PHYTOTOXICOLOGY SURVEY REPORT: INTERNATIONAL NICKEL COMPANY LIMITED, PORT COLBORNE - 1991

JULY 1994

Ontario

Ministry of
Environment
and Energy

Ontario

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August 30, 1994

Inco Limited
187 Davis Street
P. O. Box 250
Port Colborne, Ontario
L3K 5W2

Attention: Mr. Dave Reid

Dear Sir:

Re: Phytotoxicology Survey Report - July 1994
Our File No. 7-3-20

I have attached two copies of the Phytotoxicology Survey Report dated July 1994 for your information. The soil and vegetation survey was conducted in 1991. Should you have any questions with the interpretation of its contents, please contact Mr. Dave McLaughlin at (905) 456-2504.

Yours truly,

John A. Neamtz

John A. Neamtz
Senior Environmental Officer
Welland District Office
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1-800-263-1035

JAN/vt
Encl.

cc: Mr. Dave McLaughlin
Standards Development Branch
Phytotoxicology Section - MOEE

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PHYTOTOXICOLOGY SURVEY REPORT:

INTERNATIONAL NICKEL COMPANY LIMITED

PORT COLBORNE - 1991

Report prepared by:

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Standards Development Branch
Phytotoxicology Section
Ontario Ministry of Environment and Energy

Report No: SDB-003-3512-94

Phytotoxicology Survey Report:
International Nickel Company Ltd. - Port Colborne (1991)

Executive Summary

A soil and vegetation survey was conducted in the vicinity of the INCO refinery in Port Colborne in 1991. The refinery ceased commercial operation in 1984. The 1991 survey confirmed that soil to at least 10 cm in depth is still severely contaminated with Ni, and to a lesser extent, with Cu and Co. ULN and/or soil clean-up guidelines for soil Ni were exceeded beyond 6 km northeast, and beyond 2 km in the same direction for both Cu and Co. The soil nickel concentrations are sufficiently elevated to limit normal agricultural land use up to at least 4 km northeast and east of INCO. The agricultural limitations would potentially include reduced yields of cereal crops (particularly oats) on mineral soil and slightly stunted, metal-enriched vegetable crops on organic soil. The extent and severity of soil metal contamination was (essentially) unchanged from 1976.

Injury characteristic of Ni toxicity was still observed on vegetation in 1991 and during visual surveys in 1992 and 1993. However, the injury was related to uptake of Ni from contaminated soil rather than ambient emissions from the refinery. The injury was very scattered, occurred only in the immediate vicinity of INCO, and required a combination of high soil Ni concentration and sensitive tree species. Silver maple showed a significant range in the relative sensitivity to nickel toxicity.

Annual surveys are not warranted. Periodic surveys to monitor potential changes in soil metal concentrations would be useful, but need not be more frequent than 5 to 10 years. The 1991 survey was successful in better defining the area of surface soil contamination in the zone where the concentration gradient was steep (within about 3 to 4 km of INCO). However, the extent of contamination to the northeast, and east was not identified. Future soil surveys should include a grid of sample sites out to at least 8 km in the westerly directions and up to 15 km in the northerly and easterly directions.

Phytotoxicology Survey Report: International Nickel Company Ltd. - Port Colborne (1991)

Background

The Phytotoxicology Section of the Ontario Ministry of Environment and Energy (MOEE) has conducted soil and vegetation surveys in the vicinity of the International Nickel Company Ltd. (INCO) in Port Colborne periodically since 1972. These previous Phytotoxicology surveys identified elevated concentrations of nickel (Ni), copper (Cu), and cobalt (Co) in soil and vegetation. Concentrations of these elements in soil and vegetation in Port Colborne in the vicinity of INCO have consistently exceeded the Phytotoxicology Upper Limit of Normal (ULN) guidelines[Ref.1] (see appendix).

Correspondence with the MOEE Welland District office indicated that INCO ceased their Ni refining operation in 1984. The company presently has a precious metal recovery operation, an electro-cobalt refinery, utility nickel furnacing, a foundry additive plant, a shearing and shipping operation, and a research facility. Because of the much-reduced operations, current ambient emissions of Ni and other metals are estimated to be relatively minor (unquestionably they would be a small fraction of pre-1984 levels, when INCO was an operational base metal refinery).

