Phytotoxicology Soil Investigation:

INCO – Port Colborne (1999)

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Phytotoxicology Soil Investigation:

INCO – Port Colborne (1999)

Phytotoxicology Investigator/Author: Allen Kuja
Contributing Scientists:
Randall Jones
William McIlveen

Phytotoxicology and Soils Standards Section, Standards Development Branch
Ontario Ministry of the Environment

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1.0 Executive Summary

The objective of this investigation was to undertake additional sampling of soil in the two areas of impact for which contour mapping based on 1998 survey results may 1) overestimate the 100-200 ug/g Ni contamination zone, west of INCO, or 2) underestimate the 200-500 ug/g Ni contamination zone, northeast of INCO. In addition, the extent of the area for which soil Ni concentrations exceeded the soil background concentration (43 *ug*/g) was only approximated by the computer-generated contour map because soil nickel background concentrations continued to remain well over 43 *ug*/g at the furthest sample site from Port Colborne, located 13 km northeast of INCO.

Computer contour maps were derived using Surfer/Arview based on sample data provided from both 1999 and 1998 survey sites, and historical survey results with the purpose of filling in data gaps in the 1998 survey results. Inclusion of the additional data resulted in changes to the shape and size of the 43-100 *ug*/g soil Ni, 100-200 ug/g soil Ni and 200-500 *ug*/g soil Ni contour intervals, respectively. The MOE Table F soil background value for Ni is exceeded beyond a distance of 28 km northeast of INCO and over a area of 345 km^2. The Cu and Co Table F soil values are exceeded in surface soil beyond a 3 km distance in the same direction, and over areas of 7.9 and 7.2 km^2 , respectively. Soil Ni concentrations are shown to exceed the MOE Table A soil remediation criterion for up to 3 km northeast of INCO and is estimated to cover an area of almost 29 km^2. Table A Cu and Co criteria are exceeded over areas of 0.2 and 0.8 km^2, respectively. As previously mentioned, soil concentrations of Ni, Cu and Co which exceed their corresponding Table A criterion are potentially phytotoxic. The substantial increase in sample sites (a total of 200 sites) has provided a more precise estimate of the area in and around the city of Port Colborne that has been impacted by over sixty-six years of INCO emissions and atmospheric deposition.

The soil metal contamination in Port Colborne is not a threat to human health but can be potentially phytotoxic with Ni being the most toxic. Agricultural liming and fertilizer amendments should allow for remediation of the areas above the Table A 'effects-based' criteria with marginal disturbance to the impacted properties. The amount of lime and application rate will depend on the contaminant concentration, the soil physical and chemical characteristics of the soils to be remediated. At sites where the soil Ni, Cu and Co contamination only marginally exceeds Table A criteria, and the contamination is concentrated in the surface soil, deep cultivation may lower metal concentrations in the rooting zone of plants sufficiently that soil is no longer potentially phytotoxic.

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6.0 Introduction

Results of a 1998 Phytotoxicology investigation confirmed that soil to a depth of at least 15 cm in Port Colborne area is severely contaminated with nickel, and to a lesser extent with copper and cobalt [Ref. 1]. Soil nickel background concentrations (43 *ug*/g) are exceeded beyond 13 km northeast of INCO and extend over an area greater than 159 km^2, and more than 4 km in the same direction for copper 85 *u*g/g, 8.9 km^2 and cobalt (21 *u*g/g, 6.1 km^2). Soil nickel concentrations exceed the effects-based MOE soil remediation criterion (200 *u*g/g) up to 8 km northeast of the refinery, and extend over an a 19 km^2 area. The soil remediation criteria for copper (300 *u*g/g) and cobalt (50 *u*g/g) are exceeded over a 0.3 km^2 and 1.6 km^2 area, respectively.

Soil nickel concentrations exceeding the MOE generic soil criterion are potentially phytotoxic; for example, a reduction in crop yield and/or foliar injury on sensitive species of vegetation. A health study conducted by the MOE (*Technical Report: Assessment of Potential Health Risks of Reported Soil Levels of Nickel, Copper, and Cobalt in Port Colborne and Vicinity, May 1997*) and based on a multi-media assessment of potential risks concluded that no adverse health effects are anticipated to result from exposure to soil metal contamination in the Port Colborne area.

Despite an intensive sample strategy, the complete area impacted was not determined in the 1998 soil investigation. Soil nickel concentrations collected from the farthest downwind sites (>13 km) were still approximately twice expected soil background values. The computer-generated contour maps produced for the 1998 soil investigation report were statistical approximations of the spatial distribution of the different contaminants. Soil concentrations are only known with certainty at those sites for which soil was actually sampled and chemically analyzed.

Contour intervals produced by the computer program are significantly affected by the spatial distribution of the sampling sites, the accuracy of the position information of the sampling sites, and the program options used to generate the contours. The accuracy of the contours diminishes at the edges of the maps and in large areas where there are no or very few sample sites. Also, local site disturbances and data variability may have skewed the computer-generated contaminant contours resulting in an overestimation of the area to the northwest of Port Colborne with soil nickel concentrations in the 100-200 *u*g/g range, and an underestimation of the 200-500 *u*g/g nickel contamination zone lying to the northeast of INCO. Based on the 1998 investigation findings, and the contour maps that resulted from the input data, it was decided that additional sampling was warranted to identify and delineate the extent of soil Ni, Cu and Co contamination in the city of Port Colborne and the surrounding municipalities.

7.0 Objectives of 1999 Soil Investigation

The objective of this investigation was to undertake additional sampling of soil in the two areas of impact for which contour mapping based on 1998 survey results may 1) overestimate the 100-200 *u*g/g Ni contamination zone, northwest of INCO, or 2) underestimate the 200-500 *u*g/g Ni contamination zone, northeast of INCO. In addition, the extent of the area for which soil Ni concentrations exceeded the soil background concentration (43 *u*g/g) was only approximated by the computer-generated contour map because soil nickel background concentrations continued to remain well over 43 *ug*/g at the furthest sample site from Port Colborne, located 13 km northeast of INCO.

Further sampling of the surface soil (0-5 cm depth) was to be conducted at addition sites located withing the two areas of impact, as well at greater distances to the north, east and northeast of the city of Port Colborne (as far away as 18.8 km from INCO) for the purpose of filling in gaps in the 1998 data in order to generate contour maps which better define and delineate the extent of soil nickel, copper and cobalt levels in the city of Port Colborne and the surrounding region. In addition, the decision was made to include additional soil data collected from historical Phytotoxicology surveys (going back to 1990) to better define the total area for which soil nickel background concentrations (43 *u*g/g) have been exceeded.

8.0 Methodology

8.1 Soil Survey

Ecological Standards and Toxicology Section staff conducted this soil investigation on November 2 and 3, 1999. A total of 64 new surface soil (0-5 cm depth) sites were established in the city of Port Colborne and the surrounding region to more accurately delineate the spatial extent of soil nickel, copper and cobalt contamination estimated from soil data obtained from the 1998 soil survey (refer to Table 1). Details of sample sites (description, and location relative to local roads and landscape features, as well as UTM co-ordinates are summarized in Table 1. These geo-referenced co-ordinates were obtained with a Garmin 12XL satellite global positioning unit. As in the 1998 survey, selected sites included, street boulevards, residential lawns, parks, right-of-ways, commercial lawns and wood lots.

The locations of 1999 sample sites which established within the city of Port Colborne, as well as the surrounding region, are shown as open circles in Map 1. Map 1 also provides the location of 1998 surface soil sites (solid circles), 1998 soil profile sites (squares) and historical survey sites (black pentagons) going back to 1990. The more intensive network of 1999 sample sites established in and around the city of Port Colborne are shown in Map 2. Again, Map 2 also shows the location of 1998 survey sites from which data was used in developing contour maps of soil nickel, copper and cobalt concentrations in the previous Phytotoxicology survey report.

All soil samples were collected in duplicate using standard MOE field protocols [Ref. 2]. This involves using a soil coring device which cuts a cylindrical core, two centimeters in diameter, to the depth to which the corer is inserted. Each sample consists of approximately 30 cores taken throughout the designated sampling area. Soil cores were placed directly into a labelled polyethylene bag.

8.2 Use of Historical Survey Data

Surface soil data were utilized from 48 historical survey sites, dating back no further than 1990 and located in and around the municipalities of Welland, Niagara Falls and Fort Erie, for the purpose of providing additional information for developing more accurate contour maps of soil nickel, copper and cobalt concentrations in and around the city of Port Colborne. These historical sites includ Ontario Typical Range (OTR) sites, as well as industrial and residential survey sites. Information on the chosen historical survey sites, and corresponding soil concentrations of nickel, copper and cobalt associated with these sites, are shown in Table 2. The positions of historical survey sites located to the east and northeast of the city of Port Colborne, are shown in Map 2. Due to the close proximity of the 27 historical survey sites selected from within the city of Welland, the location of these sampling sites are also shown in Map 3 for greater clarity.

8.3 Sample Preparation and Analysis

Soil samples were processed at the Ecological Standards and Toxicology processing laboratory (air-dried, homogenized, ground and sieved to 355 micron size fraction, and stored in glass jars) using standard MOE protocols [Ref. 3]. Samples were then forwarded to the MOE Laboratory Services Branch for analysis of trace metals on a dry weight basis by inductively-coupled plasma-atomic emission spectrometry (ICP-AES) for total aluminum (Al), barium (Ba), beryllium (Be), calcium (Ca), cadmium (Cd), cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), Manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb) strontium (Sr), vanadium (V) and zinc (Zn). Arsenic (As) was analyzed using flameless atomic absorption spectrophotometry. A select number of soil samples, collected during the 1998 soil investigation, were re-analyzed along with the 1999 survey samples to verify data comparability and compatability.

8.4 Data Analysis, Presentation and Interpretation

Soil analytical results for each of the 18 inorganic elements were compared with Ontario soil background concentrations for non-agricultural soils (Table F *Guidelines*). These values represent the expected distribution of chemical concentrations resulting from natural geological processes and normal human activity remote from the influence of known point sources of

emissions. For those inorganic elements for which there is no Table F Guideline (i.e. Al, Ca, Fe, Mg, Mn, Sr), MOE 'Ontario Typical Range' (OTR) guidelines were utilized for comparative purposes. The OTRs are a province-wide background-based set of guidelines derived for a large number of inorganic elements and organic compounds (see Appendix B). Table F Guidelines are based on the OTRs. In addition, the analytical results were also compared with the effects-based Table A *Guidelines* for residential/parkland land uses.

For this soil investigation, Table A criteria for medium/fine textured soils were utilized as they are more appropriate for the fine textured soils encountered during the survey than the generic criteria for coarse textured soils. Table A criteria apply to potable groundwater situations (i.e. drinking water is obtained from a groundwater aquifer), which apply to most of the area of Port Colborne outside of the city core. Some areas in the investigation may be served by a municipal drinking water supply that does not rely on local groundwater. Table B Guideline criteria would apply to such sites but only if present or future groundwater (or surface water) sources of drinking water will not be adversely affected, including water for agricultural uses. For inorganic elements, the MOE Tables A and B Guideline criteria are identical. Therefore, Table A criteria will be referenced throughout this report for all sites regardless of the groundwater situation at a particular site.

8.5 Contour Maps

Contaminant contour maps were produced from the surface soil chemistry data (0-5 cm depth) for Ni, Cu, and Co, based on all of the 1999, 1998 and historical survey sites (a total of 200 sites). Two software packages were used to generate the maps. The data analysis and creation of the concentration contours was done using SURFER (Version 6.03 for Windows 95, by Golden Software Inc.). The output from SURFER was then imported into ARCVIEW GIS (Version 3.1, by Environmental Systems Research Institute Inc.) and combined with base maps, roads and water bodies to produce the final maps. Details concerning the process used to generate Maps 1-9 are provided in Appendix D.

These maps are statistical approximations of the spatial distribution of the different contaminants. Soil concentrations are only known with certainty at those sites for which soil was actually sampled and chemically analyzed. The contours produced by the program are significantly affected by the spatial distribution of the sampling sites, the accuracy of the position information of the sampling sites, and the program options used to generate the contours. The accuracy of the contours diminishes at the edges of the map and in large areas where there are no or very few sample sites. Therefore these maps should only be used as an interpretive tool to provide information on approximate areas and/or patterns of contamination and cannot be used to infer contaminant concentrations at locations not directly sampled.

9.0 Results

9.1 Analytical Data

The results for chemical analysis of 18 inorganic elements in soil collected from the November 1999 survey sites in the Port Colborne area are summarized in Table 2 (Ni, Cu, Co) and Appendices A1-A15 (Al, As, Ba, Be, Ca, Cd, Cr, Fe, Mg, Mn, Mo, Pb, Sr, V, Zn. All data are the average of duplicate soil samples (0-5 cm depth) in *ug*/g air-dry weight. In Table 2, and in each Appendix, values shown in bold face exceed the corresponding non-agricultural Table F soil background *Guideline*. For those inorganic elements for which Table F criteria have not been established (e.g. Al, Ca, Fe, Mg, Mn, Sr), the rural Ontario Typical Range (OTR) value was used as an indicator of expected soil background concentration. Data in shaded cells exceed the effects-based Table A generic soil *Guideline* for medium/fine textured soils.

9.1.1 Soil Nickel, Copper and Cobalt

The soil Ni, Cu and Co data are summarized in Table 2. Nickel concentrations in surface soil (0-5cm) exceed the Table F Guideline for non-agricultural land use (43 *u*g/g), at all but five of the 64 survey sites sampled in November 1999; 23 of these sites exceeded the Table A Guideline for Ni (200 *u*g/g). The furthest site from the source, with Ni exceeding the Table A criterion, was located 8.3 km northeast of INCO. Copper concentrations in surface soil exceeded the Table F Guideline for non-agricultural land use (85 *u*g/g) at four of the 64 survey sites; surface soil concentrations of cobalt exceed the Table F Guideline for non-agricultural land use (50 *u*g/g) at three sites of these four sites. The sites with elevated soil Cu and Co were also the sites with the highest soil Ni concentrations (i.e. sites 183, 184, 200, and 230).

9.1.2 Other Inorganic Elements

The soil Al, As, Ba, Be, Ca, Cd, Cr, Fe, Mg, Mn, Mo, Pb, Sr, V and Zn data are summarized in Appendices A1 through A15, respectively. .The analytical results show that for each sampling site, the soil concentrations for As, Ba, Cd, Cr, Mn and Pb were all within the range expected for soil background (i.e. Table F or OTR_{98} values were not exceeded). Soil Be concentrations were slightly elevated above the Table F soil background concentration at two wood lot sites (refer to Appendix A4). It has been shown that certain shale deposits can contain elevated levels of Be [Ref 4]. The soils at these two sites are very likely associated with natural shale formations.

For some of the inorganic parameters, Ca, Fe, Mg, Mo and Zn, soil concentrations exceeded background-based Table F or OTR values at a some sites (refer to Appendices A5, A8, A9, A10, and A14, respectively); MOE Table A effects–based criteria for these chemical parameters were not exceeded at any of the 1999 survey sites. Based on the random distribution

of the various exceedances for Ca, Fe, Mg, Mo and Zn, and knowledge of the refinery process of INCO, there is little reason to suspect these elevated soil concentrations to be related to emissions from the INCO smelter.

