Soil Contamination in Selected Port Colborne Woodlots: 2000

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Table of Contents

Introduction

In 1999 and 2000 scientists from the MOE Ecological Standards and Toxicology (Phytotoxicology) Section conducted numerous investigations on behalf of residents of Port Colborne to determine the extent of heavy metal soil contamination on their properties. One of these investigations included soil sampling in a rural woodlot. The results of this investigation indicated that the surface soil in the woodlot had metal concentrations, particularly nickel, that were both substantially higher than elsewhere on the property and higher than what was expected based on the extensive soil investigations conducted in the Port Colborne area by the MOE in 1998 and 1999 [1, 2]. Specifically, soil nickel concentrations from this woodlot, located north east of the INCO refinery, had soil nickel concentrations up to ten times higher than surface soil from adjacent residential lawns. The lawn soil (0-5cm depth) averaged about 1,000 µg/g nickel, whereas the surface soil (0-5 cm depth) in the adjacent woodlot ranged from 4,000 µg/g to 10,000 µg/g nickel. Based on the 1998/1999 MOE soil studies [1, 2] the expected soil nickel concentration for that area of Port Colborne is about 1,000 µg/g. Therefore, the soil nickel level of the lawn and open fields on the complainant's property was about what was expected, however, the contaminant concentrations in surface soil in the adjacent woodlot were much higher than anticipated. The Ontario soil background concentration for nickel is 43 µg/g. The MOE effects-based generic soil nickel criterion is 200 µg/g and is based on ecological protection, not human health (refer to Appendices A and B).

This information was shared with the Port Colborne Public Liaison Committee at a meeting on August 14, 2000. At this meeting, some members of the public expressed concerns about the soil contaminant levels in other woodlots in the Port Colborne area, particularly since the one woodlot that had been investigated was not the closest to INCO, and so other woodlots may be even more contaminated, but no confirmatory sampling has been conducted to prove or disprove this possibility. Furthermore, there are residential homes in some Port Colborne woodlots, and if the soil nickel levels are much higher than expected then the health risk associated with exposure to soil metal contamination may have been underestimated for those residents that live in homes in woodlots.

A human health risk assessment conducted by the MOE in 1997 and reviewed by the Regional Niagara Health Department [3] concluded there is no adverse health risk associated with exposure to nickel-contaminated soil in Pt. Colborne. However, the highest soil nickel level used in the health risk assessment was 9,750 µg/g. It was not known at that time that woodlots in the zone of aerial nickel deposition from INCO may be much more contaminated than the surrounding open areas. The potential health risks and risks to ecological receptors resulting from woodlot soil nickel levels in excess of 9,750 µg/g has not been assessed.

Following the August 14 public meeting the issue of enhanced soil contamination in Port Colborne woodlots was discussed at the Technical Sub-Committee of the Public Liaison Committee. Because some residents have homes in wooded areas, and some municipal day-use parks are wooded, the MOE agreed to conduct soil investigations of selected woodlots in Port Colborne. The objective of this MOE study was to thoroughly investigate the pattern of soil

metal contamination in a few woodlots in the highest contaminant deposition zone, and therefore evaluate the expected worse case scenario; it was not intended to define the extent of soil metal levels in all woodlots in the Port Colborne area. If very high metal contamination was identified in woodlot soil by this preliminary MOE study, then a more extensive study of many more woodlots would be conducted by INCO's consultant (Jacques Whitford Environmental) under MOE audit.

Scientists from the MOE Ecological Standards and Toxicology Section (Phytotoxicology) collected soil from five woodlots in Port Colborne in October 2000. If soil nickel levels were found to exceed 9,750 µg/g then the data would be reviewed by MOE Standards Development Branch senior regulatory toxicologists for an evaluation of human health risk associated with 1) casual or recreational use of contaminated woodlots by children, and 2) residential exposure in a home situated within a contaminated woodlot.

Methods

Sampling and Analytical Protocols

Five rural woodlots were selected for this study. At each woodlot, seven soil sampling sites were located along a transect starting in an open field on the windward side of the woodlot facing INCO , at several points within the woodlot, and in the open field beyond the leeward edge of the woodlot facing away from INCO (see Figure 1). Each sample site along the transect had to meet the following specific requirements:

Site 1. Open, uncultivated field on the windward side of the woodlot (facing INCO), between 50 and 100 m upwind of the edge of the woodlot;

Site 2. Open, uncultivated field on the outside edge of the windward side of the woodlot (facing INCO), within 10m of the drip line of the outer edge of the woodlot;

Site 3. Inside the woodlot, within 10m of the windward edge of the woodlot;

Site 4. Three sampling sites (4a, 4b, and 4c) to be located across the centre of the woodlot, along a transect at right angles to the transet from INCO. The three sample sites; 4a, 4b, and 4c, are to be located at least 50m apart and equidistant from co-dominant trees;

Site 5. Inside the woodlot, within 10m of the leeward edge of the woodlot (facing away from INCO);

Site 6. Open, uncultivated field on the outside edge of the leeward side of the woodlot (facing away from INCO), within 25m of the outer edge of the woodlot;

Site 7. Open, uncultivated field on the leeward side of the woodlot (facing away from INCO), a

minimum of 100 m downwind of the edge of the woodlot.

Standard MOE sampling protocols were followed [4]. At each sample site, a soil corer was utilized to collect duplicate surface soil samples from two depth intervals (0-5 cm and 5-10 cm). Approximately 10-12 soil cores were taken per duplicate per soil depth increment while walking a Z pattern across the designated sample area. The soil cores were placed in labelled polyethylene bags. Wherever soil duff (partially decomposed organic matter) was present it was removed so that only mineral soil was sampled. At each sample site within a woodlot the duff layer was collected, if it was present, and placed in labelled, plastic bags.

The samples were taken to the Ecological Standards and Toxicology Section laboratory for processing where they were dried, ground to pass through a 2 mm sieve, and then ground a second time to pass through a 355 micron sieve. The fine soil fraction was transferred to the MOE Laboratory Services Branch for analysis of the inorganic elements aluminum (Al), barium (Ba), beryllium (Be), cadmium (Cd), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), strontium (Sr), vanadium (V), and zinc (Zn), as well as the hydrides, arsenic (As) and selenium (Se).

Location of Selected Woodlots

Five woodlots were selected for investigation (see Figure 2). The woodlots were predominantly maple/beech woodlots containing some conifers, such as hemlock and spruce. Birch, sumac, prickly ash, and hawthorn were common around the woodlot perimeters. The one exception was Woodlot 2, which was dominated by locust trees that were of shorter stature than the maple/beech trees dominating the other woodlots. Woodlot 2 was also more open than the other woodlots. Nevertheless, although the species composition and density of Woodlot 2 differed from the other four woodlots in this study, it was included because of its close proximity and northeasterly direction relative to INCO; it lies in the direct downwind path of the prevailing growing season winds coming from the refinery.

Three of the woodlots are located within 2.5 km of the refinery in the direction of the growing season prevailing winds (east to northeast of INCO) in the area of the highest deposition zone. Two additional woodlots were selected at greater distances west and northeast of INCO. The following woodlots were selected for study:

Woodlot 1. On the south side of Hwy 3, east of Elizabeth St., about 2.2 km north-northeast of INCO (Figure 3);

Woodlot 2. On the north side of Killaly St., north of Humberstone School, east of Elizabeth St., about 1.8 km northeast of INCO (Figure 3);

Woodlot 3. South of Killaly St., between Snider Rd. and Lorraine Rd., about 1.6 km east of INCO (Figure 4);

Woodlot 4. Northeast corner of Forks Rd. East and Green Rd., about 11 km northeast of INCO (Figure 5);

Woodlot 5. Southeast corner of Hwy 3 and Bessie Rd. in Wainsfleet, about 4.2 km west of INCO (Figure 6).

Results

All results are the means of duplicate samples. Soil concentrations for the 19 inorganic parameters are presented for each of the five wood lots in Tables 1 to 5. Laboratory results were compared with MOE Table A 'effects-based' guidelines and 'background-based' Table F guidelines (refer to Appendices A and B). Where no Table F guidelines exist for an element, results were compared with Ontario Typical Range (OTR_{98}) values (refer to Appendix C).

Soil nickel, copper, cobalt, and arsenic concentrations at both sample depths for all five woodlots are illustrated in Figures 7 to 11. The Table A guidelines for nickel, copper, and cobalt were exceeded in soil from both sample depths at some sites in woodlots 1, 2, and 3. Soil arsenic, beryllium, and selenium concentrations marginally exceeded the MOE Table A guideline at a few of the sample sites at woodlot 3. Soil aluminum, cadmium, selenium, strontium, zinc, and molybdenum concentrations occasionally exceeded the Table F background-based guidelines at at least one sample site in most woodlots.

The soil nickel levels were similar in the three woodlots closest to INCO (woodlots 1, 2, and 3), and the highest woodlot nickel level was about one half the maximum level used in the MOE human health risk assessment (9,750 µg/g). The maximum soil nickel concentration detected in woodlot 1 was 4,650 µg/g; in woodlot 2 it was 5,000 µg/g; and woodlot 3 it was 4,100 µg/g. The soil metal levels were consistently higher in soil samples collected in the woodlots then in the adjacent open fields. Also, whereas the soil metal levels tended to be similar in the two depths in samples collected from the open fields, there was a strong tendency for the woodlot soil samples to have higher concentrations in the 0-5 cm depth then in the 5-10 cm samples. A more detailed description of the findings follows.

Discussion
Woodlot 1

The soil nickel concentrations at all nine sample sites at this woodlot exceeded the effects-based Table A generic criterion (200 µg/g) at both sampling depths (Table 1, Figure 7). Surface soil nickel concentrations peaked at site 3, which is situated just inside (10 m) the windward or INCO-facing side of the woodlot. The soil nickel concentration in surface soil at site 3 is 4,650 µg/g. This is almost 2.5 times the surface soil nickel concentration (1,900 µg/g) at

site 2 located in the untilled field directly in front of the forest edge, and almost seven times higher than the soil nickel concentration (690 µg/g) at the same depth at site 1 situated in the middle of the untilled field on the windward side of the woodlot.