A Phytotoxicology soil survey conducted in 1976 identified surface soil (0-5 cm) Ni concentrations as high as 23,800 µg/g (micrograms per gram - commonly referred to as parts per million or ppm). Soil Ni concentrations exceeded the ULN guideline of 60 µg/g more than 8 km downwind (east northeast) of INCO. Copper and Co concentrations were also substantially elevated in surface soil. A maximum Cu concentration of 1,787 µg/g and a maximum Co concentration of 455 µg/g occurred concurrently with the highest soil Ni concentration. There was a strong statistical co-relation among these three elements, and the concentration gradients clearly implicated INCO as the source of contamination. The number and location of the survey sample sites was insufficient to define the extent of soil contamination in both the northeast and northwest directions (background concentrations were not reached in either direction). The concentration gradient was almost exponential within 1 km of the refinery. Because there were an insufficient number of sample sites in this area it was difficult to accurately predict local pollution trends. This information has been reported in previous MOEE documents.[Ref.3,4,6]

Whereas soil surveys reflect cumulative contamination from historic pollution deposition, vegetation surveys can be used as proxy ambient air monitoring. Generally, foliage chemistry reflects the air chemistry that the plants were exposed to during the growing season. Soil metal concentrations should change slowly over time (perhaps decades) while foliar chemistry should change annually in proportion to changes in the rate of emissions from the pollution source (assuming similar meteorological conditions).

Duplicate silver maple tree foliage samples were collected from a total of 26 sites in 1991. The trees were municipal street trees, ornamental landscape trees on residential properties, or woodlot trees. Trees at Sites 1 to 24 were the same trees that were sampled in the 1986 Phytotoxicology INCO survey. Like the soil sites, tree foliage Site Numbers 25 to 30 are new sample sites for 1991. In addition, there are no foliar data for Sites 6, 13, 17, and 22, as there were no suitable sample trees at these 4 locations in 1991. Therefore up to Site 24, the foliage data from the two time periods (1986 vs 1991) are directly comparable on a site by site basis. The trees were sampled from the same general location as the soil sites. However, not all soil sites had suitable sample trees, therefore there are slightly fewer foliar sample sites than soil sample sites. Like previous Phytotoxicology surveys, the 1991 vegetation samples were collected from the mid-crown of silver maple trees from both the side facing and the opposite side of the tree crown relative to the refinery using standard field sampling protocols.[Ref.7] The vegetation samples were processed in the Phytotoxicology sample processing laboratory (oven-dried, ground, homogenized, and stored in glass jars) using standard protocols.[Ref.8] The soil and vegetation sample site locations are illustrated in Figure 1.

The processed soil and vegetation samples were submitted to the MOEE Laboratory Services Branch for analysis of total Ni, Cu, and Co on a dry weight basis by ICP-AES.[Ref.1] In addition, soil pH and Electrical Conductivity (EC) were determined in the Phytotoxicology laboratory.

The soil and vegetation data were evaluated with the Surfer[Ref.9] computer contour mapping program using the Kriging contour option and a line smoothing factor of 2. This program generates contour maps illustrating a gradient of contaminant concentrations. However, although objective and likely quite accurate (particularly with a sound field sampling strategy), these maps are still only estimates of the spacial pollution gradient and the actual concentrations are known only at the specific sample sites. Map confidence decreases in areas of low sample density. Therefore, they are most accurate closer to INCO, and accuracy and confidence decreases towards the map extremities. The soil and maple foliage metal concentration contour maps are numbered Figures 2 through 7.

Analytical Results

Electrical Conductivity and pH

The soil analytical results are summarized in Table 1. The pH and EC are reported only for the surface soil samples (0-5 cm). The pH ranged from slightly acid (5.8) to slightly alkaline (7.5). A soil pH range of between 5 and 8 is optimal for the growth of most plants. The pH of all soil samples was within this range and there was no soil pH gradient relative to INCO.

contamination are similar to previous years, indicating that the degree of soil contamination has not changed significantly since the 1976 survey.

The MOEE clean-up guideline[Ref.10] for Ni in soil, which is based on phytotoxicity, is 150 µg/g. Therefore, the soil over a significant portion of Port Colborne and the adjacent rural area is contaminated with Ni at concentrations that are potentially phytotoxic. Soil Ni concentrations between 150 and 1,000 µg/g can potentially reduce the yield of cereal crops (particularly oats) grown on mineral soil. Crops such as celery and other market garden vegetables that are grown immediately east of INCO and south of Hwy 3 on organic soil can be adversely affected at soil Ni concentrations exceeding 1,000 µg/g (stunted growth, metal-enriched tissue concentrations).