Soil Sr (Appendix A13) concentrations exceeded the background-based OTR guideline at 28 sites across the sampling area. However, there is no consistent spatial relationship between soil Sr concentrations and proximity to INCO and it is very unlikely that Sr is associated with emissions from the smelter. The unusually high frequency of OTR exceedances for Sr suggests that soil Sr concentrations in the Port Colborne area are naturally higher than the normal range for background in soil in the rest of the province.

10.0 Discussion

Like the 1998 survey results [Ref.1], the analytical results from the 64 new sites sampled in November 1999, show considerable variability in soil Ni concentrations vs. distance from the refinery. Soil Ni concentrations at some sites are relatively low compared to other sites located at similar or greater distances from INCO (refer to Table 3). This trend is also evident for both Cu and Co. This can be explained by the fact that this investigation extends across a large urban and rural area that has been impacted by INCO refinery emissions over a long period, followed by 16 years during which time the stack has not operated and any impacts would be attributed to marginal fugitive emissions only.

Sample sites were chosen that appeared to the investigators to be undisturbed or were selected based on information provided by property owners confirming the undisturbed status of the site. However, site disturbance is often not evident, or property owners may not have knowledge of changes to the property that occurred before their tenure. Landscaping activities such as the addition of topsoil or sod, places clean soil overtop of metal contaminated soil. As the sampling procedure at each of the 1999 survey sites consisted of only surface soil sampling (0 to 5 cm depth), the resultant sample would contain low metal concentrations, and therefore, the contamination at these sites is underestimated.

In the 1998 survey report, background soil Ni concentrations were not achieved in a northeast direction, the direction of the prevailing winds, even at a distance of 13 km. The 1998 survey sites farthest downwind from INCO (Sites 68, 69 and 87) had surface soil Ni concentrations that exceeded the Table F value for soil Ni (43 *u*g/g). The sampling strategy in the 1998 survey was not adequate to determine the total extent of soil Ni contamination in the region to the northeast of Port Colborne; i.e. the northeast contour boundary for soil Ni (43-100 *u*g/g) was an estimate generated by the computer mapping program. However, the area that exceeds the Table F soil background concentration for Ni, may extend much further in the directions of the municipalities of Niagara Falls and Fort Erie.

Likewise, in the 1998 soil investigation it became apparent that soil Ni concentrations likely exceeded the Table A criterion over a larger area than was represented by the 200-500 *u*g/g contour. The 200-500 *u*g/g contour interval is significant because it corresponds to the effects-based Table A Guideline soil Ni criterion (200 *u*g/g). The report concluded that additional sampling was warranted between Sites 12 and 50, and Sites 62 and 63, to more accurately define the extent of the area in which soil Ni might exceed the Table A criterion.

Contaminant contour maps were produced from the surface soil chemistry data (0 to 5cm depth) for Ni, Cu and Co, using Surfer/ArcView (Maps 4,5 and 6). These maps were based on the combined data from 1999 and 1998 survey sites, and the additional historical survey sites located in and around the cities of Welland, Niagara Falls and Fort Erie (for a total of 200 sites). With a greater number of sites, the computer was able to better define the true extent of the Ni, Cu and Co contamination that have resulted from over sixty years of INCO stack emissions. Note: For comparison purposes, Map 4 also provides an outline of the 1998 contours for the Table F and Table A soil Ni guideline criteria (dotted lines), which were based on the 1998 sampling data alone.

The addition of data from both the 1999 survey sites and historical survey sites changed the shape and size of all contour intervals for soil Ni, Cu and Co that were based on the more limited 1998 sampling data (refer to Maps, 4,5 and 6). Changes to the Cu and Co contour intervals were minor, because the deposition of the these metals was confined to a much smaller area that was adequately represented by 1998 survey site data. In contrast, soil Ni contour intervals were modified significantly in the regions both to the west and northeast of Port Colborne. To the west of INCO the 100- 200 *u*g/g soil Ni contour interval is reduced significantly in area compared to that generated from the 1998 survey data. To the northeast of INCO, both the 43-100 *u*g/g and 200-500 *u*g/g Ni contour intervals changed markedly in shape and size compared to the contour intervals that were based on the more limited 198 sampling data only (represented in Map 4 by dotted and dashed lines, respectively).

At present, soil Ni concentrations are shown to exceed the Ontario soil background concentration (Table F value of 43 *u*g/g) as far west as Wainfleet marsh. In a northerly direction, soil Ni concentrations exceed the Table F criterion as far north as Biggar Rd. (Hwy 47). In an northeasterly direction, the Table F value is exceeded beyond the Queen Elizabeth Way (just south of Niagara Falls), and to the east as far as the Niagara River near the towns of Black Creek and Douglastown, including the north end of the city of Ft. Erie. It is apparent that the estimated area that has been impacted (i.e. surface soil Ni concentrations exceed the soil background criterion of 43 *u*g/g) is significantly greater than was originally estimated from data compiled during the 1998 soil investigation.

With the inclusion of the data from the additional 1999 sampling sites, the 200-500 *u*g/g soil Ni contour interval determined by Surfer/ArcView was modified from that based on the 1998 data only. At present, soil Ni concentrations that exceed the Table A soil Ni criterion (200 *u*g/g) do not extend as far to the west as was previously predicted from the 1998 survey results.

Also, the apparent gap in the 200-500 *u*g/g contour interval which was located to the east of the city of Port Colborne (i.e. between Sites 12 and 50, and the island contour around Sites 62 and 63) is now included within the 200-500 *u*g/g contour interval based on 1999 and 1998 data combined. Soil Ni concentrations now appear to exceed the Table A criterion as far east as Whites Rd. and extends to the northeast as far as the intersection of Chippawa Rd. and Carl Rd., a distance of over 5 km from the INCO site.

Two new contour islands have appeared for the 200-500 *u*g/g contour interval, both to the north and northeast of the city of Port Colborne. Again, as was the case in the 1998 survey, additional sampling could be conducted at sites that lie between these contour islands and the sites on which the main 200-500 *u*g/g contour interval was generated by the computer mapping program to better define whether or not these contour islands should be contained within one 200-500 *u*g/g contour interval around the INCO stack. It should also be noted that the generation of a 100-200 *u*g/g soil Ni contour island in the east end of the city of Welland may in fact be the result of a local source of Ni emissions, unrelated to INCO in Port Colborne (refer to Map 4).

10.1 Total Areas Estimated to Exceed Table F/Table A Guidelines for Ni, Cu, and Co.

Three additional maps were produced for Ni, Cu and Co to display the two contour polygons that correspond to a) the Ontario soil background (Table F) value, and b) the MOE generic soil remediation (Table A) criterion based on the 1999, 1998 and historical survey data (refer to Maps, 7, 8 and 9). These polygons are statistical approximations only; soil concentrations are known with certainty only at those sites for which soil was actually sampled.

The surface areas represented by the Table A and F polygons for Ni, Cu, and Co were calculated using a feature in ArcView. These calculated areas were converted to square kilometers. The calculated areas are provided in the legends of each of Maps 7, 8 and 9. In each map, the area designated as exceeding Table F only includes the polygon where the Table F value is exceeded but does not include the area of the polygon that corresponds to the Table A guideline criterion. The total area exceeding Table F is obtained by summing the two areas calculated for the Table A polygon and the Table F polygon.

In Map 7, the polygon in mustard yellow (dark shade) represents the total area in which soil Ni concentrations in surface soil (0-5cm) has been estimated to exceed the Table A soil remediation using the Surfer/ArcView contour mapping program and the data from 1999, 1998 and historical surveys. Map 7 also shows the 1998 contour (dotted line) for the Table A soil Ni guideline based on 1998 sampling data only. The area of impact is approximately 3 km long going in an northeasterly direction from the INCO site to the Chippawa Rd./Carl Rd. intersection and as far east as Whites Rd. The impacted area is estimated to exceed the Table A soil Ni criterion is approximately 29 km^2.

The total area that exceeds the soil Ni Table F soil background criterion goes beyond the scale of Map 7. It is estimated to be 345 km^2 in area (based on addition of the Table A and F polygons) and, as previously stated, extends north into Welland, northeast to the Niagara River, as far as Grand Island N.Y., and east into the north end of Ft. Erie.

In Map 8, the polygons in dark green represent the total area in which surface soil Cu is estimated to exceed the Table A soil remediation criterion for Cu (300 *u*g/g). The three polygons represent less area (0.2 km^2 than was estimated using 1998 survey data only (0.3 km^2). One polygon is centered on the intersection of Davis St. and Kinnear St., a second is located north of Killaly St., east of Elizabeth St. and a third is further east and centred on Killaly St. between Snider Rd. and Lorraine Rd. The area estimated to exceed the Table F soil background value for Cu (85 *u*g/g) is 7.9 km^2 and is represented in pale green (light shade). The polygon extends from the Welland canal in the west, northward to Main St. East and past Lorraine Rd. to the east.

Map 9 illustrates the total areas estimated to exceed the Table A (50 *u*g/g) and Table F (21 *ug*/g) soil criteria for Co. The three polygons (in bright yellow) represent the area estimated to exceed the Table A soil Co criterion (0.8 km^2). Although larger in size, each Co polygon coincides with the polygons representing soil Cu concentrations that exceed the Table A Cu criterion. The four Co polygons represent an area (0.8 km^2) which is approximately half of the area estimated from 1998 survey data only (1.6 km^2).

The computer estimates of the areas that exceed MOE Table F and Table A soil criteria for Ni, Cu and Co are summarized in Table 4. These area estimates are derived using data from 1999, 1998 survey sites, as well as selected historical survey sites. For comparison purposes, the area estimates which were based on 1998 survey results are included.

10.2 Phytotoxicity

The MOE Table A Criteria for Ni, Cu and Co is based on phytotoxicity, as these metals are each potentially toxic to vegetation at soil concentrations much lower than those that can cause health effect, with Ni being the most toxic of the three. The mechanism for Ni phytotoxicity is not known precisely, but excessive Ni is believed to induce Fe deficiency in plants. The MOE soil nickel Table A Guideline was set at 200 *u*g/g for medium/fine textured soil as are found in the Port Colborne region. This criterion is based on lowest observable effects levels. Soil Ni concentrations in excess of 200 *u*g/g have the potential to cause injury to sensitive plant species (i.e. either in the form of reduced growth, reduced yield or foliar injury). Cereal grains such as oats, barley and ryegrass are amongst the most sensitive plants to nickel; deciduous plants and garden crops are more variable, ranging from moderately sensitive to moderately tolerant. The potential for soil contaminated with Ni, as well as Cu and Co, to cause adverse effects to vegetation is dependent on the physical and chemical characteristics of the soil and form of metal present in the soil. The areas in and around Port Colborne, which have been determined to have soil Ni concentrations above the Table A soil Ni criterion contain clay soils

with neutral soil pH. Generally Ni (as well as Cu and Co) is more available for plant uptake in more acidic soil (lower pH), sandy in nature and having a lower cation exchange capacity and little organic content. The Ni in the impacted soils is not likely to be very bioavailable because of the soil characteristics in the region. Also, soil Ni readily complexes with other elements in the soil, such as sulphur (S), iron (Fe), manganese Mn), and calcium (Ca) that will further reduce Ni availability for plant uptake.

10.3 Human Health Risks

The 1999 Phytotoxicology study better defined the areas impacted by soil Ni, Cu and Co above the Table A "effects-based" criteria. The MOE site-specific risk assessment [Ref. 5] that was done for the Port Colborne area considered all potential exposure pathways (e.g. ingestion of soil, water, garden produce; inhalation; and dermal contact with soil). The MOE risk assessment report concluded there are no adverse health effects anticipated from expose to the soil Ni, Cu and Co levels in the city of Port Colborne or the surrounding region. Also, a review of population health data did not indicate any adverse health effects were evident which may have resulted from environmental exposures to these metals in the soil.

11.0 Conclusions

Inclusion of the additional sampling data provided from the 1999 sampling stations and historical survey results, along with the 1998 survey data, produced modifications to the shape and size of the 43-100 *u*g/g soil Ni, 100-200 *u*g/g soil Ni and 200-500 *u*g/g soil Ni contour intervals, respectively in the computer generated maps for Port Colborne and the surrounding region. The MOE Table F soil background value for Ni is exceeded beyond a distance of 28 km northeast of INCO and over a area of 345 km^2. The Cu and Co Table F soil values are exceeded in surface soil beyond a 3 km distance in the same direction, and over areas of 7.9 and 7.2 km^2 , respectively. Soil Ni concentrations are shown to exceed the MOE Table A soil remediation criterion for up to 3 km northeast of INCO and is estimated to cover an area of almost 29 km^2. Table A Cu and Co criteria are exceeded over areas of 0.2 and 0.8 km^2, respectively. As previously mentioned, soil concentrations of Ni, Cu and Co which exceed their corresponding Table A criterion are potentially phytotoxic. The substantial increase in sample sites (a total of 200 sites) has provided a more precise estimate of the area in and around the city of Port Colborne that has been impacted by over sixty-six years of INCO emissions and atmospheric deposition.

The soil metal contamination in Port Colborne is not a threat to human health but can be potentially phytotoxic with Ni being the most toxic. Agricultural liming and fertilizer amendments should allow for remediation of the areas above the Table A 'effects-based' criteria with marginal disturbance to the impacted properties. The amount of lime and application rate will depend on the contaminant concentration, the soil physical and chemical characteristics of

the soils to be remediated. At sites where the soil Ni, Cu and Co contamination only marginally exceeds Table A criteria, and the contamination is concentrated in the surface soil, deep cultivation may lower metal concentrations in the rooting zone of plants sufficiently that soil is no longer potentially phytotoxic.

12.0 References

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5. Ontario Ministry of the Environment. 1997. *Technical Report: Assessment of Potential Health Risks of Reported Soil Levels of Nickel, Copper, and Cobalt in Port Colborne and Vicinity, May 1997.*

Table 1: Station Identification, Location, Description - 1999 INCO Pt. Colborne Soil Survey (Sample depth 0-5 cm)

Station No.	UTM Easting	UTM Northing	Distance from Stack (km)	Direction (degrees)	Station Description
170	640115	4748108	3,621	260	Right-of-way on north side of Lakeshore Rd. W (west of Cement Rd.)
171	640422	4748590	3,260	267	Right-of-way on west side of Cement Rd. (500 m north of Lakeshore Rd)
172	640784	4747668	3,091	249	Vacant lot on south side of Orchard Dr. (west of Cedar Dr.)
173	641168	4748461	2,527	263	Residential property at bottom end of Hampton Rd (at turn)
174	641368	4748814	2,311	271	Front yard of residence at Sugarloaf and Laketown Dr.
175	641818	4749022	1,879	278	Side yard of residence on northeast corner of Ash and Clarke
176	642307	4748844	1,374	274	H.H. Knoll Lakeview Park (Steele and Sugarloaf)
177	642860	4748740	818	269	City of Pt. Colborne Operations and Communications Services Div. site
178	640774	4749253	2,946	280	Wooded lot at southeast corner of Clarence Rd. and Westwood Dr.
179	641107	4749341	2,637	283	Side yard of residence on southwest corner of Clarence and Hampton Rd.
180	642063	4749368	1,727	291	Front lawn of Pt. Colborne Public School
181	642276	4749300	1,504	291	Boulevard in front of residence on south side of Charlott St. west of Fieldon
182	643322	4750037	1,331	344	Lawn in front of transformer station on northwest corner Janet and Killaly.
183	644182	4749948	1,295	23	Boulevard of residence on north side of Cross St. east of Elizabeh St.
184	644932	4749524	1,471	58	Right of way on Snyder Rd. south of Killaly Rd. (near RR)
185	647468	4747728	3,927	105	East side of Miller Rd. allowance (north of Pine Crest Lane)
186	647538	4745452	5,080	131	Clay road 550 m North of Pinecrest Lane W. (south of Killaly St. E)
187	643385	4750557	1,826	351	Side yard of residence on northwest corner of Crescent and Clarke
188	644125	4750550	1,850	14	Woodlot on east side of Elizabeth St. (500 m south of Hwy 3)
189	643669	4751026	2,271	360	Front yard of residence on east side of Wellington St. opposite Chestnut
190	644957	4751158	2,722	28	Boulevard of residence on north side of Hwy 3 east of Snyder Rd.
191	645776	4751210	3,229	41	Front yard of residence on west side of Babion Rd., north of Hwy 3
192	646580	4751210	3,801	50	Roadside of Carl Rd. approx. 300m North of Hwy 3 (at field entrance).
193	647421	4751264	4,506	56	Along fenceline, east side of Miller Rd., just south of Killaly Rd.