The highest copper and cobalt soil concentrations also occured at site 3 but exceeded their corresponding Table A generic criteria in the 0-5cm soil depth only. Soil copper and cobalt concentrations do not exceed their corresponding Table A criteria at any of the other eight sites in or around this woodlot. These soil nickel, copper, and cobalt peaks are not observed at the 5-10 cm depth (see Figure 7). Soil arsenic concentrations were all within the natural background range and a woodlot vs open field pattern was not consistent. However, soil arsenic concentrations in the top 5 cms of soil tended to be higher than the 5-10 cm depth, which suggests the likelihood of an aerial deposition source.

Although not as elevated as the soil levels observed at site 3, all the soil sample sites located in the centre of the woodlot (sites 4a, 4b, and 4c) had surface soil nickel concentrations that are higher than the nickel level in the open windward field at site 1. In contrast, the soil nickel concentrations at site 6, situated in the untilled field directly behind the leeward side of the woodlot, is the lowest of all nine sites sampled in this woodlot. Site 7, an untilled field site located much further downwind from the leeward edge of the woodlot, has a higher soil nickel concentration than site 6, but a slightly lower level then the windward open field site 1.

There appears to be a ‘snowfence’ effect where the windward edge of the woodlot has accumulated the highest soil metal concentrations, and soil levels diminish towards the leeward side of the woodlot. The lowest concentrations occur in the open field directly adjacent to the leeward edge of the woodlot. This suggests that the open field directly downwind of the woodlot is being screened from aerial deposition by the woodlot. This screening effect is much like the rain shadow that occurs on the leeward side of coastal mountain ranges.

Woodlot 2

Woodlot 2 is located about 500 metres south of Woodlot 1. Soil nickel concentrations at all nine sample sites, both outside and inside the woodlot, exceeded the effects-based Table A generic criterion down to the 10 cm sampling depth (Table 2, Figure 8). In this woodlot, the surface soil nickel concentration peaked at site 2, situated just in front of the INCO-facing windward side of the woodlot. The soil nickel concentration in surface soil at site 2 is 5,000 µg/g, which is comparable to the maximum soil nickel concentration observed in Woodlot 1 (4,650 µg/g). The soil nickel concentration at site 2 is almost eight times higher than the surface soil nickel concentration (630 µg/g) at site 1, situated in the windward open field. The soil nickel concentrations tend to diminish through the woodlot from the windward to the leeward sides, and then decrease again at the leeward field sites. The surface soil (0-5 cm depth) concentrations of copper and cobalt also peak at site 2.

The metal concentrations tended to be much higher in the surface soil then in the 5-10 cm

depth in the woodlot samples, and either similar or higher at depth in samples from the open fields. In general, the soil concentration gradient across the sample sites in woodlot 2 is similar to the gradient observed for woodlot 1.

There were only tilled fields present on the windward (INCO-facing) side of this woodlot. For this reason, it was necessary to situate site 1 in a grassy opening of a hedgerow located between Woodlot 2 and the refinery. It is likely that wind-blown soil from tilling operations has been deposited on the area selected as site 1, having a dilution effect on the surface (0-5 cm depth) samples, which may account for the much lower metal levels in surface vs sub-surface samples. In the 1998 MOE Port Colborne study [1] the practice of tilling soil was shown to have a homogenizing effect which reduced metal concentrations in the soil plow layer (top 20 cm).

Woodlot 3

The soil data for woodlot 3 are summarized in Table 3 and illustrated in Figure 9. Soil nickel concentrations at both sample depths and all sample sites exceeded the MOE Table A generic criterion. The surface soil nickel concentration is highest at site 3 (4,100 µg/g), located just inside the windward edge of the woodlot. Site 3 also had the highest soil copper, cobalt, and arsenic concentrations. Woodlot 3 is the only woodlot where soil arsenic levels exceeded the MOE Table A guideline of 20 µg/g. The highest soil arsenic level was 31 µg/g, which occurred in surface soil at site 3, just inside the windward side of the woodlot. Almost all soil samples inside of and immediately adjacent to the woodlot exceeded the Table A beryllium guideline. Woodlot 3 had the most number of Table F exceedences, with zinc, strontium, selenium, and cadmium exceeding background levels at several sample sites. The marginally but consistently elevated beryllium and strontium levels are likely associated with local shale deposits, as these two elements are naturally higher in Ontario shale[5].

The same concentration gradient was observed in samples collected from woodlot 3 as was observed in woodlots 1 and 2. That is, the soil metal levels were consistently higher in the woodlot then in the open fields outside of the woodlot, with the highest levels occurring at the windward woodlot edge and the lowest levels in the field adjacent to the leeward edge. The ‘snowfence/rain shadow’ pattern is evident.

Woodlot 4

Woodlot 4 is located 11 km northeast of INCO beyond the zone of high deposition but within the footprint of INCO stack emissions. The data for woodlot 4 is summarized in Table 4 and illustrated in Figure 10. Nickel is the only element that consistently exceeded the MOE Table F criterion (43 µg/g) at all seven sampling sites to a depth of 10 cm, which indicates that the nickel is anthropogenic in origin. The highest soil nickel concentration occurred in the middle of woodlot 4, rather than the windward edge, and soil nickel levels were higher in the

woodlot than in the adjacent open fields. This suggests that the aerial deposition of nickel has come from the vertical settling of the air column, rather than lateral dispersion, as appears to be the case for woodlots closer to the refinery.

Woodlot 5

The data from woodlot 5 is very similar to woodlot 4, and is summarized in Table 5 and illustrated in Figure 11. Nickel, aluminum, cadmium, selenium, and strontium exceeded the MOE Table F background-based criteria and beryllium exceeded the Table A guideline at most of the sample sites. Aluminum is the second most common element in the earth's crust and is not associated with INCO emissions. The marginally elevated strontium and beryllium are likely natural in origin, associated with local shale deposits. This woodlot is upwind of the refinery and, like woodlot 4, is outside of the major deposition zone but still within the area affected by INCO emissions. Also like woodlot 4, the highest soil nickel concentration occurred in the middle of the woodlot, rather than the windward edge, and soil nickel levels were higher in the woodlot than in the adjacent open fields. This indicates that the aerial deposition of nickel has originated from the vertical settling of the air column, rather than lateral dispersion, as would be the case for woodlots closer to and more downwind the refinery. Like woodlot 4 there is no apparent 'snowfence/rain shadow' effect.

Conclusions

Woodlots 1, 2, and 3 are located close to and downwind of INCO in the area identified by the 1998 and 1999 MOE soil investigations as having the highest soil nickel, copper, and cobalt concentrations in the Port Colborne area. Therefore they represent worst case situations. Soil metal concentration gradients from these three woodlots located in close proximity to INCO all show a similar 'snowfence/rain shadow' effect: soil metal levels are highest at the field/woodlot interface, consistently higher in the woodlot than in the adjacent fields, and lowest in the open field immediately downwind of the woodlot. In these woodlots surface soil nickel levels were between two and seven times higher inside of or at the very edge of the woodlot than in the nearby open fields.

In contrast, the woodlots located at greater distances or upwind of INCO displayed a slightly different pattern: there was no pronounced difference in soil metal levels between the windward and leeward fields but the levels are consistently higher in the centre of the woodlot than in the adjacent fields. In these woodlots surface soil nickel levels were consistently two to three times higher in the woodlot than in the nearby open fields.

Woodlots can concentrate atmospheric pollutants in at least five ways:

1) Tree leaves act as a sponge absorbing large quantities of pollutant-laden air. The

pollutants accumulate on the epidermal layers and in the leaf mesophyll cells over the growing season. When these leaves fall to the ground and decompose they release their contaminant loading to the soil.

2) The rough bark of tree branches intercepts metal particulates from the air. These particulates are removed from the bark during rain events and washed into the soil

3) The physical structure of the woodlot creates turbulence in the lateral flow of the air stream. Slowing down air movement and causing eddies results in particulates falling out of the air stream and deposition to the soil at the windward edge of the woodlot. This is exactly the principal behind snow fencing: to create turbulence and slow the flow of air so that snow precipitates behind the fence and not on the road further downwind.

4) The woodlot floor is covered in abundant organic matter and organic matter tenaciously holds inorganic metal ions, such as nickel, copper, and cobalt. Therefore, metal particulates that fall onto a forest floor are much more likely to become concentrated in the upper soil horizons and stay in the top few cms.

5) Normally the forest floor is less disturbed than an agricultural field or an urban lawn. Therefore soil contaminants that are concentrated in the upper few cms are not going to be diluted by cultivation or landscaping.

These five mechanisms were acting concurrently with the general pollutant fallout that was on-going for the many decades that INCO was an active pollution source. In retrospect, it is logical to conclude that surface soil in a woodlot would concentrate contaminants relative to surface soil in adjacent open fields.

Although the soil in all of the woodlots was observed to accumulate metal levels at rates greater than the adjacent open fields, the maximum soil nickel level observed in the 'worst-case' Port Colborne woodlots was about one half, and the average soil nickel level was only about one fifth, of the 9,750 µg/g ceiling level used in the MOE health risk assessment. The health risk assessment concluded, *based on a multi-media assessment of potential risks, no adverse health effects are anticipated to result from exposure to nickel, copper, or cobalt in soils in the Port Colborne area* [3]. The health risk assessment was based on a life time exposure to 9,750 µg/g. In contrast, recreational use of a contaminated woodlot would be periodic and of very short duration, therefore the potential for exposure is a very small fraction of the lifetime exposure assumed in the health risk assessment. Normal disturbance associated with building and landscaping a house would either substantially dilute or even bury contaminated surface soil in the woodlot. Even if the woodlot's surface soil was left entirely undisturbed, the highest contaminant levels (most sites were much lower) encountered in the three woodlots from the area of greatest atmospheric deposition ranged from about one fifth to one half of the 9,750 µg/g used in the health risk assessment. Furthermore, there were no homes in these 'worse case' woodlots. In addition, the thick organic layer in a woodlot binds the metals making them less bioavailable, forms a physical barrier between the contaminated soil and a person using the woodlot, and

restricts re-suspension of contaminant-laden dust particles. For these reasons there is no anticipated health risk associated with exposure to contaminated soil in Port Colborne woodlots, either for the occasional recreational user, or for residents who have built their homes in woodlots.

