private Housing Units (US EPA, 1996)

In the above 1996 EPA study, samples were taken in three places: outside of the main entrance to the building unit, at a selected location along the drip line of an exterior wall, and at a remote location (away from the building, but still on the property). In private housing units, the arithmetic mean at the entrance was 327 ug/g, along the drip line was 448 ug/g and at the remote sample locations the mean was 205 ug/g (US EPA, 1996). This shows a decrease in soil lead levels with increasing distance from the building (Table 7.3).

Table 7-3 Descriptive Statistics (weighted) for the Lead Measurements in Soil Samples at Each Soil Location in Private Housing Units (US EPA, 1996)

Set of data	Entrance Samples	Drip Line Samples	Remote Samples
Number of Measurements	260	249	253
Arithmetic Mean (ug/g)	327	448	205

There have been many other soil-lead studies and soil samples taken throughout the United States and Canada. A study was conducted where surface soil samples were collected and analysed from approximately 100 sites in Marion County, Indiana. It was found that lead concentrations typically ranged from 50 to 300 ug/g and decreased exponentially as samples moved away from roads, often decreasing from approximately 400 ug/g roadside, to 50 ug/g at a distance of 50 m from a road (Filippelli, 2002).

In Minneapolis, soil lead levels average 300 ug/g, which is common for an urban area. In the Phillips neighbourhood in Minnesota, soil lead levels above 1,000 ug/g are common, and levels as high as 5300 ug/g have been recorded through soil lead tests taken through a neighbourhood lead study (Zoll, 1998).

7.2.4 Literature Review on Southern Ontario Communities of Similar Age to East Side Port Colborne

A review of the MOE March 2002 report, on their soils investigation of the East Side Community of Port Colborne, indicates that the observed soil lead contamination in this community was attributed to the domestic use of lead-based paints and through the deposition of leaded paint chips and dust particles produced either during paint removal operations or from weathered paint chips of houses built before the 1970s. JWEL's historical review of the East Side Community and vicinity indicated that most of the houses were built prior to the 1950s. Based on Port Colborne municipal tax records, MOE revealed that in the East Side Community, about 40% of the houses were built before 1920, about 54% were constructed between 1920 and 1949, and only about 6% of the houses were built after 1950. Thus the potential of having exceedances of soil lead in the East Side Community due to the historical removal and weathering of old lead based paint is high (MOE 2002).

Figure 7.7 summarises an extensive survey completed by the Ministry of Environment and Energy (MOEE) in 1994. The study indicated that in Ontario, the range of lead levels in urban soils is from 5 to 845 ug/g, with a mean of 123 ug/g (MOE, 1994; MOE, 1993). Even in rural soils, there are cases where the lead levels reached 360 ug/g (MOE, 1994). Old urban areas, as shown in a survey of downtown Toronto neighbourhoods, indicated high soil lead-levels (500 ug/g), probably due to weathered lead paints and historical deposition from leaded fuels or specific point sources (MOE, 1994).

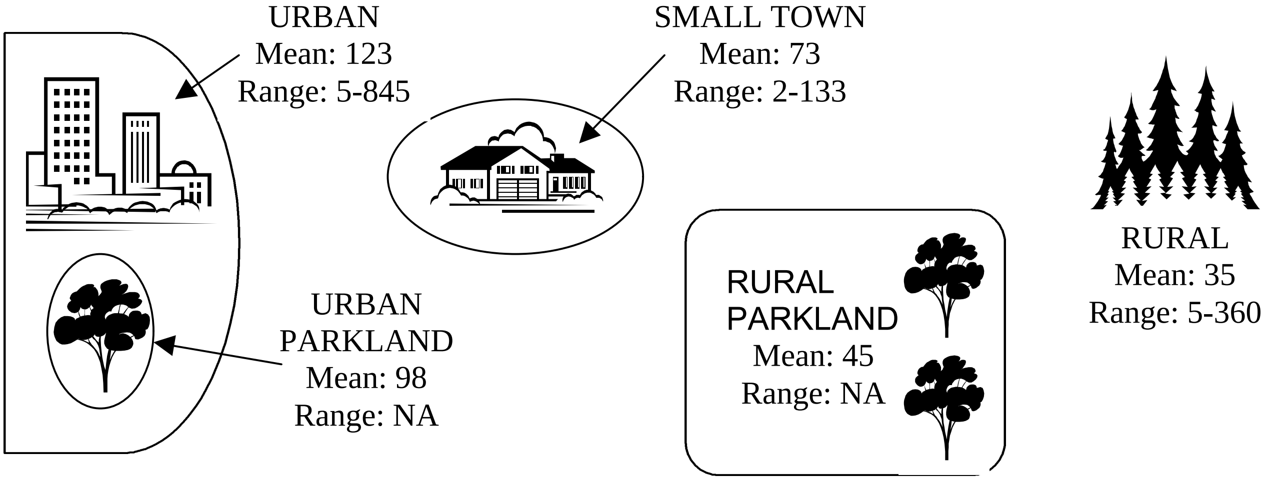


Figure 7-7 Mean Lead Levels in Soils Remote From Specific Industrial Sources (units - ug/g; NA - Data not available (MOE, 1994)