Station No.	UTM Easting	UTM Northing	Distance from Stack (km)	Direction (degrees)	Station Description
194	648267	4750989	5,104	64	East side of White Rd., 1.2 km south of 2nd Concession line.
195	649099	4751030	5,879	67	West side of right of way on Sherk Rd, 1.1 km S of 2 nd Concession Rd.
196	655615	4748457	11,941	91	West side of Pt. Albino Rd. at Mitchener Rd. (in front of cottonwoods)
197	642980	4752181	3,496	348	Boulevard of residence at end of Barrick Rd (just west of RR tracks)
198	643524	4752092	3,341	357	Right-of-way on east side of Barber Rd., south of the 2nd Concession Rd.
199	644916	4752198	3,659	20	Right-of-way on west side of Snyder Rd at intersection with 2ndConcession
200	646592	4752138	4,465	41	Woods on southwest corner of Carl Rd. and 2nd Concession Rd.
201	647416	4752165	5,060	48	SW corner of 2nd Concession and Miller Rd. (triangle between rd and field).
202	641586	4753315	5,017	335	Industrial park lawn at southwest corner of Stonebridge Rd. and Hwy 58
203	642329	4753133	4,581	343	Front lawn of Pt. Colborne Animal Control Centre (Elm and Stoneridge Rd)
204	642342	4754621	6,016	347	Side yard of residence on east side of Elm St. (½ km south of Mud Lake)
205	642866	4753686	4,997	351	Right-of-way on Invertose Dr., 50 m west of turning circle (near CASCO)
206	643306	4754390	5,647	356	Park area along Kingway , east side of canal, south of the bridge.
207	643612	4752682	3,928	359	Right-of-way at end of Barber Rd. by canal north of the Can. Seaway Corp.
208	644923	4752837	4,268	17	Right of way on west side of Snyder Rd. north of Chippawa Rd. (clay road)
209	645790	4753034	4,772	26	Right of way on west side of Babion Rd., north of the 2nd Concession Rd.
210	646575	4753128	5,246	34	West side of Carl St., 1.1 km south of 3rd Concession Rd.
211	647393	4753457	5,992	38	Right of way on east side of Miller Rd., 1.2 km N of 2nd concessioni
212	648232	4753115	6,305	46	West side of White Rd, 1.1 km south of 3rd Concession Rd.
213	649927	4752940	7,521	56	Open wooded area, east side of Brookfield Rd., 1.3 km S of 3rd Concession
214	652373	4754345	10,337	57	West side of Wilheim Rd, just south of 3rd Concession road allowance.
215	650751	4754373	9,033	52	NE corner of Concession 3 and Troup Rd.
216	649884	4754323	8,338	48	NE corner of Brookfield and 3rd Concession

Station No.	UTM Easting	UTM Northing	Distance from Stack (km)	Direction (degrees)	Station Description
217	644929	4754808	6,181	12	Backyard of residence at north end of Synder Rd. (north of Concession 3)
218	643278	4755841	7,097	357	Front yard of residence on NE corner of Crescent Dr. and Glenwood Pkwy.
219	645764	4760375	11,806	10	North side of Buchner Rd, 100m east of dead end (east of field entrance).
220	648858	4760481	12,819	24	South side of Buchner Rd., edge of woodlot east of Pearson Rd.
221	652183	4760617	14,596	36	West side of Meisener Rd., north edge of hardwood stand
222	654268	4759864	15,348	44	East end of Snyder Rd. (in a wooded area)
223	656157	4758353	15,743	52	Wooded area in ortheast corner of Lapp Rd and Netherby Rd.
224	658435	4760490	18,854	52	Open woods northeast corner of Morningstar Rd. and Sodom Rd.
225	656565	4755253	14,433	63	West side of House Rd., 3/4 way to next road south of Church St.
226	658650	4754988	16,218	67	Right-of-way on south side of Bowen Rd. just west of Hwy 116
227	656755	4752472	13,595	74	Hedgerow on south side of unopened Bertie Rd. (30 m east of House Rd)
228	648542	4750653	5,221	69	Elm tree grove on north side of Nigh Rd (west of pumping station).
229	645818	4750197	2,580	56	Side yard of resideon northeast corner of Lorraine Rd. and Killaly Rd.
230	647386	4749951	3,896	72	East side of Miller Rd. approx. 100m south of Killaly Rd.
231	649067	4750244	5,591	75	Front lawn of Gasline School, SW corner of Hwy 3 and Sherk Rd.
232	646656	4748004	3,071	104	West side of small concrete bridge near south end of Weaver Rd.
233	642353	4752787	4,244	342	Right of way on west side of Elm St. south of Stonebridge Rd.

Table 2: Additional Historical Stations used in preparation of Ni, Cu and Co Contour Maps (Sample depth 0-5 cm)

Station No.	UTM Easting	UTM Northing	Distance from Stack (km)	Direction (degrees)	Station Description	Soil Ni (ug/g)	Soil Cu (ug/g)	Soil Co (ug/g)
H1	659956	4751715	16,545	80	OTR	48	25	6.1
H2	656369	4770615	25,277	30	OTR	20	24	5.9
H3	642559	4760975	12,271	355	OTR	30	33	9.8
H4	643222	4778325	29,574	359	OTR	25	25	17
H5	641919	4761964	13,326	352	OTR	34	17	7.7
H6	644193	4761140	12,396	2	OTR	47	18	7.4
H7	642519	4761104	12,403	355	OTR	47	27	9.9
H8	641700	4758694	10,134	349	OTR	46	28	9.3
H9	654570	4772612	26,226	25	OTR	16	18	4.8
H10	654488	4772045	25,676	25	OTR	21	20	5.8
H11	652254	4771419	24,232	21	OTR	15	27	5.3
H12	653612	4770144	23,583	25	OTR	14	12	6.3
H13	654088	4772045	25,511	24	OTR	10	13	3.3
H14	652030	4772049	24,746	20	OTR	13	14	4.4
H15	642931	4761251	12,518	357	OTR	53	58	8.6
H16	642213	4762221	13,545	354	OTR	27	20	7.6
H17	642133	4764375	15,696	354	OTR	16	10	3.7
H18	641496	4763323	14,731	351	OTR	18	13	5.7

Station No.	UTM Easting	UTM Northing	Distance from Stack (km)	Direction (degrees)	Station Description	Soil Ni (ug/g)	Soil Cu (ug/g)	Soil Co (ug/g)
H19	642759	4760508	11,789	356	OTR	29	39	5.4
H20	642193	4764227	15,543	355	OTR	13	11	3.8
H21	643860	4762695	13,941	1	Atlas Steel	97	15	25
H22	643835	4762645	13,891	1	Atlas Steel	115	10	25
H23	643810	4763350	14,596	1	Altas Steel	57	11	24
H24	644330	4763760	15,019	2	Atlas Steel	48	16	21
H25	644345	4762650	13,911	3	Atlas Steel	225	9	48
H26	643960	4761910	13,158	1	Atlas Steel	135	11	33
H27	643071	4763090	14,348	358	Atlas Steel	38	7	19
H28	644130	4759740	10,994	2	Atlas Steel	42	10	21
H29	650517	4767815	20,250	20	Cyanamid	23	5	22
H30	651717	4769115	21,890	22	Cyanamid	25	20	5
H31	649017	4767115	19,121	16	Cyanamid	24	13	8
H32	648017	4765715	17,506	14	Cyanamid	39	22	8.5
H33	658280	4763980	21,095	44	Metcorp	36	27	9.1
H34	643519	4749200	473	340	K. Dube property	4100	290	95
H35	643489	4749200	483	337	K. Dube property	8000	500	130
H36	645534	4750439	2,506	48	R. Kramer property	7500	860	120
H37	645569	4750439	2,532	48	R. Kramer property	1100	27	130
H38	645570	4750472	2,555	48	R. Kramer property	2000	220	41
H39	645989	4750395	2,834	55	T. Kramer property	450	61	18

Station No.	UTM Easting	UTM Northing	Distance from Stack (km)	Direction (degrees)	Station Description	Soil Ni (ug/g)	Soil Cu (ug/g)	Soil Co (ug/g)
H40	645989	4750436	2,858	54	T. Kramer property	340	53	17
H41	643537	4762125	13,371	359	Gencorp (Atlas)	260	50	20
H42	643427	4762075	13,322	359	Gencorp (Atlas)	40	13	5
H43	643317	4762015	13,265	358	Gencorp (Atlas)	89	25	10
H44	643217	4761945	13,198	358	Gencorp (Atlas)	83	43	11
H45	643807	4762525	13,771	1	Gencorp (Atlas)	78	33	9
H46	643617	4762525	13,770	360	Gencorp (Atlas)	75	31	13
H47	643757	4761835	13,080	0	Gencorp (Atlas)	260	64	14
H48	643757	4761655	12,900	0	Gencorp (Atlas)	59	38	14

Table 3: Concentrations of nickel, copper and cobalt in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999) (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	NIckel[3]	Copper[4]	Cobalt[5]
170	right-of-way	3621	260	**185**	21	6
171	right-of-way	3260	267	**115**	36	8
172	vacant lot	3091	249	**110**	20	5
173	vacant lot	2527	263	43	11	5
174	residential	2311	271	**91**	26	8
175	residential	1879	278	**103**	26	9
176	park	1374	274	20	42	5
177	lawn	818	269	**430**	69	14
178	woodlot	2946	280	**145**	31	12
179	residential	2637	283	**83**	19	7
180	school yard	1727	291	**70**	21	10
181	boulevard	1504	291	**92**	25	7
182	lawn	1331	344	**350**	63	16
183	boulevard	1295	23	**1050**	**135**	**30**
184	right-of-way	1471	58	**1250**	**170**	**33**
185	woodlot	3927	105	**120**	19	5
186	woodlot	5080	131	**320**	63	11
187	residential	1826	351	**370**	55	17
188	woodlot	1850	14	**550**	81	21
189	residential	2271	360	**180**	42	13
190	boulevard	2722	28	**490**	70	18
191	residential	3229	41	**285**	48	14
192	field	3801	50	**430**	57	14
193	field	4506	56	**265**	44	10
194	woodlot	5104	64	**535**	66	17
195	woodlot	5879	67	**195**	32	16
196	woodlot	11941	91	43	27	7
197	boulevard	3496	348	**290**	49	11
198	right-of-way	3341	357	**145**	58	8
199	right-of-way	3659	20	**180**	39	10
200	woodlot	4465	41	**525**	**89**	17
201	lawn	5060	48	**305**	50	14
202	lawn	5017	335	**105**	27	9
203	lawn	4581	343	**71**	28	8
204	residential	6016	347	**91**	42	10
205	right-of-way	4997	351	**65**	18	8
206	park	5647	356	**185**	40	13
207	boulevard	3928	359	**255**	64	12
208	right-of-way	4268	17	**130**	30	18
209	right-of-way	4772	26	**165**	33	15
210	field	5246	34	**340**	48	11
211	field	5992	38	**160**	42	8
212	field	6305	46	**215**	41	16
213	woodlot	7521	56	**330**	52	14
214	woodlot	10337	57	**170**	42	13
215	woodlot	9033	52	**81**	29	14
216	field	8338	48	**225**	49	11
217	residential	6181	12	**95**	32	15
218	residential	7097	357	**72**	27	8
219	field	11806	10	**60**	32	12
220	woodlot	12819	24	**75**	20	14

Station No.	Land Use	Distance[1]	Direction[2]	NIckel[3]	Copper[4]	Cobalt[5]
221	woodlot	14596	36	**102**	18	6
222	woodlot	15348	44	**93**	41	12
223	woodlot	15743	52	**71**	25	18
224	woodlot	18854	52	**78**	22	12
225	woodlot	14433	63	**85**	24	14
226	field	16218	67	**60**	25	18
227	woodlot	13595	74	40	18	12
228	lawn	5221	69	43	15	13
229	residential	2580	56	**515**	83	19
230	woodlot	3896	72	**735**	**105**	**24**
231	school yard	5591	75	**71**	29	8
232	woodlot	3071	104	**108**	31	9
233	right-of-way	4244	342	**390**	67	16

1 - Distance (metres) from INCO stack 2 - Direction (degrees) from INCO stack
3 - Exceedences of background-based Table F for nickel (43 µg/g) are bolded, exceedences of effects-based Table A (200 µg/g) are shaded
4 - Exceedences of background-based Table F for copper (85 µg/g) are bolded, exceedences of effects-based Table A (300 µg/g) are shaded
5 - Exceedences of background-based Table F for cobalt (21 µg/g) are bolded, exceedences of effects-based Table A (50 µg/g) are shade

Table 4: Estimate of Areas that Exceed the MOE Table F and Table A Soil Criteria as determined by Surfer/ArcView (1999 vs. 1998 data)

Port Colborne Region	Soil Nickel		Soil Copper		Soil Cobalt	
Surveys	1999	1998	1999	1998	1999	1998
Area where 0-5 cm soil concentrations exceed Table F criterion.	345 km^2	>159 km^2	7.9 km^2	8.9 km^2	7.2 km^2	6.1 km^2
Area in which 0-5 cm soil concentrations exceed Table A criterion.	28.6 km^2	19 km^2	0.2 km^2	0.3 km^2	0.8 km^2	1.6 km^2

Appendix A1: Concentration of Aluminum (Al) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*ug*/g)

Station No.	Land Use	Distance[1]	Direction[2]	Aluminum[3]
170	right-of-way	3621	260	3550
171	right-of-way	3260	267	14000
172	vacant lot	3091	249	3450
173	vacant lot	2527	263	7400
174	residential	2311	271	17000
175	residential	1879	278	16500
176	park	1374	274	6850
177	lawn	818	269	16000
178	woodlot	2946	280	20500
179	residential	2637	283	16500
180	school yard	1727	291	17000
181	boulevard	1504	291	15000
182	lawn	1331	344	23000
183	boulevard	1295	23	13000
184	right-of-way	1471	58	19500
185	woodlot	3927	105	12000
186	woodlot	5080	131	24500
187	residential	1826	351	21000
188	woodlot	1850	14	26000
189	residential	2271	360	18000
190	boulevard	2722	28	23000
191	residential	3229	41	16500
192	field	3801	50	18500
193	field	4506	56	17000
194	woodlot	5104	64	17000
195	woodlot	5879	67	19500
196	woodlot	11941	91	12500
197	boulevard	3496	348	26000
198	right-of-way	3341	357	7400
199	right-of-way	3659	20	18000
200	woodlot	4465	41	30000
201	lawn	5060	48	16000
202	lawn	5017	335	14500
203	lawn	4581	343	18000
204	residential	6016	347	17000
205	right-of-way	4997	351	19500
206	park	5647	356	18500
207	boulevard	3928	359	14000
208	right-of-way	4268	17	25000
209	right-of-way	4772	26	20500
210	field	5246	34	13000
211	field	5992	38	11500
212	field	6305	46	23000
213	woodlot	7521	56	19500
214	woodlot	10337	57	15000
215	woodlot	9033	52	19000
216	field	8338	48	13000
217	residential	6181	12	26500

Station No.	Land Use	Distance[1]	Direction[2]	Aluminum[3]
218	residential	7097	357	19000
219	field	11806	10	17000
220	woodlot	12819	24	22500
221	woodlot	14596	36	21000
222	woodlot	15348	44	26000
223	woodlot	15743	52	22500
224	woodlot	18854	52	22000
225	woodlot	14433	63	21500
226	field	16218	67	24500
227	woodlot	13595	74	20000
228	lawn	5221	69	19000
229	residential	2580	56	16500
230	woodlot	3896	72	27500
231	school yard	5591	75	14500
232	woodlot	3071	104	12000
233	right-of-way	4244	342	19500

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Excedences of OTR_{98} for aluminum (30,000 ug/g) are shaded.