Soil Copper

Figure 3 illustrates the Cu concentrations in surface soil in 1991. Soil Cu contamination, as identified by concentrations in excess of the 100 µg/g ULN, were restricted to an area mostly east of the Welland Canal, north of INCO about 3.5 km, east about 2 km, and southeast about 3 km. Copper concentrations in excess of 600 µg/g were restricted to an area immediately east northeast and east about 600 m, southeast about 1 km, and generally between the refinery and the lakeshore. There was a very clear concentration gradient relative to INCO. Because background concentrations were obtained at the farthest sample sites in all directions, the computer-generated contours are likely quite accurate in regards to the spacial distribution of Cu contamination.

The Cu concentrations were very similar to those obtained in the 1976 survey, indicating that surface soil Cu contamination has not changed substantially in 15 years. The ULN guideline was exceeded at 18 of the 37 sample sites. Fourteen sample sites exceeded the MOEE soil clean-up guideline of 150 µg/g. This guideline is based on combined ecotoxicity, which in this case refers to the potential to cause adverse impact on soil micro-organisms. Soil bioassay studies conducted in the Phytotoxicology Controlled Environment laboratory indicated that Cu is not phytotoxic until soil concentrations exceed 1,000 µg/g.

Like Ni, and as expected, soil Cu concentrations were higher in the surface soil. These data confirm that soil Cu contamination extends to at least 10 cm in depth at sites where concentrations are excessive in surface soil.

Soil Cobalt

The extent of soil Co contamination is illustrated in Figure 4 and the data are summarized in Table 1. The ULN guideline of 25 µg/g was exceeded at 16 of the 37 sample sites, and the MOEE soil clean-up guideline (40 µg/g) was exceeded at 14 sites.

Foliar Ni concentrations exceeded the ULN guideline of 7 µg/g at 20 of the 26 sample sites (for the data from the side of the tree crown facing INCO). The ULN guidelines were not exceeded for either Cu or Co. Figure 5 illustrates the computer generated foliar Ni contours. There was a clear contamination gradient, with the highest foliar Ni concentrations (>30 µg/g) detected about 1.3 km northeast of INCO. The foliar Ni gradient is more poorly defined to the west and northwest of the refinery, because there were fewer sample trees in these directions. Despite similar contamination patterns, the apparent relationship between maple foliage and corresponding surface soil Ni concentrations was not statistically significant ($p > 0.05$).

Although there was a tendency towards increased foliar Cu concentrations close to INCO, the concentration gradient was not consistent. Figure 6 illustrates the computer-predicted foliar Cu concentrations. Three areas of elevated Cu concentrations occurred; one 3.4 km east, the second 7.7 km northeast, and the third adjacent to INCO immediately to the northeast and west. The foliar Cu concentrations are within normal background limits, which explains the inconsistency of the gradient mapping.

Figure 7 illustrates the foliar Co contours. There was a weak gradient of marginally elevated Co concentrations relative to INCO, even though foliar levels were well within background.

The mean concentrations of Ni, Cu, and Co in maple foliage from common collection trees in 1991 and 1986 are summarized in Table 3. Generally, foliar Ni concentrations in 1991 were substantially lower than in 1986. For example, the mean foliar Ni concentration in 1991 was 14 µg/g, compared to 25 µg/g in 1986. Because of the large standard deviation about the mean this difference was not statistically different ($p > 0.05$). In 1986, the INCO refinery had already been shut down for two years. The reduction in foliar Ni concentrations between 1986 and 1991 probably reflects the reduction in fugitive Ni emissions from the INCO site and a reduction in the resultant level of re-entrainment of contaminated dust. As seen in the previous section, soil Ni concentrations have not fallen in proportion to the reduction in foliar Ni levels.

The mean Cu concentration in maple foliage collected from common sample trees was 10 µg/g in 1991 compared to 12 µg/g in 1986. This difference was not statistically significant ($p > 0.05$). The mean foliar Co concentration from common sites in 1991 was <1 µg/g, compared to 1 µg/g in 1986. These data were not tested statistically because of the large number of samples with concentrations below the analytical detection limit.