In 1999 and 2000, the Ontario Ministry of the Environment, Ecological Standards and Toxicology Section conducted several phytotoxicology studies in Sarnia and Welland, Ontario. Soil samples were collected at 11 to 21 different sites on each property that required investigation. All properties were found to have surface soil lead levels exceeding the MOE health-based guideline of 200 ug/g. Soil lead concentration levels ranged from 31 to 3,400 ug/g. On one site, 10 of 14 samples showed lead concentrations over 200 ug/g. Another site showed that lead concentration in surface soil decreased with increased distance from the residence (MOE, 2000) (Figure 7.8).

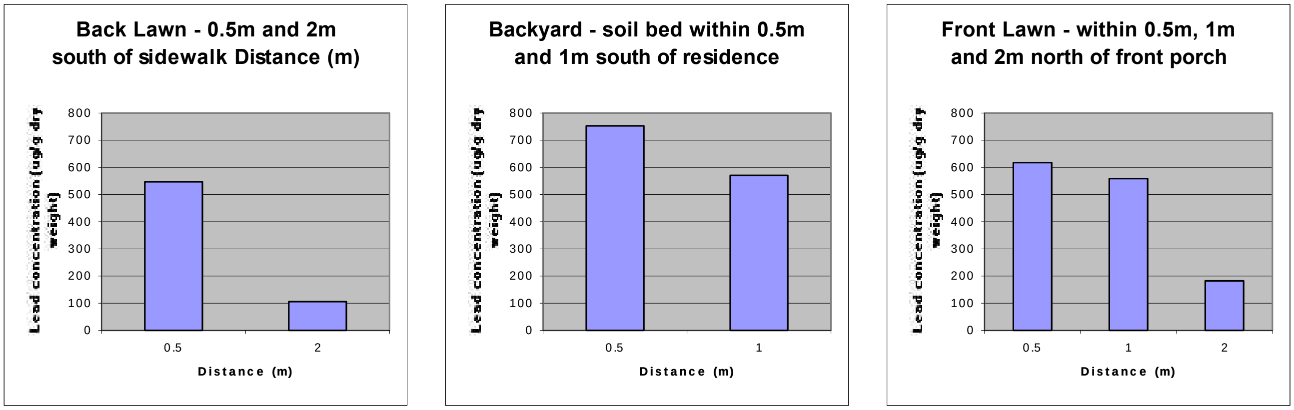


Figure 7-8 Lead Concentrations in Soil at a site in Welland, Ontario * (MOE, 2000)

A review of the MOE 2002 report shows that lead concentration in soil samples collected around the community of Welland (located approximately 15 km north of Port Colborne) are similar to those found in the East Side Community. The following is an excerpt from the MOE 2002 report:

> *"In similar investigations of several properties in Welland the soil lead levels averaged between 237 ug/g and 329 ug/g generally across the properties and ranged up to 1,796 ug/g in close proximity to painted exterior walls. The Welland homes also were very similar in age and construction to many homes in the Rodney Street community. Although not community wide studies, these recent MOE investigations in Sarnia and Welland indicated that soil lead levels like those detected in the Rodney Street community are not anomalous for older urban residential areas and can occur in the absence of a local lead source."*

According to Howard Mielke, an Associate Professor of Environmental Toxicology at Xavier University of Louisiana, who has spent 25 years characterizing lead dust patterns in urban areas, soil lead concentrations relate to city size, nearness to city centres and distance from houses or roads (Mielke, 1997a). In general, larger older cities have more soil lead contamination than smaller, older cities. Inner city areas with historical heavy traffic congestion have higher soil lead levels than outer lying residential or suburban areas. Soil near building foundations and streets typically have more lead than soils in yard areas (Mielke, 1997a).

7.2.5 Literature Review of Soil Lead from Lighthouses

Sections 7.2.1, 7.2.3 and 7.2.4 have pointed to lead-based paint, predominantly from the weathering of exterior surfaces of older homes, as the source largely responsible for higher concentrations of lead in surrounding soil in urban residential areas. The highest soil-lead concentration levels were found invariably at the foundation of buildings due to flaking of lead-based paint. However, the actual leaded paint signature is difficult to identify because of other confounding domestic, industrial or commercial influences.

To that end, JWEL has examined the soil quality around lighthouses in Canada to identify a leaded paint signature. Lighthouses are generally in remote locations, far removed from any industrial or commercial sources of lead and not exposed to historical leaded gasoline from excessive traffic activity. The only source of lead around these lighthouses would come from decomposition of lead based paints and the flaking off of paint chips from the exterior walls and then into the soil.

JWEL obtained soil analytical data (**Appendix K**) from the Coast Guard covering over 30 lighthouses in British Colombia. Data on the lighthouses used in this study are listed in Table 7.4 along with the mean lead concentrations as well as the maximum lead concentrations found in the soils around these lighthouses.