Appendix A2: Concentration of Arsenic (As) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*ug*/g)

Station No.	Land Use	Distance[1]	Direction[2]	Arsenic[3]
170	right-of-way	3621	260	4.0
171	right-of-way	3260	267	5.4
172	vacant lot	3091	249	1.8
173	vacant lot	2527	263	2.2
174	residential	2311	271	4.3
175	residential	1879	278	7.5
176	park	1374	274	3.3
177	lawn	818	269	8.4
178	woodlot	2946	280	8.1
179	residential	2637	283	4.1
180	school yard	1727	291	5.4
181	boulevard	1504	291	4.3
182	lawn	1331	344	9.3
183	boulevard	1295	23	9.2
184	right-of-way	1471	58	9.8
185	woodlot	3927	105	2.8
186	woodlot	5080	131	5.8
187	residential	1826	351	7.5
188	woodlot	1850	14	8.1
189	residential	2271	360	7.2
190	boulevard	2722	28	8.9
191	residential	3229	41	7.2
192	field	3801	50	8.5
193	field	4506	56	7.2
194	woodlot	5104	64	8.7
195	woodlot	5879	67	8.3
196	woodlot	11941	91	5.1
197	boulevard	3496	348	5.6
198	right-of-way	3341	357	5.7
199	right-of-way	3659	20	6.2
200	woodlot	4465	41	9.3
201	lawn	5060	48	6.7
202	lawn	5017	335	4.6
203	lawn	4581	343	4.7
204	residential	6016	347	7.0
205	right-of-way	4997	351	4.5
206	park	5647	356	6.8
207	boulevard	3928	359	6.6
208	right-of-way	4268	17	8.8
209	right-of-way	4772	26	9.1
210	field	5246	34	6.5
211	field	5992	38	6.0
212	field	6305	46	9.7
213	woodlot	7521	56	7.5
214	woodlot	10337	57	7.8
215	woodlot	9033	52	6.6
216	field	8338	48	6.9
217	residential	6181	12	6.1

Station No.	Land Use	Distance[1]	Direction[2]	Arsenic[3]
218	residential	7097	357	4.9
219	field	11806	10	9.6
220	woodlot	12819	24	11.0
221	woodlot	14596	36	6.6
222	woodlot	15348	44	7.6
223	woodlot	15743	52	9.7
224	woodlot	18854	52	9.8
225	woodlot	14433	63	9.6
226	field	16218	67	8.6
227	woodlot	13595	74	6.7
228	lawn	5221	69	8.0
229	residential	2580	56	8.4
230	woodlot	3896	72	14
231	school yard	5591	75	5.8
232	woodlot	3071	104	5.5
233	right-of-way	4244	342	7.8

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of background-based Table F for arsenic (17 µg/g) are bolded, excedences of effects-based Table A (25 µg/g) are shaded.

Appendix A3: Concentration of Barium (Ba) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	Barium[3]
170	right-of-way	3621	260	24.5
171	right-of-way	3260	267	85
172	vacant lot	3091	249	30
173	vacant lot	2527	263	35.5
174	residential	2311	271	92.5
175	residential	1879	278	93
176	park	1374	274	87.5
177	lawn	818	269	105
178	woodlot	2946	280	115
179	residential	2637	283	81
180	school yard	1727	291	88.5
181	boulevard	1504	291	71
182	lawn	1331	344	130
183	boulevard	1295	23	99
184	right-of-way	1471	58	125
185	woodlot	3927	105	45.5
186	woodlot	5080	131	155
187	residential	1826	351	110
188	woodlot	1850	14	150
189	residential	2271	360	110
190	boulevard	2722	28	130
191	residential	3229	41	100
192	field	3801	50	110
193	field	4506	56	94
194	woodlot	5104	64	110
195	woodlot	5879	67	130
196	woodlot	11941	91	48.5
197	boulevard	3496	348	140
198	right-of-way	3341	357	66
199	right-of-way	3659	20	98.5
200	woodlot	4465	41	170
201	lawn	5060	48	110
202	lawn	5017	335	99
203	lawn	4581	343	90
204	residential	6016	347	120
205	right-of-way	4997	351	89
206	park	5647	356	97.5
207	boulevard	3928	359	93.5
208	right-of-way	4268	17	155
209	right-of-way	4772	26	120
210	field	5246	34	59.5
211	field	5992	38	76
212	field	6305	46	150
213	woodlot	7521	56	150
214	woodlot	10337	57	125
215	woodlot	9033	52	115
216	field	8338	48	95
217	residential	6181	12	140
218	residential	7097	357	89.5

Station No.	Land Use	Distance[1]	Direction[2]	Barium[3]
219	field	11806	10	130
220	woodlot	12819	24	150
221	woodlot	14596	36	105
222	woodlot	15348	44	145
223	woodlot	15743	52	105
224	woodlot	18854	52	110
225	woodlot	14433	63	100
226	field	16218	67	115
227	woodlot	13595	74	115
228	lawn	5221	69	88.5
229	residential	2580	56	100.5
230	woodlot	3896	72	155
231	school yard	5591	75	85.5
232	woodlot	3071	104	88.5
233	right-of-way	4244	342	135

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of background-based Table F for barium (210 µg/g) are bolded, exceedences of effects-based Table A (1000 µg/g) are shaded

Appendix A4: Concentration of Beryllium (Be) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	Beryllium[3]
170	right-of-way	3621	260	0.5 < W
171	right-of-way	3260	267	0.7 < T
172	vacant lot	3091	249	0.5 < W
173	vacant lot	2527	263	0.5 < W
174	residential	2311	271	0.8 < T
175	residential	1879	278	0.7 < T
176	park	1374	274	0.5 < W
177	lawn	818	269	0.8 < T
178	woodlot	2946	280	1.0 < T
179	residential	2637	283	0.8 < T
180	school yard	1727	291	0.7 < T
181	boulevard	1504	291	0.7 < T
182	lawn	1331	344	1.1 < T
183	boulevard	1295	23	0.6 < T
184	right-of-way	1471	58	1.0 < T
185	woodlot	3927	105	1.0 < T
186	woodlot	5080	131	1.1 < T
187	residential	1826	351	0.9 < T
188	woodlot	1850	14	1.2 < T
189	residential	2271	360	0.9 < T
190	boulevard	2722	28	1.1 <T
191	residential	3229	41	0.8 < T
192	field	3801	50	0.8 < T
193	field	4506	56	0.6 < T
194	woodlot	5104	64	0.6 < T
195	woodlot	5879	67	0.9 < T
196	woodlot	11941	91	1.1 < T
197	boulevard	3496	348	1.1 < T
198	right-of-way	3341	357	0.5 < W
199	right-of-way	3659	20	0.8 < T
200	woodlot	4465	41	**1.3 < T**
201	lawn	5060	48	0.7 < T
202	lawn	5017	335	0.7 < T
203	lawn	4581	343	0.7 < T
204	residential	6016	347	0.8 < T
205	right-of-way	4997	351	0.7 < T
206	park	5647	356	0.9 < T
207	boulevard	3928	359	0.9 < T
208	right-of-way	4268	17	1.2 < T
209	right-of-way	4772	26	1.0 < T
210	field	5246	34	0.7 < T
211	field	5992	38	0.5 < W
212	field	6305	46	1.1 < T
213	woodlot	7521	56	0.8 < T
214	woodlot	10337	57	0.9 < T
215	woodlot	9033	52	1.0 < T
216	field	8338	48	0.7 < T

Station No.	Land Use	Distance[1]	Direction[2]	Beryllium[3]
217	residential	6181	12	1.1 < T
218	residential	7097	357	0.8 < T
219	field	11806	10	0.8 < T
220	woodlot	12819	24	0.9 < T
221	woodlot	14596	36	0.9 < T
222	woodlot	15348	44	**1.6 < T**
223	woodlot	15743	52	1.1 < T
224	woodlot	18854	52	0.9 < T
225	woodlot	14433	63	1.0 < T
226	field	16218	67	1.2 < T
227	woodlot	13595	74	0.9 < T
228	lawn	5221	69	0.9 < T
229	residential	2580	56	0.8 < T
230	woodlot	3896	72	1.2 < T
231	school yard	5591	75	0.6 < T
232	woodlot	3071	104	0.9 < T
233	right-of-way	4244	342	0.6 < T

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of background-based Table F for beryllium (1.2 µg/g) are bolded, exceedences of effects-based Table A (1.2 µg/g) are shaded

Appendix A5: Concentration of Calcium (Ca) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	Calcium[3]
170	right-of-way	3621	260	5550
171	right-of-way	3260	267	31000
172	vacant lot	3091	249	15000
173	vacant lot	2527	263	10500
174	residential	2311	271	10450
175	residential	1879	278	9150
176	park	1374	274	48000
177	lawn	818	269	26500
178	woodlot	2946	280	12000
179	residential	2637	283	9550
180	school yard	1727	291	6650
181	boulevard	1504	291	12500
182	lawn	1331	344	12500
183	boulevard	1295	23	34000
184	right-of-way	1471	58	27500
185	woodlot	3927	105	5850
186	woodlot	5080	131	6350
187	residential	1826	351	12000
188	woodlot	1850	14	15500
189	residential	2271	360	15000
190	boulevard	2722	28	10250
191	residential	3229	41	5200
192	field	3801	50	2950
193	field	4506	56	9400
194	woodlot	5104	64	6800
195	woodlot	5879	67	4100
196	woodlot	11941	91	3850
197	boulevard	3496	348	12350
198	right-of-way	3341	357	95500
199	right-of-way	3659	20	21000
200	woodlot	4465	41	9350
201	lawn	5060	48	15500
202	lawn	5017	335	46500
203	lawn	4581	343	5800
204	residential	6016	347	13000
205	right-of-way	4997	351	4950
206	park	5647	356	9400
207	boulevard	3928	359	36500
208	right-of-way	4268	17	6300
209	right-of-way	4772	26	5700
210	field	5246	34	7050
211	field	5992	38	33500
212	field	6305	46	7050
213	woodlot	7521	56	9150
214	woodlot	10337	57	18500
215	woodlot	9033	52	19000
216	field	8338	48	17000

Station No.	Land Use	Distance[1]	Direction[2]	Calcium[3]
Station No.	**Land Use**	**Distance[1]**	**Direction[2]**	**Calcium[3]**
217	residential	6181	12	12500
218	residential	7097	357	11950
219	field	11806	10	21500
220	woodlot	12819	24	6500
221	woodlot	14596	36	2750
222	woodlot	15348	44	5300
223	woodlot	15743	52	4750
224	woodlot	18854	52	5200
225	woodlot	14433	63	4950
226	field	16218	67	7650
227	woodlot	13595	74	6600
228	lawn	5221	69	2900
229	residential	2580	56	25500
230	woodlot	3896	72	8800
231	school yard	5591	75	15000
232	woodlot	3071	104	19000
233	right-of-way	4244	342	34500

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of OTR_{98} for calcium (55,000 ug/g) are shaded

Appendix A6: Concentration of Cadmium (Cd) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	Cadmium[3]
170	right-of-way	3621	260	0.4
171	right-of-way	3260	267	0.7
172	vacant lot	3091	249	0.4
173	vacant lot	2527	263	0.3
174	residential	2311	271	0.5
175	residential	1879	278	0.5
176	park	1374	274	0.5
177	lawn	818	269	0.7
178	woodlot	2946	280	0.8
179	residential	2637	283	0.4
180	school yard	1727	291	0.5
181	boulevard	1504	291	0.6
182	lawn	1331	344	0.6
183	boulevard	1295	23	0.4
184	right-of-way	1471	58	0.6
185	woodlot	3927	105	0.5
186	woodlot	5080	131	**1.3**
187	residential	1826	351	0.7
188	woodlot	1850	14	0.6
189	residential	2271	360	0.7
190	boulevard	2722	28	0.7
191	residential	3229	41	0.4
192	field	3801	50	0.3
193	field	4506	56	0.3
194	woodlot	5104	64	0.4
195	woodlot	5879	67	0.8
196	woodlot	11941	91	0.5
197	boulevard	3496	348	0.7
198	right-of-way	3341	357	0.4
199	right-of-way	3659	20	0.4
200	woodlot	4465	41	**1.3**
201	lawn	5060	48	0.4
202	lawn	5017	335	0.6
203	lawn	4581	343	0.3
204	residential	6016	347	0.5
205	right-of-way	4997	351	0.4
206	park	5647	356	0.9
207	boulevard	3928	359	0.6
208	right-of-way	4268	17	0.4
209	right-of-way	4772	26	0.4
210	field	5246	34	0.6
211	field	5992	38	0.4
212	field	6305	46	0.5
213	woodlot	7521	56	0.6
214	woodlot	10337	57	0.5
215	woodlot	9033	52	0.6
216	field	8338	48	0.8
217	residential	6181	12	0.7
218	residential	7097	357	0.5

Station No.	Land Use	Distance[1]	Direction[2]	Cadmium[3]
219	field	11806	10	0.6
220	woodlot	12819	24	0.9
221	woodlot	14596	36	0.7
222	woodlot	15348	44	**1.3**
223	woodlot	15743	52	0.6
224	woodlot	18854	52	0.7
225	woodlot	14433	63	0.5
226	field	16218	67	0.7
227	woodlot	13595	74	0.5
228	lawn	5221	69	0.5
229	residential	2580	56	0.4
230	woodlot	3896	72	1.0
231	school yard	5591	75	0.6
232	woodlot	3071	104	0.7
233	right-of-way	4244	342	0.4

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of background-based Table F for cadmium (1.0 µg/g) are bolded, exceedences of effects-based Table A (12 µg/g) are shaded