Even though no adverse health risk is associated with normal use of these woodlots, the soil metal concentrations are high enough to be potentially phytotoxic. Heavy metals are particularly toxic to soil micro-organisms, which break down organic matter and enhance nutrient cycling in a forest. Heavy metals may inhibit plant root growth and function and impede the uptake of moisture and essential nutrient cations. The potential for adverse ecological effects to woodlot ecology in Port Colborne has not been assessed, although an evaluation of soil contamination with respect to valued ecological receptors is part of the ecological risk assessment included in the scope of work for the Port Colborne Community Based Risk Assessment.

Since these woodlots are believed to represent the worst-case scenario there is no need to further characterize the soil contaminant status of woodlots in Port Colborne, unless this is part of the general environmental data collection for the CBRA.

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Table 1: Soil Metal Concentrations in Woodlot 1

(Means of duplicate samples taken at 0-5 cm and 5-10cm depth - µg/g dry weight)

	Site 1		Site 2		Site 3		Site 4A		Site 4B		Site 4C		Site 5		Site 6		Site 7		MOE Guidelines	
	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	Table F	Table A
Al	22,500	25,500	18,500	25,500	20,500	25,500	23,500	26,500	25,000	***29,000***	21,500	25,500	26,500	***28,500***	21,000	26,000	23,000	25,000	27000	NG
As	11	12	16	9.4	12	9.6	14	8.6	16	9	9.4	6.8	14	14	9.2	8.2	11	11	17	20
Ba	110	120	99	110	120	140	140	140	140	155	120	130	155	160	120	140	140	145	210	1000
Be	0.8<T	0.8<T	0.7<T	0.8<T	1.0<T	1.2<T	1.1<T	1.1<T	1.1<T	1.1<T	1.0<T	1.0<T	1.2<T	1.2<T	0.9<T	1.0<T	1.1<T	1.1<T	1.2	1.2
Cd	0.4<T	0.4<T	0.3<T	0.3<T	0.3<T	0.5<T	0.7<T	0.5<T	0.9<T	0.8<T	0.6<T	0.4<W	1.1	0.9<T	0.8<T	0.8<T	0.9<T	0.7<T	1	12
Ca	3,800	3,650	4,850	2,900	9,050	6,700	15,200	6,900	8,000	6,200	8,800	6,150	12,000	8,900	23,000	4,950	9,200	7,950	58000	NG
Cr	27	32	24	31	28	30	31	31	36	15	30	30	41	35	30	35	31	37	71	1000
Co	16	15	***39***	13	***56***	21	***43***	16	***36***	15	***38***	15	***24***	18	14	14	19	18	21	50
Cu	79	69	***180***	68	***320***	***119***	***230***	81	***210***	78	***230***	***95***	***145***	***98***	58	33	73	64	85	300
Fe	25,000	27,500	16,000	22,000	14,000	20,500	17,500	20,000	17,000	20,000	16,500	16,000	22,000	26,500	24,500	30,500	28,000	29,500	33000	NG
Pb	38	35	63	29	82	37	73	31	68	29	81	33	59	45	60	36	40	39	120	200
Mg	4,150	4,450	3,000	3,650	3,550	4,500	4,500	4,900	4,300	4,900	4,350	4,500	5,350	5,450	12,000	6,600	7,600	7,400	16000	NG
Mn	235	215	270	115	105	120	230	210	165	160	175	145	270	290	435	440	375	415	1300	NG
Mo	0.8<T	0.6<W	1.1<T	1.1<T	.5<W	.5<W	0.6<T	0.5<W	0.6<T	0.5<W	0.6<T	0.5<W	1.6<T	0.6<T	0.8<T	0.7<T	0.6<W	0.5<W	2.5	40
Ni	***690***	***590***	***1,900***	***640***	***4,650***	***1,150***	***2.300***	***665***	***2,150***	***535***	***2,350***	***760***	***1,200***	***770***	***390***	***235***	***570***	***515***	43	200
Se	1.5	1.3	***3.3***	1.5	***6.8***	***2.2***	***4.4***	1.9	***4.1***	1.7	***5.0***	***2.2***	***2.7***	***2.2***	1.3	0.9<T	1.6	1.5	1.9	10
Sr	30	31	37	30	68	54	***97***	41	60	51	66	49	55	46	***82***	47	40	41	78	NG
V	41	44	32	42	35	42	39	42	34	39	34	36	42	45	42	48	49	51	91	250
Zn	160	145	125	73	***205***	105	***185***	100	***185***	105	***180***	105	145	125	145	110	120	120	160	800

Data in bold underlined italic font exceed MOE Table F soil back-ground guidelines, or OTR_{98} values if no Table F guideline has been established.
Shaded data exceed MOE Table A 'effects-based' criteria for medium-fine textured soils. <T = trace amount, <W = equal to or below analytical detection limit.

Table 2: Soil Metal Concentrations in Woodlot 2

(Means of duplicate samples taken at 0-5 cm and 5-10cm depth - µg/g dry weight)

	Site 1		Site 2		Site 3		Site 4A		Site 4B		Site 4C		Site 5		Site 6		Site 7		MOE Guidelines	
	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5 cm	5-10cm	Table F	Table A
Al	18,500	15,500	12,000	12,500	13,000	14,500	16,500	18,500	16,000	19,500	16,00	17,000	***29,500***	26,500	22,500	***28,000***	25,000	***28,500***	27000	NG
As	6.4	16	***20***	8.2	15	8.3	13	8.1	12	12	11	10	16	12	8.8	7.8	6.8	7.4	17	20
Ba	94	91	77	58	85	84	84	81	98	98	93	97	165	155	125	145	140	165	210	1000
Be	0.7<T	0.7<T	0.5<W	0.5<w	0.6<T	0.6<T	0.7<T	0.8<T	0.7<T	0.8<T	0.9<T	1.0<T	1.2<T	1.2<T	0.9<T	1.0<T	1.1<T	1.2<T	1.2	1.2
Cd	0.6<T	0.7<T	0.2<W	0.3<T	0.5<T	0.5<T	0.6<T	0.6<T	0.2<W	0.3<W	0.4<T	0.5<T	0.7<T	1.0	0.9<T	1.0	0.9<T	0.9<T	1	12
Ca	8,250	7,350	4,700	2,600	2,750	2,150	10,500	13,500	10,000	10,050	7,200	7,250	9,900	10,700	24,000	8,150	9,550	8,700	58000	NG
Cr	24	24	20	16	18	17	21	20	24	24	25	26	35	36	31	36	33	40	71	1000
Co	18	***73***	***85***	21	***42***	13	***50***	***24***	***65***	***33***	***37***	***24***	***22***	21	14	14	20	20	21	50
Cu	84	***365***	***445***	***150***	***225***	89	***225***	***101***	***270***	***165***	***160***	***120***	***120***	***120***	63	34	76	74	85	300
Fe	17,000	20,000	18,500	15,500	19,000	17,500	21,500	20,000	22,000	22,500	19,500	20,000	25,500	24,000	25,000	31,500	29,000	32,500	33000	NG
Pb	30	71	82	29	55	31	60	33	70	42	67	56	51	53	60	37	39	40	120	200
Mg	5,350	4,500	2,700	2,700	3,050	3,250	3,700	3,900	4,350	4,500	3,950	4,100	5,500	5,350	12,000	6,650	8,100	8,300	16000	NG
Mn	215	365	470	350	810	855	750	735	760	810	930	940	300	270	445	455	400	445	1300	NG
Mo	0.5<W	0.5<W	0.8<T	0.5<W	0.9<T	0.5<W	0.5<W	0.5<W	0.6<T	0.5<W	0.6<T	0.5<W	0.7<T	1.3<T	0.8<T	0.6<T	0.5<W	0.8<T	2.5	40
Ni	***630***	***3,650***	***5,000***	***1,380***	***2,550***	***615***	***2,500***	***840***	***3,100***	***1,500***	***1,700***	***965***	***980***	***190***	***405***	***235***	***600***	***560***	43	200
Se	1.7	***4.4***	***6.3***	***3.2***	***3.8***	1.2	***3.5***	1.6	***4.6***	***2.3***	***2.6***	1.7	***8.3***	***2.6***	***2.4***	1.4	1.6	1.7	1.9	10
Sr	46	37	17	11	12	11	14	14	19	17	22	22	51	52	***89***	49	43	45	78	NG
V	36	37	29	28	31	32	37	39	38	43	52	53	49	43	42	49	52	58	91	250
Zn	85	***190***	***225***	97	155	94	155	93	***170***	110	135	110	140	130	155	120	130	130	160	800

Data in bold italic underline test exceed Table F soil back-ground guidelines, or OTR_{98} values if no Table F guideline has been established.
Shaded data exceed Table A 'effects-based' soil criteria for medium-fine textured soils. <T = trace amount, <W = equal to or below analytical detection limit.