Table 7-4 British Colombia Lighthouse Soil Lead Concentrations

Site Name	Maximum Soil Lead Concentration (ug/g)	Mean Soil Lead Concentration (ug/g)
Addenbroke Island	25300	869
Active Pass (Georgina Pt.)	3370	215
Ballenas Island	13800	1354
Boat Bluff	402	50
Cape Beale	3580	178
Bonilla Island	8730	1438
Carmanah Point	11500	481
Chrome Island	4170	156
Cape Scott	16400	648
Chatham Point	3770	230
Discovery Island	12800	998
Dryad Point	45800	2005
East Point (Saturna)	1390	155
Egg Island	4540	324
Entrance Island	2200	150
Estevan Point	19500	2154
Green Island	22700	946
Ivory Island	2900	488
Langara Point	6110	863
Lennard Island	12700	958
McInnes Island	60670	1102
Cape Mudge	1550	137

Site Name	Maximum Soil Lead Concentration (ug/g)	Mean Soil Lead Concentration (ug/g)
Merry Island	34300	2711
Nootka Island	9090	1224
Pachena Point	18200	1868
Pulteney Point	10700	1408
Pine Island	115000	5728
Portlock Point (Prevost Island)	337	39
Quatsino	9010	601
Scarlett Point	9810	1441
Trial Island	14100	1357
Overall Range	337 to 115000	39 to 5728

A Spearman Rank Correlation was performed on the lighthouse data to establish a lead paint-in-soil signature. The correlation results, as shown in **Appendix K** on the arithmetic means, show a relationship amongst lead, barium, and zinc, as well as, amongst lead and antimony, cobalt, iron and manganese. The strong lead: barium: zinc relationship is indicative of a lead based paint source; the same relationship evident in East Side Community soils (Section 7.3.3, Table 7.6).

7.2.6 Summary of Literature Review Findings

JWEL conducted a literature review of the common sources of lead, along with the average lead levels in soil, in old urban communities throughout the United States and Canada. Based on the information gathered, the literature review findings can be summarised as follows:

- Lead in surface soil in residential communities is commonly higher than 200 ug/g. In older, urban residential areas, lead in soil on some properties may range up to 5,300 ug/g, even when there is no local industrial source. The source of high soil lead in areas remote from industry can normally be attributed to urban and domestic activities.

- A steady stream of lead has entered the environment during this century from several urban and domestic sources, including: leaded paint, leaded gasoline, tin food and beverage cans, drinking water, lead-acid batteries, lead-glazed ceramic ware, pottery and leaded crystal.

- Lead-based paint (predominantly found in and around older homes) is often cited as the source responsible for higher concentrations of lead in the surrounding soil. The highest soil-lead concentration levels are invariably at the foundation of buildings due to flaking of lead-based paint. While leaded gasoline emissions spread their lead exposure over a wide area, lead-based paint likely contaminates a relatively small region about the residence.

- The observed lead concentrations in soil samples collected from the East Side Community (ranging up to 1,800 ug/g) have been found in the literature to be similar to those found in other communities (ranging up to 3,400 ug/g) in Southern Ontario of similar age.

- Median soil lead concentrations around British Columbia lighthouses were found to range from up to 5,728 ug/g and was attributed solely to lead-based paint. The characteristic leaded paint-in-soil signature based upon the lighthouse data is a strong lead: barium: zinc relationship.

7.3 CHARACTERISTICS OF EAST SIDE PORT COLBORNE SOIL

The literature review revealed extensive domestic/urban uses of lead-based substances in older urban residential areas such as the East Side Community. The overwhelming bulk of literature and information on urban or domestic sources of lead in older communities focuses on the historical use of lead based paints. In addition, localized areas in older urban residential areas could be contaminated with debris resulting from dumping, spillage and/or weathering of automobile batteries, old lead soldered plumbing fittings, leaded gasoline, glassware, ceramics, TV tubes, fishing sinkers and lead shots. Exposure of any of these products to the natural environment can release significant concentrations of lead to soil and water.

The following sections deal with the characterization of soils from the East Side Community with the intent of determining a link between elevated soil lead levels and the community's past domestic practices.

7.3.1 Analysis of Soil-Containing Paint Chips

As mentioned in Section 7.2.4, the MOE March 2002 report (MOE, 2002) indicated that paint chips from flaking paint are often visible on the soil in residential yards of old urban homes. Jacques Whitford's historical review of the East Side Community and vicinity indicated that most of the houses were built prior to the 1950's. Thus, the historical removal and weathering of old lead based paint may account for the observed soil lead exceedances in the East Side Community.

To determine if lead based paint chips were a potential source of elevated lead levels in surficial soil samples, Jacques Whitford visually examined for evidence of paint chips, if any, from three archived soil samples, one (1) (TP-9 at 0 to 5 cm depth) from the East Side Community and two (2), SS-6 and SS-11 at 0 to 5 cm depth in younger residential communities located to the north of the East Side Community. Soil lead concentrations in all of these three samples were above 200 ug/g. Sample TP-9 was taken from a location on Rodney Street in the East Side Community. Samples SS-6 and SS-11 were taken at residential locations 4.2 km and 1.1 km northeast and north of the Inco Refinery, respectively.