Appendix A7: Concentration of Chromium (Cr) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	Chromium[3]
170	right-of-way	3621	260	13
171	right-of-way	3260	267	21
172	vacant lot	3091	249	11
173	vacant lot	2527	263	12
174	residential	2311	271	23
175	residential	1879	278	24.5
176	park	1374	274	13.5
177	lawn	818	269	24.5
178	woodlot	2946	280	32
179	residential	2637	283	21
180	school yard	1727	291	22.5
181	boulevard	1504	291	20.5
182	lawn	1331	344	34
183	boulevard	1295	23	23
184	right-of-way	1471	58	29.5
185	woodlot	3927	105	17
186	woodlot	5080	131	30.5
187	residential	1826	351	31
188	woodlot	1850	14	39
189	residential	2271	360	29.5
190	boulevard	2722	28	39
191	residential	3229	41	24
192	field	3801	50	26.5
193	field	4506	56	24
194	woodlot	5104	64	26
195	woodlot	5879	67	30.5
196	woodlot	11941	91	18.5
197	boulevard	3496	348	36
198	right-of-way	3341	357	18
199	right-of-way	3659	20	24.5
200	woodlot	4465	41	39.5
201	lawn	5060	48	23.5
202	lawn	5017	335	23.5
203	lawn	4581	343	27
204	residential	6016	347	26.5
205	right-of-way	4997	351	25.5
206	park	5647	356	25.5
207	boulevard	3928	359	24.5
208	right-of-way	4268	17	42
209	right-of-way	4772	26	32.5
210	field	5246	34	21
211	field	5992	38	20.5
212	field	6305	46	33.5
213	woodlot	7521	56	29.5
214	woodlot	10337	57	25.5
215	woodlot	9033	52	31
216	field	8338	48	25

Station No.	Land Use	Distance[1]	Direction[2]	Chromium[3]
217	residential	6181	12	43
218	residential	7097	357	28.5
219	field	11806	10	35.5
220	woodlot	12819	24	36.5
221	woodlot	14596	36	24.5
222	woodlot	15348	44	36
223	woodlot	15743	52	40.5
224	woodlot	18854	52	37
225	woodlot	14433	63	36.5
226	field	16218	67	40.5
227	woodlot	13595	74	34.5
228	lawn	5221	69	29
229	residential	2580	56	46
230	woodlot	3896	72	36
231	school yard	5591	75	22.5
232	woodlot	3071	104	22.5
233	right-of-way	4244	342	35.5

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of background-based Table F for chromium (71 µg/g) are bolded, exceedences of effects-based Table A (1000 µg/g) are shaded

Appendix A8: Concentration of Iron (Fe) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	Iron[3]
170	right-of-way	3621	260	13000
171	right-of-way	3260	267	15000
172	vacant lot	3091	249	12000
173	vacant lot	2527	263	10000
174	residential	2311	271	17000
175	residential	1879	278	18500
176	park	1374	274	12500
177	lawn	818	269	18500
178	woodlot	2946	280	22500
179	residential	2637	283	17000
180	school yard	1727	291	19000
181	boulevard	1504	291	16000
182	lawn	1331	344	27500
183	boulevard	1295	23	17000
184	right-of-way	1471	58	21000
185	woodlot	3927	105	9950
186	woodlot	5080	131	12000
187	residential	1826	351	23500
188	woodlot	1850	14	24500
189	residential	2271	360	20500
190	boulevard	2722	28	27000
191	residential	3229	41	22000
192	field	3801	50	21500
193	field	4506	56	18500
194	woodlot	5104	64	14000
195	woodlot	5879	67	26500
196	woodlot	11941	91	19000
197	boulevard	3496	348	17500
198	right-of-way	3341	357	12500
199	right-of-way	3659	20	19000
200	woodlot	4465	41	23000
201	lawn	5060	48	20000
202	lawn	5017	335	17000
203	lawn	4581	343	20500
204	residential	6016	347	17500
205	right-of-way	4997	351	21500
206	park	5647	356	18500
207	boulevard	3928	359	18500
208	right-of-way	4268	17	32000
209	right-of-way	4772	26	27500
210	field	5246	34	15000
211	field	5992	38	15500
212	field	6305	46	28500
213	woodlot	7521	56	18000
214	woodlot	10337	57	19500
215	woodlot	9033	52	22000
216	field	8338	48	14000
217	residential	6181	12	26000
218	residential	7097	357	17500

Station No.	Land Use	Distance[1]	Direction[2]	Iron[3]
219	field	11806	10	24500
220	woodlot	12819	24	30000
221	woodlot	14596	36	9250
222	woodlot	15348	44	18000
223	woodlot	15743	52	35500
224	woodlot	18854	52	28500
225	woodlot	14433	63	28500
226	field	16218	67	33500
227	woodlot	13595	74	25000
228	lawn	5221	69	26500
229	residential	2580	56	20500
230	woodlot	3896	72	25000
231	school yard	5591	75	18500
232	woodlot	3071	104	15500
233	right-of-way	4244	342	23500

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of OTR_{98} for iron (35,000 ug/g) are shaded

Appendix A9: Concentration of Magnesium (Mg) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	Magnesium[3]
170	right-of-way	3621	260	1150
171	right-of-way	3260	267	12000
172	vacant lot	3091	249	5750
173	vacant lot	2527	263	5300
174	residential	2311	271	5450
175	residential	1879	278	5200
176	park	1374	274	9500
177	lawn	818	269	12500
178	woodlot	2946	280	4950
179	residential	2637	283	5500
180	school yard	1727	291	4850
181	boulevard	1504	291	6900
182	lawn	1331	344	7700
183	boulevard	1295	23	16000
184	right-of-way	1471	58	15500
185	woodlot	3927	105	2300
186	woodlot	5080	131	3350
187	residential	1826	351	7000
188	woodlot	1850	14	10250
189	residential	2271	360	7900
190	boulevard	2722	28	7650
191	residential	3229	41	5100
192	field	3801	50	4000
193	field	4506	56	5500
194	woodlot	5104	64	4600
195	woodlot	5879	67	4950
196	woodlot	11941	91	3750
197	boulevard	3496	348	5900
198	right-of-way	3341	357	50500
199	right-of-way	3659	20	12500
200	woodlot	4465	41	6800
201	lawn	5060	48	8100
202	lawn	5017	335	24000
203	lawn	4581	343	4850
204	residential	6016	347	4350
205	right-of-way	4997	351	4650
206	park	5647	356	4450
207	boulevard	3928	359	20000
208	right-of-way	4268	17	8100
209	right-of-way	4772	26	6400
210	field	5246	34	3350
211	field	5992	38	17500
212	field	6305	46	7450
213	woodlot	7521	56	4600
214	woodlot	10337	57	5400
215	woodlot	9033	52	8000
216	field	8338	48	5250

Station No.	Land Use	Distance[1]	Direction[2]	Magnesium[3]
217	residential	6181	12	7550
218	residential	7097	357	6450
219	field	11806	10	10250
220	woodlot	12819	24	4400
221	woodlot	14596	36	2900
222	woodlot	15348	44	4800
223	woodlot	15743	52	6000
224	woodlot	18854	52	5300
225	woodlot	14433	63	5650
226	field	16218	67	7000
227	woodlot	13595	74	7100
228	lawn	5221	69	5300
229	residential	2580	56	13000
230	woodlot	3896	72	5800
231	school yard	5591	75	9200
232	woodlot	3071	104	9100
233	right-of-way	4244	342	16500

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of OTR_{98} for magnesium (20,000 ug/g) are shaded

Appendix A10: Concentration of Manganese (Mn) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	Manganese[3]
170	right-of-way	3621	260	410
171	right-of-way	3260	267	350
172	vacant lot	3091	249	180
173	vacant lot	2527	263	160
174	residential	2311	271	310
175	residential	1879	278	385
176	park	1374	274	520
177	lawn	818	269	370
178	woodlot	2946	280	625
179	residential	2637	283	255
180	school yard	1727	291	420
181	boulevard	1504	291	280
182	lawn	1331	344	630
183	boulevard	1295	23	460
184	right-of-way	1471	58	320
185	woodlot	3927	105	145
186	woodlot	5080	131	155
187	residential	1826	351	415
188	woodlot	1850	14	405
189	residential	2271	360	350
190	boulevard	2722	28	440
191	residential	3229	41	625
192	field	3801	50	450
193	field	4506	56	335
194	woodlot	5104	64	270
195	woodlot	5879	67	725
196	woodlot	11941	91	420
197	boulevard	3496	348	220
198	right-of-way	3341	357	415
199	right-of-way	3659	20	295
200	woodlot	4465	41	200
201	lawn	5060	48	520
202	lawn	5017	335	425
203	lawn	4581	343	285
204	residential	6016	347	265
205	right-of-way	4997	351	275
206	park	5647	356	365
207	boulevard	3928	359	450
208	right-of-way	4268	17	690
209	right-of-way	4772	26	595
210	field	5246	34	590
211	field	5992	38	370
212	field	6305	46	670
213	woodlot	7521	56	325
214	woodlot	10337	57	365
215	woodlot	9033	52	430
216	field	8338	48	290

Station No.	Land Use	Distance[1]	Direction[2]	Manganese[3]
217	residential	6181	12	375
218	residential	7097	357	275
219	field	11806	10	715
220	woodlot	12819	24	1250
221	woodlot	14596	36	126
222	woodlot	15348	44	370
223	woodlot	15743	52	750
224	woodlot	18854	52	475
225	woodlot	14433	63	650
226	field	16218	67	1900
227	woodlot	13595	74	635
228	lawn	5221	69	675
229	residential	2580	56	445
230	woodlot	3896	72	405
231	school yard	5591	75	575
232	woodlot	3071	104	270
233	right-of-way	4244	342	460

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of OTR_{98} for manganese (2,200 ug/g) are shaded

Appendix 11: Concentration of Molybdenum (Mo) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	Molybdenum[3]
170	right-of-way	3621	260	0.5
171	right-of-way	3260	267	0.5
172	vacant lot	3091	249	0.5
173	vacant lot	2527	263	0.5
174	residential	2311	271	0.5
175	residential	1879	278	0.5
176	park	1374	274	0.5
177	lawn	818	269	0.6
178	woodlot	2946	280	0.5
179	residential	2637	283	0.5
180	school yard	1727	291	0.5
181	boulevard	1504	291	0.5
182	lawn	1331	344	0.9
183	boulevard	1295	23	0.6
184	right-of-way	1471	58	1.4
185	woodlot	3927	105	0.5
186	woodlot	5080	131	0.8
187	residential	1826	351	0.8
188	woodlot	1850	14	1.3
189	residential	2271	360	0.8
190	boulevard	2722	28	1.2
191	residential	3229	41	0.5
192	field	3801	50	0.5
193	field	4506	56	0.5
194	woodlot	5104	64	0.5
195	woodlot	5879	67	0.9
196	woodlot	11941	91	0.5
197	boulevard	3496	348	0.9
198	right-of-way	3341	357	1.2
199	right-of-way	3659	20	0.7
200	woodlot	4465	41	0.7
201	lawn	5060	48	0.6
202	lawn	5017	335	0.5
203	lawn	4581	343	0.9
204	residential	6016	347	0.7
205	right-of-way	4997	351	0.6
206	park	5647	356	0.5
207	boulevard	3928	359	0.8
208	right-of-way	4268	17	1.2
209	right-of-way	4772	26	0.9
210	field	5246	34	0.5
211	field	5992	38	0.5
212	field	6305	46	0.7
213	woodlot	7521	56	0.8
214	woodlot	10337	57	0.7
215	woodlot	9033	52	0.6
216	field	8338	48	1.1

Station No.	Land Use	Distance[1]	Direction[2]	Molybdenum[3]
217	residential	6181	12	0.8
218	residential	7097	357	0.5
219	field	11806	10	1.2
220	woodlot	12819	24	1.1
221	woodlot	14596	36	1.1
222	woodlot	15348	44	1.1
223	woodlot	15743	52	1.1
224	woodlot	18854	52	**7.2**
225	woodlot	14433	63	1.2
226	field	16218	67	1.1
227	woodlot	13595	74	1.1
228	lawn	5221	69	0.8
229	residential	2580	56	1.2
230	woodlot	3896	72	0.9
231	school yard	5591	75	0.5
232	woodlot	3071	104	0.5
233	right-of-way	4244	342	1.0

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of background-based Table F for molybdenum (2.5 µg/g) are bolded, exceedences of effects-based Table A (40 µg/g) are shaded

Appendix A12: Concentration of Lead (Pb) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	Lead[3]
170	right-of-way	3621	260	28
171	right-of-way	3260	267	45
172	vacant lot	3091	249	27.5
173	vacant lot	2527	263	16
174	residential	2311	271	31.5
175	residential	1879	278	35
176	park	1374	274	31.5
177	lawn	818	269	76.5
178	woodlot	2946	280	29
179	residential	2637	283	41
180	school yard	1727	291	35
181	boulevard	1504	291	39
182	lawn	1331	344	43
183	boulevard	1295	23	63.5
184	right-of-way	1471	58	37.5
185	woodlot	3927	105	19
186	woodlot	5080	131	37.5
187	residential	1826	351	38.5
188	woodlot	1850	14	47.5
189	residential	2271	360	54
190	boulevard	2722	28	44.5
191	residential	3229	41	29.5
192	field	3801	50	30
193	field	4506	56	30.5
194	woodlot	5104	64	39
195	woodlot	5879	67	33.5
196	woodlot	11941	91	26
197	boulevard	3496	348	40.5
198	right-of-way	3341	357	97.5
199	right-of-way	3659	20	29
200	woodlot	4465	41	57.5
201	lawn	5060	48	40.5
202	lawn	5017	335	44.5
203	lawn	4581	343	21
204	residential	6016	347	115
205	right-of-way	4997	351	22
206	park	5647	356	45
207	boulevard	3928	359	103.5
208	right-of-way	4268	17	25.5
209	right-of-way	4772	26	33.5
210	field	5246	34	32
211	field	5992	38	44.5
212	field	6305	46	34.5
213	woodlot	7521	56	51
214	woodlot	10337	57	27.5
215	woodlot	9033	52	21.5
216	field	8338	48	42.5

Station No.	Land Use	Distance[1]	Direction[2]	Lead[3]
217	residential	6181	12	26.5
218	residential	7097	357	35.5
219	field	11806	10	85.5
220	woodlot	12819	24	50.5
221	woodlot	14596	36	46
222	woodlot	15348	44	54
223	woodlot	15743	52	39.5
224	woodlot	18854	52	41
225	woodlot	14433	63	36.5
226	field	16218	67	45
227	woodlot	13595	74	25
228	lawn	5221	69	37.5
229	residential	2580	56	59
230	woodlot	3896	72	46.5
231	school yard	5591	75	46.5
232	woodlot	3071	104	82
233	right-of-way	4244	342	60

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of background-based Table F for lead (120 µg/g) are bolded, exceedences of effects-based Table A (200 µg/g) are shaded

Appendix A13: Concentration of Strontium (Sr) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	Strontium[3]
170	right-of-way	3621	260	14
171	right-of-way	3260	267	**135**
172	vacant lot	3091	249	34
173	vacant lot	2527	263	35
174	residential	2311	271	36
175	residential	1879	278	30
176	park	1374	274	**105**
177	lawn	818	269	**74**
178	woodlot	2946	280	25
179	residential	2637	283	26
180	school yard	1727	291	22
181	boulevard	1504	291	36
182	lawn	1331	344	**67**
183	boulevard	1295	23	**78**
184	right-of-way	1471	58	**170**
185	woodlot	3927	105	27
186	woodlot	5080	131	**110**
187	residential	1826	351	61
188	woodlot	1850	14	**92**
189	residential	2271	360	55
190	boulevard	2722	28	39
191	residential	3229	41	26
192	field	3801	50	29
193	field	4506	56	42
194	woodlot	5104	64	**215**
195	woodlot	5879	67	33
196	woodlot	11941	91	32
197	boulevard	3496	348	**165**
198	right-of-way	3341	357	**165**
199	right-of-way	3659	20	59
200	woodlot	4465	41	**115**
201	lawn	5060	48	**104**
202	lawn	5017	335	**195**
203	lawn	4581	343	38
204	residential	6016	347	**71**
205	right-of-way	4997	351	37
206	park	5647	356	**78**
207	boulevard	3928	359	**79**
208	right-of-way	4268	17	42
209	right-of-way	4772	26	44
210	field	5246	34	30
211	field	5992	38	**150**
212	field	6305	46	**140**
213	woodlot	7521	56	**130**
214	woodlot	10337	57	**135**
215	woodlot	9033	52	**71**
216	field	8338	48	**86**