Table 3: Soil Metal Concentrations in Woodlot 3

(Means of duplicate samples taken at 0-5 cm and 5-10cm depth - *μ*g/g dry weight)

	Site 1		Site 2		Site 3		Site 4A		Site 4B		Site 4C		Site 5		Site 6		Site 7		MOE Guidelines	
	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5 cm	5-10cm	Table F	Table A
Al	11,500	10,750	11,500	11,500	12,000	12,000	24,500	25,500	23,500	26,500	14,000	16,500	20,500	19,500	20,000	19,000	16,500	18,500	27000	NG
As	***18***	***20***	***27***	***28***	***31***	***26***	14	12	14	15	***22***	***21***	***21***	***20***	13	13	12	15	17	20
Ba	105	103	115	115	110	110	140	150	140	150	120	135	160	155	140	140	110	115	210	1000
Be	1.1<T	1.1<T	1.2<T	***1.3***<T	***1.3***<T	***1.4***<T	***1.3***<T	***1.4***<T	***1.4***<T	***1.6***<T	***1.3***<T	***1.6***<T	***1.4***<T	***1.5***<T	***1.5***<T	***1.5***<T	0.9<T	1.0<T	1.2	1.2
Cd	0.9<T	0.6<T	***1.2***	1.0<T	***1.4***	***1.7***	***1.1***<T	***1.1***<T	***1.3***	***1.4***	***2.0***	***1.8***	***1.6***	***1.7***	***1.6***	***1.7***	***1.2***	***1.1***	1	12
Ca	24,500	23,500	20,000	19,500	18,000	19,500	7,050	6,500	8,900	8,950	19,000	19,500	18,500	19,500	18,000	18,000	13,500	15,000	58000	NG
Cr	18	16	19	19	23	21	31	34	30	33	23	31	34	28	25	25	24	25	71	1000
Co	***31***	***33***	***63***	***61***	***79***	***53***	***24***	***22***	***29***	***29***	***58***	***52***	***42***	***31***	***29***	***30***	***38***	***42***	21	50
Cu	***270***	***280***	***455***	***440***	***540***	***425***	***135***	***135***	***190***	***195***	***405***	***385***	***255***	***225***	***210***	***220***	***185***	25	85	300
Fe	14,500	14,500	19,000	19,000	20,000	18,000	16,000	17,500	16,500	17,500	17,000	18,500	26,000	25,000	17,000	17,000	16,000	17,500	33000	NG
Pb	33	31	61	60	82	58	45	38	49	44	83	70	70	52	42	40	52	56	120	200
Mg	2,900	2,400	2,450	2,400	2,050	2,000	3,950	4,100	3,700	4,100	2,800	2,900	4,750	4,350	3,800	3,600	3,600	3,800	16000	NG
Mn	255	225	385	370	460	370	190	165	190	160	245	220	425	350	200	190	265	265	1300	NG
Mo	***2.7***	2.4	***3.0***	***3.1***	***4.2***	***4.0***	1.2<T	1.1<T	0.9<T	0.7<T	2.1<T	***2.7***<T	***2.9***	***3.3***	1.3<T	1.4<T	1.0<T	0.8<T	2.5	40
Ni	***2,000***	***2,300***	***3,900***	***3,750***	***4,100***	***2,900***	***1,040***	***970***	***1,500***	***1,600***	***3,100***	***3,100***	***1,950***	***1,600***	***1,600***	***1,700***	***1,800***	***2,150***	43	200
Se	***6.2***	***6.8***	***11***	***9.9***	***10***	***8.8***	***3.2***	***3.5***	***4.3***	***4.0***	***9.7***	***8.8***	***7.1***	***6.7***	***5.5***	***5.8***	***4.2***	***5.4***	1.9	10
Sr	***335***	***315***	***360***	***365***	***530***	***570***	75	75	***81***	***85***	***330***	***350***	***190***	***205***	***285***	***275***	78	77	78	NG
V	34	32	39	41	39	40	49	50	48	52	39	42	61	62	47	47	38	41	91	250
Zn	120	115	***190***	***180***	***180***	150	120	115	125	120	***175***	***180***	***165***	140	135	130	***175***	***220***	160	800

Data in bold italic underlined test exceed Table F soil back-ground guidelines, or OTR_{98} values if no Table F guideline has been established.
Shaded data exceed Table A 'effects-based' soil criteria for medium-fine textured soils. <T = trace amount, <W = equal to or below analytical detection limit.

Table 4: Soil Metal Concentrations in Woodlot 4

(Means of duplicate samples taken at 0-5 cm and 5-10cm depth - µg/g dry weight)

	Site 1		Site 2		Site 3		Site 4A		Site 4B		Site 4C		Site 5		Site 6		Site 7		MOE Guidelines	
	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5 cm	5-10cm	Table F	Table A
Al	22,500	25,500	23,000	24,000	13,000	14,000	11,500	12,500	12,000	13,500	13,000	14,000	11,000	23,500	26,000	***27,500***	22,500	24,000	27000	NG
As	4.5	4.7	6.2	7.2	7.4	6.5	7.7	6.1	11	7.1	5.9	6	6.9	5.3	7.3	8.4	10	8.9	17	20
Ba	125	140	120	135	66	62	47	39	32	28	80	75	53	46	140	145	140	140	210	1000
Be	1.0<T	1.0<T	0.9<T	1.0<T	0.5<W	0.5<W	0.5<W	0.5<W	0.5<W	0.5<W	0.5<W	0.5<W	0.5<W	0.5<W	1.2<T	1.2<T	1.1<T	1.1<T	1.2	1.2
Cd	0.9<T	1.0<T	0.9<T	0.7<T	0.7<T	0.5<T	0.7<T	0.3<W	0.4<T	0.4<T	0.7<T	0.5<T	0.5<T	0.5<T	0.8<T	***1.6***	0.7<T	0.5<T	1	12
Ca	5,250	4,800	17,000	21,000	2,250	1,400	1,500	850	1,200	600	3,150	2,450	2,100	1,050	25,000	2,7000	36,000	42,000	58000	NG
Cr	27	29	29	32	18	19	16	17	16	16	18	17	16	16	34	36	32	33	71	1000
Co	8.3	9.2	12	14	7.1	5.7	6.7	4.1	6.2	3.9	5.2	5.1	6.3	4.7	15	16	16	16	21	50
Cu	27	26	24	28	22	16	21	10	23	10	21	16	19	11	29	29	26	25	85	300
Fe	14,500	16,000	25,000	26,000	13,000	13,500	12,000	13,000	13,500	14,000	11,000	12,000	9,650	9,900	31,500	33,000	30,500	31,000	33000	NG
Pb	30	33	25	30	36	29	39	24	52	23	35	27	38	22	29	29	23	21	120	200
Mg	4,500	5,050	8,550	8,850	2,750	2,750	2,050	2,250	1,650	1,950	2,550	2,500	2,300	2,350	10,500	11,000	11,500	12,500	16000	NG
Mn	220	210	415	525	300	190	230	125	180	103	395	315	200	105	555	575	690	710	1300	NG
Mo	0.5<W	0.5<W	0.6<T	0.5<W	1.1<T	0.6<T	1.2<T	0.7<T	1.7<T	1.0<T	0.6<T	0.6<T	1.0<T	0.5<W	0.5<W	0.5<W	0.5<W	0.5<W	2.5	40
Ni	***69***	***69***	***67***	***66***	***140***	***85***	***160***	***63***	***185***	***58***	***110***	***83***	***130***	***67***	***61***	***63***	***54***	***52***	43	200
Se	0.9<T	0.8<T	0.6<T	0.5<T	0.8<T	0.6<T	1.1	0.<T	1.1	0.5<T	0.8<T	0.<T	0.8<T	0.4<T	0.4<T	0.5<T	0.3<T	0.2<W	1.9	10
Sr	31	30	48	61	23	17	14	10	9	7	31	27	19	13	70	76	78	***90***	78	NG
V	36	41	44	44	29	32	32	34	35	38	29	31	25	27	50	53	48	51	91	250
Zn	89	92	105	104	75	60	55	40	54	40	73	64	62	46	110	15	86	83	160	800

Data in bold italic underlined text Table F soil back-ground guidelines, or OTR_{98} values if no Table F guideline has been established.
Shaded data exceed Table A 'effects-based' soil criteria for medium-fine textured soils. <T = trace amount, <W = equal to or below analytical detection limit.

Table 5: Soil Metal Concentrations in Woodlot 5

(Means of duplicate samples taken at 0-5 cm and 5-10cm depth - µg/g dry weight)

	Site 1		Site 2		Site 3		Site 4A		Site 4B		Site 4C		Site 5		Site 6		Site 7		MOE Guidelines	
	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5cm	5-10cm	0-5 cm	5-10cm	Table F	Table A
Al	23,500	25,000	***32,500***	***37,000***	***32,500***	***35,500***	***31,000***	***28,000***	***34,000***	***39,000***	***33,000***	***38,500***	***39,500***	***44,000***	***34,500***	***37,000***	26,000	***28,500***	27000	NG
As	4.8	5.2	5.5	6.6	6.5	7.5	6.4	6.1	6.4	7.3	9.2	8.5	6.3	5.1	6.5	6.8	8	8	17	20
Ba	135	135	195	200	165	180	150	140	170	185	180	190	175	205	150	170	160	170	210	1000
Be	1.0<T	1.1<T	***1.5*<T**	***1.4*<T**	***1.5*<T**	***1.7*<T**	***1.5*<T**	***1.4*<T**	***1.7*<T**	***1.9*<T**	***1.7*<T**	***2.0*<T**	***1.7*<T**	***1.9*<T**	***1.6*<T**	***1.7*<T**	**1.2<T**	***1.3*<T**	1.2	1.2
Cd	1.0<T	0.7<T	***1.5***	***1.4***	***1.5***	***1.7***	***1.2***	0.9<T	***1.1***	***1.1***	***1.3***	***1.3***	0.9<T	0.8<T	***1.1***	***1.2***	0.8<T	0.8<T	1	12
Ca	5,350	4,700	8,600	7,100	11,500	11,500	11,500	9,700	7,500	6,700	8,700	7,250	7,750	7050	8,100	8,750	6,300	5,900	58000	NG
Cr	33	35	42	43	43	48	38	33	50	51	41	46	43	47	46	49	33	34	71	1000
Co	13	14	12	13	12	11	11	10	9.6	9.7	12	13	12	12	13	15	13	14	21	50
Cu	32	26	59	50	53	57	51	48	37	38	51	51	35	36	33	78	23	23	85	300
Fe	24,000	25,000	22,500	23,500	24,500	25,000	18,500	18,000	17,000	19,000	24,000	26,500	26,000	27,500	28,000	30,500	30,000	31,000	33000	NG
Pb	33	37	41	36	50	42	50	43	48	44	53	46	39	33	38	47	41	33	120	200
Mg	5,950	6,350	6,050	6,450	6,550	6,650	5,900	5,500	5,400	5,900	6,600	7,300	7,150	7,650	7,600	8,300	6,000	6,100	16000	NG
Mn	250	260	230	215	260	195	155	140	190	150	260	220	200	175	310	285	545	525	1300	NG
Mo	0.5<W	0.6<W	0.5<W	0.5<W	0.6<T	0.5<W	0.5<W	0.5<W	0.8<T	0.6<T	0.5<W	0.5<W	0.5<W	0.5<W	0.5<W	0.5<W	0.6<T	0.5<W	2.5	40
Ni	***72***	***79***	***82***	***85***	***115***	***105***	***115***	***100***	***110***	***105***	***120***	***100***	***76***	***60***	***79***	***87***	***61***	***63***	43	200
Se	0.6<T	0.5<T	1.6	1.6	***2.6***	***2.7***	***2.0***	**1.9**	1.4	1.4	1.6	1.5	1.2	0.9<T	1.4	1.5	0.9<T	0.8<T	1.9	10
Sr	45	39	***83***	70	***93***	***91***	65	63	66	64	57	52	70	59	***96***	***91***	22	22	78	NG
V	48	52	49	57	53	56	65	59	52	59	58	67	41	66	55	57	52	55	91	250
Zn	105	99	145	125	145	140	120	110	110	110	130	120	120	115	135	150	92	93	160	800

Data in bold italic underline text exceed Table F soil back-ground guidelines, or OTR_{98} values if no Table F guideline has been established.
Shaded data exceed Table A 'effects-based' soil criteria for medium-fine textured soils. <T = trace amount, <W = equal to or below analytical detection limit.