Jacques Whitford soil technicians sieved these archived soil samples using a 2 mm sieve and found visual evidence of paint chips in the greater than 2 mm size fraction in all three samples. These paint chips were separated from the soil mass and submitted to the Lakefield Research Laboratory for scanning electron microscope (SEM) analysis. Lead was confirmed in the paint chips extracted from all three soil samples. Copies of Lakefield's SEM spectra and photo micrographs are provided in **Appendix L.**

Of the three submitted samples for elemental analyses by SEM, the paint chips retrieved from TP-9 contained relatively more lead and less titanium. Contrary to this, the paint chips retrieved from SS-6 and SS-11 contained relatively higher titanium and lower lead content. The differences in lead and titanium compositions in these paint chips and the relative locations of TP9 in the older East Side neighbourhood compared to that of SS6 and SS11 in relatively newer neighbourhoods, suggest that most likely they represent two different generations of lead based paints. The historical background review of the east side of Port Colborne indicates that the majority of the houses in the residential communities to the north of the East Side Community were constructed after the 1950's, whereas the houses in the East Side Community were constructed before the 1950's. The paint chips retrieved from TP-9 in the East Side Community represent an earlier generation of paint (pre 1950's) when lead paint bases were common. The paint chips retrieved from SS-6 and SS-11, ie. in the residential communities to the north of the East Side Community, represent a later, or younger generation of paint (most likely post 1950's) when titanium started replacing lead as the base of paint.

To quantify the concentration of lead in the paint chips of archived samples TP-9, SS-6 and SS-11, the lead-bearing paint chips were removed from the SEM stubs and analysed chemically using ICP at the Lakefield Research laboratory. Lakefield's laboratory certificates of chemical analyses are provided in **Appendix M.** The chemical test results revealed that the analysed paint chips on the greater than 2 mm in size fraction contained 258,000-ug/g of lead in TP9, 7,500-ug/g of lead in SS-6 and 4,600-ug/g of lead in SS-11.

7.3.2 Analyses of Soil Materials Greater than 2 mm Size

For the most part, the soil chemical data for the CBRA and the reported concentrations in Section 3 of this report were based on chemical tests conducted on soil samples less than 2 mm in size as per the MOE-approved methodology HMPNSOIL-E3073A (MOE, 1994) and the CBRA analytical protocol (JWEL, 2001c). Any lead contribution from lead based paint chips in soil samples taken from older homes (e.g., TP9) that may have been larger than 2-mm in size would not have been determined and thus would not have been accounted for in the reporting of the CBRA chemical results.

To confirm the above assumption, portions of the greater than 2-mm size fraction of soils from TP-9, SS-6 and SS-11 were crushed to pass through a 2-mm sieve and submitted to Philip Laboratory in Mississauga, Ontario for ICP analysis. The Philip Laboratory certificates of chemical analyses are provided in **Appendix M.** The chemical test results of soil lead concentrations in the greater than 2-mm size fraction were 4,090-ug/g in soil TP-9 for the older community, and 133-ug/g in soil SS-6 and 567-ug/g in soil SS-11 for the younger communities. Thus the above assumption has been proven to be correct for the older East Side Community as typified by soil sample TP9.

7.3.3 Summary of Port Colborne Soil Composition

Table 7.5 summarises the analytical lead concentrations found in soil samples TP-9, SS-6 and SS-11 for:
i) the soil fraction less than 2 mm size,
ii) the soil fraction greater than 2 mm size, and
iii) the physically extracted paint chip samples.

Referenced data from the MOE report (MOE, 2002) on literature-reported lead values of paint chips and of soils from older residential communities are included in Table 7.5 for comparison purposes.

Table 7-5 Lead Concentrations in Port Colborne Soil Samples

Sample Location	Lead in Paint Chip (ug/g) Extracted	Lead in Soil (ug/g) Greater than 2 mm Size	Lead in Soil (ug/g) Less than 2mm Size
Referenced Literature Data[a]	310 000	-	890
TP-9, 0 to 5 cm depth, residential East Side Community area	258 000	4 090	341[b]
SS-6, 0 to 5 cm depth, residential area 4.2 km Northeast of Inco Refinery	7 500	133	222[b]
SS-11, 0 to 5 cm depth, residential area 1.1 km North of Inco Refinery	4 600	567	256[b]

Notes:

a	MOE Soil Investigation and Human Health Risk Assessment for the Rodney Street Community: Port Colborne, March, 2002
b	JWEL (2001b) report
-	No Data

As shown in Table 7.5, 258,000-ug/g of lead was detected in a paint chip from the older East Side Community soil (TP-9). This concentration is within the maximum literature-reported value of 310,000-ug/g in soils from older residential houses in Ontario (reported by the MOE). The paint chips retrieved from SS-6 and SS-11, in areas of homes younger than the East Side Community, contained lower concentrations of lead at 7,500-ug/g and 4,600-ug/g.