Station No.	Land Use	Distance[3]	Direction[4]	Strontium[5]
217	residential	6181	12	**94**
218	residential	7097	357	64
219	field	11806	10	57
220	woodlot	12819	24	34
221	woodlot	14596	36	25
222	woodlot	15348	44	45
223	woodlot	15743	52	30
224	woodlot	18854	52	32
225	woodlot	14433	63	33
226	field	16218	67	32
227	woodlot	13595	74	61
228	lawn	5221	69	41
229	residential	2580	56	**78**
230	woodlot	3896	72	**140**
231	school yard	5591	75	46
232	woodlot	3071	104	**101**
233	right-of-way	4244	342	**105**

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of OTR_{98} for strontium (64 µg/g) are shaded

Appendix A14: Concentration of Vanadium (V) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	Vanadium[3]
170	right-of-way	3621	260	28
171	right-of-way	3260	267	28.5
172	vacant lot	3091	249	25
173	vacant lot	2527	263	19.5
174	residential	2311	271	32
175	residential	1879	278	33.5
176	park	1374	274	17
177	lawn	818	269	33
178	woodlot	2946	280	40.5
179	residential	2637	283	30.5
180	school yard	1727	291	35.5
181	boulevard	1504	291	29.5
182	lawn	1331	344	45
183	boulevard	1295	23	32.5
184	right-of-way	1471	58	39.5
185	woodlot	3927	105	26
186	woodlot	5080	131	38.5
187	residential	1826	351	40.5
188	woodlot	1850	14	45.5
189	residential	2271	360	41
190	boulevard	2722	28	45.5
191	residential	3229	41	36.5
192	field	3801	50	34.5
193	field	4506	56	33
194	woodlot	5104	64	30
195	woodlot	5879	67	45.5
196	woodlot	11941	91	37.5
197	boulevard	3496	348	37.5
198	right-of-way	3341	357	23
199	right-of-way	3659	20	36.5
200	woodlot	4465	41	48.5
201	lawn	5060	48	36.5
202	lawn	5017	335	32
203	lawn	4581	343	36.5
204	residential	6016	347	32.5
205	right-of-way	4997	351	37.5
206	park	5647	356	36
207	boulevard	3928	359	34
208	right-of-way	4268	17	53
209	right-of-way	4772	26	44
210	field	5246	34	30
211	field	5992	38	28
212	field	6305	46	48
213	woodlot	7521	56	34
214	woodlot	10337	57	30
215	woodlot	9033	52	40
216	field	8338	48	28.5

Station No.	Land Use	Distance[1]	Direction[2]	Vanadium[3]
217	residential	6181	12	45.5
218	residential	7097	357	35.5
219	field	11806	10	35.5
220	woodlot	12819	24	55
221	woodlot	14596	36	29.5
222	woodlot	15348	44	41.5
223	woodlot	15743	52	57.5
224	woodlot	18854	52	45.5
225	woodlot	14433	63	48.5
226	field	16218	67	60
227	woodlot	13595	74	44
228	lawn	5221	69	45
229	residential	2580	56	35.5
230	woodlot	3896	72	46.5
231	school yard	5591	75	33
232	woodlot	3071	104	29.5
233	right-of-way	4244	342	40

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of background-based Table F for vanadium (91 µg/g) are bolded, exceedences of effects-based Table A (250 µg/g) are shaded

Appendix A15: Concentration of Zinc (Z) in soil (0-5 cm depth) collected in the Port Colborne area (November, 1999). (*u*g/g)

Station No.	Land Use	Distance[1]	Direction[2]	Zinc[3]
170	right-of-way	3621	260	62
171	right-of-way	3260	267	93.5
172	vacant lot	3091	249	66.5
173	vacant lot	2527	263	58.5
174	residential	2311	271	77
175	residential	1879	278	145
176	park	1374	274	160
177	lawn	818	269	140
178	woodlot	2946	280	97
179	residential	2637	283	81
180	school yard	1727	291	82.5
181	boulevard	1504	291	100
182	lawn	1331	344	130
183	boulevard	1295	23	125
184	right-of-way	1471	58	135
185	woodlot	3927	105	72
186	woodlot	5080	131	95.5
187	residential	1826	351	105
188	woodlot	1850	14	130
189	residential	2271	360	115
190	boulevard	2722	28	125
191	residential	3229	41	105
192	field	3801	50	100
193	field	4506	56	160
194	woodlot	5104	64	100
195	woodlot	5879	67	100
196	woodlot	11941	91	97.5
197	boulevard	3496	348	**180**
198	right-of-way	3341	357	110
199	right-of-way	3659	20	115
200	woodlot	4465	41	160
201	lawn	5060	48	98.5
202	lawn	5017	335	95
203	lawn	4581	343	70.5
204	residential	6016	347	**235**
205	right-of-way	4997	351	66
206	park	5647	356	130
207	boulevard	3928	359	125
208	right-of-way	4268	17	87
209	right-of-way	4772	26	94
210	field	5246	34	135
211	field	5992	38	110
212	field	6305	46	125
213	woodlot	7521	56	130
214	woodlot	10337	57	79
215	woodlot	9033	52	79.5
216	field	8338	48	150

Station No.	Land Use	Distance[1]	Direction[2]	Zinc[3]
217	residential	6181	12	135
218	residential	7097	357	87
219	field	11806	10	**190**
220	woodlot	12819	24	**185**
221	woodlot	14596	36	74
222	woodlot	15348	44	120
223	woodlot	15743	52	94
224	woodlot	18854	52	130
225	woodlot	14433	63	99.5
226	field	16218	67	**165**
227	woodlot	13595	74	105
228	lawn	5221	69	96
229	residential	2580	56	135
230	woodlot	3896	72	**170**
231	school yard	5591	75	110
232	woodlot	3071	104	99.5
233	right-of-way	4244	342	135

1 - Distance (metres) from INCO stack
2 - Direction (degrees) from INCO stack
3 - Exceedences of background-based Table F for zinc (160 µg/g) are bolded, exceedences of effects-based Table A (800 µg/g) are shaded

Appendix B
Derivation and Significance of the MOEE "Ontario Typical Range" Soil Guidelines.

The MOEE "Ontario Typical Range" (OTR) guidelines are being developed to assist in interpreting analytical data and evaluating source-related impacts on the terrestrial environment. The OTRs are used to determine if the level of a chemical parameter in soil, plants, moss bags, or snow is significantly greater than the normal background range. An exceedence of the OTR_{98} (*the OTR_{98} is the actual guideline numbe*r) may indicate the presence of a potential point source of contamination.

The OTR_{98} represents the expected range of concentrations of chemical parameters in surface soil, plants, moss bags, and snow from areas in Ontario not subjected to the influence of known point sources of pollution. The OTR_{98} represents 97.5 percent of the data in the OTR distribution. This is equivalent to the mean plus two standard deviations, which is similar to the previous MOEE "Upper Limit of Normal" (ULN) guidelines. In other words, 98 out of every 100 background samples should be lower than the OTR_{98}.

The OTR_{98} may vary between land use categories even in the absence of a point source of pollution because of natural variation and the amount and type of human activity, both past and present. Therefore, OTRs are being developed for several land use categories. The three main land use categories are Rural, New Urban, and Old Urban. Urban is defined as an area that has municipal water and sewage services. Old Urban is any area that has been developed as an urban area for more than 40 years. Rural is all other areas. These major land use categories are further broken into three subcategories; Parkland (which includes greenbelts and woodlands), Residential, and Industrial (which includes heavy industry, commercial properties such as malls, and transportation rights-of-way). Rural also includes an Agricultural category.

The OTR guidelines apply only to samples collected using standard MOEE sampling, sample preparation, and analytical protocols. Because the background data were collected in Ontario, the OTRs represent Ontario environmental conditions.

The OTRs are not the only means by which results are interpreted. Data interpretation should involve reviewing results from control samples, examining all the survey data for evidence of a pattern of contamination relative to the suspected source, and where available, comparison with effects-based guidelines. The OTRs are particularly useful where there is uncertainty regarding local background concentrations and/or insufficient samples were collected to determine a contamination gradient. OTRs are also used to determine where in the anticipated range a result falls. This can identify a potential concern even when a result falls within the guideline. For example, if all of the results from a survey are close to the OTR_{98} this could indicate that the local environment has been contaminated above the *anticipated average,* and therefore the pollution source should be more closely monitored.

The OTRs identify a range of chemical parameters resulting from natural variation and normal human activity. ***As a result, it must be stressed that values falling within a specific OTR_{98} should not be considered as acceptable or desirable levels; nor does the OTR_{98} imply toxicity to plants, animals or humans.*** Rather, the OTR_{98} is a level which, if exceeded, prompts further investigation on a case by case basis to determine the significance, if any, of the above normal concentration. Incidental, isolated or spurious exceedences of an OTR_{98} do not necessarily indicate a need for regulatory or abatement activity. However, repeated and/or extensive exceedences of an OTR_{98} that appears to be related to a potential pollution source does indicate the need for a thorough evaluation of the regulatory or abatement program. The OTR_{98} supersedes Phytotoxicology ULN guideline. The OTR program is on-going. The number of OTRs will be continuous updated as sampling is completed for the various land use categories and sample types. For more information on these guidelines please refer to *Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags, and Snow. MOEE Report Number HCB-151-3512-93, PIBs Number 2792, ISBN 0-778-1979-1*.

Appendix C
Derivation and Significance of the MOE Soil Clean-up Guidelines

The MOE soil clean-up *Guidelines* have been developed to provide guidance for cleaning up contaminated soil. The *Guidelines* are not legislated Regulations. Also, the *Guidelines* are not action levels, in that an exceedence does not automatically mean that a clean-up must be conducted. The *Guidelines* were prepared to help industrial property owners decide how to clean-up contaminated soil when property is sold and/or the land-use changes. Most municipalities insist that contaminated soil is cleaned up according to the MOE *Guidelines* before they will approve a zoning change for redevelopment, therefore, even though the *Guideline* is voluntary most industrial property owners and developers are obliged to use it. For example, the owner of an industrial property who plans to sell the land to a developer who intends to build residential housing can use the *Guideline* to clean up the soil to meet the residential land-use criteria. In this way previously-contaminated industrial land can be re-used for residential housing without concern for adverse environmental effects.

The *Guideline* contains a series of Tables (A through F), each having criteria for soil texture, soil depth, and ground water use for various land-use categories (eg, agricultural, residential, industrial). Table F *criteria* reflect the upper range of background concentrations for soil in Ontario. An exceedence of Table F indicates the likely presence of a contaminant source. Tables A through E *criteria* are effects-based and are set to protect against the potential for adverse effects to human health, ecological health, and the natural environment, whichever is the most sensitive. By protecting the most sensitive parameter the rest of the environment is protected by default. The *Guideline criteria* take into consideration the potential for adverse effects through direct contact, and through contaminant transfer from soil to indoor air, from ground water or surface water through release of volatile gases, from leaching of contaminants in soil to ground water, or from ground water discharge to surface water. However, the *Guideline criteria* ***may not*** ensure that corrosive, explosive, or unstable soil conditions will be eliminated.

If the decision is made that remedial action is needed, the *criteria* in Tables A to F of the *Guideline* can be used as clean-up targets. In some cases, because of economic or practical reasons, it may not be possible to clean up a site using the generic *criteria* in Tables A to F. The *Guideline* provides a process, called a *site specific risk assessment*, which is used to evaluate the soil contamination with respect to conditions that are unique to the contaminated site. In a *site specific risk assessment* the proponent examines all the potential pathways through which the contamination may impact the environment and must demonstrate that because of conditions unique to that site the environment and human health will not be adversely effected if contamination above the generic *criteria* in Table A to E is left in place. When contamination is present and a change in land-use is not planned, for example residential properties and public green spaces near a pollution source, the *Guideline* may be used in making decisions about the need for remediation. This is different from the previously described situation where a company that caused contamination on their own property decides to clean up the soil, usually at the insistence of the municipality who will not approve a zoning change unless remediation is conducted. Decisions on the need to undertake remedial action when the *Guideline criteria* are exceeded ***and*** where the land-use is not changing are made on a site by site basis using *site specific risk assessment* principals and are usually contingent on the contaminants having caused an adverse environmental effect or there is a demonstrated likelihood that the contamination may cause an adverse effect. Because of the long history of industrial operation and our practice of living close to our work place the soil in many communities in Ontario is contaminated above the effects-based *criteria* in the MOE *Guidelines*.

In practice, remediation of contaminated soil on privately-owned residential property and public green spaces has only been conducted in communities when the potential for adverse health effects has been demonstrated. The soil clean-up *Guidelines* were developed from published U.S. EPA and Ontario environmental data bases. Currently there are criteria for about 25 inorganic elements and about 90 organic compounds. Criteria were developed only if there were sufficient, defendable, effects-based data on the potential to cause an adverse effect. All of the criteria address human health and aquatic toxicity, but terrestrial ecological toxicity information was not available for all elements or compounds. The development of these clean-up *Guidelines* is a continuous program, and criteria for more elements and compounds will be developed as additional environmental data become available. Similarly, new information could result in future modifications to the existing *Guidelines*. For more information on the MOE's soil clean-up *Guidelines* please refer to the *Guideline for Use at Contaminated Sites in Ontario. Revised February 1997*, Ontario Ministry of Environment and Energy, PIBs 3161E01, ISBN 0-7778-6114-3.

Appendix D

Methodology for Producing Surfer/ArcView Soil Contamination Maps

Software Utilized

Two software packages were used to generate the maps. The data analysis and creation of the concentration contours was done using Surfer Version 6.03 for Windows 95 by Golden Software Inc. The output from Surfer was imported into ArcView GIS Version 3.1 by Environmental Systems Research Institute, Inc., and combined with base maps, roads and bodies of water, to produce the final maps. The base map data was CanMap Street Files for Ontario, Version 2, by Desktop Mapping Technologies Inc.

Data Used

For the contour maps produced in this report, all sampling stations at which 0-5cm depth soil samples collected in 1998 (refer to 1998 MOE report) and 1999 were used, along with sampling stations selected from historical MOE surveys, to generate the contours. Two locations from the 1998 survey, stations 10 and 27 were excluded from the analysis because the analytical results from these stations were significantly lower than surrounding stations (the surface soil at these two sites had most likely been replaced at some time in the recent past).

Mapping Process

The process involved in creating the maps was to analyze the data and create the desired contours using the Surfer program. The individual contours were exported from Surfer as AutoCad DXF files. The polygon portion of the DXF files were imported into ArcView GIS and converted into ArcView shape files. Lake Erie and the Welland canal were subtracted from each of the contour polygons where they overlapped. The resulting polygons were combined with the street and hydrographic base maps, and the station locations were imported from the Phytotoxicology Information Management System (PIMS). Layouts were then created to include a legend, labels, scale and compass and printed for the report. Areas for the Table A and Table F contour polygons were calculated using built in ArcView procedures.