Injury Symptoms

Injury characteristic of Ni toxicity was observed on the foliage of a few very susceptible silver maple trees. The Ni toxicity symptoms included tan to dark-brown necrotic lesions on the foliar margins, which were more common on the ends of the lobes than along the edges of the sinuses. More severely affected leaves would be noticeably cupped, with the ends of the leaves pointing slightly upwards. The injured trees were scattered in an area up to about 1.5 km from

Conclusions

The 1991 survey confirmed that soil to at least 10 cm in depth in the vicinity of the INCO refinery in Port Colborne is still severely contaminated with Ni, and to a lesser extent with Cu and Co at concentrations that were comparable to those encountered in the 1976 Phytotoxicology soil survey. ULN and soil clean-up guidelines for soil Ni were exceeded beyond 6 km northeast of INCO, and beyond 2 km in the same direction for both Cu and Co. Heavy metal soil contamination will persist even though ambient deposition has essentially ceased. The soil Ni concentrations are sufficiently elevated to limit normal agricultural use of the land up to at least 4 km northeast and east of INCO. The agricultural limitations would include potentially reduced yields of cereal crops (particularly oats) on mineral soil and slightly stunted, metal-enriched vegetable crops on organic soil.

Nickel is naturally present in soil at concentrations (globally) between 5 and 500 µg/g,[Ref.5] However, the Phytotoxicology ULN guideline, which reflects the range of Ni in Ontario urban soil, indicates that concentrations up to 60 µg/g are normal. Therefore, the Ni in Port Colborne soil is unquestionably source-oriented, resulting from about 70 years of historic atmospheric deposition of INCO emissions. Heavy metals, like Ni, Cu, and Co, are very persistent in soil. Since INCO emissions have essentially ceased, further increases in soil metal concentrations are unlikely. Left entirely to natural processes, subsequent reductions in soil metal concentrations will be very gradual, likely measured in decades, or longer. The 1991 soil survey indicated that, overall, soil Ni concentrations were comparable to or perhaps marginally lower than the 1976 soil survey. This marginal, and perhaps only apparent, reduction is more likely due to surface soil disturbance at some of the sample sites rather than an actual reduction in total soil metal burden. Continued cultivation of metal-contaminated agricultural land mixes the contaminated surface soil with the less-contaminated subsurface soil resulting in a dilution effect. The same amount of metal remains in the soil, it is just dispersed through a larger soil volume. Altough not an accepted or practical soil remediation procedure, repeated, deep cultivation may lower the metal concentrations in the root zone enough so that the soil is no longer potentially phytotoxic. Similarly, increasing the soil pH would reduce the availability of metals and therefore reduce the potential for metal uptake into the plant tissue. However, this would also inhibit nutrient availability and may have to be accompanied by a supplemental fertilizer program.

Common landscaping practices in the residential community in the vicinity of INCO can also dramatically affect the local surface soil metal concentrations. Constructing raised garden beds or adding topsoil and re-sodding lawns is an effective method of significantly reducing metal exposure on residential properties; however, the contamination remains buried at depth. With time, soil cultivation in agricultural areas and landscaping in residential communities could create a patchwork of "higher" and "lower" surface soil metal concentrations superimposed on the still very clear concentration gradient of Ni, Cu, and Co soil contamination in Port Colborne. As more time passes, in the absence of INCO emissions and through continued local surface soil disturbances, this mosaic of surface soil metal concentrations would become more prevalent. However, areas that have not been disturbed would remain contaminated at levels approximating those detected in the 1976 and 1991 surveys.

References

1. Ontario Ministry of the Environment. 1989. *Ontario Ministry of the Environment "Upper Limit of Normal" Contaminant Guidelines for Phytotoxicology Samples."* Report No. ARB-138-88-Phyto.

2. Ontario Ministry of the Environment. 1989. *The determination of Metals in Vegetation by ICP- AES.* Laboratory Services. Branch. Catalog. No. E3065A.1.

3. Rinne, R. J. 1990. *Phytotoxicology Assessment Surveys in the Vicinity of INCO Ltd., Port Colborne - 1985 and 1986.* Ontario Ministry of the Environment, Air Resources Branch, ISBN 0-7729-5142-X, Report No. ARB-001-88-Phyto.

4. Smith, M. L. 1975. *Phytotoxicology Investigations - International Nickel Co., Port Colborne, 1969-1974.* Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section.

5. Swain, D. J. 1955. *Trace-Element Content of Soils*. Commonw. Bur. Soil Sci. Tech Comm. No.48. Herald Printing Works, York.

6. Temple, P. J. 1976. *Phytotoxicology Assessment Surveys - 1976; International Nickel Co., Port Colborne.* Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section.

7. Ontario Ministry of the Environment. 1993. *Phytotoxicology Investigation Manual: Part 2A. Methodology for Phytotoxicology Investigators.* Report No. 015-3512-93

8. Ontario Ministry of the Environment. 1985. *Procedures Manual for Vegetation and Soils Processing Laboratory*. Phytotoxicology Section.