Another supporting line of evidence for the presence of lead paint in the East Side Community soils is that the literature quotes close association of lead with barium and zinc as key components of old lead-based paints. Table 7.6 summarises the barium, zinc and lead concentrations in samples from TP-9, SS-6 and SS-11. Barium and zinc were found at elevated levels in paint chips retrieved from TP-9 and the soil materials greater than 2 mm size in archived sample TP-9 (Table 7.6). These combined occurrences of lead, barium and zinc in the TP-9 soil sample indicate a domestic source of lead-based paint, which supports the MOE's interpretation in their March 2002 report (MOE, 2002) in that the elevated soil lead levels in the East Side Community are related to lead-based paints.

Table 7-6 Lead, Barium and Zinc Concentrations (ug/g) in Paint Chips and Soil Samples

Sample ID	Lead (ug/g)	Barium (ug/g)	Zinc (ug/g)
Paint Chip Extracted From TP-9 Soil Sample	258,000	86,000	17,000
TP-9 Soil >2 mm Size	4090	1300	1680
TP-9 Soil <2 mm Size[a]	341	145	610
Paint Chip Extracted From SS-6 Soil Sample	7500	330	1500
SS-6 Soil >2 mm Size	133	135	313
SS-6 Soil <2 mm Size[a]	222	57	98
Paint Chip Extracted From SS-11 Soil Sample	4600	380	1300
SS-11 Soil >2 mm Size	567	260	472
SS-11 Soil <2 mm Size[a]	256	127	307

Notes:
a Refer to JWEL (2001b) report

The evidence above strongly suggests that the majority of soil lead exceedances found in the older East Side Community originated primarily from the breakdown or weathering of old lead-based paints.

7.4 SUMMARY OF LITERATURE REVIEW AND SITE HISTORY

Based on the findings of the literature review and site background history of the East Side Community and similar older urban communities, JWEL concluded the following:

- The most likely source for the observed soil lead levels in the East Side of Port Colborne is the past extensive domestic/urban uses of lead-based substances.

- Elevated soil lead found in the East Side Community is mostly associated with older houses containing leaded paints constructed prior to the 1950s and other urban and domestic sources common to older urban residential communities.

- Some amount of lead may have been contributed by Inco to the East Side Community (quantification found in Section 5.4.6).

- Other potential sources of soil lead in the East Side Community, other than from domestic activity and Inco, may have come from Algoma Steel as well as light industrial operations both within and neighbouring this community, such as from gasoline stations, the Thurston Machine Works, the DWOR Salvage Yard, coal and other raw materials stockpiled along the Welland Canal, an auto body shop, CNR operations and an OPG transformer station.

8.0 DISCUSSION

8.1 RE-EVALUATION OF LEAD AS A POTENTIAL COC

A re-evaluation of lead as a potential CoC for the Port Colborne CBRA was undertaken in this report. The approach and rationale used to assess whether or not lead should be considered a CoC under each of the conditions discussed earlier in Section 1 is discussed in detail below.

Condition 1) Chemicals that were historically used or generated by the industrial source(s) or its processes.

A review of the available historical information suggests that lead was likely present in material historically processed at the Inco Refinery in Port Colborne. It was concluded that lead may have been emitted at low concentrations during historical operations at the Inco Refinery, thus satisfying Condition 1.

Condition 2) Chemicals that are present at a community level at concentrations greater than MOE generic effects-based guidelines.

The MOE generic effects-based (Table A) guideline value for lead is 200 ug/g. Data from more than one thousand locations in the Port Colborne area were compared against that guideline. Soil lead concentrations were only above the generic effects-based guideline on the Seaway Property including the former Algoma Steel and within randomly-scattered pockets in the residential East Side Community. Condition 2 has been satisfied because soil lead levels in one part of the Port Colborne Community, albeit upwind of the Inco Refinery, do exceed the MOE generic lead value.

Condition 3) Chemicals whose presence in soil show a scientific linkage to the historical operations of that industrial source(s).

In this condition, the term “scientific linkage” was understood by JWEL to entail a linkage between the emissions of a chemical from the Inco Refinery and an exceedance of the chemical in the soil (on a community-wide basis as per Condition 2), for which the Inco Refinery was a significant contributor. A significant contribution was not precisely defined, but would be based on professional judgement.

The MOE has specified that their consideration of a “scientific linkage” would be sufficient evidence linking the historic operations of the Inco Refinery to the contamination, to justify the issuance of a control order (should that eventuality be necessary). This implies that a scientific linkage must be reasonably strong if Inco is to be held responsible for it. If there is no information linking the Inco Refinery to the chemical presence in the Port Colborne soils, or the contribution of the Inco Refinery to the chemical’s presence is unclear or not significant, then no scientific linkage would be established.