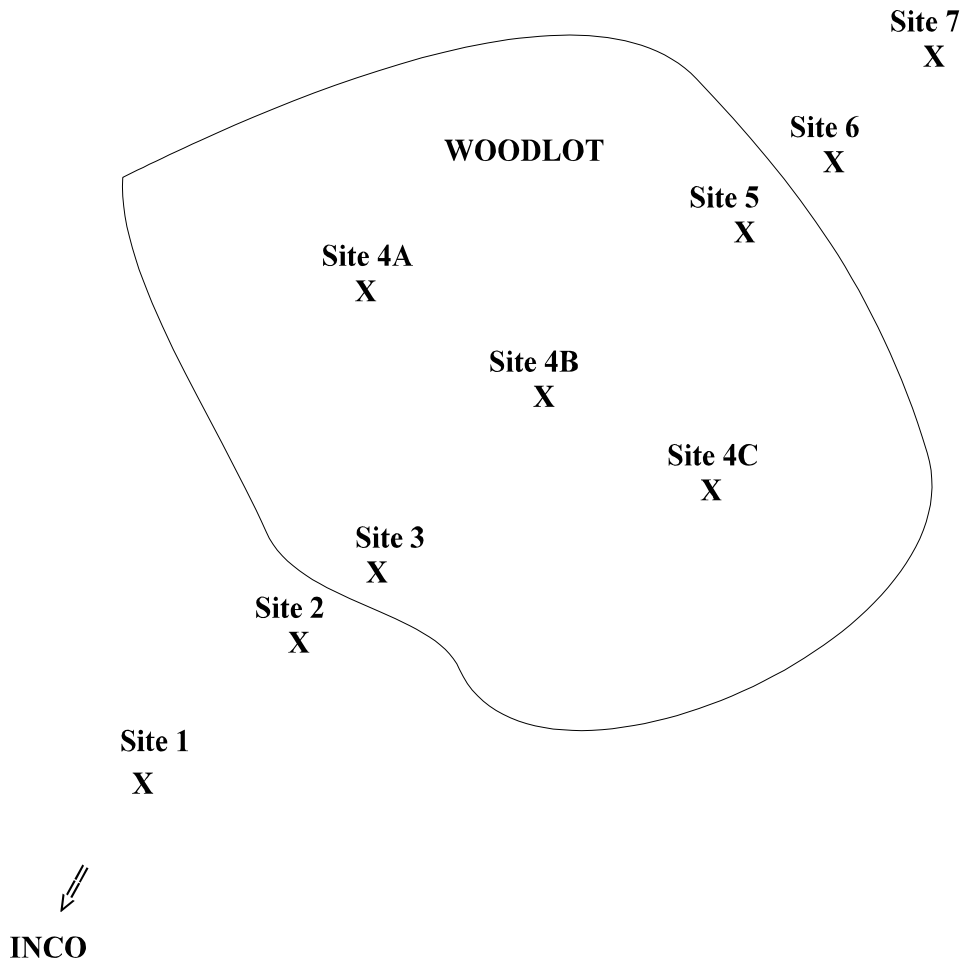


Figure 1: Hypothetical Site Locations for Selected Woodlots

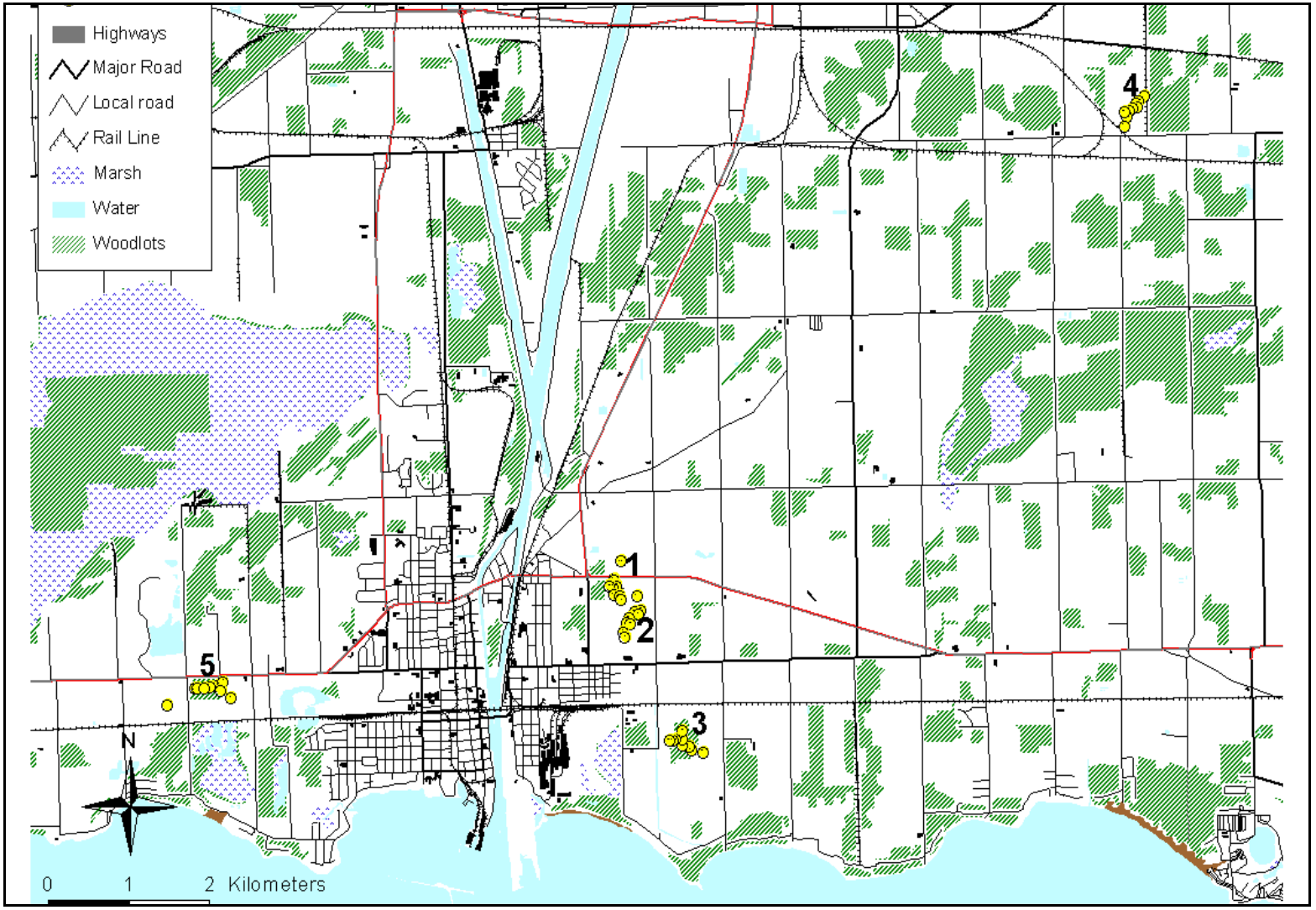


Figure 2: Map showing the locations of the five wood lots.

Figure 3: Map showing the locations of the sampling sites in wood lots 1 and 2.