9. Golden Software Inc. 1990. *Surfer.*

10. Ontario Ministry of the Environment. 1990. *Guidelines for the Decommissioning and Cleanup of Sites in Ontario*. Report Number PIBs 141E, ISBN 0-7729-5278-7

Table 1. (Continued) Nickel, Copper, and Cobalt Concentrations in Surface Soil (0-5 cm), pH and EC Collected in the Vicinity of INCO, Port Colborne, July, 1991. Selected data in Parentheses are 5-10 cm Soil.

Site No	Distance (m) & Direction from INCO	pH	Electrical Conductivity	Metal Concentrations (µg/g, dry weight)*		
				Ni	Cu	Co
21	6270 NE	6.1	0.24	225	62	12
23	6330 N	6.5	0.41	69	53	12
24	330 NNW	6.7	0.29	3400	285	12
25	1110 NNW	7.0	0.15	1600	215	98
26	1050 NW	7.2	0.19	1800	445	46
27	1330 WNW	6.2	0.21	820	120	71
28	610 S	6.6	0.28	6200	710	25
29	1440 NNW	6.8	0.41	615	94	65
30	4050 WNW	7.1	0.20	36	22	8
31	2610 NNE	7.5 (7.0)	0.23	3550 (890)	380 (155)	68 (17)
32	2940 N	7.1	0.25	125	48	8
33	2390 NNW	6.9 (7.2)	0.22 (0.20)	515 (415)	75 (58)	13 (10)
34	1330 WNW	7.1	0.24	290	45	10
35	2610 NW	6.9	0.25	165	50	15
36	1780 NW	6.8	0.20	330	81	15
37	1610 W	6.8 (7.1)	0.41 (0.20)	106 (84)	28 (30)	8 (8)
38	2220 NNW	6.6	0.23	69	38	8
39	6940 WNW	7.2 (6.2)	0.19 (0.21)	105 (82)	31 (23)	8 (6)
ULN				60	100	25

* mean of duplicate samples and analysis. Data exceeding ULN are shaded.
ULN - Phytotoxicology Upper Limit of Normal guideline for urban soil (see appendix).

Table 3. Comparison of Nickel, Copper, and Cobalt Concentrations in Unwashed Silver Maple Foliage Collected from Common Sites in 1986 and 1991.

Station No.	Distance (m) & Direction from INCO	Metal Concentration (µg/g dry weight)					
		Ni		Cu		Co	
		1986	1991	1986	1991	1986	1991
1	390 N	15	14	15	12	1	<1
2	330 W	24	15	12	11	2	<1
3	610 SW	18	13	9	5	1	<1
4	670 NNW	27	19	12	10	2	<1
5	390 NW	17	12	12	14	1	<1
7	1270 N	64	27	12	10	4	<1
8	1000 N	26	25	8	11	1	1
9	1000 NNE	120*	18	17	11	4	<1
10	1330 NE	30	37	13	12	2	1
11	2280 NE	45	26	12	10	2	<1
12	4220 NE	3	8	10	9	<1	<1
14	1050 E	11	9	14	5	<1	<1
15	2050 E	5	4	7	8	<1	<1
16	3390 E	5	6	10	17	<1	<1
18	3000 NE	11	13	12	7	<1	<1
19	7660 NE	3	9	10	11	<1	<1
20	5160 ESE	2	2	4	6	<1	<1
21	6270 NE	14	2	24	7	<1	<1
24	330 NNW	38	2	10	9	<1	<1
Mean		25	14	12	10	1	<1
t-test		NS		NS		not tested	
ULN		7		20		2	

* mean of duplicate analysis (1991) or triplicate analysis (1976).

Paired t- test, comparing 1986 and 1991 data, NS - Not significant ($p>0.05$).

ULN- Phytotoxicology Upper Limit of Normal guideline for urban tree foliage (see appendix).