As above, the only areas in the Community of Port Colborne where soil lead concentrations significantly exceeded the MOE generic Table A lead value of 200 ug/g were on the industrial lands of the Seaway Property including the former Algoma Steel (e.g., maximum exceedance 15 fold over the guideline) and the randomly-scattered pockets within the residential East Side Community (e.g., maximum exceedance 7 fold over the guideline).

To assess whether or not elevated lead concentrations in soils in the East Side Community could be scientifically linked to the historical operations of the Inco Refinery and whether the requirements for Condition 3 were met, nine (9) lines of evidence were examined. A summary of the nine lines of evidence is presented in Table 8-1.

Table 8-1 Summary of Lines of Evidence

	Line of Evidence	Section in the Report	Finding
1	Predominant wind direction	Section 5.2.2	The meteorological analysis showed that the predominant wind direction was to the northeast and that lead emitted from Inco Refinery would have deposited on soil in greater amounts to the northeast of the Refinery stacks than in the East Side Community to the west.
2	Observed lateral soil lead distribution	Section 3.2.2	The lateral soil lead distribution in the Port Colborne area indicates that the majority of sample locations had lead concentrations below the MOE Table A 200 ug/g guideline, with no visible pattern apparent downwind of Inco. Upwind of Inco, there are randomly scattered pockets of high soil lead concentrations within the East Side Community exceeding 200 ug/g to a maximum of 1,350 ug/g (0-5 cm).
3	Observed vertical soil lead distribution	Section 3.3	The patterns of vertical distribution of soil lead in areas downwind (i.e., northeast) of the Inco Refinery are not reflected by those patterns observed upwind of Inco in the area of the East Side Community.
4	Observed soil nickel:lead ratios	Sections 3.4, 6.3.1	Lower soil nickel:lead ratios in the East Side Community in comparison to those downwind (i.e., northeast) of the Inco Refinery reflect elevated soil lead in this community, which cannot be explained due to atmospheric deposition from Inco Refinery alone.
5	Predicted soil lead contribution from Inco Refinery emissions using air dispersion modelling	Sections 5.4, 8.2.5	Aerial emissions of lead from Inco were predicted to account for 0.3 % of the maximum measured soil lead concentration (1,350 ug/g at the 0-5 cm depth) in the East Side Community.
6	Predicted soil lead contribution from Inco Refinery emissions using regression modelling	Section 6.3.4	Aerial emissions of lead from Inco were predicted to account for 3.0 % of the maximum measured soil lead concentration (1,350 ug/g at the 0-5 cm depth) in the East Side Community. **The average of Inco's contribution to the community predicted through regression modelling (3%) and air dispersion modelling (0.3%) is approximately 2%, which is not significant.**

	Line of Evidence	Section in the Report	Finding
7	Historical review of East Side Community	Section 7.1	Historical review indicates that there are many potential sources of lead within the older East Side Community including domestic activities, and mixed local industry, commercial, and heavy industry.
8	Literature review of domestic sources of lead found in urban communities in North America	Section 7.2	Measured soil lead concentrations in the East Side Community, ranging up to 1,350 ug/g (0-5 cm depth), were found to be similar to those of literature-reported soil lead concentrations (i.e., ranging up to 3,400 ug/g) found in other communities of similar age in Southern Ontario. The literature identifies a major link between the higher-reported soil lead concentrations in communities and the domestic use of lead-based paint.
9	SEM Analysis of soil from the East Side Community	Section 7.3	A SEM study using optical identification and collection of X-ray spectra on soil samples from the East Side Community identified and confirmed the presence of lead-based paint chips. The concentrations of lead in the paint chips were consistent with those reported in other North American cities.

The nine lines of analysis, as presented in Table 8-1, have shown no clear evidence to support the contention that Inco was a significant contributor to the observed irregular pattern of lead exceedances in the East Side Community. Given the analysis presented above**, JWEL has concluded that Condition 3 is not satisfied.**

8.2 RELATIVE CONTRIBUTIONS OF SOURCE OF LEAD TO THE EAST SIDE COMMUNITY

To address the second objective of this study, which is to provide plausible explanation(s) for the localized, randomly-scattered areas of soil-lead exceedances (MOE, 2002) observed within the East Side Community neighbourhood, an analysis of relative contributions by sources other than Inco was undertaken. The intent of this section is to provide reasonable estimates of the relative contribution by various sources to the maximum reported soil lead concentration of 1,350 ug/g at the 0 to 5 cm depth in the East Side Community.

As shown throughout the report, there are four potential sources of lead that may have contributed to the scattered pockets of elevated levels in the East Side Community:

1. Natural Background Soil Lead Levels;
2. Algoma Steel Plant;
3. Inco Refinery; and
4. Domestic Sources (including local commercial sources located within and adjacent to the East Side Community).

The following subsections attribute the relative contribution from each source.