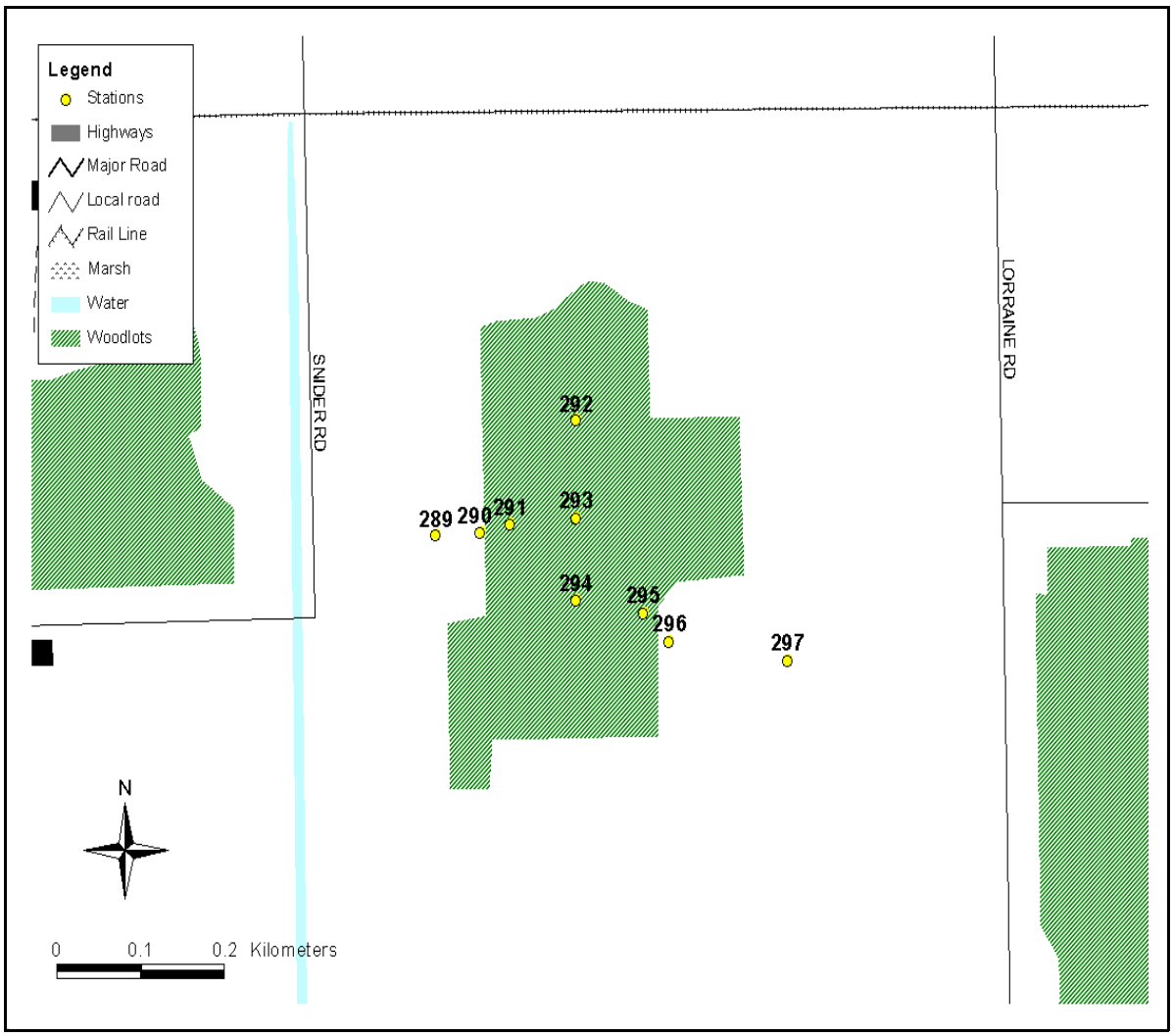


Figure 4: Map Showing the Locations of the Sampling Sites in Woodlot 3.

Figure 5: Map Showing the Locations of the Sampling Sites in Wood Lot 4.

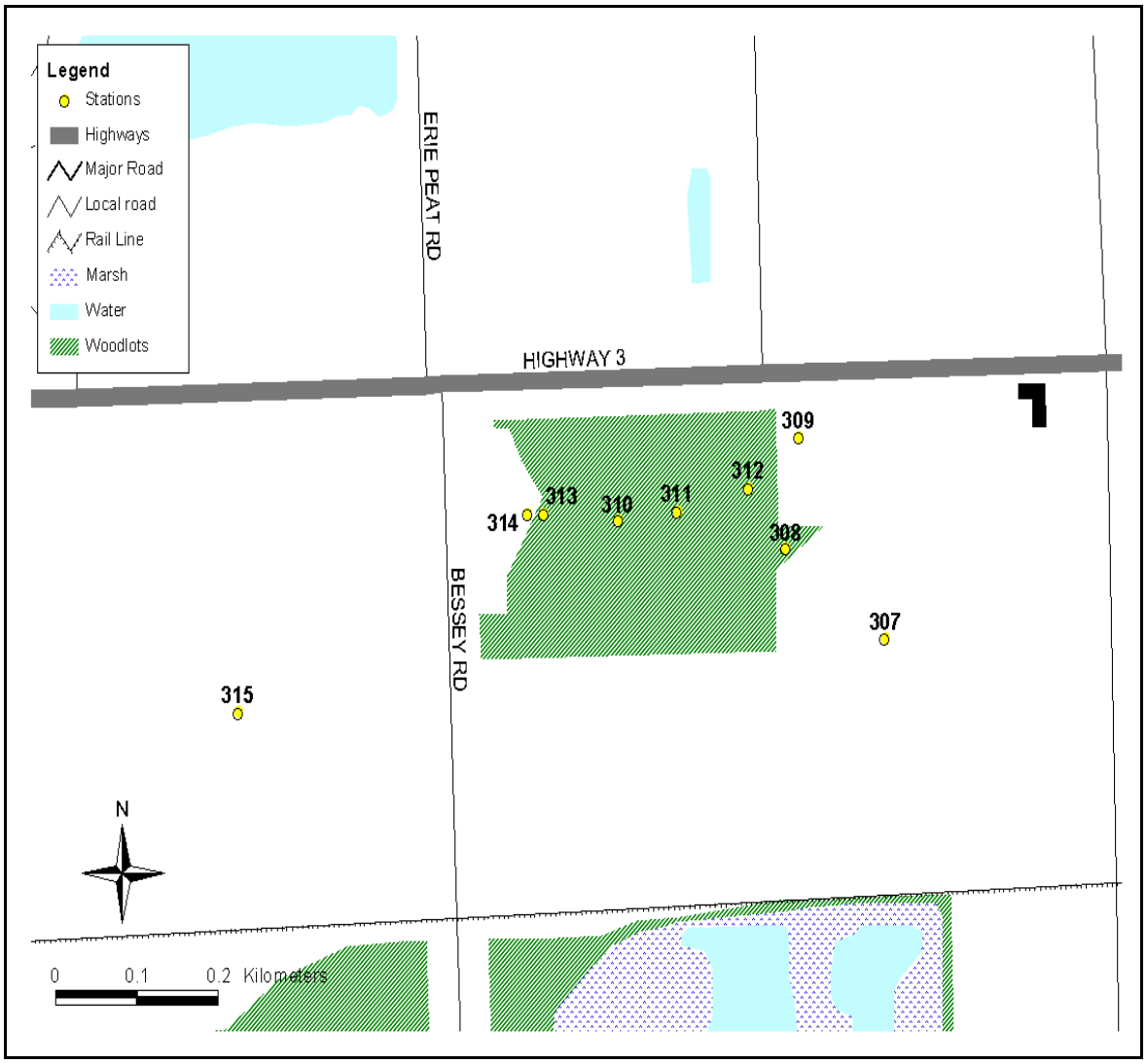


Figure 6: Map showing the location of the sampling sites in wood lot 5.

Figure 7: Soil Ni, Cu, Co, and As concentrations across Woodlot 1 (µg/g)

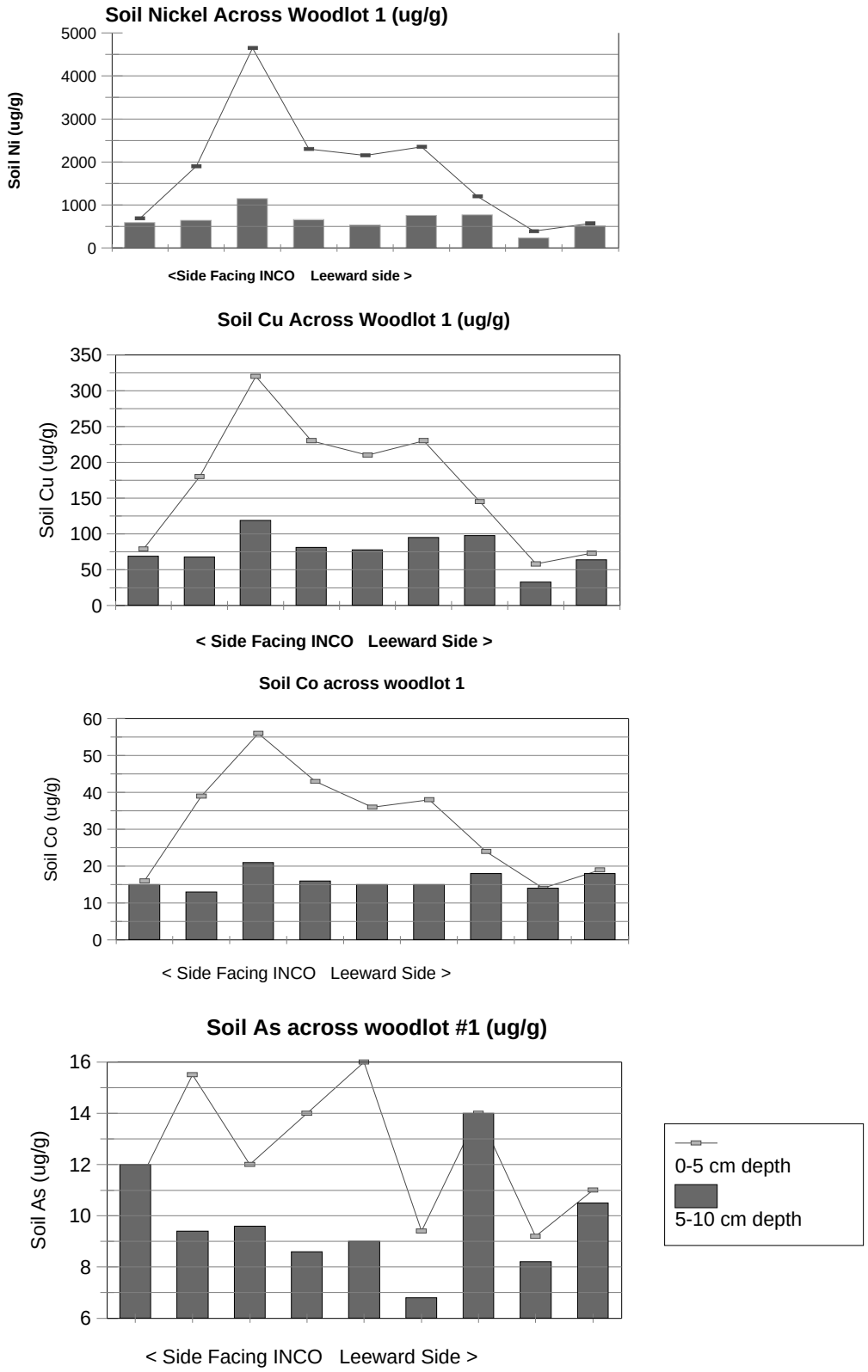


Figure 8: Soil Ni, Cu, Co, and As concentrations across Woodlot 2 (µg/g)