Surfer

For all data sets, a Krigging gridding method was used and the search option was set to use all data. For all contours, smoothing was set at high. All co-ordinates were in latitude and longitude.

Surfer Settings

Nickel Data (0 - 5 cm Results)
a. Grid Line Geometry

	Minimum	Maximum	Spacing	# of Lines
X Axis (Longitude)	-79.36º	-78.9º	.001º	461
Y Axis (Latitude)	42.85º	43.05º	.001º	201
Matrix Smoothing - weighted method, matrix centre weight = 2, rows & columns on either side = 1, distance weighting power = 2				

b. Nickel Contours: 43, 100, 200, 500, 1000, 2000, 3000, 4000
42, 200 (Table A & F)

Copper Data (0 - 5 cm Results)
a. Grid Line Geometry

	Minimum	Maximum	Spacing	# of Lines
X Axis (Longitude)	-79.36º	-78.9º	.001º	461
Y Axis (Latitude)	42.85º	43.05º	.001º	201
Matrix Smoothing - weighted method, matrix centre weight = 2, rows & columns on either side = 1, distance weighting power = 2				

b. Copper Contours: 85, 100, 150, 200, 250, 300, 350, 400, 450
85, 300 (Table A & F)

Cobalt Data (0 - 5 cm Results)
a. Grid Line Geometry

	Minimum	Maximum	Spacing	# of Lines
X Axis (Longitude)	-79.36º	-78.9º	.001º	461
Y Axis (Latitude)	42.85º	43.05º	.001º	201
Matrix Smoothing - weighted method, matrix centre weight = 2, rows & columns on either side = 1, distance weighting power = 2				

b. Cobalt Contours: 21, 50, 100
21, 50 (Table A & F)

Arc View

Base Map

A base map was created using CanMap Ontario Streetfile themes Hamilton-Niagara Roads, Ontario Major Roads, Ontario Highways, Hydrography, and Hamilton-Niagara Wetlands. To this was added all of the stations sampled in 1998 by importing the station co-ordinates and related information from the PIMS database. This base map was used as the underlying map for all other maps.

Importation and Conversion

Each of the DXF export files from Surfer were added to the base map view as DXF themes and were then converted to Arc View shape files. The DXF themes were then deleted.

Subtraction of Hydrographic Layer

The DXF export did not support polygons with holes in them but sent over the main polygon with the holes represented as separate, smaller polygons. This meant that when the DXF themes were converted to shape themes, the holes had to be created by subtracting the smaller polygons from the larger polygons. If the resultant polygon overlapped with 'Lake Erie' or the Welland Canal, these were subtracted from the polygon in a mid-step process. Smalllakes, ponds and marsh areas were not subtracted from the contour polygons.

Calculation of Area

The area of all of the polygons that made up the Table A and Table Fd polygpons for nickel, copper and colbalt were calculated using the ArcView script "View.CalculateAcreage'. The areas calculated were for the coloured areas in the legend (i.e. "Table F" area includes the area that exceeds the Table F soil criterion but not the Table A guideline).

Final Maps

A separate ArcView layout was produced for each of the maps and consisted of a base map, sampling stations, contour polygons, scale, compass, title, legend and symbol for the INCO refinery stack. Sampling stations were only labeled at locations of interest with reesect to the contour polygons. These layouts were used to print the final maps.

Appendix E

List of MOE Phytotoxicology reports of investigations conducted in the vicinity of INCO, Port Colborne (excluding investigations on private property conducted at the owner's request).

Ontario Ministry of the Environment, Phytotoxicology Section. *Vegetation Surveillance Northeast of International Nickel Co. Refinery, Port Colborne, July 1972.*

Ontario Ministry of the Environment, Phytotoxicology Section. *Phytotoxicology Surveys Conducted in the Vicinity of the International Nickel Company, Port Colborne, Ontario, 1969 - 1974.*

Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. *Phytotoxicology Surveys in the Vicinity of International Nickel Co., Port Colborne - 1975*.

Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. *Phytotoxicology Surveys in the Vicinity of International Nickel Co., Port Colborne - 1976.*

Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. *Phytotoxicology Surveys in the Vicinity of International Nickel Co., Port Colborne - 1977.*

Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. *Nickel and Other Metals in Vegetation in the Vicinity of International Nickel Company (INCO), Port Colborne - 1978.*

Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. *Phytotoxicology Surveys in the Vicinity of the INCO Refinery, Port Colborne, 1979-1980.*

Rinne, R.J. 1983. *Contamination of Vegetation by Nickel and Other Elements in the Vicinity of INCO Limited, Port Colborne - 1981*. Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. Report Number ARB-24-83-Phyto.

Rinne, R.J. 1983. *Contamination of Vegetation by Nickel and Other Elements in the Vicinity of INCO, Port Colborne - 1982*. Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. Report Number ARB-195-83-Phyto.

Rinne, R.J. 1985. *Contamination of Vegetation by Nickel and Other Elements in the Vicinity of INCO, Port Colborne - 1983, 1984.* Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. Report Number ARB-117-85-Phyto.

Rinne, R.J. 1989. *Phytotoxicology Assessment Surveys in the Vicinity of INCO Ltd., Port Colborne - 1985, 1986.* Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. Report Number ARB-001-88-Phyto.

McLaughlin, D., Bisessar, S. 1994. *Phytotoxicology Survey Report: International Nickel Company Limited, Port Colborne - 1991*. Ontario Ministry of the Environment, Standards Development Branch, Phytotoxicology Section. Report Number SDB-003-3512-92.

Kuja, A., Jones, R., McIlveen, W., McLaughlin, D. 1999. *Phytotoxicology Soil Investigation: INCO - Port Colborne.* Ontario Ministry of the Environment, Standards Development Branch, Phytotoxicology Section. Report Number SDB-031-3511-1999.

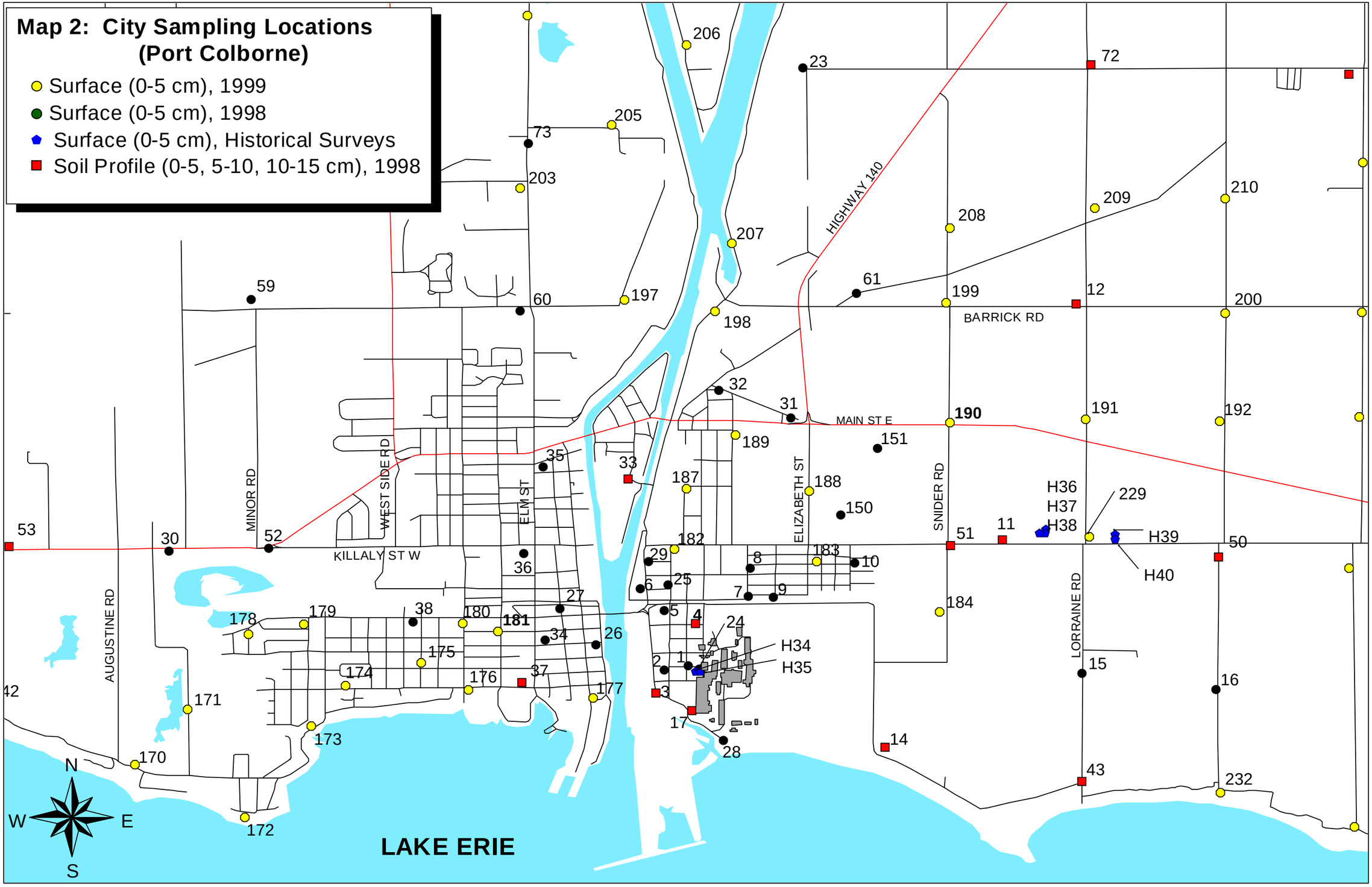
Map 1: Regional Sampling Locations

- Surface (0-5 cm), 1999
- Surface (0-5 cm), 1998
- Surface (0-5 cm), Historical Surveys
- Soil Profile (0-5, 5-10, 10-15 cm), 1998

Niagara Falls
Welland
LAKE ERIE
QUEEN ELIZABETH WAY
NETHERBY RD
FORKES RD E
3 CONCESSION RD
2 CONCESSION RD
MAIN ST E
GARRISON RD W
WEST SIDE RD
YAGER RD
DOAN'S RIDGE RD
HIGHWAY 140
POINT ABINO RD N
STEVENSVILLE RD
N
S
E
W
Scale in Kilometers
0 2 4 6

Map 2: City Sampling Locations (Port Colborne)

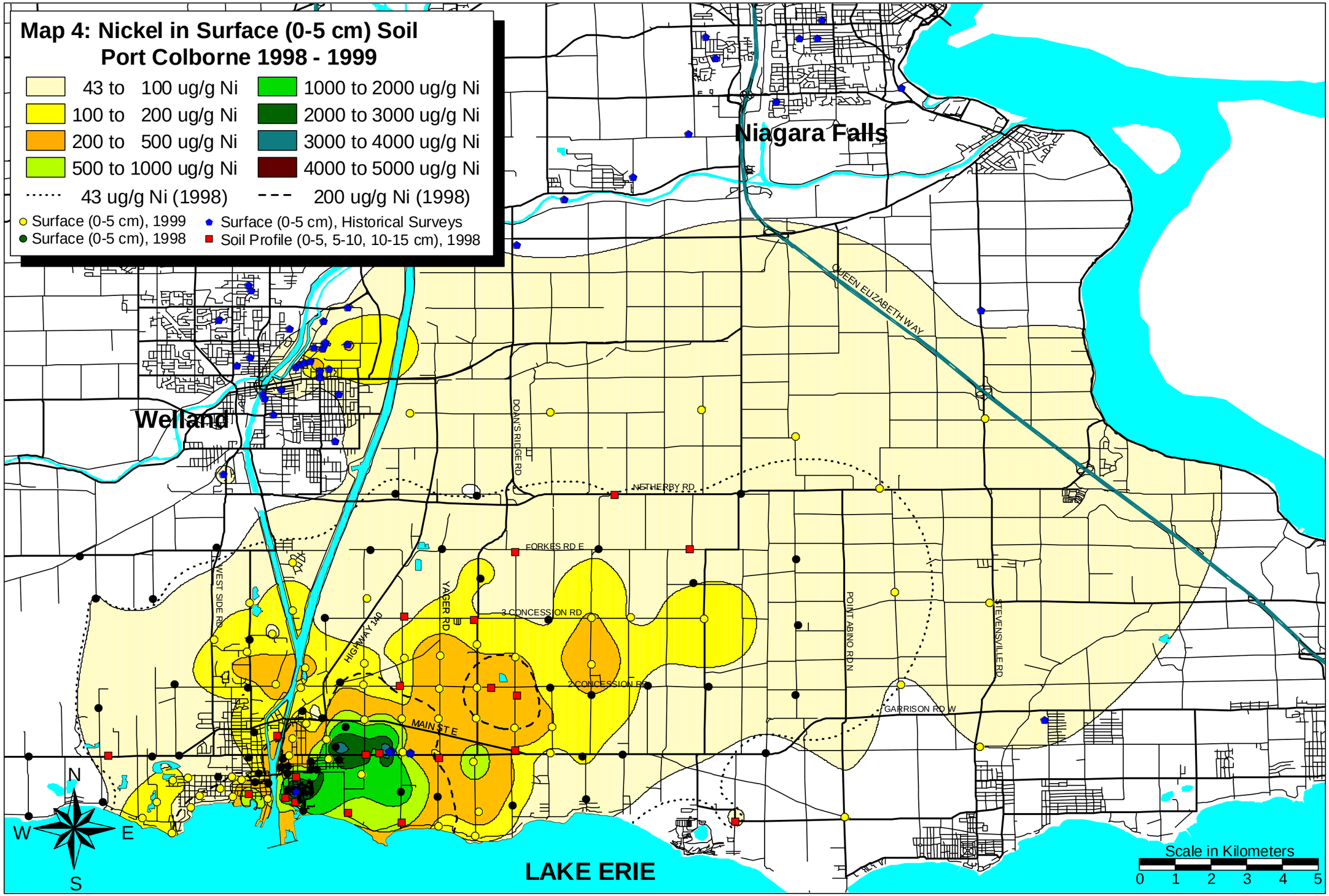
- Surface (0-5 cm), 1999
- Surface (0-5 cm), 1998
- Surface (0-5 cm), Historical Surveys
- Soil Profile (0-5, 5-10, 10-15 cm), 1998



Map 3: City Sampling Locations (Welland)

- Surface (0-5 cm), 1999
- Surface (0-5 cm), Historical Surveys

H17
H20
WOODLAWN
H24
H18
RICE
H23
H27
406 & 58
THOROLD
H21
H25
H22
H46
H45
H16
H42
H41
H5
H43
H44
H47
H26
FITCH
H48
EAST MAIN
H7
H15
H6
H3
LINCOLN
219
H19
KING
H28
ONTARIO
N
W
E
S
H8
Scale in Kilometers
0 0.5 1 1.5 2


Map 4: Nickel in Surface (0-5 cm) Soil
Port Colborne 1998 - 1999
43 to 100 ug/g Ni
100 to 200 ug/g Ni
200 to 500 ug/g Ni
500 to 1000 ug/g Ni
1000 to 2000 ug/g Ni
2000 to 3000 ug/g Ni
3000 to 4000 ug/g Ni
4000 to 5000 ug/g Ni
43 ug/g Ni (1998)
200 ug/g Ni (1998)
Surface (0-5 cm), 1999
Surface (0-5 cm), 1998
Surface (0-5 cm), Historical Surveys
Soil Profile (0-5, 5-10, 10-15 cm), 1998
Niagara Falls
Welland
QUEEN ELIZABETH WAY
DOAN'S RIDGE RD
NETHERBY RD
FORKES RD E
WEST SIDE RD
YAGER RD
HIGHWAY 140
3 CONCESSION RD
2 CONCESSION RD
MAIN ST E
POINT ABINO RD N
STEVENSVILLE RD
GARRISON RD W
N
W
E
S
LAKE ERIE
Scale in Kilometers
0 1 2 3 4 5