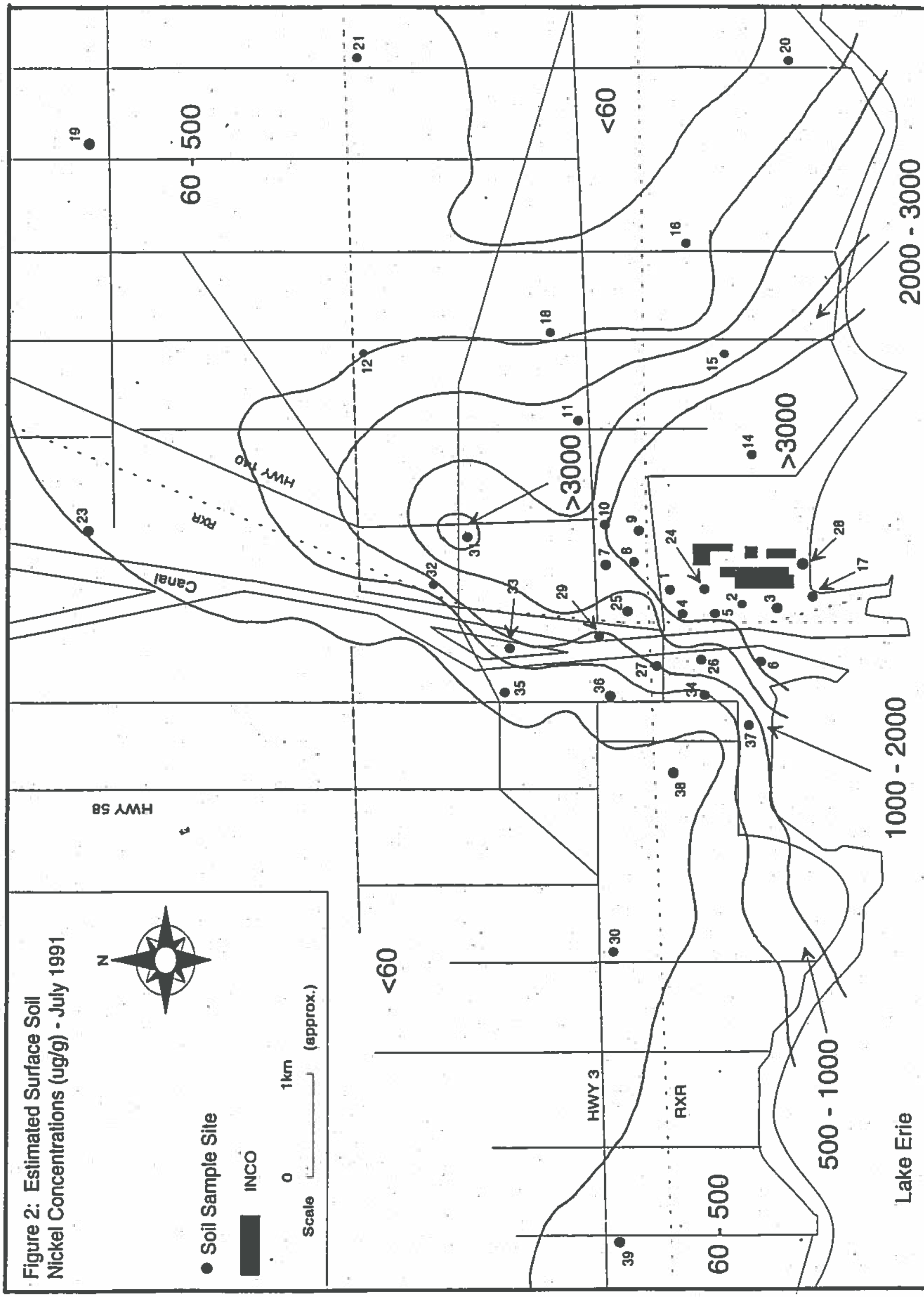


Figure 2: Estimated Surface Soil Nickel Concentrations (ug/g) - July 1991

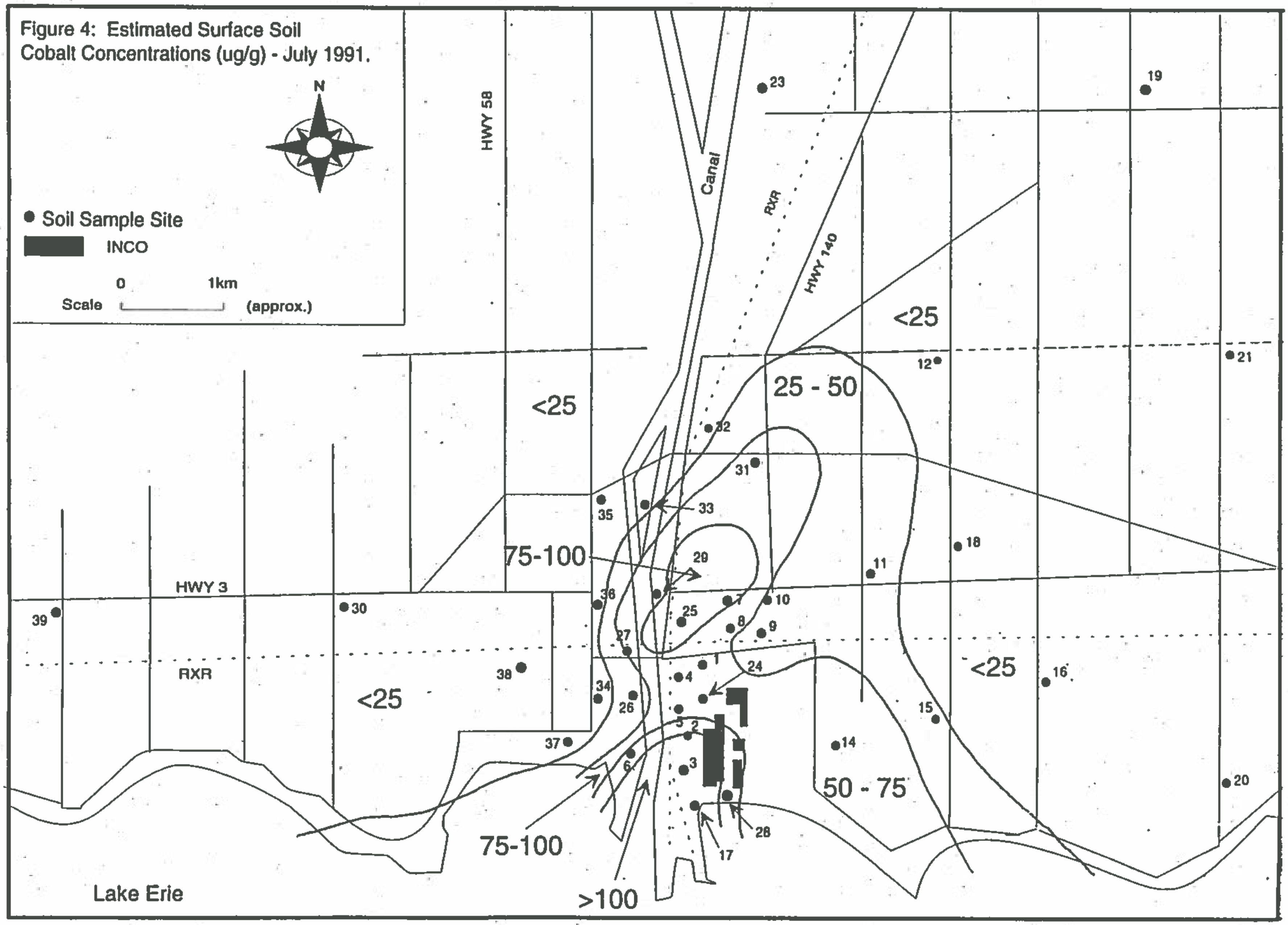
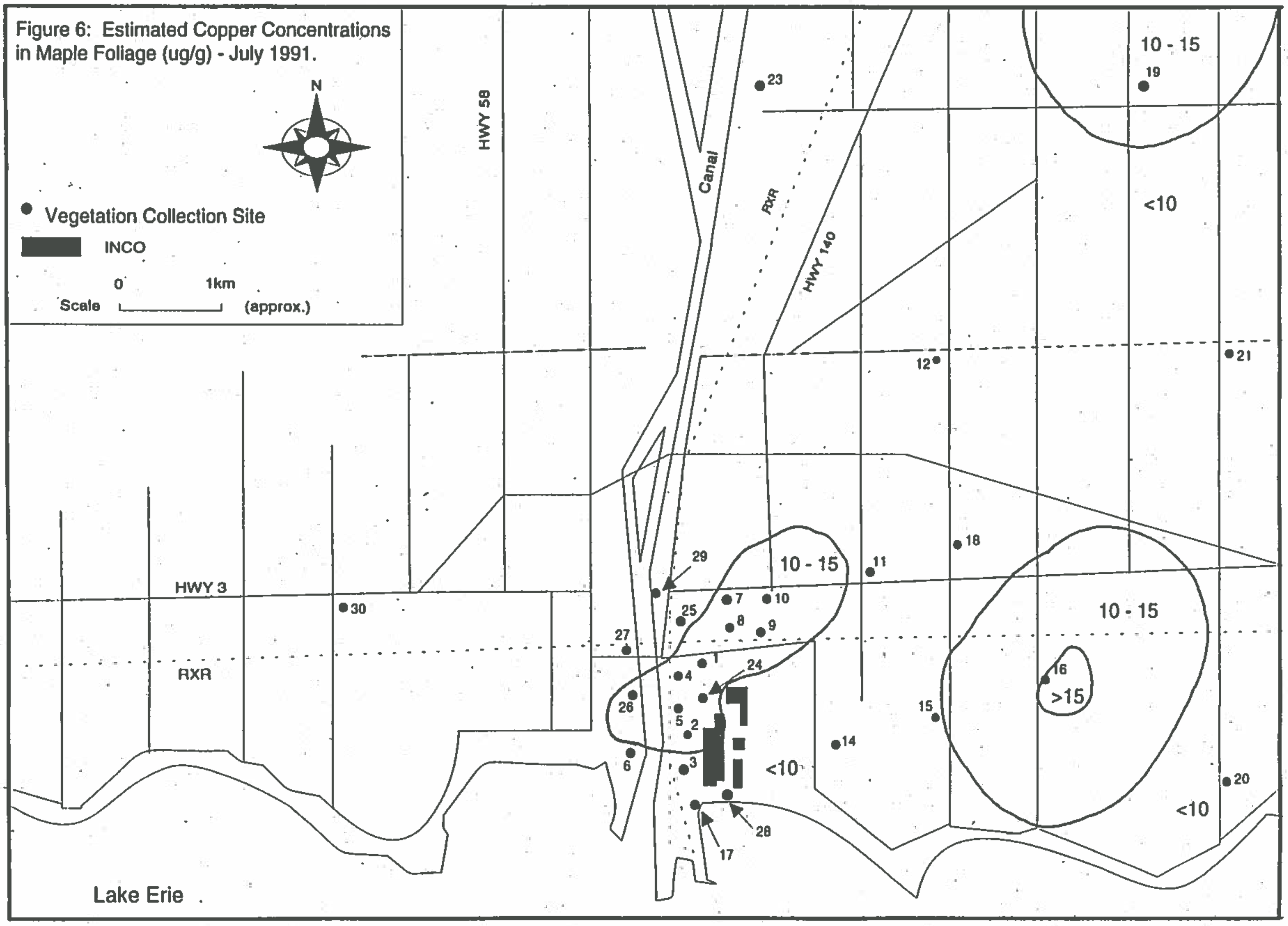