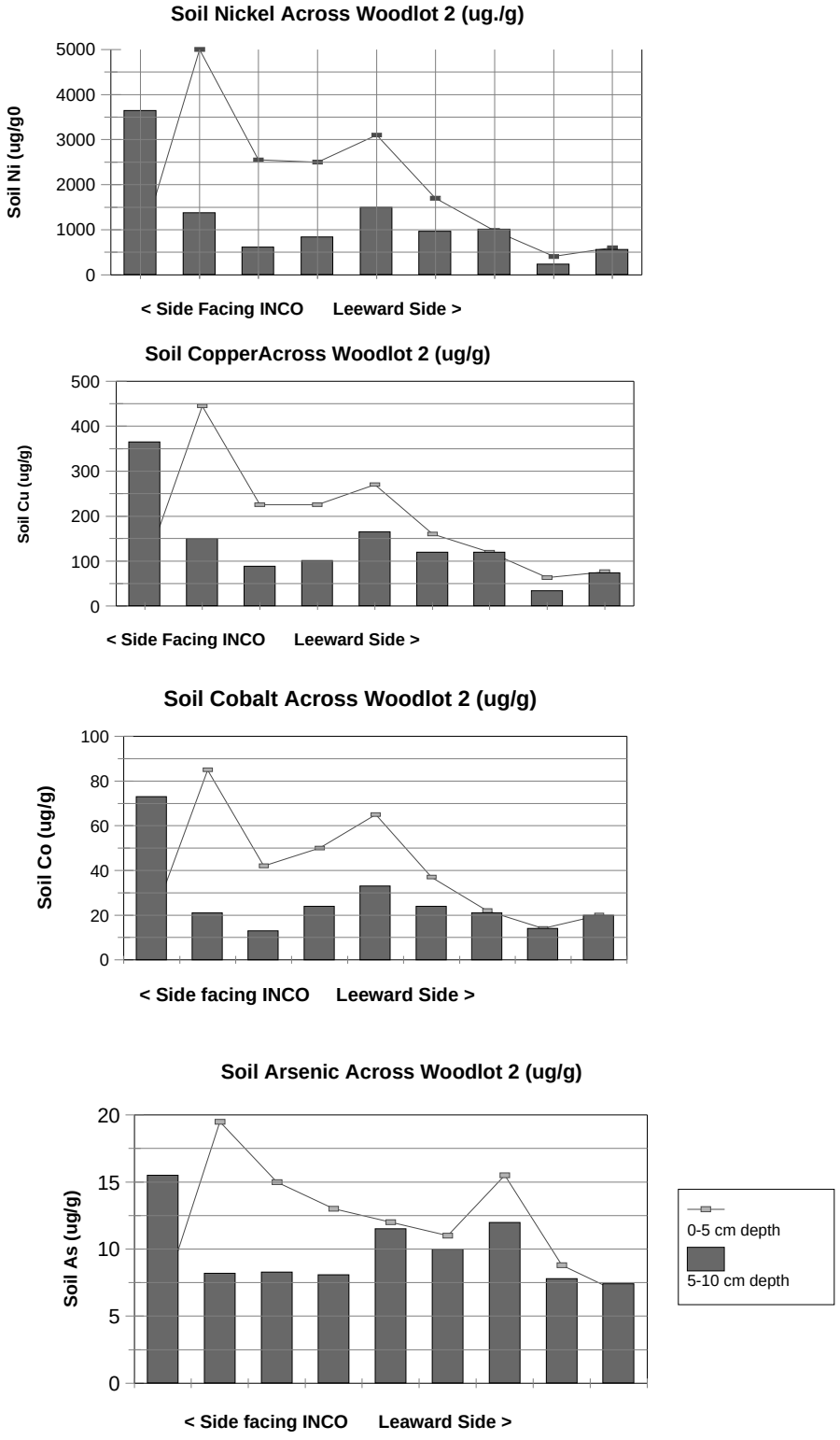


Figure 9: Soil Ni, Cu, Co, and As concentrations across Woodlot 3 (µg/g)

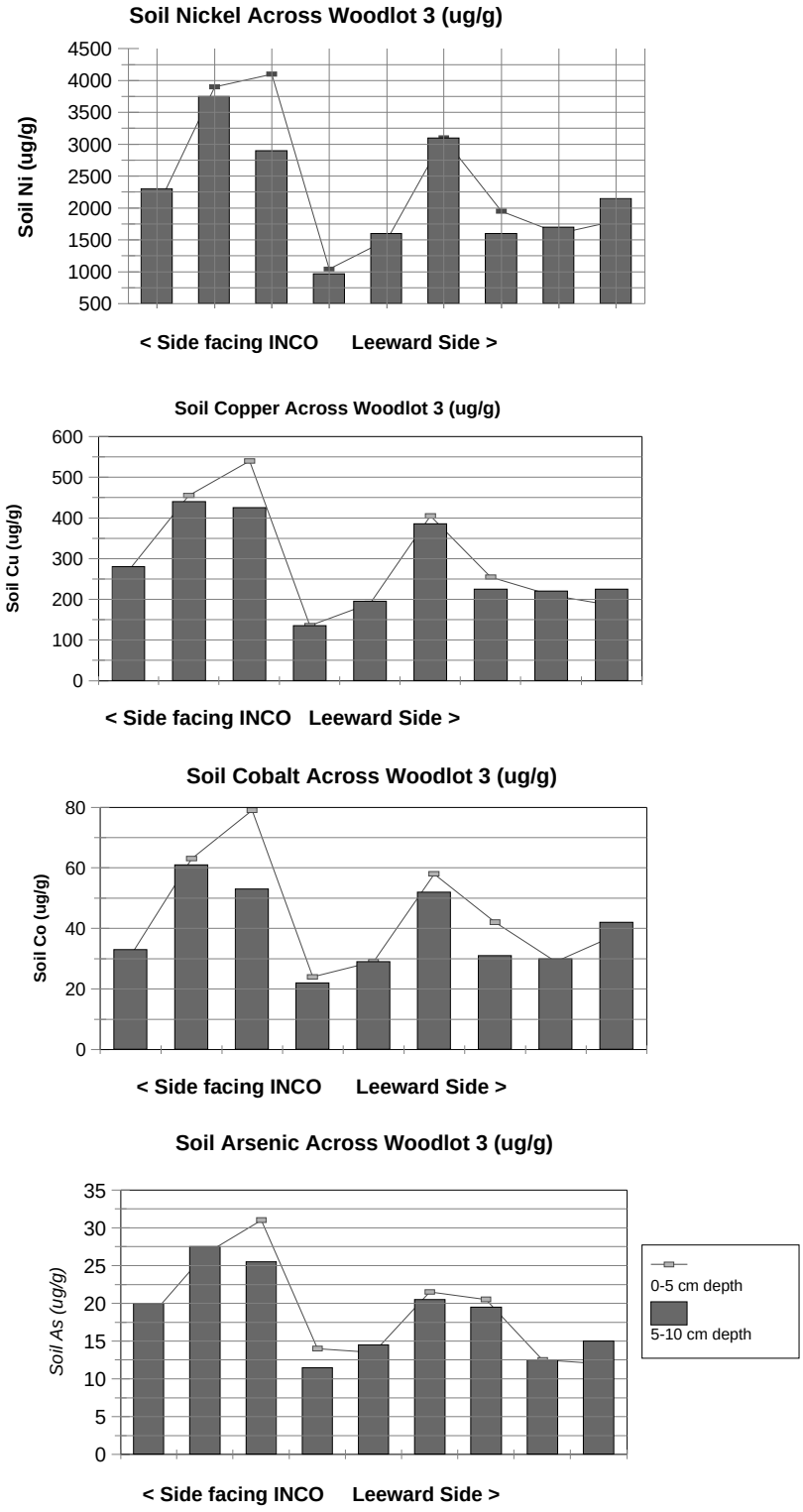


Figure 10: Soil Ni, Cu, Co, and As concentrations across Woodlot 4 (ug/g)