Map 5: Copper in Surface (0-5 cm) Soil
Port Colborne 1998 - 1999

- 85 to 100 ug/g Cu
- 100 to 150 ug/g Cu
- 150 to 200 ug/g Cu
- 200 to 250 ug/g Cu
- 250 to 300 ug/g Cu
- 300 to 350 ug/g Cu
- 350 to 400 ug/g Cu
- 400 to 450 ug/g Cu

- Surface (0-5 cm), 1999
- Surface (0-5 cm), 1998
- Surface (0-5 cm), Historical Surveys
- Soil Profile (0-5, 5-10, 10-15 cm), 1998

BARRICK RD
MAIN ST E
KILLALY ST E
ELM ST
ELIZABETH ST
SNIDER RD
LORRAINE RD
MILLER RD
N
W
E
S
LAKE ERIE
Scale in Kilometers
0
0.5
1
1.5

Map 6: Cobalt in Surface (0-5 cm) Soil
Port Colborne 1998 - 1999

21 to 50 ug/g Co

50 to 100 ug/g Co

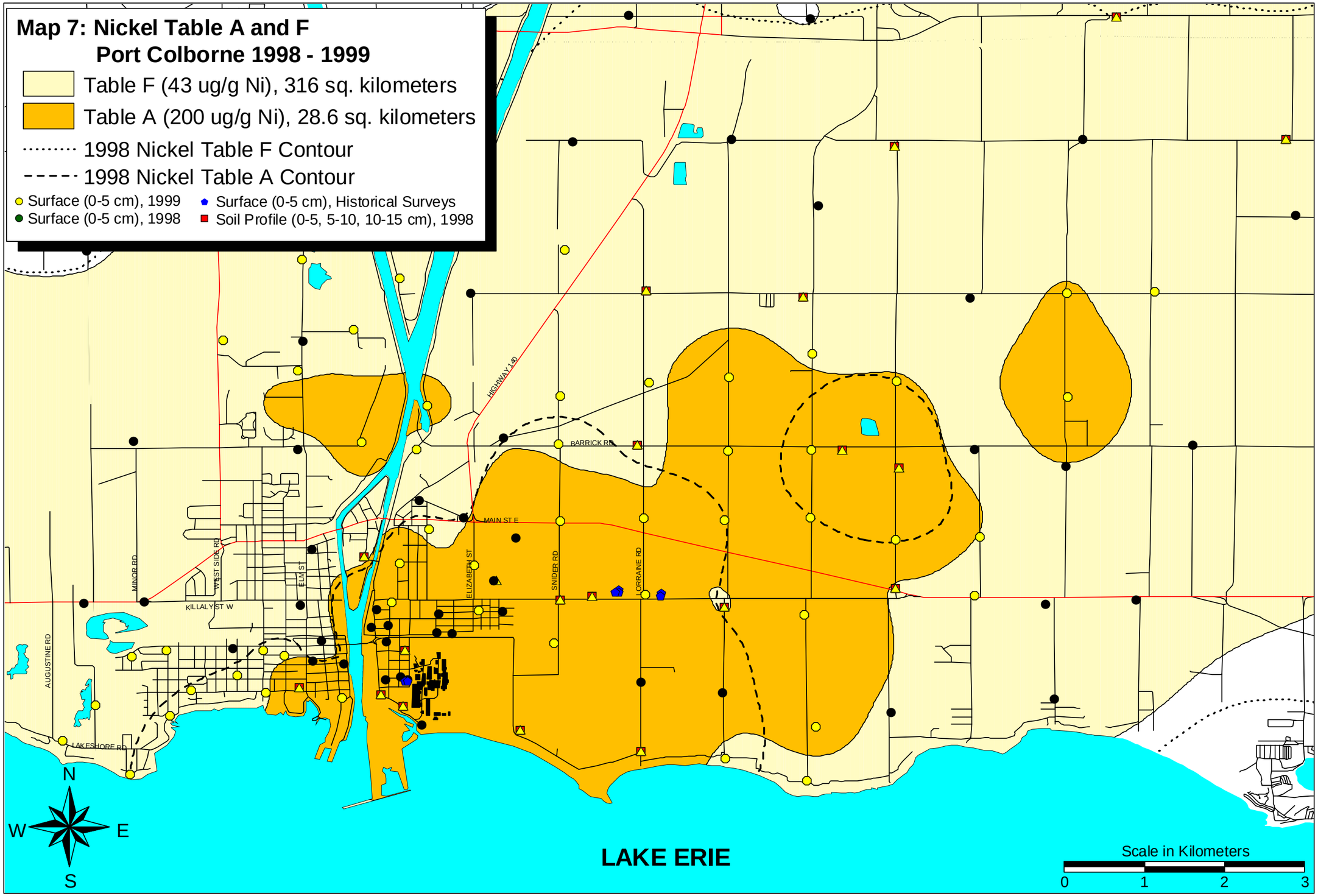
100 to 150 ug/g Co

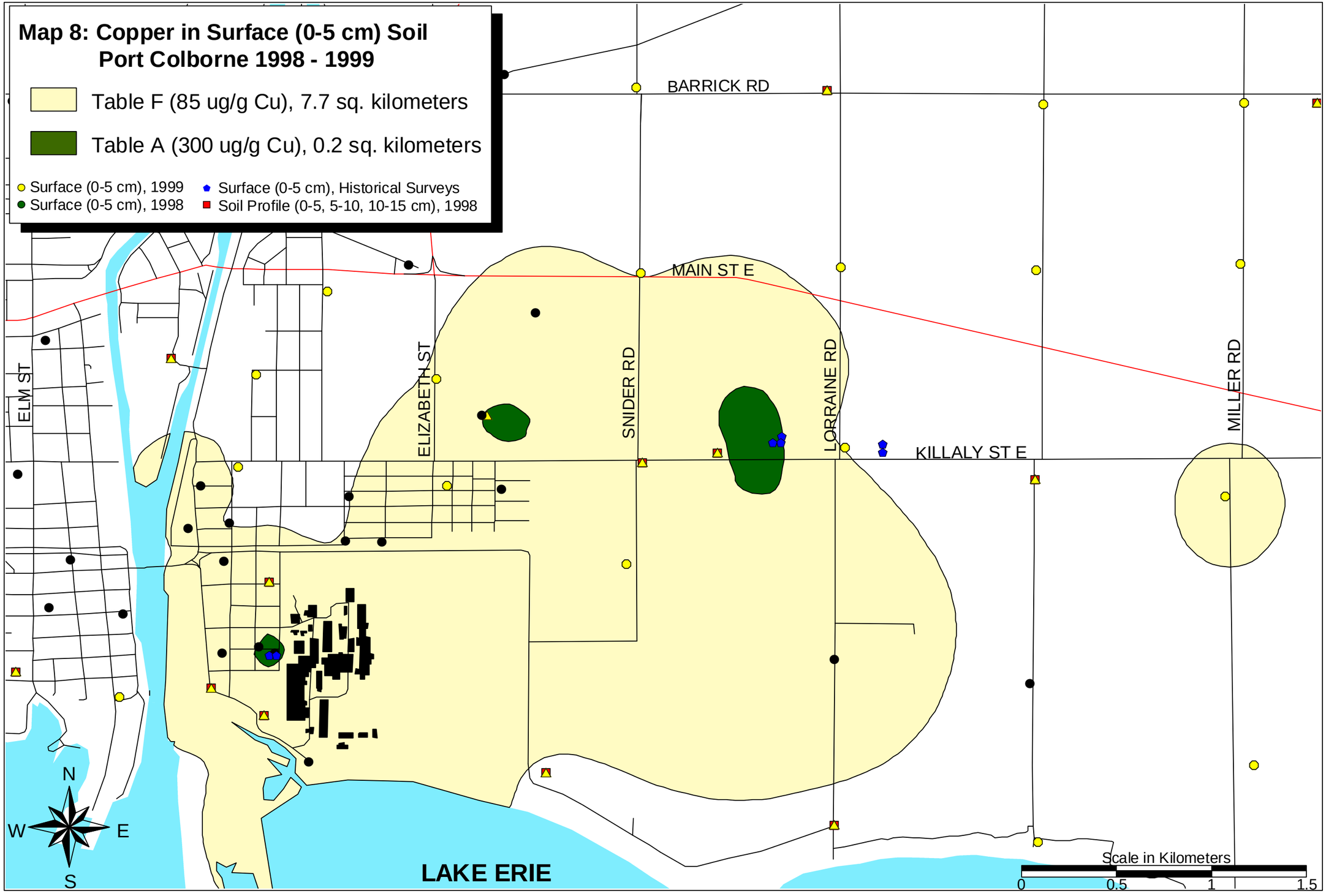
Surface (0-5 cm), 1999
Surface (0-5 cm), 1998
Surface (0-5 cm), Historical Surveys
Soil Profile (0-5, 5-10, 10-15 cm), 1998

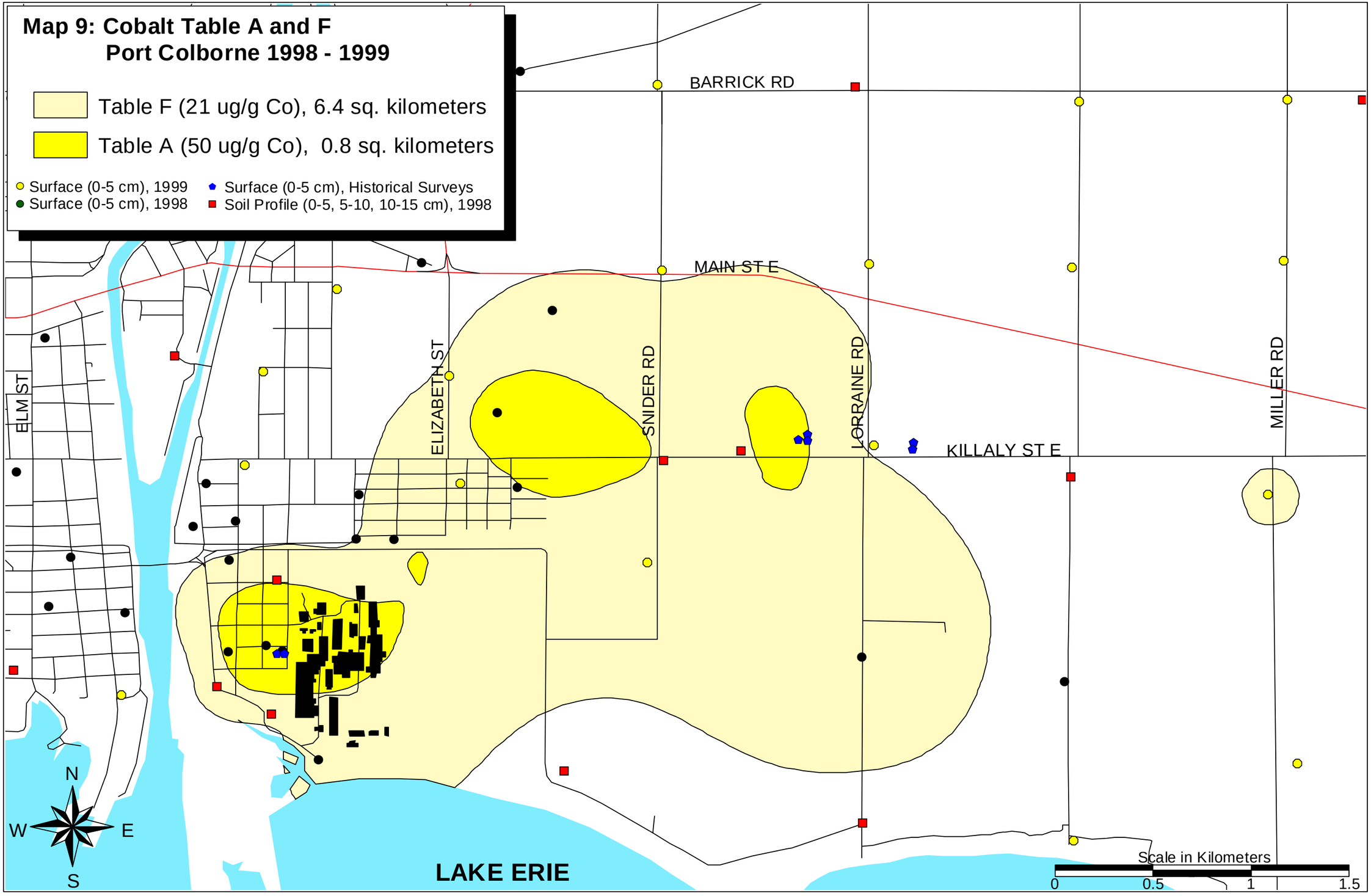
BARRICK RD
MAIN ST E
KILLALY ST E
ELM ST
ELIZABETH ST
SNIDER RD
LORRAINE RD
MILLER RD
LAKE ERIE

N
W
E
S

Scale in Kilometers
0 0.5 1 1.5


Map 7: Nickel Table A and F
Port Colborne 1998 - 1999
Table F (43 ug/g Ni), 316 sq. kilometers
Table A (200 ug/g Ni), 28.6 sq. kilometers
1998 Nickel Table F Contour
1998 Nickel Table A Contour
Surface (0-5 cm), 1999
Surface (0-5 cm), 1998
Surface (0-5 cm), Historical Surveys
Soil Profile (0-5, 5-10, 10-15 cm), 1998
HIGHWAY 140
BARRICK RD
MAIN ST E
KILLALY ST W
MINOR RD
WEST SIDE RD
ELM ST
ELIZABETH ST
SNIDER RD
LORRAINE RD
AUGUSTINE RD
LAKESHORE RD
N
W
E
S
LAKE ERIE
Scale in Kilometers
0
1
2
3


Map 8: Copper in Surface (0-5 cm) Soil
Port Colborne 1998 - 1999
Table F (85 ug/g Cu), 7.7 sq. kilometers
Table A (300 ug/g Cu), 0.2 sq. kilometers
Surface (0-5 cm), 1999
Surface (0-5 cm), 1998
Surface (0-5 cm), Historical Surveys
Soil Profile (0-5, 5-10, 10-15 cm), 1998
BARRICK RD
MAIN ST E
KILLALY ST E
ELM ST
ELIZABETH ST
SNIDER RD
LORRAINE RD
MILLER RD
N
W
E
S
LAKE ERIE
Scale in Kilometers
0
0.5
1
1.5


Map 9: Cobalt Table A and F
Port Colborne 1998 - 1999
Table F (21 ug/g Co), 6.4 sq. kilometers
Table A (50 ug/g Co), 0.8 sq. kilometers
Surface (0-5 cm), 1999
Surface (0-5 cm), 1998
Surface (0-5 cm), Historical Surveys
Soil Profile (0-5, 5-10, 10-15 cm), 1998
BARRICK RD
MAIN ST E
KILLALY ST E
ELM ST
ELIZABETH ST
SNIDER RD
LORRAINE RD
MILLER RD
N
W
E
S
LAKE ERIE
Scale in Kilometers
0
0.5
1
1.5