8.2.1 Natural Background Lead Concentrations in the East Side Community Area

The average soil lead concentration found outside the soil nickel plume in the Port Colborne CBRA study area was 33 ug/g. The maximum background soil lead concentration outside the soil nickel plume was 98 ug/g. These values agree with the Ontario Ministry of the Environment naturally-occurring Ontario Typical Range (OTR) concentrations of elements in Ontario soils (MOE, 1993). The MOE-reported mean OTR of lead in old urban parkland soils is 34 ug/g (MOE, 1993 - Figure 6.1.18) and the upper 98th percentile of naturally-occurring lead concentrations in Ontario communities was reported to be 98 ug/g. These 1993 OTR values were later updated by the MOE in the *Guideline for Use of Contaminated Sites in Ontario* (MOE, rev. 1998) to 55 ug/g for agricultural land use and 120 ug/g for all other land uses.

For the purposes of this assessment, the background concentration of soil lead inside the East Side Community was assumed to be 33 ug/g (mean value) or 2.5 % of the maximum measured soil lead concentration (1,350 ug/g at the 0-5 cm depth) in the East Side Community.

8.2.2 Algoma Contribution to Lead Concentrations in the East Side Community Area

Based on Jacques Whitford's 2003 report, *Potential CoC Identification using Emission Inventories and Dispersion Modelling of Inco and Algoma Operations*, Algoma was predicted to deposit between 2,000-10,000 ug/g of particulate in the East Side Community area. Emissions factors in US EPA AP-42 for gray iron foundries suggest that lead concentration in emissions should be typically less than 1% (assumed in this assessment to be approximately 0.5%). This would suggest that Algoma's contribution to lead in the East Side Community would have been about 10 to 50 ug/g (mean value of 30 ug/g).

For the purposes of this assessment, the concentration of soil lead inside the East Side Community attributed to Algoma Steel aerial emissions was assumed to be 30 ug/g (mean value) or 2.2 % of the maximum measured soil lead concentration (1,350 ug/g at the 0-5 cm depth) in the East Side Community.

8.2.3 Inco Contributions to Lead Concentrations in the East Side Community Area

The percentage contribution of soil lead concentrations in the East Side Community from Inco's aerial emissions was calculated using two methods. Method 1 was by air dispersion modelling and Method 2 was by regression modelling. A summary of findings by both methods is given below.

The air dispersion modelling in Section 5 of this report predicted that concentrations of soil lead in the East Side Community resulting from the Inco Refinery operations were 2 ug/g (base case scenario) to 4 ug/g (two times the base case scenario). Assuming the higher of these two predicted values, the aerial emissions of lead from Inco would account for only 0.3 % of the maximum measured soil lead concentration (1,350 ug/g at the 0-5 cm depth) in the East Side Community.

The statistical method using regression modelling in Section 6 of this report predicted 40.5 ug/g of soil lead or only 3 % of the maximum measured soil lead concentration (1,350 ug/g at the 0-5 cm depth) in the East Side Community that would have been derived from aerial emissions from the Inco Refinery.

On average, Inco's contribution to the maximum measured soil lead concentration of 1,350 ug/g (0-5 cm) in the East Side Community was approximately 2 % (average of 0.3 % and 3 % from the air dispersion modelling and regression modelling methods, respectively).

8.2.4 Domestic Sources

Section 7.0 of this report provided a detailed literature review of expected concentrations of lead in older urban residential neighbourhoods. It is known that lead-based paints used to paint the exteriors of houses have significantly contributed to soil lead levels in neighbourhoods of a similar age around Ontario, North America, and at lighthouses in British Columbia. The soil lead concentrations reported in other communities in Southern Ontario range up to 3,400 ug/g and the median soil lead concentrations around lighthouses in British Columbia were found to range up to 5,728 ug/g. Other potential sources of lead contamination from domestic sources include leaded gasoline, batteries, and numerous light industrial operations.

In order to generate the contribution of domestic sources of lead to the East Side Community using the available information from the other three source types and assuming the actual measured soil lead concentration in the community represents 100 %, the following equation was used:

Lead Concentration from Domestic Sources = Actual Measured Soil Lead Concentration in the East Side Community – Background – Inco Contribution – Algoma Contribution

This mass balance approach enables the calculation of the percent contribution of soil lead to the East Side Community from domestic sources. Findings are reported below in Tables 8-2 and 8-3. Table 8-2 reports the percentage contribution using the predicted Inco contribution derived from air dispersion modelling (method 1 in Section 8.2.3) and the percent contributions from both natural background (Section 8.2.1) and Algoma (Section 8.2.2).

Table 8-2. Lead source contributions to East Side Community – Method 1

Potential Source of Soil Lead Contribution to the East Side Community	**Relative Contribution by Source**	
	(ug/g)	**(%)**
Natural Background Soil Lead Levels in Port Colborne	33	2.5
Inco Refinery Aerial Emissions (Method 1: Air Modelling Prediction)	2(x) base case= 4	0.3
Algoma Steel Plant Aerial Emissions	30	2.2
Maximum Measured Soil Lead Concentration (0-5 cm depth) in the East Side Community	1350	100
Domestic Sources Contribution* – Method 1	**1,283 ug/g**	**95 %**

***Note:** Domestic Source Contribution = East Side Community Actual Soil Lead Concentration - Natural Background Soil Lead Concentration – Inco Refinery Lead Concentration Contribution - Algoma Steel Lead Concentration Contribution

Table 8-3 reports the percentage contribution using the predicted Inco contribution derived from regression modelling (method 2 in Section 8.2.3) and the percent contributions from both natural background (Section 8.2.1) and Algoma (Section 8.2.2).