Figure 4: Estimated Surface Soil Cobalt Concentrations (ug/g) - July 1991.

Figure 6: Estimated Copper Concentrations in Maple Foliage (ug/g) - July 1991.



Derivation and Significance of the MOEE Phytotoxicology
"Upper Limits of Normal" Contaminant Guidelines.

The MOEE Upper Limits of Normal (ULN) contaminant guidelines represent the expected maximum concentration in surface soil, foliage (trees and shrubs), grass, moss bags, and snow from areas in Ontario not exposed to the influence of a pollution source. Urban ULN guidelines are based on samples collected from urban centres, whereas rural ULN guidelines were developed from non-urbanized areas. Samples were collected by Phytotoxicology staff using standard sampling procedures (reference: *Ontario Ministry of the Environment. 1989. Ontario Ministry of the Environment "Upper Limit of Normal" Contaminant Guidelines for Phytotoxicology Samples. Phytotoxicology Section, Air Resources Branch: Technical Support Sections NE and NW Regions, Report No. ARB-138-88-Phyto. ISBN: 0-7729-5143-8.*). Chemical analyses were conducted by the MOEE Laboratory Services Branch.

The ULN is the arithmetic mean plus three standard deviations of the suitable background data for each chemical element and parameter. This represents 99% of the sample population. This means that for every 100 samples that have not been exposed to a pollution source, 99 will fall within the ULN.

The ULNs do not represent maximum desirable or allowable limits. Rather, they are an indication that concentrations that exceed the ULN may be the result of contamination from a pollution source. Concentrations that exceed the ULNs are not necessarily toxic to plants, animals, or people. Concentrations that are below the ULNs are not known to be toxic.

ULNs are not available for all elements. This is because some elements have a very large range in the natural environment and the ULN, calculated as the mean plus three standard deviations, would be unrealistically high. Also, for some elements, insufficient background data is available to confidently calculate ULNs. The MOEE Phytotoxicology ULNs are constantly being reviewed as the background environmental data base is expanded. This will result in more ULNs being established and may amend existing ULNs.