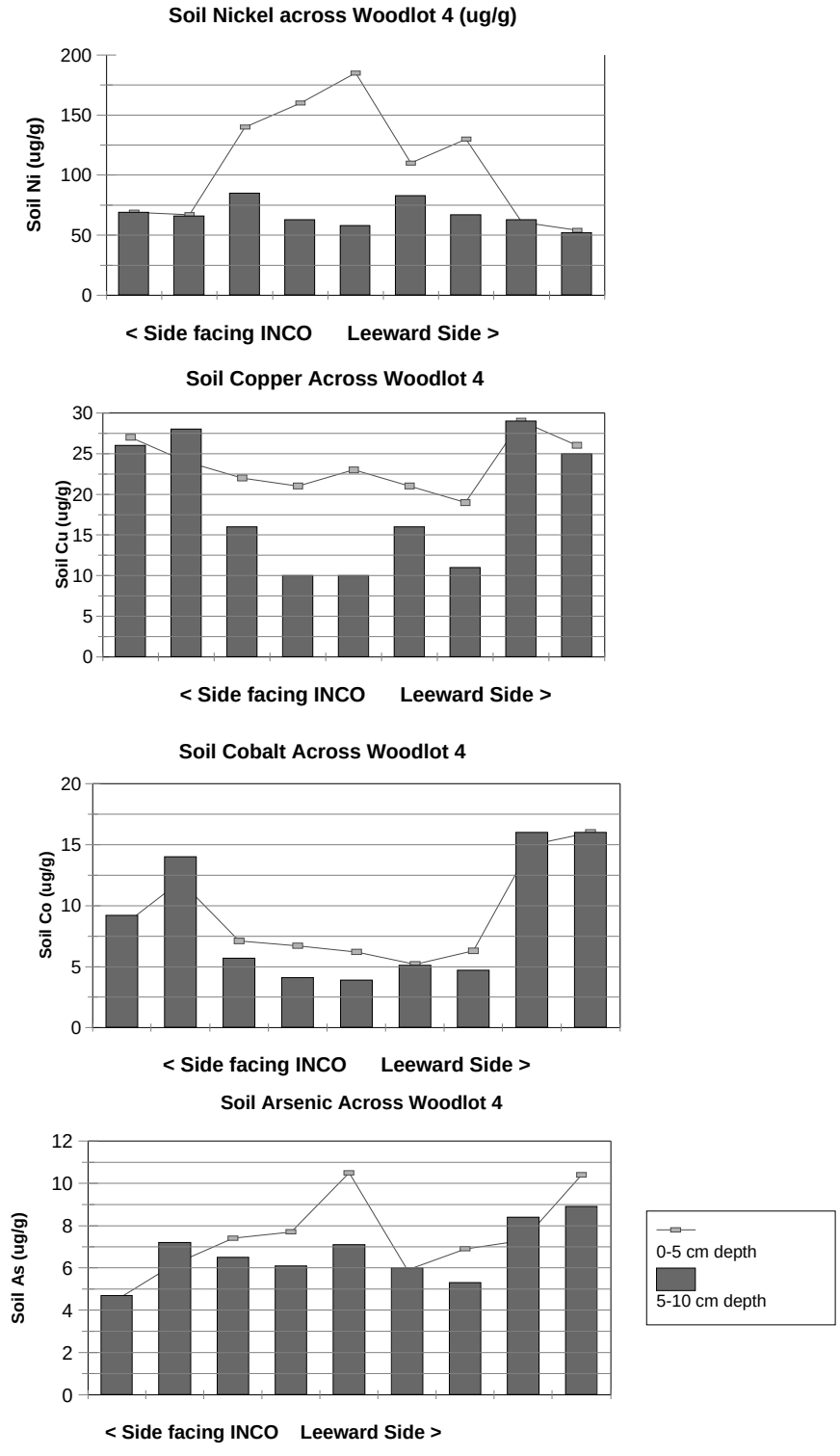
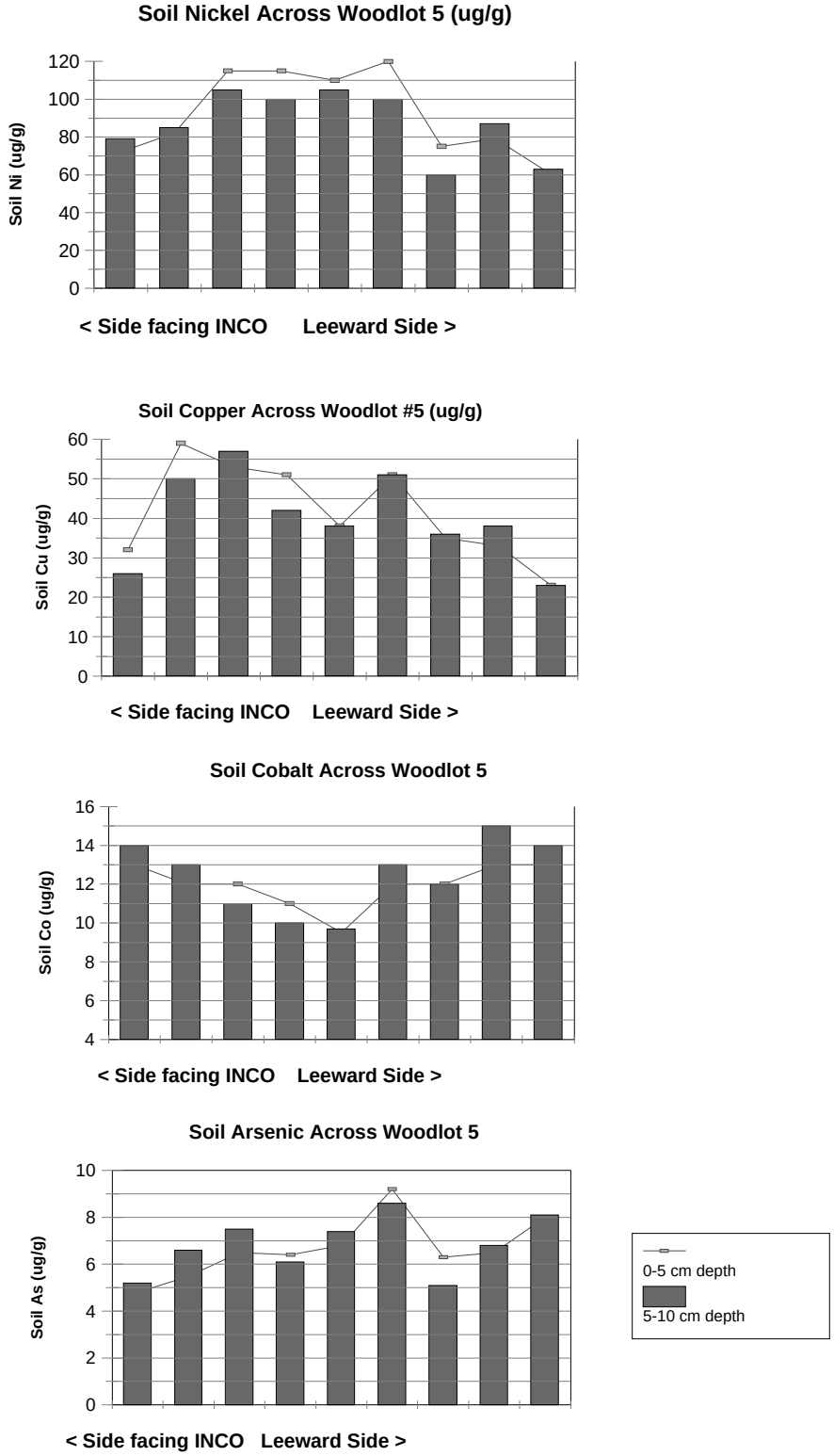


Figure 11: Soil Ni, Cu, Co, and As concentrations across Woodlot 5 (µg/g)



Appendix A
Derivation and Significance of the MOE Soil Remediation Criteria (Clean-up Guidelines)

The MOE Soil Remediation Criteria have been developed to provide guidance in cleaning up contaminated soil. They are not action levels, in that an exceedence of one or more of the criteria does not automatically mean that a clean-up must be conducted. A site clean-up may be conducted when a contaminated property is sold and/or the land use is changed. For example, the owner of an industrial property who plans to sell his/her land to a developer who intends to build residential homes can use the Remediation Criteria to clean up the soil to meet the residential land use criteria. This will allow the site to be reused for residential land-use without concern for adverse effects.

When contamination is found at a site where a change in land-use is not planned, the criteria may be used to assist in making decisions about adverse effects and the need for remediation. This is different from the previously described situation where a decision to change the land-use has already been made and the level of remediation required to rule out the potential for adverse effects is established by the new land use. Decisions on the need to undertake remedial action when the criteria are exceeded, and where the land use is not changing, require consideration of factors such as:

- the demonstrated presence or likelihood of an adverse effect (on and off property);
- an understanding of the type of protection provided by the criteria gained through knowledge of the exposure pathways and receptors which were considered in the development of the criteria, and through understanding how that combination of pathways and receptors relate to those at the site;
- an understanding of the relationship between dose and health response for sensitive receptors from all exposure pathways, including the safety and uncertainty factors that have been used in the development of the criteria;
- an understanding of the environmental characteristics of the contaminants and of the site conditions that could influence the migration of the contaminants and how this effects their exposure and response characteristics.

In each case, the decision to undertake or not undertake site remediation should entail all of these factors plus any additional factors specific to the site in question. When the decision is made that remedial action is needed, the criteria can be used as clean-up targets. If these criteria are unacceptable to the proponent undertaking the remediation, they have an option to develop local back-ground-based criteria or conduct a site specific risk assessment.

The Soil Remediation Criteria are effects-based concentrations 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. There are different Soil Remediation Criteria for soil texture, soil depth, and ground water use. The criteria have also been established so that there will not be a potential for adverse effects 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, use of these criteria may not ensure that corrosive, explosive, or unstable soil conditions will be eliminated.

The Soil Remediation Criteria 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 Soil Remediation Criteria 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 criteria. For more information on the Remediation Criteria please refer to the *Guideline for Use at Contaminated Sites in Ontario. Revised December 1996*, Ontario Ministry of Environment and Energy, PIBs 3161E01, ISBN 0-7778-5905-X. Also available through the MOE web site at www.ene.gov.on.ca.

Appendix B
Derivation and Significance of the MOE Soil Background Concentrations
(Soil Clean-up Guideline - Table F Values)

For the Ontario soil background (Table F) concentrations, rural and urban parkland Ontario Typical Range (OTR_{98}) values were used (refer to Appendix C). Ontario Typical Ranges, which represent the expected distribution of chemical concentrations resulting from natural geological processes and normal human activity , in surface soil in Ontario, remote from the influences of know point sources of emissions. For soils, the OTRs assume a given range of expected chemical concentrations for each land use category.

These ranges are based on the analytical data from pre-defined sampling, processing and analytical protocols. Complete details on the OTR development process can be found in the MOE Phytotoxicology Section report entitled "Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags and Snow" MOEE 1993. In addition, an upper limit, or action level, referred to as the OTR_{98} was developed. This value represents 97.5% (98%) of the data in the OTR distribution. From a statistical aspect, this is equivalent to the mean plus two standard deviations of a normally distributed population.

A review of the OTR database indicated that a high degree of sampling variability can occur at any given site when concentrations are at background levels, especially when sampling for organic contaminants. Therefore, replicate sampling would be necessary to address variability due to sampling, as well as analytical variability. In order to minimize costly replicate sampling and analysis to proponents in situations where there is little or no danger of effects, soil background concentrations (Table F values) were set at a value equal to the OTR_{98} plus two coefficients of variation ($OTR_{98} + 2CV_{ws}$). The coefficient of variation, in this context, is the average "within site" sampling variability around the OTR_{98} , expressed as a percent coefficient of variability (CV_{ws}). This was calculated by taking the average of the "within site" Cvs of all points between the OTR_{98} upper and lower confidence limits (MOEE, 1993). The percent value of $2CV_{ws}$ is converted to an absolute value and added to the OTR_{98} value. If the chemical concentration in a single sample is above the ($OTR_{98} + 2CV_{ws}$) value, one can be certain (with 97.5% confidence) that the OTR_{98} has been exceeded for that chemical.

As previously mentioned, rural parkland OTR_{98} values were the basis for the Table F soil background concentrations for the agricultural land use category while urban parkland OTR_{98} values were the basis for the other land use categories. The term "urban" is defined here as any property that lies within an area that is fully serviced by both municipal water and sewage systems.

References

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 "Ontario Typical Range" Soil Guidelines.

The MOE "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 MOE "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 MOE 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 the Phytotoxicology ULN guideline. The OTR program is on-going. The number of OTRs will be continuously 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*.