Table 8-3 Lead source contributions to East Side Community – Method 2

Potential Source of Soil Lead Contribution to the East Side Community	**Relative Contribution by Source**	
	(ug/g)	**(%)**
Natural Background Soil Lead Levels in Port Colborne	33	2.5
Inco Refinery Aerial Emissions (Method 2: Regression Modelling Prediction)	40.5	3.0
Algoma Steel Plant Aerial Emissions	30	2.2
Maximum Measured Soil Lead Concentration (0-5 cm depth) in the East Side Community	1350	100
Domestic Sources Contribution* – Method 1	**1,247 ug/g**	**92 %**

***Note:** Domestic Source Contribution = East Side Community Actual Soil Lead Concentration - Natural Background Soil Lead Concentration – Inco Refinery Lead Concentration Contribution - Algoma Steel Lead Concentration Contribution

The soil lead mass balances for both methods in Tables 8-2 (method 1) and 8-3 (method 2) show that the largest source responsible for the actual measured soil lead concentrations in the East Side Community is from domestic activities within the community itself. Approximately 94 % (average of 95 % and 92 % from both methods) of the reported maximum soil lead concentration of 1,350 ug/g (0-5 cm depth) in the East Side Community is attributable to domestic sources, such as lead-based paints, lead acid batteries, gasoline emissions, and other domestic activity.

The relative apportionments of soil lead concentrations from domestic sources in the East Side Community, as produced in Tables 8-2 and 8-3, are consistent with those in other communities of a similar age around North America where no industrial sources of lead are located nearby. In fact, only 15 km to the north of Port Colborne, concentrations of soil lead in the Community of Welland, Ontario have been measured in the thousands of parts per million. These concentrations have been attributed to the use of lead-based paints on the exterior of houses (MOE, 2002).

8.3 BLOOD LEAD SCREENING STUDY

Another piece of information of interest with respect to this report, are the results of a blood lead screening study of the East Side Community and the rest of Port Colborne undertaken by the Regional Niagara Public Health Department between April and June 2001. The East Side Community was defined in this study as a 10-block area of Port Colborne bordered by Louis Street to the north, the Inco Refinery to the east, the Welland Canal to the west, and Rodney Street to the south. The study was initiated because of community concerns that elevated soil lead levels may have resulted in unusual exposure, especially among children.

A summary of the report entitled "Lead Screening Report East Side Community, Port Colborne April – June, 2001" and dated August 2001 by the Regional Niagara Public Health Department (NPH) is presented in **Appendix N** of this report.

One of the major findings of the study was that the average (geometric mean) lead level of 0.11 umol/L (2.3 ug/dL) for East Side children was less than the average (geometric mean) of 0.17 umol/L (3.5 ug/dL) found in the Ontario Blood Lead Control community. These comparison blood lead results were taken from an inner city 1992 blood lead survey of a Toronto neighbourhood not located near a known point source of lead emission. The results of this blood lead screening study suggest that blood lead levels in the East-Side Community are typical of those across Ontario and the US.

9.0 CONCLUSIONS

Based on the review and evaluation of the existing soil lead data provided in JWEL's CoC reports (JWEL, 2001a,b,c) and the new information on soil lead data with respect to meeting or rejecting the three (3) CBRA CoC Conditions as outlined in Section 1.0 of this report, the following conclusions were reached:

Condition 1: **Yes.** Lead was present in some raw materials used historically by Inco in their Port Colborne operations.

Condition 2: **Yes.** There are soil lead exceedances above the MOE- Generic Guidelines in one part of the Port Colborne, in particular the residential East Side Community, located west and predominantly upwind of the Inco Refinery.

Condition 3: **No.** There is no significant scientific linkage of soil lead to the Inco Refinery.

Therefore, as one (1) of the three (3) Conditions was not met, lead is not a CoC under the Inco-led Port Colborne CBRA.

Plausible explanations for the localized, randomly-scattered areas of soil lead exceedances as high as 1,350 ug/g at the 0 to 5 cm depth (MOE, 2002) observed within the East Side Community neighbourhood were provided through a mass balance approach on the relative contributions by all potential sources. The mass balance showed that the largest source responsible for the actual measured soil lead concentrations in the East Side Community was from domestic activities within the community itself. **The reported maximum soil lead concentration 1,350 ug/g at 0-5 cm depth in the East Side Community was attributable to approximately 94% from domestic sources (e.g., lead based paints, gasoline emissions, etc.), 2.5% from natural background, 2.2% from Algoma Steel aerial emissions, and 2% from Inco Refinery aerial emissions.**

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